COURSE FILE

Academic Year : 2022-23

Subject : Satellite Communication

Year/Sem : IV B.Tech II Semester

Department : Electronics & Communication Engineering

Faculty Name : Mr. P. Rangappa

S. No	Content	Page No.
1	Time Table	1
2	Syllabus & Lesson Plan	2-5
3	Register & Sample Mid Script	6-38
4	Assignment Questions with solutions	39-52
5	Mid Question Papers	53-54
6	External Question Papers with solutions	55-76
7	CO-PO Calculation	77-86
8	External Exam Student Answer Script	87-113
9	Course Material & PPTs	114-730
10	Topics covered beyond Syllabus	731
11	Expert Suggestion	732
12	Result Analysis	733-734

Dr.Kethepalli Mallikarjuna
HOD of ECE

Dr. KETHEPALLI MALLIKARJUNA
B.E, M.Tech, Ph.D, MISTE, FIETE, MIE
Professor & HOD
Department of ECE
RGM College of Engg. & Tech. (Autonomous)
NANDYAL - 518 501, Kurnool (Dist), A.P.

Dr.T.Jayachandra Prasad
Principal

Dr. T. JAYACHANDRA PRASAD
M.E., Ph.D.
PRINCIPAL
R G M College of Engg. & Tech.,
(Autonomous)
NANDYAL-518 501, Nandyal (Dist),A.P.

R.G.M.COLLEGE OF ENGINEERING & TECHNOLOGY, NANDYAL – 518 501
DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

IV B.Tech., II-Semester **Academic Year: 2022-23**
w.e.f: 09-01-2023

A-Section : Rotation B-Section : Rotation
C-Section : RB-2140 D-Section : RB-2150

Period/ Day	Section	1 9.00 AM To 9.50 AM	2 9.50 AM To 10.40 AM	3 11.00 AM To 11.50 AM	4 01.00 PM To 01.50 PM	5 1.50 PM To 2.40 PM	6 2.40 PM To 3.30 PM	7 3.30 PM To 4.20 PM
MON	A	SC	CTC	RTOS	PROJECT			
	D	RTOS	CTC	SC				
	B	SC	RTOS	CTC				
	C	RTOS	SEM	SC				
TUE	A	RTOS	SEM	SC				
	D	SC	SEM	RTOS				
	B	RTOS	SEM	SC				
	C	SC	SC	RTOS				
WED	A	SC	SEM	RTOS				
	D	RTOS	CTC	SC				
	B	RTOS	SC	CTC				
	C	CTC	CTC	RTOS				
THU	A	RTOS	SC	CTC				
	D	SC	SEM	RTOS				
	B	RTOS	SEM	SC				
	C	SC	RTOS	SEM				
FRI	A	SC	RTOS	SEM				
	D	RTOS	CTC	SC				
	B	SC	RTOS	CTC				
	C	RTOS	SEM	SC				
SAT	A	RTOS	CTC	SC				
	D	SC	RTOS	SEM				
	B	SC	SEM	RTOS				
	C	RTOS	SC	CTC				

Subject	Section	Name of the Faculty
SC	A	Mr.P.Rangappa
RTOS	A	Miss.M.Fouzia Sulthana
CTC	A	Mr.K.Rama Krishna
SEM	A	Mr.YMSR/Mr.SVRK

Subject	Section	Name of the Faculty
SC	B	Mr.S.L.Venkata Krishna
RTOS	B	Dr.J.Sofia Priyadhashini
CTC	B	MrY.Mallikarjuna Achari
SEM	B	Dr.CV/Miss.NFS

Subject	Section	Name of the Faculty
SC	C	Mr.M.V.Raja Sekar
RTOS	C	Mr.P.Dinesh
CTC	C	Mr,Mallikarjuna Achari
SEM	C	Mr.PCS/Miss.NFS

Subject	Section	Name of the Faculty
SC	D	Mr.P.Rangappa
RTOS	D	Smt.B.Indu
CTC	D	Mr.Raja Sekar
SEM	D	Dr.NR/Dr.VNVSP

Dr.K.Mallikarjuna
HOD OF ECE

Dr. KETHEPALLI MALLIKARJUNA
B.E, M.Tech, Ph.D, MISTE, FIETE, MIE
Professor & HOD
Department of ECE
RGM College of Engg. & Tech. (Autonomous)
NANDYAL - 518 501, Kurnool (Dist), A.P.

Dr.T.Jaya Chandra Prasad
Principal

Dr. T. JAYACHANDRA PRASAD M.E.,Ph.D.,
PRINCIPAL
R G M College of Engg. & Tech.,
(Autonomous)
NANDYAL-518 501, Nandyal (Dt), A.P.

RAJEEV GANDHI MEMORIAL COLLEGE OF ENGINEERING AND TECHNOLOGY
AUTONOMOUS
DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

R G M COLLEGE OF ENGINEERING & TECHNOLOGY

IV B.Tech, II-Sem (ECE)

L	T	C
2	1	3

SATELLITE COMMUNICATION

(Professional Elective-V)

COURSE OBJECTIVES:

- To introduce the basic principles of Satellite Communication systems, orbital mechanics, launchers.
- To know the different subsystems of satellites.
- To introduce the basic concepts and designing of Satellite links.
- To introduce the basic concepts of earth station transceiver.
- To know the basics of direct broadcast satellite television
- To know the basic concepts of various multiple access techniques and GPS systems.

COURSE OUTCOMES:

- To introduce the basic principles of satellite communication system, orbital mechanics and launchers.
- To understand the concepts of satellite subsystems and designing of satellite uplink and downlinks.
- To analyze the concepts of various multiple access techniques.
- To introduce the basic concepts of direct broadcast satellite television and radio.
- To know the concepts of global positioning system and its operation.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2		1										2	
CO2			3							2	1		2		
CO3		2		1						3			2		2
CO4					3	1				2				1	
CO5							1			3		2			1

UNIT I

INTRODUCTION: Background, A brief history of satellite communications,Overview of satellite communications, frequency allocations of satellite services, design considerations of satellite communications, Advantages & Disadvantages of satellite communications.

ORBITAL MECHANICS AND LAUNCHERS: Orbital Mechanics,Developing the equations of the orbit,Kepler's three laws of planetary motion, Describing the orbit of a satellite, Locating the satellite in the orbit, Locating the satellite with respect to the earth, Orbital elements. Look Angle determination,The sub satellite point, Elevation angle calculation, Azimuth angle calculation, Specialization to geostationary satellites, Orbital perturbations,Longitudinal and Inclination changes.Orbit determination, launches and launch vehicles,Expandable launch vehicles, placing satellites into geostationary orbit.Orbital effects in communications systems performance,Orbit considerations, coverage and frequency considerations.

UNIT II

SATELLITE SUBSYSTEMS: Attitude and Orbit Control System (AOCS), Telemetry, Tracking, Command and Monitoring (TTC&M), Power system, Communication subsystems,Description of the communications systems, Transponders, Satellite antennasBasic antenna types and relationships,Equipment reliability and space qualification,Redundancy.

UNIT III

SATELLITE LINK DESIGN: Introduction, Basic transmission theory, system noise temperature and Gain to Temperature (G/T) ratio: Noise temperature, Calculation of system noise temperature, Noise figure and noise temperature, G/T ratio for earth stations.

Design of down links:link budgets, link budget example.

Uplink design, Design of satellite links for specifiedCarrier to NOISE (C/N)Combining C/N and C/I value in satellite links: Overall (C/N) with uplink and Downlink attenuation, Uplink and downlink attenuation in rain, Uplink attenuation and (C/N)up, Down link attenuation and (C/N)dn. Interference effects on complete link design. System design for specific performance, Satellite communication link design procedure.

UNIT IV

MULTIPLE ACCESSES: Introduction, Frequency Division Multiple Access (FDMA): Intermediation, Calculation of C/N with inter modulation. Time division Multiple Access (TDMA): Bits, Symbols, and

Channels, Frame structure. Reference burst and preamble, Guard times, Synchronization in TDMA networks, Transmitter power in TDMA networks, Satellite Switched TDMA, Onboard processing:Baseband processing transponders, Satellite switched TDMA with onboard processing.Demand Access Multiple Access (DAMA), Code Division Multiple access (CDMA), Spread spectrum Transmission and reception.

UNIT V

DIRECT BROADCAST SATELLITE TELIVISION AND RADIO:C band and Ku band home satellite TV, Digital DBS TV,DBS-TV system design, DBS-TV link budget, Master control station and uplink, Installation of DBS TV antennas, Satellite radio broadcasting.

UNIT VI

SATELLITE NAVIGATION & THE GLOBAL POSITIONING SYSTEM: Introduction, radio and satellite navigation, GPS Position Location principles:Position location in GPS, GPS time. GPS Receivers and codes: the C/A code.Satellite Signal Acquisition, GPS Navigation Message, GPS Signal Levels, timing accuracy, GPS C/A code accuracy, differential GPS, selective availability.

TEXT BOOKS:

1. Satellite Communications – Timothy Pratt, Charles Bostian and Jeremy Allnutt, WSE Wiley Publications, 3rd Edition, 2021.
2. Satellite Communications – Dennis Roddy, McGraw Hill, 4th Edition, 2017.

REFERENCES:

1. Satellite Communications: Design Principles – M. Richharia, BS Publications, 2nd Edition, 2003.
2. Satellite Communication – Dr.D.C Agarwal, Khanna Publications, 7th Ed.
3. Fundamentals of Satellite Communications – K.N. Raja Rao, PHI, 2013

RAJEEV GANDHI MEMORIAL COLLEGE OF ENGG.&TECH., NANDYAL-518501

LESSON PLAN

Subject: Satellite Communication | **Academic Year: 2022- 2023**
Year & Branch: IV B. Tech II Sem (ECE-A & D) | **Credits: 03**
Name of the Staff: Mr. P. Rangappa | **Classes expected: 62**

S.No	Topic	No. of Periods	No of Cumulative Periods
UNIT-I	**INTRODUCTION, ORBITAL MECHANICS AND LAUNCHERS**		
	Background, A brief history of satellite communications, Advantages, disadvantages and applications of SC	1	1
	Frequency allocation to satellite services, Design Considerations, Overview of satellite communications	1	2
	Orbital Mechanics-Developing the equations of the orbit, Kepler's three laws of planetary motion,	2	4
	Describing the orbit of a satellite, Locating the satellite in the orbit, Locating the satellite with respect to the earth, Orbit elements	2	6
	Look Angle determination-The sub satellite point, elevation angle calculation, Azimuth angle calculation	3	9
	Specialization to geostationary satellites. Orbital perturbations-Longitudinal and Inclination changes. Orbit determination	2	11
	launches and launch vehicles-Expandable launch vehicles, placing satellites into geostationary orbit	2	13
	Orbital effects in communication systems performance, Orbit considerations, coverage and frequency considerations	3	16
UNIT-II	**SATELLITE SUBSYSTEMS**		
	Attitude and orbit control system.	2	18
	Telemetry, tracking, Command and monitoring.	2	20
	power systems, communication subsystems-Description of the communications systems, Transponders	2	22
	Satellite antennas-Basic antenna types and relationships	1	23
	Satellite antennas in practice Equipment reliability and space qualification-Redundancy.	2	25
UNIT-III	**SATELLITE LINK DESIGN**		
	Introduction, Basic transmission theory, system noise temperature and Gain to Temperature (G/T) ratio-Noise temperature,	2	27
	Calculation of system noise temperature, Noise figure and noise temperature/T ratio for earth stations	2	29
	Design of down link-Link budgets, link budget example.	2	31
	up link design, Design of satellite links for specified Carrier to NOISE (C/N)-Combining C/N and C/I value in satellite links,	1	32
	Overall (C/N) with uplink and Downlink attenuation, Uplink and downlink attenuation in rain,	1	33
	Uplink attenuation and (C/N)up, Down link attenuation and (C/N)dn	1	34
	System design for specific performance, Satellite communication link design procedure.	1	35
UNIT-IV	**MULTIPLE ACCESS**		
	Introduction, Frequency division multiple access (FDMA): Intermediation,	2	37
	Calculation of C/N with inter modulation	2	39
	Time division Multiple Access (TDMA): Bits, Symbols, and Channels, Frame structure.	2	41
	Reference burst and preamble, Guard times, Synchronization in TDMA networks,	2	43
	Transmitter power in TDMA networks, Satellite Switched TDMA,	2	45
	Onboard processing-Baseband processing transponders, Satellite switched TDMA with onboard processing	1	46
	Demand Access Multiple Access (DAMA), Code Division Multiple access (CDMA), Spread spectrum transmission and reception.	1	47
UNIT-V	**DIRECT BROADCAST SATELLITE TELIVISION AND RADIO**		
	C band and Ku band home satellite TV, Digital DBS TV	2	49
	DBS TV system design,	1	50
	DBS TV link budget, Error control in digital DBS TV	1	51
	Master control station and uplink, Installation of DBS TV antennas.	2	52

	Satellite radio broadcasting,	1	53
UNIT-VI	**SATELLITE NAVIGATION & THE GLOBAL POSITIONING SYSTEM**		
	Introduction, radio and satellite navigation.	1	54
	GPS Position Location Principles-Position location in GPS, GPS time.	3	57
	GPS Receivers and codes -The C/A code. Satellite Signal Acquisition, GPS Navigation Message,	2	59
	GPS Signal Levels, timing accuracy, GPS Receiver operation, GPS C/A code accuracy, Differential GPS, Selective availability	3	62

21/01/2023

SIGNATURE OF THE FACULTY

SIGNATURE OF THE HOD

21/1/23

RGM COLLEGE OF ENGINEERING & TECHNOLOGY

(AUTONOMOUS)

NANDYAL - 518 501. Kurnool (Dist.) A.P.



(ESTD-1995)

ATTENDANCE REGISTER

IV - II SC (A/S)

ACADEMIC YEAR	: 2022-23	**SEM** : ~~I~~ / II
COURSE	: IV B.Tech ~~II Sem~~	**CLASS** : A
BRANCH / SECTION	: ECE - A	
SUBJECT & CREDITS	: Satellite Communication	
FACULTY	: Mr. P. Rangappa	

R.G.M. COLLEGE OF ENGINEERING & TECHNOLOGY (Autonomou

ATTENDANCE REGISTER

Class : IV. B Tech II Sem

Branch : ECE-A

Semister / Year

Academic Year from

Roll No.	Name	Date	09/01/23	10/01/23	11/01/23	12/01/23	17/01/23	18/01/23	19/01/23	20/01/23	21/01/23	23/01/23	25/01/23	27/01/23
			1	2	3	4	5	6	7	8	9	10	11	12
1909[A0 405	Akhila. B		A	A	1	A	2	3	4	5	6	7	8	A
407	Alfisha. m		A	A	A	A	1	2	3	4	5	6	7	A
408	Amrutha. B		A	A	A	A	A	1	A	2	3	4	5	6
411	Aparna. S		A	A	A	A	A	A	1	2	3	4	5	6
413	Aswini. m		A	A	A	A	A	A	A	1	2	3	4	5
414	Aswitha Sai. m		A	A	A	1	2	A	3	A	4	5	6	7
415	Azharuddin. m		A	1	2	3	A	4	5	6	A	7	8	9
416	Babitha Reddy. K		A	A	A	A	A	A	A	1	2	3	4	5
421	Bhargav. m		1	2	3	A	A	A	A	4	5	6	7	8
423	Bhumika. P		A	A	1	2	A	A	3	4	5	6	7	8
429	Chandra Sekar. B		1	2	3	4	A	A	A	5	6	7	8	9
434	Dhanunjay. D		A	A	A	A	A	A	1	2	3	4	5	6
436	Datta Dharani Kumari. L		A	A	A	A	1	2	3	4	5	6	7	8
441	Fayaz. S		1	A	A	A	2	3	4	A	5	6	7	8
442	Gangadadah. B		A	A	A	A	A	A	A	A	1	2	3	A
444	Ganesh Naidu. B		A	A	A	A	1	2	3	4	5	6	7	8
450	Habeeba sultana. S		A	A	1	A	2	3	4	5	6	7	8	9
451	Haleema. S		1	2	3	A	4	5	6	A	7	8	A	A
452	Hari Nandan. P		A	A	A	A	1	2	3	A	4	5	6	7
459	Hima Bindu. G		A	1	2	3	A	4	5	6	7	8	9	A
463	Jahnavi. m		1	2	3	4	5	6	7	8	9	A	10	11
466	Jaya. P		A	A	A	A	1	2	3	4	5	6	7	8
474	Kasi Viswanatha Reddy. K		1	2	3	4	A	A	5	6	A	7	8	9
478	Lakshmi Pavani. m		A	A	A	A	A	1	2	3	4	5	6	7
482	Lakshmi manasa D		A	A	A	A	1	2	3	4	5	6	7	8
486	Likhitha. K		A	A	A	A	A	1	2	3	4	5	6	7
488	Loknath. S		A	A	A	A	A	A	A	1	A	A	2	A
489	Madhavi. G		A	A	A	A	A	A	1	2	3	4	5	6
4A0	Manasa. P		1	2	3	A	A	A	4	5	6	7	8	A
4A1	Manaswi. V		A	A	A	A	A	A	1	2	3	4	5	6
Signature of Teacher														
Signature of H.O.D.														
Signature of Principal														

Roll No.	28/01/23	30/01/23	31/01/23	01/02/23	02/02/23	03/02/23	04/02/23	06/02/23	08/02/23	09/02/23	10/02/23
	13	14	15	16	17	18	19	20	21	22	23
405	9	10	11	12	13	14	15	A	16	A	17
407	8	9	A	10	11	12	A	13	14	15	16
408	7	8	A	9	10	11	A	12	13	A	14
411	7	8	A	9	10	11	A	12	13	A	A
413	6	7	A	8	9	10	A	11	12	13	14
414	8	A	A	9	10	11	A	12	A	A	A
415	10	11	12	13	14	15	16	17	18	19	20
416	6	7	A	8	9	10	A	11	12	13	14
421	A	9	A	10	11	12	A	13	14	15	16
423	9	10	11	12	13	14	A	15	16	A	17
429	10	11	12	13	14	15	16	17	18	A	19
434	A	7	A	8	9	10	A	A	11	12	13
436	9	10	11	12	13	14	15	16	17	A	18
441	9	A	10	11	12	13	14	15	16	17	18
442	4	A	A	5	6	A	A	A	A	7	8
444	9	10	11	12	13	14	A	A	A	15	16
450	10	A	11	12	13	14	A	15	16	17	18
451	A	A	9	10	11	12	13	14	15	16	17
452	8	9	10	11	12	13	14	15	16	17	A
459	A	A	A	10	11	12	13	14	15	16	17
463	12	13	14	15	16	17	18	19	20	A	21
466	A	9	10	11	12	13	A	14	15	16	17
474	10	11	12	13	14	15	A	16	17	A	18
478	A	8	9	10	11	A	12	13	14	15	A
482	9	10	11	12	13	14	A	15	16	A	17
486	8	9	10	11	12	13	14	15	16	A	17
488	A	3	4	5	6	7	A	A	8	9	10
489	A	A	7	8	9	10	11	12	13	14	15
4A0	A	A	9	10	11	12	A	A	A	A	A
4A1	7	8	9	10	11	12	A	13	14	A	15

R.G.M. COLLEGE OF ENGINEERING & TECHNOLOGY (Autonomo

ATTENDANCE REGISTER

Academic Year fro

Class : IV B Tech II Sem

Branch : BCB-A

Roll No.	Name	Date 09/01/23
		(1)
405	Akkila. B	A
407	Alfisha. m	A
408	Amrutha. B	A
411	Apasna. S	A
413	Aswini. m	A
414	Aswitha Sai. m	A
415	Azharuddin. m	A
416	Babitha Reddy. K	A
421	Bhargav. m	1
423	Bhumika. P	A
429	Chandra Sekar. B	1
434	Dhanunjay. D	A
436	Datta Dharani Kumari. L	A
441	Fayaz. S	1
442	Gangalaiah. B	A
444	Ganesh Naidu. B	A
450	Habeeba Sultana. S	A
451	Haleema. S	1
452	Hari Nandan. P	A
459	Hima Bindu. G	A
463	Jahnavi. m	1
466	Jaya. P	A
474	Kasi Viswanatha Reddy. K	1
478	Lakshmi Pavani. m	A
482	Lakshmi manasa D	A
486	Likhitha. K	A
488	Loknath. S	A
489	madhavi. G	A
490	manasa. P	1
491	manaswi. V	A
Signature of Teacher		
Signature of H.O.D.		
Signature of Principal		

Roll No.	24	25	26	27	28	29	30	31	32	33	34
	13/02/23	15/02/23	16/02/23	17/02/23	20/02/23	21/02/23	22/02/23	23/02/23	24/02/23	01/03/23	08/03/23
05	A	18	19	20	21	22	23	24	25	A	26
07	17	18	19	A	20	21	22	23	A	24	A
08	15	16	17	A	A	18	19	20	A	21	22
11	14	A	15	16	A	A	A	17	18	19	20
13	15	16	17	18	A	A	19	20	21	22	23
14	13	14	15	16	17	18	19	20	21	22	23
15	21	22	23	24	25	26	27	A	28	29	30
16	15	A	16	17	A	A	A	18	A	19	20
21	A	17	18	19	20	A	21	A	22	23	24
23	18	19	20	21	22	23	24	25	26	27	28
29	20	21	22	23	A	A	A	24	25	26	27
34	14	15	16	17	18	A	19	A	20	21	22
36	19	A	20	21	22	23	A	A	24	25	26
41	19	20	21	22	23	A	24	25	A	26	27
42	9	A	10	11	12	A	13	A	14	15	16
44	17	18	19	20	21	A	22	23	24	25	26
50	19	20	21	22	23	24	25	26	A	27	A
51	18	19	20	21	22	23	24	25	A	26	27
53	18	19	20	21	22	23	24	25	A	26	27
57	18	A	19	20	A	21	22	23	24	25	26
63	22	23	24	25	26	27	28	29	30	31	A
66	A	18	19	A	20	A	21	22	A	23	24
74	19	20	21	22	23	24	25	26	A	27	28
78	16	17	A	18	19	20	21	22	23	24	A
82	18	A	19	20	21	22	23	A	24	25	26
86	18	19	20	21	22	23	24	25	26	27	28
88	A	A	11	A	12	13	14	15	16	17	18
89	16	17	18	19	20	21	22	23	24	25	26
90	13	A	14	15	16	17	18	19	20	21	22
91	16	A	17	18	A	A	19	20	21	22	23
	P	P	P	P	P	P	P	P	P	P	P

Roll No.	35	36	37	38	39	40	41	42	43	44	45
	03/03/23	04/03/23	06/03/23	07/03/23	09/03/23	10/03/23	14/03/23	15/03/23	16/03/23	17/03/23	18/03/23
05	27	28	29	30	31	A	32	33	34	35	36
07	25	26	27	28	29	A	30	31	32	33	34
08	23	24	25	26	27	A	A	28	29	30	31
11	21	22	23	24	25	A	26	27	28	29	A
13	24	25	26	27	28	A	29	30	31	32	33
14	24	25	26	27	28	A	29	30	31	32	33
15	37	32	33	34	35	A	36	37	38	39	40
16	21	22	23	24	25	A	A	A	26	27	A
21	25	26	27	28	29	A	30	31	32	33	34
23	29	30	31	32	33	A	34	35	36	37	38
29	28	29	30	31	32	33	34	35	36	37	38
34	23	24	25	26	27	28	29	30	31	32	33
36	From 08/03/23 to →										
41	28	29	30	31	32	33	A	34	35	36	A
42	17	18	19	20	21	A	A	22	A	A	A
44	—										
50	28	29	30	31	32	33	34	35	36	37	38
51	A	28	29	30	31	32	33	34	35	36	37
53	28	29	30	31	32	33	34	35	36	37	A
57	27	28	29	30	31	32	A	33	34	35	36
63	39	33	34	35	36	37	38	39	40	41	A
66	25	26	27	28	29	30	31	32	33	34	35
74	A	29	30	31	32	33	34	35	36	37	38
78	25	26	27	28	29	30	31	32	33	34	35
82	27	28	29	30	31	A	32	33	34	35	36
86	29	30	31	32	33	34	35	36	37	38	39
88	19	20	21	22	23	24	25	26	27	28	29
89	A	27	28	29	30	A	31	32	33	34	35
90	23	24	25	26	27	28	A	29	30	31	32
91	24	25	26	27	28	29	30	31	32	33	34
	P	P	P	P	P	P	P	P	P	P	P

R.G.M. COLLEGE OF ENGINEERING & TECHNOLOGY (Autonomou

ATTENDANCE REGISTER

Class : IV. B Tech II Sem

Branch : ECE-A

Academic Year from

Roll No.	Name	09/01/23
		1
1909[A0 405	Akhila. B	A
407	Alfisha. m	A
408	Amrutha. B	A
411	Aparna. S	A
413	Aswini. m	A
414	Aswitha Sai. m	A
415	Azharuddin. m	A
416	Babitha Reddy. K	A
421	Bhargav. m	1
423	Bhumika. P	A
429	Chandra Sekar. B	1
434	Dhananjay. D	A
436	Datta Dharani Kumari. L	A
441	Fayaz. S	1
442	Gangalaiah. B	A
444	Ganesh Naidu. B	A
450	Habeeba Sultana. S	A
451	Haleema. S	1
452	Hari Nandan. P	A
454	Hima Bindu. G	A
463	Jahnavi. m	1
466	Jaya. P	A
474	Kasi Viswanatha Reddy. K	1
478	Lakshmi Pavani. m	A
488	Lakshmi Manasa D	A
486	Likhitha. K	A
488	Lokanath. S	A
489	Madhavi. G	A
440	Manasa. P	1
441	Manaswi. V	A
Signature of Teacher		
Signature of H.O.D.		
Signature of Principal		

Roll No.	20/03/23	21/03/23	23/03/23	24/03/23	25/03/23	27/03/23	28/03/23	29/03/23	31/03/23	03/04/23	04/04/23
	46	47	48	49	50	51	52	53	54	55	56
05	37	A	38	39	A	40	A	41	42	43	44
07	35	36	37	38	39	40	A	41	42	43	44
08	32	A	A	A	A	A	33	34	35	36	A
11	A	30	31	32	33	34	A	35	36	37	38
13	34	35	A	A	A	36	37	38	39	40	41
14	34	A	35	36	37	38	A	39	40	41	A
15	41	42	43	44	45	46	47	48	49	50	51
16	A	A	A	A	28	29	30	31	32	33	34
21	35	A	A	A	A	A	A	36	37	38	39
23	39	40	41	42	43	44	A	45	46	47	48
29	39	40	41	42	43	44	45	46	47	A	A
34	34	35	A	36	37	38	39	40	41	42	43
36											
41	37	A	38	39	40	A	41	42	43	44	A
42	A	A	A	A	A	A	23	24	25	26	27
44											
50	39	A	40	41	42	43	A	44	45	46	A
51	38	39	40	41	42	43	44	45	46	47	48
57	38	39	40	41	A	42	43	44	45	46	A
59	37	38	A	A	A	39	40	41	A	42	43
63	42	A	43	44	45	46	A	47	48	49	50
66	36	A	A	37	38	39	40	41	42	43	44
74	39	A	A	40	41	42	A	43	44	45	A
78	36	A	A	A	A	A	37	38	39	A	A
82	37	38	39	A	40	A	A	41	42	43	44
86	40	A	A	A	A	41	42	43	44	45	46
88	30	31	A	A	A	A	A	32	33	34	35
89	36	A	A	A	A	37	38	39	40	A	A
90	33	34	35	36	A	37	38	39	40	41	43
A1	35	36	A	A	A	37	38	39	40	A	A

Roll No.	06/04/23	10/04/23	11/04/23	13/04/23	15/04/23	17/04/23	18/04/23	19/04/23	21/04/23		
	57	58	59	60	61	62	63	64	65	66	67
05	A	45	46	47	48	49	50	51	52		
07	45	46	47	48	49	50	51	52	53		
08	39	38	39	40	41	42	43	44	45		
11	A	39	40	41	42	43	44	45	46		
13	48	43	44	45	46	47	48	49	50		
14	A	43	43	44	45	46	47	48	49		
15	A	52	53	54	55	56	57	A	58		
16	35	36	37	38	39	40	41	A	42		
21	A	40	41	42	43	44	45	46	47		
23	49	50	51	52	53	54	55	A	56		
29	A	48	49	50	51	52	53	54	55		
34	A	44	45	46	47	48	49	50	51		
36											
41	A	45	46	47	48	49	50	51	52		
42	A	28	29	30	31	32	33	34	35		
44											
50	A	47	48	49	50	51	52	53	54		
51	49	50	51	52	53	54	55	56	57		
57	A	47	48	49	50	51	52	53	54		
59	44	45	46	47	48	49	50	A	51		
63	A	51	52	53	54	55	56	57	58		
66	45	46	47	48	49	50	51	52	53		
74	A	46	47	48	49	50	51	52	53		
78	40	41	42	43	44	45	46	47	48		
82	A	45	46	47	48	49	50	A	51		
86	A	48	48	49	50	51	52	53	54		
88	36	37	38	39	40	41	42	A	43		
89	41	42	43	44	45	46	47	48	49		
90	43	44	45	46	47	48	49	A	50		
A1	A	47	42	43	44	45	46	47	48		

& TECHNOLOGY (Autonomous), NANDYAL.

REGISTER Academic Year from 2022 to 23 Teacher.....

Subject & Credits 3C BC Dept. BCG

INTERNAL / RECORD MARKS

Roll No.	Assignments 1	2	Average (A)	Internal Test 1 (25/07/22)	2 (21/08/22)	Internal Marks 75% of MAX	25%of MIN	Total (I)	Final Internal (I+A)	Remarks
05	10	10	10	13	10	9.75	2.5		23	
07	10	10	10	09	08	6.75	2		19	
08	10	10	10	15	09	11.25	3.25		24	
11	10	10	10	13	17	12.75	3.25		26	
13	10	10	10	15	13	11.25	3.25		25	
14	10	10	10	06	07	5.25	1.5		17	
15	10	10	10	12	17	12.75	3		26	
16	10	10	10	17	13	12.75	3.25		26	
21	10	10	10	13	10	9.75	2.5		23	
23	10	10	10	06	12	9	1.5		21	
29	10	10	10	17	19	14.25	4.25		29	
34	10	10	10	08	09	6.75	2		19	
36	10	10	10	16	17	12.75	4		27	
41	10	10	10	09	04	6.75	1		18	
43	10	10	10	12	03	9	0.75		20	
44	10	10	10	09	15	11.25	2.25		24	
50	10	10	10	13	14	10.5	3.25		24	
51	10	10	10	17	19	14.95	4.25		29	
52	10	10	10	11	04	8.25	1		20	
59	10	10	10	18	17	13.5	4.25		28	
63	10	10	10	10	14	10.5	2.5		23	
66	10	10	10	09	10	7.5	2.25		20	
74	10	10	10	12	13	9.75	3		23	
78	10	10	10	18	12	13.5	3		27	
82	10	10	10	16	16	12	4		26	
86	10	10	10	16	13	12	3.25		26	
88	10	10	10	14	12	10.5	3		24	
89	10	10	10	16	17	12.75	4		27	
90	10	10	10	17	13	12.75	3.25		26	
91	10	10	10	15	11	11.25	2.75		24	

R.G.M. COLLEGE OF ENGINEERING & TECHNOLOGY (Autonomou

ATTENDANCE REGISTER

Class : IV. B Tech II Sem

Branch : ECE-A

Semister / Year

Academic Year from

Roll No.	Name	Date	09/01/23	10/01/23	11/01/23	12/01/23	17/01/23	18/01/23	19/01/23	20/01/23	23/01/23	24/01/23	25/01/23	27/01/23
			1	2	3	4	5	6	7	8	9	10	11	12
M09IA0 4A5	mastan Be.S		A	A	A	A	A	1	2	3	A	A		
4B3	mounika.V		1	2	3	4	A	5	6	7	8	9	10	11
4B5	Naga Sahitya.m		1	2	3	A	5	6	7	8	9	10	11	12
4C6	Niranjan Reddy.G		1	2	3	A	A	4	5	A	6	7	8	A
4C9	padmaja.N		A	A	A	A	A	1	2	3	4	5	6	7
4D6	Pavithra.A		A	A	A	A	A	A	.					
4D9	prasanth.G		1	2	3	4	A	A	A	5	A	6	7	A
4E1	prathyusha.R		A	A	A	A	A	A	A	1	2	3	4	5
4E3	puneeth Teja.A		A	1	A	A	A	A	.					
4E4	Radhamma P		A	A	A	A	A	A	1	2	3	4	5	6
4E5	Raghavendra Reddy.P		1	2	3	A	A	A	A	A	4	5	6	A
4E8	Rajasekhar Reddy.B		A	1	2	3	A	A	A	4	5	6	7	8
4F9	Sai Divya.V		A	A	A	A	A	A	A	1	2	3	4	A
4H1	Sai mythili.N		A	1	2	A	A	3	4	5	6	7	8	A
4H2	Sai naga mounika.T		A	A	A	A	A	A	A	A	1	2	3	4
4H7	Sai sudha.P		A	A	A	A	A	A	1	2	3	4	5	6
4H8	Sai Vasthini.Y		A	A	A	A	A	1	2	3	4	5	6	7
4H3	Sairaj Kumar.D		A	A	A	A	A	A	1	2	A	3	4	5
4J4	Shailucha.V		A	A	A	A	A	A	A	A	A	1	2	3
4K0	Sivahalika.K		A	A	A	A	A	A	1	2	3	4	5	6
4K5	Sreevani.T		A	A	A	1	2	3	4	A	A	A	5	6
4K7	Subhash Reddy.M		A	A	1	A	A	2	3	A	4	5	6	7
4K8	Suchitra.G		A	A	A	A	A	1	A	2	3	4	5	6
4M9	Sumanth.D		A	A	A	A	A	A	.					
4M3	Sumanth.M		A	A	A	A	1	2	3	A	4	5	6	7
4M5	Sunandini.K		A	A	A	A	A	1	2	3	4	5	6	7
4M9	Surekha.V		A	A	A	A	1	2	3	4	5	6	7	8
4N8	Surendra Reddy.B		1	2	3	4	5	6	7	8	9	10	11	12
4N6	Susmitha.C		A	A	A	A	A	1	A	2	3	4	5	6
4P0	Thasvin.M		A	A	A	A	A	A	.					
Signature of Teacher														
Signature of H.O.D.														
Signature of Principal														

Roll No.	23/01/23	30/01/23	31/01/23	01/02/23	02/02/23	03/02/23	07/02/23	06/02/23	08/02/23	09/02/23	10/02/23
	13	14	15	16	17	18	19	20	21	22	23
A5	.	.	.			.	.	.			
B3	12	13	14	15	16	17	18	19	20	A	21
B5	A	13	14	15	16	17	A	18	19	20	21
C6	9	10	11	12	13	A	14	15	16	17	18
C9	A	8	9	10	11	12	13	14	15	A	16
D6											
D9	8	9	A	10	11	A	A	12	A	A	A
E1	6	7	A	8	9	10	A	11	12	13	14
E3											
E4	A	7	8	9	10	11	12	13	14	15	16
E5	7	A	8	9	10	11	A	12	13	A	A
E8	9	10	11	12	13	14	15	A	16	17	A
F9	A	5	6	7	8	9	10	11	12	13	14
G1	9	10	11	12	13	14	15	16	17	18	19
G2	5	6	7	8	9	10	11	12	13	14	15
G7	7	8	A	9	10	11	A	12	13	A	14
G8	A	8	A	9	10	11	A	A	12	A	13
H3	6	7	8	9	10	11	A	12	13	14	15
J4	4	5	6	7	8	9	10	11	12	13	14
K0	7	8	9	10	11	12	13	14	15	16	17
K5	7	8	A	9	10	A	A	A	A	A	A
K7	8	A	9	10	11	A	12	13	14	15	16
K8	7	8	9	10	11	12	13	14	15	16	17
M9											
M3	8	9	10	11	12	13	14	15	16	17	18
M5	8	9	10	11	12	13	14	15	16	A	17
M9	9	10	11	12	13	14	15	16	17	A	18
N8	13	14	15	16	17	A	18	19	20	A	21
N6	7	8	9	10	11	12	A	13	14	15	16
P0											

R.G.M. COLLEGE OF ENGINEERING & TECHNOLOGY (Autonom

ATTENDANCE

Class : IV. B Tech II Sem

Branch : ECE-A

REGISTER — Academic Year fr

Roll No.	Name	09/01/23
		(1)
4A5	mastan Be. S	A
4B3	mounika. V	1
4B5	Naga Sahitya. m	1
4C6	Niranjan Reddy. G	1
4C9	Padmaja. N	A
4D6	Pavithra. A	A
4D9	Prasanth. G	1
4E1	Prathyusha. B	A
4E3	Praneeth Teja. A	A
4E4	Radhamma P	A
4E5	Raghavendra Reddy. P	1
4E8	Rajasekhar Reddy. B	A
4F9	Sai Divya. V	A
4G1	Sai mythili N	A
4G2	Sai naga mounika T	A
4G7	Sai sadha. T	A
4G8	Sai Varshini. Y	A
4H3	Sairaj Kumar. D	A
4J4	Shailusha. V	A
4K0	Sivahalika. K	A
4K5	Sreevani. T	A
4K7	Subhash Reddy. Y	A
4K8	Suchitra. G	A
4M9	Sumanth. D	A
4M3	Sumanth. M	A
4M5	Sumanthi. K	A
4M9	Surekha. V	A
4N8	Surendra Reddy. B	1
4N6	Susmitha. C	A
4P0	Thasun. M	A
Signature of Teacher		
Signature of H.O.D.		
Signature of Principal		

Roll No.	24	25	26	27	28	29	30	31	32	33	34
6J5											
6J3	22	23	A	A	24	25	26	A	27	28	29
6J5	22	A	23	24	25	A	26	A	A	27	28
6C6	19	20	21	22	23	24	25	A	26	27	28
6C9	17	A	18	A	A	A	A	19	20	21	22
6D6											
6D9	13	A	14	15	16	17	18	A	19	20	21
6E1	15	16	17	18	A	A	19	20	21	22	23
6E3											
6E4	17	18	19	20	21	22	23	A	24	25	26
6E5	A	14	15	16	17	18	19	20	A	21	A
6E8	A	A	A	18	19	20	21	22	A	23	24
6F9	15	16	17	18	19	A	20	21	22	23	24
6G1	20	A	21	A	A	22	23	A	24	25	26
6G2	16	A	17	18	19	20	21	22	23	24	25
6G7	15	16	17	A	A	A	A	A	18	19	20
6G8	14	A	15	A	16	17	18	A	19	20	21
6H3	A	A	16	17	18	19	20	A	21	22	23
6J4	15	16	17	18	19	A	20	21	22	23	24
6K0	18	19	20	21	22	23	24	25	26	27	28
6K5	11	12	13	14	15	16	17	18	A	19	A
6K7	17	18	19	20	21	A	22	23	A	24	A
6K8	A	18	A	A	A	19	20	21	22	23	24
6M9											
6M3	19	20	21	22	A	A	23	24	25	26	27
6M5	18	19	20	A	A	A	21	22	A	23	24
6M9	19	A	20	A	21	22	23	24	25	A	A
6N8	A	A	22	23	A	24	25	26	A	A	27
6N6	17	18	19	20	21	22	23	24	25	26	27
6P0											

Roll No.	35	36	37	38	39	40	41	42	43	44	45
6J5											
6J3	A	30	31	32	33	A	34	35	36	37	38
6J5	29	30	31	32	33	34	35	36	37	38	39
6C6											
6C9	23	24	25	26	27	28	29	30	31	32	33
6D6											
6D9	32	23	34	25	26	A	27	28	29	30	31
6E1	24	25	26	27	28	A	29	30	31	32	A
6E3											
6E4	27	28	29	30	31	32	33	34	35	36	37
6E5	A	22	23	24	25	A	A	A	A	A	26
6E8	25	26	27	28	29	A	30	31	32	33	A
6F9	25	26	27	28	29	A	30	31	32	33	34
6G1	27	28	29	30	31	A	A	32	33	34	35
6G2	26	27	28	29	30	31	32	33	34	35	36
6G7	21	22	23	24	25	A	26	27	28	29	30
6G8	22	23	24	25	26	27	28	29	30	31	32
6H3	24	25	26	27	28	A	A	A	29	30	31
6J4	25	26	27	28	29	30	31	32	33	34	35
6K0	29	30	31	32	33	A	A	34	35	36	37
6K5	20	21	22	23	24	A	25	26	A	27	A
6K7	25	A	26	27	28	29	30	31	A	32	A
6K8	25	26	27	28	29	A	30	31	32	33	34
6M9											
6M3	28	29	30	31	32	A	33	34	35	36	37
6M5	25	26	27	28	29	A	30	31	32	33	34
6M9	A	26	27	28	29	30	31	32	33	34	35
6N8	28	A	29	30	31	32	33	34	35	36	A
6N6	28	29	30	31	32	A	33	34	35	36	37
6P0											

R.G.M. COLLEGE OF ENGINEERING & TECHNOLOGY (Autonomou

ATTENDANCE

Class : IV. B Tech II Sem

Branch : ECE-A

REGISTER Academic Year from

Roll No.	Name	20/01/23
		(1)
4A5	mastan Be.S	A
4B3	mounika.V	1
4B5	Naga Sahitya.m	1
4C6	Niranjan Reddy.G	1
4C9	padhmaja.N	A
4D6	Pavithra.A	A
4F9	prasanth.G	1
4E1	prathyusha.R	A
4E3	pruneeth Teja.A	A
4E4	Radhamma P	A
4E5	Raghavendra Reddy.P	1
4E8	Rajasekhar Reddy.B	A
4F9	Sai divya.V	A
4G1	Sai mythili.N	A
4G2	Sai naga mounika.T	A
4G7	Sai Sneha.T	A
4H8	Sai Varshini.Y	A
4J3	Sairaj Kumar.D	A
4J4	Shailusha.V	A
4K0	Sivahalika.K	A
4K5	Sreevani.T	A
4K7	Subhash Reddy.Y	A
4K8	Suchitra.G	A
4M9	Sumanth.D	A
4M3	Sumanth.M	A
4M5	Sunandhni.K	A
4M9	Surekha.V	A
4N8	surendra Reddy.B	1
4N6	Susmitha.C	A
4P0	Thasun.M	A
Signature of Teacher		
Signature of H.O.D.		
Signature of Principal		

Roll No.	20/01/23	21/01/23	23/01/23	24/01/23	25/01/23	27/01/23	28/01/23	29/01/23	31/01/23	03/02/23	04/02/23
	46	47	48	49	50	51	52	53	54	55	56
4A5					A						
4B3	39	40	A	A	41	42	43	44	45	46	47
4B5	40	A	41	42	43	44	45	46	47	48	49
4C6					A						
4C9	34	35	A	A	A	A	36	37	38	39	40
4D6					A						
4F9	32	A	A	A	33	34	A	35	36	37	38
4E1	A	A	A	A	A	33	34	35	A	36	37
4E3					A						
4E4	38	A	A	A	A	39	40	41	42	43	44
4E5	27	28	29	A	30	A	31	A	A	32	33
4E8	A	A	A	A	34	35	36	37	38	39	40
4F9	35	36	37	38	39	40	A	41	42	43	44
4G1	36	37	38	39	A	A	A	A	A	A	40
4G2	37	38	39	40	41	42	43	A	A	A	A
4G7	31	32	33	34	35	A	36	37	38	A	A
4H8	33	A	A	A	A	34	A	35	36	37	38
4J3	29	A	A	A	A	33	34	35	36	37	38
4J4	36	A	A	A	A	A	A	37	38	39	40
4K0	38	A	A	A	A	A	39	40	41	42	43
4K5	28	29	A	A	A	30	31	A	32	A	A
4K7	33	34	35	36	37	38	39	40	A	41	42
4K8	35	A	A	36	37	38	39	40	41	42	A
4M9					A						
4M3	A	38	A	A	A	39	40	41	42	43	44
4M5	35	A	A	A	A	A	36	37	38	39	A
4M9	36	37	A	A	A	A	38	39	40	41	42
4N8	37	A	38	A	A	A	39	40	A	41	42
4N6	A	A	A	A	A	38	39	40	41	42	43
4P0					A						
	P	P	P	P	P	P	P	P	P	P	P

Roll No.	06/04/23	10/04/23	11/04/23	12/04/23	15/04/23	17/04/23	18/04/23	19/04/23	20/04/23		
	57	58	59	60	61	62	63	64	65	66	67
4A5											
4B3	48	49	50	51	52	53	54	55	56		
4B5	50	51	52	53	54	55	56	57	58		
4C6											
4C9	A	41	42	43	44	45	46	47	48		
4D6											
4F9	A	39	40	41	42	43	44	45	46		
4E1	38	39	40	41	42	43	44	45	46		
4E3											
4E4	45	46	47	48	49	50	51	52	53		
4E5	A	34	35	36	37	38	39	A	40		
4E8	A	41	42	43	44	45	46	A	47		
4F9	A	45	46	47	48	49	50	A	51		
4G1	41	42	43	44	45	46	47	48	49		
4G2	A	44	45	46	47	48	49	50	51		
4G7	A	39	40	41	42	43	44	A	45		
4H8	A	39	40	41	42	43	44	45	46		
4J3	A	39	40	41	42	43	44	45	46		
4J4	A	41	42	43	44	45	46	A	47		
4K0	44	45	46	47	48	49	50	A	51		
4K5	A	33	34	35	36	37	38	39	40		
4K7	A	43	44	45	46	47	48	49	50		
4K8	A	43	44	45	46	47	48	49	50		
4M9											
4M3	A	45	46	47	48	49	50	51	52		
4M5	40	41	42	43	44	45	46	47	48		
4M9	A	43	44	45	46	47	48	49	50		
4N8	A	43	44	45	46	47	48	A	49		
4N6	44	45	46	47	48	49	50	51	52		
4P0											
	P	P	P	P	P	P	P	P	P		

& TECHNOLOGY (Autonomous), NANDYAL.

REGISTER Academic Year from 2022 to 23 Teacher

Subject & Credits Sc & 3 Dept BCB

INTERNAL / RECORD MARKS

Roll No.	Assignments 1	2	Average (A)	Internal Test 1	2	Internal Marks 75% of MAX	25%of MIN	Total (I)	Final Internal (I+A)	Remarks
A3	10	10	10	17	19	14.25	4.25		29	
B3	10	10	10	15	17	12.75	3.75		27	
B5	10	10	10	15	11	11.25	3.75		24	
C6	10	10	10	13	AB	9.75	0		20	
C9	10	10	10	13	12	9.75	3		23	
D6	10	10	10	AB	11	8.25	0		19	
D9	10	10	10	09	14	10.5	2.25		23	
E1	10	10	10	17	11	12.75	2.75		26	
E3	10	10	10	11	AB	8.25	0		19	
E4	10	10	10	17	14	12.75	3.5		27	
E5	10	10	10	09	11	8.25	2.25		21	
E8	10	10	10	12	16	12	3		25	
F9	10	10	10	19	19	14.25	4.75		29	
G1	10	10	10	14	14	10.5	3.5		24	
G2	10	10	10	18	15	13.5	3.75		28	
G7	10	10	10	15	AB	11.25	0		29	
G8	10	10	10	15	14	11.25	3.5		25	
H3	10	10	10	09	07	6.75	1.75		19	
J4	10	10	10	15	14	11.25	3.5		25	
K0	10	10	10	16	15	12	3.75		26	
K5	10	10	10	13	10	9.75	2.5		23	
K7	10	10	10	16	07	12	1.75		24	
K8	10	10	10	12	07	9	1.75		21	
M2	10	10	10	AB	09	6.75	0		17	
M3	10	10	10	14	10	10.5	2.5		23	
M5	10	10	10	16	14	12	3.5		26	
M9	10	10	10	16	12	12	3		25	
N2	10	10	10	17	15	12.75	3.75		27	
N6	10	10	10	13	08	9.75	2		22	
P0	10	10	10	AB	17	12.75	0		23	

R.G.M. COLLEGE OF ENGINEERING & TECHNOLOGY (Autonomous)

ATTENDANCE REGISTER

Class : IV. B.Tech II Sem

Branch : ECE - A

Semister / Year

Roll No.	Name	09/01/23	10/01/23	11/01/23	12/01/23	17/01/23	18/01/23	19/01/23	20/01/23	21/01/23	23/01/23	25/01/23	27/01/23
		1	2	3	4	5	6	7	8	9	10	11	12
19091A0484	Vaishnavi.m	1	2	3	A	A	4	A	5	6	7	8	9
481	Vasundhara.C	A	A	A	A	A	1	2	3	4	5	6	7
486	Venkata madhuri.N	A	A	A	A	A	A	A	1	2	3	4	5
4R1	Vijay kumari.B	A	A	A	A	A	A	A	1	2	3	4	5
450	Vyshnavi.A	A	A	A	A	A	1	A	2	3	4	5	A
459	Vyshnavi.L	A	A	A	A	A	1	2	3	4	5	6	7
455	Yerikalatadi.K	A	A	A	A	1	2	3	4	5	6	7	8
456	Yugandhar Reddy.S	1	2	3	4	5	6	7	8	9	10	11	12
20095A0401	Afrin.S	A	A	1	2	3	4	5	6	7	8	9	10
493	Venkata Sai.P	A	A	A	A	A	A	-	16/01/2023				
		P	P	P	P	P	P	P	P				
19095A0409	patan Imrankhan (19/11/2003)	←	From				→	A	1	2	A	3	4

Signature of Teacher	P	P	P	P	P	P	P	P	P	P	P	P
Signature of H.O.D.												
Signature of Principal												

Roll No.	28/01/23	30/01/23	31/01/23	01/02/23	02/02/23	03/02/23	04/02/23	06/02/23	08/02/23	09/02/23	10/02/23
	13	14	15	16	17	18	19	20	21	22	23
484	10	11	12	13	14	15	16	17	18	A	19
481	8	9	10	11	12	13	14	15	16	A	A
486	6	7	8	9	10	11	A	A	12	13	14
4R1	6	7	A	8	9	10	A	11	12	13	14
450	6	7	8	9	10	11	12	13	A	14	15
459	A	8	A	9	10	11	A	12	13	A	14
455	A	9	10	11	12	13	A	14	15	A	16
456	13	14	15	16	17	18	A	19	20	21	22
401	11	12	13	14	15	A	16	17	A	A	18
493											
409											
	P	P	P	P	P	P	P	P	P	P	P

R.G.M. COLLEGE OF ENGINEERING & TECHNOLOGY (Autonomous)

ATTENDANCE REGISTER

Class : IV. B.Tech II Sem

Branch : ECE - A

Roll No.	Name	Date 6/11/23
19091A04 404	Vaishnavi.m	1
401	Vasundhara.c	A
406	Venkata madhuri.N	A
421	Vijay kumar.B	A
430	Vyshnavi.A	A
452	Vyshnavi.L	A
455	Yerikalatah.K	A
456	yugandhar Reddy.S	1
20091A04 401	Abrin.S	A
403	Venkata Sai-P	A
		P
17691A04 409	patan Imrankhan (19/11/2023)	←

R.G.M. COLLEGE OF ENGINEERING & TECHNOLOGY (Autonomous)

ATTENDANCE REGISTER

Class : IV - B.Tech II Sem

Branch : ECE - A

Roll No.	Name	Date 09/01/23
484	Vaishnavi.m	1
401	Vasundhara.c	A
486	Venkata madhuri.N	A
481	Vijay Kumar.B	A
450	Vyshnavi.A	A
452	Vyshnavi.L	A
455	Yerikaladah.K	A
456	Yugandhar Reddy.S	1
401	Abrin.S	A
483	Venkata Sai.P	A
		P
409	Patan Imrankhan (19/11/2003)	←
	Signature of Teacher	P
	Signature of H.O.D.	
	Signature of Principal	

	20/01/23	21/01/23	23/01/23	24/01/23	25/01/23	27/01/23	28/01/23	29/01/23	31/01/23	03/02/23	04/02/23
Roll No.	46	47	48	49	50	51	52	53	54	55	56
484	A	A	A	A	A	A	A	A	40	41	42
401	33	34	35	36	37	38	39	40	41	42	43
486	A	A	A	A	A	35	36	37	38	39	40
481	31	32	33	34	35	36	37	38	39	A	A
450	37	A	A	A	A	A	A	38	39	40	41
452	28	29	A	30	31	32	33	34	A	A	A
455	34	A	35	36	A	37	38	39	40	41	42
456	40	A	A	41	A	42	43	44	45	46	A
401	36	37	38	A	39	40	41	42	43	44	45
23											
02											
	P	P	P	P	P	P	P	P	P	P	P

	06/07/23	10/04/23	11/07/23	13/07/23	15/07/23	17/07/23	18/07/23	19/07/23	20/07/23		
Roll No.	57	58	59	60	61	62	63	64	65	66	67
484	43	44	45	46	47	48	49	50	51		
401	A	44	45	46	47	48	49	50	51		
486	A	41	42	43	44	45	46	47	48		
481	A	40	41	42	43	44	45	46	47		
450	42	43	44	45	46	47	48	49	50		
452	A	43	44	45	46	47	48	49	50		
455	A	43	44	45	46	47	48	49	50		
456	A	47	48	49	50	51	52	A	53		
401	46	47	48	49	50	51	52	A	53		
23											
02											
	P	P	P	P	P	P	P	P	P		

& TECHNOLOGY (Autonomous), NANDYAL.

REGISTER Academic Year from 2022 to 23 Teacher

Subject & Credits SC & 3 Dept ECE

INTERNAL / RECORD MARKS

Roll No.	Assignments 1	2	Average (A)	Internal Test 1	2	Internal Marks 75% of MAX	25%of MIN	Total (I)	Final Internal (I+A)	Remarks
04	10	10	10	16	12	12	3		25	
01	10	10	10	18	17	13.5	4.25		28	
06	10	10	10	13	06	9.75	1.5		22	
07	10	10	10	08	12	9	2		21	
30	10	10	10	11	09	8.25	2.25		21	
52	10	10	10	17	AB	12.75	0		23	
55	10	10	10	11	15	11.25	2.75		24	
56	10	10	10	12	19	14.25	3		28	
01	10	10	10	15	19	14.25	3.75		28	
23	10	10	10	AB	15	11.25	0		22	
02										

LECTURE RECORD

Subject : SC (A)
Total Exams 2
Credits : 3
Each for 3 hr & 2 hr hrs.
Internal Mid Exam Marks : 30
Total quizes
Internal Quiz Marks : 2
No. of Assignment 2

S.No.	Date	Topic Covered / Exercise Completed	Remarks: No of periods	Remarks: Cumul.
		UNIT-I		
1	09/01/2023	Introduction	1	1
2	10/01/2023	Background and history of Satellite communications.	1	2
3	11/01/2023	overview of Satellite communication, Frequency allocation to satellite services	1	3
4	12/01/2023	Design considerations of S.C	1	4
5	17/01/2023	advantages & disadvantages of Sat.	1	5
6	18/01/2023	Applications of Satellite communication	1	6
7	19/01/2023	orbital mechanics - Developing the equations of orbit, Kepler's laws	1	7
8	20/01/2023	describing the orbit of Satellite, locating the Satellite in orbit	1	8
9	21/01/2023	Locating the Satellite with respect to surface of earth, orbital elements	1	9
10	23/01/2023	problems related to T, a, e etc	1	10
11	25/01/2023	Look Angles Determination	1	11
12	27/01/2023	Look Angles Determination	1	12
13	28/01/2023	orbital perturbations	1	13
14	30/01/2023	Launches & Launch Vehicles, placing the Satellite in GEO orbit	1	14
15	31/01/2023	orbital effects on Communication System	1	15
16	01/02/2023 & 02/02/2023	project reviews	2	17
17	03/02/2022	Review of the Unit-1	1	18
18	04/02/2023	problems on Doppler Shift, Orbit	1	19
		UNIT-II		
19	06/02/2023	Attitude control System	1	20
20	08/02/2023	Telemetry, Tracking & monitoring System	1	21
21	09/02/2023	power System, Communication Systems	1	22
22	10/02/2023	Satellite antennas, Space qualification, Redundancy	1	23
23	13/02/2023	Reliability & expectation	1	24
		UNIT-III		
24	15/02/2023	Introduction, Basic transmission theory	1	25
25	16/02/2023	System noise temperature, G/T, C/T, NR.	1	26
26	17/02/2023	Downlink design	1	27
27	20/02/2023	uplink design	1	28
28	21/02/2023	Specified C/N ratio	1	29

LECTURE RECORD

S.No.	Date	Topic Covered / Exercise Completed	Remarks: no of periods	Remarks: cumulative periods
29	29/03/23	overall C/N0 with uplink radio attenuation, downlink attenuation	1	30
30	23/03/23	Design procedure, encircle problems	1	31
31	24/03/23	problems & their solutions	1	32
32	01/03/23	mid-I papers solutions	1	33
		UNIT-IV		
33	02/03/23	Introduction to multiple Access techniques	1	34
34	03/03/23	Frequency division multiple Access, Intermodulation	1	35
35	04/03/23	TDMA, bits, symbols, Frame Structure	1	36
36	06/03/23	Synchronization in TDMA, power tx, guard times, Sat switched TDMA	2	37 39
37	07/03 to 09/03	project Reviews	1	40
38	10/03/2023	DAMA, problems	1	41
39	14/03/2023	CDMA and example		
		UNIT-VI		
40	15/03/2023	Introduction, radio & satellite navigation	1	42
41	16/03/2023	Gps position location principles, Gps time	1	43
42	17/03/2023	Gps Receivers & codes	1	44
43	18/03/2023	Gps codes	1	45
44	20/03/2023	satellite signal Acquisition, Gps navigation message	1	46
45	21/03/2023	Gps signal levels	1	47
46	23/03/2023	Timing Accuracy, C/A code Accuracy	1	48
47	24/03/2023	Differential Gps, Selective availability	1	49
48	25/03/2023	Gps codes - generation of C/A code	1	50
49	27/03/2023	Signal generation in Gps satellite	1	51
50	28/03/2023	Revision of multiple Access techniques	1	52
51	29/03/2023	Revision of Gps	1	53
		UNIT-V		
52	31/03/2023	orbital considerations - Types of orbits	1	54
		Types of orbits	1	55
53	03/04/2023	coverage & frequency considerations	1	56
54	04/04/2023	coverage & frequency considerations	1	57
55	06/04/23	continuation		

LECTURE RECORD

S.No.	Date	Topic Covered / Exercise Completed	Remarks	
56	10/04/23 & 11/04/23	} project 3rd review	2	59
57	13/04/23	Introduction to DBS-TV, frequency bands used in Home satellite TV	1	60
58	15/04/23	DBS-TV Receiver block diagram	1	61
59	17/04/23	DBS-TV link budget	1	62
60	18/04/23	DBS-TV marked uplink station	1	63
61	19/04/23	Installation of DBS-TV	1	64
62	20/04/23	Revision	1	65

X

20/4/23.

S.No. 93836

RAJEEV GANDHI MEMORIAL COLLEGE OF ENGINEERING & TECHNOLOGY
AUTONOMOUS
Accredited by NAAC of UGC, New Delhi with 'A' Grade:: Accredited by NBA
Affiliated to JNT University Anantapur
Nandyal - 518 501, Kurnool Dist, A.P.

(ESTD-1995)

INTERNAL EXAMINATIONS ANSWER BOOKLET

NAME OF THE STUDENT: G. Jaswanth Reg. No. 1 9 0 9 1 A 0 4 6 5

	Autonomous	2	3	4	5
A	1		2		1
B	1	22	1		3
C					
D					
E	0				
Total	2	22	3		4
Grand Total :(In Figures)	112=12				
(in Words):	ONE TWO				

NAME OF THE SUBJECT: Satellite Communication
INTERNAL EXAM : I / II
Date of Exam: 25/02/2023 (FN/AN)
Course : B.Tech. / M.Tech./ MBA / MCA
Year : IV Sem.: II
Branch: ECE

Signature of the Invigilator

(Start Writing From Here)

Q5)

b) We want to calculated look angles and Azimuthal angle

Given that

the earth station latitude is 52.0° and longitude is 0°

and the sub satellite point is 66.0°E

① Central angle of satellite (γ)

$\cos(\gamma) = \cos(LE)\cos(ls - lc)$

$= \cos(52.0)\cos(66-0)$

$= \cos(52)\cos(66)$

$\cos(\gamma) = 0.2504$

$\gamma = 75.6989°E$

∴ Since γ is less than 81 then it is visible in earth station

② Elevation angle (El) :-

$El = \tan^{-1}(6.9867 \times 10^{3} \text{ km} - \cos\gamma/\sin\gamma) - \gamma$

$El = \tan^{-1}[6.9867 \times 10^{3} \text{ km} - 0.2504/\sin(75.698)] - 75.698$

$El = 5.094$ (or) 5.084

③ Intermediate angle (α) :-

$$\alpha = \frac{\tan^{-1}(ls - le)}{\sin(le)}$$

$$\alpha = \frac{\tan^{-1}(66-0)}{\sin(75.698)}$$

$\alpha = 70.968$

④ Azimuthal angle $= 180° - \alpha$

$= 180 - 70.968$

$= 109.02$

Q3)

a) telemetry and monitoring system is satellites are Excellent operation in Communication satellites

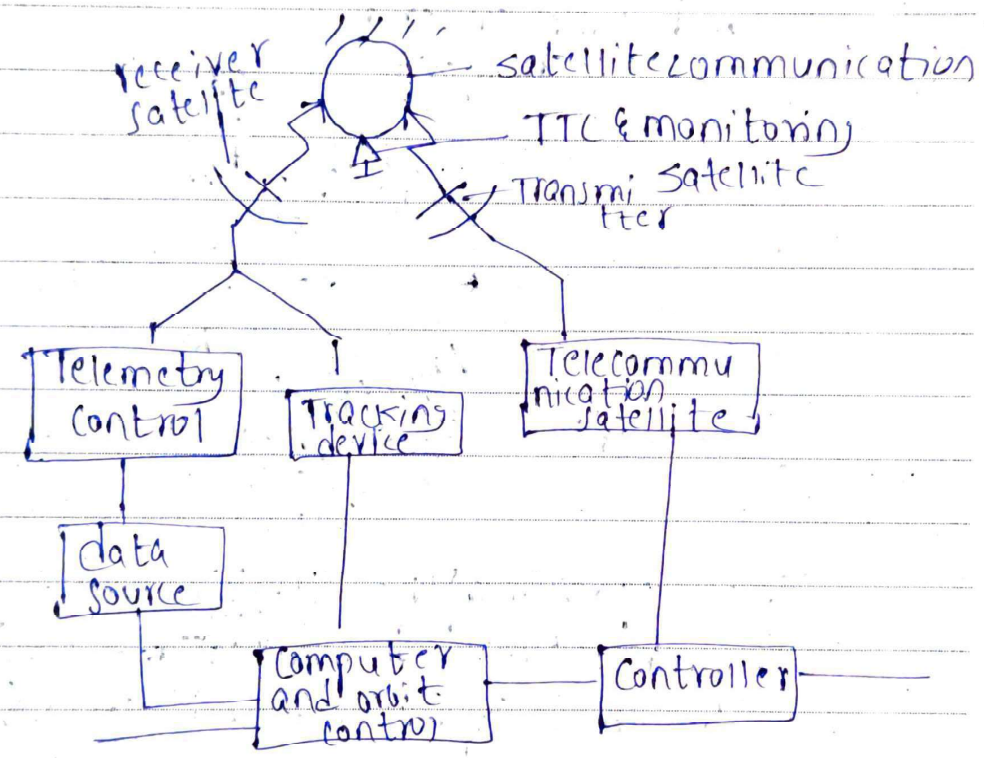
It is owned and third party may be under Control of this operation

-> Monitoring the satellite is collect the data from different sensors from satellite and it can send the data of the earth station

-> The telemetry tracking Command and monitoring communication plays major role in satellites the tracking is used to detect the current orbit of the

satellite and it has computer and orbit controller is there

→ The command is used to send the arguments from earth station to satellite and then the monitoring is monitor allover 100 satelites and collect the data then send the data to earth station

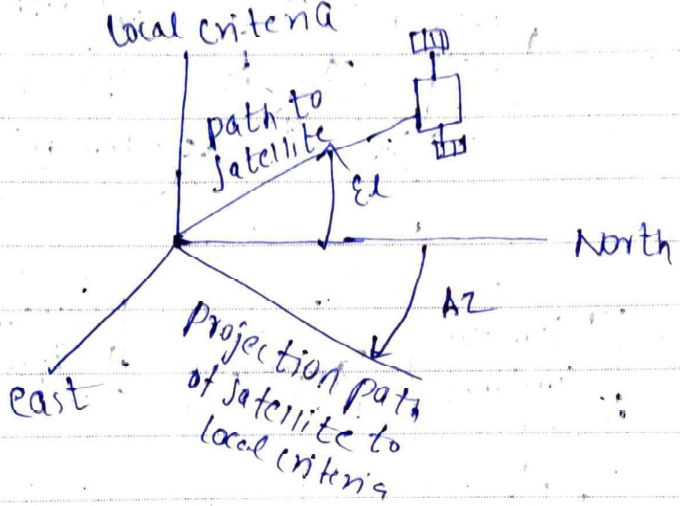


→ The above figure shows the process of telemetry Tracking Command and monitoring satellite

→ The TTC & monitoring device has all tracking and commanding and then monitoring These all the during major function is satellite communication

Q3) b)

The elevation angle is one of the type in look angles. The elevation angle hay used to upper zone of north region and it has travelled the path to satellite and then the elevation angle is situated between north and local criteria.



The Expression of the Elevation angle is

$$El = \tan^{-1}\left[6.9836 - \cos\theta / \sin\theta \right] - \theta$$

The above Expression is the Elevation angle

El = Elevation angle of the Satellite

Cosθ = central angle of Satellite

The Elevation angle hay used the Equation due to find the range of the satellite Communication and then the Elevation angle has major type of look angle and then it has traveled in North direction and through the satellite

Q2)

b) The bathtub curve for probability of failure and this used to calculate the reliability of Satellite System

$$R(t) = \frac{N_s(t)}{N_0}$$

$N_f(t) = N_0 - N_s(t)$ N_0 = total No of satellites

$N_f(t) = N_0 - N_s(t)$

mean time before failure = $\frac{\sum_{i=1}^{N_s} t_i}{N_0}$

Average time rate = $\frac{1}{\lambda} = 1/N_s \frac{N_f}{\Delta t}$

$$1/\lambda = 1/N_s \cdot \frac{N_f}{\Delta t}$$

$$1/\lambda = 1/N_s \cdot \frac{dN_s}{dt}$$

$$1/\lambda = \frac{1}{R N_0} \cdot \frac{d(R N_0)}{dt}$$

$$1/\lambda = \frac{d}{dt}$$

$$\therefore \boxed{R = e^{-\lambda t}} \quad \boxed{R = e^{-\lambda t}}$$

This is the reliability of Satellite system

Q5)

a) The orbital elements has some of the elements are used to locate the orbital plane with respect to the earth station

--> The satellite communication the transmitter is higher than the receiver here the transmitter and receiver are the elements

In satellite the orbit plane has the spherical wave has converted in to orbit plan by using reflecter antenna.

→ The horn antenna and reflector antenna has used to converted spherical into orbit plane

→ The North direction the orbit plane has located this founded we want to use Tracking device is used to detect the location of the orbit plane.

→ The Horn and reflector antenna are very useful in this orbit plane with respect to earth station

→ power energy and subsatellite point and then some of the elements are occured in this orbital plane in earth station

Q1)

a) Satellite is a communication device and it is used to transmits the information from sender to receiver by using microwave frequencies and this satellites has mobile satellite service and Navigational satellite services etc

freq range		band designations
0.1 - 0.2	—	Vm
0.2 - 1.0	—	[illegible]
1.0 - 2.0	—	L

2.0 - 4.0	—	C
4.0 - 8.0	—	X
8.0 - 18.0	—	m
12.0 - 18.0	—	ku
18.0 - 40.0	—	K
40 - 75	—	ka
75 - 110	—	M
110 - 300	—	X
300 - 3000	—	um

e) The Subsatellite point is in satellite communication hay satellites are divided in subsatellity like latitude and ~~alter~~ longitude and it hay ranges are there. The satellite latitude and longitude hay sub satellite points are there.

→ The uplink frequency is higher than down link frequency because it hay C band and frequency band hay used in uplink frequency that's why always uplink frequency is higher than downlink frequency

16)

The Equation of orbital period in satellite Communication is

$$T^2 = \frac{4\pi^2 a^3}{u}$$

$$a^3 = \frac{T^2 u}{4\pi^2}$$

$$a = \left(\frac{T^2 u}{4\pi^2}\right)^{1/3} = \left(\frac{T^2 u}{4\pi^2}\right)^{1/3}$$

S.No. 77195

RAJEEV GANDHI MEMORIAL COLLEGE OF ENGINEERING & TECHNOLOGY

AUTONOMOUS

Accredited by NAAC of UGC, New Delhi with 'A' Grade:: Accredited by NBA

Affiliated to JNT University Anantapur

Nandyal - 518 501, Kurnool Dist, A.P.

(ESTD-1995)

INTERNAL EXAMINATIONS ANSWER BOOKLET

NAME OF THE STUDENT: B. Ganesh Naidu Reg. No. 19091A0449

	1	2	3	4	5
A	1	12		2	1
B		2		22	22
C	1				
D	0				
E	1				
Total	3	32		42	32
Grand Total :(In Figures)	42+15				
(in Words):	one FIVE				

NAME OF THE SUBJECT: SC

INTERNAL EXAM : I / II

Date of Exam: 21/04/2023 (FN/AN)

Course : B.Tech. / M.Tech./ MBA / MCA

Year : IV Sem.: II

Branch: ECE

21/04

Signature of the Invigilator

(Start Writing From Here)

20

1 a) The technique in which the transponder in Satellite is able to carry more then one Signal is known as Multiple Access Techniques.

Types of Multiple Access Techniques are

(i) Frequency Divison Multiple Access (FDMA)

(ii) Time Divison Multiple Access

(iii) Coded Divison Multiple Access.

c) There are mainly two codes are used in Gps Satellites.

(i) P-code (Precise Code)

(ii) C/A code (Coorse Code).

(i) Precise code is generally used for the

Authorized Services like Military this is modulated at 10.23 Mbps.

(ii) C/A code (Coarse Code) :-

This is used for public services / generally used by public which is modulated at 1.023 Mbps.

e) GPS satellite Navigation Message :-

The GPS satellite Navigation Message consists of the information about the satellite position and health of the satellite.

Structure :-

Header	data frame 1	data frame 2 & 3	data frame 4	data frame 5

Header :- consists of telemetry data and health of satellite.

data frame 1 :- consists info about satellite correlation.

data frame 2 & 3 :- consists info about ephemeral data of 1-25 / higher satellites.

data frame 4 :- consists info about 1-24 satellites.

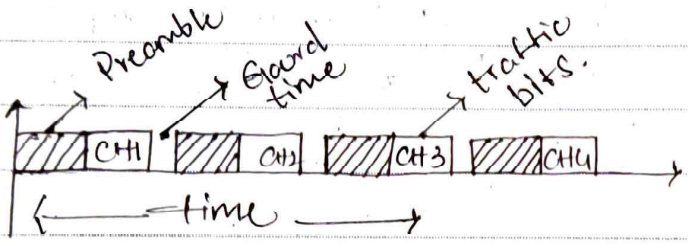
data frame 5 :- malace data of satellite health of satellites.

Q2

a) Time Divison Multiple Accessing :-

In the time divison multiple accessing the user gets accessi to the satellite baied on the allocated time slots.

Structure of TDMA :-



Preamble :-

This will contain the info about the synchro nization of data.

Traffic bits :-

This contains the actual information that we want to send.

Guard time :-

This is used to ~~geuard the~~ avoid the collison between the collison of the data bits.

In TDMA, the information is stered in form of brusts (large data).

The data brusts are generally sent to the satellite sequentially.

The receiver has to be aware about the when to send the data. If not there will a chance of data ~~burst~~ loss / collison.

To send these large data bursts we need high powered transmitter for easy transmission of data

~~This TDMA is operated in~~

In TDMA signals are transmitted through the in digital manner. compared to FDMA this has the lower errors and more speed.

b) Given,

Number of earth stations (N) = 5.

Frame duration (T_{frame}) = 2ms = 200μs.

Permeable time (T_{per}) = 20μs.

Gaurd bands (T_g) = 5μs.

* Data brust duration $T_d = \frac{[T_{frame} - N(T_g + T_{per})]}{N}$

$= \frac{200\mu s - 5[20\mu s + 5\mu s]}{5}$

$= \frac{200\mu s - 5[25\mu s]}{5} = \frac{200\mu s - 125\mu s}{5}$

$= \frac{75\mu s}{5} = 15\mu s.$

$T_d = 15\mu s.$

$$C_b = \frac{T_d \times R_b}{T_{frame}}$$

Where R_b = bit rate

for QPSK $R_b = 2$ (baud rate)

$= 2$ (30 M baud)

$= 60$ M baud.

$$= \frac{150 \times 10^{-6} \times 60 \times 10^6}{200 \times 10^{-6}} = 4.5 \times 10^6.$$

Number of channels

$$n = \frac{C_b}{T_{rec}} = \frac{4.5 \times 10^6}{200 \times 10^3 \times 64} = 7.03$$

$n = 7$

7 channels can be formed.

Q4)

a) GPS Space segment:-

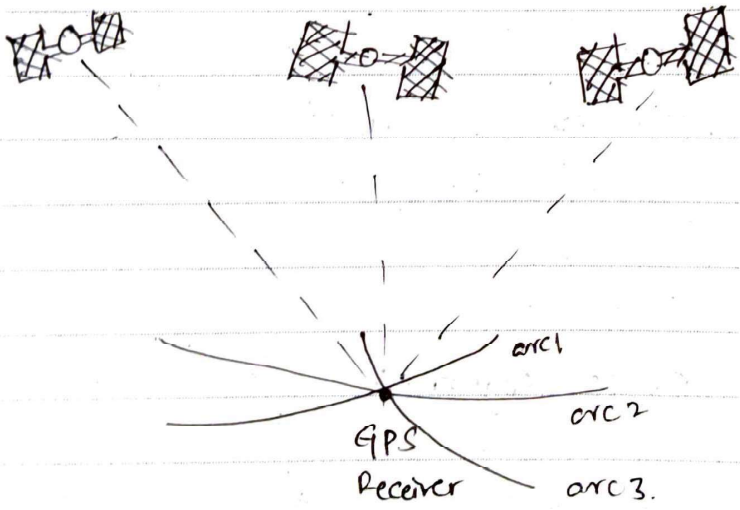
* For the working of GPS, around 60 satellites are used which continously revolve around the earth.

* These satellites are place at the MEO orbit which is at a height of 20,200 kms from the earth.

* To find the position one GPS receiver we will use group of four Satellites which is called as constellation.

* These four satellite are separated by 60° latitude with each other to get the Precise location and to get the better result.

b) Principle that is used to locate the Position in GPS.



To find out the position of the GPS receiver we will firstly sends the high powered RF signals to the GPS receiver.

These RF signal will have the ~~higher~~ velocity of the light.

By using the advanced digital clocks we will measure the time taken by the signal to reach the GPS receiver.

By using the speed and different equation the distance is calculated.

Now, satelite as the center and the distance as radius we will draw three arc. Where the intersection of two points takes place.

Here ignore the farthest point and consider the closest point.

By performing the different operations / calculations we can get the longitude and lattiude of the GPS receiver.

We can also measure the location in Rectangular co-ordinate system which takes the earth as its center and known as Earth fixed Earth centered co-ordinate system.

Let the A & B are two points in the Rectangular co-ordinate system then the distance between them is defined as

$$R^2 = (U_A - X_i)^2 + (U_B - X_i)^2 + (U_C - X_i)^2$$

the distance between the satellite and GPS receiver is given as.

$R_i = T_i \times C$.

T_i = Propagation delay.

C = Speed of RF signal.

we will also use the fourth satellite for the GPS ~~because~~ for syncronization and as reference.

5) Timing Accuracy:-

a) ~~Timing accuracy in GPS means to obtain the location of the GPS accurately respective to time.~~

To locate the position of the GPS receiver accurately at specific time. The high the accuracy ~~high the~~ increases the efficiency of GPS.

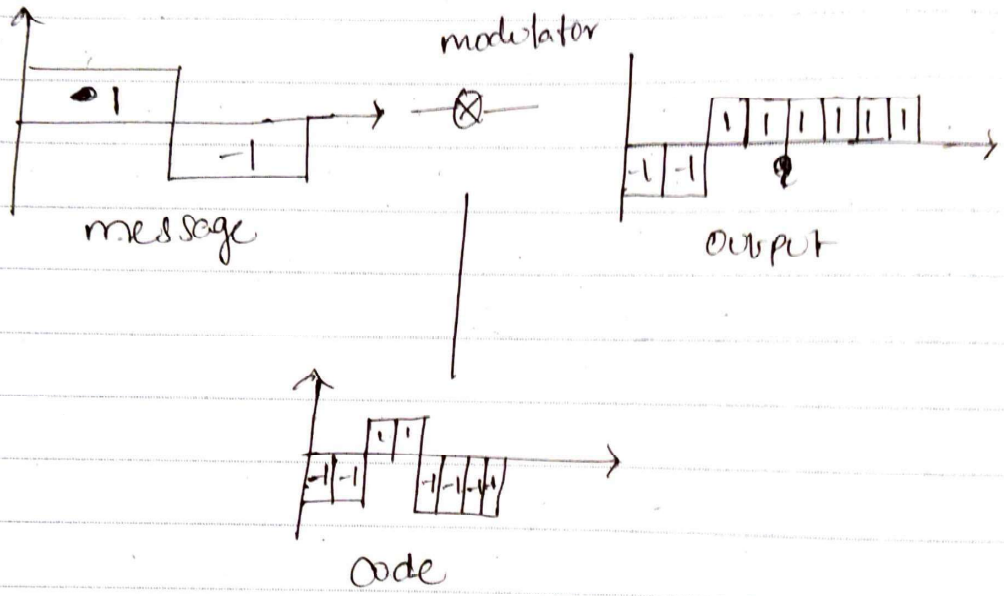
Major sources of errors in GPS:-

* Weaker signals
* [redacted] Manufacturing errors.
* Response Delays.
* choosing low power modulation.

b) Code divison Mulbiple Access:

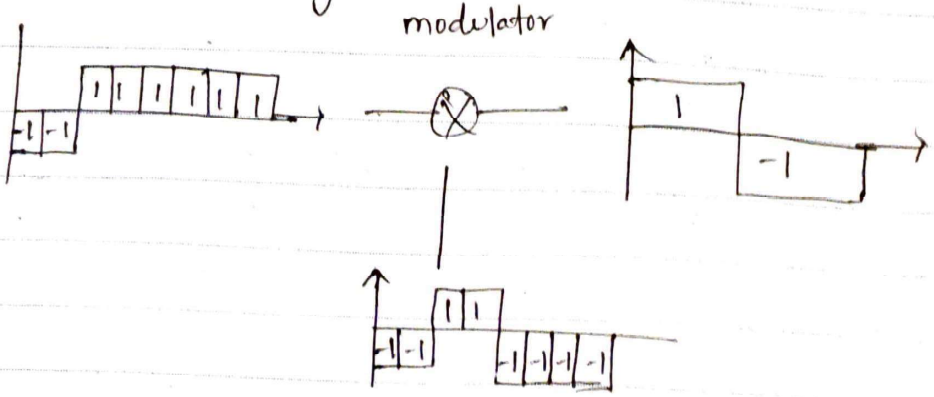
In code divison multiple access ofer will get access to satellites at any frequency and time but the messages are ~~[redacted]~~ retrived / transmitted on the basis of codes.

Transmitting of data in CDMA:



Here the +1 is considered as one e.(1) and -1 is considered as '0'.

The output is 'sent' through the channel and this output when reaches the receiver they have to perform the multiplication with same code to avoid any errors.



By multiplying the received code at receiver we can retrive the message that we send.

22

1

d) 'L' frequency band is used for home satelite TV.

5



Assignments

SC ASSIGNMENT-I

1) LEO satellite is in a circular polar orbit with an altitude of 1000km.A transmitter on the satellite has frequency of 2.65GHz.Find

a) The velocity of the satellite in orbit.

b) The component of velocity toward an observer at an earth station as the satellite appears over the horizon, for an observer who is in the plane of the satellite orbit.

2 A) Explain in detail about attitude and orbit control systems in satellites.

B) Draw the simplified diagram of single conversion 6/4GHz Transponder.

3A) Calculate the system noise temperature and G/T ratio of simplified earth station receiver.

B) What is significance path loss in satellite communication?

Satellite Communication

V. Mounika
19091A04B3
ECE-A.

Assignment - I

(1) A LEO satellite is in a circular polar orbit with an altitude of 1000km. A transmitter on the satellite has frequency of 2.65 GHz. Find.

a) The velocity of the satellite in orbit

b) The component of velocity toward the observer at an earth station as the satellite appears over the origin, for an observer who is in the plain of satellite orbit.

Sol: a) $T^2 = \frac{4\pi^2}{\mu} a^3$ Given $h = 1000km$

$r = 6378$. $\mu = 3.98 \times 10^5$

$T^2 = \frac{4\pi^2 (7378)}{3.98 \times 10^5}$

$a = r + h$

$= 6378 + 1000$

$a = 7378$.

$T^2 = 3.977 \times 10^7 s^2$.

$T^2 = 6306.94$ sec

Velocity $V = \frac{2\pi a}{T} = \frac{2 \times 3.14 \times 7378}{6306.94}$.

$V = 7.35$ km/sec

b) The component velocity towards an observer in the plain of orbit as the satellite appear over the origin $V_r = V \cos\theta$

$\cos\theta = \frac{r_e}{r_e + h} = \frac{6378}{7378} = 0.8645$.

$V_r = V \cos\theta$.

$= 7.35 \times 0.8645$.

$V_r = 6.354$ km/s $V_r = 6354$ m/s

2a) Explain in detail about altitude & orbital control system in detail.

Sl:- * The altitude of a satellite is its position in the space and its orientation

* This subsystem i.e Aocs consists of rocket motors that are used to move the satellite back to the correct orbit when external forces cause it to drift off station and gas jets or inertial devices that control the altitude of a satellite.

* The altitude and orbit of a satellite must be control so that satellite's antennas point toward the earth and so that user knows where in the sky to look for the satellite.

* Some forces acting on an orbiting satellite that tends to change its altitude and orbit are.
→ Gravitational fields of the sun and moon
→ Irregularities in the earth's gravitational field.
→ solar pressure from the sun
→ variation in the earth's magnetic field.

Attitude control system:-

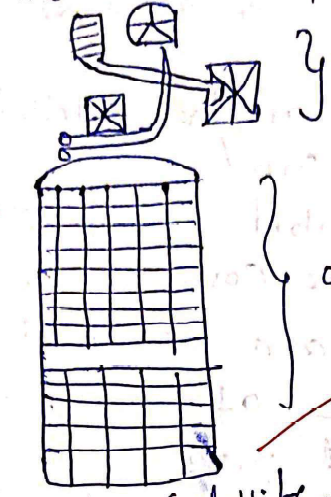
→ There are two ways to make a satellite stable when it is in orbit and weightless.
① spinning the satellite (i.e spin stabilization)
② using momentum wheels. (i.e 3-axis stabilization).

① spin stabilization:-

* The entire body of the satellite can be rotated at a rate 30 to 100 rpm, to create gyroscopic force that provides stability of the spin axis and keeps it pointing in the same direction. such satellites are called spinners.

* As shown in the following figure spinner satellite consists of a cylindrical drum covered with solar cells that contains the power systems and the rocket

motors. The communication system is mounted at the top of the drum and is driven by an electric motor in the opposite direction to the rotation of the satellite body to keep the antennas pointing toward the earth.



spinner Satellite.

2) 3-Axis stabilization Satellite :-

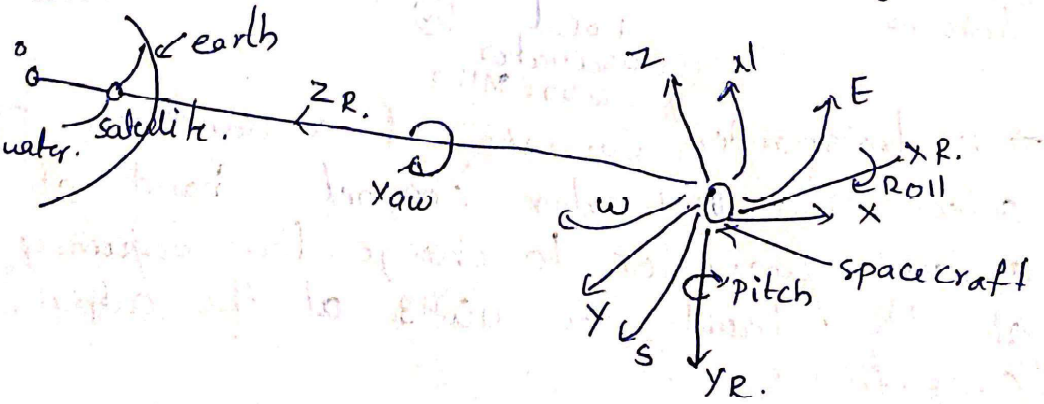
→ A satellite can be stabilized by one or more momentum wheels.

→ This is called three axis stabilized satellite.

→ The momentum wheel is usually a solid metal disk driven by an electric motor

→ Either threre must be one momentum wheel for each of the three axis of the satellite or, a single momentum wheel can be mounted.

→ In 3-axis stabilized satellite, one pair of jets is needed for each axis to provide for rotation in both direction of pitch, roll and yaw. with 3-momentum wheels rotation of the satellite about each axis can be Commanded by earth station



Orbital Control system:-

→ A geostationary orbit must be circular at a correct altitude on the equatorial plane.

→ If the orbit is not circular, velocity change is to be made along the orbit for altitude correction, z-axis gas Jet is used.

→ Various forces acting on the satellite will pull the satellite out of the correct orbit.

→ The function of orbit control system is to return the satellite into the correct orbit.

→ Some forces acting on a Geo stat satellite are

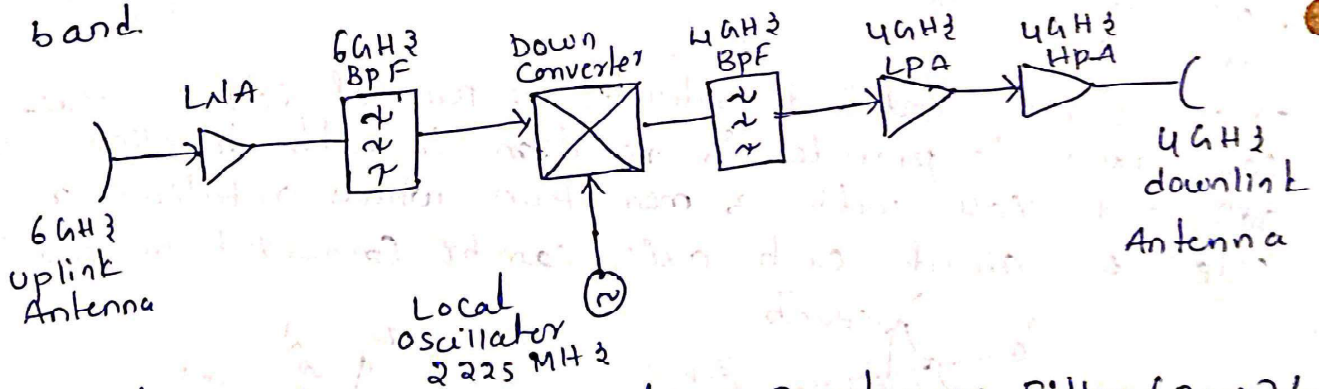
*The gravitation forces of moon and sun, which cause inclination of orbital plane.

* Non spherical shape of earth around the equator which causes drift of subsatellite point.

2.b. Draw simplified single conversion transponder for 6/4 GHz band.

*The bands currently used for the majority of services are 6/4 GHz, 14/11 GHz and 30/20 GHz coming into service.

*The below diagram shows a simplified block diagram of a satellite communication subsystem for the 6/4 GHz band.



→ A transponder consists of a Band pass Filter (BPF) to select the particular channel's band of frequencies, a down converter to change the frequency from 6GHz at the input to 4GHz at the output, and an o/p amplifier.

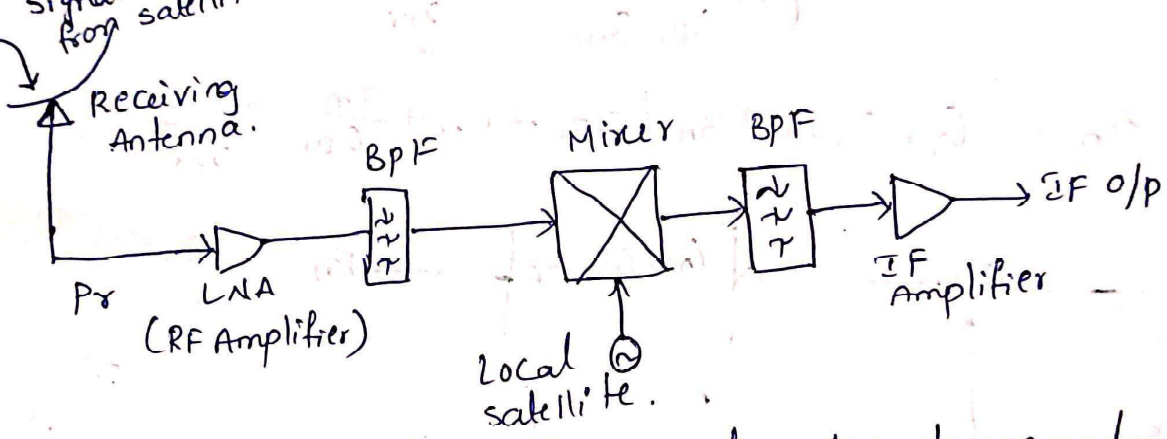
→ The o/p power amplifier is usually a solid state power amplifier. And if very high o/p power is required, then travelling wave tube amplifier is used as a o/p power amplifier.

→ The local oscillator is at 2225 MHz to provide the appropriate shift in frequency from 6GHz uplink frequency to the 4GHz downlink frequency

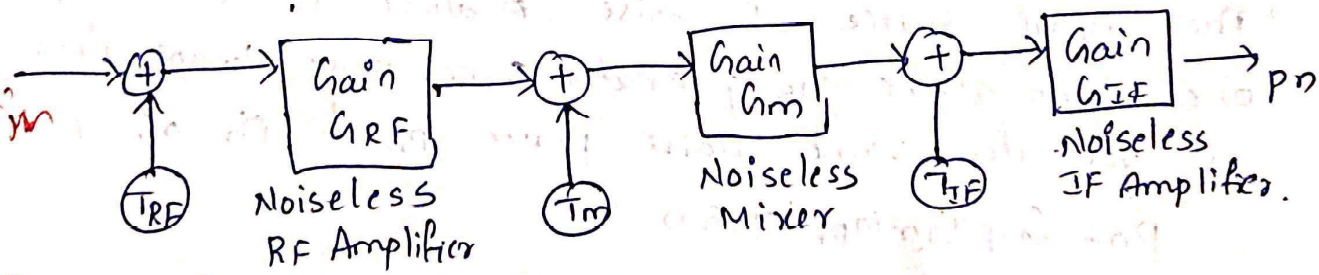
→ A BPF after the mixer removes unwanted frequencies resulting from the down conversion operation.

3.a) Calculate system noise temperature & G/T ratio of s.c

System Noise Temperature :-



→ For the purpose of analysis of noise temperature, the above receiver can be represented by an equivalent circuit as shown below.



→ In the above figure G_{RF}, G_m, G_{IF} are the gains of RF amplifier, mixer and IF Amplifier T_{RF}, T_m, T_{IF} are the equivalent noise temperatures of RF amplifier, mixer, IF amplifier.

→ T_{in} is the noise temperature of antenna.

→ The noisy devices in the receiver are replaced by equivalent devices (noiseless) with the same gains and noise generators at the input to each block, such that the block produces the same noise at the o/p as the device it replaces.

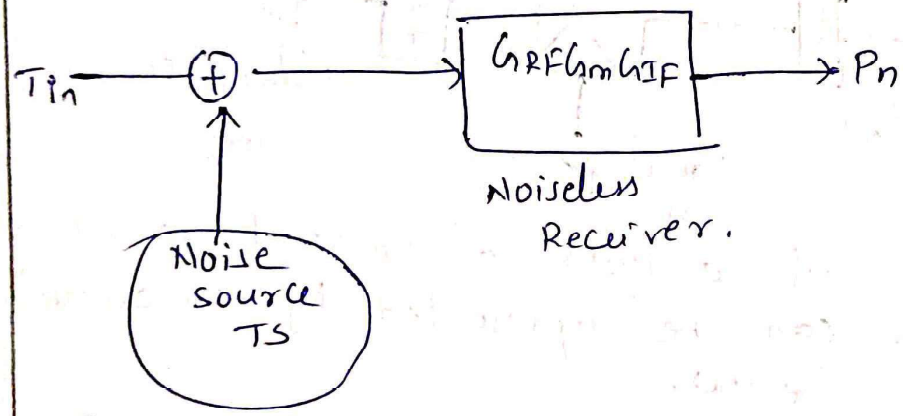
→ From the above figure, the total noise power at the o/p of IF amplifier of the receiver is given by

$$P_n = G_{IF} k T_{IF} B_n + G_{IF} G_m k T_m B_n + G_{IF} G_m G_{RF} k B_n (T_{RF} + T_m)$$

The above equation can be rewritten as

$$P_n = G_{IF} G_m G_{RF} \left[\frac{k T_{IF} B_n}{G_{RF} G_m} + \frac{k T_m B_n}{G_{RF}} + (T_{RF} + T_{in}) k B_n \right]$$

$$P_n = G_{IF} G_m G_{RF} k B_n \left[T_{RF} + T_{in} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_{RF} G_m} \right]$$



The signal source of noise in above figure with noise temperature T_S generates some noise temperature T_S generates some noise power P_n at its o/p if

$$P_n = G_{IF} G_m G_{RF} k T_S B_n$$

$$k T_S B_n = k B_n \left[T_{in} + T_{RF} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_m G_{RF}} \right]$$

$$\boxed{T_S = \left[T_{in} + T_{RF} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_m G_{RF}} \right]}$$

$\therefore T_S$ is the equivalent noise temperature.

G/T ratio :-

We know received power, $P_r = \frac{P_t G_t G_r}{\left(\frac{4\pi R}{\lambda}\right)^2}$

and noise power $P_n = kT_s B_n$.

The link equation can be rewritten interms of $\left(\frac{C}{N}\right)$ at earth station as

$$\left[\frac{C}{N}\right] = \left[\frac{P_t G_t G_r}{T_s k B_n}\right]\left[\frac{\lambda}{4\pi R}\right]^2$$

$$\left[\frac{C}{N}\right] = \left[\frac{P_t G_t}{k B_n}\right]\left[\frac{\lambda}{4\pi R}\right]^2\left[\frac{G_r}{T_s}\right]$$

Here $\frac{C}{N} \propto \frac{G_r}{T_s}$

The ratio $\frac{G_r}{T_s}$ is called $\frac{G}{T}$ ratio in dB/k.

The $\frac{G}{T}$ ratio is used to specify the quality of a receiving earth station or a satellite receiving system, since increasing G_r/T_s increases the received $\frac{C}{N}$ ratio.

3.b) What is the significance of path loss in S.C?

Path loss is the reduction of power density of are signal as it propogate through space. path loss is the major component in the analysis and design of the link budget of a satellite communication system. Pathloss may be due to many effects such as free-space loss, refraction, reflection and absorption. path loss is also influenced by terrain contours, environment, propogation medium and the height, location of antennas.

Path loss in increases with decreasing of received power (P_r).

$\therefore$ path loss $= \left(\frac{4\pi R}{\lambda}\right)^2$

pathloss is also called as free space transmission loss (FSTL).

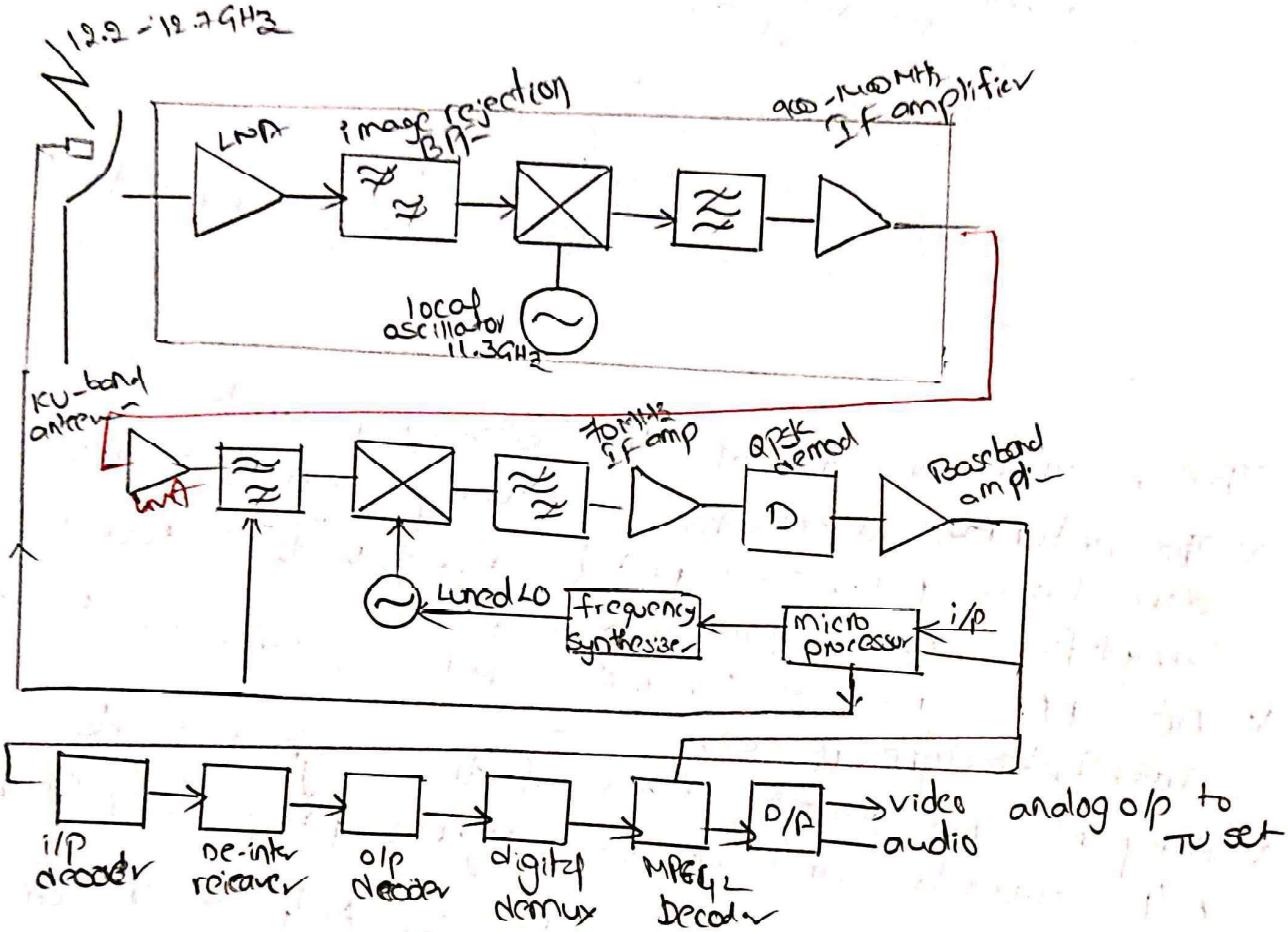
SC ASSIGNMENT-II

1. Explain the block diagram of DBS-TV receiver with neat sketch.
2. Draw and explain the block diagram of GPS receiver in detail.
3. Explain in detail about the TDMA frame structure.

Satellite Communication
Assignment - II

D. Sumanth
19091A04M2
IV - B. Tech
ECE - A

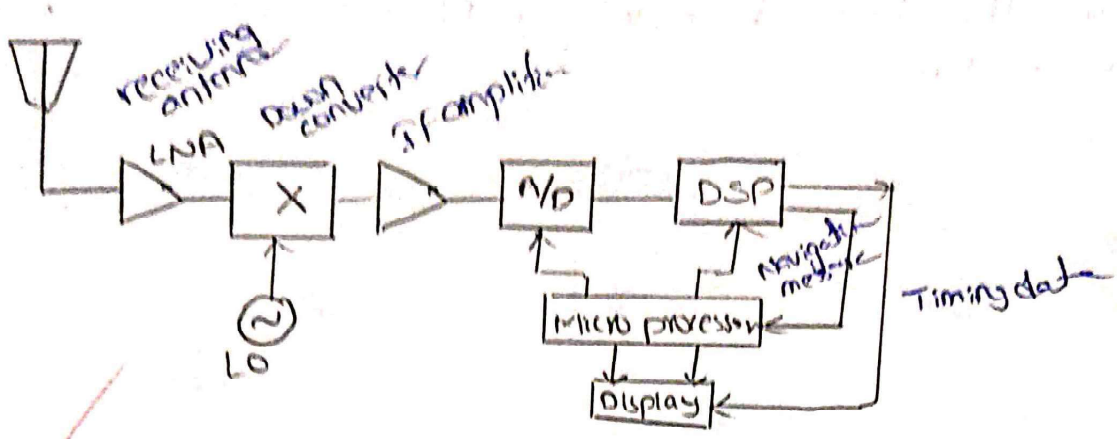
1. Explain the block diagram of DBS-TV receiver with neat sketch.



Block Diagram of DSB-TV receiver

The figure shows a block diagram of a DBS-TV receiver. The entire front end of the receiver is located at the antenna feed in the form of a LNA to minimize loss of signal and hence to maintain the lower possible system noise temperature. The electronic polorizer is switched by changing the voltage supplied to the LNB via the cable that interconnects the antenna and setup receiver. The entire 12.2 to 12.7 GHz band is down converted by the LNB to 900 - 1400 MHz band where cable causes losses are much lower than at Ku-band.

2. Explain the GPS receiver with neat block diagram



The receiver consists of the following units

* The antenna used for receiving signals is of circularly polarized patch type, with a low noise amplifier (LNA) placed over it.
* An IF signal of bandwidth 2MHz is generated by the super heterodyne receiver
* Samping and quantization of this signal is done by A/D converter and digital signal processing (DSP) unit.

The process is carried out with the help of I and Q techniques

I - Inphase carrier
Q - quadrature phase carrier

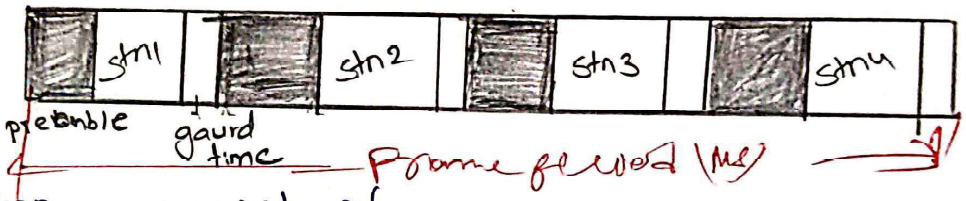
* DSP unit consists of

1) A C/A code generator
2) A correlator that chooses the required gold code
3) A microprocessor that makes the timing measurements

3. Explain about TDMA frame structure in detail.

TDMA frame structure:

* TDMA frame contains the signals transmitted by all earth stations in TDMA network.
* It has a fixed length
* Gaurd times b/w each burst are used to avoid collision of adjacent earth station data.
* Frame exists only on satellite transponder and on down link - from satellite.



TDMA frame consists of

1) Preamble: It contains synchronization and other data essential to the operation of network, before sending data preamble also contains carrier and bit clock synchronization waveforms

2) Traffic: This is the actual data

3) Gaurd band: gaurd bands are used in b/w the earth stations to avoid collisions of data.

College Code: 09

R-19

Rajeev Gandhi Memorial College of Engineering & Technology

Autonomous

NANDYAL-518501

IV B. Tech II-Semester Mid-I *Examinations*

Satellite Communications

Electronics & Communication Engineering

Max. Marks: 20 Date: 25-02-2023 Time: 2 Hours

Note: 1. Answer first question compulsorily. (5 x 1 = 5 Marks)

2.Answer Any *THREE* from 2 to 5 questions. (3 x 5 = 15 Marks)

Q.1	a)	What is satellite? List the frequency band designations in common use for satellite services.	1M	CO1	BL1
	b)	Develop the equation for orbital period in satellite communications.	1M	CO1	BL3
	c)	Write the Friss transmission equation for the power received by earth station.	1M	CO2	BL1
	d)	What are the ways for placing the satellites into geostationary orbit?	1M	CO1	BL1
	e)	What is subsatellite point? And why uplink frequency is higher than down link frequency?	1M	CO2	BL2
Q.2	a)	Explain the Kepler's three laws of planetary motion.	2M	CO1	BL2
	b)	Explain 'bathtub curve for probability of failure' that is used to calculate the reliability of a satellite subsystem.	3M	CO2	BL3
Q.3	a)	Explain in detail about telemetry and monitoring systems in satellites.	2M	CO2	BL2
	b)	Define elevation angle and derive the expression for it.	3M	CO2	BL3
Q.4	a)	An amplifier has a noise figure of 1.78 and then what is its equivalent noise temperature.	2M	CO2	BL1
	b)	A satellite at a distance of 40000km from a point on the earth surface radiates a power of 10W from an antenna with a gain of 17db in the direction of observer. Find the flux density at the receiving point and power received by an antenna at this point with an effective area of $10m^2$.	3M	CO2	BL3
Q.5	a)	Explain in detail how to locate the orbital plane with respect to the earth and specify the orbital elements.	2M	CO1	BL2
	b)	An earth station situated in docklands of London; England needs to calculate look angle to a GEO stationary satellite in Indian ocean operated by INTEL SAT. The details of earth station site and the satellite are as follows. Earth station latitude and longitudes are 52.0^0 N and 0^0, Satellite longitude sub satellite point is 66.0^0E.	3M	CO1	BL3

****

College Code: 09

R-19

Rajeev Gandhi Memorial College of Engineering & Technology

Autonomous

NANDYAL-518501

IV B. Tech II-Semester Mid-II *Examinations*

Satellite Communications

Electronics & Communication Engineering

Max. Marks: 20 Date: 21-04-2023 Time: 2 Hours

Note: 1. Answer the first question compulsorily. (5 x 1 = 5 Marks)

2. Answer Any *THREE* from 2 to 5 questions. (3 x 5 = 15 Marks)

Q.1	a)	What is the multiple access technique? List out fundamental types of multiple access techniques.	1M	CO3	BL1
	b)	What is the purpose of Molniya orbit?	1M	CO1	BL2
	c)	What are the different codes used in GPS Satellites?	1M	CO5	BL2
	d)	What are the frequency bands used for Home Satellite TV?	1M	CO4	BL1
	e)	What is meant by GPS Satellite navigation message?	1M	CO5	BL2
Q.2	a)	Describe the operation of TDMA scheme.	2M	CO3	BL3
	b)	A TDMA network of five earth stations shares single transponder equally. The frame duration is 2.0ms, the preamble time per station is 20μs and guard bands of 5μs are used between bursts. Transmission bursts are QPSK at 30 Mbaud. Calculate the number of 64kbps voice channels that each TDMA earth stations can transit. If the earth stations send data rather the digital speech, is the transmission rate of earth station in Mbps.	3M	CO3	BL3
Q.3	a)	Explain the coverage of LEO satellite with inclined orbit.	2M	CO1	BL2
	b)	Draw and explain the block diagram of a DBS – TV receiver system.	3M	CO4	BL3
Q.4	a)	Discuss the GPS space segment.	2M	CO5	BL2
	b)	Explain the principles that are used to locate the position in the GPS.	3M	CO5	BL3
5	a)	What is timing accuracy in GPS? And list the major sources of errors in GPS receiver.	2M	CO5	BL2
	b)	Explain the principle behind spectrum spreading and dispreading and this is used to minimize the interference in a CDMA system.	3M	CO3	BL3

****



DEPARTMENT OF ECE

Previous Question Papers And Solutions

RGM COLLEGE OF ENGINEERING & TECHNOLOGY (AUTONOMOUS)

01st July 2023

IV B.Tech. II Sem. (R19) End Examinations (Supplementary)

SATELLITE COMMUNICATION

ECE

Time: 3 Hrs **Total Marks: 70**

Note 1:Answer Question No.1 (Compulsory) and 4 from the remaining

2:All Questions Carry Equal Marks

1a Discuss the various satellite services in brief.

b Write short notes on power systems in satellite communications.

c Write short notes about uplink attenuation.

d Write the disadvantage of VHF and UHF frequency band.

e What are the types of satellites used in GPS?

f Differentiate multiplexing with multiple accesses.

g What is sub satellite point in satellite communications?

2 a) Explain in detail about position location principle and receivers and codes. (7)
b) Explain GPS space segment. (7)

3 a) List different types of orbits to be considered in the design of satellite communication. (4)
b) Explain different types of orbits to be considered in the design of satellite communication. (10)

4 a) A satellite has 4GHz receiver with the following gains and noise temperatures. T_{IN}=25k T_{RF}=50k T_{IF}=1000k T_M=500k G_{RF}=23dB G_{IF}=30Db. Calculate the system noise temperature assuming that the mixture has a gain G_M=0dB. Recalculate the system noise temperature when the mixture has a 10dB loss. How can the noise temperature of the receiver be minimized when the mixture has a loss of 10dB? (7)
b) What is system noise temperature and how it will affect the performance of receiver? (7)

5 a) Draw the block diagram of typical onboard control system for a spinner satellite and explain its operation. (10)
b) What is the term despun in satellites? (4)

6 a) Explain the functioning of demand assigned FDMA and TDMA schemes. (8)
b) What are the advantages of FDMA over TDMA scheme? (6)

7 a) Explain the overview of satellite communications. (8)
b) Explain the various reasons for preferring satellites than optical fibers which are providing very high band width. (6)

- xxx -

RGM college of Engineering & Technology (Autonomous)

01st July 2023 (1/20)

IV. B.Tech II Sem (R19) Bral Examinations (Supple)

Satellite Communication code: A04411980723

ECE marks: 70

scheme of Evaluation

1@ These are the service provided by satellite are
Fixed satellite services (FSS)
Broadcasting satellite services (BSS)
mobile satellite services (MSS)
Navigational satellite services (NSS)
meteorological satellite services (MetS).
* mobile satellite service is the Telecommunication services include telephone calls and services provided to telephone companies, as well as wireless, mobile and cellular network providers.
* Broadcasting services include radio & television delivered directly to the consumer & mobile broadcasting services. [2m]

(b) Power system is a vital subsystem, which provides the power required for working of a satellite. mainly, the solar cells (or panels) and rechargable batteries are used in these systems. [2m]

(c) In satellite communication, an uplink is the link from a ground station up to a satellite. In uplink attenuation, rain fall results in attenuation of radio waves by scattering, and absorption, of energy from the wave. Rain attenuation increases with increasing frequency. [2m]

(d) Very high frequency (VHF) is the ITU designation for the range of radio frequency electromagnetic

waves (radio waves) from 30 to 300 MHz. Frequencies immediately below VHF are denoted high frequency (HF), and the next higher frequencies are known as ultra high frequency (UHF)

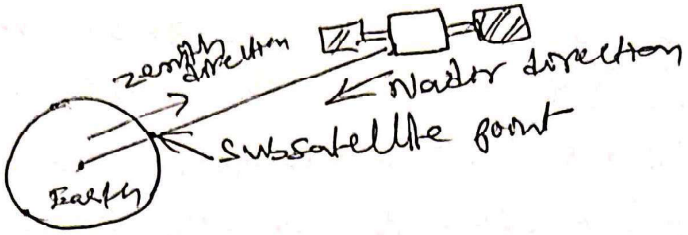
* VHF radio waves propagate mainly by line-of-sight, so they are blocked by hills and mountains. i.e shorter range, can't get signals through wall & windows.
* Another limitation of VHF frequencies is that they are often line of sight. It's range will be less outside when compared to VHF. [2m]

(e) The types of satellites used in GPS are
* personal GPS
* Commercial GPS
* military GPS
* GPS devices for personal use are meant to be used by the general public for things like navigating to a destination.
* Commercial GPS are used by companies & businesses [2]

(f) * multiplexing is the process of combining a no. of signals into a single signal, so that it can be processed by a single amplifier or transmitted over a single radio channel. The multiplexing applies to signals that are generated at one location. [3m]
* The ability of the satellite to carry many signals at the same time is known as multiple access. multiple access refers to signals from a no. of different geographical locations. [2m]

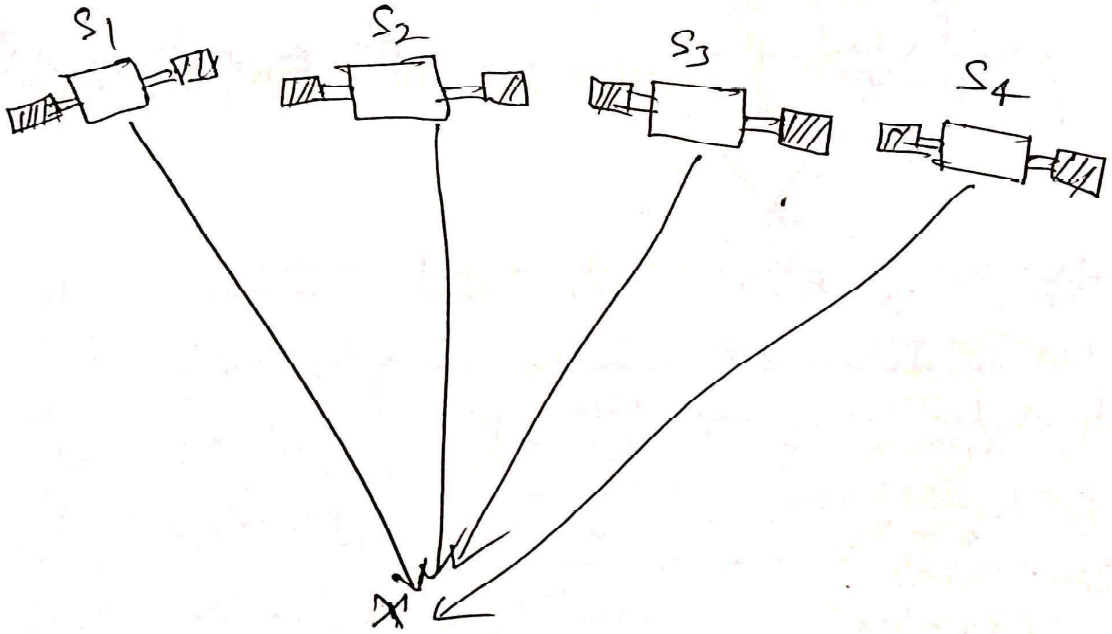
(g) The subsatellite point is the location on the surface of the earth that lies directly between the

satellite and center of the earth.



[2m]

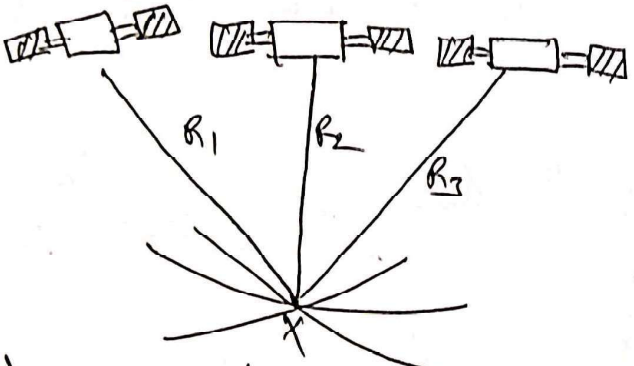
2@ The basic requirement of a satellite navigation system like GPS is that there must be 4 satellites transmitting coded signals from known positions. Three satellites are required to provide the three distance measurements, and the 4th to remove receiver clock error. Figure shows the general arrangement of position location with GPS.



The 3-satellites provide distance information when the GPS receiver makes with ~~GPS~~ three measurements of range R_i, from the receiver to 3-known points. Each distance R_i can be the radius of a sphere with a GPS satellite at its center. The receiver

lies at the intersection of three such spheres, with a satellite at the center of each sphere. Define the coordinates of the GPS receiver & the GPS satellites in a rectangular coordinate system with its origin at the center of the earth. This is called the earth centered earth fixed (ECEF) coordinate system.

The receiver coordinates are (U_x, U_y, U_z), and the four satellites have coordinates (X_i, Y_i, Z_i), where $i = 1,2,3,4$. The measured distance to satellite i is called a pseudorange, PR_i



$$PR_i = T_i \times C$$

$$R^2 = (x_A - x_B)^2 + (y_A - y_B)^2 + (z_A - z_B)^2$$

[4 marks]

The equations which relate ~~travel~~ pseudorange to time delay are called ranging equations.

$$(X_1 - U_x)^2 + (Y_1 - U_y)^2 + (Z_1 - U_z)^2 = (PR_1 - T_c)^2$$
$$(X_2 - U_x)^2 + (Y_2 - U_y)^2 + (Z_2 - U_z)^2 = (PR_2 - T_c)^2$$
$$(X_3 - U_x)^2 + (Y_3 - U_y)^2 + (Z_3 - U_z)^2 = (PR_3 - T_c)^2$$
$$(X_4 - U_x)^2 + (Y_4 - U_y)^2 + (Z_4 - U_z)^2 = (PR_4 - T_c)^2$$

where T is receiver clock error (offset or bias)

GPS Receivers & Codes:-

GPS satellites transmit using pseudorandom sequence (PN) codes. All 24 satellites transmit on L1

code at the same carrier frequency, 1575.42 MHz, called L1, using BPSK modulation.
The P-code is transmitted using BPSK modulation at the L2 carrier frequency of 1227.6 MHz, and is also transmitted with BPSK modulation on the L1 carrier frequency, in phase quadrature with the C/A code BPSK modulation.

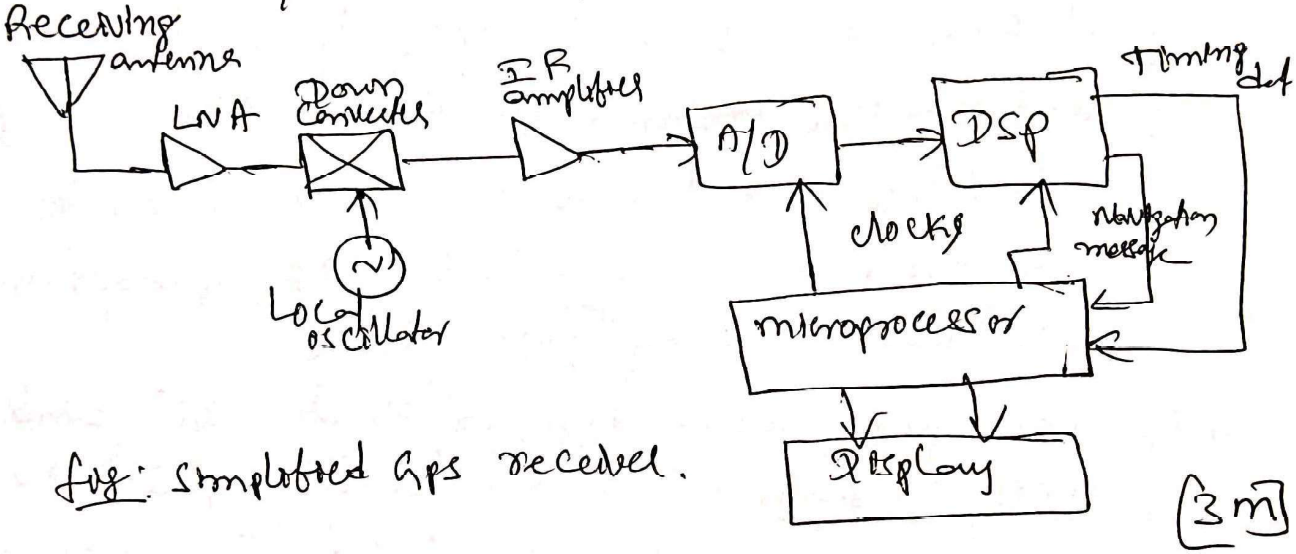


fig: simplified GPS receiver. (3M)

(b) The GPS space segment consists of 24 satellites in medium earth orbit (MEO) at a nominal altitude of 20,200 km with an orbital inclination of 55°. The satellites are clustered in groups of four, called constellations, with each constellation seperated by 60° in longitude. The orbital period is approximately one-half a sidereal day 11 hr 58 min. So the same satellites appear in the same position in the sky twice each day. The satellites carry station-keeping fuel and are

maintained in the required orbits by occasional station-keeping maneuvers, just like GEO satellite the orbits of the 24 GPS satellites ensure that any time, anywhere in the world, a GPS receiver can pick up signals from at least four satellites. up to 10 satellites may be visible at some times, and more than four satellites are visible nearly all of the time. Replacement satellites are launched as needed, so there may be more than 24 operational GPS satellites at any given time.

3 @ There are several types of Earth orbit, and each offers certain advantages and capabilities.

* LEO (Low earth orbit): LEO is commonly used for communication and remote sensing satellite systems, as well as the International space station (ISS) and Hubble Space Telescope.

* MEO (medium Earth orbit):
MEO is commonly used for navigation systems, including the U.S. Global positioning System (GPS).

* GEO (Geostationary orbit (GEO) or Geosynchronous orbit (GSO)):-

Objects in GSO have an orbital speed that matches the Earth's rotation, yielding a constant position over a single longitude. GEO is a kind of GSO.

GEO & GSO are used for telecommunications & Earth observation.

* Polar orbit (PO)
* Sun-synchronous orbit (SSO)
* Highly-Elliptical orbit (HEO) [4m]

b) Types of orbits: (based on shape)

1) Circular orbit
2) Elliptical orbit

orbits are classified interms of height from earth surface:

1) Low earth orbit (LEO) – Altitude from earth surface is 500 to 1500km. LEO is commonly used for communication and remote sensing satellite systems, as well as the International space station (ISS) and Hubble space telescope.
2) Medium(or) middle Earth orbit (MEO): The altitude of this orbit is 5000 km to 10,000 km. This is commonly used for navigation systems, including the U.S. Global positioning system (GPS)
3) GEO (Geostationary orbit): This orbit altitude approximately 36,000 km from earth surface. Objects in GEO have an orbital speed that matches the earth's rotation, yielding a consistent position over a single longitude. GEO is a kind of GSO (Geosynchronous orbit), GEOs GSO are used for telecommunications & Earth observation.

(4) Polar orbit: within 30° of earth's poles, the polar orbit is used for satellites providing reconnaissance, weather tracking, measuring atmospheric conditions, and long term earth observation.

(5) Sun-synchronous orbit (SSO): A type of polar orbit, SSO objects are synchronous are with the sun, such that they pass over an earth region at the same local time every day

(6) Highly Elliptical orbit (HEO): An HEO is oblong, with one end nearer the Earth and other more distant. Satellites in HEO are suited for communications, satellite radio, remote sensing and other applications. [3m]

For circular orbit

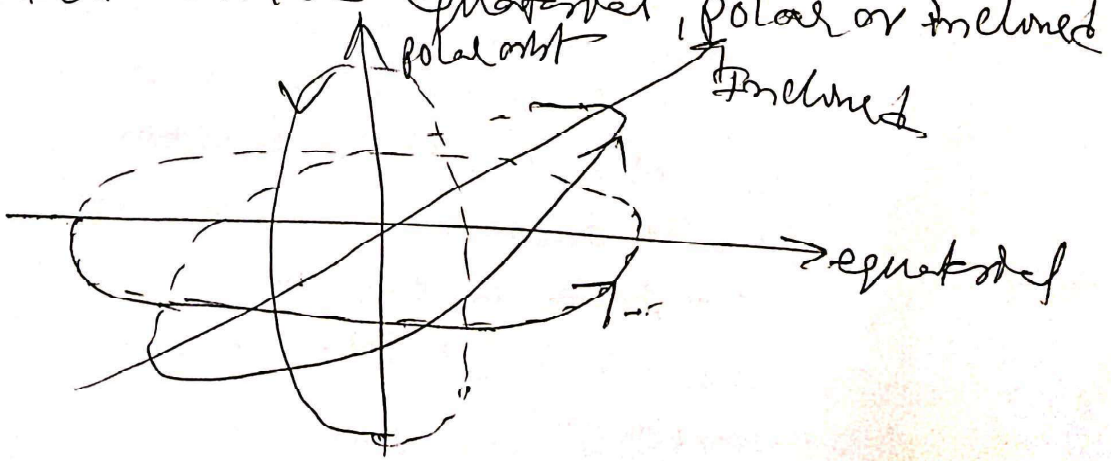
To send a satellite at a height 'h' the required velocity is

$$v = \sqrt{\frac{g}{r+h}}$$

r → radius of earth (6378 km)

g → gravitational coefficient

A satellite rotates around the earth with an orbit, that can be equatorial, polar or inclined



For circular orbit, required velocity of satellite,

$$v_s = \sqrt{\frac{g_0}{r_{eth}}}$$

The orbit period and angular velocity are related by $t_s \cdot \omega_s = 2\pi$, $\omega_s \rightarrow$ angular velocity in rad/sec

$$\therefore t_s = \frac{2\pi}{\omega_s}$$

Velocity of satellite $v_s = (r_{eth})\omega_s$.

$$\therefore v_s = \frac{\sqrt{g_0}}{(r_{eth})^{1/2}}, \quad \omega_s = \frac{r_e}{r_{eth}}$$

$$\therefore t_s = \frac{2\pi}{\omega_s} = \frac{2\pi}{\sqrt{g_0}} \cdot (r_{eth})^{3/2}$$

$$\therefore \boxed{t_s = \frac{2\pi}{\sqrt{g_0}} \cdot (r_{eth})^{3/2}}$$ [2m]

7@ Given data

$T_{in} = 25K$ $\quad G_{RP} = 23\,dB$

$T_{RP} = 50K$ $\quad G_{RP} = 10\,dB$

$T_{IP} = 1000K$

$T_m = 500K$

The system noise temperature is given by

$$T_s = [T_{in} + T_{RP} + T_m / G_{RP} + T_{IP} / (G_m \cdot G_{RP})]$$

$$= [25 + 50 + 500/200 + (1000/200)] = 87.5K.$$

If the mixer had a loss, as is usually the case, the effect of the IF amplifier would be greater. For $G_m = -10\,dB$, the linear value is $G_m = 0.1$ as a ratio. Then

$$T_s = [25 + 50 + (500/200) + (1000/20)] = 137.5K$$

The lowest system noise temperatures are obtained by using a high gain LNA. Suppose we increase the LNA gain in this example to $G_{RR} = 50\,dB$, $G_{RR} = 10^5$

$$T_S = [25 + 50 + (500/10^5) + (1000/10^4)]$$

$$= 75.1\,K$$

The high gain of the RR LNA amplifier has made the system noise temperature almost as low as it can go : $T_S = T_{in} + T_{RR} = 75\,K$. LNAs for use in satellite receivers usually have gains in the range 40-50 dB.

The term "noise temperature" is generally used to present how much thermal noise is generated from active or passive devices in the receiving system. The noise power P_n is written as noise temperature as follows :

$$P_n = K T_n B$$

* The received system performance is determined by system noise temperature, T_S.
* T_S is also known as effective input noise temperature of the receiver.
* ET is defined as the noise temperature of a noise source located at the i/p of a noiseless receiver, which would produce same contribution to receiver output noise as internal noise of actual system itself.

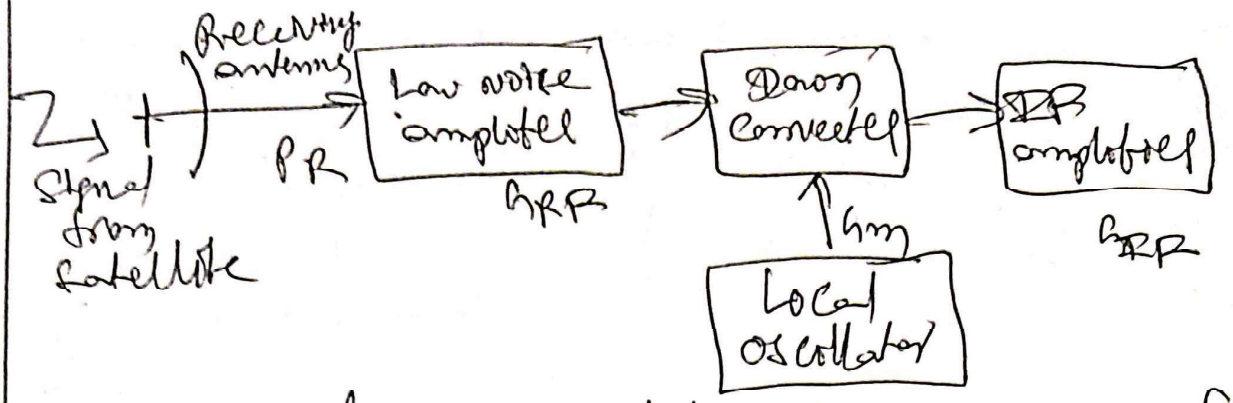


fig: Earth station Receiver [4m]

$P_n = KT_S \cdot B\, G$.

After drawing the equivalent circuit of Receiver Total noise power at the output of IF amplifier is

$$P_n = G_{IF} G_m G_{RF} \cdot K_B \left(T_{RF} + T_{in} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_m G_{RF}}\right) \quad (1)$$

with system noise temperature T_S, the noise power P_n at the output of RF amplifier is

$$P_n = G_{RF} \cdot G_m \cdot G_{IF} \cdot K \cdot T_S \cdot B. \quad (2)$$

From equation (1) & (2)

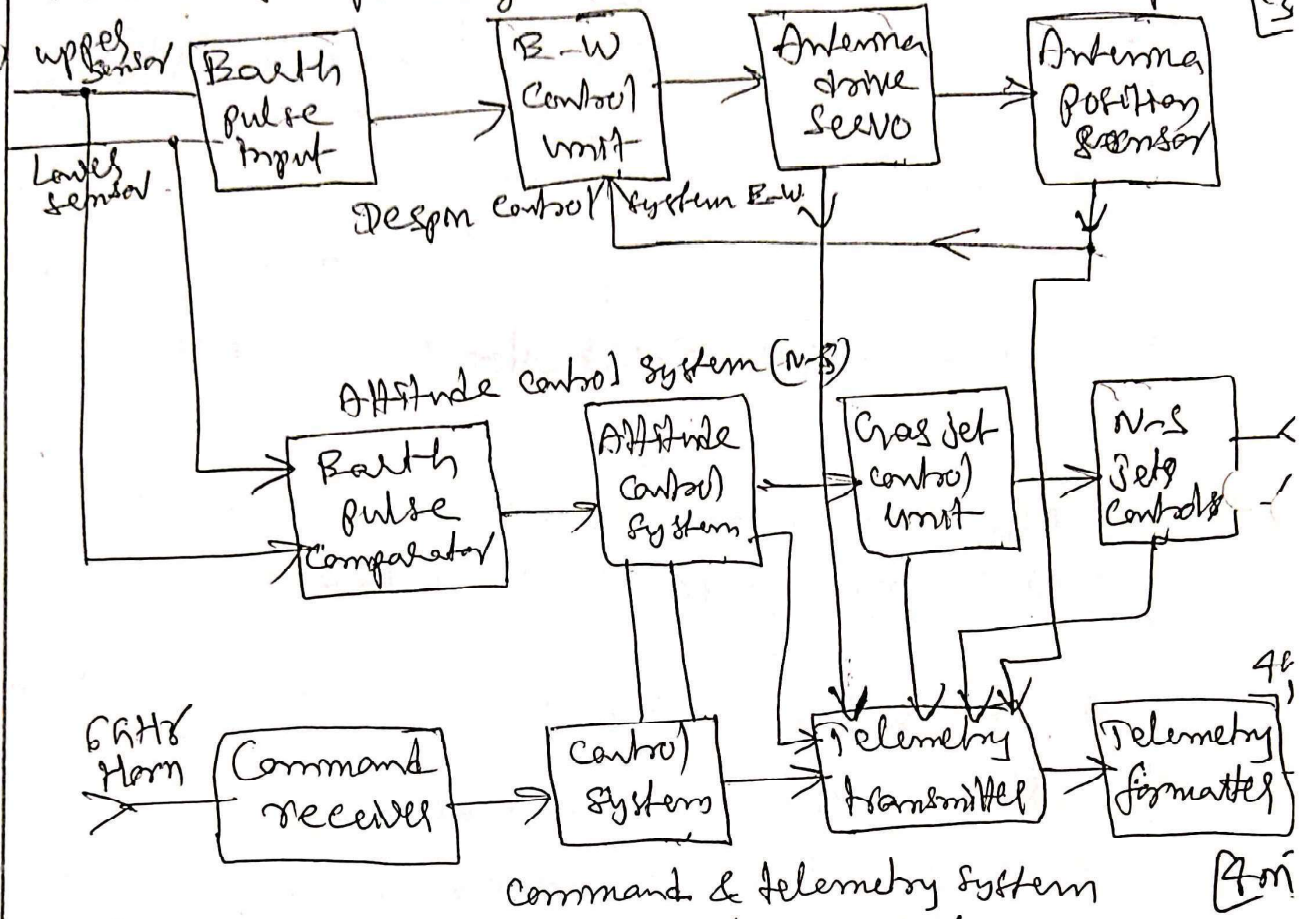
$$T_S = T_{RF} + T_{in} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_m \cdot G_{RF}}$$

Since the gain of each stage is added in the receiver so the succeeding stages contribute less & less noise.

It shows that the noise temperature of the 2nd stage is divided by the power gain of the 1st stage when referred to the input. Therefore, in order to keep the overall system noise as low as possible, the 1st stage should

have high power gain as well as noise temperature

5(a)



Command & telemetry system

4m

for: typical onboard control system for a spinned satellite.

Arc jets or ion thrusters are mainly used for north-south station keeping, where the greatest use of fuel is required for station-keeping manoeuvres. Arc jets or ion thrusters lack the total thrust required to move satellite quickly but a small, continuous thrust is adequate to maintain N-S & E-W position keeping

Let us define a set of reference cartesian axes (X_R, Y_R, Z_R) with the satellite at the origin.

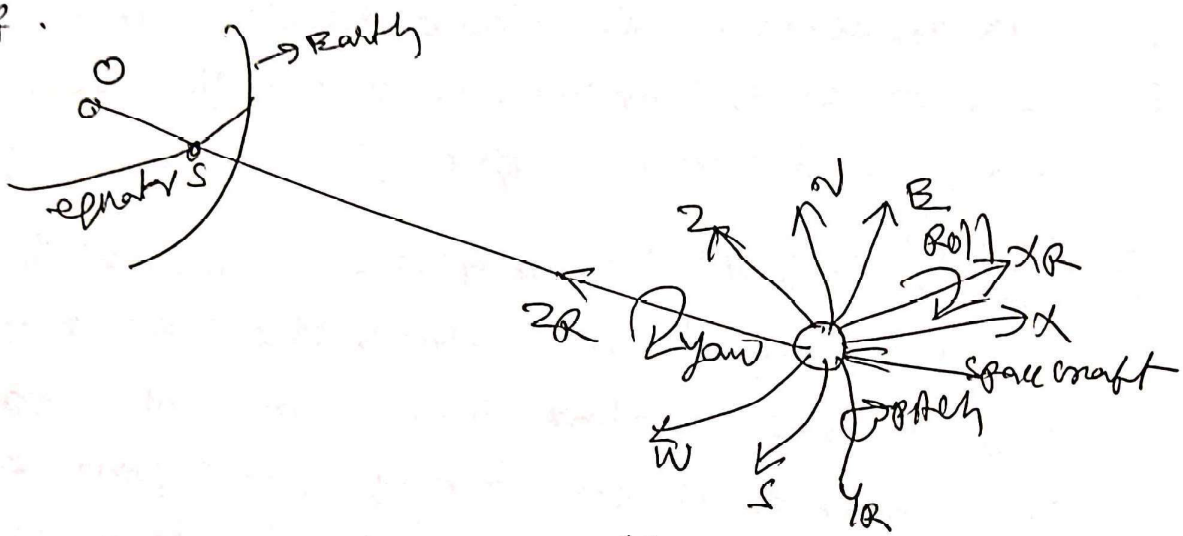
Z_R → directed toward the centre of earth & is in plane of satellite orbit.

X_R → tangent to the orbital plane & lies in the orbital plane.

Y_R → perpendicular to the orbital plane.

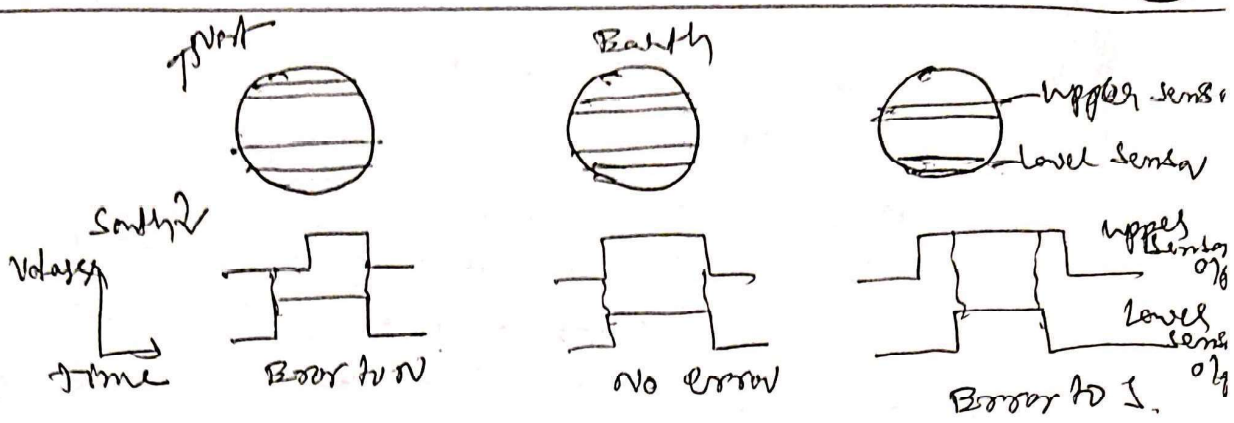
Note: For a satellite serving the Northern Hemisphere, the directions of the X_R & Y_R axes are nominally east & south.

A second set of Cartesian axes, X, Y, Z are shown in fig.



For a spinner type satellite, the axis of rotation is usually the Y-axis, which is maintained close to the Y_R axis, perpendicular to the orbital plane. Pitch correction is required only on the despun antenna system and can be obtained by varying the speed of the despin motor. Yaw and Roll are controlled by pulsing radially mounted jets at the appropriate instant as the body of the satellite rotates.

This figure illustrates how an infrared sensor on the spinning body of a satellite can be used to control pointing toward the earth.

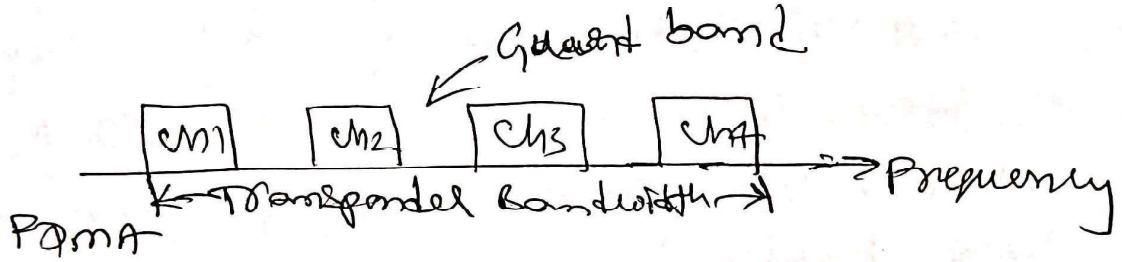


The control system will be more complex for a 3-axis stabilized satellite and may employ an onboard computer to process the sensor data and and command the gas jets and momentum [6M] wheels.

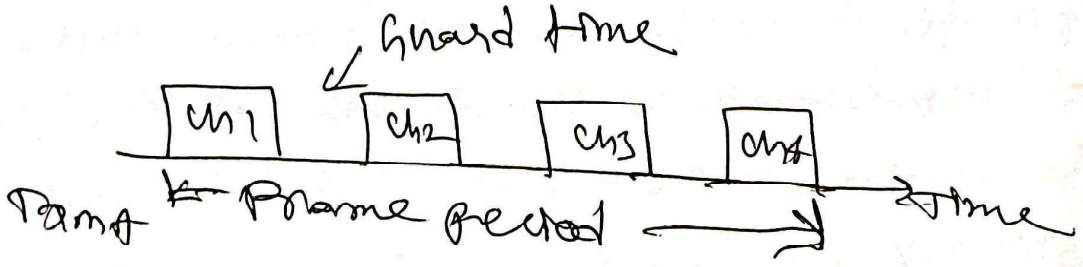
(b) A spinner satellite consists of a cylindrical drum covered in solar cells that contains the power systems & the rocket motors. The communication system is mounted at the top of the drum and is driven by an electric motor in the opposite direction to the rotation of the satellite body to keep the antennas pointing towards the earth. Such satellites are called despun.

In the early days of satellite communication despun antennas were not used, so antennas with a circular symmetric pattern were employed. These antennas have low gain & are now used only for basic TTC & M systems that must operate regardless of the satellite's orientation. By despinning the antennas & transponders, no RF rotating joints are needed in the communication system. [4M]

6(a) In frequency division multiple access (FDMA) all users share the satellite at the same time, but each user transmits at a unique allocated frequency. This approach to sharing the frequency spectrum is familiar to us all, as it is the way that radio broadcasting has always shared the air waves. Each radio station is allocated a frequency and a bandwidth, and transmits its signals within that piece of the frequency spectrum. FDMA can be used with analog or digital signals.



In time division multiple access (TDMA) each user is allocated a unique time slot at the satellite so that signals pass through the transponder sequentially. Because TDMA causes delays in transmission, it is used only with digital signals.



[4m]

In these classic multiple access techniques some resource is shared. If the proportion allocated to each earth station is fixed in advance, the system is called fixed access (FA) or preassigned access (PA).

If the resource is allocated as needed depending on changing traffic conditions, the multiple access technique is called "demand access (DA)".

Demand access blurs some of the distinct between FDMA & TDMA, since stations in an FDMA-DA system transmit only when they have traffic. Demand access with FDMA is widely used in VSAT systems, where earth stations may have traffic to send only intermittently. Fixed assignment would be wasteful of transponder capacity, so demand assignment is used.

Similarly, a group of earth stations may access part of the bandwidth of a transponder using TDMA, while other TDMA groups of earth stations share different sections of the transponder bandwidth. This approach has been used in both VSAT and mobile satellite systems.

[4m]

(b) * FDMA is a continuous transmission scheme, fewer bits are needed for overhead purposes as compared to TDMA
* The complexity of FDMA system is lower when compared to TDMA and CDMA systems, through this changing as digital signal processing methods improve for TDMA and CDMA. FDMA it is technically simple to implement.
* FDMA is a very reliable, well-established, and straightforward protocol.
* All stations may constantly run for 24 hrs without waiting for their chance.
* It reduces the inter-symbol interference.
* The reduced information bit rate can have a positive impact on capacity.
* In terms of hardware resources, it is very simple and easy to use.

7(a) Satellite communication systems exist because the earth is a sphere. Radio waves travel in straight lines at the microwave frequencies used for wideband communications, so a repeater is needed to convey signals over long distances. Satellites, because they can link places on the earth that are 1000's of miles apart, are a good place to locate a repeater, and a GEO

Satellite is the best place of all. A repeater is simply a receiver linked to a transmitter, always using different radio frequencies, that can receive a signal from one earth station, amplify it, and retransmit it to another earth station. The repeater derives its name from 19th century telegraph links, which had a maximum length of about 50 miles. Telegraph repeater stations were required every 50 miles in a long-distance link so that the morse code signals could be resent before they became too weak to read.

The majority of communication satellite are in geostationary earth orbit, at an altitude 35,786 km. Satellite communication systems are dominated by the need to receive very weak signals. In the early days, very large receiving antennas, with diameters upto 30m, were needed to collect sufficient signal power to drive video signals or multiplexed telephone channels. As satellites have become larger, heavier, and more powerful, smaller earth station antennas have become feasible, and direct broadcast satellite TV (DBS-TV) receiving systems

can use dish antennas as small as 0.5m in diameter. [4M]

Satellite systems operate in the microwave and millimeter wave frequency bands, using frequencies between 1 & 50 GHz. Above 10GHz, rain causes significant attenuation of the signal. Above 20GHz, attenuation in heavy rain can cause sufficient attenuation that the link will fail.

For the 1st 20 years of satellite communications, analog signals were widely used, with most links employing frequency modulation (FM). Wideband FM can operate at low C/N, in the 5 to 15dB, but adds a S/N improvement so that video & telephone signals can be delivered with S/N of 50dB.

The move toward digital communications in terrestrial telephone and data transmissions has been mirrored by a similar move toward digital transmission over satellite links. Almost all other signals are digital - telephony, data, DBS-TV, radio broadcasting, & navigation with GPS all use digital signalling techniques. [4M]

(b) Satellite communication is convenient and effective for very long-distance communication. For point-to-point short distance communication, optical communication is appropriate and effective.

20/20

there is delay in transmission with satellite communication. There is negligible or no delay with optical communication.

Satellite communication is best suited for rough terrains, poorly connected areas and places where it is difficult to lay wires. On the other hand, fibers are suited for urban areas with good infrastructures, where it is convenient to lay communication lines.

Satellite costs are independent of distance satellite can ~~operate~~ capture the images of nuclear weapons present on the earth. Satellt Can locate natural resources, mines, rivers, lakes etc on earth.

In satelles the bandwidth is limited, we can affect the quality of communication, where optical fibers, have High bandwidth, which allows for high-speed data transfer.

Prepared by
P. Rangappa
Assistant professor
Dept. of ECE.
RNSCET.

4/3/25.

CO-PO Attainment

Academic Year : **2022-23**

Regulations : **R19**

Year : **IV/Sem: II**

Batch : **19**

Branch : **ECE**

Subject (Code) : **Satellite Communication(A0441198)**

Name of the Faculty : **Mr.P.Rangappa**

External Question Paper marks: COs						
Q.No.	CO 1	CO 2	CO 3	CO 4	CO 5	Total
1 a)			2			2
b)	2					2
c)					2	2
d)	2					2
e)	2					2
f)		2				2
g)			2			2
2 a)			6			6
b)			8			8
c)						0
3 a)			6			6
b)			8			8
c)						0
4 a)	4					4
b)	10					10
c)						0
5 a)				7		7
b)				7		7
c)						0
6 a)		7				7
b)		7				7
c)						0
7 a)		7				7
b)		7				7
c)						0
Total	**20**	**30**	**32**	**14**	**2**	**98**

Mid I Marks: COs						
Q.No.	CO 1	CO 2	CO 3	CO 4	CO 5	Total
1 a)	1					1
b)			1			1
c)		1				1
d)	1					1
e)			1			1
2 a)	3					3
b)				2		2
3 a)			3			3
b)					2	2
4 a)					3	3
b)		2				2
5 a)			3			3
b)			2			2
Total	5	3	10	2	5	25

Mid II Marks: COs						
Q.No.	CO 1	CO 2	CO 3	CO 4	CO 5	Total
1 a)	1					1
b)		1				1
c)			1			1
d)				1		1
e)					1	1
2 a)	2					2
b)				3		3
3 a)		3				3
b)					2	2
4 a)			3			3
b)				2		2
5 a)					3	3
b)	2					2
Total	5	4	4	6	6	25

Total	10	7	14	8	11	50

Assignment 1 Marks --> Cos						
	CO 1	**CO2**	**CO3**	**CO4**	**CO5**	**Total**
	2	**2**	**2**	**2**	**2**	**10**
Total	2	2	2	2	2	10

Assignment 2 Marks --> Cos						
	CO1	**CO2**	**CO2**	**CO4**	**CO5**	**Total**
	2	**2**	**2**	**2**	**2**	**10**
Total	2	2	2	2	2	10

Total	4	4	4	4	4	20

S.No	Reg.No.	Internal marks	Assignment marks	Final Internal marks	Total Final Marks	External Marks	% of IM	% of AM	% of EM	N CO 1	N CO 2	N CO 3	N CO 4	N CO 5
1	19091A0405	13	10	23	69	46	65	100	65.71	68.95	68.25	67.83	70.08	74.07
2	19091A0407	9	10	19	66	47	45	100	67.14	66.02	67.28	65.23	66.80	63.09
3	19091A0408	14	10	24	68	44	70	100	62.86	67.93	66.45	66.61	69.25	76.36
4	19091A0411	16	10	26	67	41	80	100	58.57	66.88	64.02	65.23	68.53	81.20
5	19091A0413	15	10	25	67	42	75	100	60.00	66.90	64.65	65.38	68.42	78.65
6	19091A0414	7	10	17	51	34	35	100	48.57	50.97	51.04	49.45	52.48	54.08
7	19091A0415	16	10	26	64	38	80	100	54.29	63.86	60.52	62.02	65.71	80.42
8	19091A0416	16	10	26	71	45	80	100	64.29	70.91	68.69	69.52	72.29	82.24
9	19091A0421	13	10	23	62	39	65	100	55.71	61.91	60.08	60.33	63.50	72.25
10	19091A0423	11	10	21	73	52	55	100	74.29	73.02	74.19	72.43	73.61	70.02
11	19091A0429	19	10	29	76	47	95	100	67.14	75.88	72.62	74.42	77.33	91.19
12	19091A0434	9	10	19	52	33	45	100	47.14	51.93	50.94	50.22	53.65	59.44
13	19091A0436	17	10	27	70	43	85	100	61.43	69.88	66.89	68.30	71.47	84.53
14	19091A0441	8	10	18	62	44	40	100	62.86	62.01	63.25	61.09	62.93	59.50
15	19091A0442	10	10	20	52	32	50	100	45.71	51.91	50.31	50.07	53.76	61.99
16	19091A0444	14	10	24	64	40	70	100	57.14	63.90	61.78	62.32	65.49	75.32
17	19091A0450	14	10	24	68	44	70	100	62.86	67.93	66.45	66.61	69.25	76.36
18	19091A0451	19	10	29	76	47	95	100	67.14	75.88	72.62	74.42	77.33	91.19
19	19091A0452	10	10	20	62	42	50	100	60.00	61.97	61.98	60.79	63.16	64.60
20	19091A0459	18	10	28	80	52	90	100	74.29	79.92	77.92	78.86	80.98	89.69
21	19091A0463	13	10	23	58	35	65	100	50.00	57.89	55.41	56.04	59.74	71.20
22	19091A0466	10	10	20	71	51	50	100	72.86	71.03	72.49	70.44	71.62	66.94
23	19091A0474	13	10	23	66	43	65	100	61.43	65.94	64.75	64.62	67.26	73.29
24	19091A0478	17	10	27	77	50	85	100	71.43	76.92	75.06	75.80	78.05	86.36
25	19091A0482	16	10	26	77	51	80	100	72.86	76.94	75.69	75.95	77.93	83.81
26	19091A0486	16	10	26	71	45	80	100	64.29	70.91	68.69	69.52	72.29	82.24
27	19091A0488	14	10	24	65	41	70	100	58.57	64.91	62.95	63.39	66.43	75.58
28	19091A0489	17	10	27	79	52	85	100	74.29	78.93	77.39	77.94	79.92	86.88
29	19091A04A0	16	10	26	68	42	80	100	60.00	67.89	65.19	66.30	69.47	81.46
30	19091A04A1	14	10	24	72	48	70	100	68.57	71.95	71.12	70.90	73.01	77.40
31	19091A04A5	19	10	29	74	45	95	100	64.29	73.86	70.29	72.28	75.45	90.67
32	19091A04B3	17	10	27	59	32	85	100	45.71	58.81	54.05	56.50	61.13	81.66
33	19091A04B5	14	10	24	68	44	70	100	62.86	67.93	66.45	66.61	69.25	76.36
34	19091A04C6	10	10	20	64	44	50	100	62.86	63.98	64.32	62.93	65.04	65.12

35	19091A04C9	13	10	23	76	53	65	100	75.71	76.00	76.42	75.34	76.65	75.90
36	19091A04D6	9	10	19	71	52	45	100	74.29	71.05	73.12	70.59	71.50	64.40
37	19091A04D9	13	10	23	78	55	65	100	78.57	78.01	78.76	77.48	78.53	76.42
38	19091A04E1	16	10	26	78	52	80	100	74.29	77.95	76.86	77.02	78.87	84.07
39	19091A04E3	9	10	19	68	49	45	100	70.00	68.03	69.62	67.37	68.68	63.61
40	19091A04E4	17	10	27	77	50	85	100	71.43	76.92	75.06	75.80	78.05	86.36
41	19091A04E5	11	10	21	67	46	55	100	65.71	66.98	67.18	66.00	67.97	68.45
42	19091A04E8	15	10	25	78	53	75	100	75.71	77.97	77.49	77.18	78.76	81.52
43	19091A04F9	19	10	29	79	50	95	100	71.43	78.89	76.12	77.64	80.15	91.98
44	19091A04G1	14	10	24	78	54	70	100	77.14	77.99	78.12	77.33	78.65	78.97
45	19091A04G2	18	10	28	84	56	90	100	80.00	83.94	82.59	83.15	84.74	90.73
46	19091A04G7	12	10	22	66	44	60	100	62.86	65.96	65.38	64.77	67.14	70.74
47	19091A04G8	15	10	25	85	60	75	100	85.71	85.01	85.66	84.68	85.34	83.34
48	19091A04H3	9	10	19	74	55	45	100	78.57	74.06	76.62	73.81	74.32	65.18
49	19091A04J4	15	10	25	74	49	75	100	70.00	73.94	72.82	72.89	75.00	80.47
50	19091A04K0	16	10	26	78	52	80	100	74.29	77.95	76.86	77.02	78.87	84.07
51	19091A04K5	13	10	23	64	41	65	100	58.57	63.92	62.42	62.47	65.38	72.77
52	19091A04K7	14	10	24	69	45	70	100	64.29	68.93	67.62	67.68	70.19	76.62
53	19091A04K8	11	10	21	72	51	55	100	72.86	72.01	73.02	71.36	72.67	69.75
54	19091A04M2	7	10	17	61	44	35	100	62.86	61.03	62.72	60.17	61.88	56.69
55	19091A04M3	13	10	23	63	40	65	100	57.14	62.92	61.25	61.40	64.44	72.51
56	19091A04M5	16	10	26	76	50	80	100	71.43	75.94	74.52	74.88	76.99	83.55
57	19091A04M9	15	10	25	75	50	75	100	71.43	74.95	73.99	73.96	75.94	80.74
58	19091A04N2	17	10	27	79	52	85	100	74.29	78.93	77.39	77.94	79.92	86.88
59	19091A04N6	12	10	22	72	50	60	100	71.43	71.99	72.39	71.20	72.78	72.30
60	19091A04P0	13	10	23	77	54	65	100	77.14	77.00	77.59	76.41	77.59	76.16
61	19091A04P4	15	10	25	79	54	75	100	77.14	78.97	78.66	78.25	79.70	81.78
62	19091A04Q1	18	10	28	77	49	90	100	70.00	76.90	74.42	75.65	78.16	88.91
63	19091A04Q6	12	10	22	68	46	60	100	65.71	67.97	67.72	66.92	69.02	71.26
64	19091A04R1	11	10	21	79	58	55	100	82.86	79.05	81.19	78.86	79.25	71.58
65	19091A04S0	11	10	21	71	50	55	100	71.43	71.01	71.85	70.28	71.73	69.49
66	19091A04S2	13	10	23	76	53	65	100	75.71	76.00	76.42	75.34	76.65	75.90
67	19091A04S5	14	10	24	69	45	70	100	64.29	68.93	67.62	67.68	70.19	76.62
68	19091A04S6	18	10	28	85	57	90	100	81.43	84.95	83.76	84.22	85.68	90.99
69	20095A0401	18	10	28	71	43	90	100	61.43	70.87	67.42	69.21	72.52	87.34
70	20095A0423	12	10	22	75	53	60	100	75.71	75.01	75.89	74.42	75.60	73.09
71	18091A04A3	17	10	27	75	48	85	100	68.57	74.91	72.72	73.66	76.17	85.83
72	19091A0404	14	10	24	63	39	70	100	55.71	62.90	60.62	61.25	64.55	75.06
73	19091A0410	17	10	27	72	45	85	100	64.29	71.89	69.22	70.44	73.35	85.05
74	19091A0417	17	10	27	63	36	85	100	51.43	62.84	58.72	60.79	64.89	82.71
75	19091A0419	9	10	19	64	45	45	100	64.29	64.00	64.95	63.08	64.92	62.57
76	19091A0424	13	10	23	73	50	65	100	71.43	72.98	72.92	72.12	73.83	75.11
77	19091A0426	10	10	20	61	41	50	100	58.57	60.97	60.82	59.72	62.22	64.34
78	19091A0428	11	10	21	65	44	55	100	62.86	64.97	64.85	63.85	66.09	67.93

79	19091A0431	12	10	22	63	41	60	100	58.57	62.94	61.88	61.55	64.32	69.96
80	19091A0432	13	10	23	71	48	65	100	68.57	70.97	70.59	69.98	71.95	74.59
81	19091A0437	17	10	27	68	41	85	100	58.57	67.87	64.55	66.15	69.59	84.01
82	19091A0446	6	10	16	48	32	30	100	45.71	47.97	48.18	46.39	49.55	50.75
83	19091A0454	14	10	24	70	46	70	100	65.71	69.94	68.79	68.75	71.13	76.88
84	19091A0455	15	10	25	65	40	75	100	57.14	64.89	62.32	63.24	66.54	78.13
85	19091A0456	14	10	24	62	38	70	100	54.29	61.89	59.45	60.18	63.61	74.80
86	19091A0460	15	10	25	74	49	75	100	70.00	73.94	72.82	72.89	75.00	80.47
87	19091A0462	12	10	22	58	36	60	100	51.43	57.91	56.05	56.19	59.62	68.65
88	19091A0464	13	10	23	57	34	65	100	48.57	56.88	54.25	54.97	58.80	70.94
89	19091A0467	11	10	21	71	50	55	100	71.43	71.01	71.85	70.28	71.73	69.49
90	19091A0469	15	10	25	74	49	75	100	70.00	73.94	72.82	72.89	75.00	80.47
91	19091A0479	14	10	24	68	44	70	100	62.86	67.93	66.45	66.61	69.25	76.36
92	19091A0480	16	10	26	71	45	80	100	64.29	70.91	68.69	69.52	72.29	82.24
93	19091A0481	13	10	23	60	37	65	100	52.86	59.90	57.75	58.19	61.62	71.73
94	19091A0490	12	10	22	65	43	60	100	61.43	64.95	64.22	63.70	66.20	70.48
95	19091A0491	8	10	18	56	38	40	100	54.29	55.98	56.25	54.66	57.29	57.94
96	19091A0495	13	10	23	70	47	65	100	67.14	69.96	69.42	68.91	71.02	74.33
97	19091A0498	19	10	29	73	44	95	100	62.86	72.86	69.12	71.21	74.51	90.41
98	19091A04A4	11	10	21	56	35	55	100	50.00	55.92	54.35	54.20	57.63	65.58
99	19091A04A6	18	10	28	73	45	90	100	64.29	72.88	69.75	71.36	74.40	87.86
100	19091A04A7	12	10	22	71	49	60	100	70.00	70.99	71.22	70.13	71.84	72.04
101	19091A04A9	9	10	19	54	35	45	100	50.00	53.94	53.28	52.36	55.53	59.96
102	19091A04B1	14	10	24	60	36	70	100	51.43	59.88	57.11	58.03	61.73	74.28
103	19091A04B4	17	10	27	67	40	85	100	57.14	66.86	63.38	65.08	68.65	83.75
104	19091A04B9	12	10	22	60	38	60	100	54.29	59.92	58.38	58.34	61.50	69.18
105	19091A04C2	13	10	23	66	43	65	100	61.43	65.94	64.75	64.62	67.26	73.29
106	19091A04C4	13	10	23	68	45	65	100	64.29	67.95	67.09	66.76	69.14	73.81
107	19091A04C5	15	10	25	70	45	75	100	64.29	69.92	68.15	68.60	71.24	79.43
108	19091A04C8	17	10	27	81	54	85	100	77.14	80.95	79.72	80.09	81.80	87.40
109	19091A04D2	13	10	23	63	40	65	100	57.14	62.92	61.25	61.40	64.44	72.51
110	19091A04D8	10	10	20	76	56	50	100	80.00	76.06	78.32	75.80	76.32	68.25
111	19091A04E0	13	10	23	67	44	65	100	62.86	66.94	65.92	65.69	68.20	73.55
112	19091A04E7	14	10	24	75	51	70	100	72.86	74.97	74.62	74.11	75.83	78.19
113	19091A04E9	15	10	25	74	49	75	100	70.00	73.94	72.82	72.89	75.00	80.47
114	19091A04F0	13	10	23	82	59	65	100	84.29	82.03	83.43	81.77	82.29	77.46
115	19091A04F6	15	10	25	80	55	75	100	78.57	79.98	79.82	79.32	80.64	82.04
116	19091A04F8	9	10	19	68	49	45	100	70.00	68.03	69.62	67.37	68.68	63.61
117	19091A04G0	10	10	20	62	42	50	100	60.00	61.97	61.98	60.79	63.16	64.60
118	19091A04G9	12	10	22	76	54	60	100	77.14	76.02	77.06	75.49	76.54	73.35
119	19091A04H2	14	10	24	61	37	70	100	52.86	60.89	58.28	59.10	62.67	74.54
120	19091A04H4	5	10	15	61	46	25	100	65.71	61.07	63.98	60.48	61.65	51.59
121	19091A04J2	12	10	22	73	51	60	100	72.86	73.00	73.55	72.28	73.72	72.57
122	19091A04K2	14	10	24	70	46	70	100	65.71	69.94	68.79	68.75	71.13	76.88

123	19091A04K6	18	10	28	60	32	90	100	45.71	59.80	54.58	57.42	62.18	84.47
124	19091A04M1	8	10	18	54	36	40	100	51.43	53.96	53.91	52.52	55.41	57.41
125	19091A04M8	19	10	29	92	63	95	100	90.00	91.97	91.30	91.58	92.37	95.36
126	19091A04N3	16	10	26	68	42	80	100	60.00	67.89	65.19	66.30	69.47	81.46
127	19091A04N5	12	10	22	67	45	60	100	64.29	66.96	66.55	65.84	68.08	71.00
128	19091A04N7	7	10	17	76	59	35	100	84.29	76.12	80.22	76.26	75.98	60.60
129	19091A04P1	11	10	21	69	48	55	100	68.57	68.99	69.52	68.14	69.85	68.97
130	19091A04P8	17	10	27	87	60	85	100	85.71	86.98	86.73	86.52	87.44	88.96
131	19091A04Q2	17	10	27	78	51	85	100	72.86	77.93	76.22	76.87	78.98	86.62
132	19091A04Q3	18	10	28	75	47	90	100	67.14	74.89	72.09	73.50	76.28	88.38
133	19091A04R2	9	10	19	72	53	45	100	75.71	72.05	74.29	71.66	72.44	64.66
134	19091A04R4	12	10	22	75	53	60	100	75.71	75.01	75.89	74.42	75.60	73.09
135	19091A04S1	17	10	27	79	52	85	100	74.29	78.93	77.39	77.94	79.92	86.88
136	20095A0403	18	10	28	78	50	90	100	71.43	77.91	75.59	76.72	79.10	89.17
137	20095A0410	15	10	25	64	39	75	100	55.71	63.88	61.15	62.17	65.60	77.87
138	20095A0413	10	10	20	66	46	50	100	65.71	66.00	66.65	65.08	66.92	65.64
139	20095A0415	10	10	20	59	39	50	100	55.71	58.95	58.48	57.57	60.34	63.82
140	20095A0422	13	10	23	69	46	65	100	65.71	68.95	68.25	67.83	70.08	74.07
141	18091A0485	15	10	25	65	40	75	100	57.14	64.89	62.32	63.24	66.54	78.13
142	19091A0409	14	10	24	65	41	70	100	58.57	64.91	62.95	63.39	66.43	75.58
143	19091A0418	13	10	23	66	43	65	100	61.43	65.94	64.75	64.62	67.26	73.29
144	19091A0422	15	10	25	76	51	75	100	72.86	75.96	75.16	75.03	76.88	81.00
145	19091A0430	11	10	21	50	29	55	100	41.43	49.88	47.34	47.77	51.99	64.02
146	19091A0438	14	10	24	65	41	70	100	58.57	64.91	62.95	63.39	66.43	75.58
147	19091A0440	15	10	25	75	50	75	100	71.43	74.95	73.99	73.96	75.94	80.74
148	19091A0443	10	10	20	60	40	50	100	57.14	59.96	59.65	58.64	61.28	64.08
149	19091A0448	17	10	27	66	39	85	100	55.71	65.86	62.22	64.01	67.71	83.49
150	19091A0457	16	10	26	79	53	80	100	75.71	78.95	78.02	78.10	79.81	84.33
151	19091A0468	7	10	17	55	38	35	100	54.29	54.99	55.71	53.74	56.24	55.13
152	19091A0470	14	10	24	67	43	70	100	61.43	66.92	65.28	65.54	68.31	76.10
153	19091A0472	14	10	24	65	41	70	100	58.57	64.91	62.95	63.39	66.43	75.58
154	19091A0473	12	10	22	53	31	60	100	44.29	52.88	50.21	50.83	54.92	67.35
155	19091A0476	13	10	23	57	34	65	100	48.57	56.88	54.25	54.97	58.80	70.94
156	19091A0477	9	10	19	60	41	45	100	58.57	59.98	60.28	58.80	61.17	61.53
157	19091A0483	9	10	19	64	45	45	100	64.29	64.00	64.95	63.08	64.92	62.57
158	19091A0487	10	10	20	50	30	50	100	42.86	49.90	47.98	47.92	51.88	61.47
159	19091A0494	17	10	27	76	49	85	100	70.00	75.92	73.89	74.73	77.11	86.09
160	19091A0497	8	10	18	64	46	40	100	65.71	64.02	65.58	63.24	64.81	60.02
161	19091A0499	17	10	27	71	44	85	100	62.86	70.89	68.05	69.37	72.41	84.79
162	19091A04A2	10	10	20	65	45	50	100	64.29	64.99	65.48	64.00	65.98	65.38
163	19091A04A8	13	10	23	66	43	65	100	61.43	65.94	64.75	64.62	67.26	73.29
164	19091A04B0	12	10	22	64	42	60	100	60.00	63.94	63.05	62.63	65.26	70.22
165	19091A04B2	15	10	25	72	47	75	100	67.14	71.93	70.49	70.75	73.12	79.95
166	19091A04B8	15	10	25	71	46	75	100	65.71	70.93	69.32	69.67	72.18	79.69

167	19091A04C0	7	10	17	48	31	35	100	44.29	47.95	47.54	46.24	49.66	53.30
168	19091A04D0	9	10	19	63	44	45	100	62.86	63.00	63.78	62.01	63.98	62.31
169	19091A04D1	9	10	19	60	41	45	100	58.57	59.98	60.28	58.80	61.17	61.53
170	19091A04D7	10	10	20	63	43	50	100	61.43	62.98	63.15	61.86	64.10	64.86
171	19091A04E2	16	10	26	75	49	80	100	70.00	74.93	73.36	73.81	76.05	83.28
172	19091A04E6	8	10	18	67	49	40	100	70.00	67.04	69.08	66.45	67.63	60.80
173	19091A04F3	17	10	27	75	48	85	100	68.57	74.91	72.72	73.66	76.17	85.83
174	19091A04F5	9	10	19	60	41	45	100	58.57	59.98	60.28	58.80	61.17	61.53
175	19091A04G3	15	10	25	84	59	75	100	84.29	84.00	84.49	83.61	84.40	83.08
176	19091A04G4	12	10	22	56	34	60	100	48.57	55.90	53.71	54.05	57.74	68.13
177	19091A04H5	13	10	23	80	57	65	100	81.43	80.02	81.09	79.63	80.41	76.94
178	19091A04H7	9	10	19	58	39	45	100	55.71	57.97	57.95	56.65	59.29	61.01
179	19091A04H8	10	10	20	60	40	50	100	57.14	59.96	59.65	58.64	61.28	64.08
180	19091A04J5	16	10	26	70	44	80	100	62.86	69.90	67.52	68.45	71.35	81.98
181	19091A04J6	9	10	19	68	49	45	100	70.00	68.03	69.62	67.37	68.68	63.61
182	19091A04J7	16	10	26	80	54	80	100	77.14	79.96	79.19	79.17	80.75	84.59
183	19091A04J8	14	10	24	67	43	70	100	61.43	66.92	65.28	65.54	68.31	76.10
184	19091A04K1	14	10	24	70	46	70	100	65.71	69.94	68.79	68.75	71.13	76.88
185	19091A04K4	12	10	22	55	33	60	100	47.14	54.89	52.55	52.98	56.80	67.87
186	19091A04M0	13	10	23	73	50	65	100	71.43	72.98	72.92	72.12	73.83	75.11
187	19091A04M4	15	10	25	64	39	75	100	55.71	63.88	61.15	62.17	65.60	77.87
188	19091A04N1	10	10	20	55	35	50	100	50.00	54.93	53.81	53.28	56.58	62.77
189	19091A04P2	11	10	21	70	49	55	100	70.00	70.00	70.69	69.21	70.79	69.23
190	19091A04P3	10	10	20	63	43	50	100	61.43	62.98	63.15	61.86	64.10	64.86
191	19091A04P7	16	10	26	68	42	80	100	60.00	67.89	65.19	66.30	69.47	81.46
192	19091A04Q0	9	10	19	57	38	45	100	54.29	56.96	56.78	55.58	58.35	60.75
193	19091A04Q4	14	10	24	72	48	70	100	68.57	71.95	71.12	70.90	73.01	77.40
194	19091A04Q5	14	10	24	68	44	70	100	62.86	67.93	66.45	66.61	69.25	76.36
195	19091A04R0	14	10	24	52	28	70	100	40.00	51.83	47.78	49.46	54.21	72.19
196	19091A04R5	13	10	23	69	46	65	100	65.71	68.95	68.25	67.83	70.08	74.07
197	19091A04R6	14	10	24	64	40	70	100	57.14	63.90	61.78	62.32	65.49	75.32
198	19091A04R7	10	10	20	61	41	50	100	58.57	60.97	60.82	59.72	62.22	64.34
199	19091A04S3	13	10	23	75	52	65	100	74.29	74.99	75.26	74.27	75.71	75.64
200	19091A04S4	10	10	20	64	44	50	100	62.86	63.98	64.32	62.93	65.04	65.12
201	20095A0405	11	10	21	68	47	55	100	67.14	67.99	68.35	67.07	68.91	68.71
202	20095A0406	16	10	26	61	35	80	100	50.00	60.85	57.02	58.80	62.89	79.64
203	20095A0408	16	10	26	81	55	80	100	78.57	80.97	80.36	80.24	81.69	84.85
204	20095A0409	11	10	21	67	46	55	100	65.71	66.98	67.18	66.00	67.97	68.45
205	20095A0412	11	10	21	56	35	55	100	50.00	55.92	54.35	54.20	57.63	65.58
206	20095A0416	9	10	19	62	43	45	100	61.43	61.99	62.62	60.94	63.05	62.05
207	20095A0417	15	10	25	71	46	75	100	65.71	70.93	69.32	69.67	72.18	79.69
208	20095A0419	16	10	26	77	51	80	100	72.86	76.94	75.69	75.95	77.93	83.81
209	20095A0425	18	10	28	82	54	90	100	77.14	81.93	80.26	81.01	82.86	90.21
210	19091A0401	5	10	15	47	32	25	100	45.71	46.98	47.64	45.47	48.50	47.94

211	19091A0402	3	10	13	50	37	15	100	52.86	50.04	52.41	48.99	51.09	43.62
212	19091A0403	8	10	18	43	25	40	100	35.71	42.90	41.07	40.72	45.08	54.55
213	19091A0420	3	10	13	51	38	15	100	54.29	51.05	53.58	50.06	52.03	43.88
214	19091A0425	5	10	15	55	40	25	100	57.14	55.03	56.98	54.05	56.02	50.03
215	19091A0427	6	10	16	59	43	30	100	61.43	59.03	61.01	58.18	59.89	53.62
216	19091A0435	7	10	17	60	43	35	100	61.43	60.02	61.55	59.10	60.94	56.43
217	19091A0439	10	10	20	54	34	50	100	48.57	53.92	52.65	52.21	55.64	62.51
218	19091A0445	9	10	19	61	42	45	100	60.00	60.99	61.45	59.87	62.11	61.79
219	19091A0447	4	10	14	40	26	20	100	37.14	39.96	40.11	38.12	41.80	43.57
220	19091A0449	10	10	20	53	33	50	100	47.14	52.92	51.48	51.14	54.70	62.25
221	19091A0453	9	10	19	49	30	45	100	42.86	48.91	47.44	47.00	50.83	58.66
222	19091A0458	11	10	21	59	38	55	100	54.29	58.93	57.85	57.42	60.45	66.37
223	19091A0461	5	10	15	41	26	25	100	37.14	40.95	40.64	39.04	42.86	46.38
224	19091A0465	11	10	21	57	36	55	100	51.43	56.92	55.51	55.27	58.57	65.84
225	19091A0475	8	10	18	58	40	40	100	57.14	57.99	58.58	56.81	59.17	58.46
226	19091A0484	6	10	16	48	32	30	100	45.71	47.97	48.18	46.39	49.55	50.75
227	19091A0492	7	10	17	55	38	35	100	54.29	54.99	55.71	53.74	56.24	55.13
228	19091A0493	6	10	16	54	38	30	100	54.29	54.00	55.18	52.82	55.19	52.31
229	19091A0496	8	10	18	51	33	40	100	47.14	50.95	50.41	49.30	52.59	56.63
230	19091A04A3	0	10	10	46	36	0	100	51.43	46.08	49.64	45.16	46.99	34.93
231	19091A04B7	9	10	19	53	34	45	100	48.57	52.94	52.11	51.29	54.59	59.70
232	19091A04C3	8	10	18	63	45	40	100	64.29	63.02	64.42	62.17	63.87	59.76
233	19091A04C7	2	10	12	52	40	10	100	57.14	52.07	55.38	51.29	52.86	41.60
234	19091A04D3	10	10	20	68	48	50	100	68.57	68.01	68.99	67.22	68.80	66.16
235	19091A04D4	6	10	16	55	39	30	100	55.71	55.01	56.35	53.89	56.13	52.58
236	19091A04D5	11	10	21	85	64	55	100	91.43	85.09	88.19	85.29	84.89	73.14
237	19091A04F2	5	10	15	60	45	25	100	64.29	60.06	62.82	59.41	60.71	51.33
238	19091A04F4	6	10	16	41	25	30	100	35.71	40.93	40.01	38.89	42.97	48.93
239	19091A04F7	12	10	22	79	57	60	100	81.43	79.03	80.56	78.71	79.36	74.13
240	19091A04G5	10	10	20	64	44	50	100	62.86	63.98	64.32	62.93	65.04	65.12
241	19091A04G6	8	10	18	60	42	40	100	60.00	60.00	60.92	58.95	61.05	58.98
242	19091A04H0	5	10	15	43	28	25	100	40.00	42.96	42.97	41.18	44.74	46.90
243	19091A04H1	6	10	16	52	36	30	100	51.43	51.99	52.84	50.68	53.31	51.79
244	19091A04H6	8	10	18	58	40	40	100	57.14	57.99	58.58	56.81	59.17	58.46
245	19091A04H9	3	10	13	59	46	15	100	65.71	59.09	62.91	58.64	59.55	45.97
246	19091A04J0	3	10	13	40	27	15	100	38.57	39.98	40.74	38.27	41.69	41.02
247	19091A04J1	10	10	20	73	53	50	100	75.71	73.04	74.82	72.58	73.50	67.47
248	19091A04J3	6	10	16	50	34	30	100	48.57	49.98	50.51	48.53	51.43	51.27
249	19091A04J9	7	10	17	47	30	35	100	42.86	46.94	46.38	45.16	48.72	53.04
250	19091A04K3	8	10	18	52	34	40	100	48.57	51.95	51.58	50.37	53.53	56.89
251	19091A04K9	7	10	17	69	52	35	100	74.29	69.07	72.05	68.75	69.40	58.77
252	19091A04M6	3	10	13	44	31	15	100	44.29	44.00	45.41	42.56	45.45	42.06
253	19091A04M7	4	10	14	57	43	20	100	61.43	57.06	59.95	56.34	57.78	48.00
254	19091A04N0	6	10	16	57	41	30	100	58.57	57.02	58.68	56.04	58.01	53.10

255	19091A04N8	0	10	10	56	46	0	100	65.71	56.14	61.31	55.88	56.39	37.54
256	19091A04P5	4	10	14	41	27	20	100	38.57	40.97	41.27	39.19	42.74	43.83
257	19091A04P6	5	10	15	56	41	25	100	58.57	56.04	58.15	55.12	56.95	50.29
258	19091A04P9	2	10	12	40	28	10	100	40.00	40.00	41.37	38.42	41.58	38.47
259	19091A04Q7	16	10	26	69	43	80	100	61.43	68.89	66.35	67.38	70.41	81.72
260	19091A04Q8	9	10	19	60	41	45	100	58.57	59.98	60.28	58.80	61.17	61.53
261	19091A04Q9	4	10	14	48	34	20	100	48.57	48.01	49.44	46.70	49.32	45.65
262	19091A04R3	6	10	16	61	45	30	100	64.29	61.05	63.35	60.33	61.77	54.14
263	19091A04R9	2	10	12	40	28	10	100	40.00	40.00	41.37	38.42	41.58	38.47
264	20095A0402	5	10	15	52	37	25	100	52.86	52.01	53.48	50.83	53.20	49.24
265	20095A0404	14	10	24	78	54	70	100	77.14	77.99	78.12	77.33	78.65	78.97
266	20095A0407	7	10	17	45	28	35	100	40.00	44.93	44.04	43.02	46.84	52.52
267	20095A0411	9	10	19	64	45	45	100	64.29	64.00	64.95	63.08	64.92	62.57
268	20095A0414	10	10	20	59	39	50	100	55.71	58.95	58.48	57.57	60.34	63.82
269	20095A0418	6	10	16	57	41	30	100	58.57	57.02	58.68	56.04	58.01	53.10
270	20095A0420	4	10	14	28	14	20	100	20.00	27.89	26.10	25.25	30.53	40.44
271	20095A0424	17	10	27	70	43	85	100	61.43	69.88	66.89	68.30	71.47	84.53

R19	**Regulation Weightage of Marks**	
Final exam	**Internal tests**	**Ass/Quiz**
70	**20**	**10**
0.7	**0.2**	**0.1**

Weightage marks for each CO						
	CO 1	**CO 2**	**CO 3**	**CO 4**	**CO 5**	**Total**
EM	20	30	32	14	2	98
IM	10	7	14	8	11	50
AM	4	4	4	4	4	20

% Weightage of each CO						
	CO 1	**CO 2**	**CO 3**	**CO 4**	**CO 5**	**Total**
EM (%)	20.40816	30.61224	32.65306	14.28571	2.040816	100
IM (%)	20	14	28	16	22	100
AM (%)	20	20	20	20	20	100
Avg	20.28571	26.22857	30.45714	15.2	7.828571	100

	CO 1		CO 2		CO 3		CO 4		CO 5	
	No. of students Attained	Weightage Points	No. of students Attained	Weightage Points	No. of students Attained	Weightage Points	No. of students Attained	Weightage Points	No. of students Attained	Weightage Points
>= 60%	190	3	193	3	182	3	204	3	214	3
40% to 60%	78	2	77	2	81	2	66	2	53	2
<40%	3	1	1	1	8	1	1	1	4	1
Total No. of students	271		271		271		271		271	
Atainment value		2.69		2.71		2.64		2.75		2.77
% of Attainment		70.11		71.22		67.16		75.28		78.97
Attained or not		YES		YES		YES		YES		YES

IV Year Threshold (%)
60

CO	CO Attainment Value	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CO 1	2.69	3	2		1										2	
CO 2	2.71			3							2	1		2		
CO 3	2.64		2		1						3			2		2
CO 4	2.75					3	1				2				1	
CO 5	2.77							1			3		2			1
SC		2.69	2.67	2.71	2.67	2.75	2.75	2.77	-	-	2.72	2.71	2.77	2.68	2.71	2.69

(ESTD-1995)

1.a The modulation schemes used in satellite communication are as follows:

→ For analog signal mostly used modulation technique is FM (frequency modulation), ~~since~~ there are other modulation techniques are present like AM (amplitude modulation) & phase modulation.

→ For digital signals generally used modulation techniques in ~~satellite~~ satellite communication are –

Subject: Satellite Communication
Q.P. Code: A0441198R0423

For Office Use	11441091

VALUATION-II

Q.No.	1	2	3	4	5	6	7
A							
B							
C							
D							
E							
F							
G							
TOTAL							

GRAND TOTAL

(in words)

Signature of the Examiner

Signature of the Scrutinizer

Subject: Satellite Communication
Q.P. Code: A0441198R0423

For Office Use	11441091

VALUATION-I

Q.No.	1	2	3	4	5	6	7
A	2	5	5	4	5		
B	2	5	6	8	5		
C	2						
D	2						
E	2						
F	1						
G	1						
TOTAL	12	10	10	12	10		

GRAND TOTAL 54

(in words) FIVE FOUR

Signature of the Examiner

Signature of the Scrutinizer

For Office Use 11441091

(ESTD-1995)

1.a The modulation schemes used in satellite communication are as follows:

→ For analog signal mostly used modulation technique is FM (frequency Modulation), ~~since~~ there are other modulation techniques are present like AM (amplitude modulation) & phase modulation.

→ For digital signals generally used modulation techniques in ~~analog~~ ~~co~~ satellite communication are —

QPSK – (Quadrature Phase shift Keying)

BPSK – (Binary phase shift Keying)

QAM – (Quadrature Amplitude modulation)

1.b) GEO Synchronous orbit: The orbit (or) the path followed by the GEO stationary (~~orbit ie~~) ~~stationary or~~ satellite is generally called as GEO stationary orbit, because it travels with the speed, ~~eq~~ which makes it to appear as a stationary to the user.

And this orbit is always above the equator & it is in synchronous with the earth, so it is called GEO synchronous orbit.

For the use of Evaluator Only

Q.No	Marks
1(a)	2

Q.No	Marks
1(b)	2

Q.No	Marks

(ESTD-1995)

1.c The major sources of error in a GPS receiver are as follows –

* Ionospheric delay,
* Troposphere delay,
* Receiver noise,
* Multipath,
* Selective availability when switched on,
* Errors in clock & ephemeris ~~& et~~ and etc.;

1.d Comparison b/w LEO & MEO are as follows –

LEO	MEO
* LEO stands for Lower earth orbit.	* MEO stands for Medium earth orbit.
* These are at a height of 500 km to 1500 km from the earth surface.	* These are at a height of 10,000 km to 15000 km from the earth surface.
* Its time period is less compared with MEO.	* Its time period is more compared with LEO.
* It is easy to place the satellite in LEO.	* It is not that much easy like LEO.
* Eg: Sun Synchronous orbit.	* Eg:- GPS system orbit.

For the use of Evaluator Only

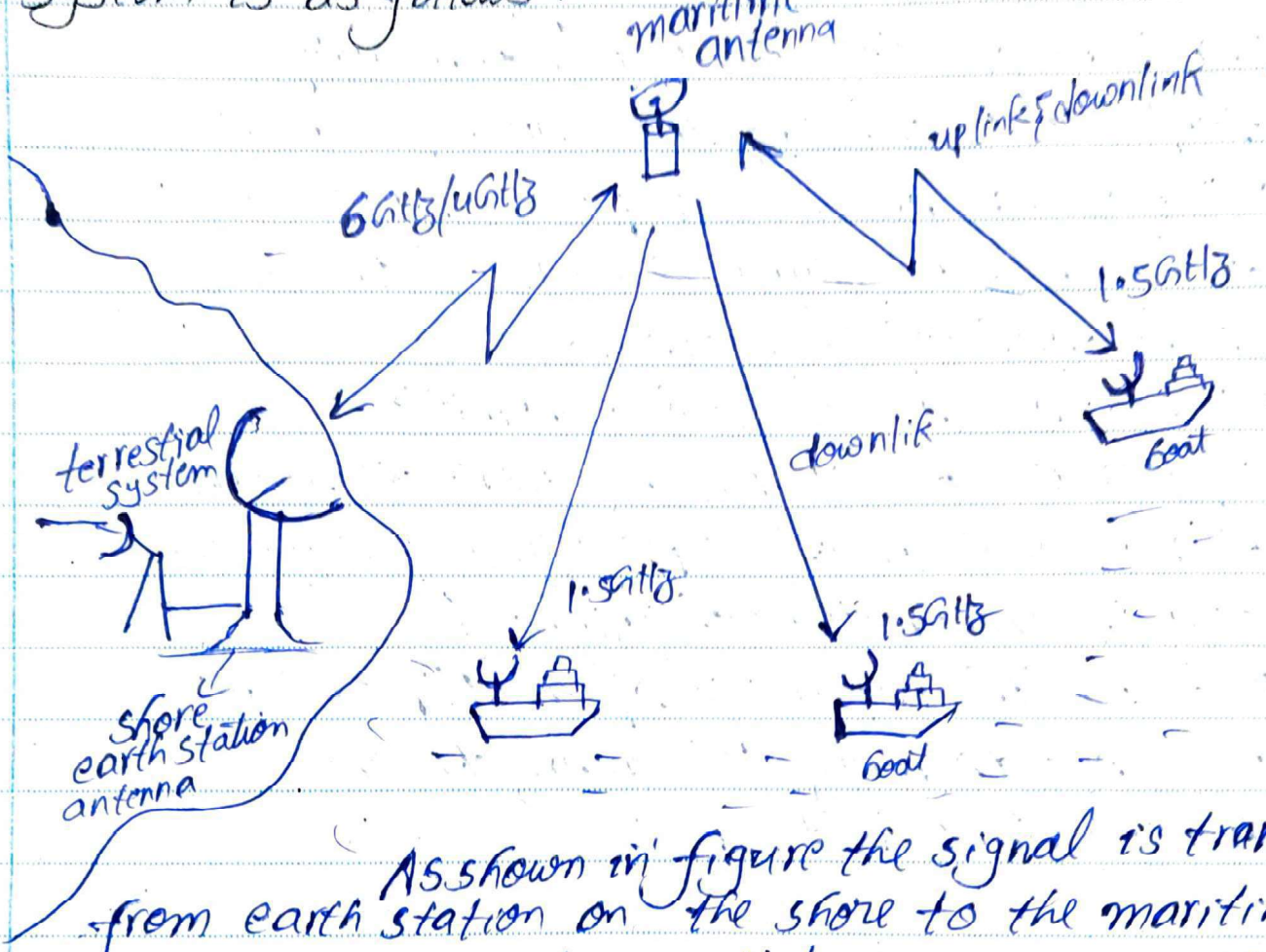
Q.No	Marks
1(c)	2

Q.No	Marks
1(d)	2

Q.No	Marks

(ESTD-1995)

1.e Block diagrame of maritime satellite communication system is as follows:



As shown in figure the signal is transferred from earth station on the shore to the maritime satellite, late it was transmitted from there to the destination boats.

For the use of Evaluator Only

Q.No	Marks
1(e)	2

Q.No	Marks

Q.No	Marks

(ESTD-1995)

1.f Transponders significance in satellite communication:

Transponders are generally present main parts on satellites which has ~~som~~ many significance, some of them are as follows -

* These are act as a repeaters, it means ~~the~~ to increase the signal strength & transmits to the earth station receivers.
* They are act as both transmitters & responders i.e., it does two works it means it responds to the input signal & it ~~is~~ also used to transmitting the signal.
* It has the capability of multiple accessing i.e., one to many (or) many to one transmissions and etc.,

1.g) Advantages of narrow band TDMA:

As we know that in TDMA the time is allocated for different stations & when narrow band is ~~t~~ used in TDMA then we can use less power in transmission i.e., transmitting complexity is reduced & we can also send more data.

For the use of Evaluator Only

Q.No	Marks
1(f)	1

Q.No	Marks
1(g)	1

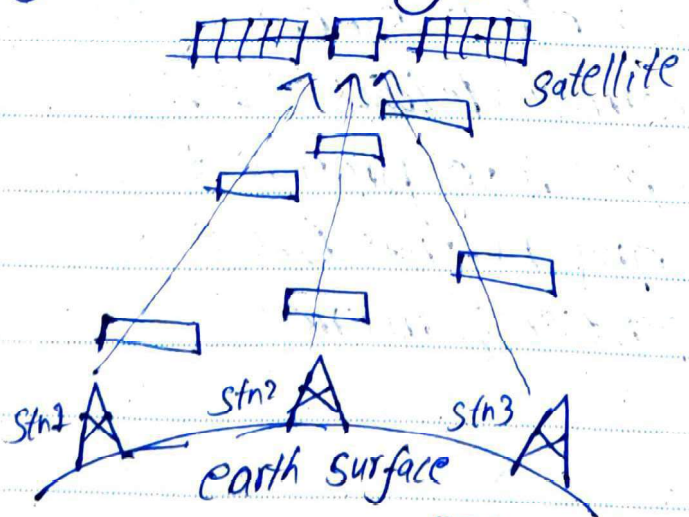
Q.No	Marks

By using narrow band we can get high gain at the receiver end & it is generally obtained by using satellite switching.

Applications: It is used in many ~~places~~ applications where high gain is required & i.e., quality signal is required with high gain. Eg:- In military applications and broadcasting in movie theatres & etc.,

3a) TDMA frame:

It exists only in the satellite transponder because at the time of sending (or) receiving different earth stations gives different traffic data bits at their specified times, it means there is no overlap in timings as shown in figure :-



For the use of Evaluator Only

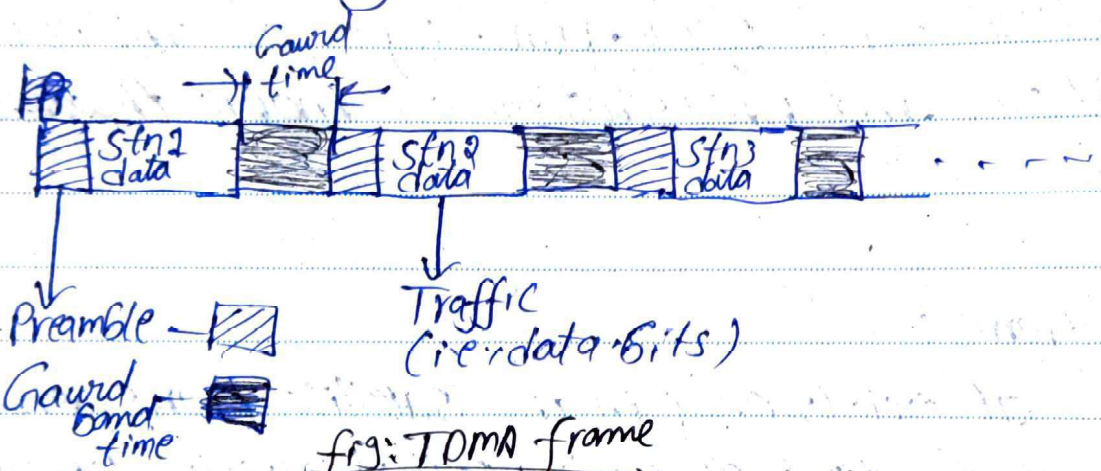
Q.No	Marks

Q.No	Marks

Q.No	Marks

(ESTD-1995)

As shown in figure each time only one station data is present, at the transponder all the data from all the stations is collected & represent it as a one unit called TDMA frame.



frg: TDMA frame

Explanation:

Preamble: It is present in the head part i.e; in front of the data bits it is useful for maintaining clock synchronization timing information, carrier details & other identification details are also present in it. It doesnt generates any revenue but it is helpful in correct reception & in error controling.

For the use of Evaluator Only

Q.No	Marks

Q.No	Marks
3(a)	5

Q.No	Marks

(ESTD-1995)

Traffic: It is nothing but bits of message data i.e, need to be transfer to the other stations on the earth.

Gaurd time:

It is the time gap between two earth stations data, it helps in preventing the overlaping of the data of two earth stations. As it is the time that the satellite need to wait, so it is not allowed to to take more time it is acceptable only in small ranges.

By like this the frame is present in the transponder, later it is sent to the different earth stations.

3.6) Comparison between TDMA and CDMA are as follows:

TDMA	CDMA
* It is one of the technique in multiple access & it is abbreviated as Time Division multiple access.	* It is one of the technique used in multiple access & it is abbreviated as Code Division multiple access.

For the use of Evaluator Only

Q.No	Marks

Q.No	Marks
3,6,7	5

Q.No	Marks

(ESTD-1995)

* Its frequency is constant for all earth stations i.e., all can operate at any freq in allowed bandwidth.	* COMA also operates at ~~constant~~ of frequency is also same as TDMA i.e., all earth stations can operate at any freq.
* Different earth stations are allocated at different times at which they can send (or) receive the data.	* There is no any time allocation is present, in COMA any ~~satellite~~ station can send (or) receive the data at any time.
* Same type of coding technique is mostly used.	* Each station wants to use different coding techniques & only specific receivers knows that code, who can access the data.
* It is mainly used for ~~it~~ digital signals.	* It is also used for digital signals.

For the use of Evaluator Only

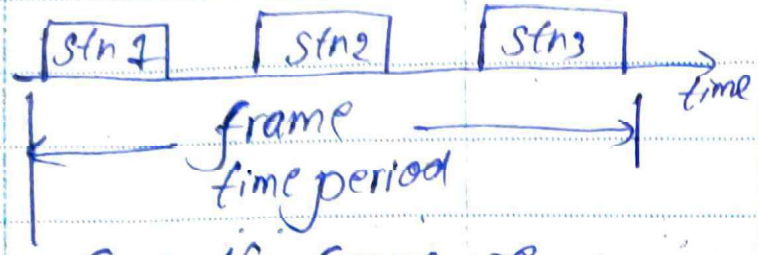
Q.No	Marks

Q.No	Marks

Q.No	Marks

(ESTD-1995)

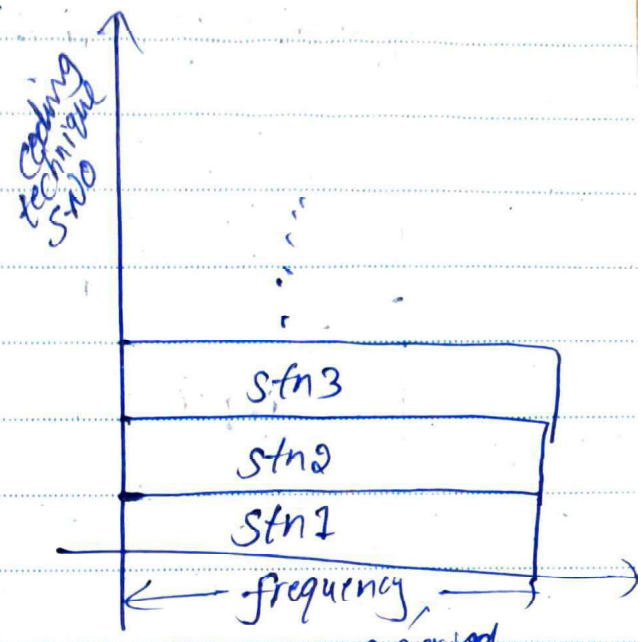
*



from the figure we observe that different times are assigned for different stations for transmission.

* There is no other name for TDMA.

*



from figure we observe that different stns has different coding techniques but all can use at all times with all frequencies.

* It is also called as spread spectrum system.

~~and it~~.

[P.T.O]

For the use of Evaluator Only

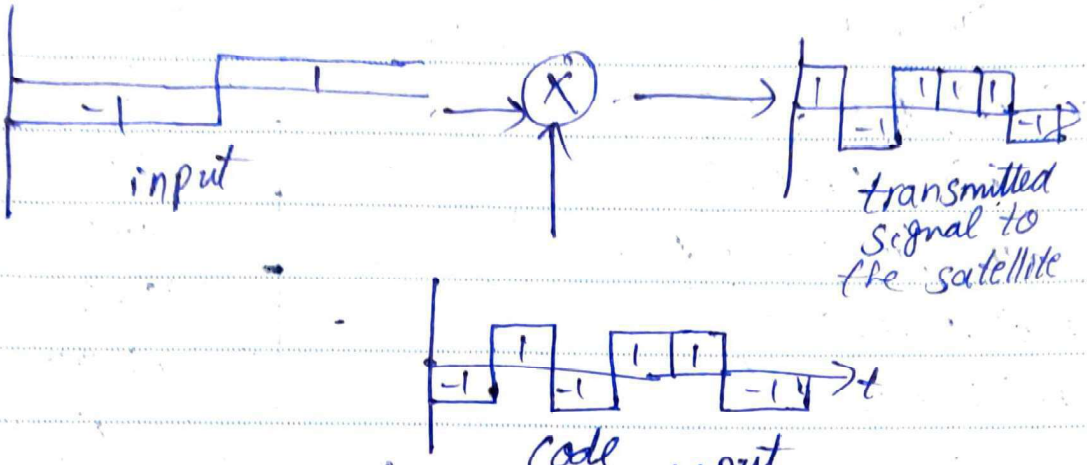
Q.No	Marks

Q.No	Marks

Q.No	Marks

(ESTD-1995)

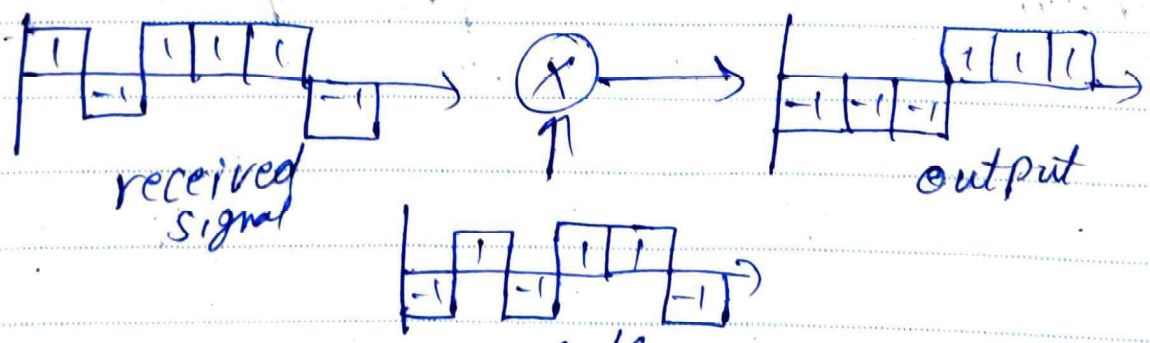
Explanation of CDMA transmission & reception:



Here as shown in figure ~~at~~ is transmitted just by multiplying it with the code & the obtained data sequence is transmitted.

Eg: $-1 \times -1 = +1$, $-1 \times 1 = -1$

at receiver



again, multiplying the received signal with the code, we will get the original signal back.

For the use of Evaluator Only

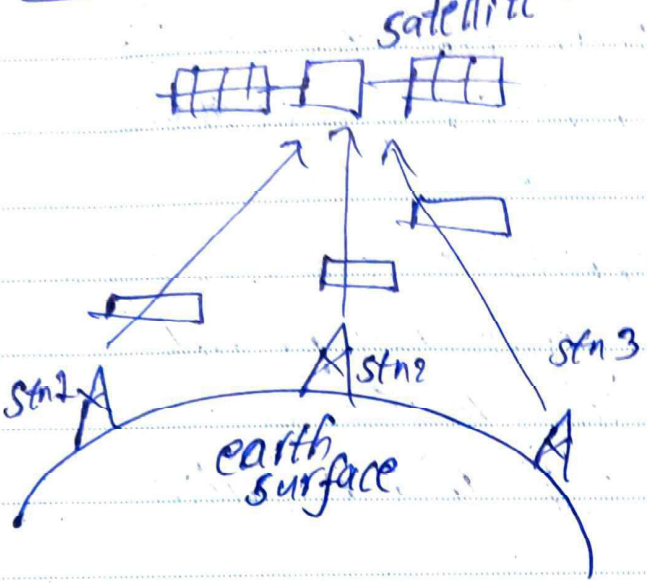
Q.No	Marks

Q.No	Marks

Q.No	Marks

(ESTD-1995)

TDMA explanation:



As shown in the figure only one earth station can send & receive the data at a particular time just as shown in figure. inorder to prevent the collision of data (i.e., overlaping).

4 a) Classification of the satellites based on the altitudes are as follows —

1) LEO
2) MEO
3) GEO

1) LEO (lower earth orbit): These are the orbits which are close to the earth surface; generally present at heights of 500km to 1500 km from the earth surface.

And as there are very close to the earth

For the use of Evaluator Only

Q.No	Marks

Q.No	Marks

Q.No	Marks

(ESTD-1995)

surface, these are mainly used for monitoring the earth & it is easy to place the satellite in that orbit & these orbits are generally elliptical in shape.

2) MEO (medium earth orbits): These are the orbits which are generally present at a heights of 10,000 km to 15,000 km from the earth surface & these are also elliptical in shape.

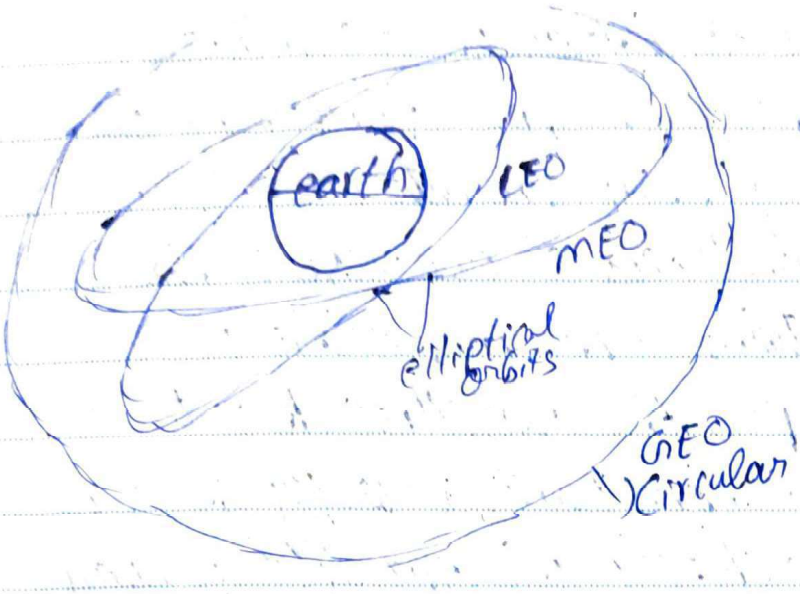
3) GEO (Geo stationary earth orbit): These are the orbits present above the earth surface at an altitude of 35,786 km and these are called as GEO stationary because its time period is equal to the earths rotation period, so it appears as stationary to the person on the earth surface and these orbits are generally circular in shape and present above the equator without inclination with equator plane

Q.No	Marks

For the use of Evaluator Only

Q.No	Marks
4(a)	4

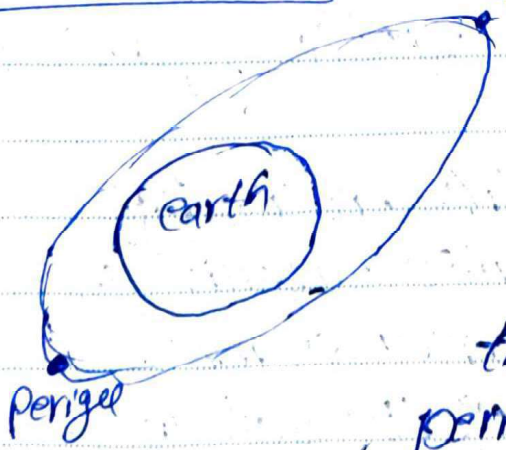
Q.No	Marks



4.6) Performance characteristics of different altitude satellites are as explained below —

We know that based on the altitute the satellite orbits are classified as — 1) LEO
2) MEO &
3) GEO.

1) LEO satellites :



These are the satellites very close to the earth with an altitude range of 500 to 1500 km from the surface, due to this reason these satellites has less time period, so it can rotate many times during a single day, its

For the use of Evaluator Only

Q.No	Marks

Q.No	Marks
4(b)	8

Q.No	Marks

(ESTD-1995)

time period is equal to 90 minutes around. And as these are very close to the earth they can monitor the earth atmospheric conditions & etc;, so it has many applications. As this orbit is in elliptical shape, the satellite doesn't move with the constant velocity so it is not possible to detect the satellite position in the orbit.

2) MEO satellites: The satellites which are revolving around the earth in a MEO orbit i.e; which are at a height of 10,000 km to 15,000 km are called as MEO satellites. the are also present in elliptical shape, these satellites present above the LEO satellites.

Same as LEO satellites, it is difficult to find the position of MEO satellites in the orbit and its time period is more than the time period of LEO satellites.

For the use of Evaluator Only

Q.No	Marks

Q.No	Marks

Q.No	Marks

(ESTD-1995)

These satellites has more coverage area than the LEO satellites i.e., it has less scan angle.



3) GEO satellite: These are the satellites which are present above the earth surface at a height of 35,786 km and the orbits of the GEO satellites are circular in shape, due to this reason it always moves with a constant velocity. so its position can be found easily on the orbit.

These satellites appeared as stationary to the observer on the earth surface because these satellites moves with the same speed of the earth due to this reason the satellite is always pointing the same region at any period during its revolution. So by using this we can make all the data transmissions with in the area easily.

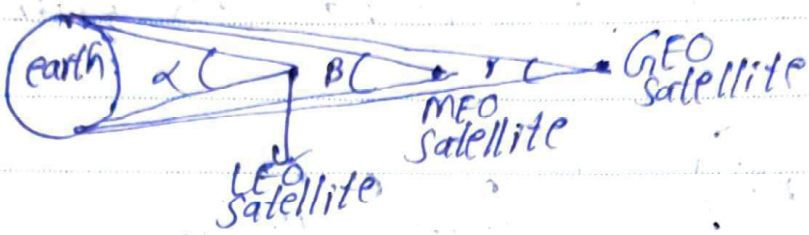
It has more coverage area than LEO & MEO because these are at more height than them.

For the use of Evaluator Only

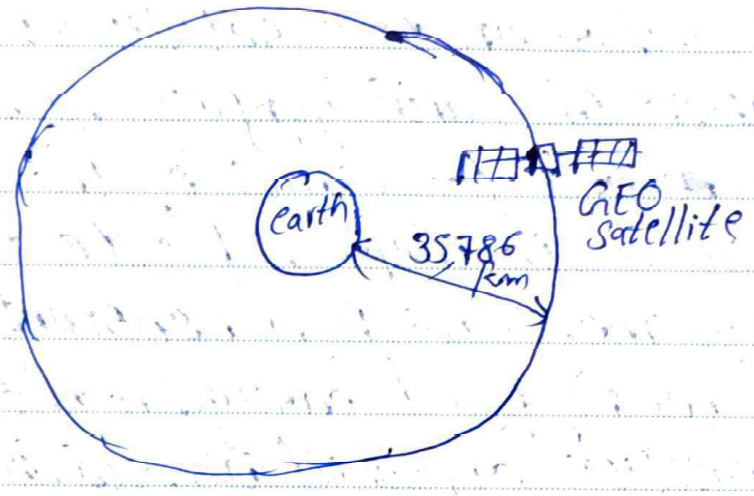
Q.No	Marks

Q.No	Marks

Q.No	Marks



It has less scan angle compared with LEO & MEO.



The GEO satellite (~~general~~) is ~~diffcul~~ difficult to launch into the orbit compared to other satellites. And we need to transmit the signal with more power from the earth station to GEO satellite than MEO & LEO because these are at heigher altitudes than LEO & MEO satellites & C/N ratio is very less

For the use of Evaluator Only

Q.No	Marks

Q.No	Marks

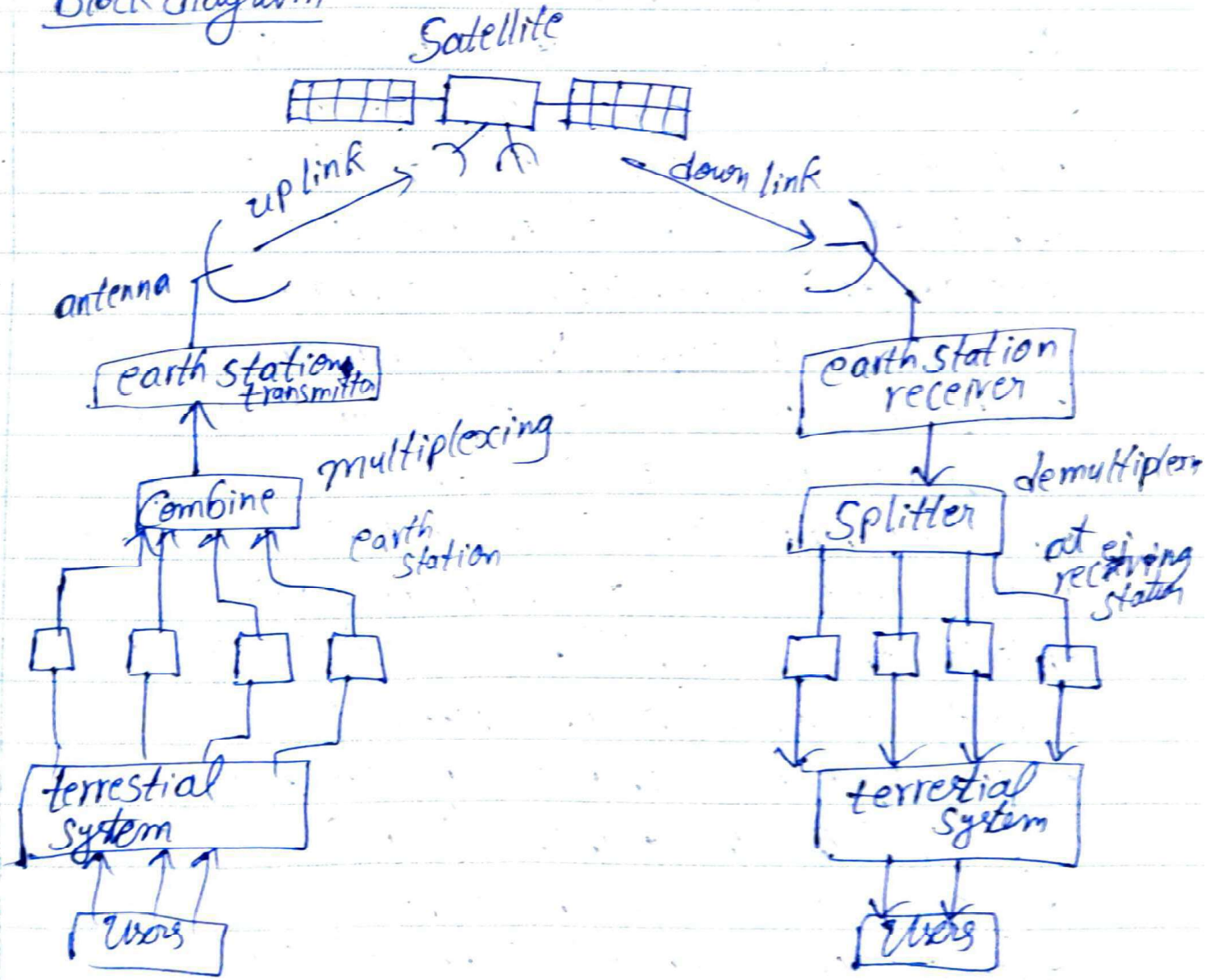
Q.No	Marks

(ESTD-1995)

for the received signals from the GEO satellites than the ~~xxx~~ MEO & LEO satellites.

5a) Transmitting & receiving at earth station:

Block diagram



For the use of Evaluator Only

Q.No	Marks

Q.No	Marks

Q.No	Marks

As shown in the block diagram data of different ~~th~~ users is sent to the earth station through the terestial system just as local transmission lines, at earth ~~s~~ station each signal is modulated & ~~diff~~ conditioned with different properties, after this all the signals are combined to form a ~~sig~~ single signal i.e., multiplexing which is again sent to satellite through the transmitting antenna.

After receiving the signal the transponder in the satellite again sends the signal to the receiver earth station. where an antenna at the earth station receives the signal & which is again splitted into several signals & demultiplexed and it is sent to the different users using the terrestial system.

Like this the transmitting & reception is takes placed at the earth station which is as shown in the

Q.No	Marks

For the use of Evaluator Only

Q.No	Marks

Q.No	Marks
5(a)	5

(ESTD-1995)

block diagram, where the each signal is conditioned ~~to~~ individually to the required frequency, phase & power which is represented by the square block in the block diagram.

5.6) Advantages of DBSTV system:

There are several advantages for DBSTV system, some of them are as explained below -

* By using DBSTV system the users can easily upgrade their subscription (or) pack i.e., the channels they are willing to see unlike contacting any operator.
* By using DBSTV system we can get the high quality output than the normal cable TV.
* As in DBSTV system the signals are directly transmitted to the earth through air, there is only less usage of cables so easy to maintenance.
* Unlike normal cable systems there are less chance of occurring interruptions in signals because in normal cable systems there may be more chance of occuring wire cuts in any place throught the transmission compared to DBSTV.

For the use of Evaluator Only

Q.No	Marks
5(b)	6

Q.No	Marks

Q.No	Marks

* In DBSTV live broadcasting is done easily and one can watch live sitting anywhere in the coverage region.
* It also makes the operators with more profits because for normal systems the prices increases if we need to give the connection for the distant places. But where as in DBSTV no need of cables for long distance.
* And in DBSTV once the satellite is sent for particular area coveraging then its price is fixed ~~for~~ i.e., no increase in price any number of subscribers can use it, this will get the more profits to the provider.
* It also prevents the many issues that happens due to the hanging of cables due to normal broadcasting system.

For the use of Evaluator Only

Q.No	Marks

Q.No	Marks

Q.No	Mark

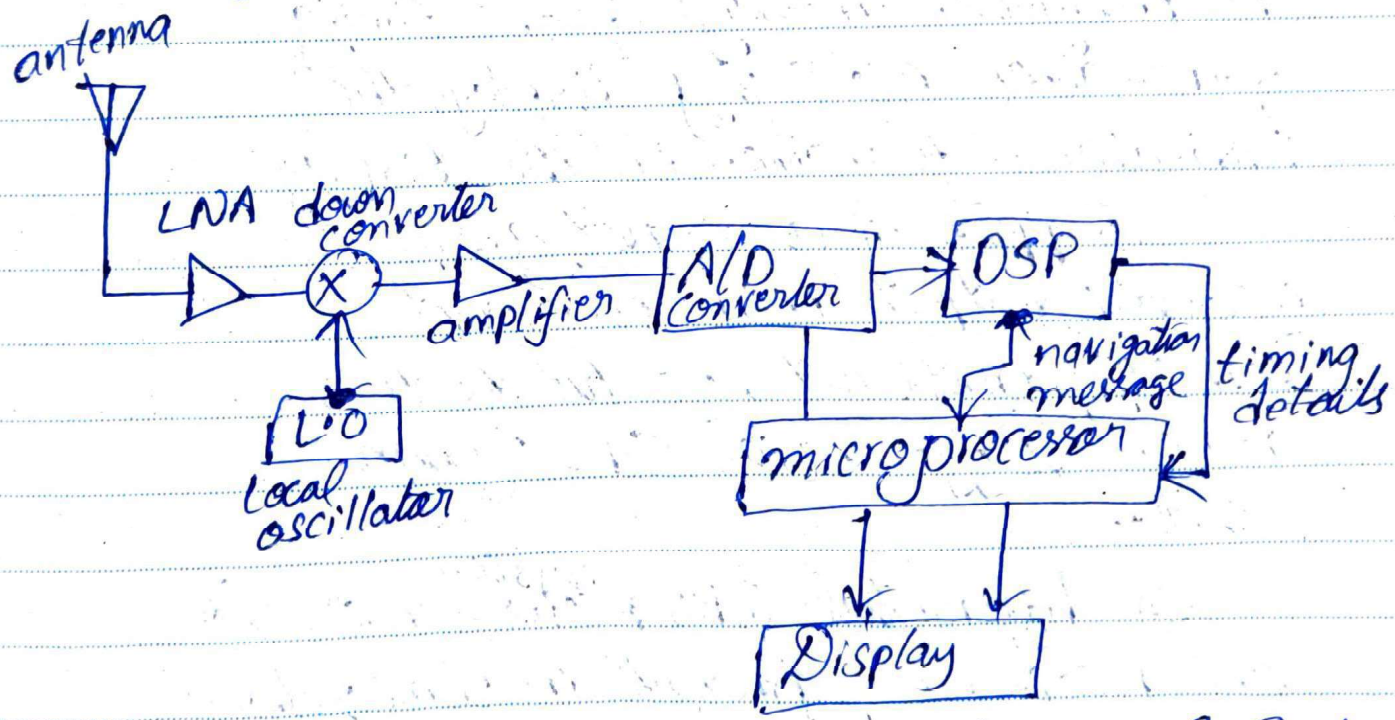
(ESTD-1995)

2.a) **Differential GPS :**

It is one of the technique used in the GPS receiver when the receiving location is not find accurately at this time more than one receiver is used, this type of technique is called Differential GPS.

Normal GPS receiver :

Block diagram



Here the antenna receives the signal & it was given to the low noise amplifier which reduces the noise strength, later it is converted

For the use of Evaluator Only

Q.No	Marks

Q.No	Marks

Q.No	Marks

to the required frequency using down converter & then it is amplified & given to the Analog to digital converter which converts the analog signal to the digital form & the obtained signal is given to the digital signal processing block, where signal is processed & the timing details are extracted which are given to the processor, which takes the navigation message & the timing information block & displays the navigation information in the display.

Suppose if it is not giving the accurate output then it is not correctly positioned, so due to this reason Differential GPS system is used..

In differential GPS ~~receivers~~ system more than one receiver are present in some systems both are parallelly perform the operations & in some systems if any receiver is not working then it is

For the use of Evaluator Only

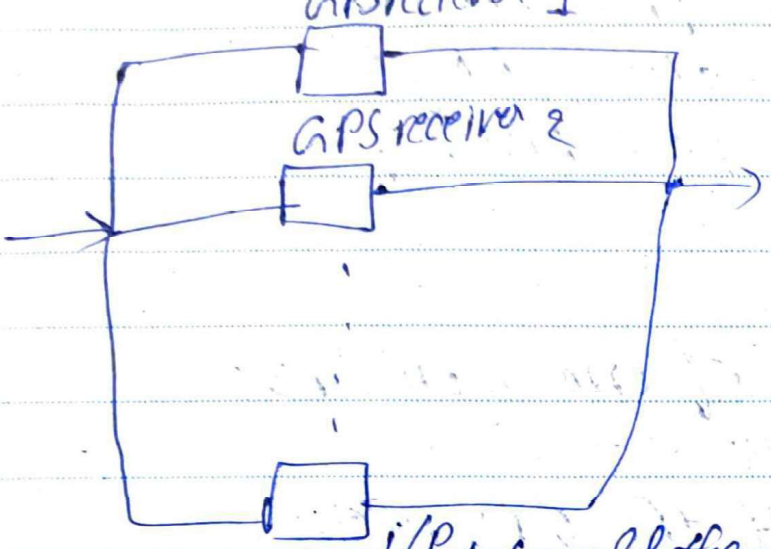
Q.No	Marks

Q.No	Marks

Q.No	Marks

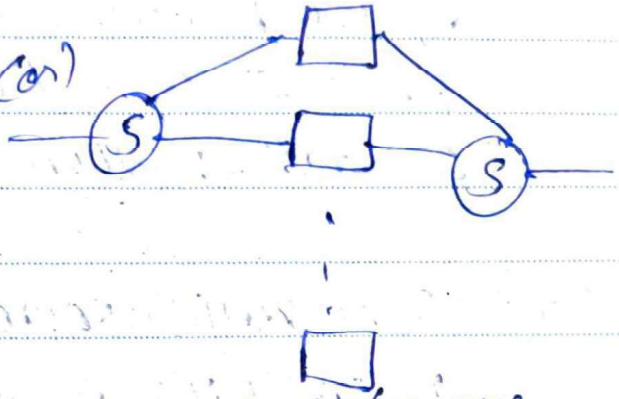
(ESTD-1995)

switched to the another receiver which is available



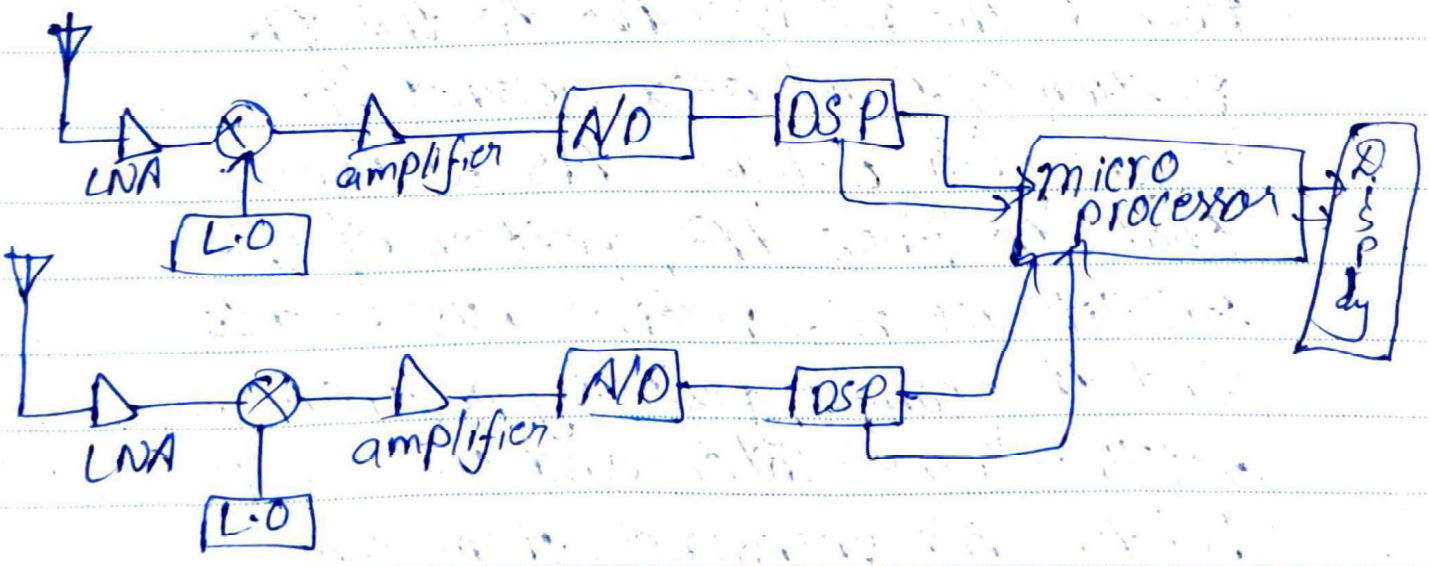
Parallelly i/p sent to all the receivers & o/p is collected

(or)



Switches are used to use the other receivers based on our requirement

Block diagram of DGPS with two receivers in parallel :



For the use of Evaluator Only

Q.No	Marks
2(a)	5

Q.No	Marks

Q.No	Marks

It is same as normal GPS receiver but here the processed data of two receivers is collected by the processor to get accurate data o/p i.e. accurate position.

2.6) The major sources of errors in GPS receiver are as follows —

* Receiver noise: If the GPS receiver has any problem then there is a chance of noise occuring (or) due to the collisions of several data signals there may be a chance of generating noise in the receiver due to this the position is found ~~accu~~ accurately.

* Ionospheric delay: As we know that to know the position of the (~~satellite we r~~) receiver, we need to send the sample pulse signal from the satellites in constellation and the corresponding times are measured, from that times we can calculate the pseudo

Q.No	Marks

For the use of Evaluator Only

Q.No	Marks

Q.No	Mar

ranges, while the signal is transmitted, before reaching the earth ~~sth~~ GPS receiver on earth it has to travel several distance & while travelling some delay is occured due to the ionospheric ~~dela~~ layer in atmosphere, due to this there is an error in the receiver position.

* Tropospheric delay: Just like ionospheric delay, troposphere also wastes some time; due to this there is an error in distance calculation i.e., indirectly in position calculation.

* Selective availability: It is (~~the~~). the degradation of the C/A code accuracy during the national emergency time, this was done by the government to stop the spreading of the news at emergency times & only military persons can use. So when the selective availability is turned ON then there is an error in the receivers portion.

* Clock error: As time is very much needed in calculating the distance; so if there is error in the clock whether at the GPS receiver end (or) in satellite this leads to the error in accuracy of calculating the position.

For the use of Evaluator Only

Q.No	Marks

Q.No	Marks
2(b)	5

Q.No	Marks

(ESTD-1995)

* Ephemeris data: If ephemeris data is not present correctly then we can't identify the position of other satellites ~~in~~ at the receiver so it leads to the error in calculating the position at the receiver.
* Correlator problems: As it is need to compare the 1023 bits of C/A code the correlator needs to be fast & it wants to work more precisely if there is a problem in correlator, which leads to the error in the GPS receiver, which in turn leads to the error in calculating correct position.
* Multiple path: It is also one of the reason for occuring errors in GPS receiver.

Q.No	Marks

For the use of Evaluator Only

Q.No	Marks

Q.No	Ma

RAJEEV GANDHI MEMORIAL COLLEGE OF ENGINEERING AND TECHNOLOGY
(AUTONOMOUS)

DEPARTMENT OF ECE

COURSE FILE

(A0441198) Satellite Communication

Prepared
By
Mr.P.Rangappa,
Assistant Professor,
Department of ECE,
RGMCET, Nandyal.



DEPARTMENT OF ECE

UNIT I

INTRODUCTION:

- Background,
- A brief history of satellite communications,
- Overview of satellite communications,
- frequency allocations of satellite services,
- design considerations of satellite communications,
- Advantages & Disadvantages of satellite communications.

ORBITAL MECHANICS AND LAUNCHERS:

- Orbital Mechanics, Developing the equations of the orbit,
- Kepler's three laws of planetary motion,
- Describing the orbit of a satellite,
- Locating the satellite in the orbit,
- Locating the satellite with respect to the earth,
- Orbital elements ,The sub satellite point,
- Look Angle determination: Elevation angle calculation, Azimuth angle calculation,
- Specialization to geostationary satellites,
- Orbital perturbations: Longitudinal and Inclination changes.
- Orbit determination,
- Launches and Launch Vehicles: Expendable launch vehicles,
- Placing satellites into geostationary orbit.
- Orbital effects in communications systems performance,
- Orbit considerations, coverage and frequency considerations.

UNIT: I

INTRODUCTION:

→ A satellite is an artificial object or Machine, which has been intentionally placed into orbit.

→ Such objects are sometimes called artificial satellites to distinguish them from natural satellites.

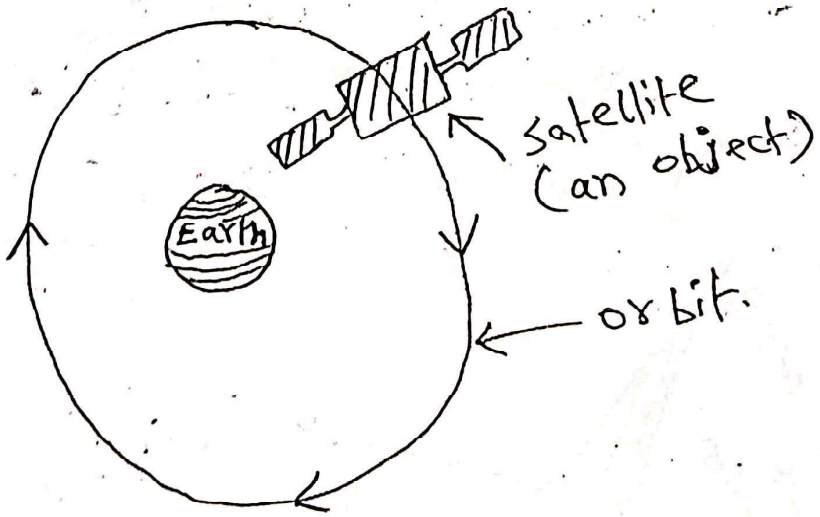
→ So a satellite is a object or machine that is launched into space in a orbit and moves around earth or another planet or another body in space.

→ examples for natural satellites.

→ Earth is a natural satellite, because it rotates around 'sun'

→ Moon is a natural satellite, because it rotates around 'earth'

→ An orbit is a gravitationally curved path of an object (satellite) around a planet (earth)



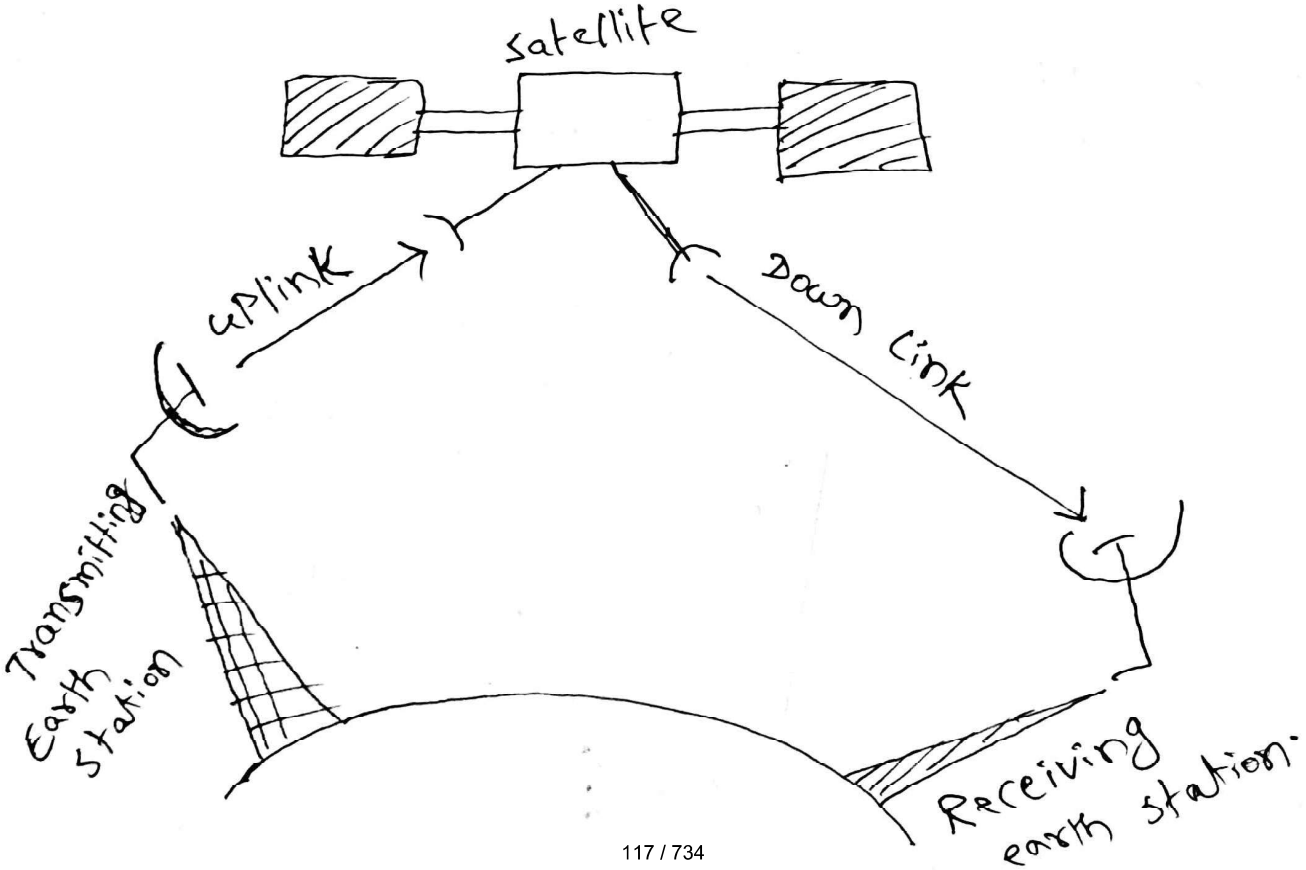
→ A Rocket is used to Launch a satellite into orbit. so Rocket is called a launch vehicle.

→ Rocket works on the principle of Newton's third Law of motion. (i.e for every action, there is an equal and opposite reaction).

→ Rocket's action is to push down on the ground with the force of it's powerful engines, and the reaction is that the ground pushes rocket upwards with an equal force.

Satellite communication:

Satellite communication is the process of conveying messages in the form of audio, video and text by means of radio and T.V. broadcasts using satellites stationed in outerspace in Geostationary orbits.



Main parts of satellite:

→ Apart from transmitting earth station and receiving eath station, a satellite in orbit consists of one or more transponders, power source.

→ A satellite transponder receives signals from transmitting earth station over a range of uplink frequencies, amplifies them, and retransmits the signals on a different set of downlink frequencies to the receivers on earth, without changing the contents of the received signal. (i.e repeating the same signal to different locations on earth)

→ Hence a satellite is also called as RF repeater.

→ A Transponder containg antennas, An amplifier.

→ Transmitter — Responder = Transponder.

→ A Power source in a satellite may be a solar cell or solar panel and battery.

→ Transponders, antennas and switching systems ~~are cattle~~ alltogether is called "payload"

Historical development of satellite communication (A Brief history of satellite communication):

→ Satellite communication began in october-4, 1957 with the launch of a small satellite called "SPUTNIK I", by USSR. This is the first artificial earth satellite. And it sparked the space race between United states and USSR.

→ This satellite got failed to provide communication; but it demonstrated that satellites can be launched in the orbit by powerful rockets.

→ After SPUTNIK-I, in 1957 November-3, USSR launched SPUTNIK-II satellite.

→ After that united states succesfully launched EXPLORER I, in January 31, 1958. But the first succesful message transmitted back to earth is by "Project ~~score~~ SCORE" satellite, in December 1958.

→ The communicatio satellites, Telstar-I and II were launched in 1962, July and May 1963.

→ on December 20, 1961, the U.S congress recommended that the Interrational Telecommunications union (ITU) Should examine the aspects of space communication for which international co-operation would be necessary.

→ In August 1962, U.S congress passed the "communication satellite

→ In 1964 INTELSAT (International Telecommunications Satellite organization) was found and the first Satellite (INTELSAT-I) was launched into geostationary orbit. This consists of two 6/4 GHz transponder, each with 25 MHz bandwidth and 36 kg weight.

→ Around 140 countries are involved in INTELSAT organization. The first Intelsat satellite, INTELSAT-1 (Formerly Early Bird) was launched on April-16, 1965

→ In mid-1963, 99% of satellites had been launched into LEO (Low Earth orbit), and slightly higher medium earth orbit (MEO)

→ It is easy to launch satellites in to LEO, MEO when compared to GEO (Geostationary Earth orbit)

→ 1965, USSR launched a communication satellite MOLNYA

→ Canada was the first country to build a National Telecommunication system using GEO satellite Anika 1A in MAY 1974.

→ The history of Indian satellite communication starts with the launching of a satellite called "Aryabhatta" on 19th April, 1975

→ In the 1970's and 1980's there was rapid development of GEO satellite systems for international, regional and domestic telephone traffic and video distribution

→ In 1979, International Maritime satellite organization (INMARSAT) was established for Mobile communication

→ By the end of 1983, telephone traffic carried by the US domestic satellite systems earned more revenue than the Intelsat system.

→ In 1989-90 global Mobile communication service was extended to land mobile and geonatical use.

→ The three LEO satellite systems (Iridium, Globalstar, and orbcomm) are developed in between 1990 and 2000

→ The implementation of a LEO and MEO satellite system for mobile communication has proved much more costly than anticipated, and the capacity of the system is relatively small compared to GEO satellite system, leading to a higher cost per transmit bit.

→ In Year 2000-2005, broadband personal communications were introduced and number of LEO & MEO Satellite systems were made operational.

→ In 2000, a significant reduction in the call charges can be achieved by the use of personal VSAT's (Very small aperture Terminal system) which can Provide various broadband services.

→ By the Year 2000, GPS (Global Positioning system) came.

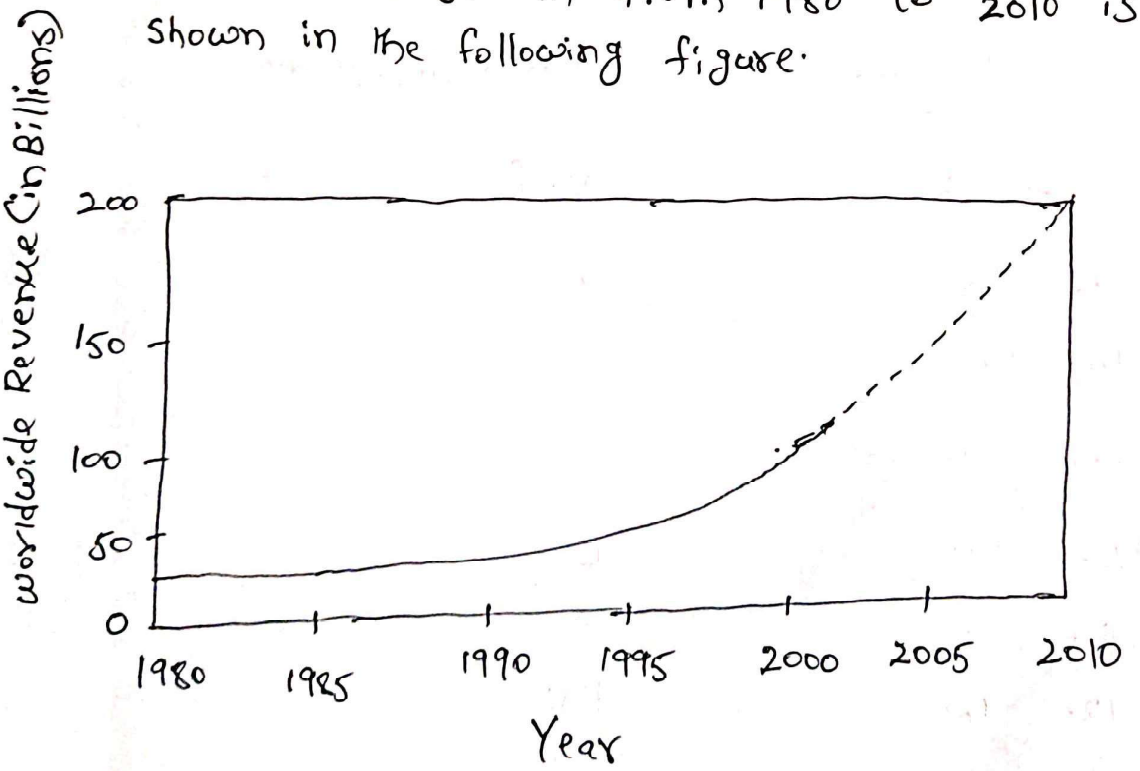
→ In the next decade (i.e from Year 2000 onwards), the mobile communication through satellites is expected to be a major growth area and hence the satellites will play a crucial role in the development of mobile communication

→ The revenues earned by the GEO satellite has been increasing since 2000 and in U.S.A there were 14 million customers of DBS-TV (Direct Broadcast satellite T.V). High power transmitters and high gain antennas of earth stations have increased the capacity of GEO satellite, and inturn increases the revenues.

→ GEO satellites have always been the backbone of commercial satellite communication industry.

→ large GEO satellites can serve one third of the earth's surface, and can carry upto 4 Gbps of data, or transmit upto 16 high power direct broadcast satellite T.V (DBS-TV) signals, each of which can deliver several video channels

The revenue growth from 1980 to 2010 is shown in the following figure.



Frequency allocations for satellite services:

→ Allocating frequencies to satellite services is a complicated process which requires international coordination and planning. This is carried out under the control of International Telecommunication union (ITU)

→ Some of the services provided by satellites are

Fixed satellite services (FSS)
Broadcasting satellite services (BSS)
Mobile satellite services
Navigational satellite services
Meteorological satellite services.

The frequency band designations for satellite services is shown below

Frequency Range, GHz	Band designation
0.1 – 0.3	VHF
0.3 – 1.0	UHF
1.0 – 2.0	L
2.0 – 4.0	S
4.0 – 8.0	C
8.0 – 12.0	X
12.0 – 18.0	KU
18.0 – 27.0	K
27.0 – 40.0	Ka
40.0 – 75	V

75 - 110 ——— W

110 - 300 ——— mm

300 - 3000 ——— μm

→ The Ku band is the one used at present for direct broadcast satellites. And this band is also used for certain fixed satellite services.

→ The C band is used for fixed satellite services, and no direct broadcast services are allowed in this band.

→ The VHf band is used for certain mobile and navigational services. And also VHf band is used for data transfer from weather satellites.

→ The L-band is used for mobile satellite services and navigation systems.

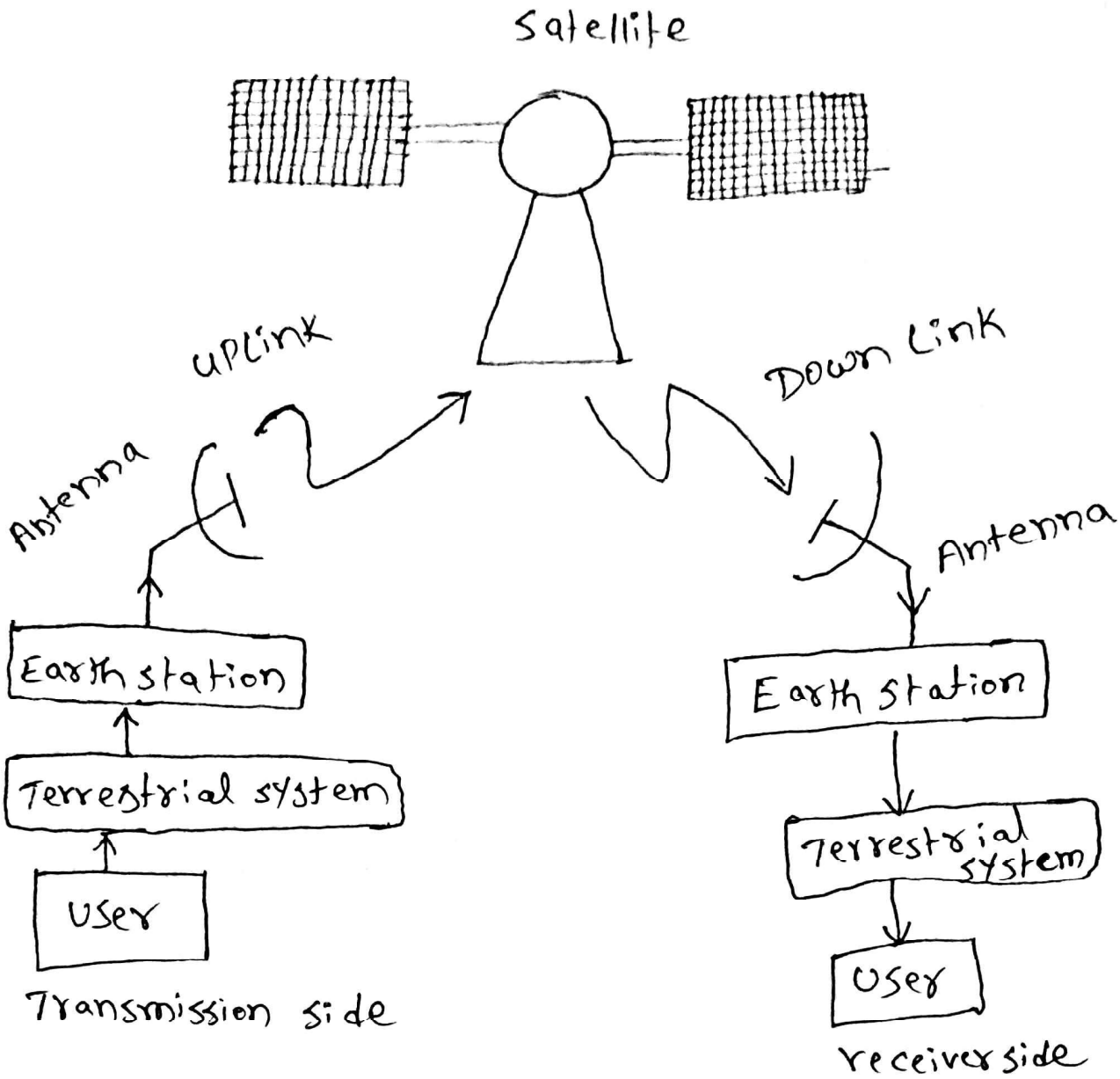
→ V-band is used for intersatellite communications.

→ X-band is used for mobile radio relay and military

→ FSS is a type of mobile telephone service that allows users in a specific area to make & receive cellphone calls. FSS systems mcell phone towers are placed in strategic, fixed locations & provide service 1000's of individual users simultaneously

→ BSS signals txd or retxd by space stations are intended for direct reception by general public.

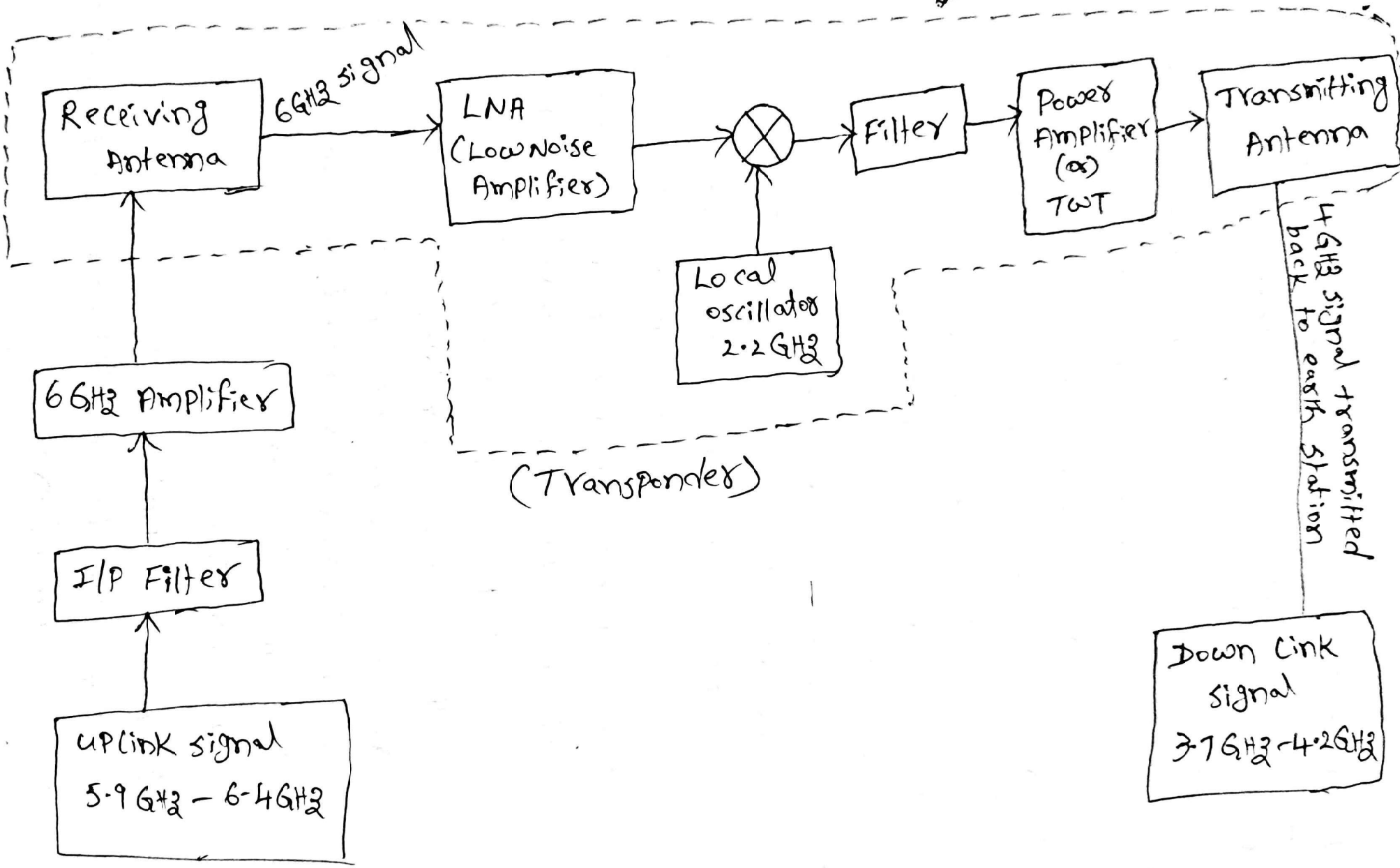
Satellite communication:



→ A satellite is a powerful long distance and Point to multipoint communication system

→ A communication satellite (COM SAT) is an R·F repeater

Block diagram of satellite communication



→ The transmitting earth station consists of a ~~dish antenna~~ Parabolic dish antenna, which can transmit a High frequency (5.9 to 6.4 GHz) Microwave signal. This frequency is called as uplink frequency

→ From the earth station transmitting antenna 6 GHz signal is transmitted to satellite.

→ Hence the uplinked signal to satellite is 6 GHz.

→ 6 GHz uplinked signal is received by satellite.

→ Then the transponder in the satellite receives uplink signal

→ The Transponder consists of

① An input band limiting device (BPF)

② LNA (Low Noise Amplifier) to amplify the signals received from the earth station.

③ A frequency translator (Normally composed of an oscillator and frequency Mixer)

ie Mixer + LO (Local oscillator)

This frequency translator is used to convert the frequency of the received signal to the frequency required for the transmitted signal

④ An o/p BPF

⑤ A Power Amplifier

(This can be a TWT or Solid state Amplifier)

→ So 6GHz uplink signal is amplified using LNA. This amplified signal is then down-converted to 4GHz. It is sent through a filter and then power amplified

→ The Local oscillator frequency ~~of~~ is 2.2GHz for C-band.

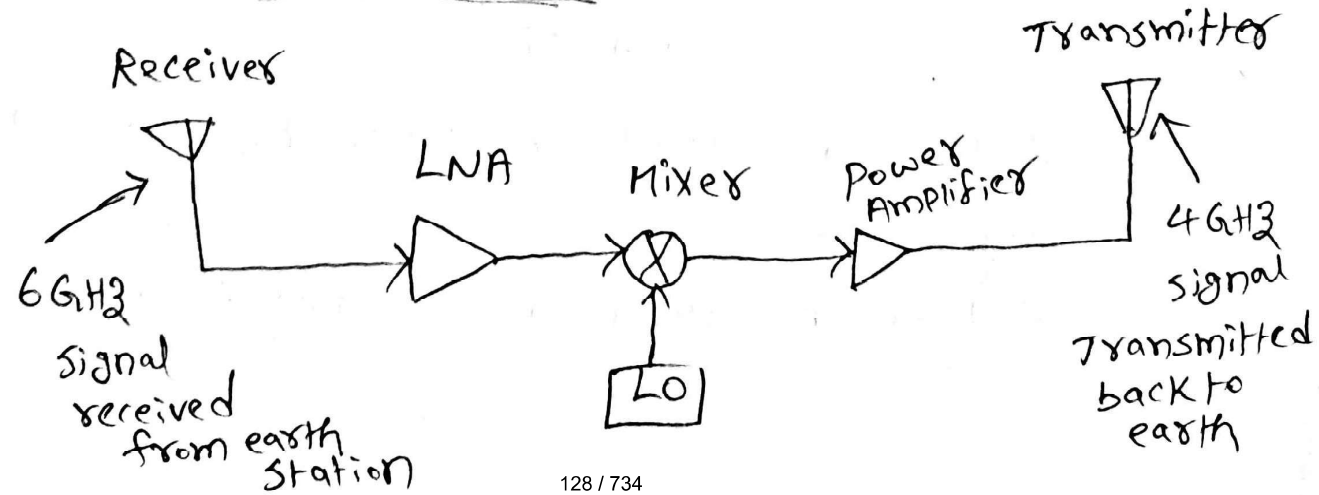
→ This signal is then retransmitted towards receiving earth station.

→ Hence a communication satellite acts as repeater station. It receives the signal, amplifies it and then transmitted over a other (down) frequencies to avoid interference between the uplink signal and Down link signal.

→ Hence two way communication is established with the help of Transponder

→ A communication satellite can have multi transponders.

A Transponder
(Block diagram)



Applications of satellite communication:

① satellites are used in mobile communication.
② satellites are used in the communication of T.V and Telephone.
③ satellites are used for data transfer such as e-mail, internet
④ satellites are used in Remote sensing applications (Generally with the help of Low Earth orbit satellites.
⑤ Earth observation can be done with the help of LEO satellites.
⑥ Meteorological applications:
   - weather Monitoring
   - weather survey
   - steady of different layers and amount of ozone contents in the atmosphere.
⑦ satellites are used in Radio broadcasting applications.
⑧ satellites are used in internet communication.

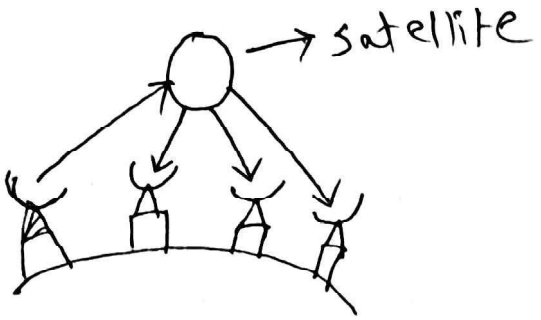
⑨ satellites are used in GPS (Global Positioning system) ie Navigational applications.

⑩ satellites are used in Military applications like short distance local communication from one camp to another, to study the location of enemy, e.t.c

⑪ Point-to-multipoint communication.

Advantages of satellite communication:

① Point-to-multi point communication



i.e Multiple access points are available in satellite communication system.

② 24/7 communication can be achieved with the help of satellite communication

③ The signal quality of satellite communication is high.

④ Mobile communication:

By using satellite communication, we can establish communication between two continents, or to any mobile units in any parts of world.

⑤ Satellite communication is used for Long distance communication or across oceans.

⑥ Audio and video broadcasting, High Transmission capability DTH (Direct to Home) Technology.

⑦ Military services:

Data which is communicated in this service is generally encripted, so that it can be secured.

⑧ A weather monitoring system can be established by using satellite communication.

⑨ Weather forecasting services.

⑩ Satellites are used to provide voice & data communication to air crafts, ships, land vehicles etc

⑪ Direct Broadcast satellite-TV system (DBS-TV)

⑫ A satellite, being placed, above the earth in orbit, it can cover more area on earth, when compare to terrestrial communication system on earth.

Disadvantages of satellite communication:

① High Cost:

The cost for initial design and launching of the satellite in the orbit results in extreamly high

② careful Techno-economic study is required before introduction of this system.

③ This is a loss of service to large area

④ It is impossible to correct any defect after launching the satellite. Hence the reliability of this system is less.

⑤ Propagation delay occurs, if the satellite orbit is very high from the ~~service~~ surface

⑥ Satellite communication is distributed by solar activities and cyclones in the space.

Advantages of satellites over optical fibers:

① The satellite costs are independent of distance.

② satellite can capture the images of nuclear weapons present on the earth

③ By using a satellite the image and location of enemies can be captured.

④ satellite can locate natural resources, mines, rivers, lakes etc on earth.

⑤ GPS: using global Positioning system, any location on the earth can be located.

⑥ T.V. distribution: The DBS-TV provides direct home broadcasting of T.V.

⑦ satellite broadband Internet

⑧ Rescue and Navigation purposes

Design considerations of satellite communication:

① selection of radio frequency:

An important parameter in designing of a satellite system is the selection of radio frequency for a given application.

The selection of radio frequency can be decided by the special needs of the application, the expected Propagation characteristics, state of technology, radio regulations and spectrum availability.

ITU manages the allocation of RF spectrum, so that, radio system may coexist without interference.

② Type of Modulation and coding Technique:

A Further design aspect is the selection of an optimum modulation and coding scheme. The choice is based on the type of message, radio link characteristics and earth station complexity.

Note: Modulation is a process of mixing baseband signal to carrier

→ coding refers to process of providing protection to message signals against corruption of RF signal by incorporating redundant bits with in the baseband digital signals.

→ The characteristics of baseband signals also influence the modulation and coding schemes.

③ There may be many earth stations which share a common satellite, hence it is necessary to use appropriate methods for accessing the satellite.

④ Size of coverage area

⑤ characteristics of earth station

⑥ Earth station size and complexity

⑦ The size and shape of the service area and technology related to space craft and earth station.

⑧ Aircraft Technology used

⑨ Path attenuation, polarization

⑩ Noise

⑪ Atmospheric observations

⑫ scattering

⑬ signal observations

⑭ Diffraction, weather conditions.

⑮ absorption and scattering by clouds, fogs and inospheric effects

SATELLITE ORBIT:

Orbit: The path of a satellite around the earth is called satellite orbit

(or) orbit is a gravitationally curved path of a satellite around earth.

→ The path in which satellite goes round the earth is called **orbit path**. And the distance from the center of the earth to the satellite is called **orbit radius**

Types of orbits:

① Circular orbit

② Elliptical orbit

orbit period: Time taken by the satellite to complete one revolution.

(or)

orbit period is a period to revolve one revolution around the earth.

→ Orbits are classified interms of hight i.e altitude from the earth serface.

① Low Earth orbit (LEO)

[Altitude: (500 – 1500 km)]

② Middle Earth orbit (MEO)
(or) Medium Earth orbit

[Altitude: 5000 to 10,000 km]

③ Geostationary Earth orbit (GEO)

altitude: Approximately 36,000 km
36,786km

→ <u>For a circular orbit:</u>

To send a satellite at a height 'h', the required velocity is

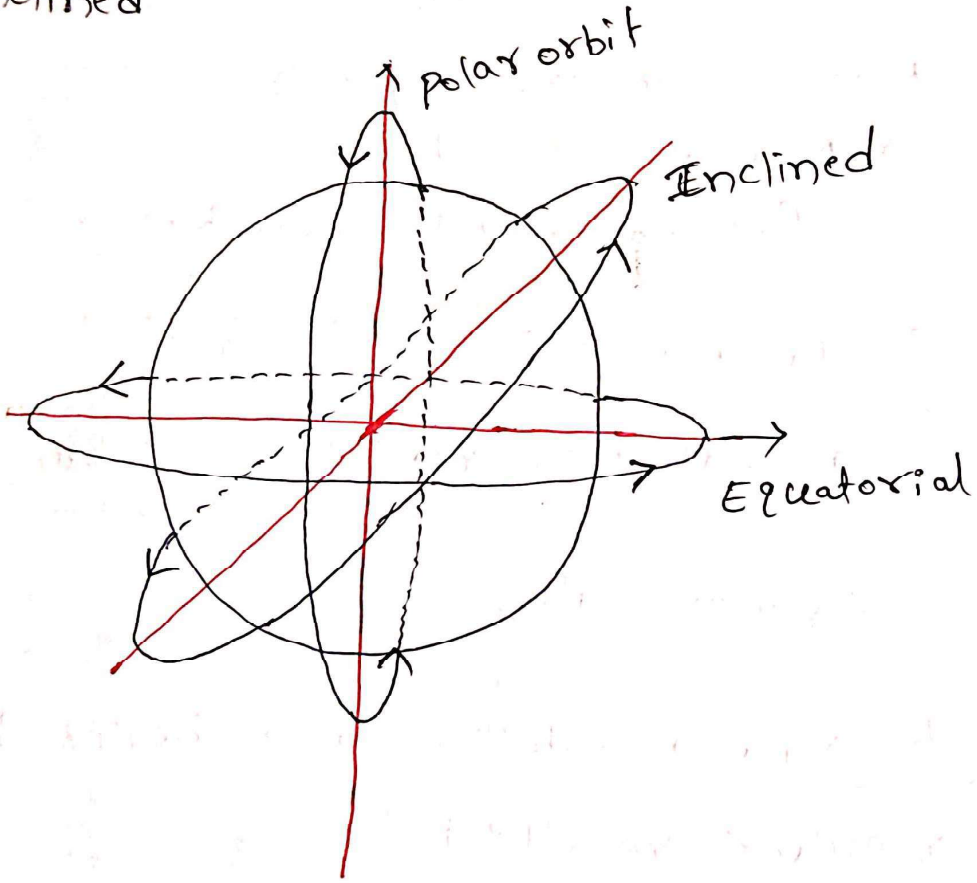
$$V = \sqrt{\frac{g}{r_e + h}}$$

Where r_e = Radius of earth (6,378 km)

g = Acceleration due to gravity
(or) Gravitational coefficient

→ The motion of satellite around the earth is similar to planetary motion (i.e how planets revolve around SUN)

→ A satellite rotates around the earth with an orbit, that can be equatorial, polar or inclined



$\frac{g_0}{r_{earth}} = \omega_{earth}^2$

$\omega_s = \sqrt{\frac{g_0}{(r_{earth})^3}}$

$t_s = \frac{2\pi}{\sqrt{g_0}}$

→ The satellite encircles the earth with an orbit that may be elliptical or circular

→ For a circular orbit, to place a satellite at a height 'h' from the earth surface, the required velocity of a satellite is

$$V_s = \sqrt{\frac{g_0}{r_e + h}} \rightarrow (1)$$

where r_e = earth radius (6378 km)

h = orbit altitude

g_0 = Gravitational coefficient

$= (1.4 \times 10^{16})\ ft^3/sec^2$

Note: 1 nautical mile = 1.852 km (1 nm)

1 mile = 1.6 km

→ The time t_s for an orbiting satellite to complete one revolution (i.e orbit period)

→ The orbit period and angular velocity are related by

$$t_s \cdot \omega_s = 2\pi$$

where ω_s is the angular velocity in rad/sec

$$\therefore t_s = \frac{2\pi}{\omega_s} \longrightarrow (2)$$

→ The velocity of satellite is

$$V_s = (r_e + h)\,\omega_s \longrightarrow (3)$$

→ From (1) $V_s = \dfrac{\sqrt{g_0}}{(r_e+h)^{1/2}}$

→ ~~Substitute (3) in above (1)~~

~~V_s~~

From (3) $\omega_s = \dfrac{V_s}{(r_e+h)}$

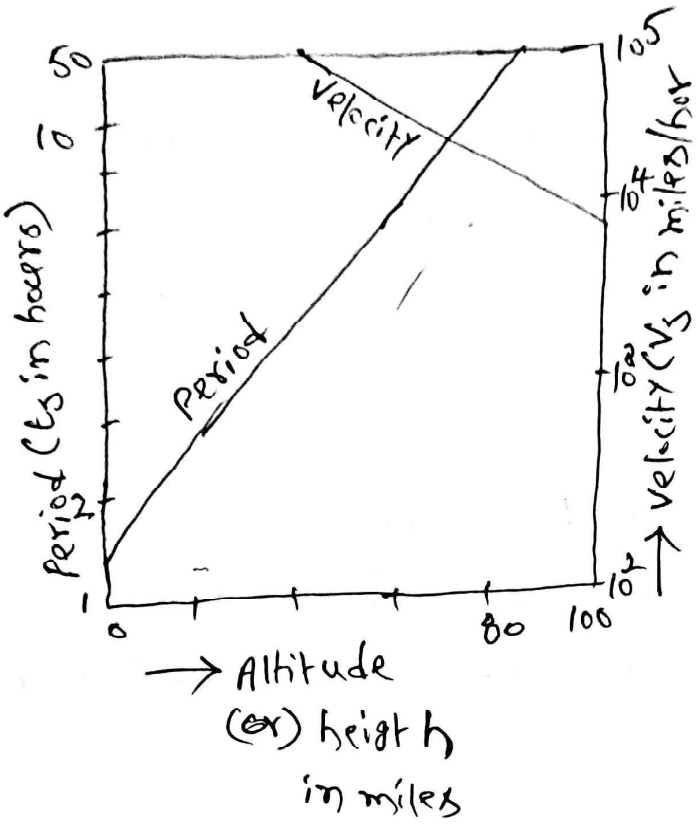
Substitute $V_s = \dfrac{\sqrt{g_0}}{(r_e+h)^{1/2}}$

$$\therefore \omega_s = \frac{\sqrt{g_0}}{(r_e+h)^{3/2}}$$

$$\therefore t_s = \frac{2\pi}{\omega_s} = \frac{2\pi}{\sqrt{g_0}}(r_e+h)^{3/2}$$

$$\boxed{\therefore t_s = \frac{2\pi}{\sqrt{g_0}}(r_e+h)^{3/2}} \longrightarrow (4)$$

→ Drawing the graph between equations (1) and (4)



→ From the plots (1) and (4) equations, we can conclude

(1) As the orbit altitude increases, the required satellite velocity decreases

(2) As the orbit altitude increases, the orbit period increases

→ In case of synchronous or geostationary ~~orbit~~ satellite, the velocity of satellite is equal to rotation speed of earth. Hence a satellite in Geostationary orbit appear to be fixed at ~~sky~~ a specific point in the sky, when viewed from the earth.

→ The majority of communication satellites are in Geostationary earth orbit (GEO) at an altitude of 35,786 km

→ Radio signals get weaker in proportion to the square of the distance travelled.

→ So signals reaching a satellite are always very weak.

→ Similarly signals received on earth from a satellite are also very weak, because of limits on the ~~cost~~ weight of GEO satellites and the electrical power ~~that~~ they can generate using solar cells

Overview of satellite communications

→ Satellite communication systems exist because the earth is a sphere.

→ Radio waves travel in straight lines at the microwave frequencies used for wideband communications

→ So a repeater is needed to convey signals over long distances.

→ A satellite is best place to locate repeater.

→ A GEO satellite is the best place ~~of~~ of all, to locate repeater.

→ The majority of ~~satellite~~ communication satellites

are in GEO, at an altitude of 35,786 km.

→ signals reaching a satellite, and signals received on earth from a satellite are always very weak.

→ Hence a repeater is required, to receive, amplify and retransmits the signal.

→ A GEO satellite Life time is 10 to 15 years.

→ Satellite communication systems are dominated by the need to receive very weak signals. In the ~~early~~ early days very large receiving antennas, with diameters up to 30 m, were needed to collect sufficient signal power to drive video signals, or multiplexed telephone channels.

→ As satellites have become larger, heavier, and more powerful, smaller earth station antennas have become feasible, and DBS-TV receiving systems can use dish antennas as small as 0.5 m in diameter

→ Satellite systems operate in the microwave and millimeter wave frequency bands, using frequencies 1 to ~~[illegible]~~ 50 GHz.

→ for The first 20 years of satellite communication, Analog signals were widely used. These links mostly used FM.

→ Now a days for the satellites digital communication (signals) are using.

→ The signals Telephony, Data, DBS-TV, Radio broadcasting, and navigation with GPS are using digital signalling techniques.

Orbital Mechanics:

Developing the equations of the orbit:

→ Newton's Laws of motion describe the motion of a body.

→ Newton's Laws of motion can be encapsulated into four equations:

$$S = ut + \left(\frac{1}{2}\right) at^2 \longrightarrow (1)$$

$$v^2 = u^2 + 2at \longrightarrow (2)$$

$$v = u + at \longrightarrow (3)$$

$$P = ma \text{ (or) } F = ma \longrightarrow (4)$$

where s is the distance travelled from time $t=0$.
u is the initial velocity of the object at time $t=0$.
v is the final velocity of the object at time t.
a is the acceleration of the object
P is the force acting on the object.
m is the mass of the object.

→ Acceleration can be positive or negative, depending on the direction it is acting withrespect to the velocity vector.

→ The above eq (4) helps us to understand the motion of a satellite in a stable orbit.

→ eq ④ states that force acting on a body is equal to the mass of the body multiplied by the resulting acceleration of the body. $F = ma$

→ Alternatively, the resulting acceleration, is the ratio of the force acting on the body, to the mass of the body. $a = \frac{F}{m}$

→ Hence for a given force, lighter the mass of the body, higher the acceleration will be.

→ In a stable orbit, there are two main forces acting on a satellite

a. moving away from a center, acting in a direction away from a center

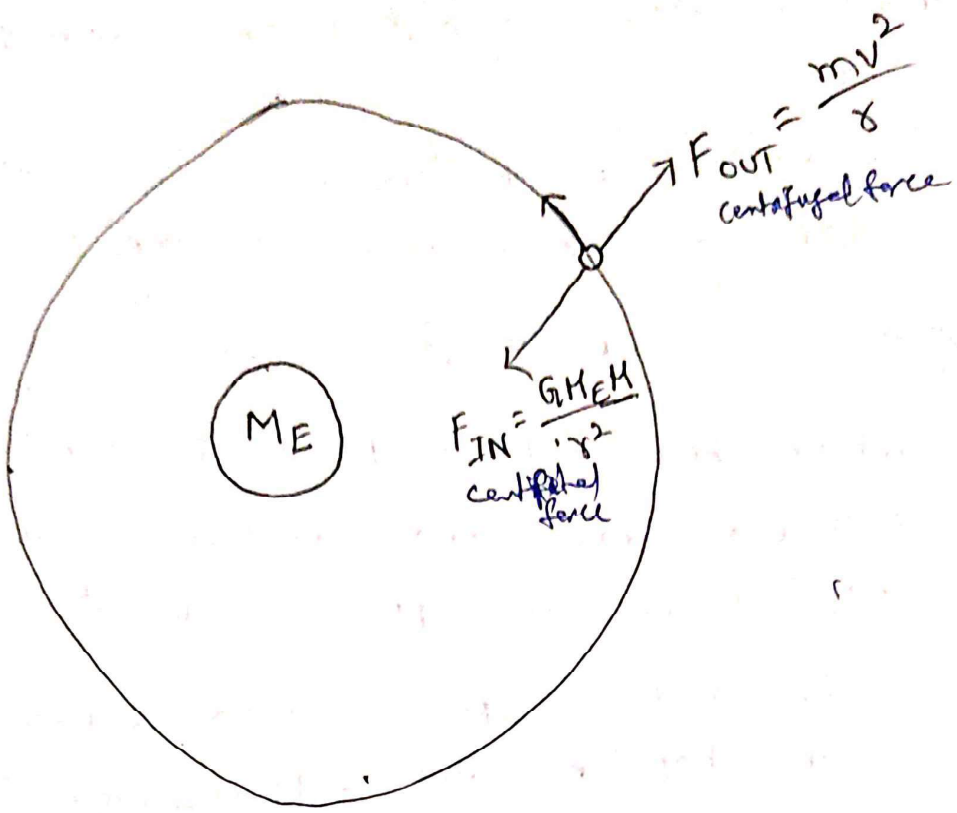
① A centrifugal[a] force due to the kinetic energy of the satellite, which attempts to fling the satellite into a higher orbit.

b. pulling inward (gravity)

② A centripetal[b] force due to the gravitational attraction of the planet about which the satellite is orbitting, which attempts to pull the satellite down toward the planet

→ If these two forces are equal, then the satellite will remain in a stable orbit.

→ The below figure shows two opposing forces on a satellite in a stable orbit.



fig; Forces acting on a satellite in a stable orbit around the earth

→ The satellite has mass 'm', and it is travelling with velocity, V in the plane of orbit

→ Force = mass x acceleration = ma - (Newton)

→ Unit of force is a Newton, denoted by 'N'

→ A Newton is the force required to accelerate a mass of 1 kg with an acceleration of $1 m/s^2$.

→ Hence the unit of a Newton is $(Kg) \times m/s^2$

→ The standard acceleration due to gravity at the earth's surface is $9.80665 \times 10^{-3} km/s^2$. (i.e $981 cm/s^2$)

→ This value decreases with height above the earth's surface.

→ The acceleration, a, due to gravity at a distance, r from the center of the earth is

acceleration due to gravity

$$a = \mu / r^2 \ km/s^2$$

r=radius hence so neglected

where the constant μ is the product of universal gravitational constant G and the mass of the earth M_E $\mu = m_{E.h}$

→ The product GM_E is called Kepler's constant and has the value $3.986004418 \times 10^5 \ km^3/s^2$

→ The universal gravitational constant is

$$G = 6.672 \times 10^{-11} \ Nm^2/kg^2$$

or $6.672 \times 10^{-20} \ km^3/kg\,s^2$ in the older units.

→ Since force = mass x acceleration, the centripetal force acting on the satellite is

$$F_{IN} = m \times (\mu / r^2)$$

$$= m \times (GM_E / r^2)$$

→ The centrifugal acceleration is given by

$$a = \frac{v^2}{r}$$

∴ The centrifugal force is given as

$$F_{OUT} = m \times (v^2/r)$$

→ If the forces on the satellites are balanced. Then

$$F_{IN} = F_{OUT}$$

$$\therefore \cancel{m \times (GMe/r^2) = m \times (v^2/r)}$$

$$\therefore m \times (\mu/r^2) = m \times (v^2/r)$$

Hence the velocity, v of a satellite in a circular orbit is given by

$$v = (\mu/r)^{1/2}$$

→ If the orbit is circular, the distance travelled by a satellite in one orbit around a planet is $2\pi r$, where r is the radius of the orbit from the satellite to the center of the planet.

→ since the distance divided by velocity equals time to travel that distance, the period of satellite's orbit, T, will be

$$T = \frac{2\pi r}{v} = (2\pi r) \Big/ \left[(\mu/r)^{1/2} \right]$$

$$\boxed{T = \frac{2\pi r^{3/2}}{\mu^{1/2}}} \Rightarrow r = \left(\frac{T^2 \mu}{4\pi^2} \right)^{1/3}$$

$$= \left[\frac{(8.6164)^2 \cdot (3.986 \times 10^5)}{4\pi^2} \right]^{1/3} \simeq 42164 \text{ km}$$

Earth radius $\simeq$ 6378 km, orbit height = 42164 − 6378 = 35786 km

→ A number of coordinate systems and reference planes can be used to describe the orbit of a satellite around a planet.

① Initial coordinate system
(or) Cartesian coordinate system
(or) geocentric coordinate system

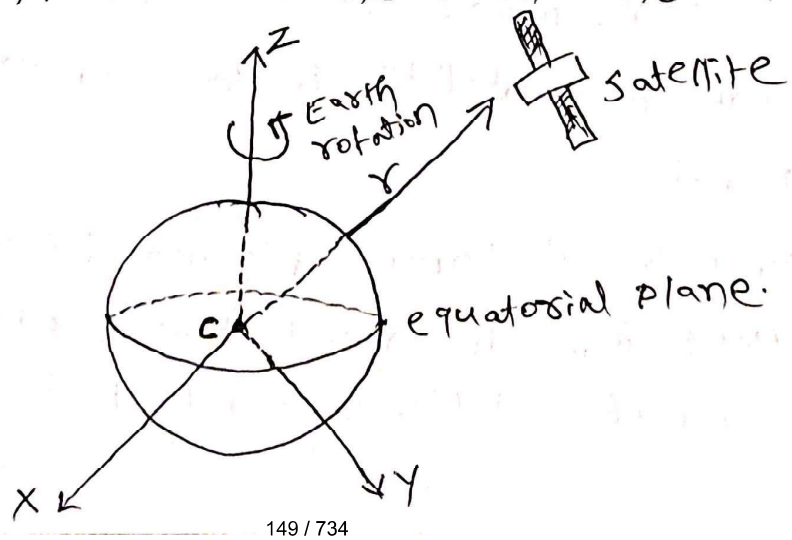
② orbital plane coordinate system.

③ polar coordinate system.

① Initial coordinate system:

It is used to describe the relationship between the earth and a satellite.

fig ①:



→ It is the simplest coordinate system.

→ In this system, the geographical axes of the earth is the principle axis

→ The rotational axis of the earth is about the axis CZ, where C is the center of the earth, and CZ passes through the geographic north Pole.

→ Axes CX, CY and CZ are mutually orthogonal axis, with CX and CY passing through the earth's geographic equator

→ The vector 'r' locates the moving satellite with respect to the center of the earth.

orbital plane coordinate system:

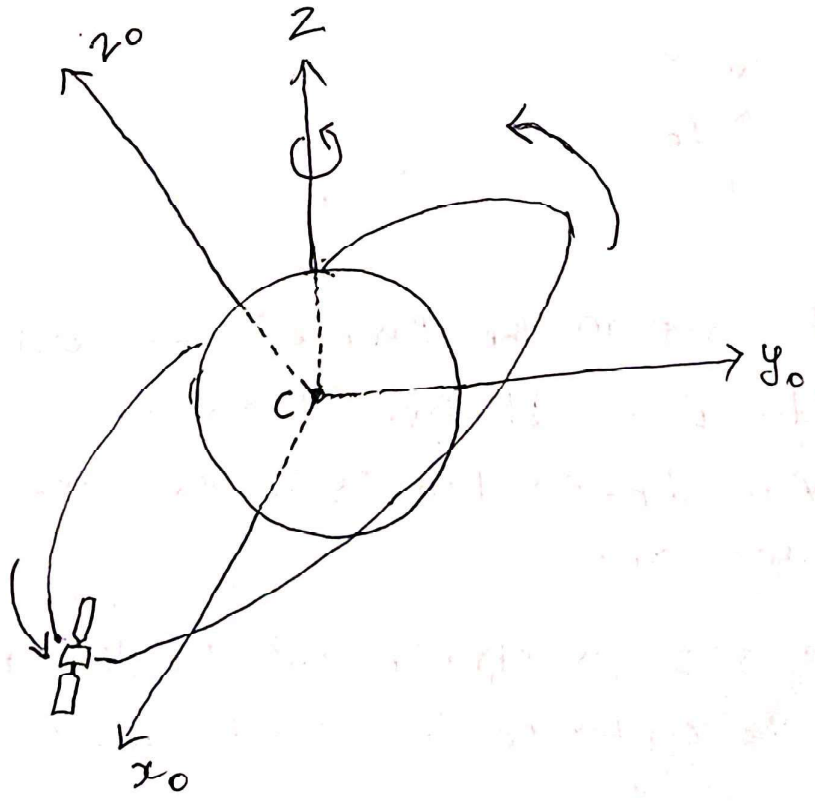


fig ②

→ In this coordinate system, the orbital plane of the satellite is used as the reference plane

→ The orthogonal axes x_o and y_o lie in the orbital plane.

→ The third axis z_o is perpendicular to the orbital plane. The geographical Z-axis of the earth does not lie in the same direction as the z_o axis except for satellite orbits that are exactly in the plane of the geographical equator

Polar coordinate system:

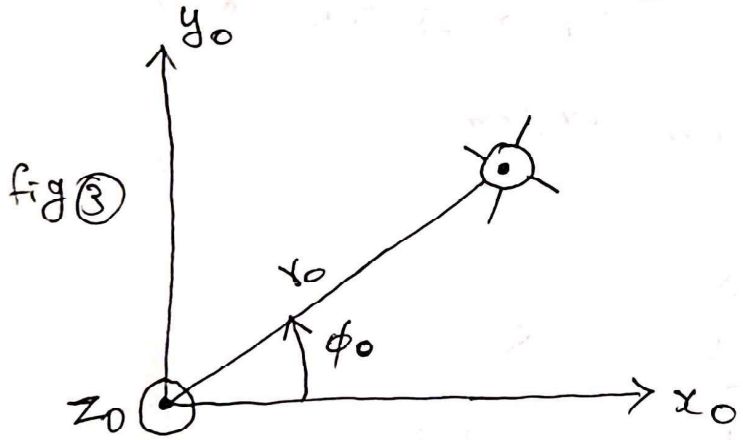


fig ③

→ In this system the plane of the orbit coincides with the plane of paper.

→ The ~~of~~ coordinate system is in the plane of satellite's orbit.

→ The axis z_o is straight out of the paper from the center of the earth, and is normal

∴ to the plane of satellite's orbit.

→ The satellite's position is described interms of the radius from the center of the earth r_0 and the angle this radius makes with the x_0 axis, ϕ_0.

Equation of satellite orbit in polar Coordinate system:

with the coordinate system setup as shown in fig ①, and with the satellite of mass 'm' located at a vector distance 'r' from the center of the earth, the gravitational force 'F' on the satellite is given by

$$\bar{F} = -\frac{GM_E m \bar{r}}{r^3} \longrightarrow (A)$$

→ where M_E is the mass of the earth and $G = 6.672 \times 10^{-11}\ Nm^2/kg^2$

→ But force = mass × acceleration

$$\therefore \bar{F} = m \cdot \frac{d^2\bar{r}}{dt^2} \longrightarrow (B)$$

→ By equating (A) and (B)

$$-\frac{\bar{r}}{r^3}\cdot\mu = \frac{d^2\bar{r}}{dt^2} \quad : \text{where } \mu = -GME$$

$$\Rightarrow \frac{d^2\bar{r}}{dt^2} + \frac{\bar{r}}{r^3}\cdot\mu = 0 \quad \text{—— (c)}$$

→ This is a second-order linear differential equation and it's solution will involve six undetermined constants called the orbital elements.

→ The orbit described by these orbital elements can be shown to lie in a plane and to have a constant angular momentum.

→ The solution to the above (c) equation is difficult since the second derivative of $\bar{r}$ involves the second derivative of the unit vector '$\bar{r}$'

→ To remove this dependence, a different set of coordinates can be chosen to describe the location of the satellite such that the unit vectors in the three axes are constant.

→ This coordinate system uses the plane of the satellite's orbit as the reference plane. This is shown in fig (2).

$$\bar{r} = x_o\hat{x}_o + y_o\hat{y}_o$$

→ Equation (c) interms of the new coordinate axes x_o, y_o and z_o gives

$$\hat{x}_o\left[\frac{d^2x_o}{dt^2}\right] + \hat{y}_o\left[\frac{d^2y_o}{dt^2}\right] + \frac{\mu[x_o\hat{x}_o + y_o\hat{y}_o]}{[x_o^2 + y_o^2]^{3/2}} = 0 \quad \text{(VII)} \rightarrow \text{(D)}$$

→ The above equation (D) is easier to solve if it is expressed in a polar coordinate system, rather than cartesian coordinate system.

→ The polar coordinate system is shown in fig (3).

with polar coordinate system

$$x_o = r_o \cos\phi_o$$

$$y_o = r_o \sin\phi_o$$

$$\hat{x}_o = \hat{r}_o \cos\phi_o - \hat{\phi}_o \sin\phi_o$$

$$\hat{y}_o = \hat{\phi}_o \cos\phi_o + \hat{r}_o \sin\phi_o$$

→ and equating the vector components of r_o and ϕ_o in eq (D)

$$\frac{d^2r_o}{dt^2} - r_o\left(\frac{d\phi_o}{dt}\right) = -\frac{\mu}{r_o^2}$$

and $$r_o\left(\frac{d^2\phi_o}{dt^2}\right) + 2\left(\frac{dr_o}{dt}\right)\left(\frac{d\phi_o}{dt}\right) = 0$$

→ using standard mathematical procedures, The equation for the radius of satellite's orbit (r_o) can be expressed as

$$r_0 = \frac{p}{1 + e\cos(\phi_0 - \theta_0)}$$

where θ_0 is a constant and 'e' is the eccentricity of an ellipse, whose semilatus rectum p is given by

$$p = \frac{(h^2)}{\mu}$$

→ h is the magnitude of the orbital angular momentum of the satellite.

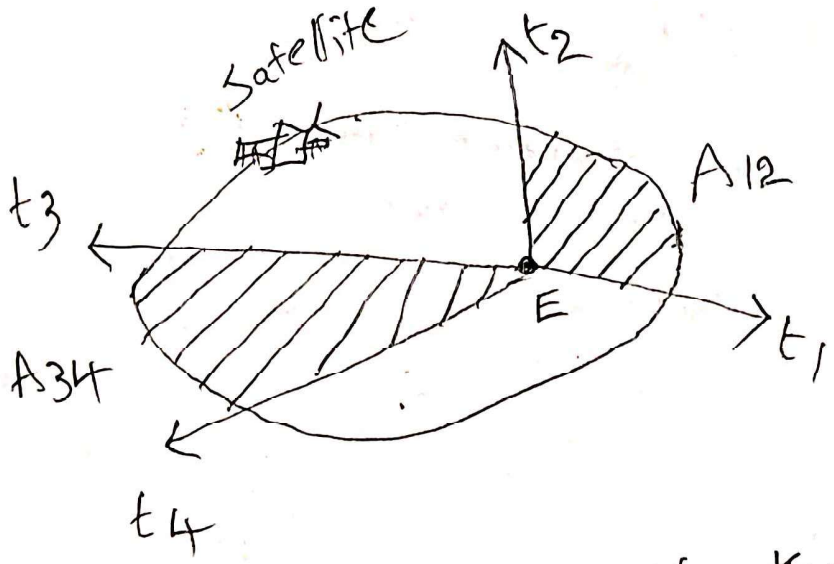
→ The equation of orbit is an ellipse and it is Kepler's first law of planetary motion.

Kepler's Three Laws of planetary Motion:

Three laws are

① The orbit of any smaller body about a larger body is always an ellipse, with the center of mass of the larger body as one of the two foci

② The orbit of smaller body sweeps out equal areas in equal time.



Satellite is in the orbit that is revolving around the earth E.
When the satellite moves in the orbit between the times t_1 and t_2, then satellite sweeps an area denoted by A_{12}.

when the satellite moves in orbit between times t_3 and t_4, then satellite sweeps an area denoted by A_{34}

If $t_1 - t_2 = t_3 - t_4$ then $A_{12} = A_{34}$

(3) The square of the period of revolution of the smaller body about larger body equals a constant multiplied by the third power of the semimajor axis of the orbital ellipse.

That is, $$T^2 = \frac{(4\pi^2 a^3)}{\mu}$$

Where T = orbital Period

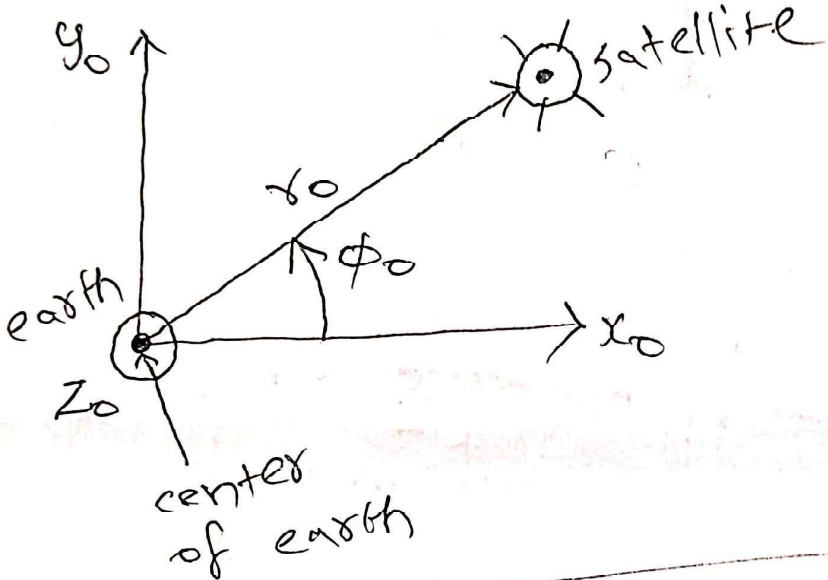
a = semimajor axis of orbital ellipse

μ = Kepler's constant

Note: If orbit is circular then a becomes 'r'

Describing the orbit of a satellite:

→ In polar coordinate system, the satellite position is described in terms of the radius from the center of the earth (r_o) and the angle this radius makes with the x_o axis is ϕ_o



* A no. of coordinate system & reference planes can be used to describe the orbit of sat around a planet
1. Initial CS or geocentric CS (or) cartesian CS
2. orbital plane CS
3. polar CS
↳ plane of orbit coincides with the plane of paper.

> **Note:** r_o is the radius of satellite orbit (i.e distance from center of earth to satellite position in orbit

The equation of satellite's orbit radius is given by

$$r_o = \frac{P}{1 + e\cos\phi_o}$$

Where P is the semilatus rectum of ellipse

and $p = \frac{h^2}{\mu}$

where h is the magnitude of the orbital angular momentum of satellite.

e = eccentricity of ellipse.

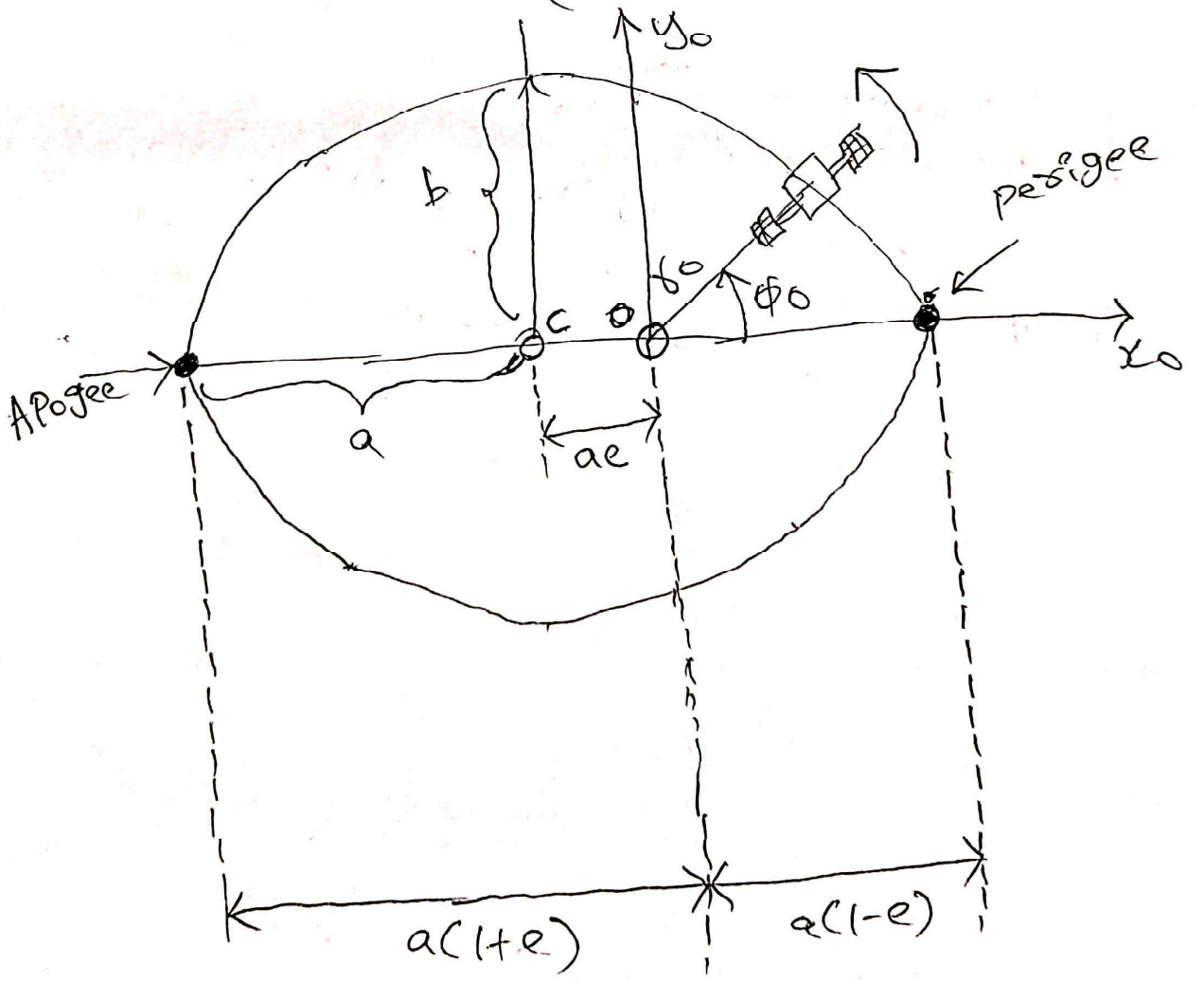
→ The lengths a and b of the semimajor axis and semiminor axis are

$$a = \frac{p}{(1-e^2)}$$

$$b = \frac{a}{(1-e^2)^{1/2}}$$

$e = \frac{co}{a}$

$co = ae$



O: center of earth

C: center of ellipse

→ The point in the orbit, where the satellite is closest to earth is called "perigee". and the point where the satellite is farthest from the earth is called "apogee"

The differential area swept out by the vector, r_0 from the origin to the satellite in time dt is given by

$$dA = 0.5 r_0^2 \left(\frac{d\phi_0}{dt}\right) dt = 0.5 h dt$$

h is the magnitude of the orbital momentum of the satellite.

→ The radius vector (r_0) of the satellite can be seen to sweep out equal areas in equal times. This is Kepler's second law of planetary motion.

→ By equating area of ellipse (πab) to the area swept out in one orbital revolution, we can derive the expression for orbital period (T) as

$$T^2 = \frac{4\pi^2 a^3}{\mu} \longrightarrow (A)$$

This equation is the mathematical expression for Kepler's third law of planetary motion.

Equation A gives the period of orbit (i.e for most general case, elliptical orbit.)

→ This equation A, gives the period of any satellite orbit

→ This equation (A) is used in every GPS receiver in the calculation of position of GPS satellite. And also orbital radius of GEO satellite can be calculated by this equation.

→ The orbital period of a GEO satellite is exactly equal to the period of rotation of earth i.e 23h 56min 4.1 s

→ To be perfectly Geostationary, the orbit of satellite must have three features

① It must be exactly circular (i.e $e = 0$) (e: eccentricity)

② It must be at correct altitude (i.e correct period)

③ It must be in plane of equator (i.e zero inclination w.r.t the equator)

Locating the satellite in the orbit

we know the equation of orbit is

$$r_0 = \frac{p}{1+e\cos\phi_0}$$

and $a = \frac{p}{1-e^2} \Rightarrow p = a(1-e^2)$

$$\therefore r_0 = \frac{a(1-e^2)}{1+e\cos\phi_0}$$

→ The angle ϕ_0 that is measured from x_0 axis is called 'true anomaly'

Note: Anomaly = Angular distance of a planet from its Perihelion or Perigee

Perihelion is the point on the orbit of a planet that is closest to the sun.

→ The point on the orbit farthest from the sun is aphelion

The rectangular coordinates of the satellite are given by

$$x_0 = r_0\cos\phi_0$$
$$y_0 = r_0\sin\phi_0$$

The average angular velocity of satellite is given by

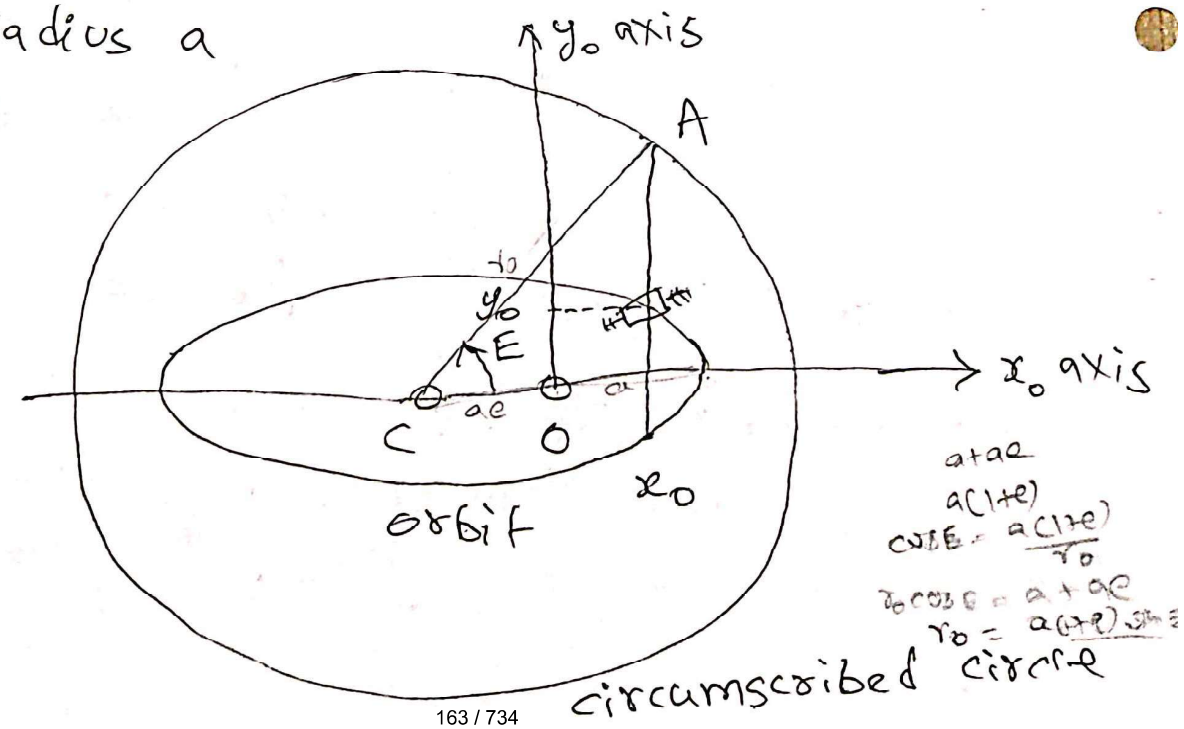
$$n = \frac{2\pi}{T} \qquad T^2 = \frac{4\pi^2 a^3}{\mu}$$

$$\therefore n = \frac{\sqrt{\mu}}{\sqrt{a^3}} \qquad T = 2\pi\sqrt{\frac{a^3}{\mu}}$$

$$\boxed{n = \frac{\mu^{1/2}}{a^{3/2}}}$$

→ For an elliptical orbit, the instantaneous angular velocity will vary with the position of satellite around the orbit.

→ Hence satellite location in the orbital plane coordinate system can be measured by enclosing the elliptical orbit with a circumscribed circle of radius a



$a + ae$

$a(1+e)$

$\cos E = \frac{a(1+e)}{r_0}$

$r_0 \cos\theta = a + ae$

$r_0 = a(1+e)\cos\theta$

Draw a vertical line through the position of satellite. Then the line intersects the circumscribed circle at point "A".

> A line drawn from center of ellipse(c) to point "A" makes an angle with x_o axis, i.e E (eccentric anomaly of satellite)

→ If is related to radius r_o by $r_o = \frac{p}{1+e\cos\phi_o}$

$$r_o = a(1-e\cos E)$$

$r_o = a - ae\cos E$
$ae\cos E = a - r_o$
$\cos E = \frac{a-r_o}{ae} =$

⇒ If t_p is the time of perisee

$\eta dt = (1-e\cos E)dE$ integrate

$\int \eta dt = \int (1-e\cos E)dE$

$$\eta(t-t_p) = E - e\sin E$$

Here $\eta(t-t_p)$ is Mean anomaly (M)

$$\therefore M = \eta(t-t_p) = E - e\sin E$$

→ If we know t_p, e(eccentricity), and a (length of semimajor axis), then we have the following equations to determine the coordinates (r_o, ϕ_o) and (x_o, y_o) of the satellite in orbital plane

The process is

① calculate n using $n = \frac{2\pi}{T} = \frac{\mu^{1/2}}{a^{3/2}}$

② calculate M using ~~$M = n(t - t_p)$~~

~~$M = E - e$~~

$M = n(t - t_p) = E - e \sin E$

③ Solve above equation, find the value E

④ Find r_0 from E using the equation $a - r_0 = ae\cos E$

$r_0 = a(1 - e\cos E)$

⑤ Solve the equation $r_0 = \frac{a(1-e^2)}{1 + e\cos\phi_0}$ for ϕ_0

⑥ use equations $x_0 = r_0 \cos\phi_0$

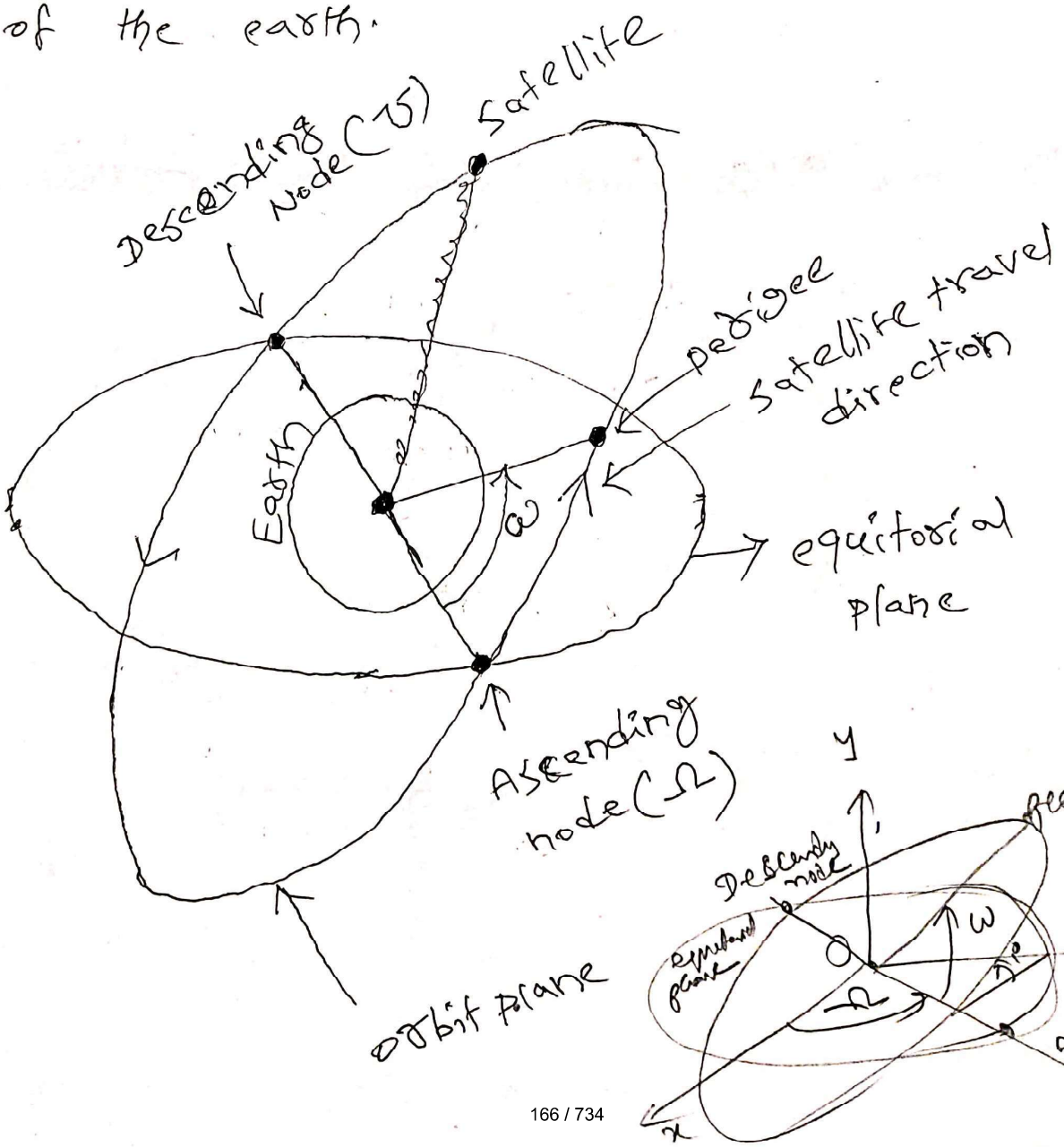
$y_0 = r_0 \sin\phi_0$

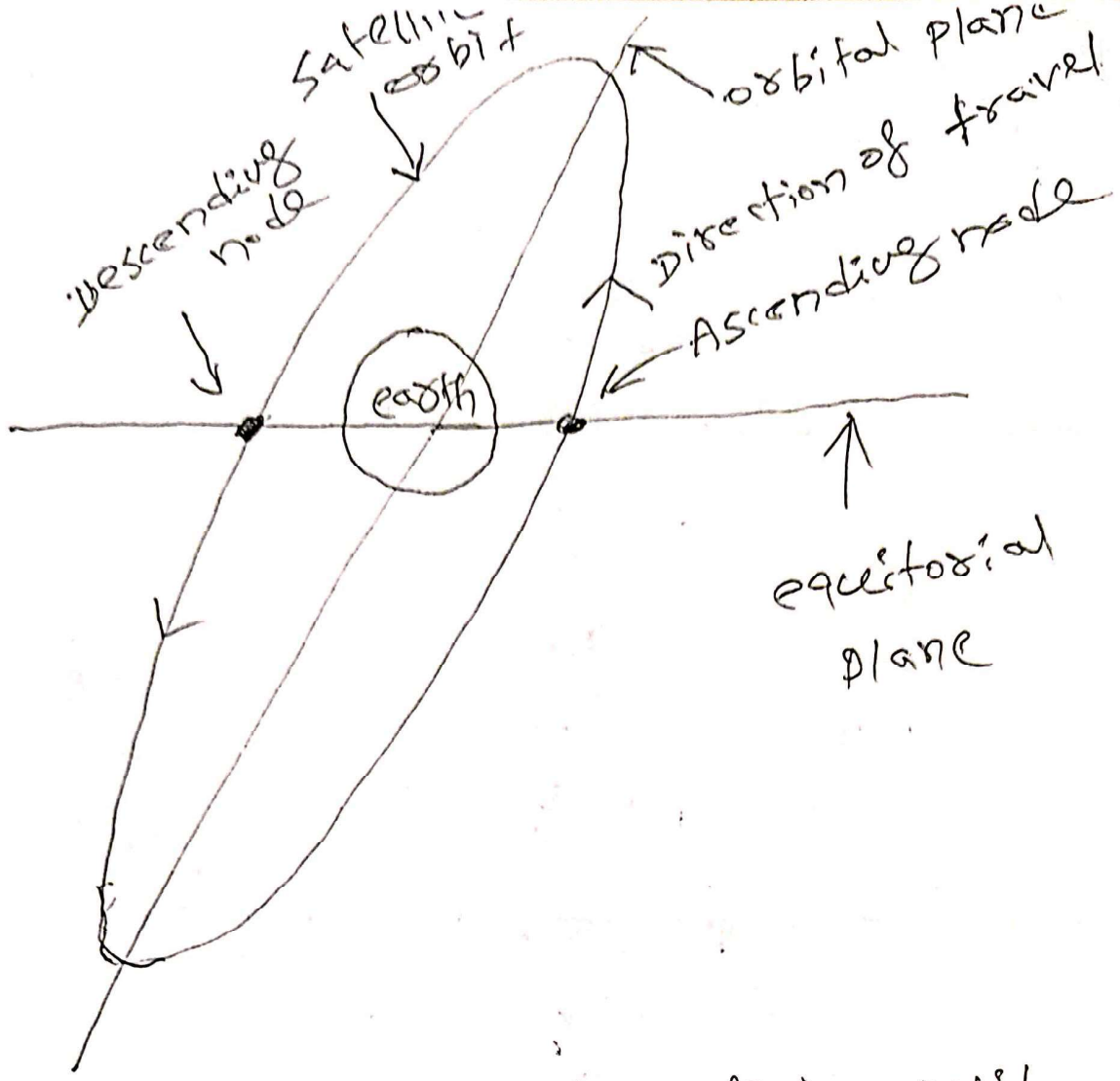
to calculate x_0 and y_0

Locating the satellite with respect to the Earth:

→ In previous topic, satellite was located with respect to center of earth. ie satellite location is at (x_o, y_o, z_o) on the orbital plane.

→ In this topic satellite location is not with respect to center of earth. The satellite location is with respect to a point on the rotating surface of the earth.



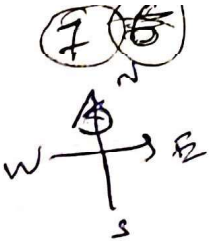


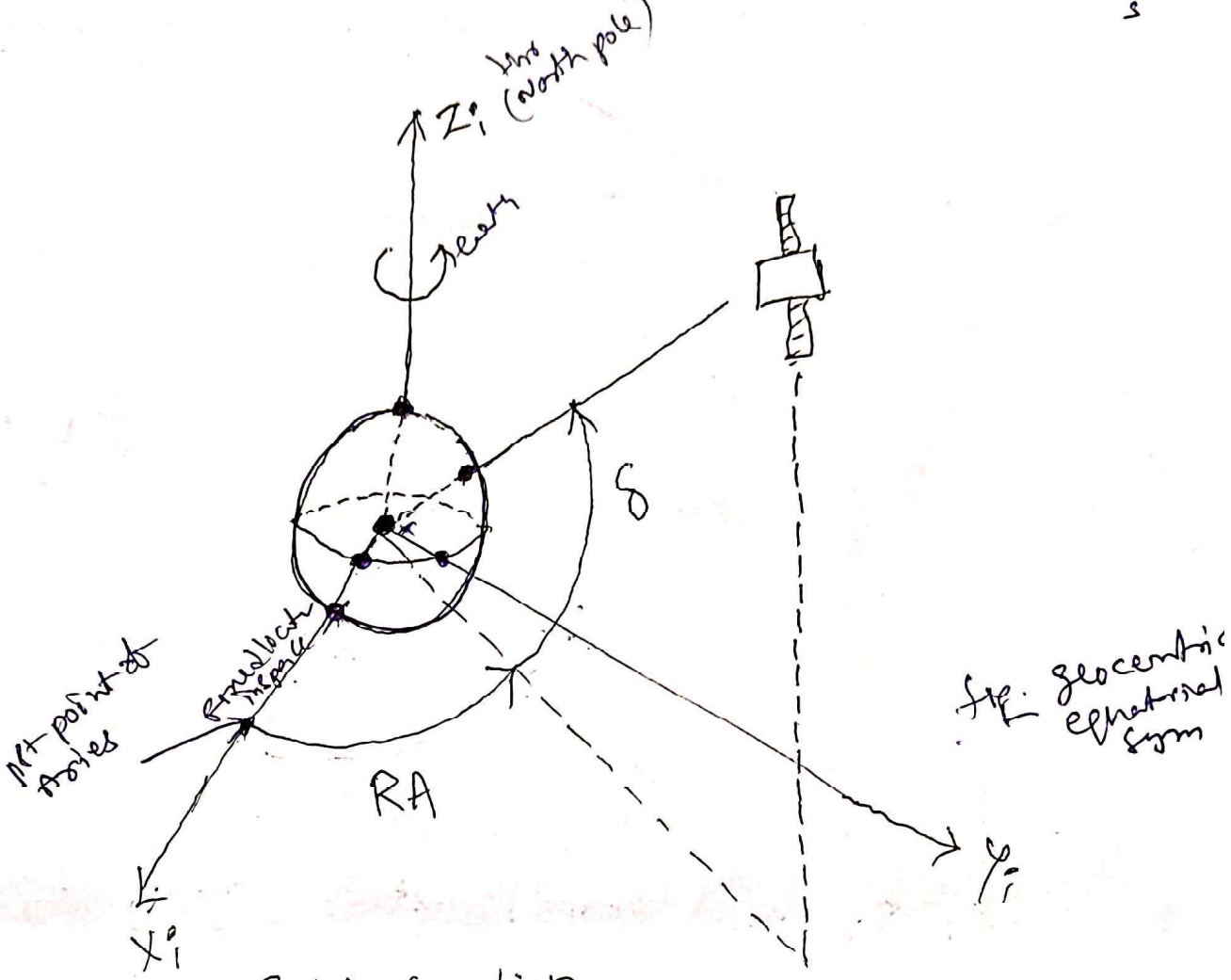
→ The two points at which orbit penetrates the equitorial plane are called nodes.

→ The satellite moves upward through the equitorial plane at the ascending node.

→ The satellite moves downward through the equitorial plane at the descending node.

Now consider Geocentric equatorial coordinate system as shown below.





δ: declination

→ In this coordinate system the rotational axis of the earth is Z_i axis.

→ The (x_i, y_i) plane contains the earth equator and is called 'equitorial plane'.

→ The angular distance from X_i axis to eastward direction in the equitorial plane is called 'Right Ascension' (RA)

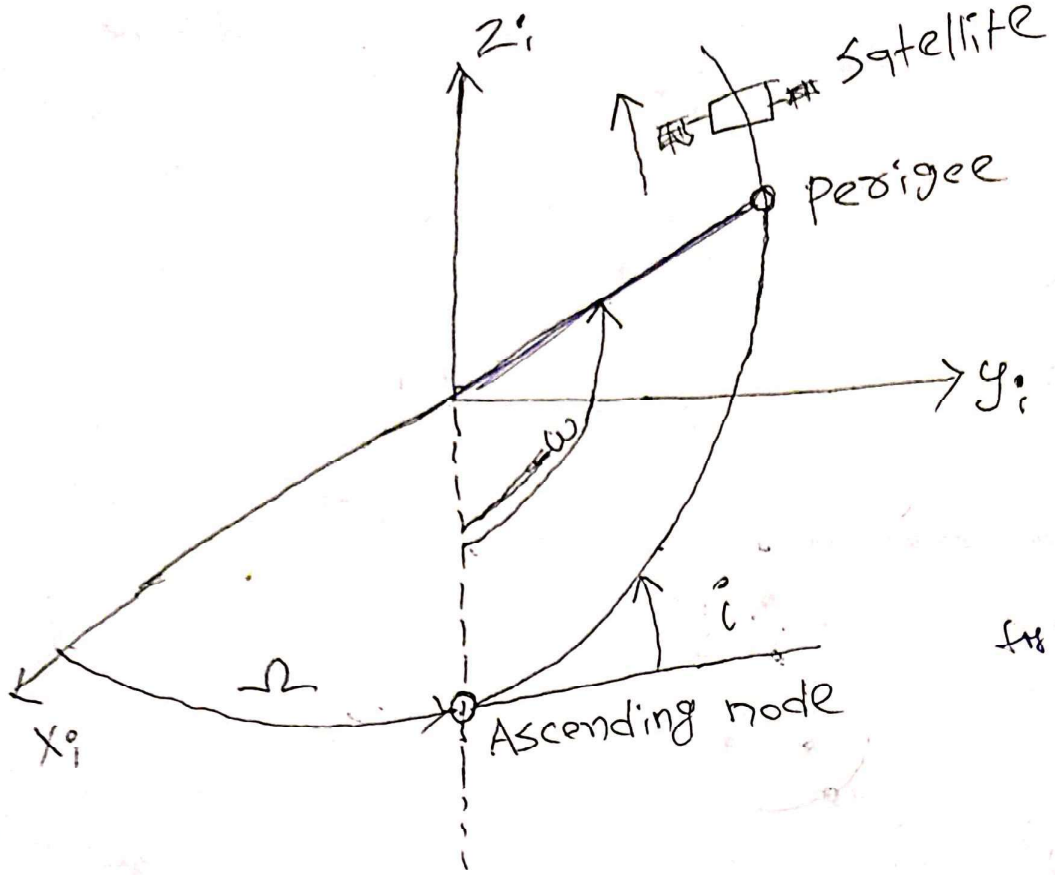


fig: Locating the orbit in geocentric equatorial system

→ Right Ascention of Ascending Node (RAAN) is called "Ω"

→ The angle between orbital plane and equitorial plane is called inclination (i).

→ To locate orbital coordinate system with respect to equitorial coordinate system, the element called "argument of perigee west" (ω) is needed. ω is the angle measured along the orbit from ascending node to the perigee

→ The variables Ω & i together locate the orbital plane w.r.to the equatorial plane.

Orbital elements:

To specify the exact position of an orbiting satellite at a given instant, we need the orbital elements.

To specify the absolute coordinates of the satellite at time "t", we need to know six orbital elements.

1. eccentricity (e)
2. Semimajor axis (a)
3. time of perigee (t_p)
4. Right Ascension of Ascending Node (Ω)
5. inclination (i)
6. argument of perigee west (ω)

Note: t_p can be substituted by mean Anomaly (M)

(More than 6-quantities can be used to describe a unique orbital path & there is some arbitrariness in exactly which 6-quantities are used.)

Problems

1. The earth rotates once per sidereal day of 23h 56 min 4.09s. Find the radius of GEO orbit

Sol: The orbital period (T) is given of

$$T^2 = \frac{(4\pi^2 a^3)}{\mu}$$

Note: Here 'a' is radius of orbit

$\Rightarrow$ orbit radius a is given by

$$a^3 = \frac{T^2 \mu}{(4\pi^2)} \rightarrow (1)$$

$$\Rightarrow a = \left(\frac{T^2 \mu}{4\pi^2}\right)^{1/3}$$

If is given earth rotational Time period ~~is~~ (T) of 23h 56m 4.09s

→ For a GEO orbit, the orbit period is same as the time period of earth rotational time period.

∴ orbit period (T) = 23h 56m 4.09s

$$T = 86,164.09 \text{ sec}$$

$$\mu = 3.986004418 \times 10^5 \text{ km}^3/\text{s}^2$$

From equation (1)

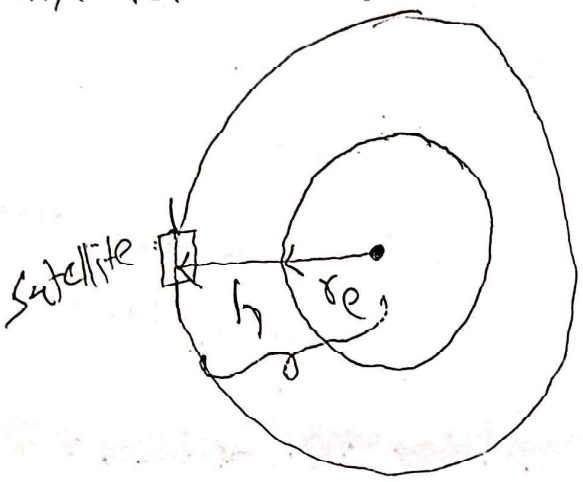
$$a^3 = \frac{(86,164.1s)^2 \times 3.986004418 \times 10^5 \text{ km}^3/\text{s}^2}{4\pi^2}$$

$$a^3 = 7.496020511 \times 10^{13} \text{ km}^3$$

$$\Rightarrow a = 42,164.17 \text{ km}$$

(2) Calculate the period of space shuttle satellite orbit, when the satellite is at an altitude of 250 Km above the earth surface (i.e LEO orbit).
Consider mean earth's radius is 6378.14 Km. And the orbit is circular. Also find the velocity of satellite in orbit

Soln:



r_{eth} = radius of orbit (a)

$\therefore a = 6378.14 + 250$

$a = 6628.14$ Km

Given altitude (h) = 250 Km

radius of earth (r_e) = 6378.14 KM

The period of orbit (T) is

$$T^2 = \frac{4\pi^2 a^3}{\mu}$$

$$\therefore T^2 = \frac{4\pi^2 \times (6628.14)^3 \text{ Km}^3}{3.986004418 \times 10^5 \text{ Km}^3/\text{s}^2}$$

$$\therefore T^2 = 2.884011145 \times 10^7 \text{ s}^2$$

Hence period of orbit is $T = 5370.30$ secs
$= 89$ min 30.3 sec

Calculation of satellite velocity:-

Circumference of the orbit $= 2\pi a$

$= 41,645.83$ km.

= distance travelled by satellite (d).

Hence velocity of satellite $(V) = \frac{d}{t}$

$\therefore V = \frac{41,645.83}{5370.13} = 7.755$ km/s

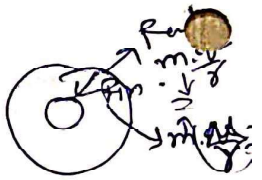
Velocity can also calculated by

$V = \left(\frac{\mu}{\gamma}\right)^{1/2}$

$\mu = 3.98 \times 10^5$ km^3/s^2

$r = (6378.14 + 250)$

$\therefore v = 7.755$ km/s



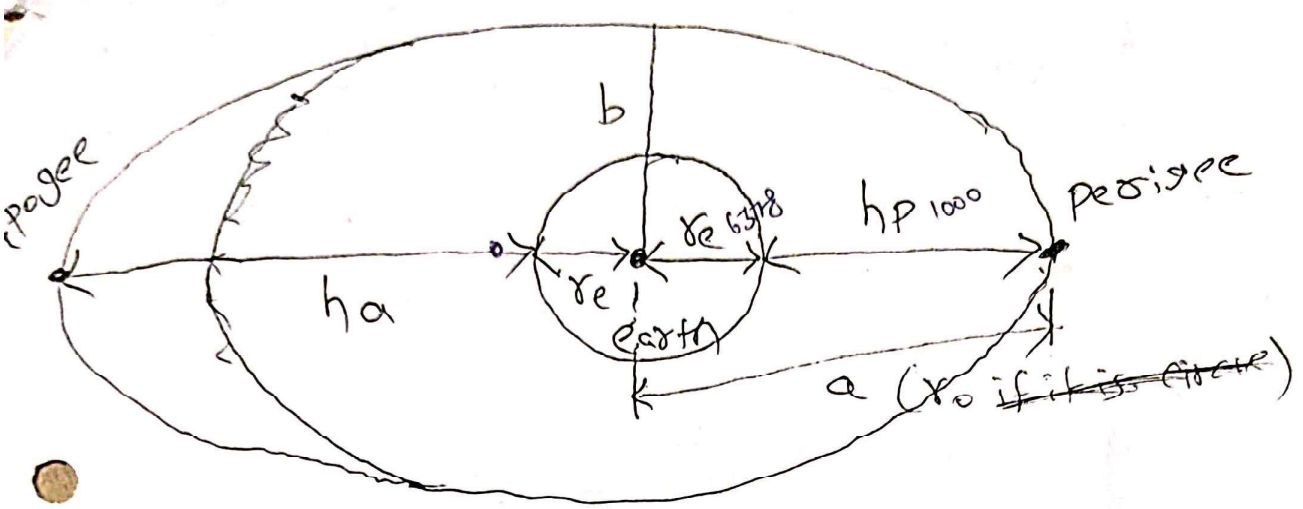
(3) A satellite is in an elliptical orbit with a perigee of 1000 Km and an apogee of 4000 km. using a mean earth radius of 6378.14 Km, find the period of orbit in hours, minutes, and seconds. Also find the eccentricity of the orbit

Sol:- Given h_p (perigee height) = 1000 Km

h_a (apogee height) = 4000 Km

radius of earth $(r_e) = 6378.14$ KM

Major axis of the elliptical orbit is a straight line between the apogee and perigee



Semimajor axis length a is given by

$a = r_e + h_p$

$$2a = 2r_e + h_p + h_a$$

$$2a = 2(6378.14) + 1000 + 4000 = 17,756.28 \text{ Km}$$

$$\Rightarrow a = 8878.14 \text{ Km}$$

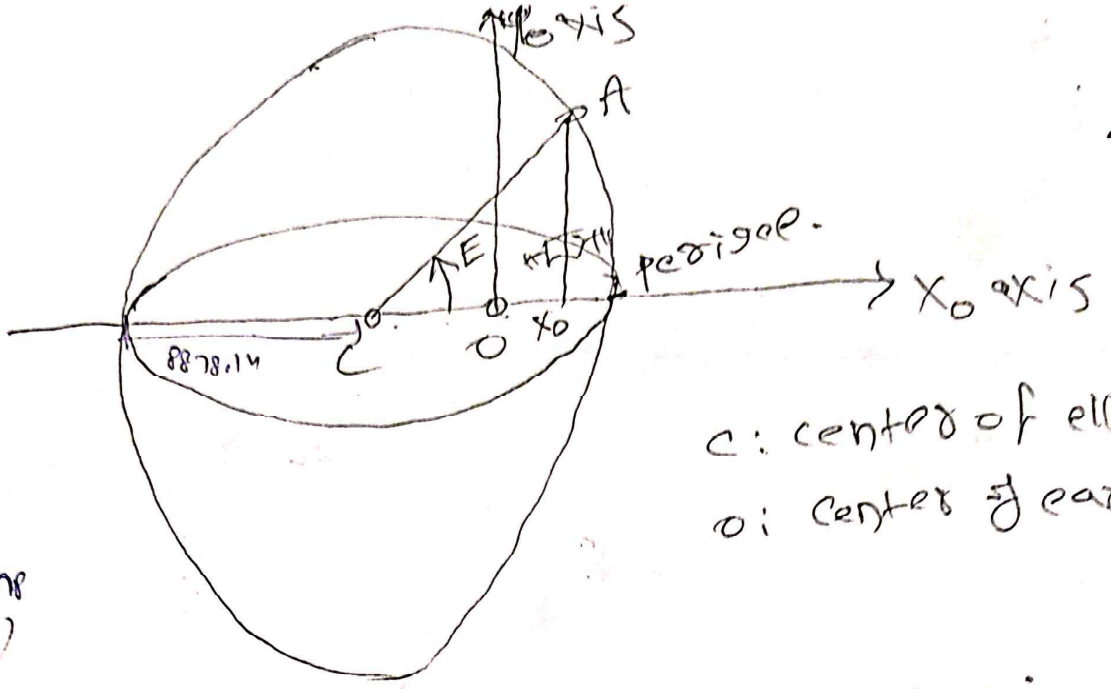
The orbital period (T) is

$$T^2 = \frac{4\pi^2 a^3}{\mu} = \frac{4\pi^2 \times (8878.14)^3 \text{ Km}^3}{3.98600441 8 \times 10^5 \text{ Km}^3/\text{s}^2}$$

$$T^2 = 6.930872802 \times 10^7 \text{ s}^2$$

$$T = 8325.1864 \text{ S} = 138 \text{ min } 45.195$$

$$T = 2\text{h } 18 \text{ min } 45.19\text{S}$$



C: center of ellipse
O: center of earth

$e = \frac{co}{a}$

$co = ae$

$co = a - re - hp$

$co = a - (re + hp)$

$= 1 -$

$e = \frac{co}{a}$

$=$

we know the orbit radius (r_0) is

$$r_0 = a(1 - e\cos E) \qquad E = \text{eccentric Anamolly}$$

If the satellite is at perigee point in the orbit, then $E = 0 \therefore \cos E = 1$

Now from fig ① $r_0 = re + hp$



$$r_0 = a(1 - e\cos E)$$

$$\therefore r_0 = a(1 - e)$$

$co = a - hp - re$

$$\therefore re + hp = a(1 - e)$$

$$e = \frac{1 - (re + hp)}{a} = \frac{1 - 7,378.14}{8878.14}$$

$re + hp = 1 - e$

$e = 1 - (re + hp)$

$$\therefore e = 0.169$$

another solution

$e = \frac{co}{a} = \frac{8878.14 -}{}$

hat $r_e = co + a$

$co = hat\, r_e - a$

$\therefore e = \frac{co}{a} = 0.169$

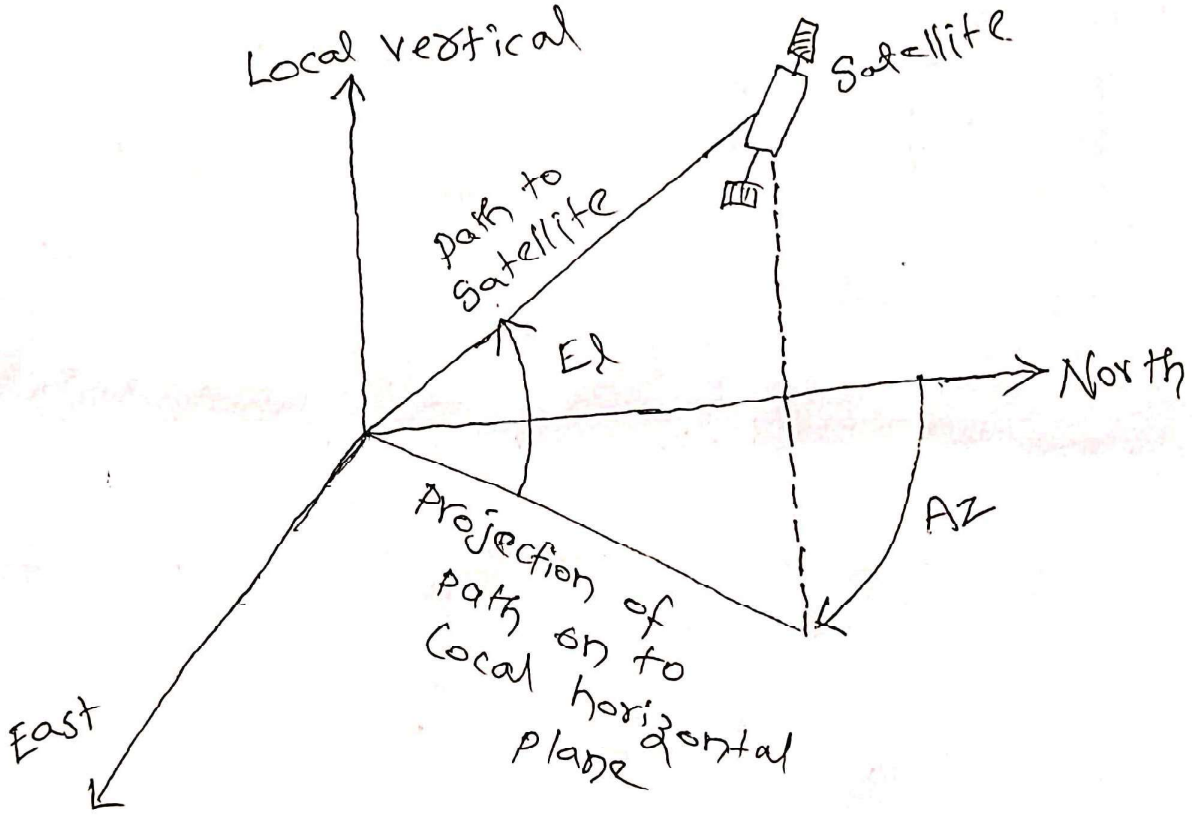
Look Angle Determination:

→ The coordinates to which an earth station antenna must be pointed to communicate with a satellite are called the "look angles"

These are of two

① Azimuth angle (AZ)

② Elevation angle (El)



Azimuth angle is measured from true north in an eastward direction to the projection of satellite path on to the local horizontal plane

i.e

Azimuth angle is measured eastward (clockwise direction) from geographic north

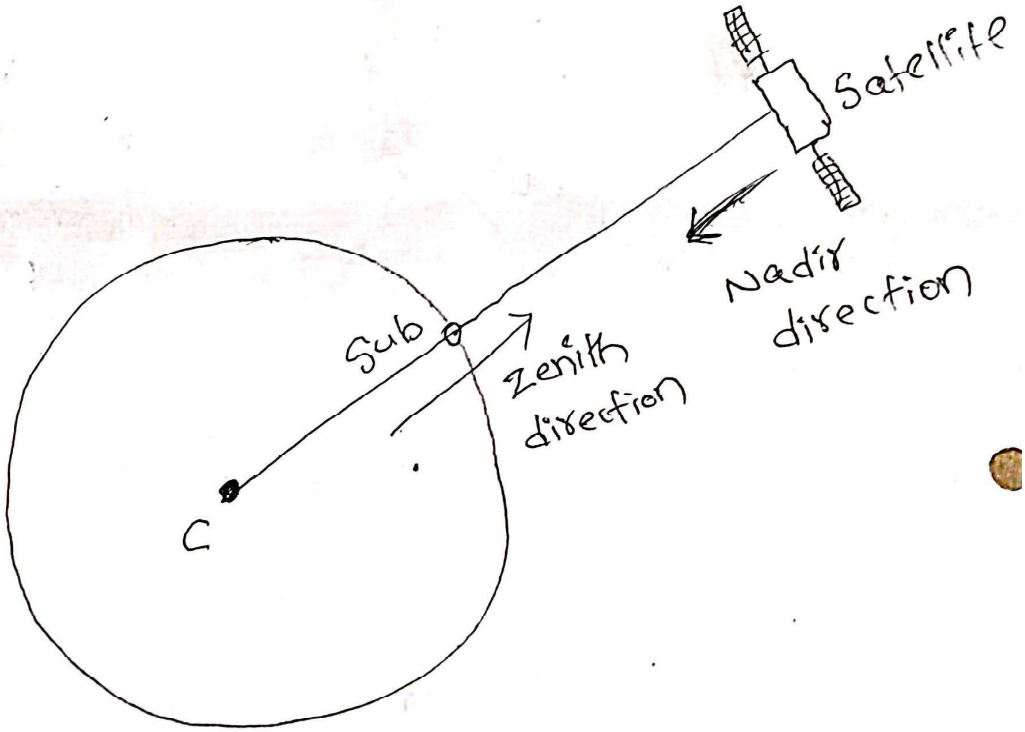
to the projection of satellite path on a (locally) horizontal plane at the earth station.

Elevation angle is the angle measured upward from the local horizontal plane at the earth station to the satellite path.

→ Earth station antenna points for "locking at" the sat directly

Subsatellite point:

The subsatellite point is the location on the surface of the earth that lies directly between the satellite and the center of the earth.



C: center of earth

Sub: Subsatellite point.

To an observer of a satellite, standing at the subsatellite point, the satellite will appear to be directly overhead, in the zenith direction from the observing location.

→ The zenith and nadir paths are in opposite directions along the same path.

→ The communications coverage region on the earth from a satellite is defined by the angles measured from nadir at the satellite to the edges of coverage

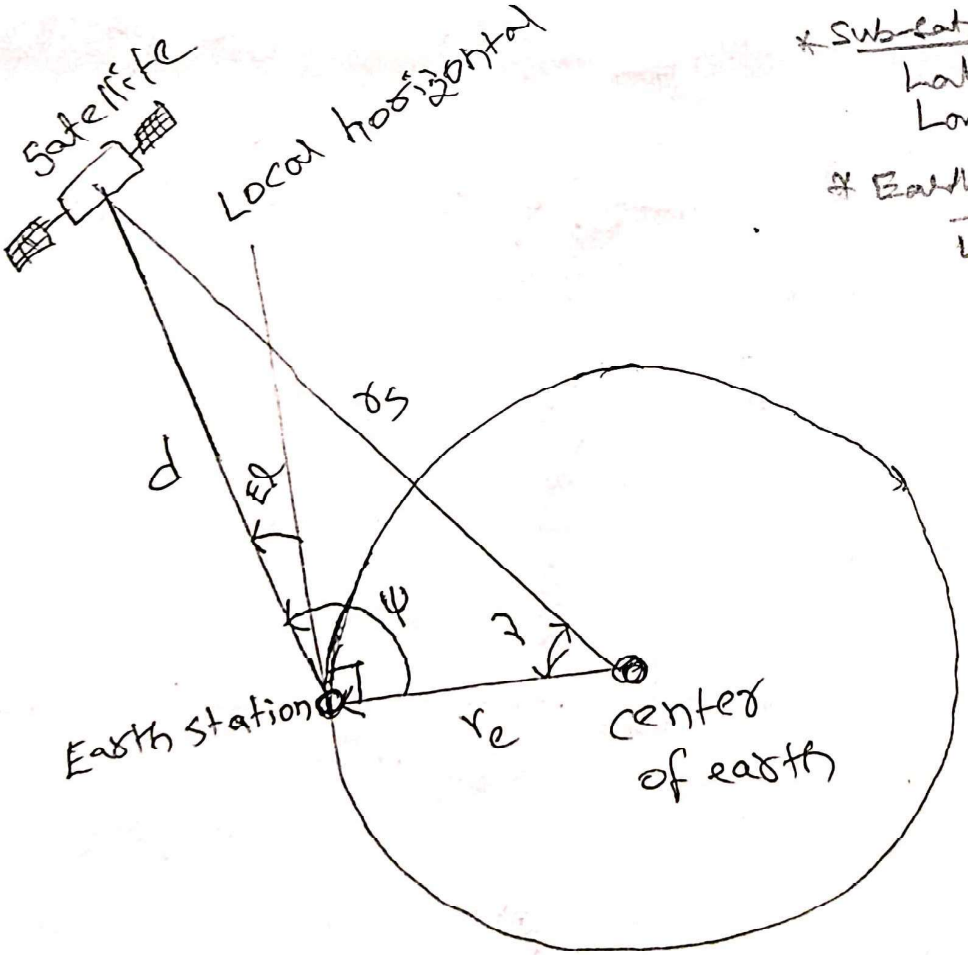
Note: From subsatellite point, satellite is in upward direction (zenith direction)

→ From satellite, subsatellite point is in downward direction (nadir direction)

Elevation angle calculation:

Sat coordinate

* Sub-sat point
  Latitude L_S
  Longitude l_S
* Earth station location
  Latitude L_E
  Longitude l_E



Above figure shows the geometry of the elevation angle calculation.

→ r_s is the vector from the center of earth to the satellite

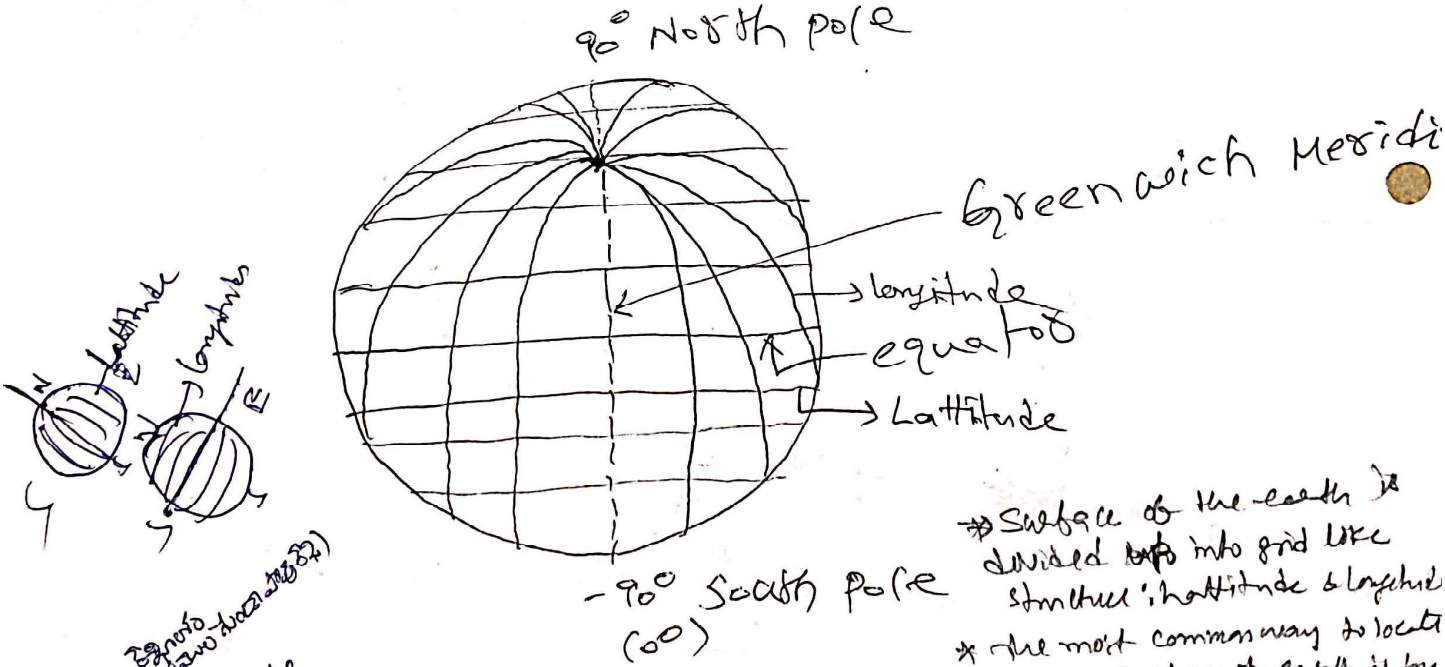
→ r_e is the vector from the center of earth to the earth station

→ d is the vector from the earth station to the satellite

These three vectors lie in the same plane and form a triangle

→ The central angle (γ) is measured between r_e and r_s. i.e It is the angle between the earth station and the satellite.

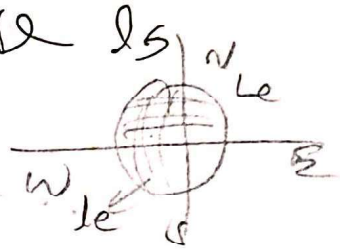
→ ψ is the angle from r_e to d



* Surface of the earth is divided into grid like structure; lattitude & longitude
* the most common way to locate points on surface of earth is by standard, geographic coordinates called Lattitude & longitude, measured in degrees, they represent angular distances from center of earth

Lattitude: Angular distance, measured in degrees, or north or south of equator
longitude: " " " " from a ref. longitudinal line or Greenwich, London

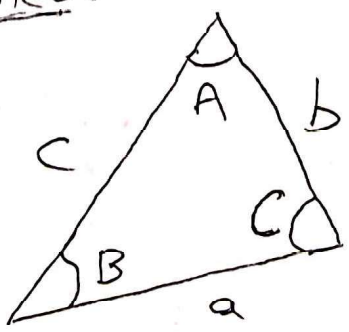
γ is related to the earth station north Lattitude L_e (L_e is the number of degrees in latitude that the earth station is north from equator) and west longitude l_e (l_e is the number of degrees in longitude that the earth station is west from Greenwich meridian) and the subsatellite point at the north latitude L_s and west longitude l_s by



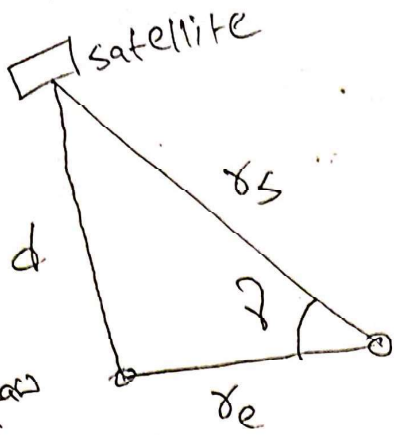
$$\cos(\gamma) = \cos(L_e)\cos(L_s)\cos(l_s - l_e) + \sin(L_e)\sin(L_s)$$

Note: For Lattitude denotion is L
For longitude " " l
For earth station suffix is e
For subsatellite point suffix is "s"

Law of cosines:



$$a^2 = b^2 + c^2 - 2bc\cos(A)$$
$$b^2 = a^2 + c^2 - 2ac\cos(B)$$
$$c^2 = a^2 + b^2 - 2ab\cdot\cos(C)$$



from the Law of cosines

$$\therefore d^2 = r_e^2 + r_s^2 - 2 r_e r_s \cos(\gamma)$$

$$d^2 = r_s^2 \left[\frac{r_e^2}{r_s^2} + 1 - \frac{2 r_e \cos(\gamma)}{r_s} \right]$$

$$d = r_s \left[1 + \left(\frac{r_e}{r_s} \right)^2 - 2 \left(\frac{r_e}{r_s} \right) \cdot \cos(\gamma) \right]^{1/2} \rightarrow (1)$$

Since horizontal plane at the earth station is perpendicular to r_e, the elevation angle (El) is given by

$$El = \psi - 90^\circ \rightarrow (2) \Rightarrow \boxed{\psi = 90^\circ + El}$$

By the law of sines, we have

$$\frac{r_s}{\sin(\psi)} = \frac{d}{\sin(\gamma)} \rightarrow (3)$$

$$\frac{r_s}{\sin(90^\circ + El)} = \frac{d}{\sin(\gamma)}$$

$$\frac{r_s}{\cos(El)} = \frac{d}{\sin(\gamma)}$$

$$\Rightarrow \cos(EL) = \frac{r_s \cdot \sin(\gamma)}{d}$$

$$\cos(EL) = \frac{\sin(\gamma)}{\left[1 + \left(\frac{r_e}{r_s}\right)^2 - 2\left(\frac{r_e}{r_s}\right)\cos(\gamma)\right]^{1/2}}$$

Azimuth Angle calculation :

→ It is difficult to calculate, Azimuth Angle when compared to Elevation angle calcalation.

→ In order to calculate Azimuth angle, we should know whether the subsatellite point is east or west of the earth station, and in which hemispheres the earth station and the subsatellite points are located

Specialization to Geostationary satellites :

→ For Geostationary satellites, the subsatellite point is on the equator at longitude l_s, and the Lattitude L_s is 0.

→ we know central angle ~~is~~ (γ) is given by

$$\cos(\gamma) = \cos(L_e)\cos(L_s)\cos(l_s - l_e) + \sin(L_e)\sin(L_s)$$

since $L_s = 0$

$$\cos(\gamma) = \cos(L_e)\cos(l_s - l_e)$$

→ We know the distance (d) from earth station to satellite is given by

$$d = r_s \left[1 + \left(\frac{r_e}{r_s}\right)^2 - 2\left(\frac{r_e}{r_s}\right)\cos(\gamma) \right]^{1/2}$$

For Geostationary satellite, the orbit radius (r_s) is 42,164.17 km

and we know r_e = 6,378.137 KM.

→ ∴ r_s = 42,164.17 km , r_e = 6,378.137 KM

$$\therefore d = 42{,}164.17 \left[1.02288235 - 0.30253825\cos(\gamma) \right]^{1/2} \text{ KM}$$

→ Elevation angle at the earth station is

$$\cos(El) = \frac{r_s \sin(\gamma)}{d}$$

$$\therefore \cos(El) = \frac{\sin(\gamma)}{\left[1 + \left(\frac{r_e}{r_s}\right)^2 - 2\left(\frac{r_e}{r_s}\right)\cos(\gamma)\right]^{1/2}}$$

$$\therefore \cos(El) = \frac{\sin(\gamma)}{\left[1.02288235 - 0.30253825\cos(\gamma)\right]^{1/2}}$$

$$El = \tan^{-1}\left[(6.6107345 - \cos\gamma)/\sin\gamma\right] - \gamma$$

And the intermediate angle is given by

$$\alpha = \tan^{-1}\left[\frac{\tan|(l_s - l_e)|}{\sin(L_e)}\right]$$

α → about the correct quadrant to be found since the azimuthal direction can lie anywhere b/w 0° (North) and clockwise (360°).

Now Azimuth look angle (Az) can be found from

case ①: Earth station is in the Northern Hemisphere with

(a) satellite to the SE of earth station:

$$Az = 180^\circ - \alpha$$

(b) satellite to the SW of earth station:

$$Az = 180^\circ + \alpha$$

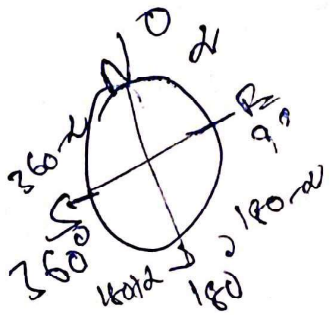
case ②: Earth station in the southern Hemisphere with

(c) satellite to the NE of earth station:

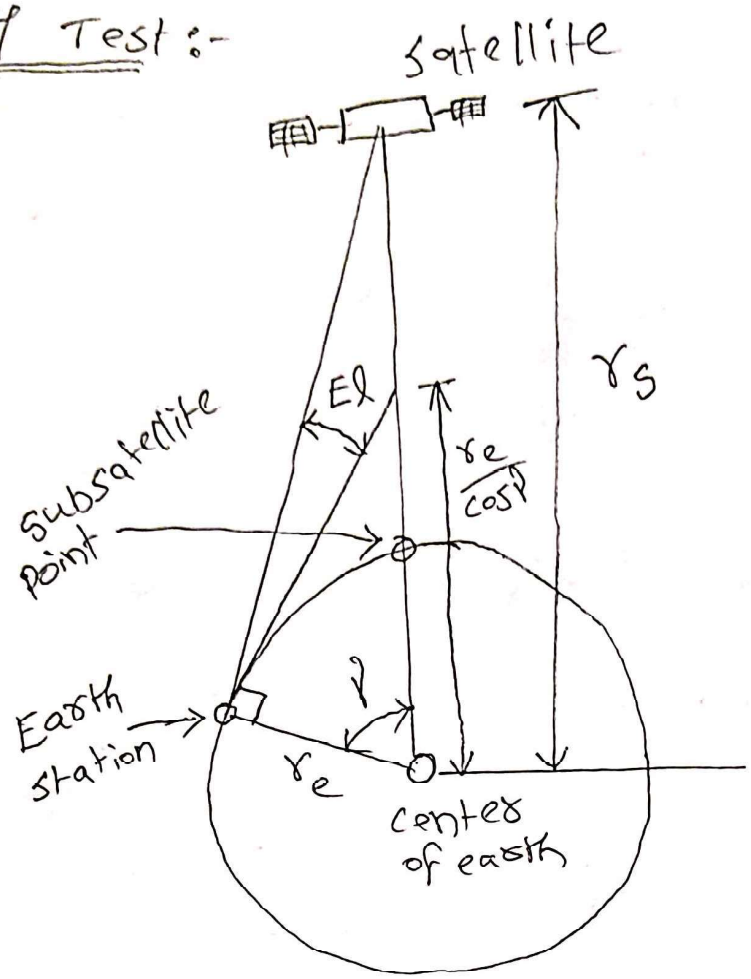
$$Az = \alpha$$

(d) satellite to the NW of earth station:

$$Az = 360^\circ - \alpha$$



Visibility Test :-



→ A satellite is said to be visible from the earth station, if it's elevation angle (El) is positive (i.e $El \geq 0^\circ$).

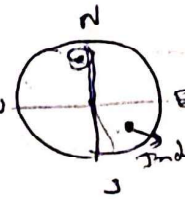
→ A positive or zero elevation angle requires the condition

$$r_s \geq \frac{r_e}{\cos(\gamma)}$$

$$\Rightarrow \gamma \leq \cos^{-1}\left(\frac{r_e}{r_s}\right)$$

→ For a nominal geostationary orbit $\gamma \leq 81.3^\circ$ for the satellite to be visible.

Problem: An earth station is situated at Docklands of London, England. Then calculate the look angles of that earth station to a geostationary satellite in the indian ocean operated by Intelsat. The details of the earth station site and the satellite are as follows:



Earth station latitude and longitude are $52.0^\circ N$ and 0°

Satellite longitude (subsatellite point) is $66^\circ E$

$L_e = 52^\circ$
$l_e = 0$
$l_s = 66^\circ$

Sol: We have to calculate Look angles [i.e Elevation angle (El) and Azimuth angle (Az)]

Latitude	Longitude
$L_e = 52^\circ$	$l_e = 0^\circ$
$L_s = 0$	$l_s = 66^\circ$

Step ①: Find the central angle (γ)

$$\cos(\gamma) = \cos(L_e)\cos(L_s)\cos(l_s - l_e) + \sin(L_e)\sin(L_s)$$

($L_s = 0^\circ$, $l_s - l_e = 66^\circ$)

$$\cos(\gamma) = \cos(L_e)\cos(l_s - l_e)$$

$$= \cos(52^\circ)\cos(66 - 0)$$

$$= \cos(52^\circ)\cos(66^\circ)$$

$$\cos(\gamma) = 0.2504$$

$$\Rightarrow \gamma = 75.4981^\circ$$

Since γ is less than 81.3° so the satellite is visible from the earth station.

Step②: Find the elevation angle(El)

$$El = \tan^{-1}\left[(6.6107345 - \cos\beta)/\sin\beta\right] - \beta$$

$$= \tan^{-1}\left[(6.6107345 - 0.2504)\sin(75.4981)\right] - 75.4981$$

$$El = 5.847^\circ$$

Step③: Find the intermediate angle(α)

$$\alpha = \tan^{-1}\left[\frac{\tan|(L_s - L_e)}{\sin(L_e)}\right]$$

$$\alpha = \tan^{-1}\left[(\tan(66 - 0))/\sin(52)\right]$$

$$\alpha = 70.667^\circ$$

Step④: Find the Azimuth angle (Az):

The earth station is in the Northern Hemisphere and the satellite is in the South east of the earth station

$$\therefore Az = 180^\circ - \alpha = (80^\circ - 70.667^\circ)$$

$$Az = 109.333^\circ \text{ (clockwise from true North)}$$

Orbital Perturbations:

Note: perturbations: Deviation from regular path.

The ideal perfect orbit is "Keplerian orbit" (i.e elliptical orbit). For this orbit properties are constant with time. But in practice satellite and earth are effected by

(i) asymmetry of the earth's gravitational field

(ii) gravitational fields of sun and Moon.

(iii) Solar radiation pressure

(iv) Atmospheric drag (at orbital altitude is caused by frequent collisions of gas molecules with the sat. It is major cause of orbital decay for satellites in LEO)

All these factors make the perfect Elliptical orbit to deviate from the original path.

The six orbital elements ($a, e, t_p, \Omega, i, \omega$) vary with time because of perturbations.

→ For a orbit which is effected by perturbations, the priod is called "anomalistic period"

→ Some other influences that cause the perfect orbit to deviate from it's original path are

C1, C9, D8, E0, E9, 10, 11, 12 A

Longitudinal changes:

Effect's of the earth's oblateness:

→ Earth is not a perfect sphere. And also not a perfect ellipse.

→ The irregular shape of earth, nonsphericity of the earth, non circularity of earth equitorial

radius, and Mascons (Mass concentration) lead to non uniform gravitational field around earth. Hence the force on the orbiting satellite will vary with position. There are some regions on earth where the gravitational attraction is higher, referred as mass cons.

→ A geostationary satellite ~~has to~~ is required to maintain a constant longitudinal position over the equator

* A GEO sat is weightless when it is in orbit. The smallest force on sat will cause it to accelerate & then drift away from its normal location.

→ The additional force toward the nearest equitorial bulge leads to the variation of longitudinal location of the satellite.

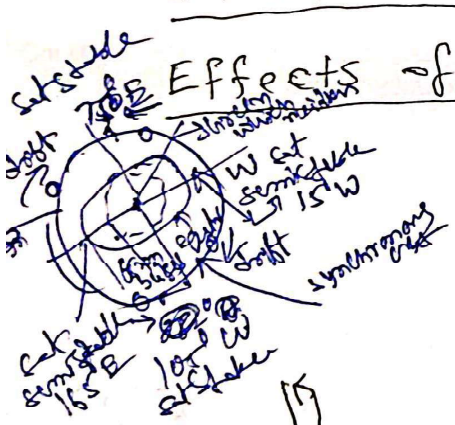
→ For a geostationary orbit, there are 4 equilibrium points in GEO orbit:

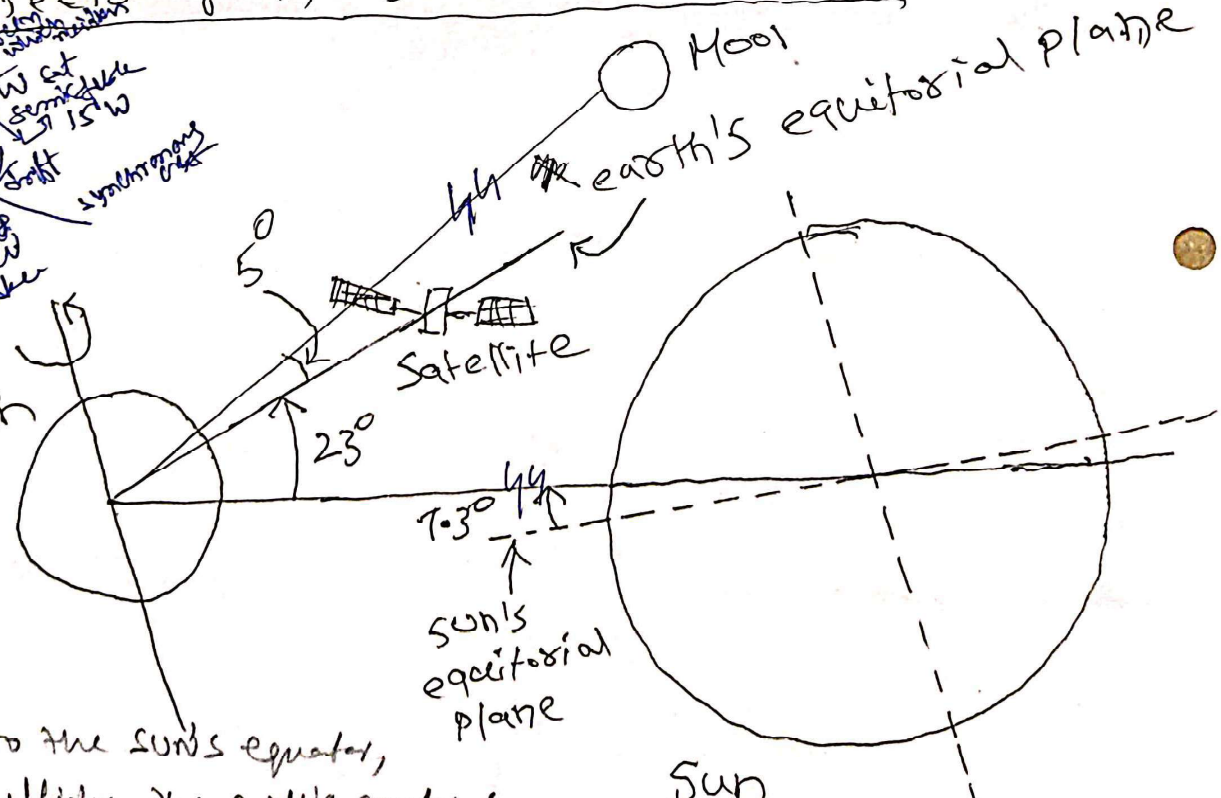
Two stable points (about 75°E and 252°E) — it will will tend drift back to stable point without thrusters firing

Two unstable points (around 162°E and 348°E) — if sat is perturbed ~~from~~ slightly from one of unstable points, it will immediately begin to accelerate its drift toward nearest stable point.

Inclination Changes:

Effects of the sun and the Moon:





* Due to the sun's equator, the elliptic, the earth's equator & moon's orbital plane around earth are all different, A sat in orbit around the earth will be subjected to a variety of out-of-plane forces.

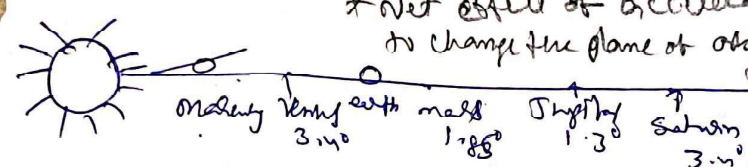
→ The plane of earth's orbit around the sun is the ecliptic. This plane is at an inclination of 7.3° to the equitorial plane of the sun.

→ The earth is tilted about 23° away from the normal to the ecliptic.

→ The moon circles the earth with an inclination of around 5° to the equitorial plane of earth

* The mass of SUN is larger than that of the moon but moon is closer to Earth than SUN.
For this reason, acceleration force induced by moon on GEO sat is twice as large that of the SUN.
* Net effect of acceleration forces by moon & SUN on GEO sat is to change the plane of orbit an initial avg rate of change of 0.85°/yr from equatorial plane

Solar sym



Quasi-means not exactly semi equal

Ecliptic pla
(or)
eclipse
(Transit)

Q: Drift with a GEO stationary satellite:
A quasi-GEO sat is in a circular equatorial orbit close to geosynchronous altitude. The quasi GEO sat, however, does not have a period of one sideral day; its orbital period is exactly 24h - one solar day. calculate
a) the radius of orbit
b) the rate of drift around the equator of subsat point in degree per (solar) day. An observer on earth sees that the sat is drifting across the sky.
c) Is the sat moving toward the east or toward the west?

Sol: (i) orbital period, $T^2 = \frac{4\pi^2 a^3}{M}$

$$a^3 = \frac{T^2 M}{4\pi^2} = \frac{(86400)^2 \times 3.986004418 \times 10^5}{4\pi^2} = 7.5371216 \times 1$$

$\therefore a = 42,241.095$ km

(ii) orbital period of sat (one solar day) is longer than a sideral day by 3 min 55.9 s = 235.9 s. This will cause the sub sat point to drift at a rate of $360° \times \frac{235.9}{86400}$ per day (or) 0.983° per day

Earth rotates from W to anticlockwise

(iii) Earth moves toward the east at a faster rate than sat, so the drift will appear to an observer on the earth to be toward the west.

* when both SUN & MOON are acting on same side of sat orbit, the rate of change of plane of geo sat's orbit will be higher than avg.

* opposite side → less than avg.

→ The various planes (i.e the sun's equator, the ecliptic, the earth's equator, and the moon's orbital plane around the earth) are all different. Hence a satellite in orbit around the earth will be subjected to a variety of out-of-plane forces.

Orbit Determination:

→ orbit determination requires three angular position Measurements.

→ Each angular Position measurement will provide two equations. one equation gives the azimuth angle as a function of six orbital elements And other equation gives the elevation angle as a function of six orbital elements.

Launches and Launch Vehicles

→ A Launch vehicle is used to launch a satellite (i.e placing a satellite) in the orbit.

→ In order to place a satellite in the orbit, we should know (i) the exact velocity vector of the satellite, (ii) The correct height of the orbit.

→ In any earth satellite launch, the largest fraction of the energy expended by the rocket (launch vehicle) is used to accelerate the vehicle from rest until it is about 20 miles (32 Km) above the earth.

→ For the efficient use of fuel, the launching will be in stages. This is called "staging"

→ Mainly there are two types of launch vehicles:

① Expendable Launch vehicles (ELV)

② Reusable " " (RLV)

→ In Expendable launch vehicles, have multiple stages. whenever each stage is completed, the completed portion of the launcher is expended until the Final stage placed the satellite in the orbit.

→ The space shuttle, called the "space Transportation system" (STS) by NASA, is partially reusable.

→ In RLV, shuttle vehicle itself is flown back to earth for refurbishment and reuse.

Some launch vehicle selection ~~process~~ Factors:-

price/cost

Reliability

↳ Recent launch success/failure history

Dependable launch schedule

urgency of your launch requirement

performance

Spacecraft fit to launcher (size, acoustic and vibration environment)

Flight proven (see Recent launch history)

Safety issues

Launch site locations

Availability

What is the launcher backlog of orders?

What is the launch site backlog of launches?

Market issues

What will the market bear at this particular time.

Decision making process to select a rocket:

price / cost

Reliability
- Recent failures

Dependable launch schedule
- urgency of the customer

performance

Spacecraft fit

Flight Proven

Safety

Launch site Location

Availability - Launch site; vehicle; schedule;

Market conditions - what the market will bear

- cost to manufacturer
- "performance" or throw-weight to orbit
- Reliability
- shedule dependability
- Market forces
- Insurance

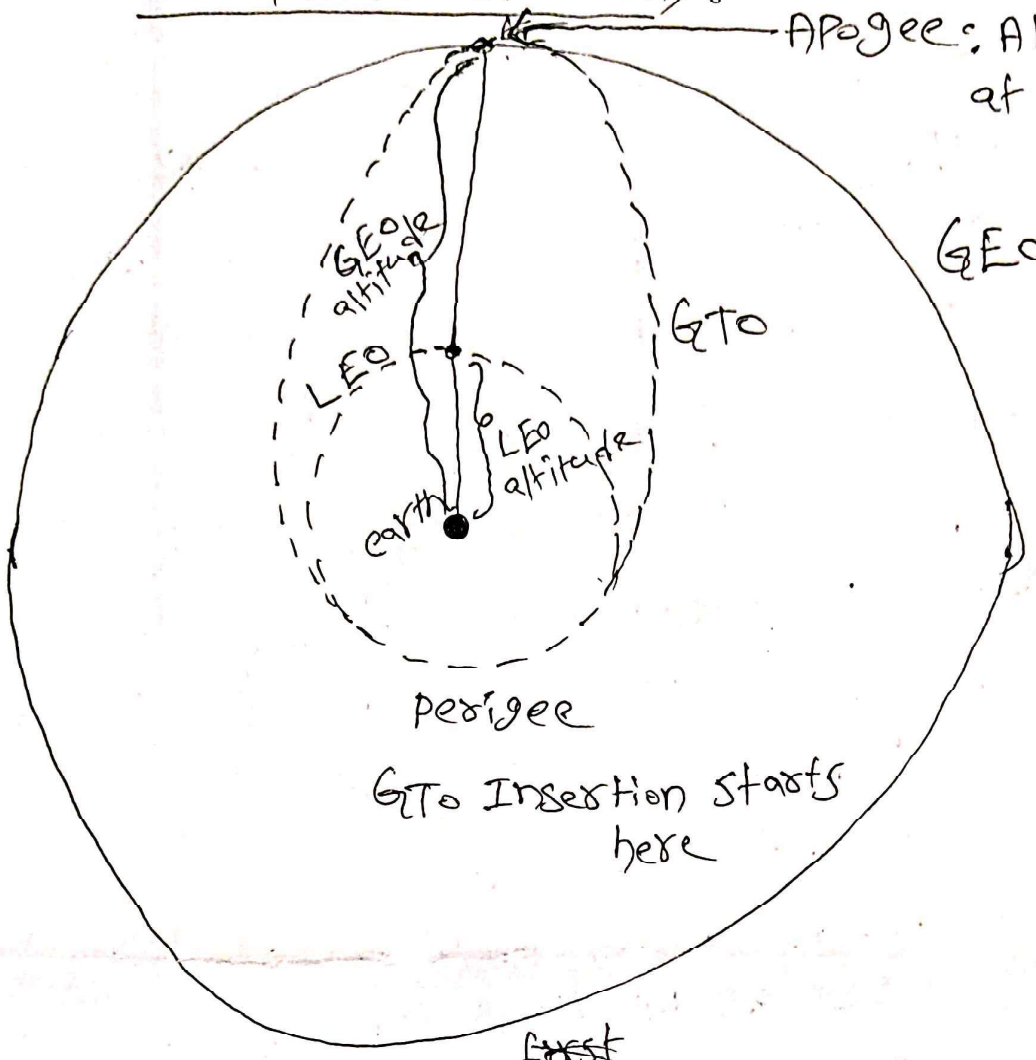
Placing the satellites into Geostationary orbit:

There are three methods are there to place a satellite into Geostationary orbit,

1. Geostationary Transfer orbit and AKM
2. Geostationary transfer orbit with slow orbit Raising
3. Direct Insertion to GEO

① Geostationary Transfer orbit and AKM:

(GTO / AKM approach):



~~first~~

→ ~~In this approach the spacecraft is~~ (i.e) ~~satellite into LEO (low Earth orbit)~~ ~~with final rocket stage still attached~~

→ In this approach first the spacecraft (i.e) satellite is placed into LEO (Low Earth orbit), with ~~final~~ rocket final stage still attached

→ After the orbital elements measurement, in the LEO orbit, the rocket final stage is reignited in LEO And then the spacecraft is launched

into GTO (Geostationary Transfer orbit)

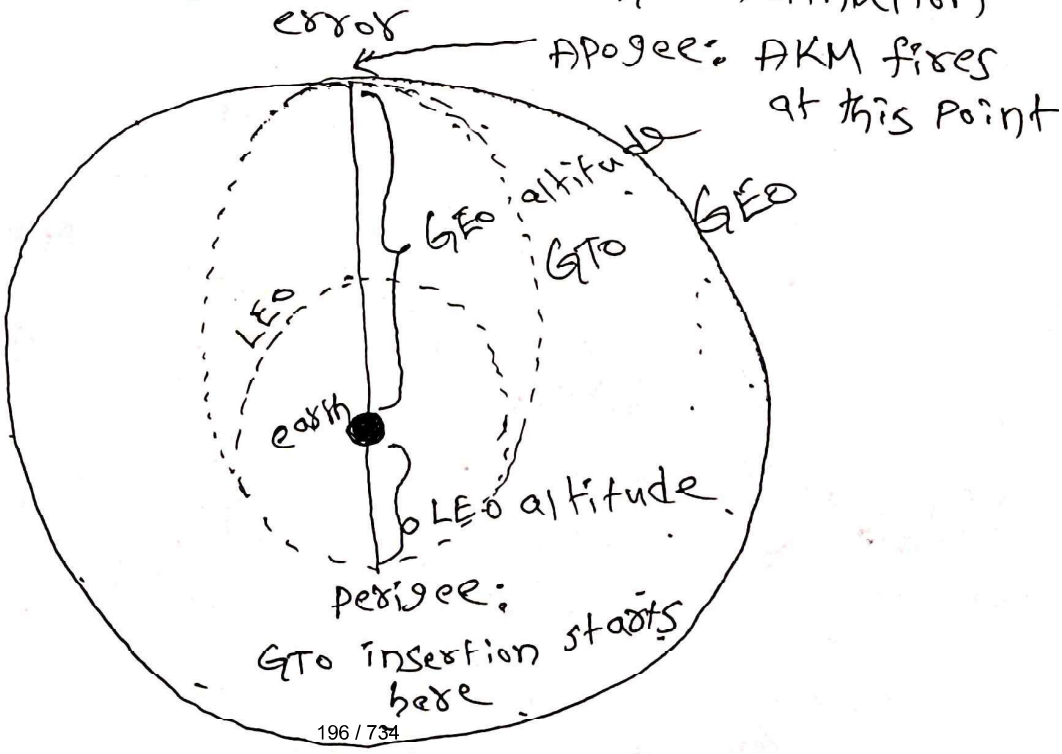
Note: GTO is the orbit between LEO and GEO.

→ GTO has a perigee that is the original LEO orbit altitude. And GTO has apogee that is GEO altitude.

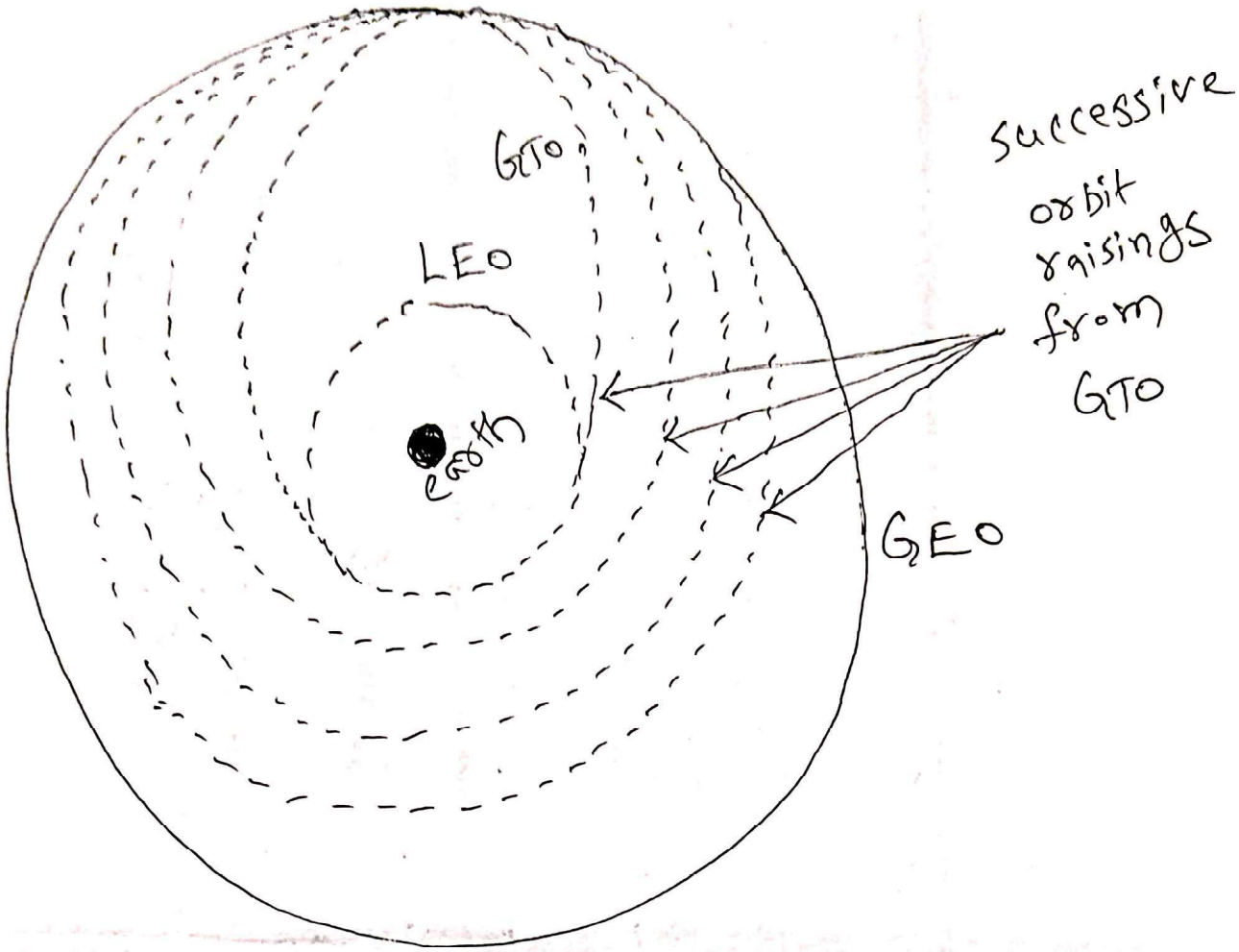
→ Again, after few orbits in the GTO, while the orbital elements are measured, a rocket motor (Generally contained with in the satellite itself) is ignited i.e fired at apogee and GTO is raised until it is circular (i.e Geostationary orbit)

→ Since rocket motor fires at apogee, it is called apogee Kick Motor (AKM)

→ AKM is used to (i) circularized the orbit (ii) to remove any inclination error



② GTO with slow orbit Raising:



→ In this approach the spacecraft thrusters are used to raise the orbit from GTO to GEO over a number of burns, instead of apogee Kick motor. (AKM)

Note: Thruster is a device or machine used to accelerate the satellite

→ Hence in this approach satellite orbit is raised to GEO from GTO with the help of thrusters instead of AKM

→ The satellite has two power levels of thrusters. They are

① More powerful ~~maneuvers~~ orbit raising maneuvers. Maneuvers are the skillful movement techniques. Theage maneuvers are used to raise the orbit from GTO to GEO

② Low thrust maneuvers: ~~that~~ used ~~to~~ for on-orbit process.

→ satellite will use ~~more~~ less ~~power~~ ~~of~~ fuel to raise its orbit from GTO to GEO. But satellite ~~use~~ ~~less~~ can retain more fuel for its on-orbit operations

③ Direct Insertion to GTO:

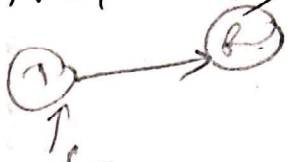
→ In the previous two approaches, first the satellite is placed in LEO; Next the satellite is placed in GTO. From GTO finally satellite is placed in GEO.

→ But in this approach satellite is placed directly in to GEO.

Orbital effects in communications systems performance:

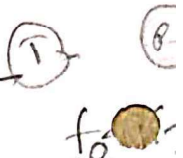
Doppler shift:-

→ The frequency of transmitter when it is at rest (i.e the true transmitter frequency) is f_T



→ The frequency of receiver is f_R $f_R > f_T$

Then f_R is higher than f_T when the transmitter is moving toward the receiver. And f_R is lower than f_T when the transmitter is moving away from the receiver



→ Mathematical relation between f_T & f_R is

$$\frac{f_R - f_T}{f_T} = \frac{\Delta f}{f_T} = \frac{V_T}{v_p}$$

where V_T = The component of transmitter velocity directed toward the receiver

v_p = Phase velocity of light = c

= 3×10^8 m/s in free space

From the above relation

$$\Delta f = \frac{V_T f_I}{v_p} = \frac{V_T f_T}{c} = \frac{V_T}{\lambda}$$

where λ = wavelength of transmitted signal = $\frac{f_T}{c}$ $\left(\lambda = \frac{c}{f}\right)$

Here Δf is change in frequency.

→ If transmitter is moving away from the receiver, then V_T is negative

→ This change in frequency (Δf) is called "Doppler shift" or "Doppler effect" or "Doppler".

→ For LEO satellites, the Doppler shift is used in frequency tracking receivers.

∴ Doppler shift for a LEO satellite:

A low earth orbit satellite is in a circular polar orbit with an altitude, h, of 1000 km. A transmitter on the satellite has a freq of 2.65 GHz. Find

(i) The velocity of the sat in orbit.

(ii) The component of velocity toward an observer at an earth station as the sat appears over the horizon, for an observer who is in the plane of the sat. orbit.

(iii) Hence, find the Doppler shift of the received signal at the earth station. Use a mean earth radius value, Re of 6378 km.

The sat also carries a Ka-band transmitter at 20.0 GHz

(iv) Find the Doppler shift for this signal when it is received by the same observer.

(i) $T^2 = \frac{4\pi^2}{M} a^3 \Rightarrow T^2 = \frac{4\pi^2 (6378+1000)^3}{3.986004418 \times 10^5} = 3.977754 \times 10^7 s^2$

$\therefore T = 6306.94 s$

circumference of orbit is $2\pi a = 46,357.3$ km

$\therefore$ velocity of sat in orbit, $V_s = \frac{2\pi a}{T} = \frac{46357.3}{6306.94} = 7.35$ km/s

(ii) The component of velocity toward an observer in the plane of the orbit as the sat appears over the horizon is given by

$$v_r = v_s \cos\theta \quad -$$

where $\theta \rightarrow$ angle b/n sat-velocity vector & direction of the observer at the sat.

The angle θ can be found from simple geometry to be



$$\cos\theta = \frac{r_e}{r_e + h} = \frac{6378}{7378} = 0.8645$$

Hence the component of sat velocity toward the observer is

$$v_r = v_s \cos\theta = 6.354 \text{ km/s} = 6354 \text{ m/s}$$

(iii) Doppler shift of the received signal is given by

$$\Delta f = \frac{v_r f_T}{c} = \frac{v_r}{\lambda}$$

Hence, for this satellite & observer, with a transmitter freq of 2.65 GHz, $\lambda = \frac{c}{f} = \frac{3 \times 10^8}{2.65 \text{ G}} = 0.1132 \text{ m}$

& Doppler shift in received signal is

$$\Delta f = \frac{v_r}{\lambda} = \frac{6354}{0.1132} = 56,130 \text{ Hz} = 56.13 \text{ kHz}$$

(iv) A Ka-band transmitter with freq 20.0 GHz has a wavelength of 0.015 m. The corresponding Doppler shift at the receiver is

$$\Delta f = \frac{v_r}{\lambda} = \frac{6354}{0.015} = 423.60 \text{ kHz}$$

Doppler shift at Ka band with a LEO sat can be very large & requires a fast freq tracking receiver. Ka-band LEO satellites are better suited to wideband signals than narrowband voice communications.

Range variations:

→ For geostationary satellites, the position of satellite with respect to the earth exhibits a cyclic daily variation

→ The variation in satellite position will lead to a variation in range between the satellite and user terminals.

Solar eclipse:

→ A satellite is said to be in eclipse, when the earth prevents sunlight from reaching to satellite.



i.e when the satellite is in the shadow of the earth

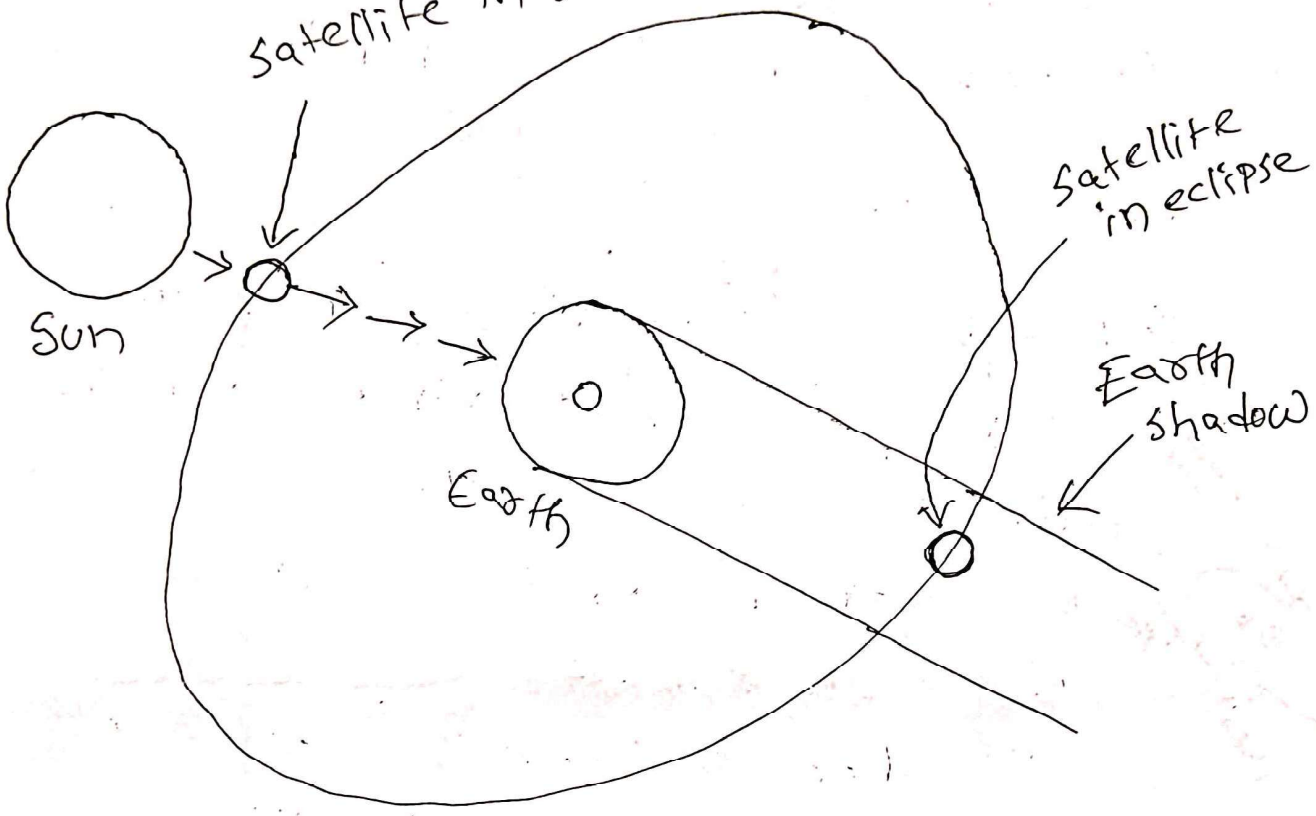
(or) when the ~~satellite~~ earth is in between sun and satellite.

→ For a geostationary satellites, eclipses occur during two periods that begin 23 days before the equinoxes and end 23 days after the equinox periods.

Note: equinox days are about March 21 and about September 23

In these days the sun, the earth, and the satellite are in the same plane

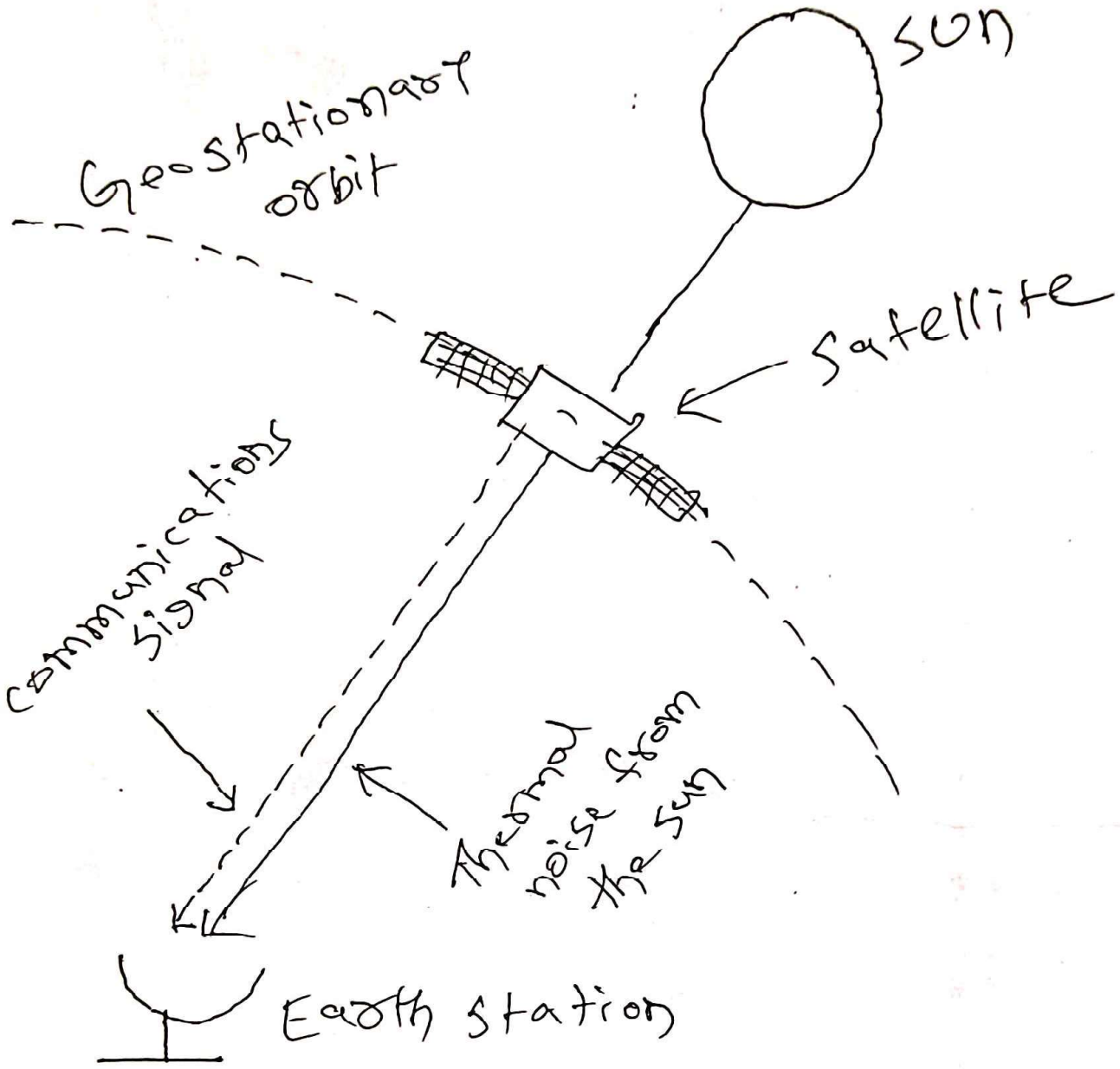
→ During full eclipse, a satellite will not receive power from its solar array. Hence satellite must operate entirely from it's batteries (Nickel-Hydrogen battery).



Sun Transit outage:-

→ When the satellite is passing infront of the sun on the sunlit side of earth, the earth station antenna receives not only the signal from satellite but also noise temperature transmitted by the sun.

The added noise temperature will cause fade margin of the receiver and an outage will occur. (i.e sun transit outage)



Low Earth orbit and Non-Geostationary Satellite system

Orbit considerations:

1. Equatorial orbits
2. Inclined "
3. Elliptical "
4. Molniya "
5) Radiation belts
5) Sun Synchronous orbit



→ The motion of a satellite in the orbit is determined by the "orbital mechanics".

→ while the satellite moves in such a way as to balance centrifugal and centripetal forces, the earth is also in motion beneath it.

→ Earth also moves around the sun.

→ solar system (with sun as center) is orbitting around the center of home galaxy.

Before launching any sat the following orbit considerations are to be followed
* determine the type of orbit
* calculate the centripetal & centrifugal forces
* ca in velocity of sat
* Determine the time period of the orbit

→ Hence there is a complex relationship between the various motions of the natural and artificial bodies

Equitorial orbits:

→ Equitorial orbits lie exactly in the plane of the geographical equator of the earth. i.e orbital path lies directly above the equator at all times.

→ A satellite in equatorial orbit will have two periods

(i) A real orbital period which is denoted by, T

$T = 23.9344$ hours, i.e one sidereal day.

Note: we know T can be calculated by $T = \frac{2\pi r^{3/2}}{\mu^{1/2}}$ or $T^2 = \frac{4\pi^2 r^3}{\mu}$

(ii) The apparent orbital period to the observer on the equator will be denoted by P hours

where $P = \frac{24T}{24-T}$ hours

where T = real orbital period.

→ The difference between real orbital period (T), and apparent orbital period (P) shows the

orbital height (km)	orbital period T (hr)	orbital period Apparent (hr)	observing time (hr)
500	1.408	1.496	0.183
1K	1.527	1.688	0.283
5K	1.752	1.890	0.587
10K	5.794	7.645	8.894
35.786			

206 / 734

time that the satellite is visible to the observer.

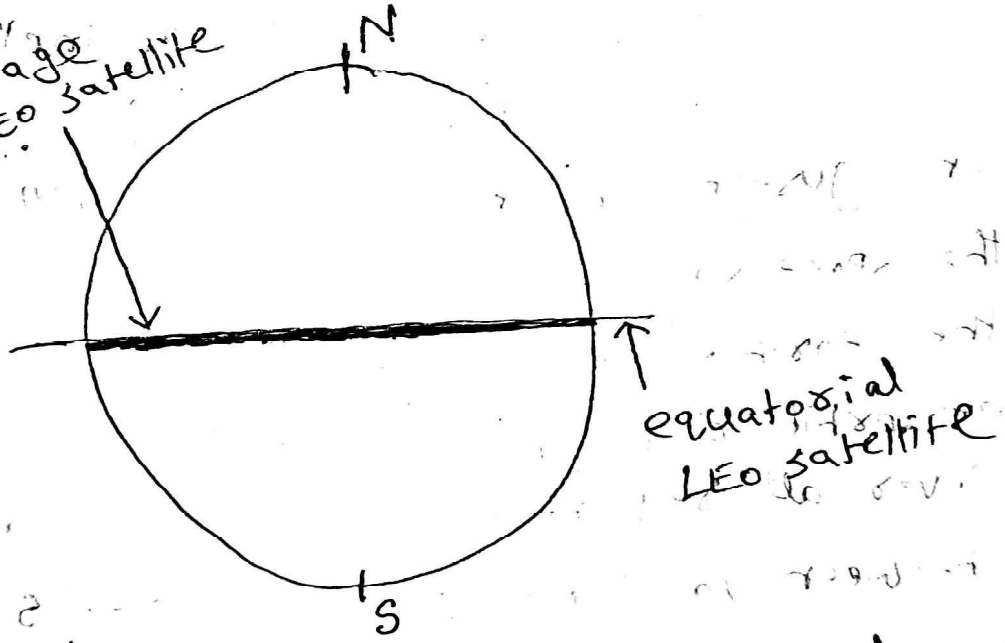
Note: prograde orbit: proceeding from west to east

retrograde orbit: from east to west.

Inclined orbits:

→ Greater the inclination of the orbit, larger the coverage area of satellite.

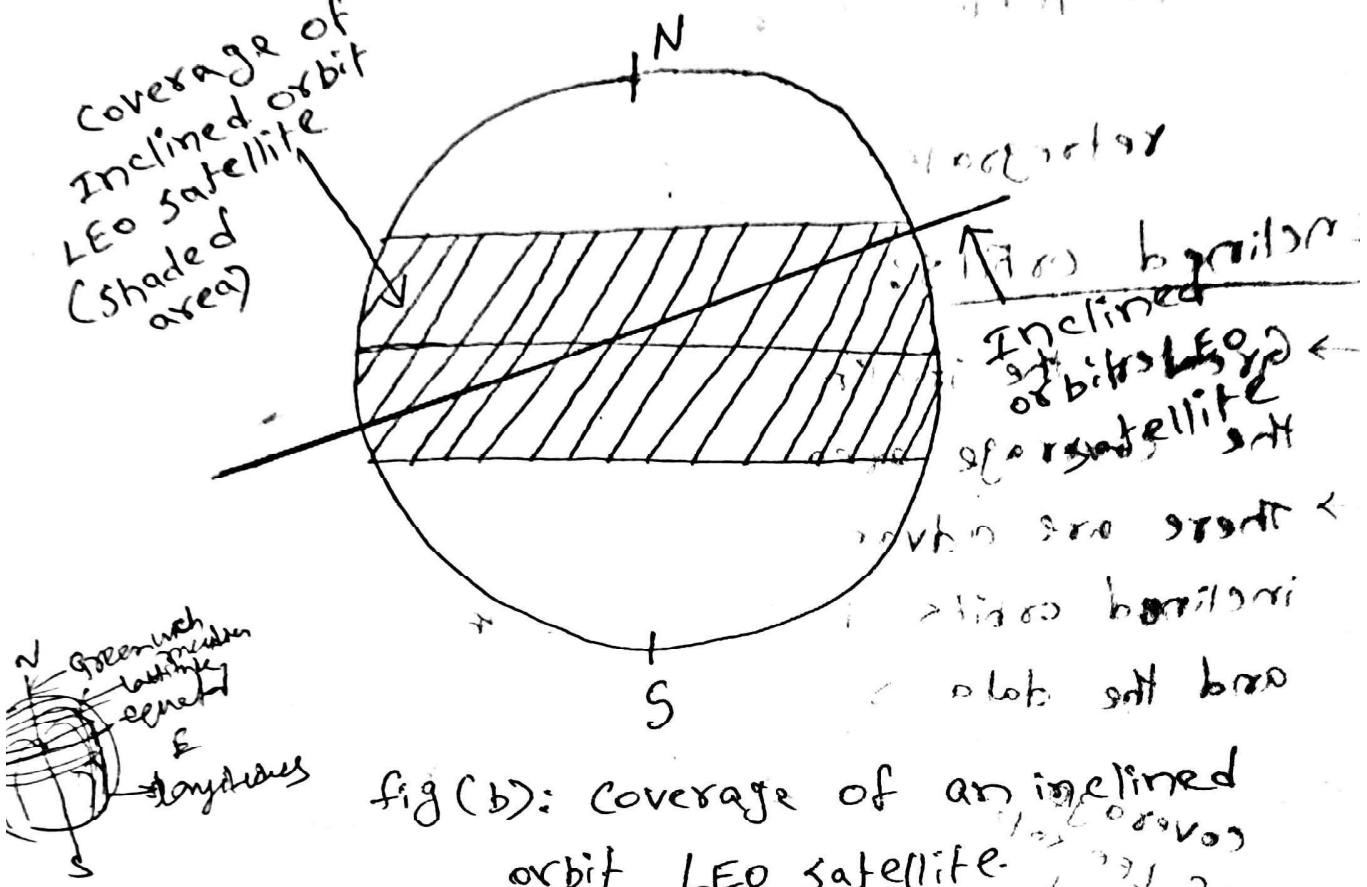
→ There are advantages and disadvantages to inclined orbits depending on the mission goals and the data recovery requirements.



fig(a): coverage of equatorial orbit LEO satellite

→ In the above figure, equatorial orbit is shown. orbital inclination is 0 with respect to equatorial line.

→ Hence the satellite will pass only over the equator. i.e the satellite will cover the earth region that is close to equator.



fig(b): Coverage of an inclined orbit LEO satellite.

→ In figure(b), the inclined orbit will take the spacecraft, at one time or another, over the earth's entire surface. For example an orbit with an inclination of 30° will cover all regions that lie approximately between latitudes 30°N and 30°S

→ The superior coverage (i.e large coverage) of the earth with an inclined orbit satellite is counterbalanced the disadvantage of inclined orbit. And this disadvantage is master control station (MCS) will not be able to communicate

directly with the satellite on every orbit as in case of equatorial orbit satellite.

→ one simple & low cost, solution to pass data between inclined orbit satellite and MCS is to design the satellite to store data acquired over many orbits and then, when the satellite passes near to MCS (i.e with in radio range of MCS), it will dump data rapidly into the MCS. This is called "Store and forward" approach.

→ other approach to send data from inclined orbit satellite to MCS is real time data transfer into MCS from inclined orbit satellite to MCS via GEO satellite.

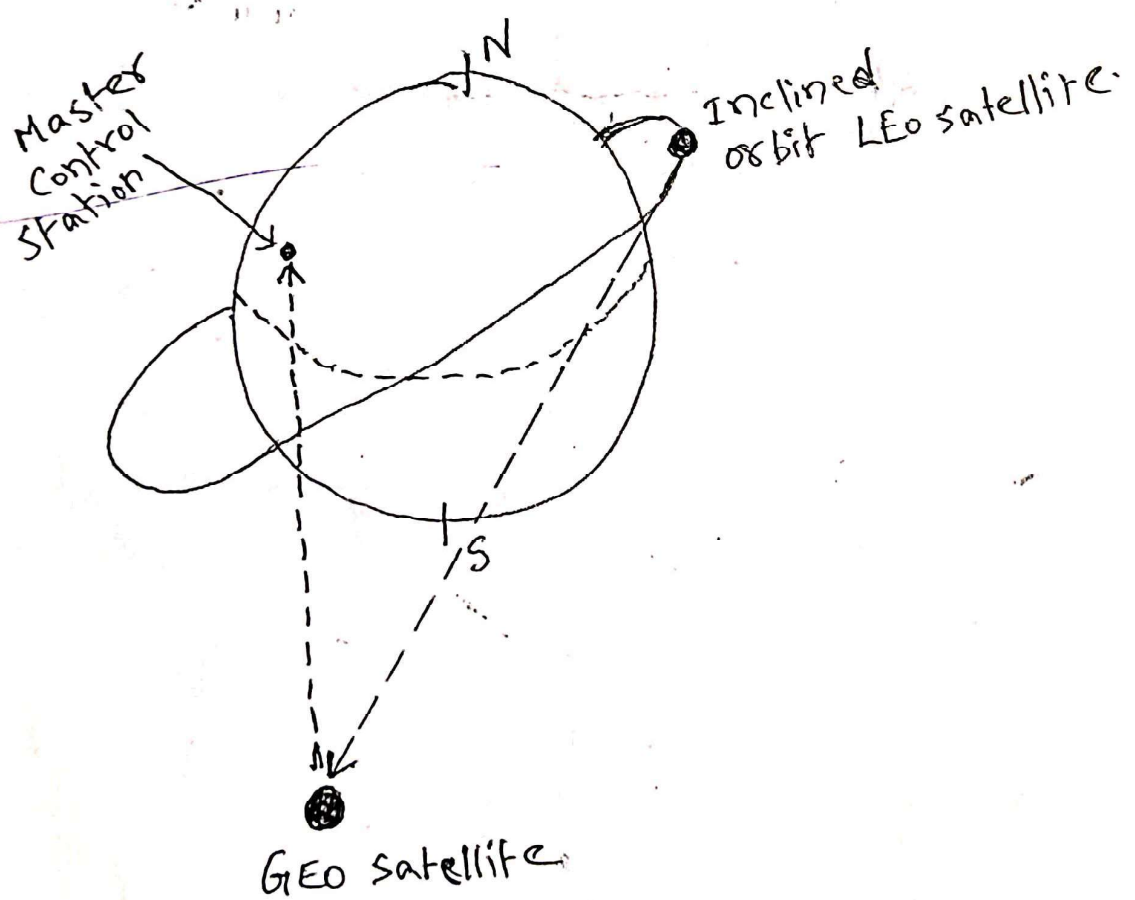
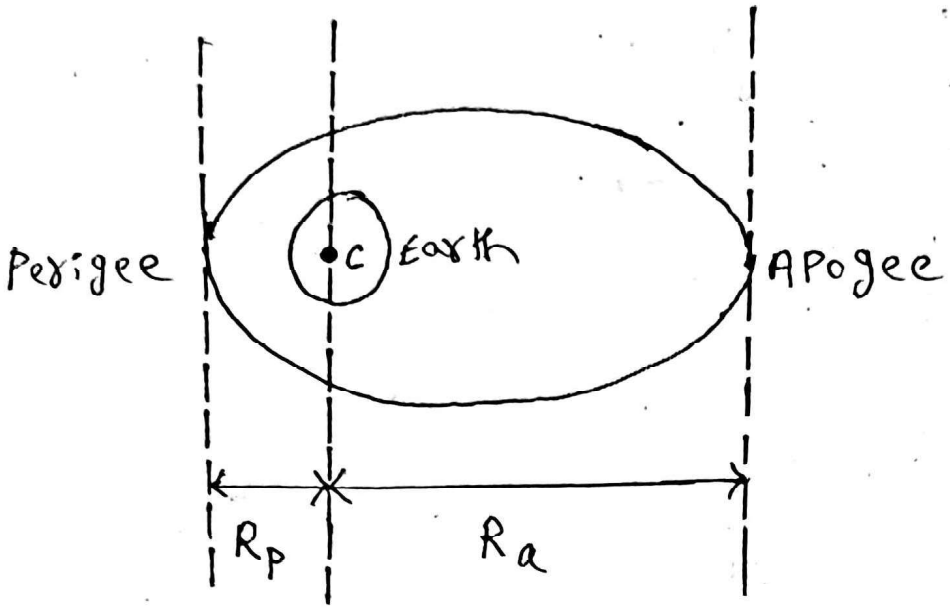


fig: Real time data transfer via GEO satellite.

Elliptical orbits:



→ An elliptical orbit will have nonzero eccentricity.

→ The elliptical orbit eccentricity (e) can be determined by the following formula:

$$e^2 = 1 - \left(\frac{b^2}{a^2}\right)$$

Where a = length of semimajor Axis

b = length of semiminor Axis.

→ eccentricity (e) can also be calculated by

$$e = \frac{(R_a - R_p)}{(R_a + R_p)}$$

Where R_a = distance between center of earth (c) and apogee point of the orbit.

R_p = distance between center of earth (c) and perigee point of the orbit.

→ If the orbit is exactly circular then $a=b$ and $R_a=R_p$ and $e=0$.

→ But practically no orbit is truely circular. Approximate practical value of $e=10^{-3}$ or less.

→ The eccentricity is ~~the~~ another way of describing the variation in the radius of the orbit.

→ If R_{av} is the average radius of an orbit from center of earth, then the variation Δ_R in the orbital radius is given by

$$\boxed{\Delta_R = \pm e R_{av}}$$

e = eccentricity

For a GEO sat $R_{av} = 42,164.17$ km with an eccentricity of 10^{-4}, ΔR will be ± 4.2 km.

For LEO circular $\simeq 800$ km, $e = 10^{-4}$, $\Delta R = \pm 0.7178$ km

Molniya orbit:

→ This is a special case of highly elliptical orbit (HEO)

* One of the more famous orbit has $e \simeq 0.74$. This is a special case of a highly elliptical orbit (HEO) known as molniya orbit.

→ The former soviet union had a difficult communications design problem. It was the largest country (Russia) in the world. It was having 11 time zones.

→ A single GEO satellite can not reach that far north over 11 time zones simultaneously. (i.e A single GEO satellite can not cover 11 time zones simultaneously).

→ Hence a new type of orbit was required to provide good communication coverage, which was called the molniya system as shown below.

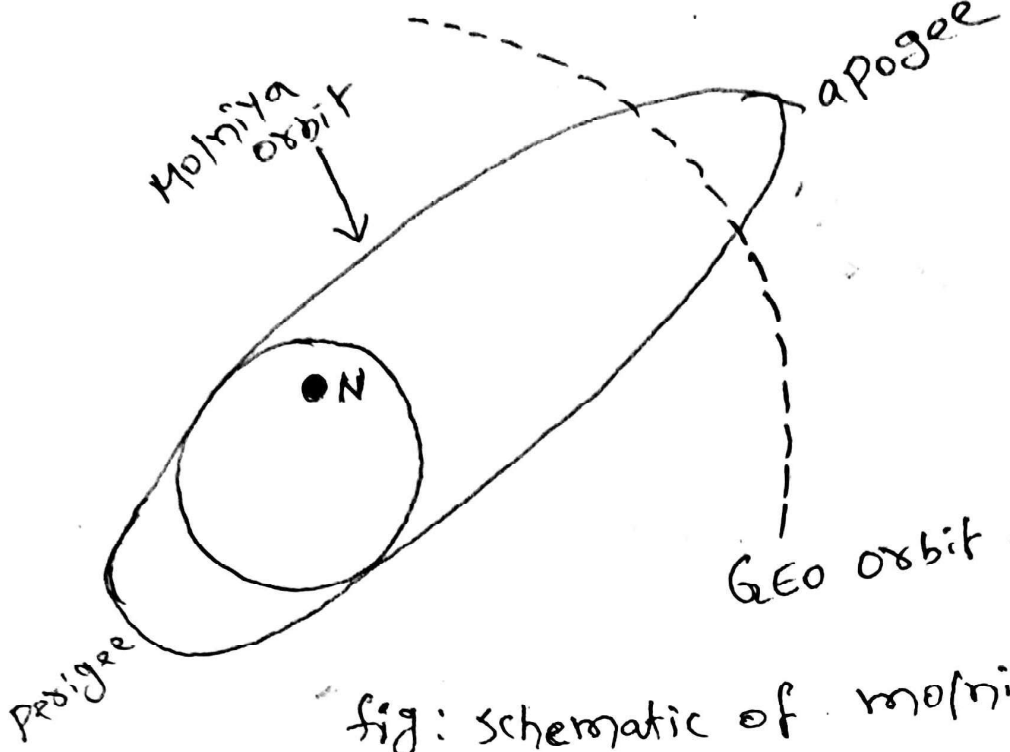


fig: schematic of molniya orbit

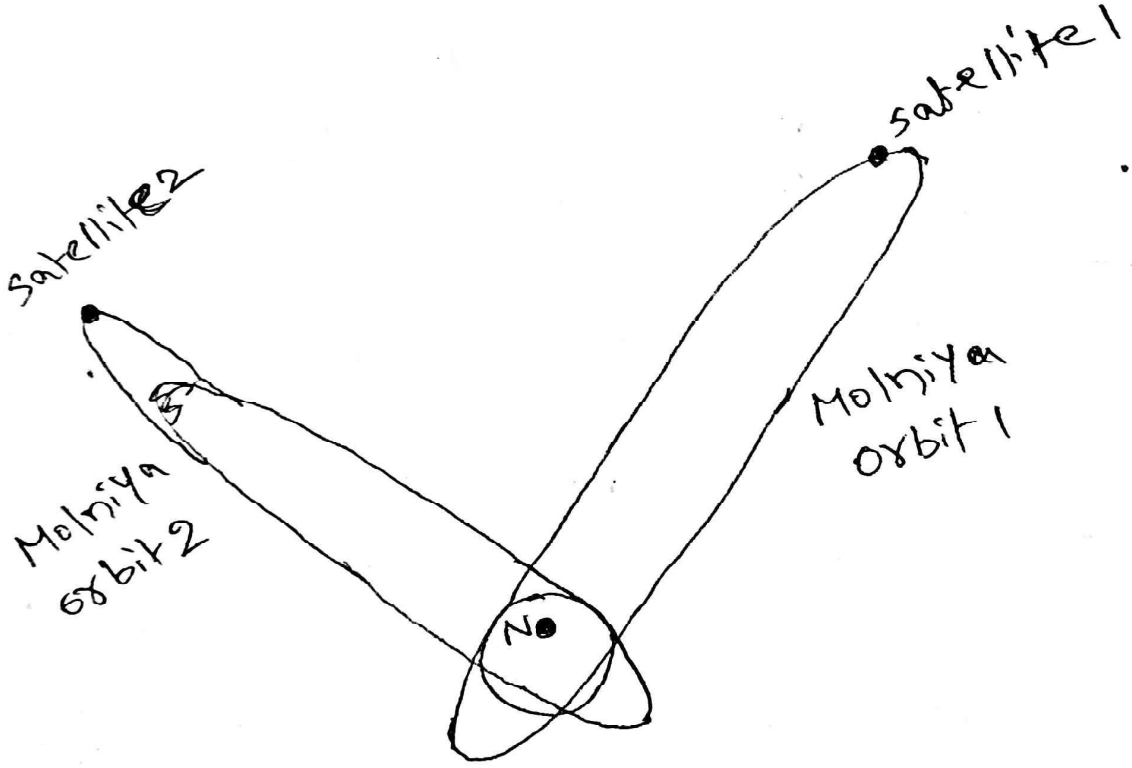


fig: operational Molniya system.

→ The first molniya satellite was launched in April 1965 and it gave it's name to both the system of the satellites and to the unique orbit.

* orbit

i.e Molniya orbit
Molniya satellite
Molniya system

→ The word molniya means flash of lightening in Russian language.

→ The apogee of the molniya orbit is at an altitude of 39,152 Km and the perigee is at an altitude of 500 Km. The orbital period is 11 hours and 38 min. (≅ 12 hr) And the orbital inclination is 62.9°

→ This combination of apogee, perigee and inclination ensures that the ground track of the molniya orbit repeats every other orbit.

→ As shown in the above figure(2) molniya orbits 1 and 2 are seperated by 180°
~~Two satellites can cover entire Russia in 24 hr, seperated by 180°~~

Radiation effects:

→ The effect of radiation on electronics in space is generally seperated out into two main aspects

(i) Total dose
(ii) single event upsets

Total dose is simply the cumulative effect of radiation over the life time of electronics in space and it is mainly due to ~~trapp~~

trapped electrons and Protons in the Van Allen belts.

→ Single event upsets are caused by heavy ions ejected from the sun.

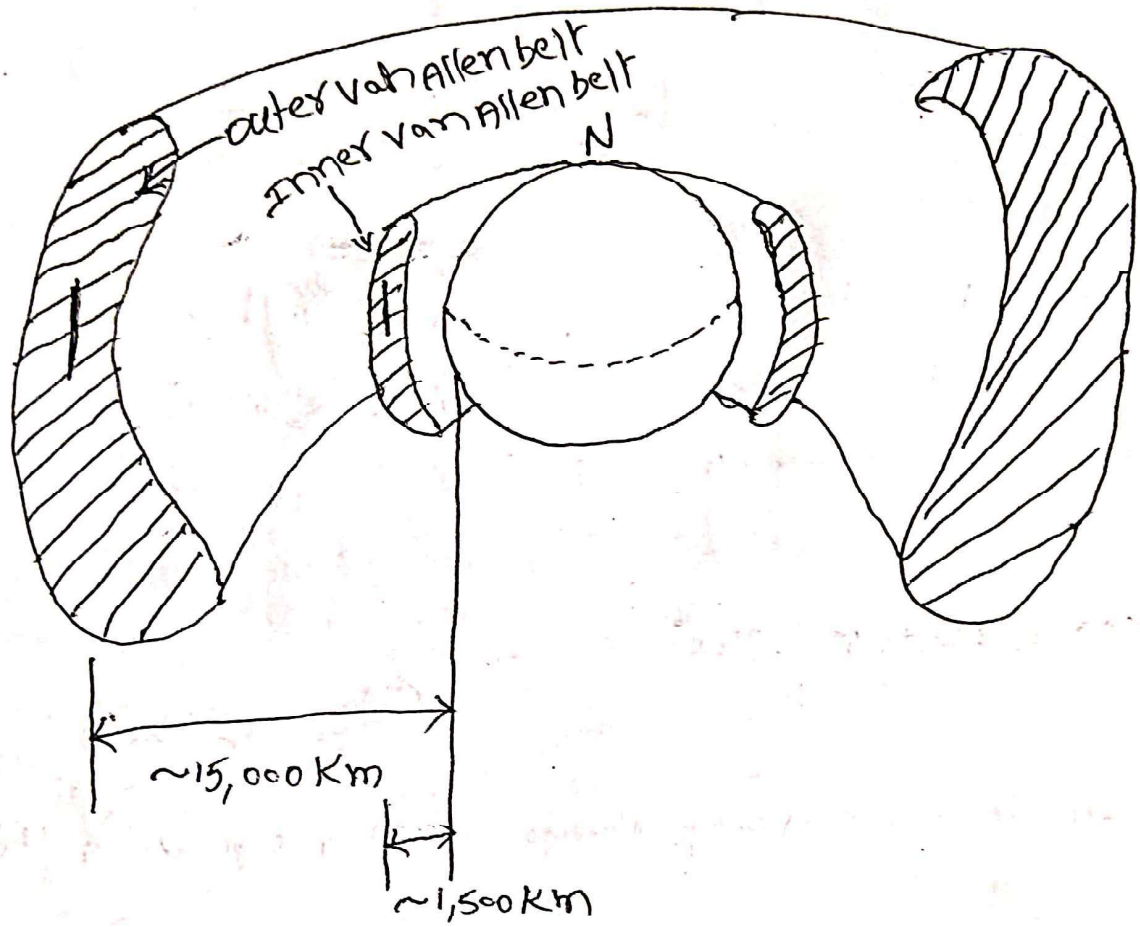


fig: Pictorial representation of two Van Allen belt radiation.

→ Van Allen belt is the zone of energetic charged particals, that is captured by earth magnetic field.

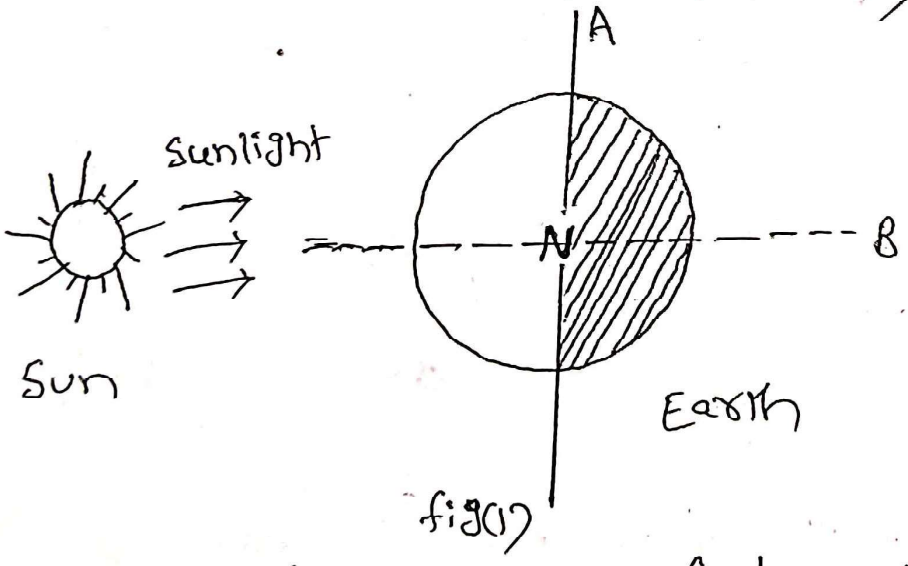
inner belt - 1000 km above from Earth surface
outer " - 15,000 km "

Sun synchronous orbit:

→ A sun synchronous orbit is a special form of LEO where the plane of the orbit maintains a constant aspect angle with the direction to the sun.

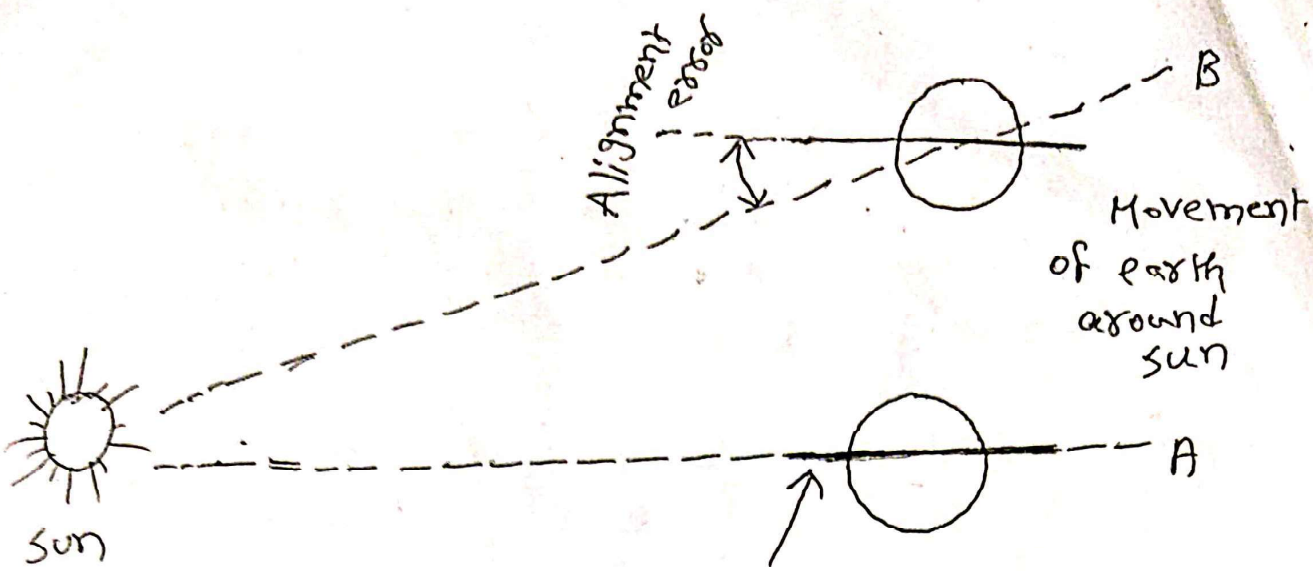
→ Some satellite missions require a specific orbit with such a constant relation to the direction of the sunlight.

→ one example is an earth resources satellite that requires a large amount of direct sunlight to illuminate the region below the satellite so that photographs can be taken (Meterological satellite)



fig(i)

fig: Examples of two sunsynchronous orbits (i.e orbital planes A and B). Earth is viewed from north Pole (N).



fig(2)

Plane of satellite's orbit around earth

fig: Illustration of alignment changes of orbital plane of a satellite due to the movement of earth around SUN

→ There are two advantages in this orbit first, the satellite need not have a large battery capacity for ~~ellipse~~ eclipse operations since it is always illuminated.

→ second, since the shadows are so long on the region being surveyed, changes in terrain or structures will be immediately obvious.

→ fig2 illustrates how the ~~see~~ sunsynchronous

orbit is achieved.

→ If a satellite is in a perfectly circular LEO orbit over the poles of the earth, a carefully timed launch would put the orbit in such a position that the sun is directly behind the satellite on the sun direction side of the first orbit. This is position 'A' in fig (2).

→ However, after some short time, the earth will have moved in it's orbit around the sun plane of the satellite's orbit (now in position B) will no longer be aligned with the direction of the sun light.

→ In order to make the satellite's orbital plane always keep moving with the apparant change in position of sun, it must be launched into a retrograde orbit.

Coverage and frequency considerations:

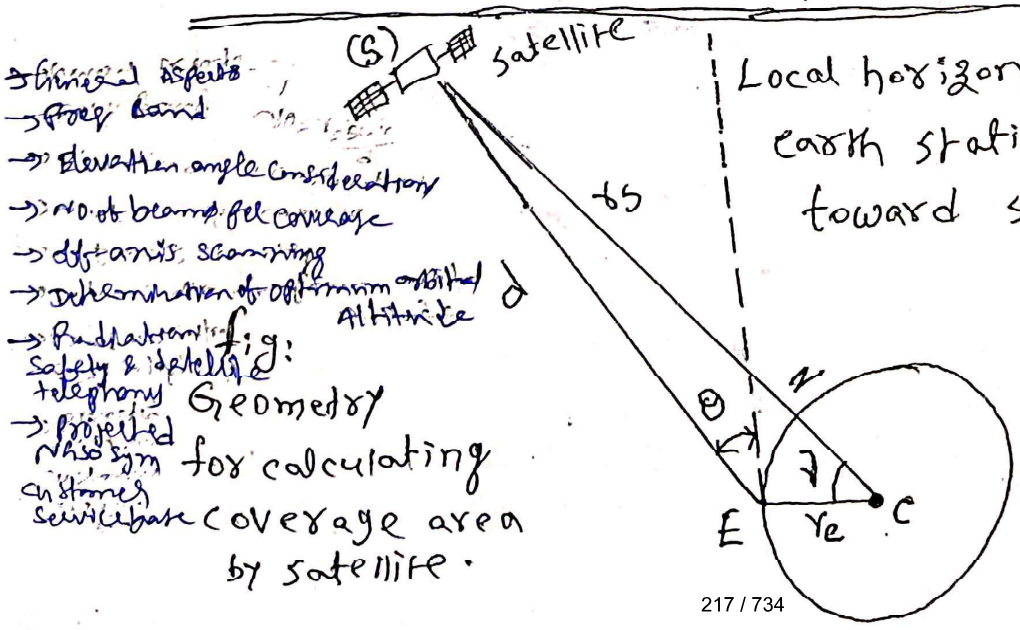


fig: Geometry for calculating coverage area by satellite.

→ Let us consider, the geometrical aspects of determining an optimum coverage.

E : Earth station
S : satellite
C : center of earth
d : distance from satellite (S) and E
r_s : " " " and C (center of earth)

γ : central angle
θ : elevation angle.
r_e : radius of earth.

→ A spacecraft orbits at distance, "r_s" from the center of earth 'C'. The elevation angle to the satellite is θ using the sine rule

$$\left[\frac{r_s}{\sin(90+\theta)}\right] = \left[\frac{d}{\sin\gamma}\right]$$

$$\Rightarrow \cos(\theta) = \left[\frac{r_s \cdot \sin\gamma}{d}\right]$$

→ consider a LEO satellite with a coverage zone on the earth's surface that has an area Am^2. The transponder on the

Satellite with o/p power P_t watts, and EIRP from the satellite of $P_t G_t$ watts

→ The average flux density across the coverage zone is therefore

$$F \approx \frac{P_t G_t}{A} \text{ watts/m}^2$$

→ The value of the flux density is independent of frequency. The mobile receiver has an antenna that is nearly omnidirectional with a gain G_r, the effective receiving area of this antenna is given by

$$A_e = \frac{G_r d^2}{4\pi} \qquad G_r = \frac{4\pi}{\lambda^2} A_e$$

→ The received power at the mobile earth station is given by

$$P_r = F \times A_e$$

$$P_r = \frac{P_t G_t G_r d^2}{4\pi A} \text{ watts}$$

→ Thus the received power at the mobile terminal with omnidirectional antenna increases as the square of the ~~frequency~~ wavelength. (or)

P_r decreases as square of frequency

→ The lower the RF frequency, the greater the received power for any coverage zone.

→ This is the reason why L-band is allocated for mobile satellite services.

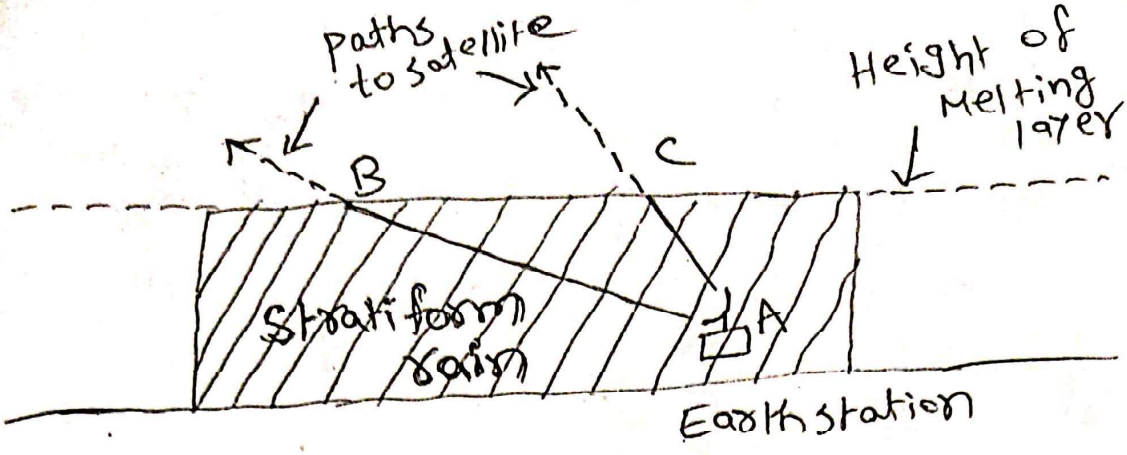
Elevation angle considerations:

→ The rain attenuation can cause significant attenuation on a slant path.

→ At Ka band (30/20 GHz), even light rain can cause appreciable signal loss.

→ Light rain is usually stratified, so the higher the elevation angle, the lower the rain attenuation for a given rain fall rate.

→ Most commercial satellite systems require that earth stations operate above certain minimum elevation angles



→ The above diagram illustrates the decrease in path through rain as elevation angle to the satellite increases.

→ Light rain is generally formed at the melting layer height in stratiform clouds. Since the rain is uniform, the total path attenuation will be given by the length of signal path, in the rain.

→ The higher the elevation angle path (AC) will therefore suffer less attenuation than the lower elevation angle path (AB)

→ Increasing the altitude of the satellite's orbit will increase the coverage area. Alternatively, the altitude can remain fixed and the beamwidth

increased inorder to cover a larger surface area.

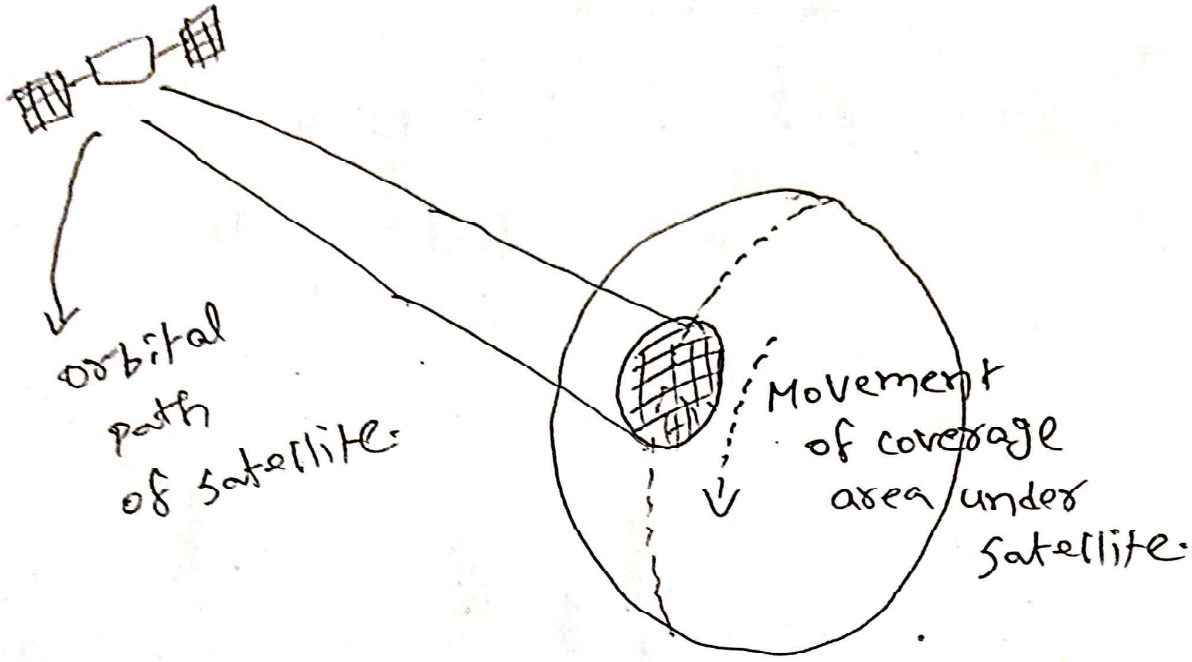


fig: Illustration of coverage area under a satellite.

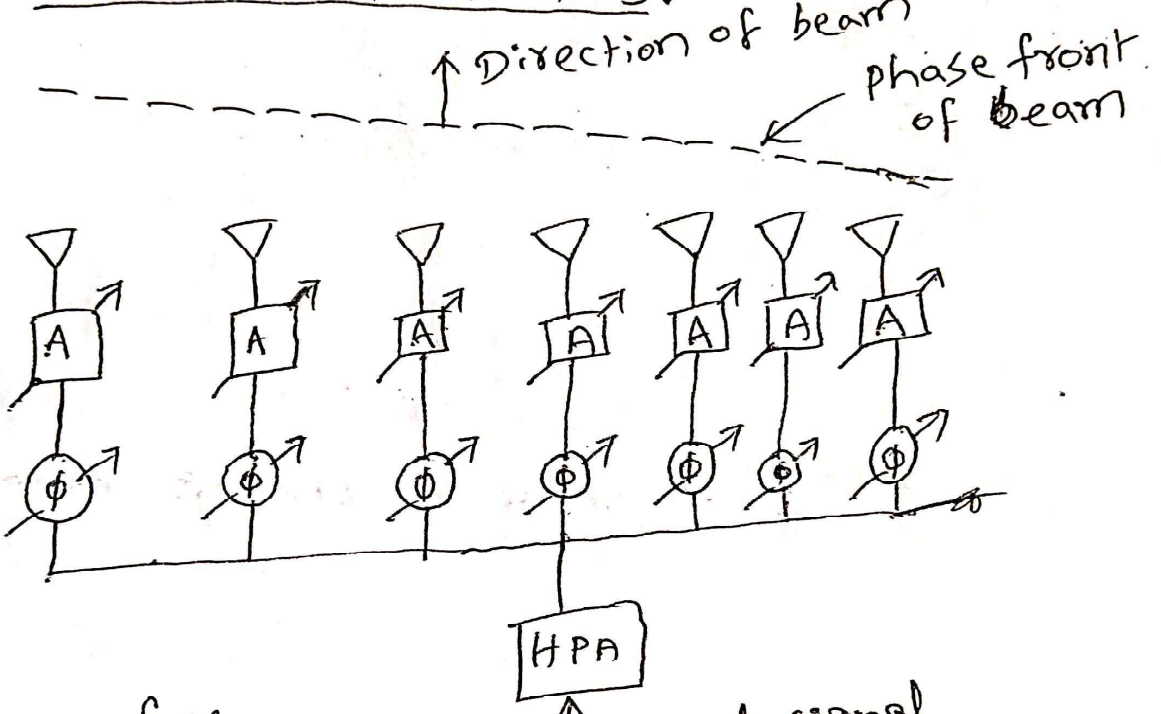
Off Axis scanning:

→ The design of a point-to-point wireless communication system requires that the antennas at either end be directed toward each other for maximum gain advantage.

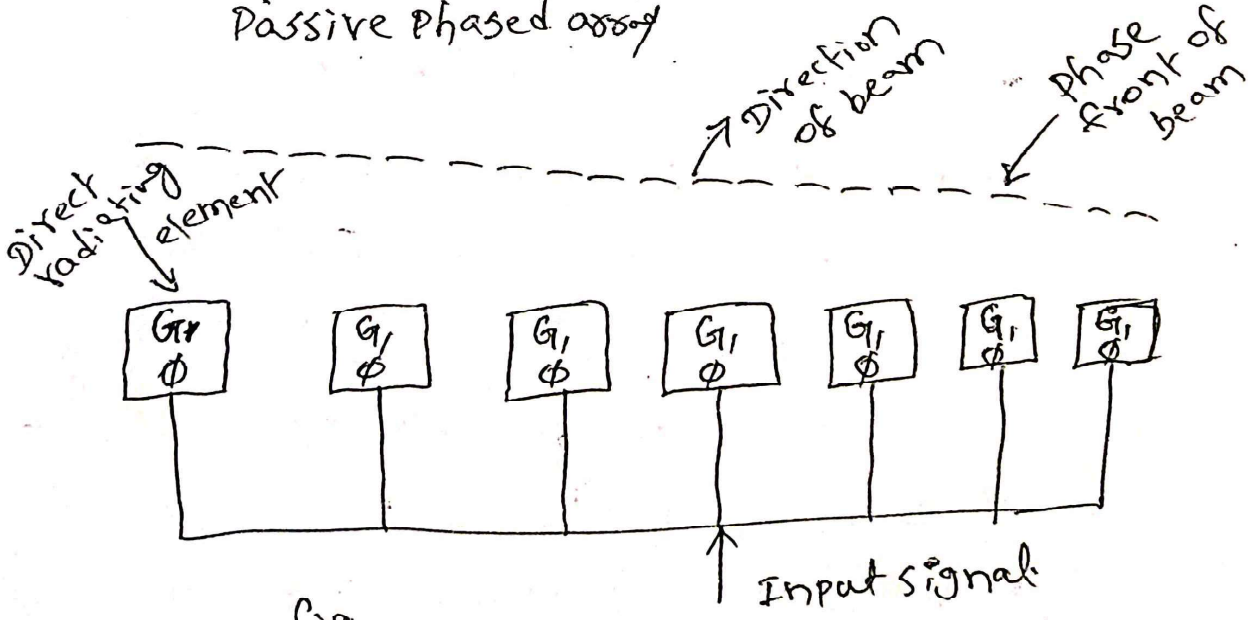
→ If the transmitting antenna has to communicate with more than receiving antenna, and if these antennas are

are located in different positions, a compromise must be taken between the gain of transmitting antenna toward various receiving antennas.

Scan Angle control Mechanisms for Phased array antennas:



fig(1): Passive Phased array



fig(2): Direct radiating array

→ In fig (1) i.e in passive phased array a high power Amplifier (HPA) has the power devided up among a number of different feedlines.

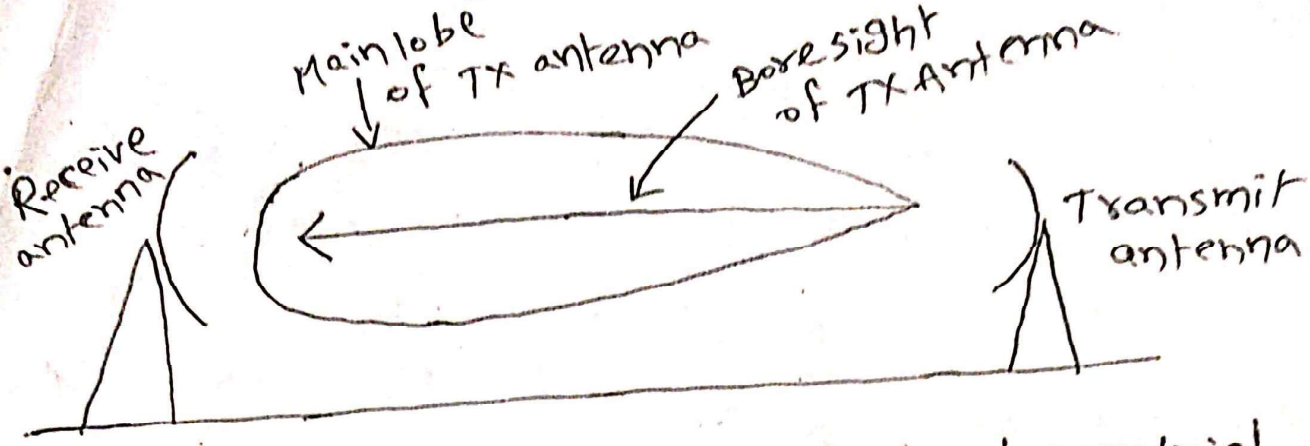
→ Each feed line is acted on by a variable phase change (ϕ) and variable Attenuator (A) device.

→ The sum of many phases and amplitudes generated by the feedhorn cluster will develop the antenna coverage.

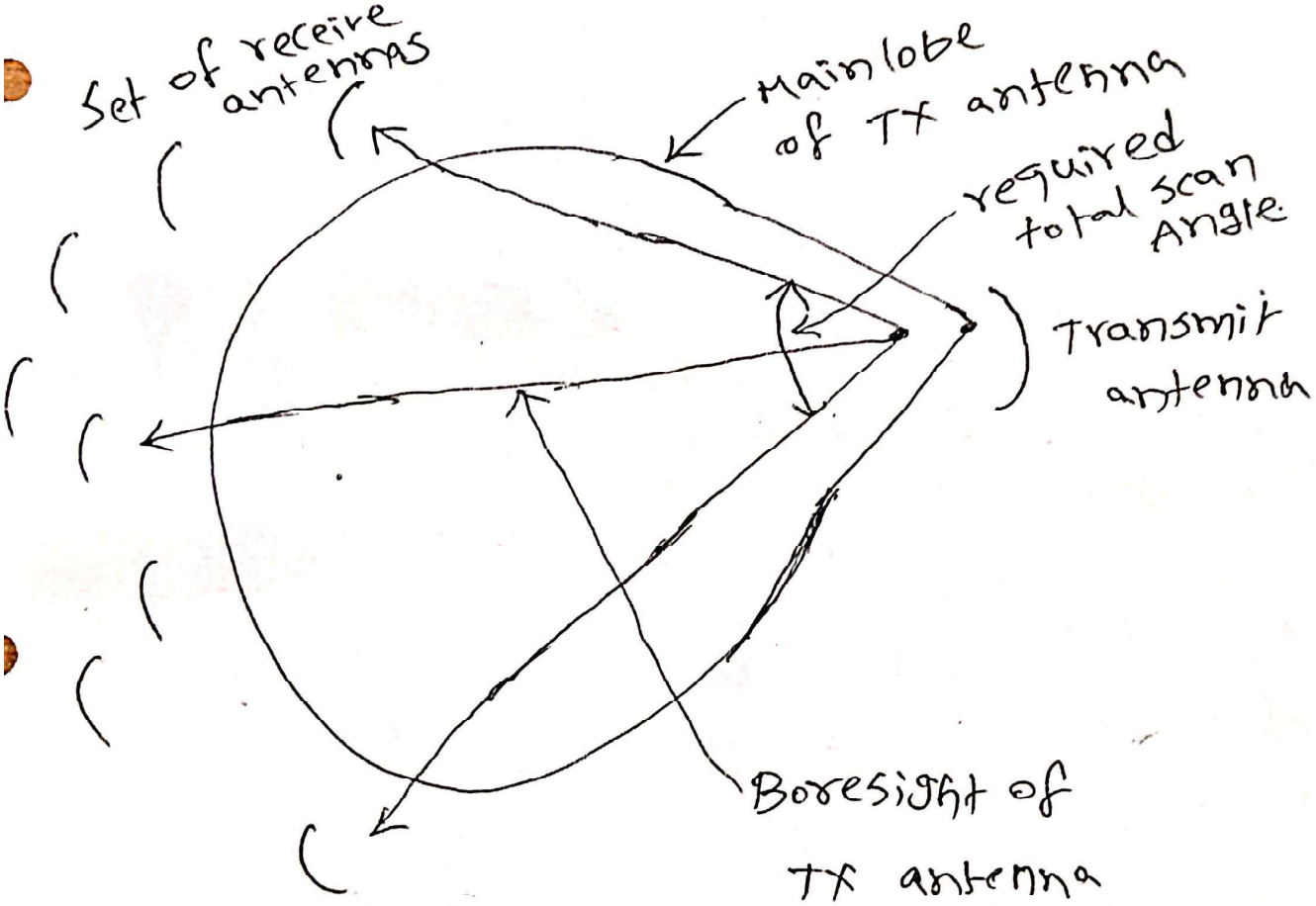
→ In fig(2), i.e Direct radiating array:

* The phase and amplitude are controlled by the direct radiating device at the end of the feed line.

* The amplitude is controlled by gain of radiating amplifier (G) and phase, ϕ, can either be controlled within the amplifier unit itself or by a phase element associated with the radiating device.



fig(1): Point-to-point LOS terrestrial communication link.



fig(2): Point-to-multipoint communication.

→ In fig(1), the TX antenna illuminates the receive antenna along it's electrical boresight, providing the max gain for the link.

→ The receive antenna has it's electrical boresight directed toward the tx antenna. The TX and RX antennas gains are therefore maximized.

→ In fig(2), a Pt-to-multi point system, the transmit antenna has to cover a number of receive antenna spread over a large total scan angle.

→ This system use a single wide angle ~~beam~~ beam to cover the receive antennas.

orbit	LEO		MEO		GEO
orbital height	750 km	1860 km	10000 km	14000 km	35786 km
scan Angle	57.2°	47.1°	21.5°	17.1°	8.25°

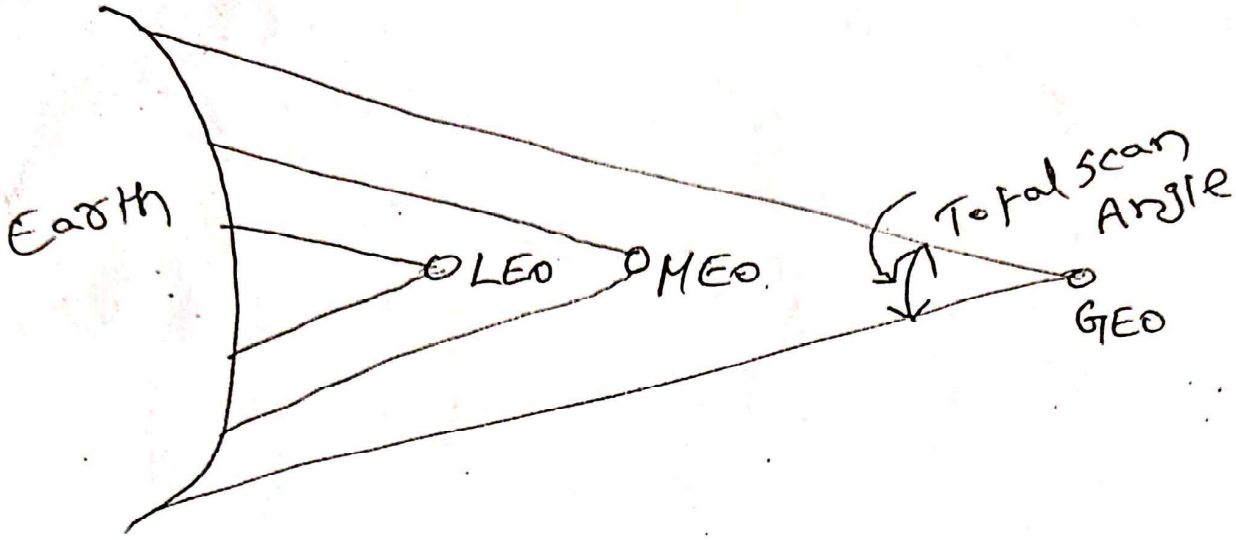
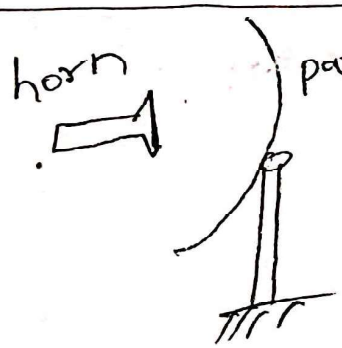


fig: Schematic of the total scan angles for LEO, MEO & GEO

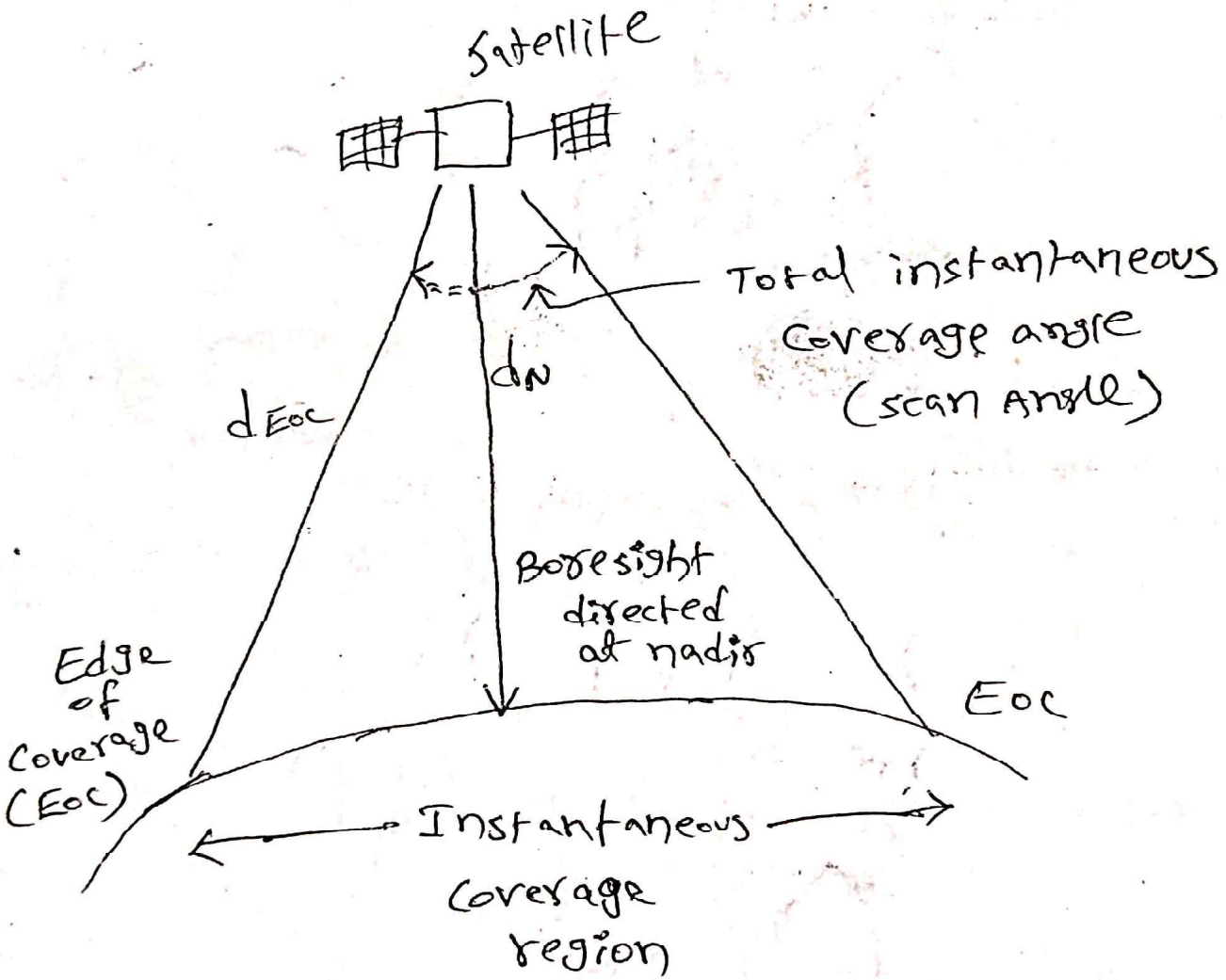


If feed horn is moved away from focus, then the plane wave that is present at aperture of antenna becomes distorted: This effect is called ~~Coma~~ "Coma"

→ The phase of signal in the radiating elements determines the steering

of the beam; it is usual to have the main beam Axis directed at nadir.

→ This will lead to the 'edge-of-coverage users" suffering two loss components that are larger than a signal transmitted in the nadir direction.



Phased array scan Angle

UNIT II

SATELLITE SUBSYSTEMS:

- Attitude and Orbit Control System (AOCS),
- Telemetry, Tracking, Command and Monitoring (TTC&M),
- Power system,
- Communication subsystems,
- Description of the communications systems,
- Transponders,
- Satellite antennas
- Basic antenna types and relationships,
- Equipment reliability and space qualification and Redundancy.

UNIT: II

Satellite Subsystems

→ The major subsystems required on the satellite are

1. Attitude and orbit control system (AOCS)
2. Telemetry, Tracking, command and monitoring (TTC&M system)
3. Power system
4. communications subsystems
5. satellite antennas (W, H, R, A)

① Attitude and orbit control system (AOCS):

→ The attitude of a satellite is it's position in the space, and it's orientation ~~towards Earth station~~. [i.e in which direction satellite is seeing].

→ This subsystem i.e AOCS consists of rocket motors that are used to move the satellite back to the correct orbit when external forces cause it to drift off station and gas jets or inertial devices that control the attitude of a satellite.

→ The attitude and orbit of a satellite must be controlled so that the satellite's antennas point toward the earth and so that the user knows where in the sky to look for the satellite.

- Some forces acting on an orbiting satellite that tend to change it's attitude and orbit are
  - Gravitational fields of the sun and moon
  - Irregularities in the earth's gravitational field
  - Solar pressure from the sun
  - Variations in the earth's magnetic field.

→ Gravitational fields from the sun and moon cause the orbit of a GEO satellite to change with time.

→ At GEO orbit altitude, the moon's gravitational force is twice to the gravitational force of sun.

→ The moon's orbit is inclined to the equatorial plane by approximately 5°

→ The plane of earth's rotation around the sun is inclined by 23° to the earth's equatorial plane.

→ The orbital control system of the satellite must be ~~also~~ able to move the satellite back into the equatorial plane before the orbital inclination becomes excessive.

→ LEO satellites are less effected by gravitational fields of the sun and the moon, since they are closer to earth than GEO satellite.

→ Earth, not a perfect sphere. At the equator, there are bulges of about 65 m at longitudes 162° E and 348° E. Then the satellite is accelerated towards one of two ~~stable~~ stable points in the GEO orbit at longitudes 75° E and 252° E.

→ To maintain accurate station keeping, the satellite must be periodically accelerated in the opposite direction to the forces acting on it

→ This is done by station keeping maneuvers, using small rocket motors (called gas jets or thrusters) that can be controlled from the earth via TTC & M system.

~~Attitude control system~~:

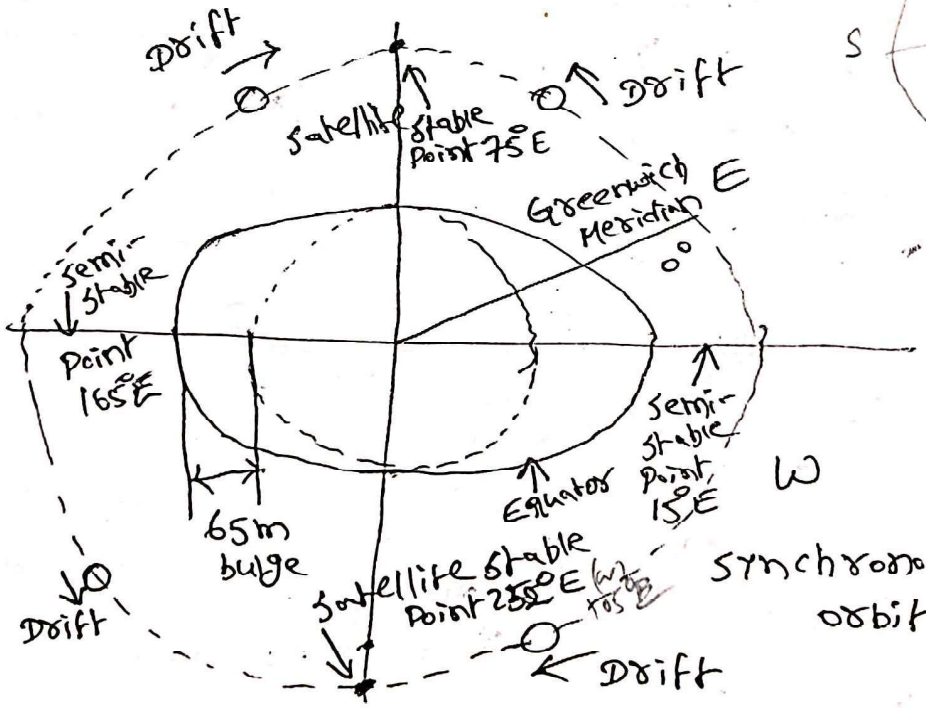


fig: Forces on a synchronous satellite.

Attitude control system:

→ There are two ways to make a satellite stable when it is in orbit and weightless

① Spinning the satellite (i.e spin stabilization)

① Using momentum wheels

(i.e 3-axis stabilization)

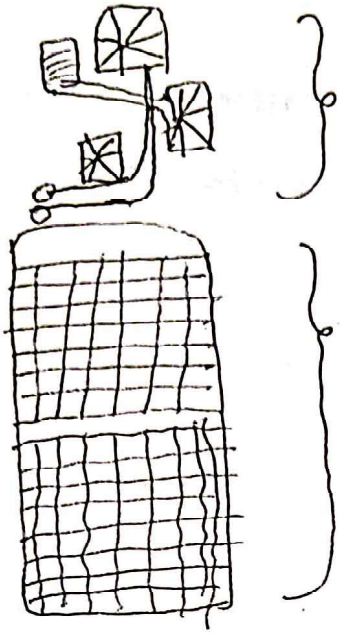
① Spin stabilization:

→ The entire body of the satellite can be rotated at a rate 30 to 100 rpm, to create gyroscopic force that provides stability of the spin axis and keeps it pointing in the same direction. Such satellites are called spinners. Example is Hughes 376 (Now Boing 376)

→ As shown in the following figure spinner satellite (i.e the spinner) consists of a cylindrical drum covered with solar cells that contains the power systems and the rocket motors. The communication system is ~~mounted~~ mounted at the top of the drum and is driven by an electric motor in the opposite direction to the rotation of the satellite body to ~~keep~~ keep the antennas pointing toward the earth.

1. It is a device used for measuring or maintaining orientation & angular velocity. It is a spinning wheel on which the axis of rotation (spin axis)

→ Such satellites are called ~~despun~~ despun



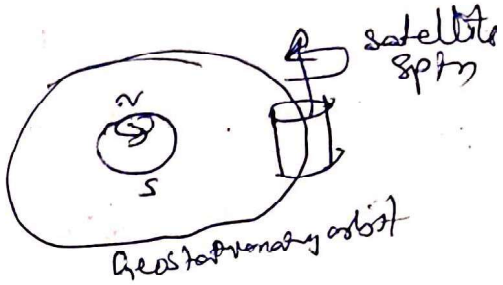


fig (a) spinner satellite

→ At the appropriate point in the launch phase, the satellite is ~~spo~~ spun up by operating small radial gasjets on the periphery of the drum.

→ Then the despin system operates so that the main TTC & M antenna could point toward the earth.

② 3-Axis stabilization satellite (using Momentum wheels)

→ A satellite can be stabilized by one or more momentum wheels.

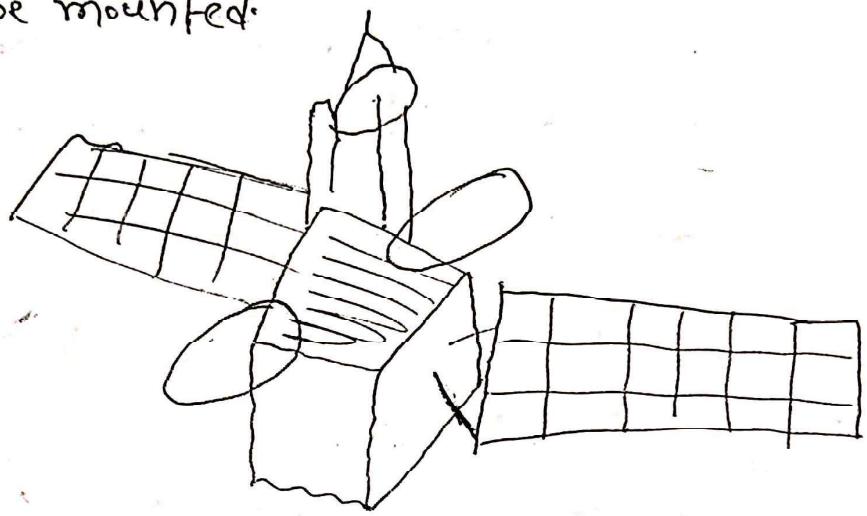
→ This is called three axis stabilized satellite.

→ Example is Hughes (Boeing) 701 series

→ The momentum ~~disc~~ wheel is usually a solid metal disk driven by an electric motor.

→ Either there must be one momentum wheel for each of the three axis of the satellite, or a single momentum wheel can be mounted.

→ Generally for each satellite axis, one wheel will be mounted.



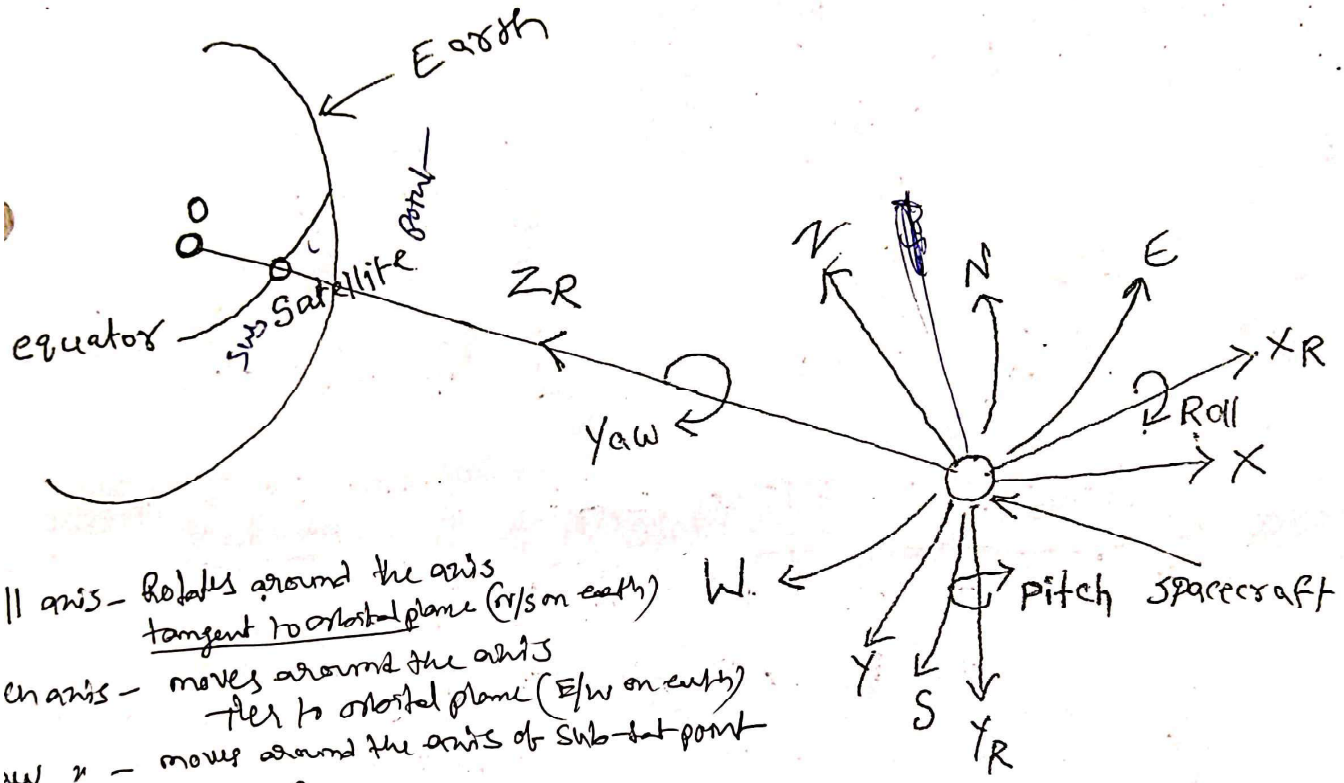
fig(b): 3-Axis stabilized satellite.

→ In 3-Axis stabilized satellite, one pair of jets is needed for each axis to provide for rotation in both directions of pitch, roll and yaw. with 3-momentum wheels, rotation of the satellite about each axis can be commanded from the earth station by increasing or decreasing the appropriate speed of momentum wheel, which is called 3-axis stabilization.

→ An additional set of controls, allowing only one jet on a given axis to be operated, provides velocity increments in x, y and z directions.

→ When motion is required along a given axis, the appropriate gas jet is operated for a specified period of time to achieve the desired velocity.

→ There are two types of rocket motors used on the satellites: The bipropellant thruster and arc jets (or) ion thrusters.

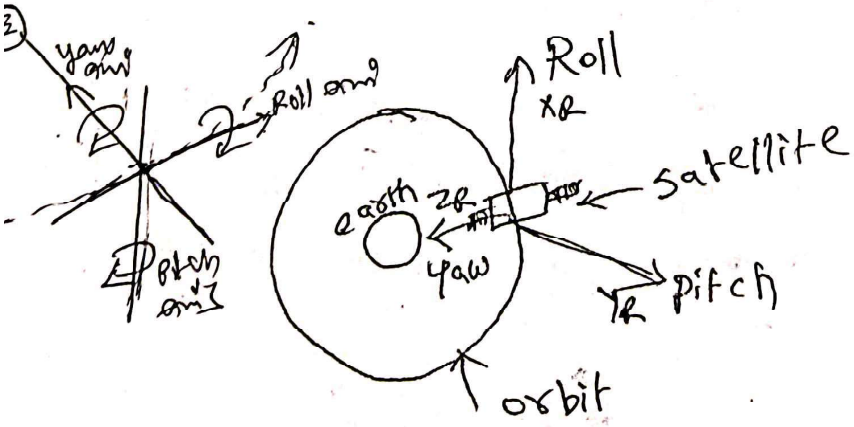


ll axis – Rotates around the axis tangent to orbital plane (N/S on earth)

ch axis – moves around the axis ⊥ to orbital plane (E/W on earth)

aw " – moves around the axis of sub-sat point

fig (a) (Forces on satellite)



Yaw → Z_R → towards center of earth & lies in orbital plane

Roll – X_R – ⊥ to Z_R & lies in orbital plane

pitch – Y_R → ⊥ to "

X_R, Y_R, Z_R → ref. cartesian axis with sat at origin w.r.to local of sat

X, Y, Z → ref. axis w.r.to orientation of sat

pitch axis is normal to orbital plane

roll " perpendicular to the other two, i.e tangential to the orbit & lies along the satellite velocity vector.

→ Define a set of reference cartesian axes (X_R, Y_R, Z_R) with the satellite at the origin as shown in the above figure.

→ X_R, Y_R, Z_R are the reference axis with respect to the location of the satellite.

→ X, Y, Z are the reference axis with respect to the orientation of the satellite.

→ The Z_R axis is directed toward the center of the earth and lies in the orbital plane.

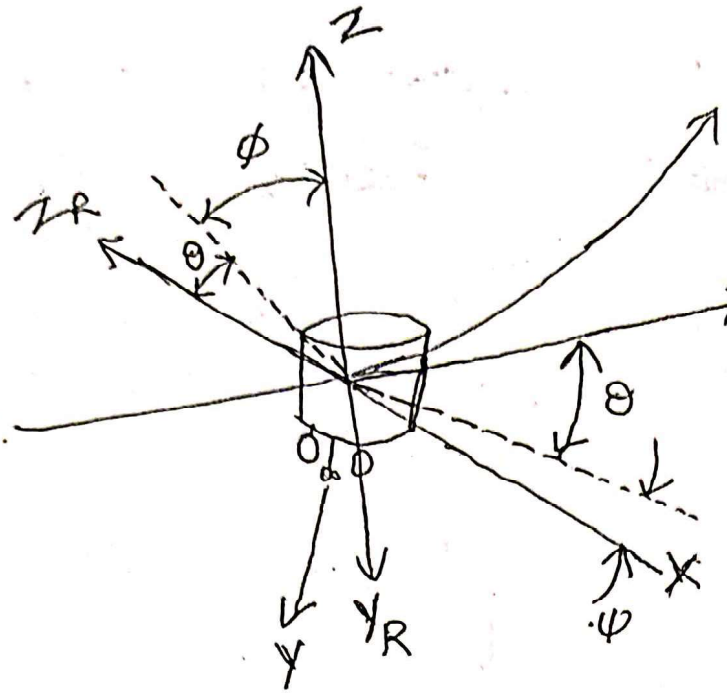
→ X_R axis is perpendicular to the Z_R axis and lies in the orbital plane.

→ Y_R axis is perpendicular to the orbital plane.

→ The set X_R, Y_R, Z_R are defined with respect to location of the satellite.

→ X, R, Z are the second set of cartesian axes and these are ~~defined~~ defined the orientation of satellite.

→ The satellite must be stabilized with respect to the reference axis to maintain accurate pointing of it's antenna beams.



If attitude changes, then θ, ϕ and ψ changes, Hence variation in attitude can be determined

fig(b): Relationship between axes of a satellite.

→ Changes in the satellite's attitude cause the angles θ, ϕ, and ψ in the above figure to vary as the X, Y, and Z axes move relative to the fixed reference axes X_R, Y_R and Z_R.

→ When large narrow beam antennas are used, the satellite may have to be stabilized within $\pm 0.1^\circ$ on earth axis.

→ The reference for the attitude control system may be the outer edge of earth's disk, as observed with infrared sensors on the spinning body of a satellite can be used to N-S control in pointing toward the earth ~~sensor~~ as shown in below diagram.

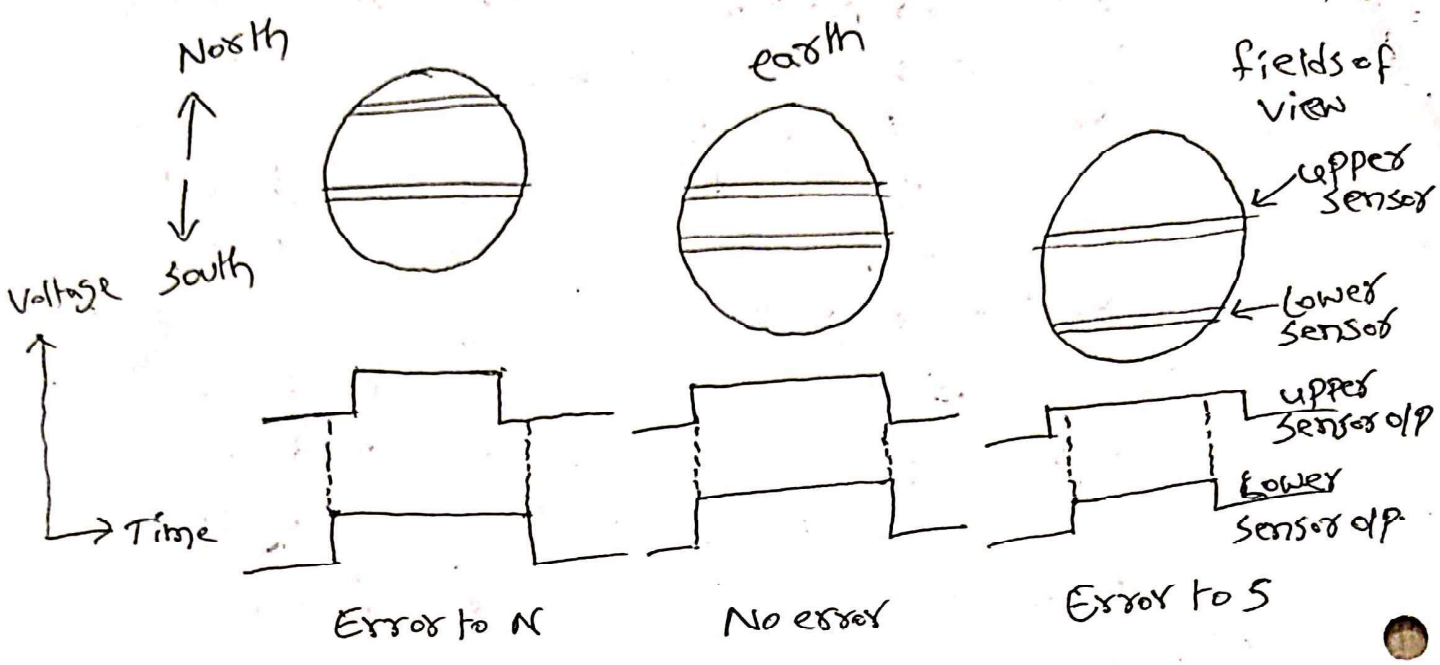


fig: principle of N-S control of a spinner satellite using Infrared earth sensors.

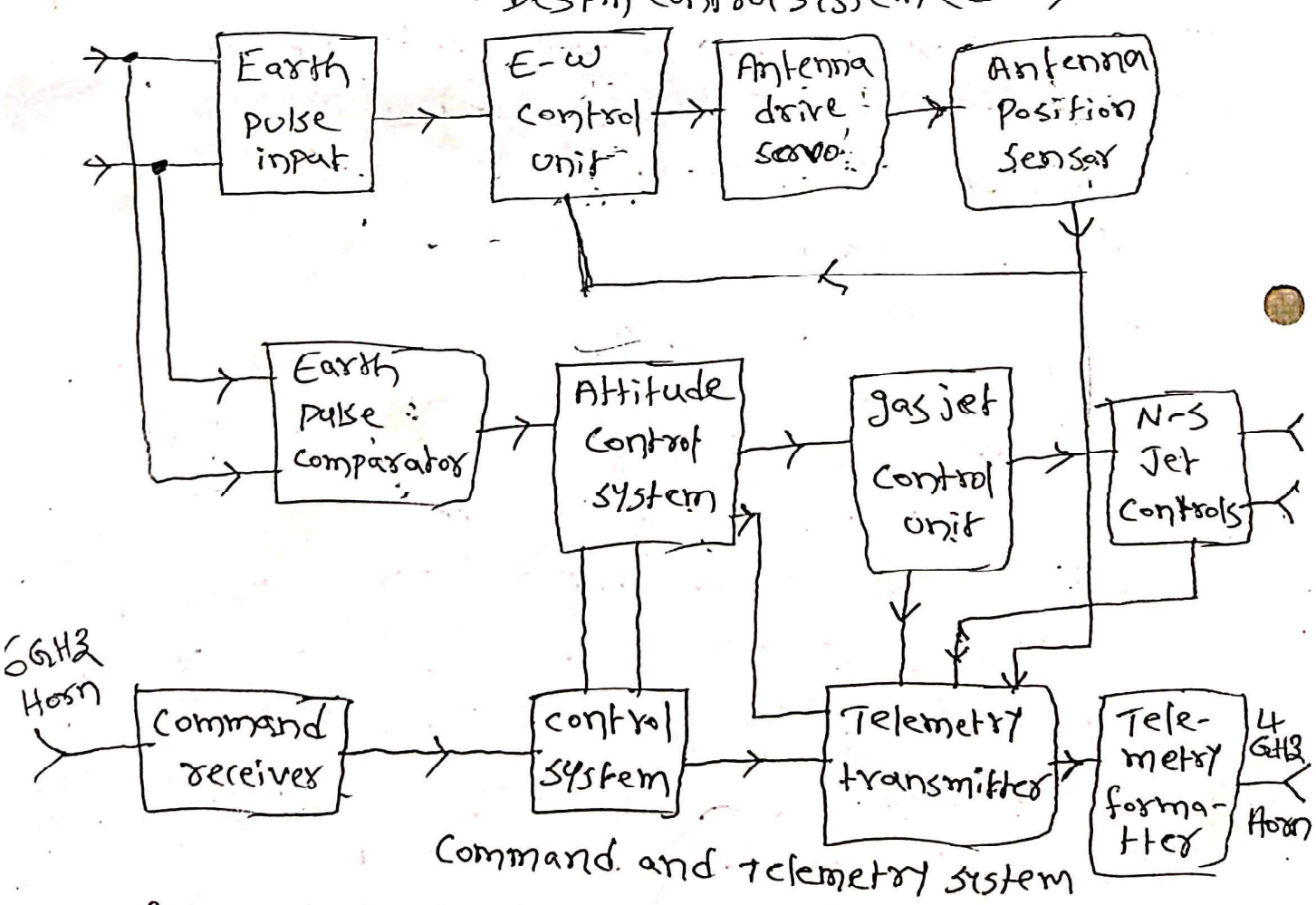


fig: TYPical onboard sat control system for a spinner satellite.

→ As shown in the above figure, in an on-board control system, an E-W control unit [ECU] executes various control operations in response to supply power voltage from a battery.

→ A switch i/p circuit called earth pulse i/p samples the ON/OFF states of external switches periodically under control of a micro computer

→ The EPC [Earth Pulse comparator] controls the momentum of space craft, so that it does not exceeds upper limit and lower limit. The gas jets are usually used to control the altitude of the satellite

→ The N-S Jet control unit is used to have a control over satellite, so that it correctly points towards the earthstation.

→ The telemetry system collects the data from many sensors on the satellite through the telemetry link to monitor and control the satellitels health.

Orbital control system:

→ A geostationary orbit must be circular at a correct altitude on the equatorial plane.

→ If the orbit is not circular, velocity change is to be made along the orbit. For altitude correction, Z-axis gas Jet is used.

→ Various forces acting on the satellite will pull the satellite out of the correct orbit

→ The function of orbit control system is to return the satellite into the correct orbit.

→ Some forces acting on a GEO satellite are

- The gravitation forces of moon and sun, which cause inclination of orbital plane.
- Non spherical shape of earth around the equator, which causes drift of the subsatellite point.

→ Because of these forces, satellite will deviate from the correct orbit. Then orbit control system has to put the satellite in the correct orbit.

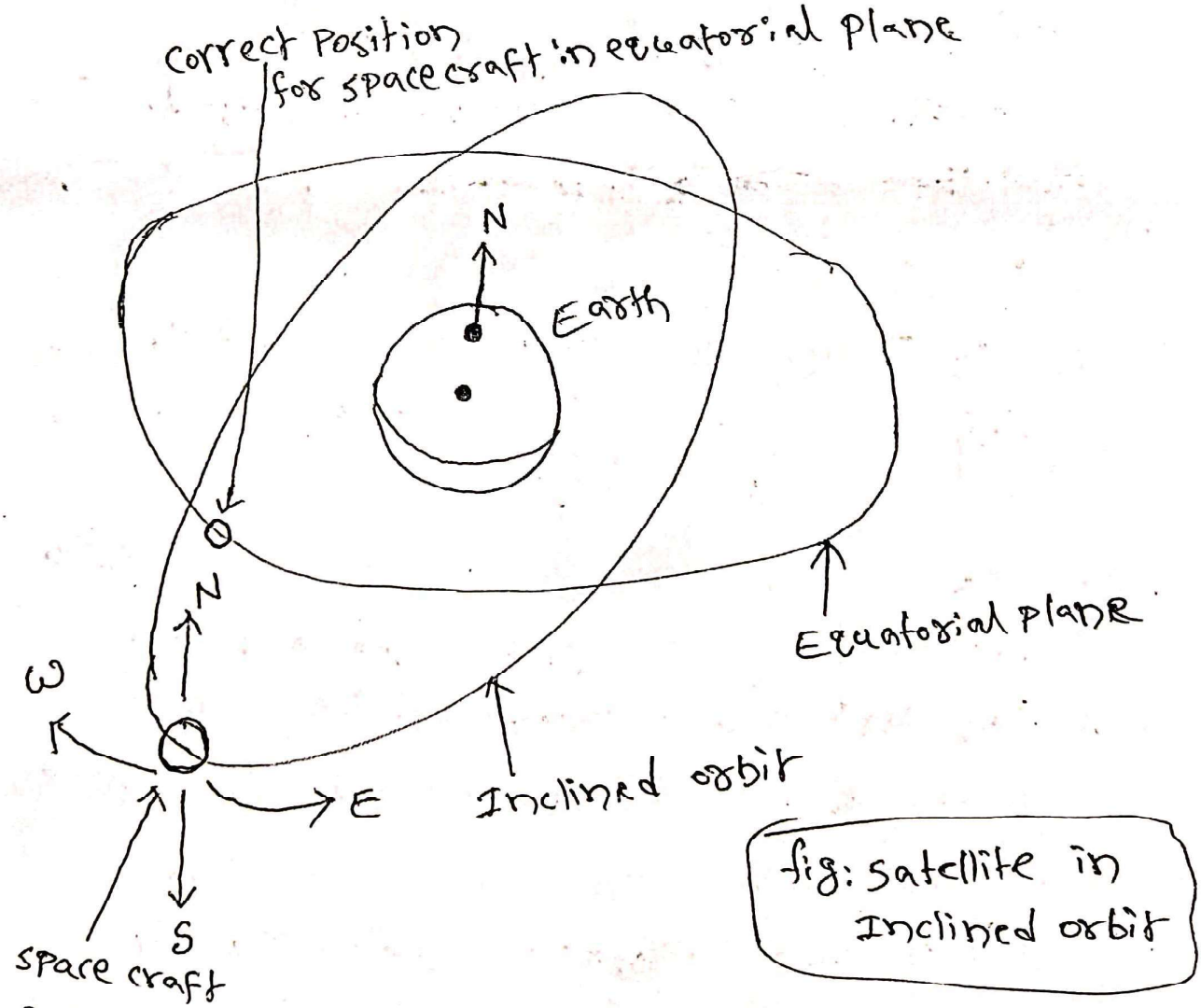


fig: satellite in Inclined orbit

→ Inclination of an orbit increases at about 0.85° per year

→ The above figure shows the diagram of an inclined orbital plane close to the geostationary orbit.

→ Most GEO satellites are specified to remain within a box of ±0.05°, and so in practice, corrections called a north-south station keeping maneuvers are made every 2 to 4 weeks to keep the error small.

→ It has become normal to split the E-W and N-S maneuvers, so that at intervals of 2 weeks the E-W corrections are made first and then after 2 more weeks, the N-S corrections are made.

→ correcting the inclination of the satellite orbit requires more fuel to be expended than for any other orbital correction

→ East-west station keeping is effected by the use of the x-axis jets of the satellite.

→ East-west station keeping requires only a modest amount of fuel and it is necessary on all geostationary communications satellites to maintain the spacing between adjacent satellites.

→ LEO and MEO satellites also need AOC system to maintain the correct orbit and attitude for continuous communication

TTC & M [Telemetry, Tracking, Command and Monitoring System]

→ TTC & M system is essential to the successful operation of communications satellite.

→ TTC & M earth station may be owned and operated by the satellite owner, or it may be owned by a third party and provide TTC & M services under contract.

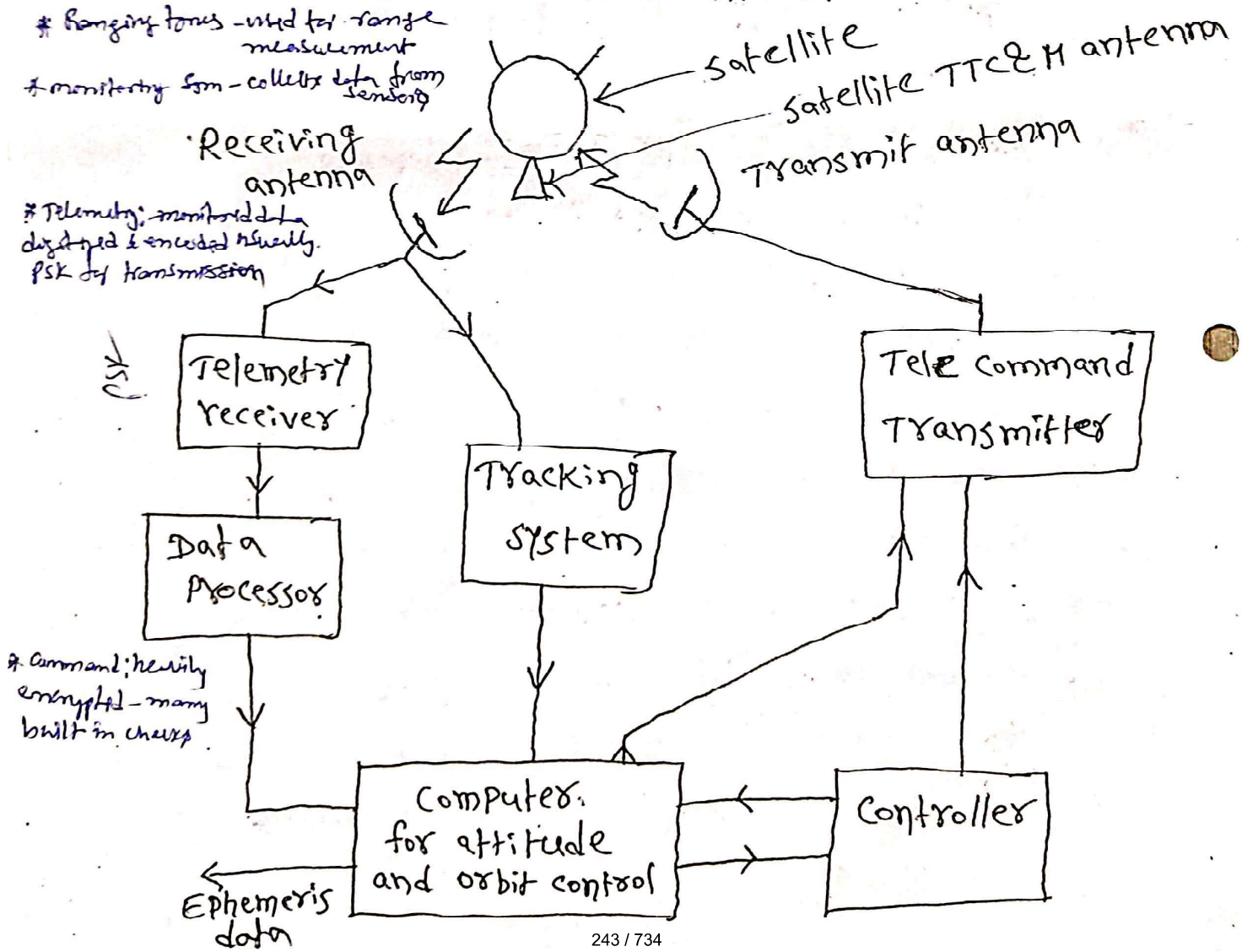


fig: Typical tracking, telemetry, command and monitoring system.

Telemetry and Monitoring System:

→ The monitoring system collects data from many sensors with in the satellite and sends these data to the controlling earth station.

→ There may be several hundred sensors located on the satellite to monitor pressure in the fuel tanks, voltage and current in the power conditioning unit, current drawn by each subsystem, and critical voltages and currents in the communications electronics. To maintain temperature of subsystems to be in a predetermined limit, temperature sensors are used.

→ The sensor data, the status of each subsystem, and the positions of switches in the communication system are reported back to the earth by the telemetry system.

→ Telemetry data are usually digitized and transmitted as phase shift keying (PSK) of a low power telemetry carrier using time division techniques.

→ A low data rate is normally used to allow the receiver at the earth station to have a narrow bandwidth and thus maintain a high carrier to noise ratio.

→ At the controlling earth station, a computer can be used to monitor, store and decode the telemetry data so that the status of any system (or) sensor on the satellite can be determined immediately by the controller on the earth.

→ Alarms can also be sounded if any ~~vital~~ vital parameter goes outside allowable limits.

Tracking:

→ A number of techniques can be used to determine the current orbit of a satellite.

→ Velocity and acceleration sensors on the satellite can be used to establish the change in orbit from the last known position, by integration of the data.

→ To determine the orbital elements, the following parameters are used.

① Accurate angular measurements from the earth station antenna.

② Range.

→ Active determination of range can be achieved by transmitting a pulse, or sequence of pulses, to the satellite and observing the time delay before the pulse is received again.

→ The propagation delay in the satellite transponder must be accurately known, and more than one earth station may make range measurements.

→ If a sufficient number of earth stations with an adequate seperation are observing the satellite, it's position can be established by triangulation from the earth station by simultaneous range measurements.

→ with precision equipment at the earth stations, the position of the satellite can be determined with in 10 min

→ Ranging tones are used for range measurement.

Command:

→ A secure and effective command structure is required for the successful launch and operation of any communications satellite.

→ The command system is used to make changes in attitude and corrections to the orbit and to control communication system.

→ During launch command system is used to

(i) control the firing of AKM (Apogee Kick Motor)

(ii) to spin up a spinner

(iii) to extend the solar sails and antennas of a 3-Axis stabilized satellite.

→ The command structure must ~~Possesses~~ Possess safeguards against unauthorized attempts to make changes to the satellite's operation, and also against inadvertent operation of a control due error in a received command.

→ Encryption of commands and responses is used to Provide security in the command system.

→ As shown in figure, the system will originate commands at the control terminal of the computer

→ The control code is converted into a command word, which is sent in a TDM frame, to the satellite

→ After checking ~~the~~ for validity in the satellite, the word is sent back to the control station via the telemetry link, where it is checked again in the computer

→ If it is found to have been received correctly, an execute instruction will be sent to the satellite so that the command is executed. This entire process may take 5 or 10 sec, but minimizes the risk of erroneous commands causing a satellite malfunction.

Power Systems: (Sun is a powerful source of energy)

→ All communications satellites obtain their electrical power from solar cells, which convert incident sunlight into electrical energy.

→ Solar cells do not convert all this incident energy into electrical power: Their efficiency is typically 20 to 25% at begining of life (BOL), but falls with time because of aging of the cells, and etching of the surface by micrometeor impacts.

→ A spin stabilized satellite usually has a cylindrical body covered in solar cells. Because the solar cells are on a cylindrical surface, half of the cells are not illuminated at all, and at the edges of the illuminated half, the low angle of incidence results in little electrical power being generated.

→ A three axis stabilized satellite can make better use of its solar cell area, since the cells can be arranged on flat panels that can be rotated to maintain normal incidence of the sunlight. So more electrical power is generated in 3-Axis stabilized satellite when compare to spinner satellite.

→ A satellite must carry batteries to power the subsystems during launch and during eclipses.

→ Eclipses occur twice per year, around the spring and fall equinoxes, when the earth's shadow passes across the satellite

→ The longest duration of eclipse is 70 min, occuring around March 21 and September 21 each year.

→ To avoid the need for large, heavy batteries, part or all of the communications system load may be shutdown during eclipse, but this technique is rarely used when telephony or data traffic is carried.

→ Batteries are usually of the nickel-hydrogen type which do not gas when charging and have good reliability and long life, and can be safely discharged to 70% of their capacity.

→ A Power conditioning unit controls the charging current and dumps excess current from the solar cells into heaters (or) load resistors on the cold side of the satellite.

communications subsystems:

→ Since ~~this is the~~ the communications system earns the revenue for the system operator, these satellites are designed to provide the largest traffic capacity.

→ communications satellites are used for relaying voice, video and data communication

→ the satellite transponders have limited o/p power and earth stations are atleast 36,000 Km away from a GEO satellite. so the received power level, even with large aperture earth station antennas, is very small and rarely exceeds 10^{-10} w.

→ For the system to perform satisfactorily, the signal power must exceed the power of the noise generated in the receiver by between 5 and 25 dB. with low power transmitters, narrow receiver band widths have to be used to maintain the required signal to noise ratio's.

→ the frequency bands currently used for satellite services are

- c band (6/4 GHz)
- Ku band (14/11 GHz)
- Ka band (30/20 GHz)

Transponders:

→ Signals (known as carriers) transmitted by an earth station are received at the satellite by either a zone beam (or) a spot beam antenna.

→ Zone beams can receive from transmitters any where within the coverage zone, whereas spot beams have limited coverage.

→ The bands currently used for the majority of services are 6/4 GHz, 14/11 GHz and 30/20 GHz coming into service.

→ The below diagram shows a simplified block-diagram of a satellite communication subsystem for the 6/4 GHz band.

→ The 500 MHz bandwidth is devided up into channels, often 36 MHz wide, which are each handled by a seperate transponder.

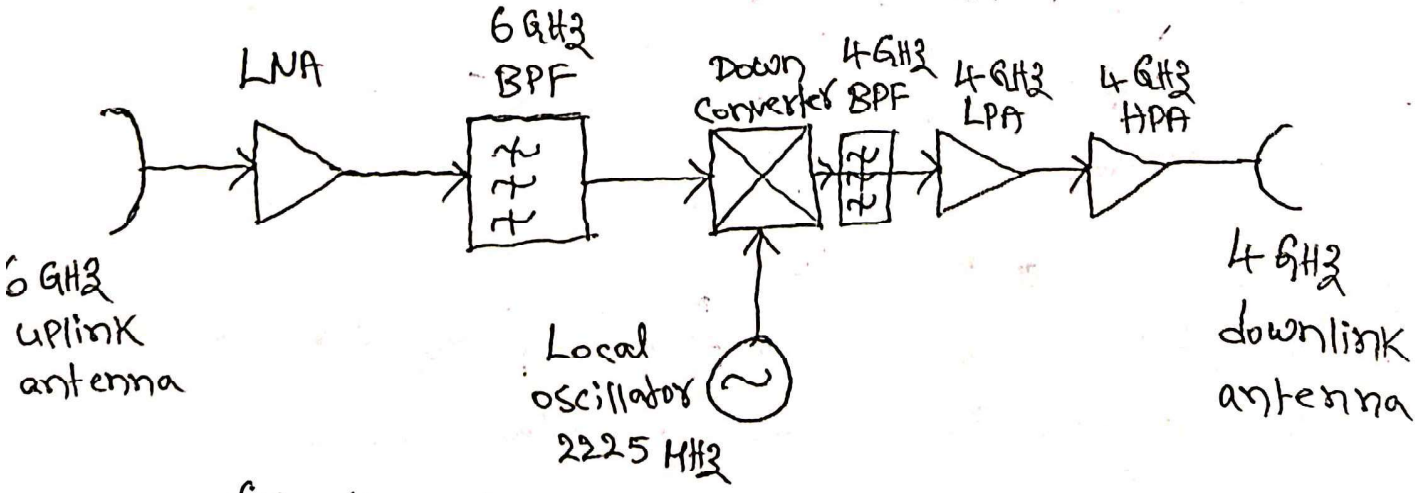


fig: Simplified single conversion transponder (bent pipe) for 6/4 GHz band.

→ A Transponder consists of a Band Pass Filter (BPF) to select the particular channel's band of frequencies, a down converter to change the frequency from 6 GHz at the input to 4 GHz at the output, and an output amplifier

→ The output Power amplifier is usually a solid state Power amplifier (SSPA). And if very high output Power (>50 w) is required, then travelling wave tube amplifier (TWTA) is used as a output Power amplifier.

→ The Local oscillator is at 2225 MHz. to provide the appropriate shift in frequency from 6 GHz uplink frequency to the 4 GHz downlink frequency

→ A BPF after the mixer removes unwanted frequencies resulting from the down conversion operation.

→ The attenuator can be controlled via the uplink command system to set the gain of the transponder

→ Redundancy is provided for the high Power amplifiers (HPA) in each transponder by including a spare TWT or SSPA that can be switched into circuit if the primary Power amplifier fails.

→ The communication system has many transponders, some of which may be spares; typically 12 to 44 active transponders are carried by a high capacity satellite.

→ Many domestic satellites operating in the 6/4 GHz band carry 24 active transponders.

→ When more than one signal shares a transponder (using FDMA) the power amplifier must be run below it's maximum output power to maintain linearity and reduce intermodulation products.

→ The degree to which the transmitter o/p power is reduced below it's peak output is called "output backoff"

→ Transponders for use in 14/11 GHz bands normally employ a double frequency conversion

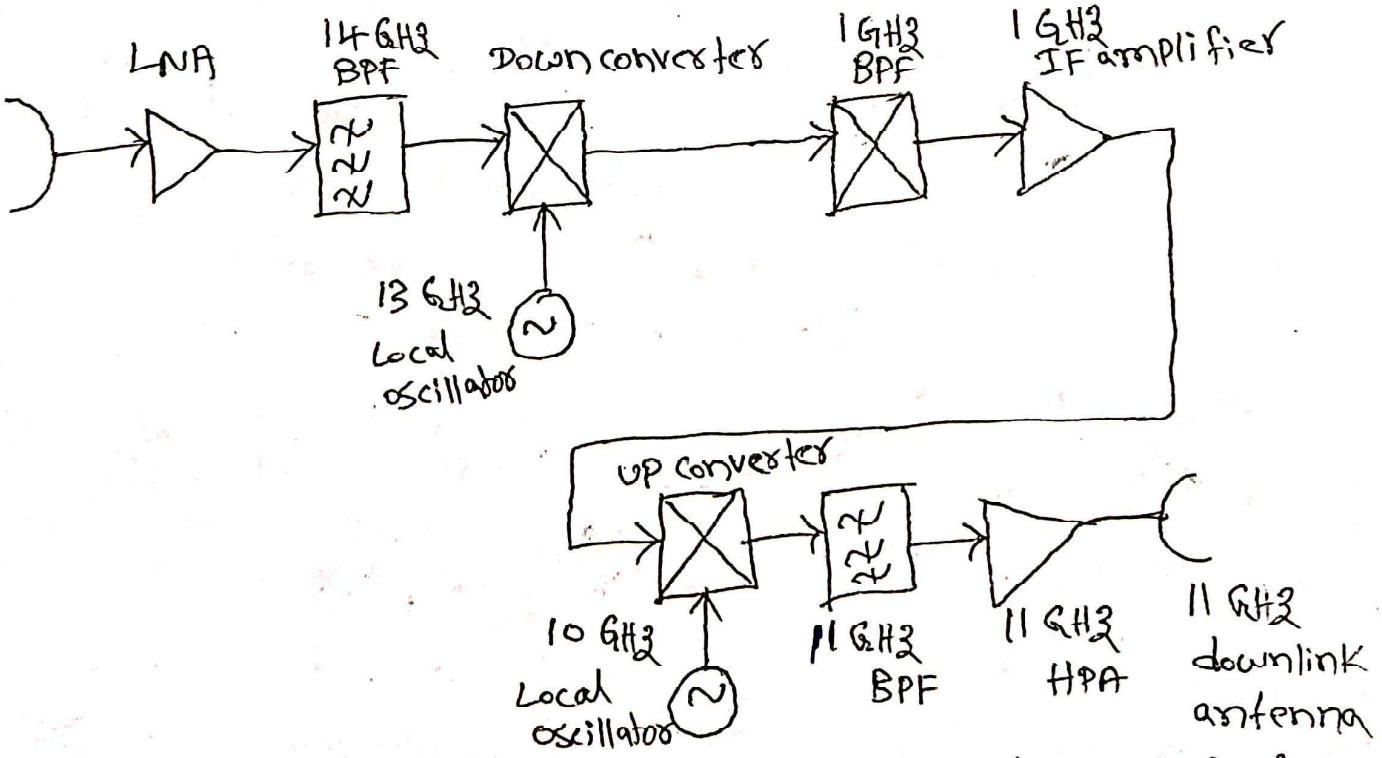


Fig: Simplified double conversion transponder (bent pipe) for 14/11 GHz band.

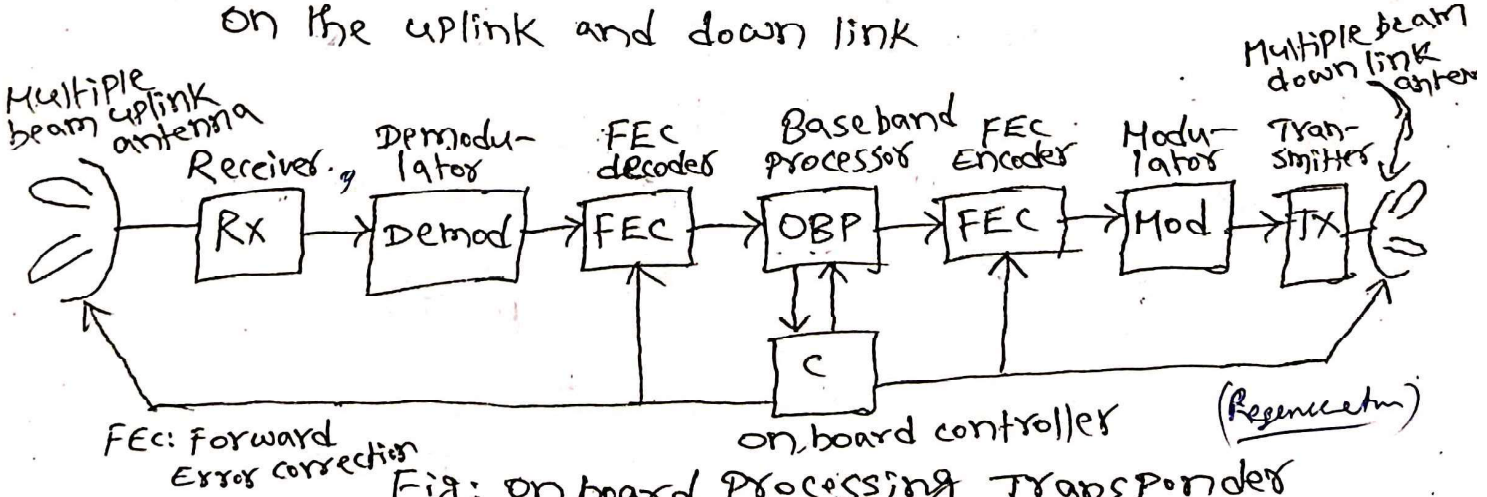
→ It is easier to make filters, amplifiers and equalizers at an Intermediate Frequency (IF) such as 1100 MHz, than at 14 or 11 GHz.

→ So the incoming 14 GHz carrier is translated to an IF of around 1 GHz.

→ The amplification and filtering are performed at 1 GHz and then high level carrier is translated back to 11 GHz for amplification by HPA.

→ On board processing may also be used to advantage to switch between the uplink access technique (ex: MF-TDMA i.e Multi-frequency TDMA) and downlink access technique (ex: TDM) so that the small earth stations may access each other directly via the satellite.

→ The processor can provide the data storage needed for a switched-beam system and also can perform error correction independently on the uplink and down link



Fig; on board Processing Transponder

Satellite Antennas:

Four main types of antennas are used on satellites. These are

① wire antennas : Monopoles and dipoles.

② Horn antennas

③ Reflector antennas

④ Array antennas.

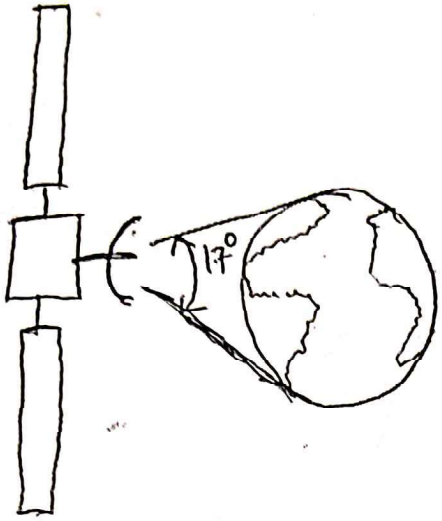
→ wire antennas are used primarily at VHf and UHf to provide communications for the TTC&M systems. They are positioned with great care on the body of the satellite in an attempt to provide omnidirectional coverage

→ An 'antenna pattern' is a plot of field strength in the far field of the antenna, when the antenna is driven by a transmitter.

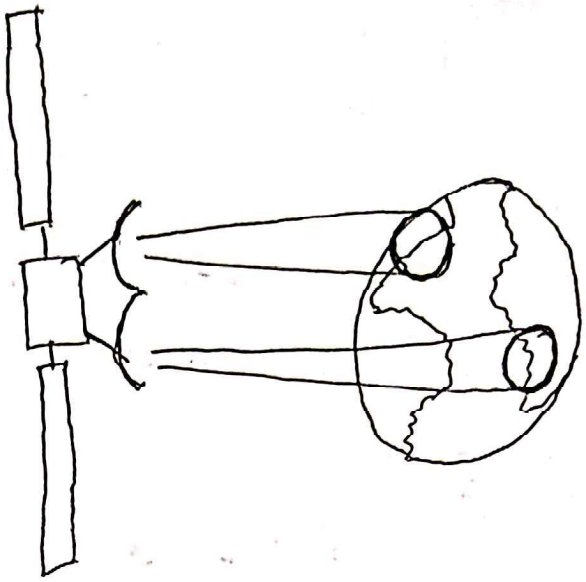
→ The gain of an antenna is a measure of the antennals capability to direct energy in one direction, rather than all around.

→ Reciprocity means that an antenna has the same gain and pattern at any given frequency whether it transmits or receives.

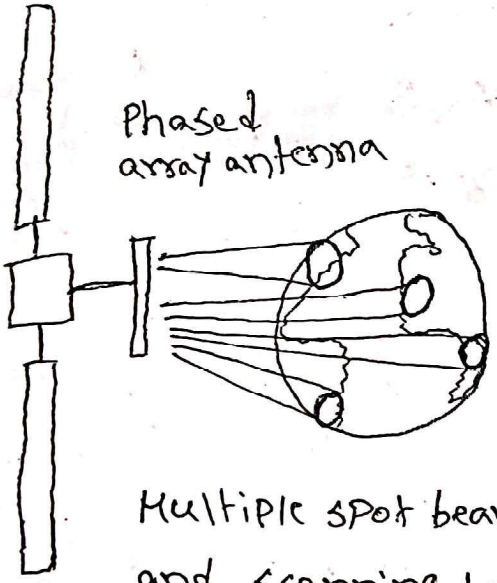
→ Below figures shows the typical satellite antenna coverage zones.



Global beam
[Horn antenna]

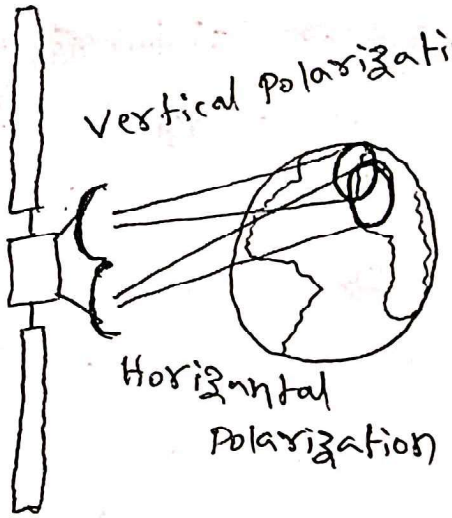


Spot beams
[Reflector Antennas]



Phased array antenna

Multiple spot beams and scanning beams.



orthogonally Polarized beams.

fig; Typical satellite antenna patterns and coverage zones.

→ The pattern is usually frequently specified by it's 3-db beamwidth

→ 3 db beamwidth is the angle between the directions in which the radiated (or received) field falls to half the power in the direction of maximum field strength.

→ A satellite antenna is used to provide coverage of a certain area, or zone on the earth's surface.

Horn Antenna:

→ Horn antennas are used for ~~wide coverage~~ global coverage.

→ The antenna for the global beam is usually a waveguide horn

→ Horn antennas are used at microwave frequencies when relatively wide beams are required, as for global coverage. But it is difficult to obtain gains much greater than 23 db (or) beamwidths narrow than about 10° with horn antennas.

→ A horn antenna is a flared section of waveguide.

→ Horns are also used for feeds for reflectors.

→ Horns and reflectors are examples for aperture antennas, that launch a wave into free space from a waveguide.

Reflector Antennas:

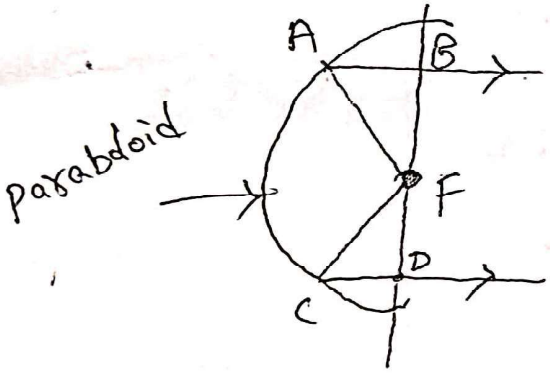
→ for higher gains (or) narrow beamwidths a reflector antenna (or) array must be used.

→ Reflector antennas are illuminated by horns.

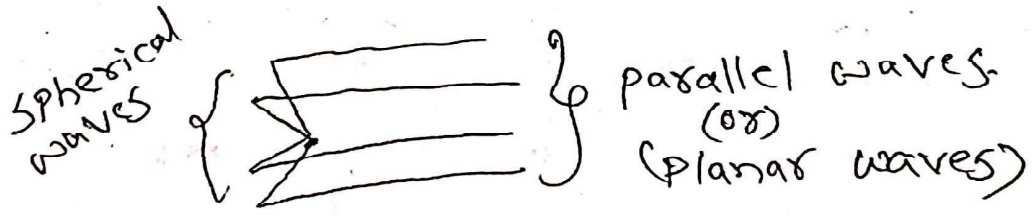
→ Reflector antennas provide larger aperture when compare to a horn antenna ~~also~~ alone.

→ For maximum gain, it is necessary to generate a plane wave in the aperture of the reflector. This is achieved by choosing a reflector profile that has equal path lengths from the feed to the aperture, so that all the energy radiated by the feed and reflected by the reflector reaches the aperture with the same phase angle and creates uniform phase front.

→ one example for this is a paraboloid, with a feed placed at it's focus.



$FA + AB = FC + CD$



→ so a horn antenna converts a spherical waves in to planar waves

→ Generally paraboloids are used in Earth station But For satellite, modified paraboloid reflector is used for perticular coverage zone.

08734

Phased Array antennas:

→ Scanning beams and shaped beams require Phased array antennas (or) reflector antennas with Phased array feeds.

→ Phased array antennas are also used on Satellites to create multiple beams from a single aperture.

→ Phased array antennas are used by Iridium or Global star to generate upto 16 beams from a single aperture.

→ The following approximate relationships (formulas) will be used to guide selection of antenna for a communication satellite

→ Aperture antenna gain (G)

$$G = \eta_A \frac{4\pi A}{d^2}$$

where η_A : Aperture efficiency

A : Area of antenna aperture. (m^2)

d : operating wavelength (m)

→ If the aperture is circular, then

$$G = \eta_A \left(\frac{\pi D}{d}\right)^2$$

where D: Diameter of circular aperture (m)

→ The 3 db beam width in a given plane, for an antenna with dimension D in that plane is

$$\theta_{3dB} \simeq \frac{75\lambda}{D} \text{ degrees}$$

where θ_{3dB} is the beamwidth between half power points of an antenna.

D = aperture dimension

→ For an antenna with aperture $\eta_A = 60\%$, then gain is approximately

$$G = 33{,}000 / (\theta_{3db})^2$$

Satellite antennas in practice:

→ In an ideal satellite, there would be one antenna beam for each earth station, completely isolated from all other beams, for transmit and receive.

→ However if two earth stations are 300 Km apart on the earth's surface and the

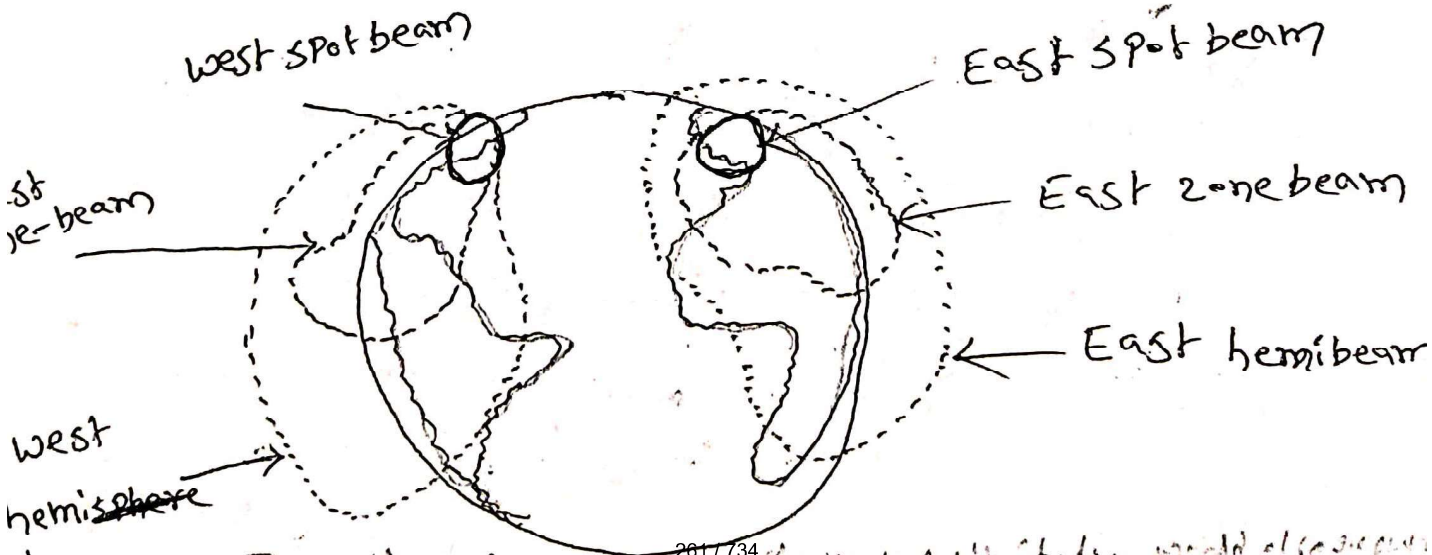
satellite is on the geostationary orbit, their angular seperation at the satellite is 0.5°.

For θ_{3dB} to be 0.5°, D/λ must be 150, which requires an aperture diameter of 11.3 m at 4 GHz.

⇒ Antennas of large dimensions (as mentioned above) have been used on some satellites

→ However at 20 GHz, an antenna with D/λ = 150, is only 1.5 m wide and such an antenna can readily be flown on a 30/20 GHz satellite.

→ The largest reflector on the satellite transmits at 4 GHz to produce "peanut" shaped patterns for the zone beams, which are designed to concentrate the transmitted energy onto densely populated areas like North America and western Europe where much telecommunications traffic is generated.



→ To provide a separate beam

→ Above figure shows the coverage zones provided by the typical Intelsat satellite.

Same beam to provide more channels per sat.

Equipment reliability and space qualification

→ ~~The satellite must have high reliability.~~

→ The components of a satellite must have high reliability.

Two approaches are used.

① Space qualification of every part of satellite to ensure that the satellite has a long life.

② Redundancy of most critical components to provide continued operation when one component fails.

Space qualification:

→ The First stage ~~in~~ for providing high reliability in a satellite is by selection and screening of every component used.

→ components are selected based on history.

→ only the components having high reliability under outer ~~space~~ space conditions will be selected.

⇒ Each component is tested individually. This process is called quality control or quality assurance.

→ once the individual components and subsystems have been space qualified, the complete satellite must be tested.

→ In a satellite design, 3 prototype models are built and Tested.

① Mechanical Model:

→ It contains all mechanical and structural parts in satellite.

→ It is tested to ensure that all the moving parts operates correctly in ~~vacuum~~ vacuum, over wide temperature range.

→ Vibrational & shock Testings are also done

② Thermal Model :-

→ It will include whether all electronic packages and other components must be maintained at correct temperature or not.

→ often thermal, vacuum, and vibration Tests of entire satellite will be done in a vacuum chamber, hence it is called 'Shake and bake Test'

③ electrical Model :-

→ It contains all electronic components and Tested under Vacuum.

→ space qualification is more expensive.

→ If failure of one component reduce the communication capacity of satellite, a backup or redundant unit will be provided.

→ when one unit fails, the backup automatically switched into operation by command from ground.

UNIT III

SATELLITE LINK DESIGN:

- Introduction, Basic transmission theory,
- system noise temperature and Gain to Temperature (G/T) ratio: Noise temperature,
- Calculation of system noise temperature, Noise figure and noise temperature, G/T ratio for earth stations.
- Design of down links: link budgets, link budget example.
- Uplink design, Design of satellite links for specified Carrier to NOISE (C/N)
- Combining C/N and C/I value in satellite links: Overall (C/N) with uplink and Downlink attenuation,
- Uplink and downlink attenuation in rain, Uplink attenuation and (C/N)up, Down link attenuation and (C/N)dn.
- System design for specific performance,
- Satellite communication link design procedure.

Satellite Link Design.

Introduction:

→ The design of satellite communication system is a complex process, requiring compromises between many factors, to achieve the best performance at an acceptable cost.

→ weight is the most critical factor in the design of any satellite.

→ Heavier the satellite, the higher the cost.

(about 25000 $/kg)

→ And the capital cost must be recovered over it's life time by selling communication services

→ The weight of satellite is because of two factors

① The number of o/p power of the transponders on the satellite.

② The weight of station keeping fuel

→ The other factors that inflence the satellite communication system design are

① The choice of frequency band

[6/4 GHz, 14/11 GHz, 30/20 GHz]

② Atmospheric propagation effects.

③ Multiple access techniques.

→ Rain the atmosphere attenuates radio signals.

→ The effect is more severe with increase in frequency.

→ Attenuation through rain increases roughly as the square of frequency. So a satellite operating at 30 GHz suffers four times as much attenuation as an uplink 6 GHz.

~~Basic Transmission~~ 1&2 are performance objectives

→ "Baseband channel BER (or) S/N is determined by C/N ratio at input to demodulator at receiver.

→ There are two links of satellite.

① Up Link ② Down link

Hence two signal ~~paths~~ paths.

Basic Transmission Theory:

→ Calculation of the power received by an Earth station from a satellite transmitter is fundamental to understand satellite communication

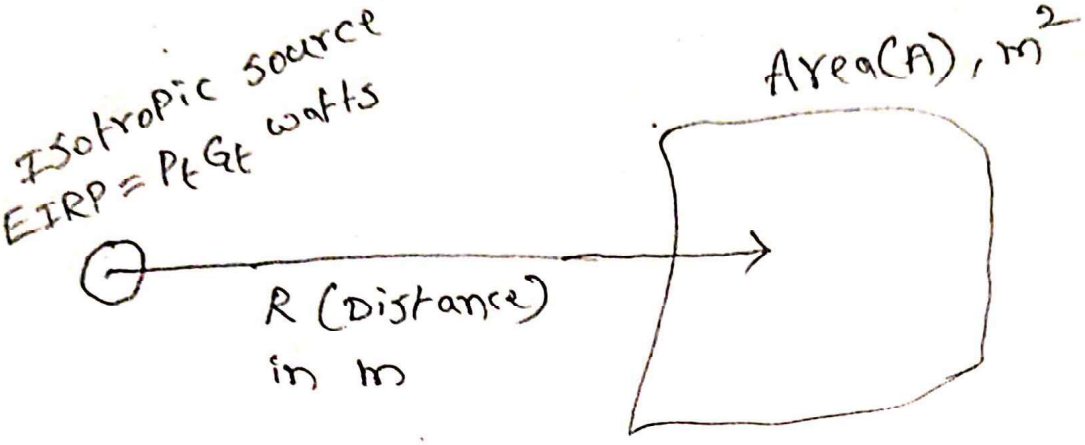


fig: flux density produced by Isotropic source.

→ consider a transmitting source, in freespace, radiating a total power, P_t watts uniformly in all directions

→ At a distance R meters from the isotropic source transmitting RF power P_t watts, the flux density crossing the surface of a sphere with radius R is given by

$$F = \frac{P_t}{4\pi R^2} \quad w/m^2 \longrightarrow (1)$$

→ For a transmitter with o/p P_t watts driving a lossless antenna with gain G_t, then the flux density in the direction of antenna boresight

at a distance R meters is given by

$$F = \frac{P_t G_t}{4\pi R^2} \quad w/m^2 \longrightarrow (2)$$

The Product $P_t G_t$ is called Effective isotropically radiated Power [EIRP]

→ For real antenna, gain $G(\theta)$ is

$$G(\theta) = \frac{P(\theta)}{P_o/4\pi}$$

where $P(\theta)$ = Power radiated per unit solid angle by the antenna.

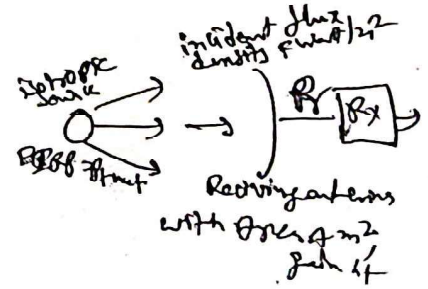
P_o = Total Power radiated by antenna.

$G(\theta)$ = Gain of antenna at an angle θ

→ Angle θ is taken in a direction where maximum Power is radiated (boresight direction of antenna)

→ If we had an ideal receiving antenna, with an aperture area of A_r, m^2, then received Power

$$P_r = F \times A_e \text{ watts} \longrightarrow (3)$$



where A_e = effective aperture

Practical antenna

$$\Rightarrow A_e = \eta_A \cdot A_r$$

where A_r = Physical aperture area.

→ Hence the power received by a real antenna with a physical receiving area A_r, and effective aperture area, A_e is given by

$$P_r = \frac{P_t G_t A_e}{4\pi R^2} \text{ watts}$$

→ The fundamental relationship in antenna theory is that gain and effective aperture are related by

$$G_r = \frac{4\pi A_e}{\lambda^2}$$

$$\Rightarrow A_e = \frac{G_r \lambda^2}{4\pi}$$

$$\therefore P_r = \frac{P_t G_t G_r}{(4\pi R/\lambda)^2} \text{ watts}$$

→ equation called Link equation
→ essential calculation of power received in any radio link.

→ In the above equation, the received power (P_r) decreases with increase in $(4\pi R/\lambda)$ value.

→ Hence $(4\pi R/\lambda)$ is called path loss (L_p) or free space transmission loss [FSTL]

$$\therefore P_r = \frac{\text{EIRP} \times \text{Receiving antenna gain}}{\text{path loss}}$$

→ Expressing the above equation interms of decibels

$$P_r = EIRP + G_r - L_p \quad dBW$$

Note: dBW is decibel watts

where $EIRP = 10\log_{10}^{(P_t G_t)}$ dBW

$$G_r = 10\log_{10}^{(4\pi A_e/\lambda^2)} \quad dB$$

$$L_p = 10\log_{10}^{(4\pi R/\lambda)^2} \quad dB$$

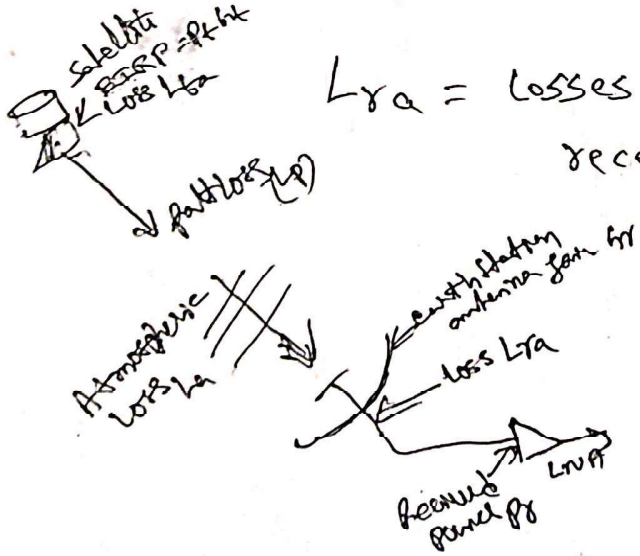
$$L_p = 20\log_{10}^{(4\pi R/\lambda)} \quad dB$$

$$\therefore P_r = EIRP + G_r - L_p - L_a - L_{ta} - L_{ra} \quad dBW$$

where L_a = Attenuation in atmosphere

L_{ta} = Losses associated with transmitting antenna

L_{ra} = Losses associated with receiving antenna



) In a satellite communication system, the satellite is at a height of 36,000 Km above the earth. The frequency used is 4 GHz and the transmitting antenna gain is 75 dB and the receiving antenna gain is 45 dB. Then calculate (i) The Free space Transmission Loss (ii) The received Power, when the transmitter Power is 200 watts

Sol:- Given distance (d) = 36000 km = 36000×10^3 m

$f = 4\ GHz = 4 \times 10^9\ Hz$

$G_t = 75\ dB$

$G_r = 45\ dB$

(i) Free space transmission Loss (FSTL):-

$$FSTL = 10 \log_{10} \left(\frac{4\pi d}{\lambda}\right)^2$$

$$\lambda = \frac{c}{f}$$

$$\therefore FSTL = 10 \log_{10} \left(\frac{4\pi d}{c/f}\right)^2 = 20 \log_{10} \frac{4\pi df}{c}$$

where c = velocity of light

$= 3 \times 10^8$ m/sec

$$\therefore FSTL = 20 \log_{10}\left(\frac{4\pi \times 36000 \times 10^3 \times 4 \times 10^9}{3 \times 10^8}\right)$$

$$\boxed{FSTL = 195.6\ dB}$$

(ii) Received Power in dBw is given by

~~$P_r = EIRP + G_R$~~

$$P_r = EIRP + G_r - 10\log\left(\frac{4\pi d}{\lambda}\right)^2$$

$$P_r = EIRP + G_r - FSTL$$

$$EIRP = P_t G_t$$

EIRP in decibels is $EIRP = 10\log(P_t G_t)$

$$EIRP = 10\log P_t + 10\log G_t$$

$$= 10\log 200 + 75$$

$$= 23 + 75$$

$$= 98\ dBw$$

Note: G_t is given in dB. So

Consider $10\log G_t = 75\ dB$

But P_t is given interms of watts (i.e $P_t = 200$ watts)

So convert P_t into watts.

Hence take $10\log 200$

$\therefore P_r = 98 + 45 - 195.6$

$$\boxed{P_r = -52.6 \text{ dBW}}$$

2) → If $R = 36,000$ Km (i.e distance, d)

$P_t = 5$ watts, $G_t = 16$ dB, $G_r = 45$ dB

$f = 11$ GHz, Then calculate P_r.

Sol:

$$P_r = \frac{P_t G_t G_r}{(4\pi R/d)^2}$$

$G_t = 16$ dB

$$\therefore G_t = \text{AntiLog}\left[\frac{16}{10}\right] = \text{AntiLog}(1.6)$$

$$= 39.81$$

$$G_r = \text{AntiLog}\left[\frac{45}{10}\right] = \text{AntiLog}(4.5)$$

$$= 31622.7$$

$$\therefore P_r = \frac{P_t G_t G_r}{(4\pi R/d)^2} = \frac{5 \times 39.81 \times 31622.7}{\left(4\pi \times 36000 \times 10^3 \Big/ \frac{3\times10^8}{11\times10^9}\right)^2}$$

Note: $d = \frac{c}{f} = \frac{3\times10^8}{11\times10^9} = \frac{3}{11} \times 10^{-1}$ m

$$P_r = \frac{5 \times 39.81 \times 31622.7}{(4\pi \times 36 \times 10^6 / 0.027)^2}$$

$$P_r = 2.2876 \times 10^{-14} = -136.4 \text{ dBw}$$

System noise Temperature, C/N and G/T ratios:

→ Noise temperature is a useful concept in communication system's receiver, since it provides a way of determining how much thermal noise generated by active and passive devices in the receiving system.

→ Noise Power is given by

$$P_n = K \cdot T_p B_n$$

where K = Boltzman's constant $= 1.39 \times 10^{-23}$ J/K

T_p = Physical temperature of source in Kelvin degrees.

B_n = Noise band width in which the noise Power is measured in Hz.

P_n = Available noise Power in watts

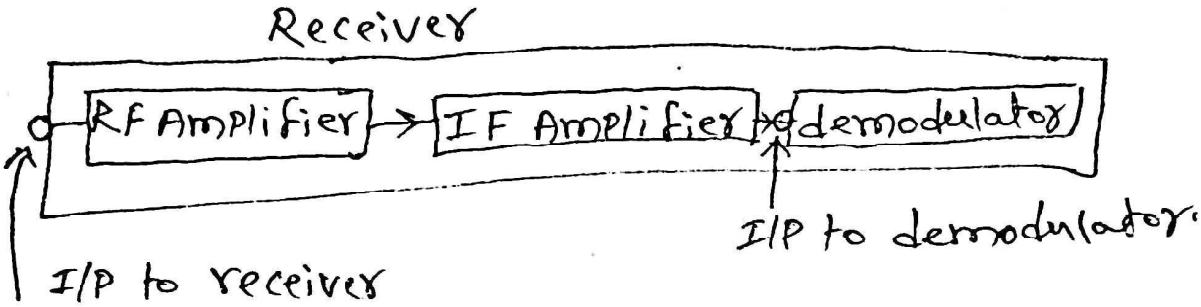
$K \cdot T_p$ = Noise Power spectral density in watts per Hertz.

→ To determine the performance of a receiving system we need to be able to find the total

thermal noise power against which the signal must be demodulated. We do this by determining the system noise temperature (T_s)

→ The noise power due to thermal noise at the receiver input is $P_n = K \cdot T_s B_n$

→ In general receiver, before demodulator there are RF amplifier and IF amplifier



→ If G_r is the overall gain of these cascaded amplifier (RF Amplifier + IF Amplifier), then the noise power at the demodulator input is

$$P_n = G_r K T_s B_n$$

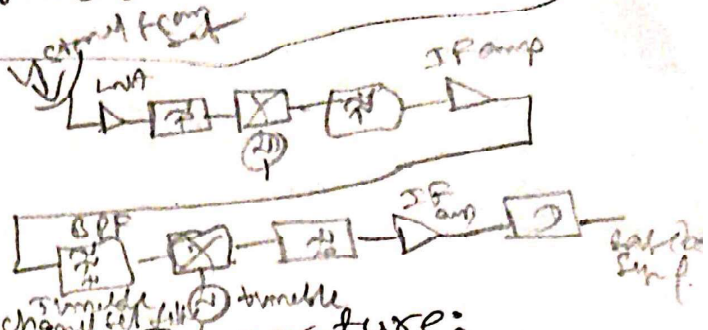
→ If P_r is the power reaching at the input of the receiver, then the signal power reaching at the input of demodulator is $P_r G_r$

→ Hence carrier to noise ratio at the demodulator input is $\left(\frac{C}{N}\right) = \frac{P_r \cdot G_r}{G_r K T_s B_n} = \frac{P_r}{K T_s B_n}$

Note: $\frac{C}{N}$ ratio is $\frac{\text{carrier Power}}{\text{Noise Power}}$ ratio.

Here carrier Power = signal Power = $P_r \cdot G$

$$\therefore \left[\frac{C}{N}\right] = \frac{P_r}{K T_s B_n}$$



BW → 1500 MHz
1st IF → 900 to 1400 MHz, 2nd IF – 70 MHz

Calculation of system Noise Temperature:

LNA → amplifies a sat signal without significantly degrading its $\frac{S}{N}$ ratio. They increase the amplitude of weak RF signals, which assists processing as part of a receiver ckt 2.4 & 5 GHz

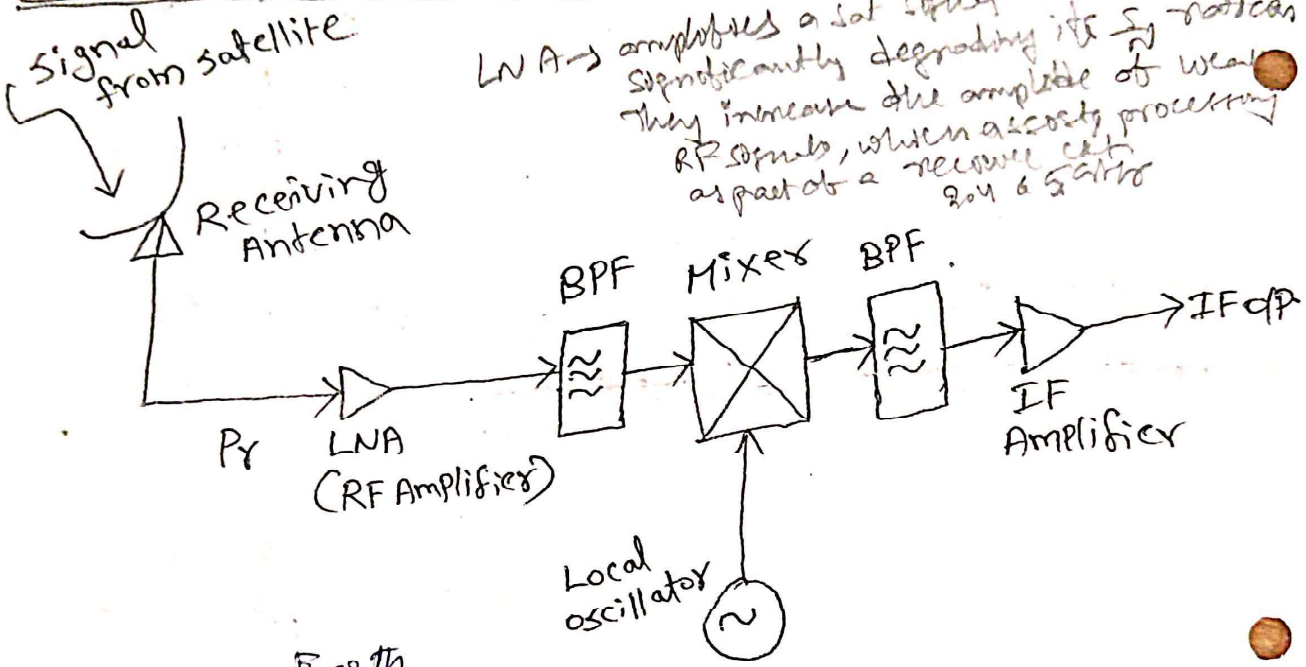


fig: (~~Satellite~~ Earth receiver)

→ For the purpose of analysis of noise temperature, the above receiver can be represented by an equivalent circuit as shown below.

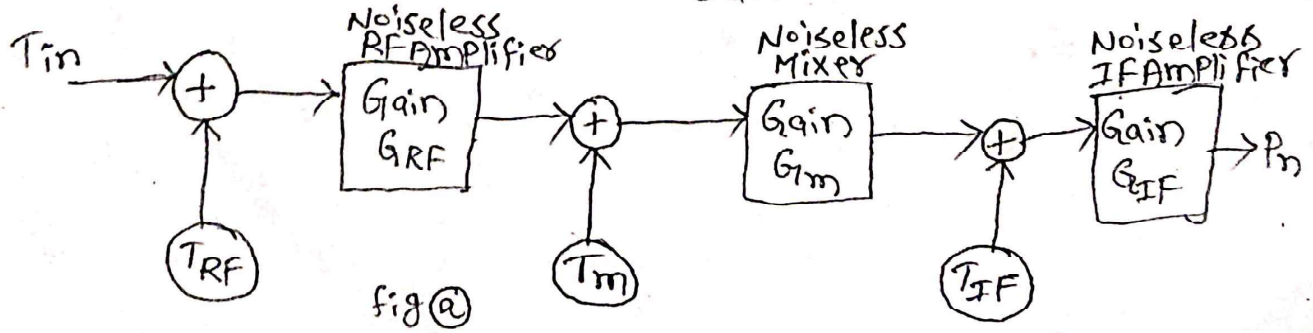


fig (a)

→ In the above figure G_{RF}, G_m, G_{IF} are the gains of RF amplifier, Mixer and IF Amplifier

T_{RF}, T_m, T_{IF} are the ~~Noise~~ equivalent noise temperatures of RF amplifier, Mixer, IF amplifier.

→ T_{in} is the Noise temperature of antenna.

→ The noisy devices in the receiver are replaced by equivalent devices (noiseless) with the same gain and noise generator at the input to ~~the~~ each block, such that the block produces the same noise at the output as the device it replaces

→ From the above figure, the total noise power at the o/p of IF amplifier of the receiver is given by

$$P_n = G_{IF} K T_{IF} B_n + G_{IF} G_m K T_m B_n + G_{IF} G_m G_{RF} K B_n (T_{RF} + T_{in})$$

The above equation can be rewritten as

$$P_n = G_{IF} G_m G_{RF} \left[\frac{K T_{IF} B_n}{G_{RF} G_m} + \frac{K T_m B_n}{G_{RF}} + (T_{RF} + T_{in}) K B_n \right]$$

$$P_n = G_{IF} G_m G_{RF} K B_n \left[T_{RF} + T_{in} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_{RF} G_m} \right]$$

$P_n =$ $G_{IF} G_m G_{RF} K T_n B_n$

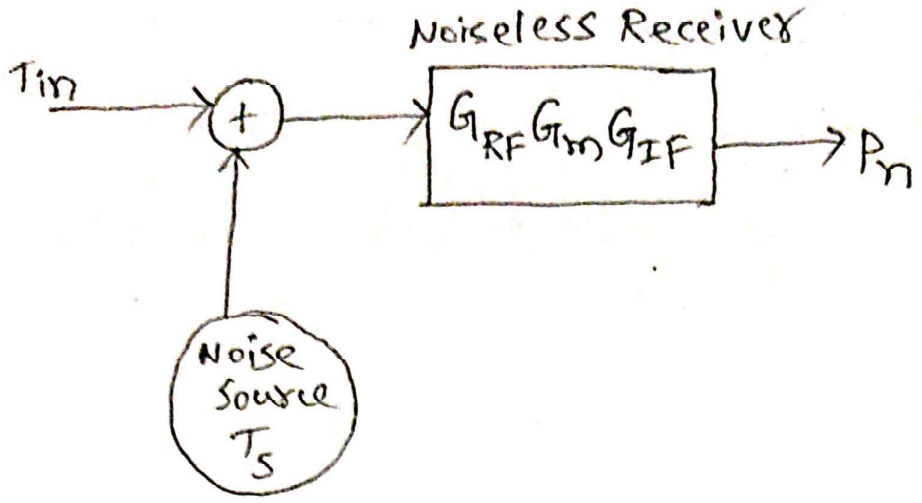


fig (b): Equivalent of fig (a)

→ The single source of noise in above figure, with noise temperature T_s generates same noise power P_n at it's o/p if

$$P_n \simeq G_{IF}G_m G_{RF} \cdot KT_s B_n$$

→ The noise power from fig (a) (b) will be same as noise power from fig (a) if

$$KT_s B_n = KB_n \left[T_{in} + T_{RF} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_m G_{RF}} \right]$$

→ Hence the equivalent noise source in fig (b) has a system noise temperature, T_s

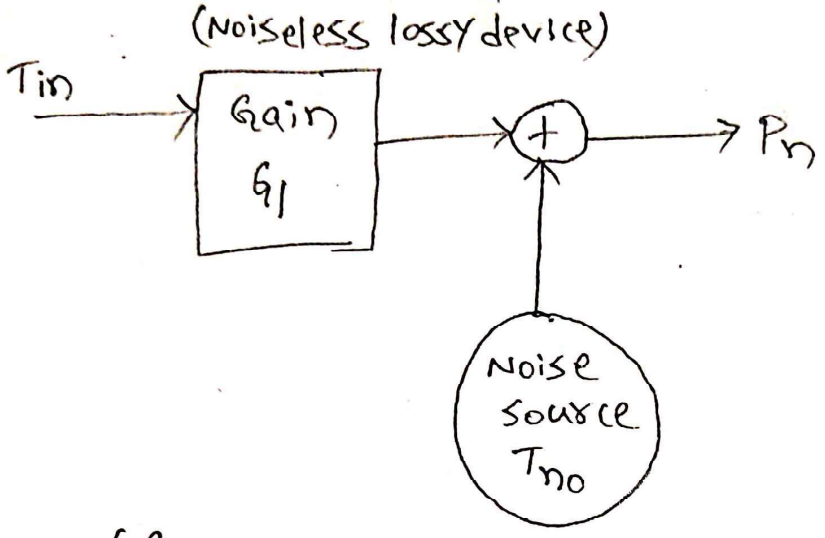
where $$T_s = \left[T_{in} + T_{RF} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_m G_{RF}} \right]$$

→ To deal with noise that reaches receiver after passing a lossy medium (ex: Rain drops),

Then we need different model as shown below.

→ In this case additional noise will radiate.

→ Hence the noisy model for equivalent o/p noise source is shown below.



(fig; Noisy model for a lossy device)

→ It produces a noise temperature T_{no}, ∞

where $\boxed{T_{no} = T_p(1 - G_1)}$

In the above equation G_1 is the linear gain (less than unity, not in dB) of the attenuating device or medium

and T_p = Physical Temperature of the device in degrees Kelvin

→ For an attenuation of A dB, the value of G_1 is given by

~~$G_1 = \log$~~ $\boxed{G_1 = 10^{A/10}}$

Noise Figure [N.F]:

It is defined as the ratio of signal to noise ratio at the i/p side to the signal to noise ratio at the o/p side

$$\text{Noise Figure}(N.F) = \frac{[S/N]_{in}}{[S/N]_{out}}$$

→ Noise Figure is frequently ~~used~~ used to specify the noise generated with in a device

→ Noise temperature : $T_d = T_0(N.F-1)$

Where T_0 is the reference temperature used to calculate noise figure (NF) (Generally $T_0 = 290^\circ K$)

Note: T_d is the amplifier device noise temperature

(3) → An amplifier has a quoted Noise Figure of 2.5 dB. Then find the equivalent noise temperature.

Sol:- Given $N.F = 2.5\,dB = 1.78$

We know Noise Temperature is

$$T_d = T_0[N.F-1]$$

$$T_d = 290[1.78-1] = 226^\circ K$$

• G/T ratio for Earth stations:

→ we know received power, $P_r = \frac{P_t G_t G_r}{\left(\frac{4\pi R}{\lambda}\right)^2}$

and noise power $P_n = KT_s B_n$

∴ The link equation can be rewritten interms of (C/N) at Earth station as

$$\left[\frac{C}{N}\right] = \left[\frac{P_t G_t G_r}{KT_s B_n}\right]\left[\frac{\lambda}{4\pi R}\right]^2$$

$$\left[\frac{C}{N}\right] = \left[\frac{P_t G_t}{KB_n}\right]\left[\frac{\lambda}{4\pi R}\right]^2\left[\frac{G_r}{T_s}\right]$$

Hence $\frac{C}{N} \propto \frac{G_r}{T_s}$

→ The ratio $\frac{G_r}{T_s}$ is called $\frac{G}{T}$ ratio in dB/K

→ $\frac{G}{T}$ ratio is used to specify the quality of a receiving Earth station or a satellite receiving system, since increasing G_r/T_s increases the received C/N ratio.

④ → Calculate the noise temperature of a 6GHz receiver system having the following gains and noise temperature

$T_{IF} = 75K$ $T_{RF} = 75K$ $T_m = 400K$ $T_{IF} = 1000k$

$T_{in} = 75K$

$G_{RF} = 23\,dB$ $G_m = 0\,dB$ $G_{IF} = 35\,dB$

Sol: System noise temperature is given by

$$T_S = T_{in} + T_{RF} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_m G_{RF}}$$

$$\therefore T_S = 75 + 75 + \frac{400}{200} + \frac{1000}{200}$$

$$T_S = 157\,K$$

(5) → A satellite at a distance of 36,000 km from the surface of the earth radiates a power of 4 watts from an antenna of gain 15 dB. Find the flux density and power received by an antenna of effective area $12\,m^2$. If the receiving antenna has a gain of 50 dB, then calculate the received power.

Sol:

$$G_T = 15\,dB = \text{antilog}\left(\frac{15}{10}\right) = 31.62$$

Flux density at a point R from the antenna is $F = \frac{P_t G_t}{4\pi R^2}$

Given $P_t = 4$ watts

$G_t = 15$ dB $= 31.62$

$\therefore$ Flux density $= \dfrac{4 \times 31.62}{4 \times 3.14 \times (36000)^2}$ w/m^2

Flux density $(F) = 7.77 \times 10^{-15}$ w/m^2

Power received by receiving antenna with aperture $12\,m^2$ is

$P_r = F \times A_r = 7.77 \times 10^{-15} \times 12$ watts

$\therefore P_r = 0.093 \times 10^{-12}$ watts

$\therefore$ Received Power (i.e power at the o/p of receiving antenna) $= G_r \cdot P_r$

given $G_r = 50$ dB $=$ Antilog $\left(\frac{50}{10}\right)$

$\therefore G_r P_r =$ Antilog $(5) \times 0.093 \times 10^{-12}$

$= 0.093 \times 10^{-7}$ watts

~~Design of downlinks:~~

(6) → A satellite at a distance of 40,000 km from a point on the earth's surface radiates a power of 10 watts from an antenna with a gain of 17 dB in the direction of the observer. Find the flux density at the receiving point, and the power received by an antenna at this point with an effective area of $10m^2$.

Sol: Given $R = 40,000$ km

$P_t = 10$ watts

$G_t = 17\ dB = \text{Antilog}\left(\frac{17}{10}\right) = 50$.

Flux density, $F = \frac{P_t G_t}{4\pi R^2}$ w/m^2

$\therefore F = \frac{10 \times 50}{4\pi (40,000)^2}$ w/m^2

$F = 2.49 \times 10^{-14}$ w/m^2

The power received with an effective area of $10m^2$ is

Given $A_e = 10$

$\therefore$ Power received, $P_r = F \times A_e$ watts

$= 2.49 \times 10^{-14} \times 10$ watts

$\therefore P_r = 2.49 \times 10^{-13}$ watts

Flux density in decibels is

$$F = \frac{P_t G_t}{4\pi R^2}$$

$$= 10\log(P_t G_t) - [10\log 4\pi R^2]$$

$$= 10\log(P_t G_t) - [10\log 4\pi + 10\log R^2]$$

$$= [10\log P_t G_t - 10\log 4\pi - 20\log R]$$

$$= 27 - 11 - 152$$

$$F = -136 \text{ dB } (W/m^2)$$

received Power in decibels:

$$P_r = F \times A_e$$

$$= 10\log F + 10\log A_e$$

~~$-10\log$~~

$$P_r = -136 + 10 = -126 \text{ dBW}$$

Note: $10\log 10 = 10 \times 1 = 10$

(7) → For the satellite in the above problem, which is operating at a frequency of 11 GHz. If receiving antenna gain is 52.3 dB. Find the received power

Sol: received power in decibels is

$$P_r = EIRP + G_r - \text{Path Loss (dBW)}$$

$$EIRP = 10\log(P_t G_t) = 10\log(10 \times 50)$$

$$= 27$$

$$\text{Path Loss} = \left(\frac{4\pi R}{d}\right)^2 = 10\log\left(\frac{4\pi R}{d}\right)^2$$

$$= 20\log\left(\frac{4\pi R}{d}\right)$$

$$= \cancel{20\log_{10}(4\pi R}$$

$$= 20\log_{10}\left(\frac{4\pi \times 4\times 10^{7}}{3\times 10^{8}/11\times 10^{9}}\right)$$

$$= 205.3 \text{ dB}$$

Note:
$R = 40{,}000 \text{ km}$
$= 40{,}000 \times 10^{3} \text{ m}$
$= 4\times 10^{7} \text{ m}$

$$\therefore P_r = EIRP + G_{2r} - \text{Path loss dBW}$$

$$P_r = 27 + 52.3 - 205.3$$

$$P_r = -126 \text{ dBW}$$

→ An earth station antenna has a diameter of 30m, an overall efficiency of 68%, and it is used to receive a signal at 4150 MHz. At this frequency, the system noise temperature is 79K when the antenna points at the satellite at an elevation angle of 28°. What is the earth station G/T ratio under these conditions.

If heavy rain causes the sky temperature to increase so that the system noise temperature rises to 88K, then find new G/T value?

Sol:- Given $f = 4150\ MHz = 4150 \times 10^6\ Hz$

$$\lambda = \frac{c}{f} = \frac{3\times10^8}{4150\times10^6} = \frac{3\times10^2}{4150} = 0.0723\ m$$

For a circular aperture, the gain is

$$G_r = \eta_A \left(\frac{\pi D}{\lambda}\right)^2$$

where η_A = aperture efficiency

$= 68\% = 0.68$

D = Diameter of aperture

$= 30\ m$

$$\therefore G_r = 0.68\left[\frac{\pi \times 30}{0.0723}\right]^2 = 0.68\left[\frac{94.248}{0.0723}\right]^2$$

$$G_R = 0.68\left[\frac{\pi D}{\lambda}\right]^2 = 1155516.88$$

$$G_R = 1.155 \times 10^6$$

In decibels $G_{dB} = 10\log_{10}^{1.155\times10^6}$

$$G_R = 63.75\,dB$$

Given $T_S = \cancel{88K}\ 79K$

Convert T_S into dBK

$$T_S = 10\log_{10}^{79} = 18.97\,dBK$$
$$\simeq 19\,dBK$$

$\frac{G}{T}$ ratio in dB/K is given by

(G) in dB $- T_S$ in dBK

$$\frac{G}{T} = 63.75 - 19 = 44.75\ dB/K$$

If $T_S = 88K$, then

$$\frac{G}{T} = 63.75 - 19.4$$
$$\frac{G}{T} = 44.35\ dB/K$$

$T_S = 10\log_{10}^{88} = 19.4$

Design of down Links:

→ Satellite communication system design involves the compramisation of system parameters that meets the specification at lowest cost.

→ Any satellite link can be designed with very large antennas to achieve high $\frac{C}{N}$ ratios under all conditions, but the cost will be high.

→ All ~~communications~~ satellite communications links are affected by rain attenuation

→ Rain attenuation effect on a 6/4 GHz band satellite link is small when compared to 14/11 GHz band and 30/20 GHz band.

→ Satellite links are designed to achieve reliabilities of 99.5 to 99.99%, averaged over a long period of time, typically a year.

→ That means the C/N ratio in the receiver will fall below the minimum permissible value for proper operation of the link for between 0.5 and 0.01% of specified time; the link is then said to suffer an outage

→ C-band links can be designed to achieve 99.99% reliability because the rain attenuation rarely exceeds 1 or 2 dB.

→ The time corresponds to 0.01% of a year is 52 minits.

→ At this level of probability, rain attenuation is not stable and wide fluctuations occur from year to year

→ outages occur in heavy rain, usually in thunderstorms. And thunderstorm occurrence varies widely.

→ outage times of 0.1 to 0.5% of a ~~year~~ year (8 to 40 h) are usually tolerated in Ka-band links.

→ The allowable outage time for a link depends in part on the traffic carried

→ Telephone ~~channels~~ traffic needs real-time channels. C band or Ku band is used for voice channels with links having small outage time.

→ For internet access Ka band is suited.

Link budget: It is an accounting of all the gains & losses in a transmission system

→ Link budget is a tabular method for evaluating the received power and noise power in radio link.

→ $\frac{S}{N}$ ratio calculation is simplified by the use of Link budget.

→ For any change in parameter values, the results can be recalculated by using link budget.

→ Link budget for each transponder is calculated and it is repeated for every radio link

→ The factors that effect the uplink and downlink design in geostationary satellite system are ~~clas~~ classified based on system elements ~~based~~ in three categories

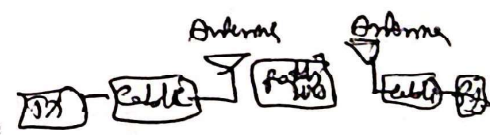
① **Factors related to Earthstation:**

Pt, At
Gr
Gw
Ts

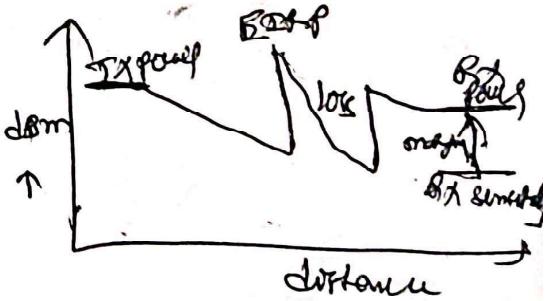
- Transmitted Power and gain of antenna.
- The gain of receiving antenna that is associated with sensitivity of Earth station
- Total $\frac{C}{N}$ ratio value.
- System noise temperature.

② **Factors related to channel:**

- Type of modulation and coding
- operated frequency is associated with path loss.
- Total $\frac{C}{N}$ ratio value.



③ **Factors related to satellite:**



- Type of transponder
- Total $\frac{C}{N}$ ratio value.
- Transponder gain
- $\frac{G}{T}$ ratio (Figure of merit)
- Radiation pattern, EIRP

→ few db of link margin to allow for attenuation

Link margin: difference b/n min. expected power received & receiver's sensitivity

$L_{km} = \left\{ \begin{matrix} \text{min Expected} \\ \text{power Received} \end{matrix} \right\} - \left\{ \begin{matrix} \text{Receiver} \\ \text{sensitivity} \end{matrix} \right\}$

Receiver's sensitivity represents the received power at which the receiver will stop working

→ In a two-way satellite communication link, there will be four separate links, each requiring a calculation of C/N.

→ When a bent pipe transponder is used the uplink and downlink C/N ratios must be combined to give an overall C/N ratio.

→ The calculation of C/N ratio in a satellite link is based on two equations for Received signal power and receiver noise power

→ The received carrier power in dBwatts is given by

$$P_r = EIRP + G_r - L_p - L_a - L_{ta} - L_{ra} \quad dBW$$

→ A receiving terminal with a system noise temperature "T_s K", and a noise bandwidth "B_n" Hz, has a noise power "P_n" referred to the o/p terminals of the antenna where

$$P_n = KT_s B_n \quad \text{watts}$$

→ The receiving system noise power is usually expressed in 'db watts' as

$$N = K + T_s + B_n \quad dBW$$

Where K is Boltzmann's constant, T_s is the system noise temperature in dBK, and B_n is the noise bandwidth of the receiver in dBHz.

Uplink Design:

→ The uplink design is easier than the Downlink in many cases, since an accurately specified carrier power must be presented at the satellite transponder and it is often feasible to use much higher power transmitters at earth station when compared to satellite transmitters.

→ But VSAT systems use earth stations with small antennas and transmitter power below 5 W, giving low uplink EIRP
(Very small aperture Terminal) (serves hosted business users)

→ In mobile systems the uplink from the satellite telephone is usually the link with the lowest C/N ratio.

→ The cost of transmitters is high when compared to cost of receiving equipment in satellite communication system

→ The major growth in satellite communications has been in Point-to-multipoint transmission, as in cable TV distribution and direct broadcast Satellite Television.

→ The satellite ~~receiver is~~ a transponder is a quasilinear amplifier and the received carrier level determines the o/p level.

→ When TWT amplifier is used as HPA in transponder, and if FDMA is used, the HPA must be run with a predetermined O/B. backoff to avoid intermodulation products appearing at the output.

→ The o/p backoff is typically 1 to 3 dB when more than one signal is present in the transponder, and is determined by the uplink carrier power level received at the spacecraft.

→ Accurate control of the power received by the earth-station is therefore essential, which is easily achieved in a fixed network of earthstations.

→ where a large number of earth stations access a single transponder using FDMA, such as in some VSAT networks and Intelsat satellites, transponder o/p backoff 5 to 7 dB may be required to maintain low Intermodulation Product

→ Earth station transmitter power is set by the power level required at the input to the transponder. This can be done in one of two ways. Either a specific flux density is required at the satellite, or a specific power level is required at the i/p to the transponder

→ Analysis of uplink requires calculation of the power level at the input to the transponder so that uplink C/N ratio can be found.

→ The link equation is used for this calculation

→ when C/N ratio is specified for the transponder, the calculation of required transmit power can be calculated directly.

→ Let $(C/N)_{up}$ be the specified C/N ratio in the transponder, measured in a noise

bandwidth B_n Hz.

→ The bandwidth B_n is the bandwidth of BPF in the IF stage of the earth station receiver for which the uplink signal is intended.

→ Even if B_n is much less than the transponder bandwidth, it is important that the uplink C/N ratio be calculated in the bandwidth of the receiver, not the bandwidth of the transponder.

→ The noise power at transponder i/p is N_{XP} W.

$$N_{XP} = K + T_{XP} + B_n \text{ dBW}$$

where T_{XP} = system noise temperature of the transponder in dBK

and B_n units are dBHz.

→ The power received at the input to the transponder is P_{rxp}

$$P_{rxp} = P_t + G_t + G_r - L_p - L_{up} \text{ dBW}$$

where $P_t G_t$ is the uplink earth station EIRP in dBW

G_r = satellite receiving antenna gain in dB; in the direction of uplink earth-station

L_p = path loss in dB

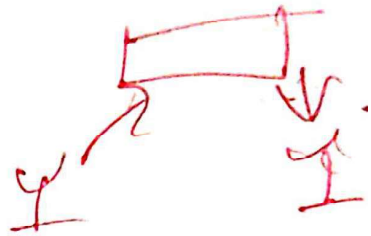
L_{up} = upling losses other than path loss

→ The value of $(C/N)_{up}$ at the LNA input of satellite receiver is given by

$$C/N = 10 \log_{10} \frac{A_r}{KT_S B_n} = P_{rxp} - N_{xp} \text{ dB}$$

→ The received power at the transponder i/p is also given by

$$P_{rxp} = N + \frac{C}{N} \text{ dBW}$$



→ In general

$$P_{rxp} = P_{sat} - BO_o - G_{xp} \text{ dBW}$$

where P_{sat} is the saturated power o/p of the transponder in dBW

BO_o = o/p Backoff in dB

G_{xp} = Gain of transponder in dB.

→ It is not always possible to trade-off transmitter power against uplink antenna size.

→ Uplink Power control (UPC) can be used to combat uplink rain attenuation.

→ Since downlink frequency is different from uplink frequency, a downlink attenuation of A dB must be scaled to estimate uplink attenuation.

→ The scaling factor is typically $\left(\frac{f_{up}}{f_{down}}\right)^a$

where a is in between 2.0 and 2.4

→ The uplink attenuation is given by

$$A_{up} = A_{down} \times \left(\frac{f_{up}}{f_{down}}\right)^a \text{ dB}$$

Ku-band 14/11.25 GHz [22]

Where A_{up} = Estimated uplink rain attenuatio

A_{down} = Measured downlink rain attenuatio

→ For a value of $a = 2.2$ and $\frac{f_{up}}{f_{down}} = 1.22$, the factor $\left(\frac{f_{up}}{f_{down}}\right)^a = 1.56$.

Hence a downlink rain attenuation of

→ 3dB would give an estimated uplink attenuatio of 4.7 dB.

$T_s = T_{in} + T_{RF} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_{RF} G_{IF}}$

$T_m = T_p (1 - G_1)$, $G_1 = 1$

$T_d = T_0 (NF - 1)$

→ This uplink attenuation value applies only to rain attenuation.

→ uplink Power control can not be applied until a certain amount of attenuation has built up in the link. This is typically around 2dB for the downlink, and about 3dB for a Ka-band uplink.

→ As rain begins to affect the link between the earthstation and the satellite, the

uplink C/N ratio in the transponder will fall until opc starts to operate in the Earthstation transmitter

→ Attenuation on the uplink cause the C/N ratio in the transponder to fall

→ uplink budget is given by the equation

$$P_r = EIRP + G_r - L_p - L_a - L_{ta} - L_{ra} - L_{pt} \text{ dBW}$$

Where L_{pt} = Pointing loss (Antenna Pattern Loss)

From the above equation

$$P_t = P_r - G_t - G_r + L_p + L_a + L_{ta} + L_{ra} + L_{pt} \text{ dBW}$$

→ Antenna received power is

$$P_r = EIRP + G_r - L_p - L_a - L_{ta} - L_{ra} \text{ dBW}$$

uplink design equation is

$$\left[\frac{C}{N}\right]_{uplink} = 10\log_{10} \frac{P_r}{KT_sB_n} \text{ dBW}$$

we know $P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi R}\right)^2$

$$\therefore \left(\frac{C}{N}\right)_{UL} = 10\log_{10} \frac{P_t G_t G_r}{KT_sB_n} \left(\frac{\lambda}{4\pi R}\right)^2 \text{ dBW}$$

$$\left(\frac{C}{N}\right)_{UL} = 10\log P_t G_t - 20\log L_p + 10\log\left(\frac{G_r}{T_s}\right) - 10\log L_a - 10\log k - (BO)_i \quad dBW$$

where $(BO)_i$ = i/p Backoff

Why uplink frequency is higher than downlink frequency

→ The frequency of the carrier transmitted by earthstation to satellite is uplink frequency

→ The frequency of the carrier transmitted by satellite is called down link frequency.

→ Always uplink frequency is taken greater than downlink frequency because of limitation of power generation at satellite.

$$P_r = P_t G_t G_r \left[\frac{d}{4\pi R}\right]^2$$

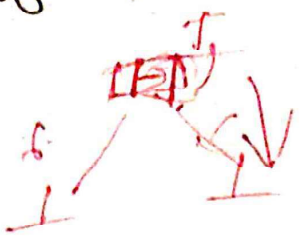
$$\Rightarrow P_t = \frac{P_r}{G_t G_r}\left[\frac{4\pi R}{d}\right]^2$$

$$P_t = \frac{P_r}{G_t G_r}\left[\frac{4\pi f R}{c}\right]^2 \rightarrow (1)$$

consider a constant received power and assume $G_t G_r = 1$.

Then eq① can be written as

$$P_t \propto f^2$$



→ Hence the transmitted power by an antenna is proportional to square of the frequency of the carrier at constant received power

→ Satellite transmitters have less power when compared to Earth station transmitters.

→ so low frequency carrier would require less transmitted power than higher frequency carrier to produce the same power.

→ Hence down link frequency is taken as less than uplink frequency.

→ Consider a 6/4 GHz system,

i.e $f_{uplink} = 6\,GHz$ $f_{downlink} = 4\,GHz$

At constant P_r, $P_t \propto f^2$

$$\therefore \frac{P_{t\,downlink}}{P_{t\,uplink}} = \left[\frac{f_{downlink}}{f_{uplink}}\right]^2 \Rightarrow \left(\frac{4}{6}\right)^2 = 0.44$$

$$\Rightarrow P_{t\,downlink} = 0.44\, P_{t\,uplink}$$

i.e $P_{t\,downlink}$ = 40% of $P_{t\,uplink}$

(9) → In a satellite uplink, the transmitter system has a loss of 1dB while the transmitter antenna has a gain of 55dB. There is an atmospheric loss of 2dB, a free space loss of 200dB. The receiving system has a bandwidth of 36MHz and noise temperature of 1000K. If the desired SNR is 35dB. Then find [receiving antenna has a gain of 20dB]

① The required transmitter power

② The receiver noise Power

If the flux density of the satellite should not exceed -75 dB w/m^2, obtain the trade-off possible between the receiver antenna gain and transmitter power. Assume Boltzman constant = -228.6 dBw/Hz/K

Sol:- Given L_t i.e Transmitter loss = 1dB

$$G_t = 55 \text{ dB}$$

Atmospheric loss, $L_a = 2$ dB

Free space loss (or) path loss, $L_p = 200$ dB

$$G_r = 20 \text{ dB}$$

Bandwidth of receiving system = $B = 36 \text{ MHz} = 36 \times 10^6$

Noise Temperature, $T_s = 1000$ K

$$\frac{S}{N} \text{ (or) } \frac{C}{N} = 35 \text{ dB}$$

$K = -228.6$ dBw/Hz/K , $F = -75$ dB w/m^2

$P_t = ?$

$P_n = ?$

Step ①: we know that equation for noise power is $P_n = KT_sB$

$\therefore P_n = 10\text{Log}(K) + 10\text{Log}(T_s) + 10\text{Log}(B)$

T_s in dB $= 10\text{Log}_{10}(1000) = 30$ dBK

B in dB $= 10\text{Log}_{10}(36\times10^6) = 75.56$ dBHz

$\therefore P_n = -228.6 + 30 + 75.56$

$\therefore P_n = -123.03$ dBw = Noise Power

Step ②: we know that

$$\frac{C}{N} = \frac{P_r}{KT_sB} = \frac{P_r}{P_n}$$

$$\therefore P_r = \frac{C}{N} \times P_n = \left[\frac{C}{N}\right]_{dB} + P_n \text{ dB}$$

$P_r = 35 + (-123.03)$

$P_r = -88.03$ dBw = received Power

Step③:- But $P_r = EIRP + G_r - losses$

$$EIRP = P_r - G_r + losses$$

$$\therefore EIRP = (-88.03) - (20) + (L_t + L_a + L_p)$$

$$EIRP = -108.03 + 1 + 2 + 200$$

$$\therefore EIRP = 94.97 \text{ dBW}$$

Step④: $EIRP = P_t G_t$

$$\therefore P_t = \frac{EIRP}{G_t}$$

P_t in dBW = EIRP in dBW − G_t in dB

$$\therefore P_t = 94.97 - 55$$

$$P_t = 39.96 \text{ dBW}$$

Given $F = -75 \text{ dBW/m}^2$

and $F = \frac{P_r}{A_e}$ Note: A_e = effective aperture

$$\Rightarrow A_e \cdot F = P_r$$

$$A_e = \frac{P_r}{F}$$

In decibels $A_e = P_r - F$

$$\therefore A_e = (-88.03) - (-75) = -13.03 \text{ dB m}^2$$

To find new G_r, P_t we need to find A_e, R

To find R:

Flux density(F) $= \frac{P_t G_t}{4\pi R^2}$ w/m²

In decibels

$$F = [EIRP (i.e\ P_t G_t)] - 10\log(4\pi) - 20\log R$$

$$\Rightarrow -75 = 94.97 - 11 - 20\log R$$

$$20\log R = 158.97$$

$$2(10\log R) = 158.97$$

$$10\log R = \frac{158.97}{2} = 79.485 \text{ dBm}$$

$\therefore$ R (i.e distance) in decibels = 79.485 dBr

→ we know $P_r = \left(\frac{P_{t\,new} G_t}{4\pi R^2}\right) A_e$

$$\Rightarrow P_{t\,new} = \frac{P_r 4\pi R^2}{G_t A_e}$$

In decibels

$$P_{tnew} = [P_r] + 10\log 4\pi + 20\log R - [G_t] - [A_e]$$

$$P_{tnew} = -86.03 + 11 + (2 \times 79.48) - 55 - (-13.03)$$

$$\therefore P_{tnew} = 39.97 \text{ dB}$$

To find G_r:-

$$P_r = EIRP - G_{r\,new} - (L_p + L_a + L_t)$$

$$-88.03 = 94.97 - G_{r\,new} - (200 + 2 + 1)$$

$$G_{r\,new} = 94.97 + 88.03 - 203$$

$$\therefore G_{r\,new} = -20\ dB$$

$\therefore$ Transmitted power, $P_{t\,new} = 39.97\ dB$

But the gain of receiving antenna is decreased

$$\therefore G_{r\,new} = -G_r$$

$$\therefore G_r = 20\ dB \Rightarrow G_{r\,new} = -20\ dB$$

Design for specified $\frac{C}{N}$:

Combining C/N and C/I values in satellite links.

→ The BER or S/N ratio in the base band channel of an earth station receiver is determined by the ratio of the carrier power to the noise power in the IF amplifier at the i/p to the demodulator

→ The noise present in the IF amplifier comes from many sources.

→ The noise in the earthstation IF amplifier will have contributions from the receiver, the receiving antenna, SKY noise, the satellite transponder from which it receives signal, and the adjacent satellites and terrestrial transmitters which share the same frequency band.

→ The method used to add these noise contributions together in a hypothetical reference circuit.

→ The other method is addition of $\frac{C}{N}$ and $\frac{C}{I}$ (carrier-to-Interference)

→ when more than one C/N ratio is present in the link, we add the individual C/N ratios reciprocally to obtain overall C/N ratio i.e $\left(\frac{C}{N}\right)_0$.

→ The overall C/N ratio [i.e $(C/N)_0$] is measured in the earth station at the o/p of IF amplifier

$$\left(\frac{C}{N}\right)_0 = \frac{1}{\frac{1}{\left(\frac{C}{N}\right)_1} + \frac{1}{\left(\frac{C}{N}\right)_2} + \frac{1}{\left(\frac{C}{N}\right)_3} + \cdots}$$

→ This is called as reciprocal $\frac{C}{N}$ formula.

→ All C values in the above equation are same

→ Expanding the formula by crossmultiplying gives overall $(C/N)_0$ as power gain

$$\left[\frac{C}{N}\right]_0 = \frac{1}{\left(\frac{N_1}{C} + \frac{N_2}{C} + \frac{N_3}{C} + \cdots\right)}$$

$$\left(\frac{C}{N}\right)_0 = \frac{C}{(N_1 + N_2 + N_3 + \cdots)}$$

In decibel units

$$\left(\frac{C}{N}\right)_0 = C\ dBW - 10\log_{10}(N_1 + N_2 + N_3 + \cdots)\ dBW$$

→ The satellite always transmits noise as well as signal, so C/N ratio measured at the receiver will always gives $(C/N)_0$

→ overall C/N ratio $\left(\left(\frac{C}{N}\right)_0\right)$ is the combination of transponder and earth station C/N ratios.

→ To calculate performance of a satellite link we must therefore determine the uplink $(C/N)_{up}$ ratio in the transponder and downlink $(C/N)_{down}$ ratio in the earth station receiver.

→ we must also consider whether there is any interference present in the satellite receiver or earth station receiver.

→ If the Inter Modulation (IM) power level in the transponder is ~~known~~ known, a C/I value can be found and included in the

calculation of overall $(C/N)_0$ ratio

→ Interference from adjacent satellites is likely whenever small receiving antennas are used as with VSATS (very small aperture terminals) and DBS-TV receivers.

→ since C/N values are usually calculated from power and noise budgets, their values are typically in decibels.

Rules of thumb for estimating $(C/N)_0$ from two C/N values:

→ If C/N values are equal, $(C/N)_0$ is 3dB lower than either value.

→ If one C/N value is 10dB smaller than the other value, $(C/N)_0$ is 0.4 dB lower than the smaller of the (C/N) values.

→ If one C/N value is 20 dB or more greater than the other C/N value, the overall $(C/N)_0$ is equal to the smaller of the two C/N values with in the accuracy of decibel calculations (± 0.1 dB)

overall $(C/N)_0$ with uplink and downlink attenuation:

→ Most satellite links are designed with link margins to allow for attenuation that may occur in the link or increase in noise power caused by Interference

→ The effect of a change in the uplink C/N ratio has a different impact on overall $(C/N)_0$ depending on the operating mode and gain of the transponder.

→ There are three different ~~types~~ transponder types or operating modes:

~~Linear mode~~

Linear transponder: $P_{out} = P_{in} + G_{XP}$ dBW

Non linear transponder: $P_{out} = P_{in} + G_{XP} - \Delta G$ dBW

Regenerative transponder: P_{out} = Constant dBW

where P_{in} is the power delivered by the satellite's receiving antenna to the i/p of the transponder.

P_{out} is the power delivered by the transponder HPA to the i/p of the satellite's transmitting antenna.

G_{XP} is the gain of transponder

and all parameters are in decibel units.

→ The parameter ΔG is dependent on P_{in} and accounts for the loss of gain caused by the non linear saturation characteristics of a transponder

→ The maximum o/p power from a transponder is called the saturated o/p power. It is the nominal transponder power o/p rating.

→ When a transponder is operated at saturated o/p power level, the transponder's Input-output characteristic is highly non linear

→ When a transponder is operated close to its saturated o/p power level, digital waveforms are changed, resulting Inter symbol Interference (ISI), and FDMA operation results in the generation of IM products by ~~multiplying~~ multiplication of the individual signals.

→ Transponders are usually operated with "o/p backoff", to make characteristics more nearly linear

→ The exact amount of output backoff required depends on the specific characteristics of the transponder and the signal it carries.

→ Typical values of output backoff are
1 dB for a single FM or PSK carrier to
3 dB for FDMA operation with several carriers.

→ The corresponding i/p backoff values might be 3 dB and 5 dB

Uplink and Down link Attenuation in Rain:

→ Rain attenuation effects uplinks and down links differently.

→ Usually we assume that rain attenuation is occuring on either the uplink or downlink, but not on both at the same time.

→ This is usually true for earth stations that are well seperated geographically, but not if they are close together (< 20 Km)

→ Heavy rain occurs with a somewhat random geographic distribution for less than 1% of the time. So the probability of significant attenuation occuring on both the uplink and downlink simultaneously is small.

Uplink Attenuation and $(C/N)_{up}$:

→ The transponder receiver noise temperature will not vary when the rain is present in the uplink path to the satellite.

→ The satellite receiving antenna beam is wide. It can see large area on the earth surface.

→ For a linear transponder with the rain attenuation in the uplink of A_{up} dB

$$\left(\frac{C}{N}\right)_{o\ uplink\ rain} = \left(\frac{C}{N}\right)_{o\ clear\ air} - A_{up}\ dB.$$

→ If the transponder is non linear, the reduction in the i/p power caused by uplink attenuation

of A_{up} dB results in a smaller reduction in o/p power, by an amount ΔG

$$\left(\frac{C}{N}\right)_{\text{o uplink rain}} = (C/N)_{\text{o clear air}} - A_{up} + \Delta G \text{ dB}$$

→ If the transponder is digital and regenerative or incorporates an Automatic Gain control (AGC) system to maintain a constant o/p power level.

$$(C/N)_{\text{o uplink rain}} = (C/N)_{\text{o clear air}} \text{ dB.}$$

→ The corresponding system noise temperature for the transponder on a GEO satellite is in the range 400 to 500K

→ Rain attenuation on the uplink path to the satellite reduces the power at the satellite's receiver i/p; and thus reduces $(C/N)_{up}$ in direct proportion to the attenuation on the slant path.

→ The above equation (i.e regenerative transponde equation $(C/N)_o$ ratio) will hold only if the received signal is above threshold and BER of recovered digital signal in the transponder is small.

Down Link attenuation and $(C/N)_{dn}$:

→ The earthstation receiver noise temperature can change very significantly when rain is present in the downlink path from the satellite.

→ The SKY noise temperature can increase to close to the physical temperature of the individual rain drops, particularly in very heavy rain.

→ The downlink ~~$(C/N)_{dn\ rain} = (C/N)_{dn\ clear\ air}$~~

$$\left(\frac{C}{N}\right)_{dn\ rain} = (C/N)_{dn\ clear\ air} - A_{rain} - \Delta N_{rain}\ dB$$

Where N = Noise Power

→ The overall C/N is then given by

$$\left(\frac{C}{N}\right)_0 = \frac{1}{\left[\frac{1}{(C/N)_{dn\ rain}} + \frac{1}{(C/N)_{up}}\right]}\ dB.$$

System design for specific performance:

→ A typical two-way satellite communication link consists of four seperate paths.

an outbound uplink path from terminal to the satellite and outbound downlink to the second terminal;
an inbound uplink from second terminal to the satellite; and an inbound downlink to the first terminal

→ DBS-TV system is a one-way system.

Satellite communication Link Design procedure.

→ The design procedure for a one-way satellite communication link involves following 10 steps.

① Determine the frequency band in which the system must operate.

② Determine the communications parameters of the satellite. Estimate any values that are not known.

③ Determine the parameters of the parameters of transmitting and receiving earth stations.

④ Establish an uplink budget and transponder noise power budget to find $(C/N)_{up}$ in the transponder.

⑤ Find the o/p power of transponder based on transponder gain or o/p backoff

⑥ Establish a downlink power and noise budget for the receiving earth station. calculate $(C/N)_{dn}$ and $(C/N)_0$ for a station at the edge of coverage zone (worst case)

(7) Calculate S/N or BER in the baseband channel. Find the link margins.

(8) Evaluate the results and compare with the specification requirements. change parameters of the system as required to obtain the acceptable $(C/N)_0$ or $(S/N)_0$ or BER values.

(9) Determine the propagation conditions under which the link must operate. calculate outage times for the uplinks and down links.

(10) Redesign the system by changing some parameters if the link margins are inadequate. check that all parameters are reasonable, and that the design can be implemented within the expected budget.

(10) → For an EIRP of 100 dBW, a carrier frequency of 10 GHz and the distance between earth-station and satellite is of 36000 km. calculate CNR (carrier to noise Ratio) in 10 MHz bandwidth if the ground station G/T is 20 dB/K.

Assume Boltzman's constant $K = -228.6$ dBJ/K

Sol:- Given EIRP = 100 dBW, $f_c = 10\text{GHz} = 10 \times 10^9$ Hz.

$R = 36{,}000$ km

$G/T = 20$ dB/K $\quad B_n = 10\text{MHz} = 10 \times 10^6$ Hz.

CNR i.e. $\frac{C}{N}$ = EIRP − losses + $\frac{G}{T}$ − k − B_n

B_n in dBHz = $10\log_{10}(10\times10^6)$ = $10\log_{10}10^7$ = 7×10

$\therefore B_n = 70$ dBHz.

Losses = $10\log_{10}\left(\frac{4\pi R}{\lambda}\right)^2$ = 203.53

$\therefore$ CNR = 100 − 203.53 + 20 − (−228.6) − 70

$P_r = \frac{P_t G_t G_r}{\left(\frac{4\pi R}{\lambda}\right)^2}$

$P_n = KT_sB_n$

$\left(\frac{C}{N}\right) = \frac{P_t G_t G_r}{KTB_n}\left(\frac{\lambda}{4\pi R}\right)^2$

$= \frac{P_t G_t}{KB_n}\left(\frac{\lambda}{4\pi R}\right)^2$

CNR = 75.07 dB

(11) → Thermal Noise in an Earthstation receiver results in a $(C/N)_{dn}$ ratio of 20 dB. A signal is received from a bent pipe transponder with a carrier to noise ratio $(C/N)_{up}$ = 20 dB. Find overall $(C/N)_0$ at the earth station. And if the transponder introduces Intermodulation products with (C/I) ratio = 24 dB, what is the overall $(C/N)_0$ ratio at the receiving earth station.

Sol:-

$$\left[\frac{C}{N}\right]_0 = \left[\frac{1}{\frac{1}{(C/N)_{up}} + \frac{1}{(C/N)_{dn}}}\right] = \frac{1}{\frac{1}{100}+\frac{1}{100}} = \frac{1}{0.01+0.01}$$

$$\left[\frac{C}{N}\right]_0 = 50 \text{ or } 17 \text{ dB}$$

→ If Intermodulation products with $\frac{C}{I}$ = 24 dB is considered. Then

$$\left[\frac{C}{N}\right]_0 = \frac{1}{0.01+0.004+0.004} = 41.7 \text{ or } 162.2 \text{ dB}$$

UNIT IV

MULTIPLE ACCESSES:

- Introduction,
- Frequency Division Multiple Accesses (FDMA): Intermediation, Calculation of C/N with intermodulation.
- Time division Multiple Access (TDMA): Bits, Symbols, and Channels, Frame structure. Reference burst and preamble, Guard times,
- Synchronization in TDMA networks, Transmitter power in TDMA networks, Satellite Switched TDMA,
- Onboard processing: Baseband processing transponders,
- Satellite switched TDMA with onboard processing.
- Demand Access Multiple Access (DAMA),
- Code Division Multiple Access (CDMA), Spread spectrum Transmission and reception.

UNIT: IV MULTIPLE ACCESS

→ The ability of the satellite to carry many signals at the same time is called "Multiple Access".

→ The technique in which a single satellite transponder is used by two or more pairs of earth stations at the same time is known as "Multiple Access technique"

→ Multiple Access VS Multiplexing

Multiple Access is the process of carrying different signals.

Multiplexing is the process of combining several signals at only one location (ie earth station)

→ There are three basic forms of Multiple Access techniques.

① FDMA - time is same

② TDMA - frequency is same

③ CDMA - Time and frequency same.

① FDMA: In FDMA all users share the satellite at the same time, but each user transmits at a unique allocated frequency.

ex: Radio broadcasting.

→ FDMA can be used with analog or digital signals.

② TDMA: In TDMA each user is allocated a unique time slot at the satellite so that signals pass through the transponder sequentially. Since TDMA causes delays in transmission, it is used only with digital signals.

③ CDMA: In CDMA all users transmit to the Satellite on the same frequency and at the same time

→ In CDMA, each signal is associated with a particular code that is used to spread the signal in frequency and time.

→ All such coded signals will be received simultaneously at an earth station, by decoding the coded signals.

→ The earth station can recover the desired signal by correlation process.

→ CDMA is a digital technique.

Note: Mobile communication uses both CDMA technology and GSM

In each Multiple Access technique some unique property of the signal (i.e frequency, time or code) is used to label the transmission.

→ signals at one earth station are combined by multiplexing, and then share the satellite transponder with signals from other earth stations by Multiple Access.

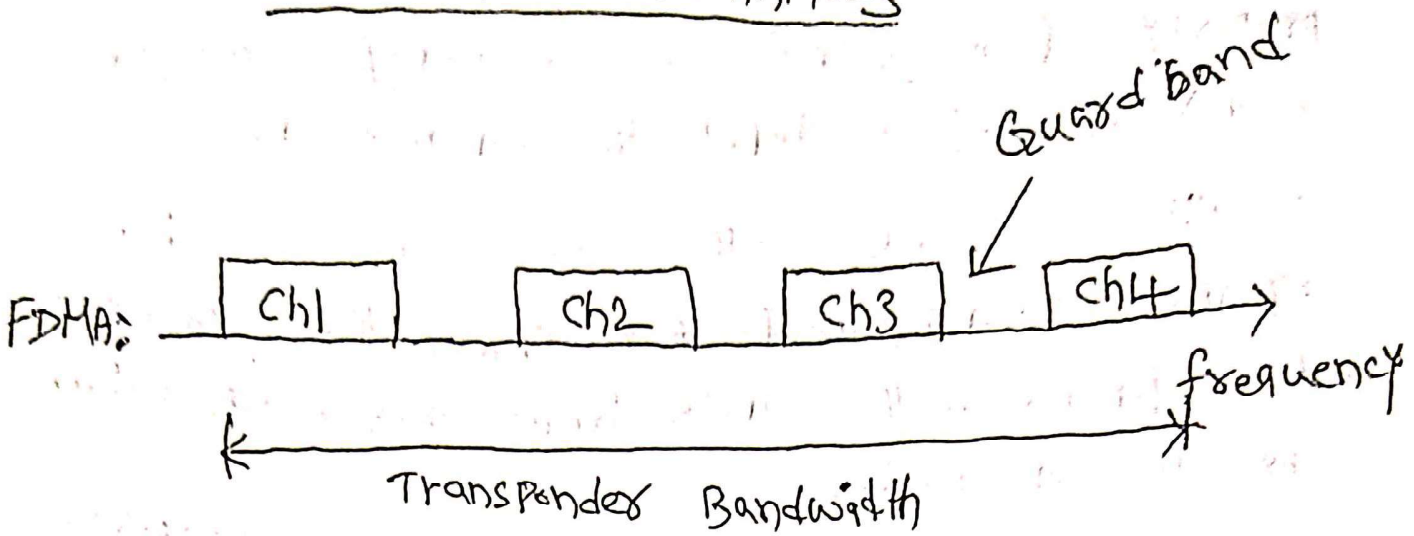
→ In all these earth stations, some resource is shared.

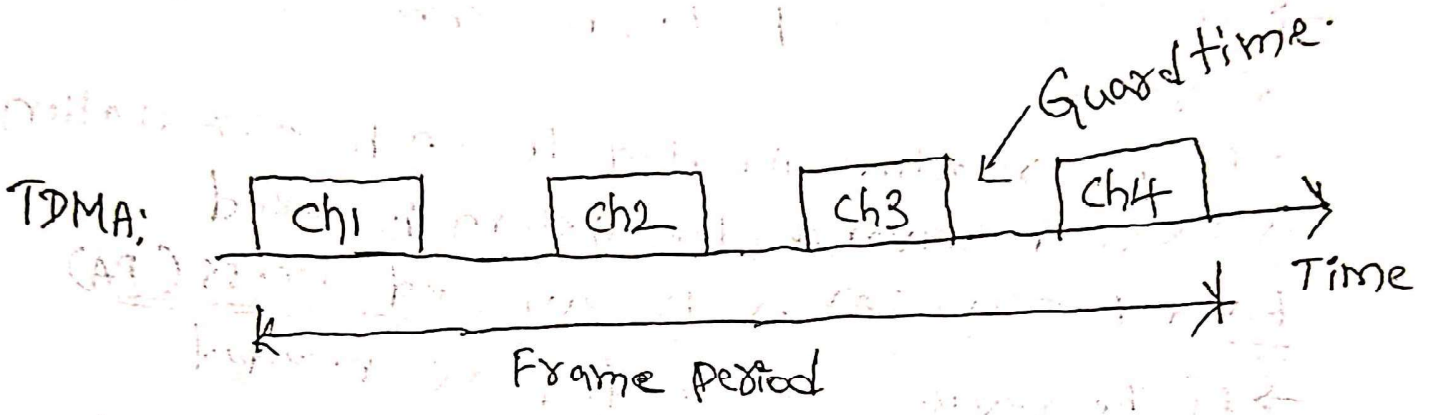
→ If the proportion allocated to each earth station is fixed in advance, the system is called Fixed Access (FA) or Preassigned access (PA)

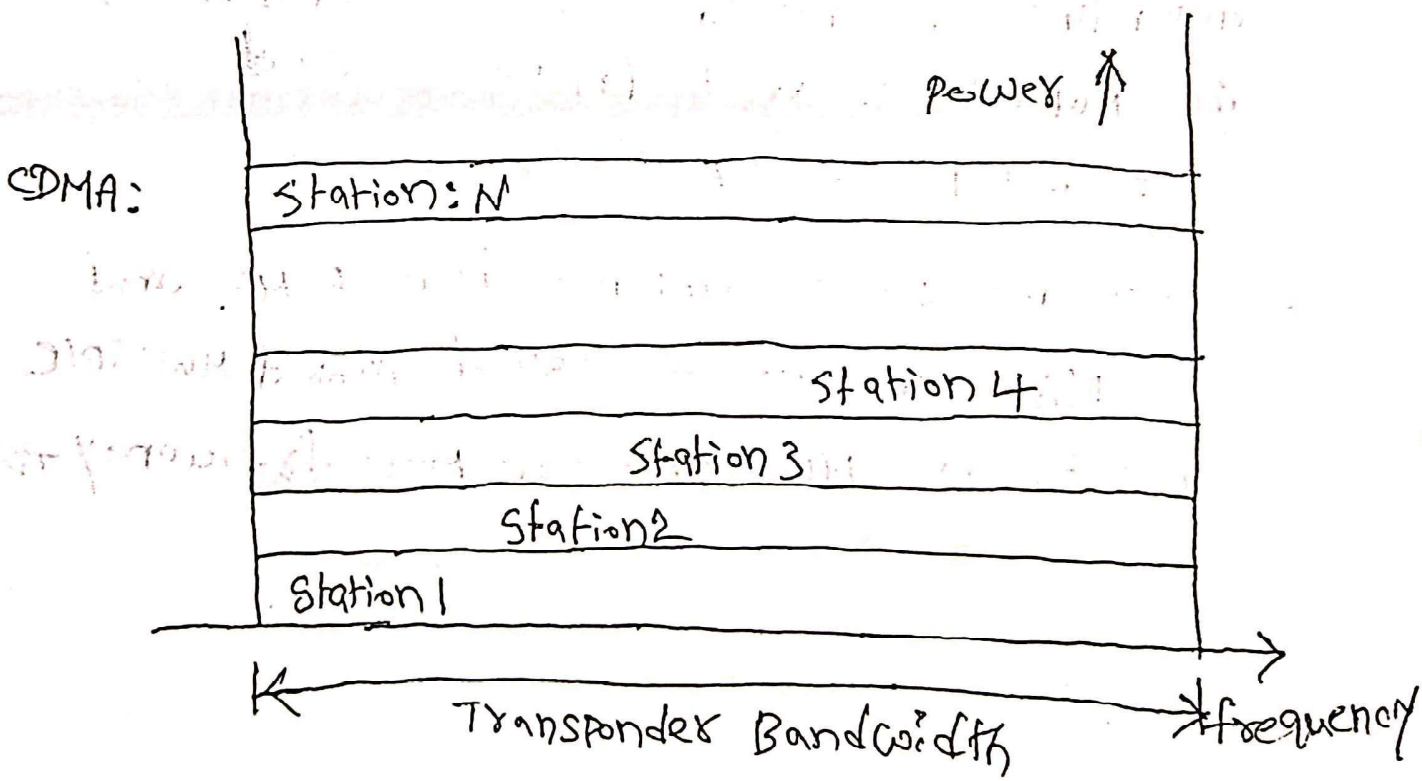
→ If the resource is allocated as needed depending on changing traffic conditions, then the Multiple access technique is called 'Demand Access' (DA)

→ Systems which combines both FDMA and TDMA techniques are called Hybrid Multiple Access or MF-TDMA (i.e Multi frequency TDMA)

Multiple Access Techniques







FDMA:

→ FDMA was the first multiple Access technique used in satellite communication.

→ FDM was the primary method of Multiplexing telephone channels.

→ FDM is based on channel groups.

→ The basic channel is called the voice channel and it has a band width of 4 KHz (0 to 4 KHz).

→ The channel groups are based on multiples of voice channels as shown below.

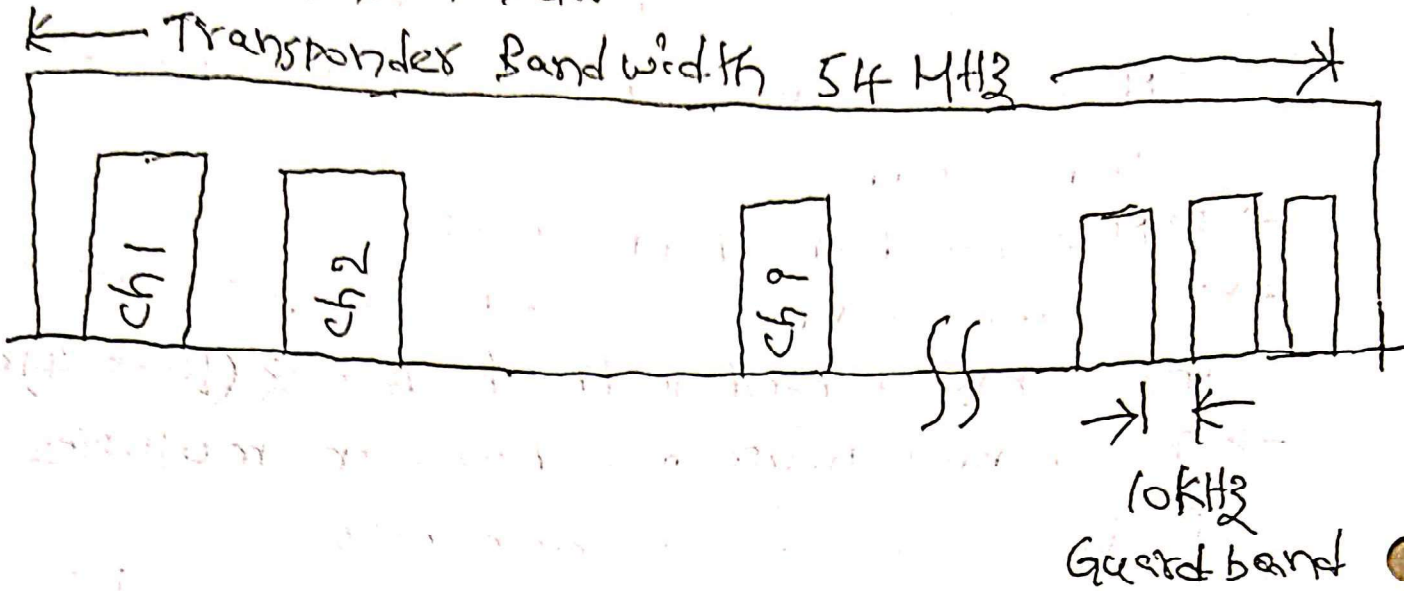
Multiplex Level	Voice circuits (or) voice channels	Frequency Band (KHz)	Bandwidth (KHz)
Voice channel	1	0 – 4	4
Basic Group	12	60 – 108	48
Super group	60	312 – 552	240

→ A Group i.e Basic group is made up of 12 voice channels.

→ A super Group (60 voice channels) is made of 5 basic groups (12 voice channels).

→ FDM was the primary method of Multiplexing telephone channels.

KU band transponder Bandwidth filled with a large number of FDMA-SCPC digital speech channels is shown below



→ RF Bandwidth of each channel is 40 KHz and 10 KHz Guardbands between channels.

→ Main advantage of FDMA is that filters can be used to seperate signals.

→ In FDMA, when an earth station sends one signal on a carrier, then FDMA technique is called "single channel per carrier (SCPC)"

→ when more signals sent on a carrier, that is called "Multiple channels per carrier (MCPC)"

→ FDMA has disadvantage in satellite communication, when the satellite transponder is non linear

→ TWTA (Travelling wave tube Amplifier) is more prone to nonlinear, when compared to solid state HPA (SSHPA)

→ Non linearity of the transponder causes, reduction in $\left(\frac{C}{N}\right)_0$ at earth station receiver when FDMA is used, because IM products are generated in the transponder.

→ some of the IM (InterModulation) products will be with in the transponder bandwidth and leads to interference

Intermodulation:

→ IM products are generated whenever more than one signal is carried by a non linear device.

→ some times filtering can be used to remove the IM products, but if they are with in the bandwidth of transponder, they can not be filtered out

To illustrate the generation of third order IM products, we will model the nonlinear characteristics of transponder HPA with cubic voltage relationship and apply two unmodulated carriers at frequencies f_1 and f_2 at the input of amplifier

$$V_{out} = AV_{in} + b(V_{in})^3$$

$A \gg b$

V_{out} = Amplifier o/p signal voltage

→ The amplifier i/p signal is

$$V_{in} = V_1 \cos\omega_1 t + V_2 \cos\omega_2 t$$

$$\therefore V_{out} = AV_1\cos\omega_1 t + AV_2\cos\omega_2 t + b\left[V_1\cos\omega_1 t + V_2\cos\omega_2 t\right]^3$$

$$V_{out} = \underbrace{AV_1\cos\omega_1 t + AV_2\cos\omega_2 t}_{\text{linear term}} + \underbrace{b\left[V_1\cos\omega_1 t + V_2\cos\omega_2 t\right]^3}_{\text{cubic term}}$$

→ The linear term in the above equation simply amplifies the input signal by a voltage gain "A". so with these frequency no interference (intermodulation products) occur

Now the cubic ~~fac~~ term is given by

$$V_{3out} = b\left[V_1\cos\omega_1 t + V_2\cos\omega_2 t\right]^3$$

$$V_{3out} = b\left[V_1^3\cos^3\omega_1 t + V_2^3\cos^3\omega_2 t + 3V_1^2\cos^2\omega_1 t\, V_2\cos\omega_2 t + 3V_2^2\cos^2\omega_2 t\, V_1\cos\omega_1 t\right]$$

Note: The Magnitude of IM products depends on parameter 'b', which describes the nonlinearity of transponder

⇒ The third order IM frequency components ~~are~~ in the above equation are

Note: $\cos^2 a = \frac{1}{2}(\cos 2a + 1)$

$$V_{IM} = bV_1^2 \times V_2\left[\cos\omega_2 t \times \left(\tfrac{1}{2}(\cos 2\omega_1 t + 1)\right)\right] + bV_2^2 \times V_1\left[\cos\omega_1 t \times \left(\tfrac{1}{2}(\cos 2\omega_2 t + 1)\right)\right]$$

Note: Neglect $\frac{1}{2}$ terms in above equation because our interest is on frequency not on amplitude of signal

$\frac{1}{2}$ is amplitude

$$\therefore V_{IM} = bV_1^2 \times V_2\left[\cos\omega_2 t \cos 2\omega_1 t + \cos\omega_2 t\right] + bV_2^2 \times V_1\left[\cos\omega_1 t \cos 2\omega_2 t + \cos\omega_1 t\right]$$

① ②

→ In the above equation $\cos \omega_2 t$ and $\cos \omega_1 t$ terms have frequencies f_2 and f_1. These frequencies add to wanted output of amplifier. So with these frequency terms, there is no IM product.

→ So third order IM products are generated by $f_2 \times 2f_1$ and $f_1 \times 2f_2$ terms in the above equation

Note: $\cos a \cos b = \cos(a+b) + \cos(a-b)$

∴ Third order products are

$$V'_{IM} = b v_1^2 \times V_2 \left[\cos(2\omega_1 t + \omega_2 t) + \cos(2\omega_1 t - \omega_2 t)\right]$$

$$+ b V_2^2 \times V_1 \left[\cos(2\omega_2 t + \omega_1 t) + \cos(2\omega_2 t - \omega_1 t)\right]$$

→ One can filter out sum terms in the above equation [i.e $\cos(2\omega_1 t + \omega_2 t)$ and $\cos(2\omega_2 t + \omega_1 t)$]

But the difference terms with frequencies $2f_1 - f_2$ and $2f_2 - f_1$ may fall with in the transponder bandwidth

Note: $2f_1 - f_2$ means $\cos(2\omega_1 t - \omega_2 t)$ ($f_1 - f_2$) and $\cos(2\omega_2 t - \omega_1 t)$ ($f_2 \; f_1$) means $2f_2 - f_1$ in the above equation

→ The interference problem i.e IM products will not produce if the frequency components will not fall with in the transponder bandwidth. IM products will develop only with frequencies, that fall with in transponder bandwidth.

→ Hence the two terms in the above equation i.e $2f_1 - f_2$ in $\cos(2\omega_1 t - \omega_2 t)$ and $2f_2 - f_1$ in $\cos(2\omega_2 t - \omega_1 t)$ are known as third-order IM products of HPA

∴ Third order IM products are given by

$$V_{3IM} = bV_1^2 V_2 \cos(2\omega_1 t - \omega_2 t) + bV_2^2 V_1 \cos(2\omega_2 t - \omega_1 t)$$

→ In the above equation, the magnitudes of IM products depends on the parameter 'b', which describes the non linearity of transponder.

→ The wanted output from the amplifier is

$$V_{out} = AV_1 \cos\omega_1 t + AV_2 \cos\omega_2 t$$

→ The total power of the wanted output from HPA, referenced to 1 ohm load is

$P_{out} = A^2 (P_1 + P_2)$ Watts

P_1 and P_2 are power levels of wanted signals.

→ The power of IM products at the output of HPA is

$$P_{IM} = b^2 (P_1^3 + P_2^3) \text{ watts}$$

→ As the nonlinearity of the amplifier increases (i.e with larger b/A ratio), the IM products becomes large.

→ It can be seen that IM products increase in proportion to the cubes of signal powers

Calculation of C/N with Intermodulation:-

(7)

Intermodulation between carriers in a non-linear transponder adds unwanted products into the transponder bandwidth that are treated as the interference called "Guassian noise"

The output-back off of a transponder reduces the output power level of all carriers, which therefore reduces the (C/N) ratio in the transponder. The transponder C/N ratio appears as $(C/N)_{up}$ in the calculation of the overall $(C/N)_0$ ratio in the earth station receiver. IM noise in the transponder is defined by another (C/N) ratio, $(C/N)_{IM}$

$$\left[\frac{C}{N}\right]_0 = \frac{1}{\left[\frac{1}{(C/N)_{up}} + \frac{1}{(C/N)_{dn}} + \frac{1}{(C/N)_{IM}}\right]}$$

Time Division Multiple Access (TDMA) :-

* In TDMA, all earth stations will be allocated a unique time ~~slot~~ slot.
* In TDMA, a number of earth stations transmits bursts of RF signals, through a transponder.

Note: burst = large data

* TDMA systems are digital, it has advantages over FDMA
* TDMA ~~systems~~ signals are digital and can be devided by time.
* Hence TDMA systems are easily reconfigured for changing traffic demands, are resistant to noise and interference.
* one major advantage of TDMA is only one signal is present in the satellite transponder at one time.
* All earth stations should send high bit rate (data bursts) to the satellite transponder, hence earth station

transmitters require high transmitter power.

* TDMA is not suited for narrow band signals.
* Non linearity in the transponder in TDMA, ~~(illegible)~~ causes ISI (Inter symbol interference)

* Data bursts of different earth stations arrive sequentially at transponder.
* The frame has a length from 125 μs to many milliseconds.
* Each earth station must know exactly when to transmit (with in milliseconds), so that RF bursts arriving at satellite, from different earth stations don't overlap - For this synchronization among earth stations is needed.
* A time overlap of two RF signals is called "collision". It results data loss.

* A receiving earth station must synchronize its receiver to each of the sequential burst.

* BPSK or QPSK modulation is used in TDMA Technique.

Bits, symbols, and channels:-

→ A bit is a fundamental unit in the digital transmission. [bit '0' or '1']

→ bit stream is described by its 'bit rate'

i.e bps (bits per second)

or Kbps, Mbps

→ Bit stream must be modulated onto a RF carrier for transmission to the satellite. Generally PSK modulation is used.

→ In BPSK, the logical data states of bits '1', and '0' are converted into two opposite phase states of RF carrier

i.e 0° for bit '1'

180° for bit '0'

→ In QPSK, two bits at a time are converted into one of the four Phase states of RF carrier

→ The state of RF carrier is called a "symbol"

→ symbol rate is in units of bauds, or symbols per second

→ For BPSK, bit rate = baud rate

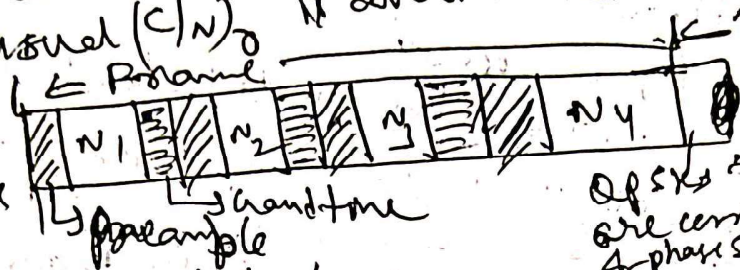
→ For QPSK, bit rate = 2 (baud rate)

→ To find Bandwidth of RF signal, symbol rate is used.

→ Some times, QAM Modulation is used to achieve high overall C/N. i.e high $(C/N)_o$

Bits & pieces

→ Digital data is broken down into bits
→ Symbols are representations of data in a bit
→ Bit rate = no. of bits transferred / sec
→ Baud rate = no. of symbols transferred
→ " determines B.W of a signal
→ QAM can be used for transmission, if a higher than usual $(C/N)_0$ is available.



BPSK → 1 & 0 are converted into two opposite phase states of RF carrier 0° & 180°.

QPSK → two bits at a time are converted into one of 4 phase states of RF carrier $-\frac{\pi}{4}, \frac{3\pi}{4}, \frac{5\pi}{4}, \frac{7\pi}{4}$

Bursting with data:

→ Data in TDMA n/w is sent as bursts
→ proper synchronization of bursts is required for it to be framed properly
→ A master station transmits a ref burst on which rest of the ESS start transmitting
→ Each frame has one, & its preamble, of the incoming data traffic.
→ Reducing this overhead can improve efficiency

$1 - \frac{\text{overhead bits}}{\text{Total bits}}$ (or) $\frac{\text{traffic bits}}{\text{Total bits}}$

Guardians

→ Guard times small empty slots b/n traffic. They are important to avoid crashing of multiple data bits
→ If collision occurs, multiple data is lost
→ Longer guard times can effect efficiency, but improve reliability & safety
→ typical guard times range from 1-5 μs

digital speech channel requires a continuous bit rate of

r_{sp} → Serial transmission at a rate

R_b → Transmitted bit rate at TDMA sym

$$T_d = \frac{T_{frame} - N(t_g + t_{pre})}{N}$$

$$C_b = \frac{T_{frame} - N(t_g + t_{pre})}{N} \times \frac{R_b}{T_{frame}}$$

$$n = \frac{T_{frame} - N(t_g + t_{pre})}{N} \times \frac{R_b}{T_{frame} \times r_{sp}}$$

Reference burst

→ A " is a preamble followed by no traffic bits

→ In some systems, a separate ref burst may be transmitted by one of the stations designated as master station.

Synchronization

* Each E.S operating in a TDMA n/w must transmit their RF bursts at precisely controlled times such that bursts from each of ES's arrive at sat in correct sequence.

→ one station is designated as the master station, & may generate a ref burst to mark the start of the frame (SOTF → start of transmit frame)

→ Each of station within the n/w has a time slot within the frame & must maintain its transmission within that timeslot.

→ There are guard times at either end of each station's burst, which define the accuracy that burst timing must achieve

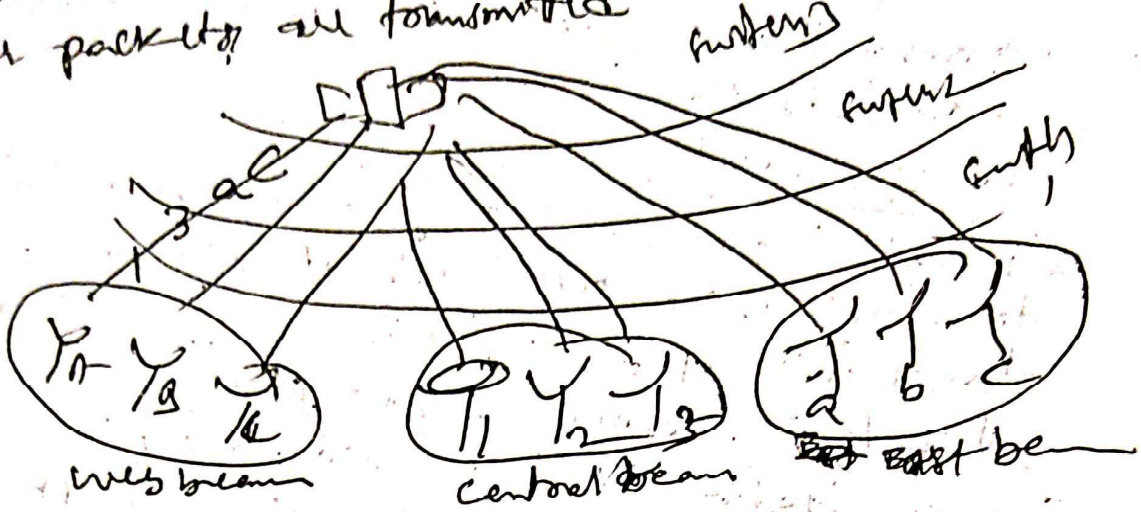
Sat Switched TDMA

→ Instead of using single antenna beam to maintain continuous communication with its entire coverage zone, the sat has no. of narrow antenna beams that can be used sequentially to cover the zone

→ A narrow antenna beam has a higher gain than broad beam, which increases sat EIRP & therefore increases capacity of downlink.

→ uplink signals received by sat are demodulated to recover the bit streams, which are switched as sequence of packets are addressed to different receiving ES's.

→ Sat creates TDMA frames of data that contain packets addressed to specific E.S.S, & switches its transit beams to the direction of receiving E.S as packets are transmitted



Adv

→ Flexible bit rate
→ No freq guadbands
→ Extended battery life
→ No need of precise narrowband filters
→ Cost effective technology

disadv

→ Requires timing synchronization
→ Demand high peak power on uplink

onboard processing

→ Generally sat use bent pipe tr which simply amplifies a signal received from E.S & retransmits it back to E.S.
→ The disadv of bent pipe tr is that is not well suited to uplinks from small E.S.S, especially in Ka band
→ The solution is baseband processing tr or onboard processing

Baseband processing tr

→ It has a Rx & Tx similar to those found in an E.S
→ The Rxed signal from uplink is connected to an IF & demodulated to recover the baseband signal, which is then processed
→ The baseband signal is modulated onto a carrier at downlink freq & fixed back to earth
→ The adv of this process is that uplink & downlink signal format need not to be the same & (L/N) of uplink & downlink are not tied together through reciprocal formula
→ Separation of uplink & downlink signals allows different modulation methods to be used, as well as flexible error correction codes.

CDMA is transmitted in short bursts ...

→ All users can use whole B.W, all the time

→ The data need not be synched or be filtered

→ It can allow users with more needs utilize the B.W more, while conserving it when idled

→ ~~The~~ Transmission times or frequencies are irrelevant here, & there is hardly any spectrum allocation.

→ Currently used method is D.S.S.S.

→ It is a scheme in which no of users can occupy all of the tr. B.W all of the time.

→ CDMA signals are encoded such that information from an individual transmitter can be recovered by a receiving station that knows the the code being used.

→ Each Rxing station is allocated a CDMA code, any traxing station that wants to send data to E.S must use the correct code.

→ CDMA codes are typically 16-bits to many thousand of bits in length, & bits of a CDMA are called chips

How it works

→ Any E.S can code their data based on a CDMA code, obeying a set of rules defined by an organization

→ This code can be 16-bits to several thousand bits long

→ Since multiple stations can saturate the B.W without much effort, this sym is highly efficient.

→ The Rx needs the same code used by the Transmitter

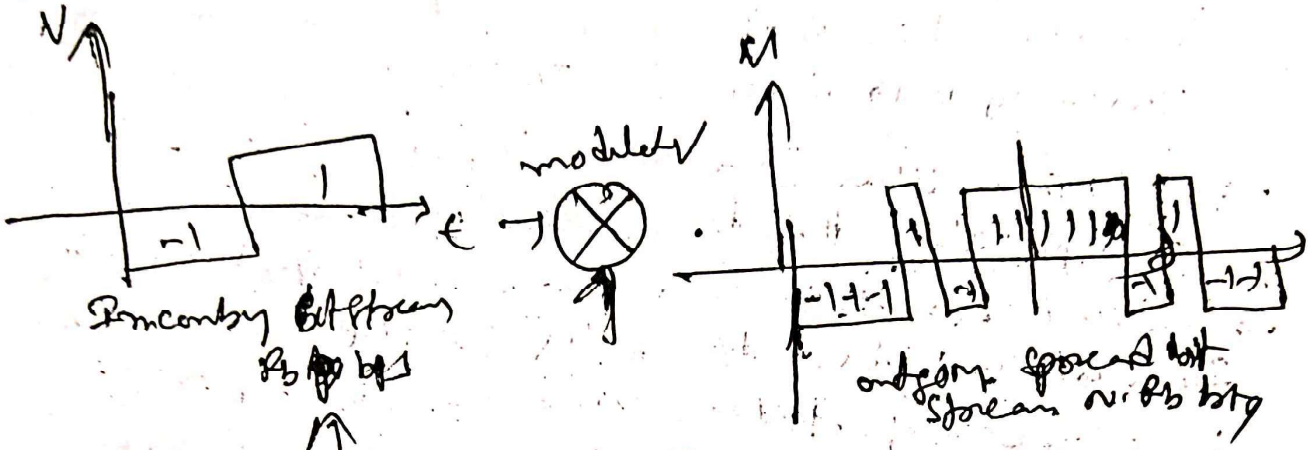
→ CDMA chip seq modulates the data bits of original msg &
Chip rate is always much > data rate



This greatly increases the speed of digital transmission.

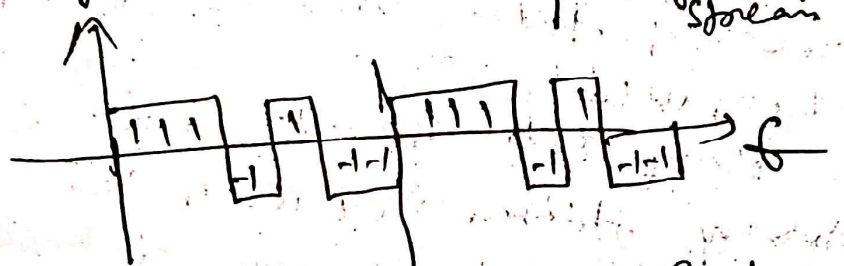
→ CDMA is also known as spread spectrum.

→ D.S.S.S is the only current type used in SC

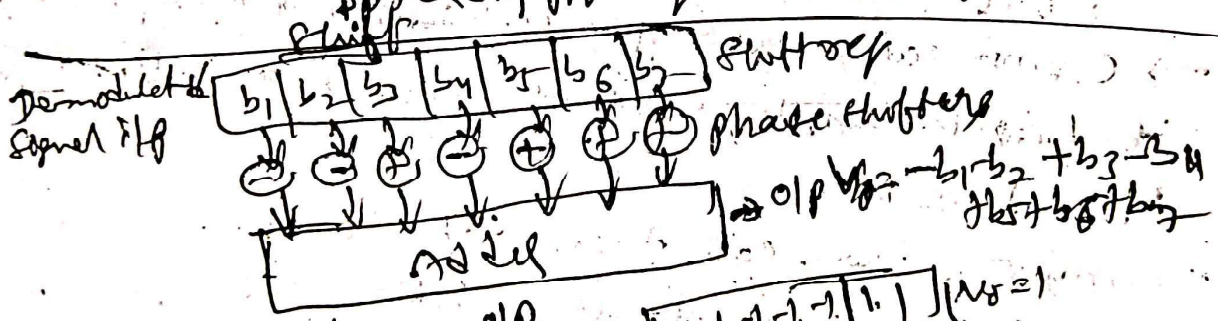


Incoming bit stream Rb bps

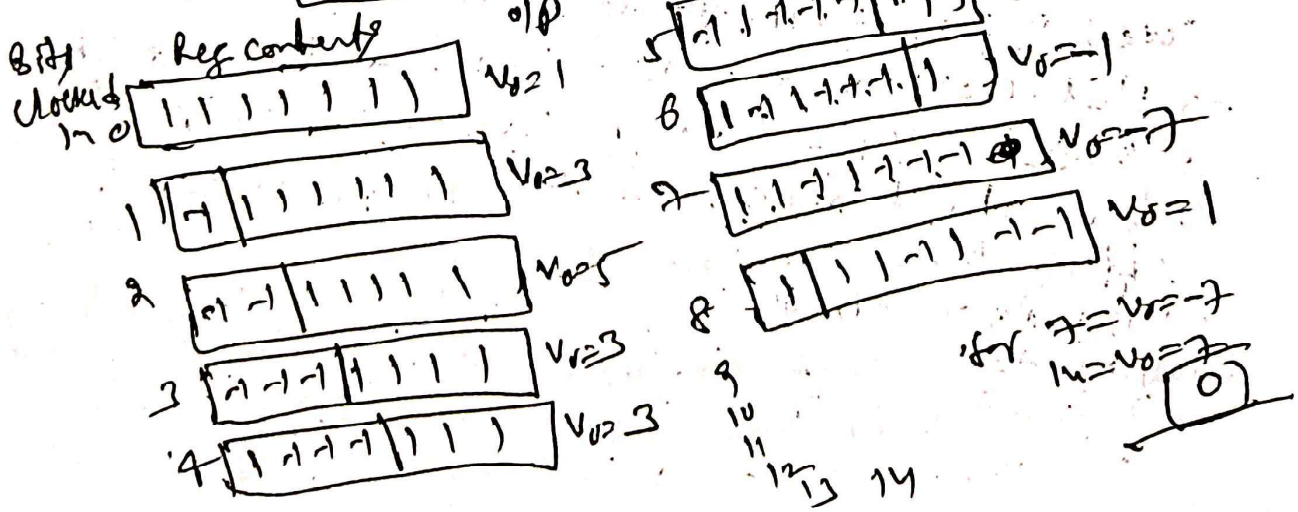
outgoing spread bit stream N.Rb bps



Spreading pn sequence N.Rb bps.



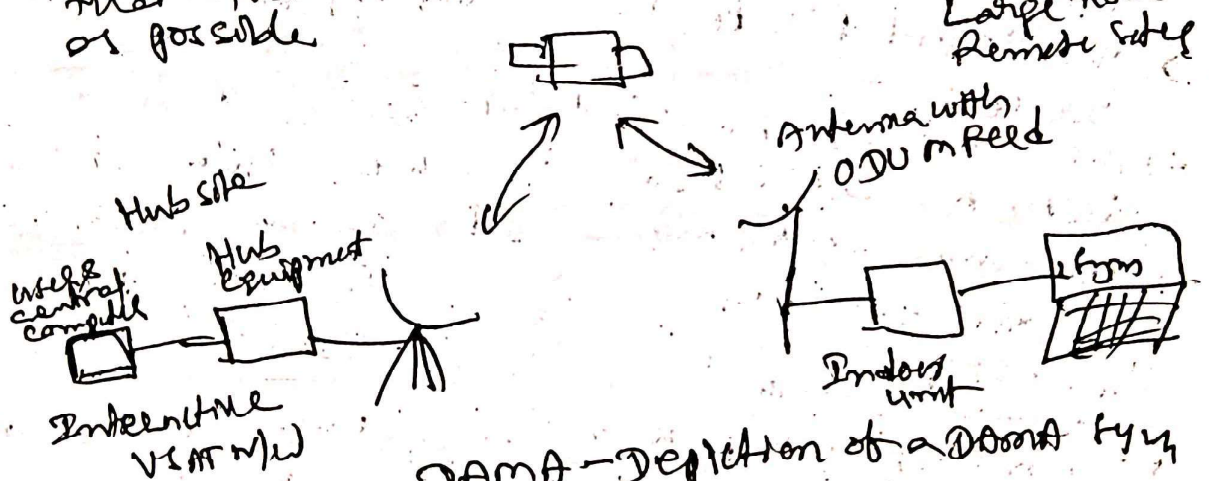
→ o/p $V_0 = -b_1 - b_2 + b_3 - b_4 + b_5 + b_6 + b_7$



Demand Assigned MA (DAMA)

→ This technique is used when link b/n station & sat is not a constant one.
→ This helps assign B.W according to demand.
→ This can be implemented on TDMA (or) as a combination with FDMA & TDMA
→ Commonly used in VSAT (very small aperture terminal) sym

→ DAMA can be used in any S.C link where traffic from an E.S. is intermittent.
→ D.A allows a sat channel to be allocated to a user on demand, rather than continuously, which greatly increases the no. of simultaneous users who can served by the sym.
→ most SCPC-FDMA sym uses D.A to ensure that the available B.W in a tr is used as fully as possible



DAMA - Depiction of a DAMA sym

How it works

→ There are two different types of channels in DAMA
① Common signalling channel (CSC)
② Communication channel (CC) (or) comm N/W
→ A user wishes to enter CC 1st calls the controlling E.S using CSC & then controller allocates a pair of channels to that user
→ Bent pipe transponders then accept the data & retransmits
→ Receivers should listen in sync continuously to retrieve the data.
→ CSC is operated in RA mode
CSC are located at ends of the tr-B.W.

→ When E.S wants to access the sat, it transmits a control packet to sat on the CSC freq & waits for a reply.

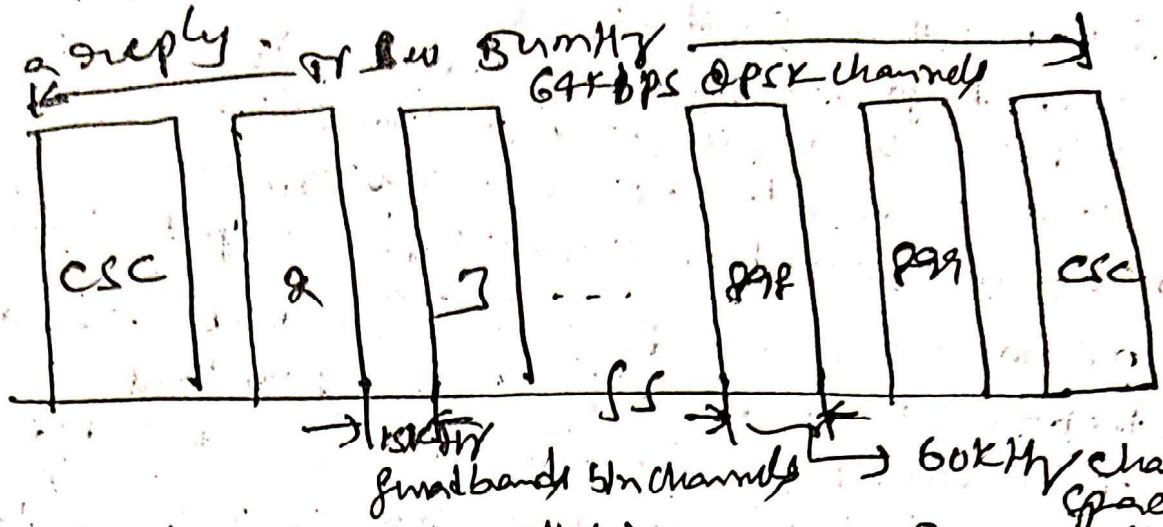


fig: Freq plan for a 54 MHz for carrying 900 DA channels. Each ch has occupied B.W. of 45KHz & carries one 64KBPS signal. ch 1 & ch 900 are CSC's used by demand assignment sym to set up access to the other 898 channels.

→ The control packet is received by hub E.S & decoded.

→ The control packet contains source address & destination address, also it includes ~~other~~ CRC.

→ The control station measures duration of the connection in ~~order~~ order to ~~generate~~ generate billing data.

When it is used

→ DAMA is used in military environments due due to the relative simplicity of implementation & ease of modeling.

→ It can operate with bent pipe transponders & thus requires no security on sat side

→ The master & slave stations can upgrade compressions without expensive sat ~~replacements~~ replacements

UNIT V

DIRECT BROADCAST SATELLITE TELIVISION AND RADIO:

- C band and Ku band home satellite TV,
- Digital DBS TV,
- DBS-TV link budget,
- Master control station and uplink,
- Installation of DBS TV antennas,
- Satellite radio broadcasting.

UNIT-V : DBS-TV

(1)

* DBS refers to satellite television(TV) sym in which the subscribers, or end users, receive signals directly from geostationary satellites.
* signals are broadcast in digital format at microwave frequencies.
* DBS is the descendant of direct-to-home(DTH) Sat services
* A DBS subscriber installation consists of a dish antenna, 2 to 3 feet (60 to 90 cm) in diameter, a conventional TV set, a signal converter placed next to TV set, and a length of coaxial cable b/n dish & converter.
The dish intercepts M wave signals directly from sat. The converter produces o/p that can be viewed on TV receiver.
* A no. of companies provide DBS & DTH service throughout the world. In united states, Direct TV & Echostar are main vendors. Both of these corporations also provide Sat internet service, which can be purchased for a monthly fee in addition to, or instead DBS TV service.
* Sat Band TV & Internet services are popular in rural areas where conventional cable service is not available.
* DBS TV is also favored by urban & suburban subscribers who are not satisfied with quality or quality of TV programming available on conventional cable.

The 1st time that a GEO sat was used extensively for video transmission was for the Tokyo olympic games in 1968, which were broadcast live in the united states using a link through an early Intelsat sat over the pacific ocean.

* Satellites are a very effective way to distribute wideband signals & there was a rapid growth in use of C-band transponders for video signals, using FM & one transponder for each video signal
* Ku-band satellites & compressed digital video signals followed, making it possible to transmit several video signals through one transponder, with corresponding savings in transmission costs.

* Fig ① shows earth station complex at Virginia Tech, in Blacksburg, Virginia, which is equipped to uplink analog & digital video signals for distribution to educational institutions.

⇒ * The large Antenna is a 9cm C-band cassegrain antenna used to transmit analog video FM-TV C-band signals to a domestic satellite.

The antenna is equipped with two 3kW C-Band transmitters connected to orthogonal polarization ports on antenna feed allowing simultaneous transmission of two video signals to two orthogonally polarized transponders on sat.

⇒ The smaller antenna is a 5.5m Ku-band cassegrain uplink antenna used to transmit multiple digital compressed video signals.

⇒ The Antenna at right is a simulsat antenna. The reflector is a paraboloc torcus antenna aligned with the GEO arc & has 7-feeds. Each feed illuminates a section of the reflector which approximates a paraboloid.



- video distribution & direct broadcast television (DBS-TV) have become a major source of revenue for the sat. communications industry.
- The rapid growth of digital DBS-TV may increase the % of industry's revenues that come from video services even further during the 1st decade of 2000's.
- In 2001, 2 direct broadcast sat-radio services began operation in the united states using S-band. Repeaters are used in city areas to overcome the problem of sat visibility around tall buildings.

C-Band & KU-Band Home Sat. TV:-

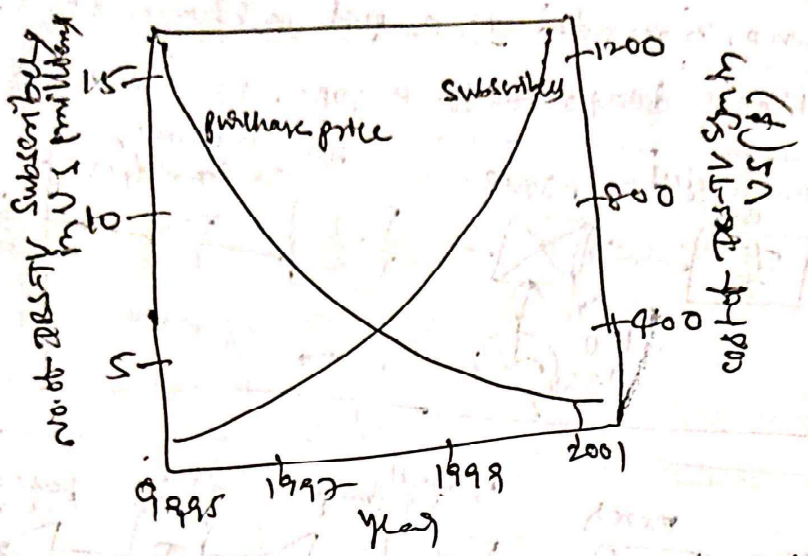
- In early 1980s, the development of low-noise GaAs FET amplifiers for C-band, and improved threshold extension demodulators for video signal receivers, allowed much smaller diameter antennas to be used to receive C-band FM video signals distributed through CBO satellites.
- A market rapidly developed in US for home satellite TV systems using 3m & 3.6m dish antennas (10 ft & 12 ft diameter) & set top receivers, that could receive video signals from domestic CBO satellites,
- At that time, signals were not scrambled, so owners of satellite dishes could receive a wide range of TV programming free of charge.
- An estimated 4 to 5 million C-band & KU-band FM sat. TV systems were sold in US by the time that KU-band direct broadcast Sat TV arrived in 1990s, using digital transmission & 0.5m dishes
- DSB-TV originally started in Europe & US in 1980s using analog FM transmission in KU-band.
- Sat TV was much more successful in Europe than in US in 198

* The market for DBS-TV Syms. grew slowly in 1980s, & then they rapidly after the introduction of high capacity digital DBS-TV satellites in the 1990s.

Digital DBS TV:

* In 1990s, digital video transmission became feasible, & several Syms were developed in US in 12.2 to 12.7 GHz band allocated to DBS-TV service.
* The development of low cost Ku-band antennas & receivers, and high-speed digital Integrated circuits specifically for DBS-TV that incorporate QPSK demodulation, error control, decryption, and MPEG decoding made DBS-TV practical.
* The DSP is incorporated in a single IC that implements the digital video standard used by all the DBS-TV systems, DBS-D.
* Direct TV, a fully digital DBS-TV sys owned by Hughes Electronics corporation, began limited service in 1994 with a single GEO Sat at 101° W Longitude.
* The 1st sat, called DBS-1, was launched in Dec-1993, & was followed by 2-more satellites, DBS-2 & DBS-3 in 1994 & 1995.
* A 4th Sat was added in 1999,
  5th " launched in 2000 with a transmit antenna capable of providing spot beams, using locations of 101° W & 109° W.
* The EchoStar communications corporation started service with its DTH network in Mar-1996 with a single Sat at 119° W.
* In 2001 there were 6-EchoStar Sat's in orbit, at longitudes 61.5° W, 119° W & 110° W. DTH n/w had 5-million Customers. Ref Table.

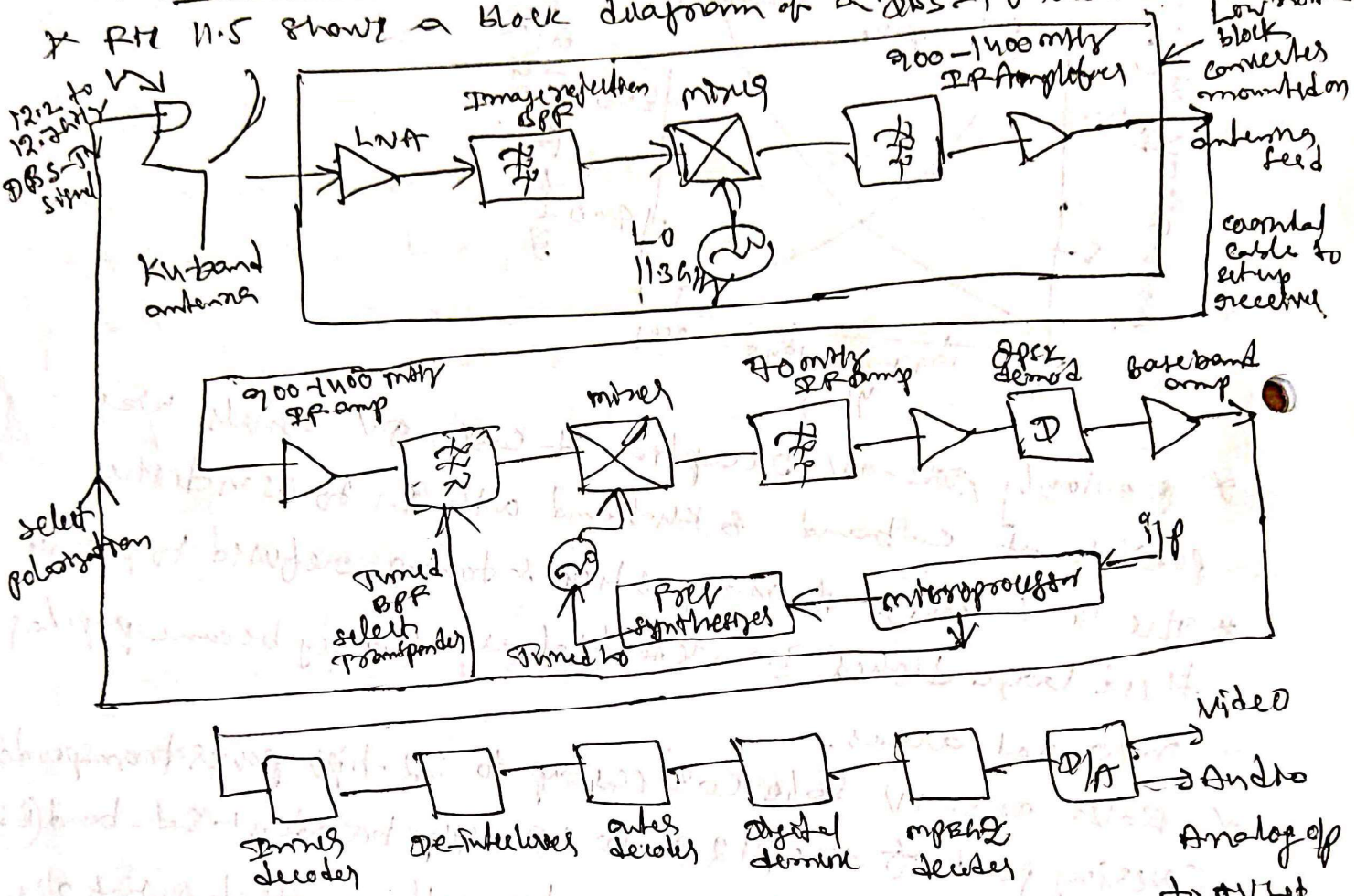
Fig ① shows rapid growth in subscribers to DBS-TV syst.



* previously, DBS-TV reception of cable TV signals was possible at c-band & Ku-band with 2.5 to 3.5 m dishes.
* the local govts of many cities & towns refused to permit these large dishes in residential areas, they became popular in rural areas.
* Each DBS-TV Sate. carries up to 32 high-power transponders covering part of the 12.2 to 12.7 GHz broadcast sat band (BSS).
* DBS-TV receiving antennas are typically an offset parabolic reflector design with the feed below the antenna aperture.

* A direct TV receiving antenna mounted on the wall of a house is shown in fig 11.4a. &
a dish-network antenna mounted on a post is shown fig 11.4b

* Fig 11.5 shows a block diagram of a DBS-TV receiver.



* The entire front-end of the receiver is located at the antenna feed in the form of an LNB (low noise block) to minimize loss of signal & hence to maintain lowest possible system noise temperature.
* The electronic polarizer is switched by changing the voltage supplied to the LNB via cable that interconnects the antenna & set-top receiver
* The entire 12.2 – 12.7 GHz band is down converted by the LNB to the 900 – 1400 MHz, where cable losses are much lower than at Ku band.

* The down converter consists of a dielectric resonator local oscillator and mixer, followed by an RF amplifier & band-pass filter.
* The high gain LNB can drive 100 m of coaxial cable without any reduction in signal quality.
* Where longer cable runs are needed, amplifiers for the 900-1400 MHz band can be used to boost the signal strength.
* The set-top box accepts the entire 500 MHz band & seperates out the individual transponder frequencies. Any one of these frequencies can be selected on demand by the user.
* The user enters a desired channel number into the set-top box using an IR remote control, eg. channel 362, which is converted via a stored look-up table in the receiver to an RF channel freq & polarization.
* The signal from the required transponder is then selected by the receiver by setting the correct polarization at the antenna & tuning the set-top LO to the appropriate RF channel freq.
* The QPSK signal is then demodulated. The result is a multiplexed bit stream, typically at a bit rate upto 40 mbps, which contains the bits for channel 362 & several other video signals.
* The bit stream is encrypted and contains error control coding bits & data bits.
* The bit stream is processed to correct & detect errors, de-interleaved, and decrypted.
* A digital demux then extracts the bits for the wanted channel 362 in this example, a MPEG 2 decoder and finally generates analog video & audio signals with D/A converters to drive TV set.

* The look-up table in the receiver that relates channel numbers to frequencies, polarizations, and instructions for the IRD demux is downloaded from the Sat on a regular schedule.
* The Sat is also used to address individual receivers and to load another look-up table that specifies which channels the user is authorized to receive.
* If user fails to pay, disconnected for failure.
* pay per view channels are handled differently from broadcast channels.
* The customer own the DBS-TV receiving equipment & is responsible for its maintenance, so there are no service calls by Sat-TV providers.

master control station & uplinks.

* DBS TV satellites are relay devices that provide a very large coverage area serving millions of customers.
* the many signals that are broadcast by satellites are collected at a master control station & uplinked to the satellites by a group of large antennas with fade margins subsequent to overcome any expected rain fade.
* the video & audio signals that are uplinked to the DBS-TV satellites are available in prerecorded form on video tape or disc, or are collected from other satellites or fiber-optic lines.
* This is a large operation which requires substantial resources & a stable labor force.
* Fig ① shows the master control station of DISH network sys operated by Echostar communications corporation. the location is in U.S
* The uplink station must transmit 100's of signals to the DBS-TV satellites 24 h a day, 365 days a year.
* most of the signals are prerecorded, either from sat feeds which are used to distribute new video & audio program material, or from archived material.
* The uplink stations have 100's of tape & video disc players, all under computer control, which supply the video & audio signals for each channel.
* the signals are mainly stored in digital form, allowing direct multiplexing into bit streams for the individual transponders.

→ Analog signals must be digitized & compressed before being multiplexed with other signals into the bit streams that are sent to each transponder.

* A simplified block diagram of the transmitting equipment at an uplink station is shown in fig.

* one uplink antenna will typically transmit up to 16 RF channels to one DBS-TV sat.

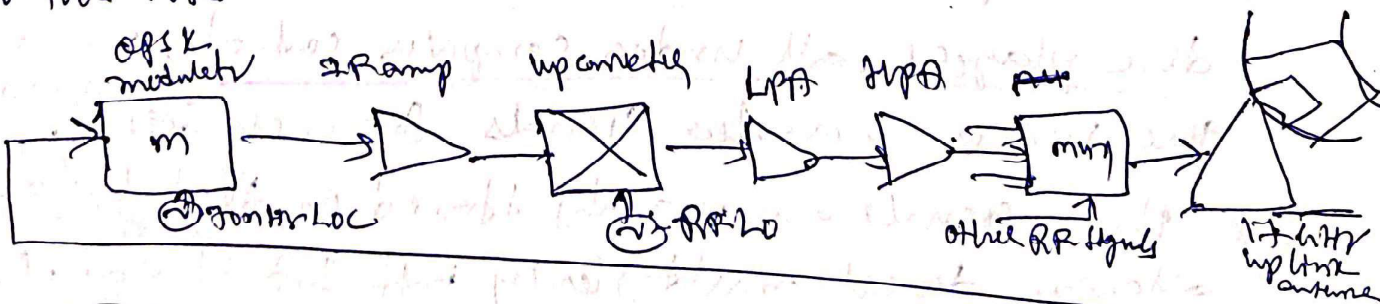
* Each RF signal is a dpsk modulated Ku-band carriers with a symbol rate of up to 20Mbps, occupying a B.W up to 27MHz.

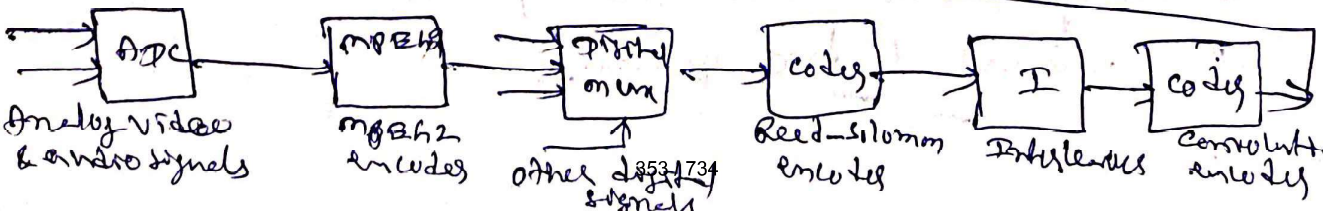
* The encoded, compressed, & multiplexed bit stream drives a video exciter which generates QPSK modulation at an intermediate freq carrier, typically at 70MHz.

* The 70MHz signal is upconverted to the transponder i/p freq in the transmitter, which contains a TWT-HPA.

* The HPA is usually rated at a much higher power than its normal operating o/p power level, which provides sufficient o/p backoff of the HPA to ensure linear operation.

* The signals from any no. of HPAs are multiplexed together in microwave combiner & sent to antenna feed for transmission to the sat.





DBS-TV-Link Budget:

A representative link budget for a GBO DBS-TV sys serving the United States is shown in Eg. Table

Table: Link Budget for Ku-band DBS-TV receives

Downlink power budget	
Transponder o/p power, 160W	22.0 dBW
Antenna beam onaxis gain	36.5 dB
Path loss at 12.2GHz, 38,500km path	-205.9 dB
Rcvg antenna gain on axis	33.5 dB
Beam contour loss	-3.0 dB
Miscellaneous & gaseous attenuation losses	-0.8 dB
Received power, C	-117.7 dBW
Noise power budget	
Boltzmann's constant, K	-228.6 dBW/K/Hz
Sys noise temp, clear air, 145K	21.6 dBK
Receiver noise BW, 20MHz	73.0 dBHz
Noise power, N	-134.0 dBW
C/N in clear air	16.3 dB
Link margin over 8.6-dB threshold	7.7 dB
Link availability throughout U.S	Better than 99.97%

* path length of 38,500km is max-expected path length for a receiver in U.S & a sat at longitude 101°W.
* The threshold $\frac{C}{N}$ value is set at 8.6 dB, corresponding to a sys using QPSK with an implementation margin of 0.8dB, forward error correction coding that produces 6dB of coding gain, & a max BER of 10^{-6}.
* This requires a clear air C/N ratio in the DBS-TV receiver of 8.6 + 5.7 = 14.3 dB in clear air.

1) Link margin gain of 7.7 dB is achieved for a receiver located on the -3 dB contour of sat antenna beam.
→ Earth stations close to the -6 dB contours of the sat beam have a link margin of 4.7 dB.
→ A receiver located in SE States of US, within -2 dB contours of sat beam, has a link margin of 2.7 dB.

2) Transponder o/p power is 160 W, corresponding to a to 4 with a saturated o/p power of 200 W & 1 dB output backoff.
• A small amount of o/p backoff is normally used to avoid excessive AM-PM & PM-AM conversion in transponder.

3) The gain of this antenna is 33.5 dB at 12.2 GHz assuming an aperture efficiency of 65%

4) The noise power budget of the link is based on a receiver noise B.W of 20 MHz,
an antenna noise temp of 35 K in clear air, &
a 12 GHz LNA with a noise temp of 110 K.
The result is a noise power of -134 dBW in a noise B.W of 20 MHz referred to i/p of LNA, a clear air C/N ratio of 14.3 dB.

UNIT VI

SATELLITE NAVIGATION & THE GLOBAL POSITIONING SYSTEM:

- Introduction,
- radio and satellite navigation,
- GPS Position Location principles: Position location in GPS, GPS time.
- GPS Receivers and codes: the C/A code.
- Satellite Signal Acquisition,
- GPS Navigation Message,
- GPS Signal Levels,
- timing accuracy,
- GPS C/A code accuracy,
- differential GPS,
- Selective availability.

UNIT VI

Satellite Navigation & The Global Positioning System

→ The global positioning satellite system (GPS) is used for the purpose of navigation and position location.

→ Satellite navigation is the field of measurement and ranging through the use of satellite positioning system.

→ The GPS system, originally called NAVSTAR. It was developed as a military navigation system for guiding missiles, ships, and aircraft to their target.

→ GPS satellites transmit L-band signals that are modulated by the following codes

(i) The C/A (coarse acquisition) code- This code was made available to the public

(ii) P-code :- This code is for only authorized users. (Mainly for military users) to achieve positioning accuracy of 3 meters.

→ The initial use of satellites was simply for Positioning and location. These activities, that were first based on using Doppler frequency shifts as a satellite orbited above, were scientific.

→ The GPS space segment consists of 24 satellites in MEO (Medium Earth orbit) at a nominal altitude of 20,200 Km with an orbital inclination of 55°

→ The satellites are arranged in groups of ~~four~~ four, ~~Each group~~ called constellations, with each constellation seperated by 60° in longitude. The orbital period is approximately one half a sidereal day (11 hours 58 min)

→ The orbits of the 24 GPS satellites ensure that at any time, any where in the world, a GPS receiver can pick up signals from at least four satellites

→ The former USSR built and operated a Global navigation system, that is very similar to GPS. That global Navigation system is known as GLONASS (Global Navigation Satellite System)

→ NAVSTAR is a US-based navigation system.

→ Early navigation systems, that are relied on Doppler shift technology were only accurate within a precision of hundereds of meters.

→ But Today's advanced satellite navigation systems are accurate with in a precision of few meters or in centimeters.

Radio and satellite Navigation:

→ Prior to the development of radio, Navigation was by compass and landmarks on land, and by the sun and stars at sea.

→ Neither technique provides high accuracy. And Shipwrecks (i.e distruction of ships or Accidents of ships in sea) occured due to inaccurate navigation and foggy weather.

→ People often got lost in wilderness area on land.

→ With a GPS receiver and a map, it is impossible to get lost.

→ GPS receivers are very popular with airplane pilots, owners of sea-going boats and wilderness hikers.

Note: wilderness area is an area of ~~land~~ land that is protected by govt and can only be used for activities that do not harm the land's natural condition.

(or) wilderness area = Natural area

wilderness hikers means those who are walking in wilderness area.

The development of aircraft that could fly above the clouds, made radio navigation essential.

GPS can provide a single navigation system with better accuracy and reliability than all earlier radio navigation aids.

> GPS was proceeded by an ~~earth~~ earlier satellite navigation system called Transit, built for the U.S. Navy for ship navigation, which achieved much lower accuracy when compare to GPS.

→ Transit satellites were in low earth orbits.

→ Transit satellites were unable to provide continuous position data.

→ Main disadvantage of Transit satellite is a long time is required to obtain an accurate position fix.

→ A similar system called SARSAT (Search and Rescue aided), is used to find Emergency locator transmitters [ELTs] on aircraft that have crashed. These satellites are search and rescue satellites.

→ since GPS satellite's with high accuracy, than SARSAT system, GPS satellite phones will replace the SARSAT system.

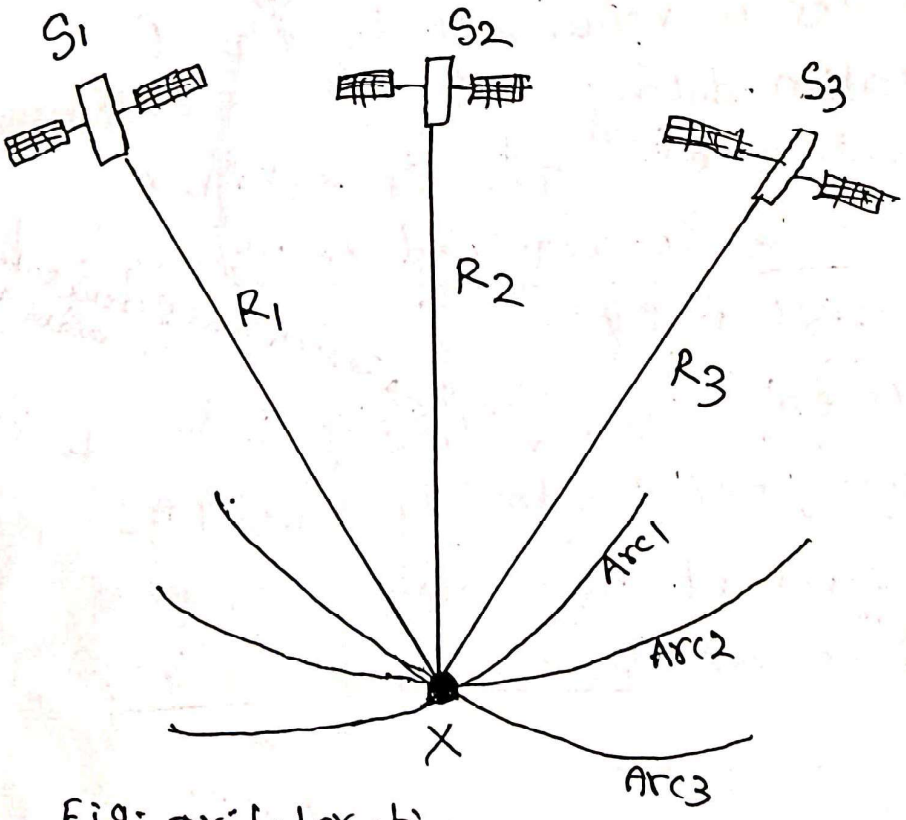
GPS Position Location principles:

→ The position of a GPS receiver can be found by trilateration method.

→ Trilateration method is one of the simplest and most accurate methods of locating unknown position; or unknown points like GPS receiver.

→ we find out the position of GPS receiver with respect to three unknown positions in the space (i.e satellite positions)

Position Location in GPS:



GPS receiver is located at point 'X'

Fig: Trilateration method

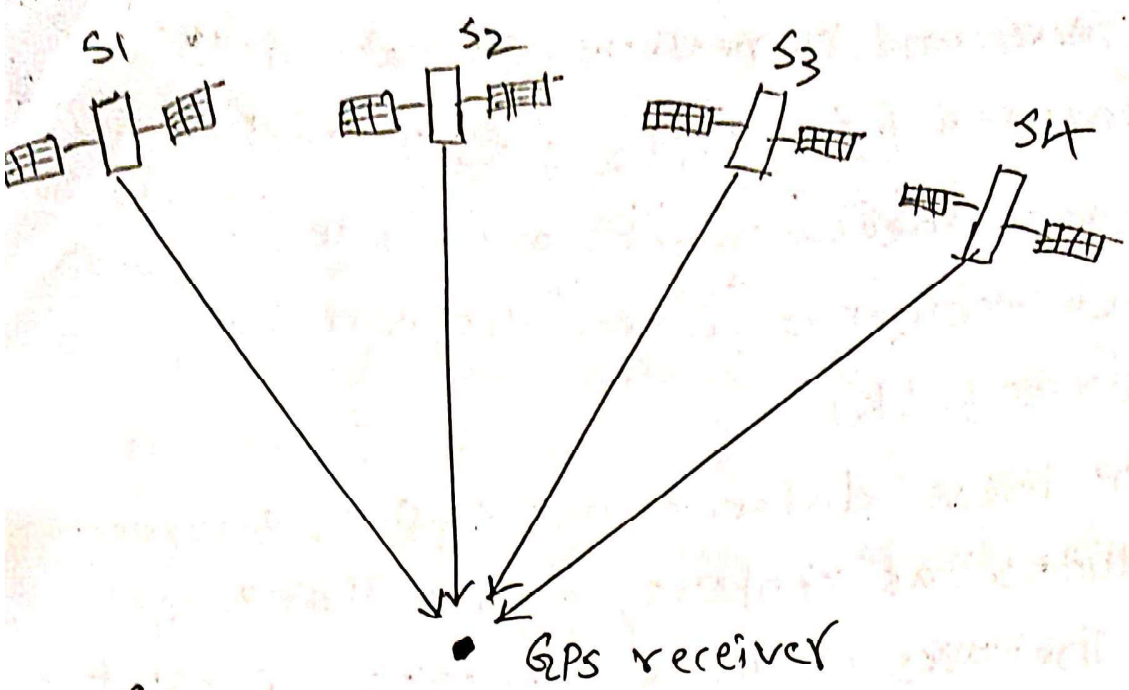


fig: Four satellite arrangement of locating GPS receiver.

→ Before finding the position of GPS receiver, it is needed to know the distance between each satellite and GPS receiver. This is done, by transmitting a RF pulse to the receiver.

→ The time taken by this pulse to travel between GPS satellite and GPS receiver is measured with reference to the high accuracy modern digital clock present at both the GPS receiver and satellite.

→ The speed of this pulse is equal to the velocity of light, i.e $c = 3 \times 10^8$ m/sec.

→ Hence time and speed can be found.

→ with this knowledge, the distance between

the GPS receiver and corresponding satellite can be measured [i.e R_1, R_2 & R_3 respectively]

→ These distance measurements are called range measurements. Each distance is called a range(R)

→ Now with these distances as radius and the satellites as centers, draw three spheres. The arcs of these spheres intersect at two points. We exclude the point at the far end, but the other intersection point gives the position of GPS receiver.

→ These arcs intersect at point X, form three equations which when solved gives the lattitude, longitude and elevation information of the GPS receiver.

→ The difficult task in this technique is to maintain synchronization between the receiver and the satellite

→ Fourth satellite is used to minimize the clock errors. i.e clock errors in the receiver must be corrected with the help of fourth satellite as shown in figure.

we define the coordinates of GPS receiver and GPS satellite in a rectangular coordinate system with its origin at the center of earth. This is called Earth centered Earth fixed coordinate system [ECEF].

→ Receiver coordinates are (U_x, U_y, U_z) and four satellites have ~~cord~~ coordinates (X_i, Y_i, Z_i), where $i = 1, 2, 3, 4$.

→ The measured distance to satellite i is called a Pseudorange, PR_i

$$PR_i = T_i \times C$$

where T_i = propagation time delay between the satellite (i) and GPS receiver.

C = velocity of EM wave.

→ In general, the distance, R, between two points A and B in a rectangular coordinate system is given by

$$R^2 = (x_A - x_B)^2 + (y_A - y_B)^2 + (z_A - z_B)^2$$

→ The equations which relate Pseudorange to time delay are called ranging equations:

$$(X_1 - U_x)^2 + (Y_1 - U_y)^2 + (Z_1 - U_z)^2 = (PR_1 - TC)^2$$
$$(X_2 - U_x)^2 + (Y_2 - U_y)^2 + (Z_2 - U_z)^2 = (PR_2 - TC)^2$$
$$(X_3 - U_x)^2 + (Y_3 - U_y)^2 + (Z_3 - U_z)^2 = (PR_3 - TC)^2$$
$$(X_4 - U_x)^2 + (Y_4 - U_y)^2 + (Z_4 - U_z)^2 = (PR_4 - TC)^2$$

Where τ = receiver clock error (offset, or, bias)

→ "Selective availability (SA)", will make the accuracy of C/A code receivers to be degraded in the event of national emergency

GPS Receivers and codes:

GPS receiver:

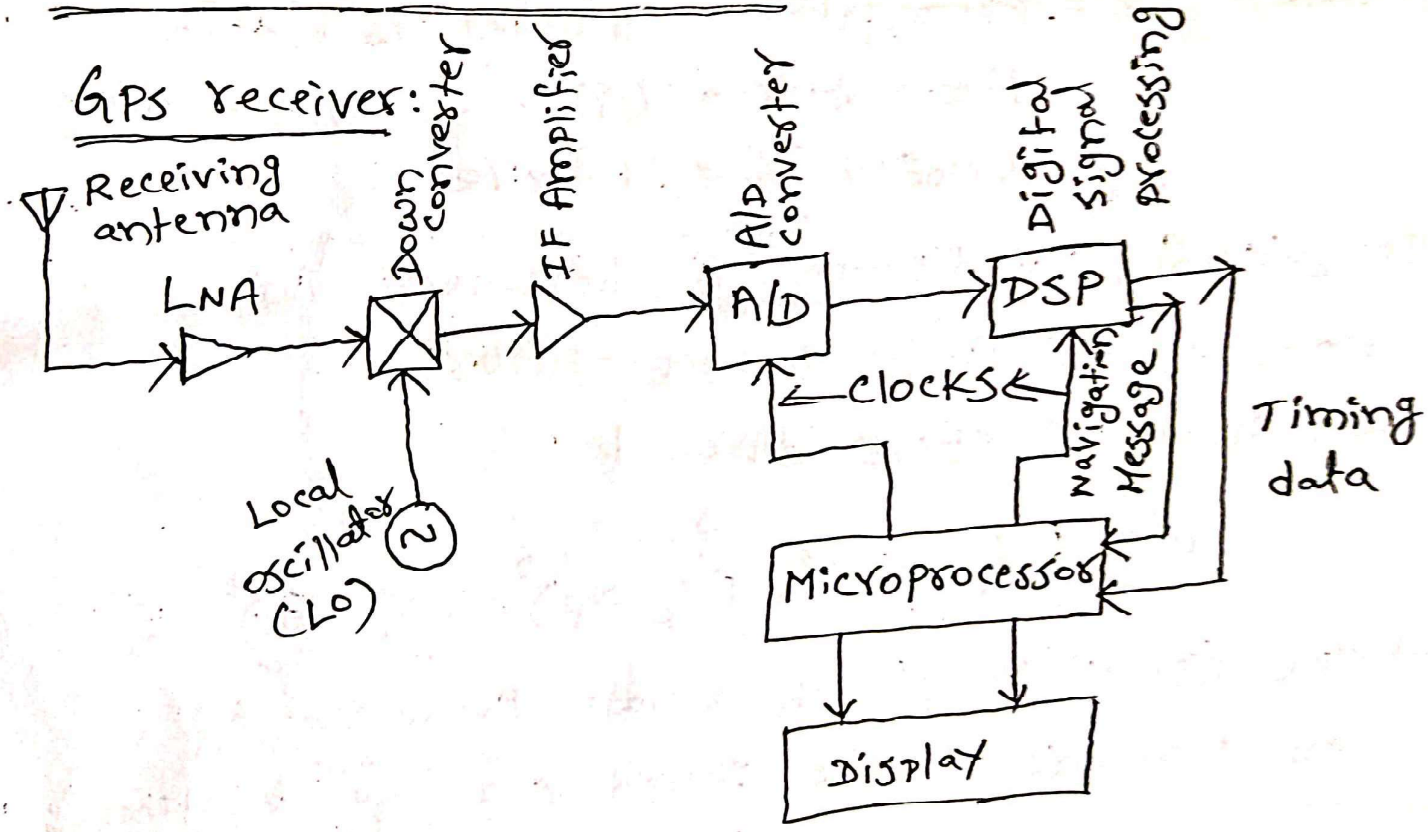


fig: GPS receiver
(C/A code GPS receiver)

* The block diagram of a GPS receiver is shown above.

- The receiver consists of the following units
  - * The antenna used for receiving signal is of circularly polarized patch type, with a Low Noise Amplifier (LNA) placed over it.
  - * An IF signal of bandwidth 2MHz is generated by the superheterodyne receiver.
  - * sampling and quantization of this signal is done by A/D converter and Digital signal Processing (DSP) unit. This process is carried out with the help of 'I' and 'Q' techniques.

Note: I: Inphase carrier
Q: Quadrature phase carrier

  - * DSP unit consists of
    (1) A C/A code generator
    (2) A correlator that chooses the required gold code sequence (i.e C/A code sequence)
    (3) A Microprocessor that makes the timing measurements

→ Finally the current position of the receiver is calculated

GPS codes:

→ GPS satellites transmit signals by using pseudorandom sequence (PN) codes.

→ GPS satellites transmit L-band signals.

- GPS satellites transmits two signals with different frequencies L_1 and L_2
- L_1 signal is modulated by 1.023 MBPS PN sequence, called C/A code (i.e coarse acquisition) that is available for public use.
- L_2 signal is modulated by 10.23 MBPS PN sequence, called P-code (i.e precise code) that is used by military positioning system.
- P-code is transmitted in encripted form, called y-code.
- GPS satellite is made a Direct sequence Spread spectrum system (DSSS) by transmitting C/A and P code over L_1 and L_2 frequency bands.

GPS sys provides two categories of services —
(1) precise positioning service (PPS) → P & C/A code
(2) standard " " (SPS) → C/A code

(1) C/A Code:

→ The signals from different GPS satellites are seperated at the receiver.

→ All the C/A codes that are transmitted by GPS satellites are 1023 bits gold codes.

→ The codes are generated from ~~two~~ two m-sequences of 1023 bits known as G_1 and G_2

→ These signals are multiplied together with different time offsets to produce the GPS C/A gold codes.

→ Shift registers and feedback taps are used to produce the m-sequences which is a maximum length ~~of~~ PN sequence

→ A shift register with n-stages can generate a PN sequence of $2^n - 1$ bits.

→ Hence the sequences G_1 and G_2 are 1023 bits long ($n = 10 : 2^{10} - 1 = 1023$)

→ The PN sequences G_1 and G_2 are both generated by 10-bit-shift registers.

→ Both G_1 and G_2 are 1023 bits ~~long~~ long.

→ Clock rate for C/A code is 1.023 MHz.

→ An algorithm is used to generate a C/A code in the GPS system.

→ The algorithm contains ID (Identification number) of GPS satellite.

→ Depending upon this ID number a single code is generated for specific satellite.

→ The C/A code sequence for ID number, i is given as

$$C_i(t) = G_1(t) \times G_2(t + 10iT_c) \longrightarrow (1)$$

where T_c = clock period for C/A code.

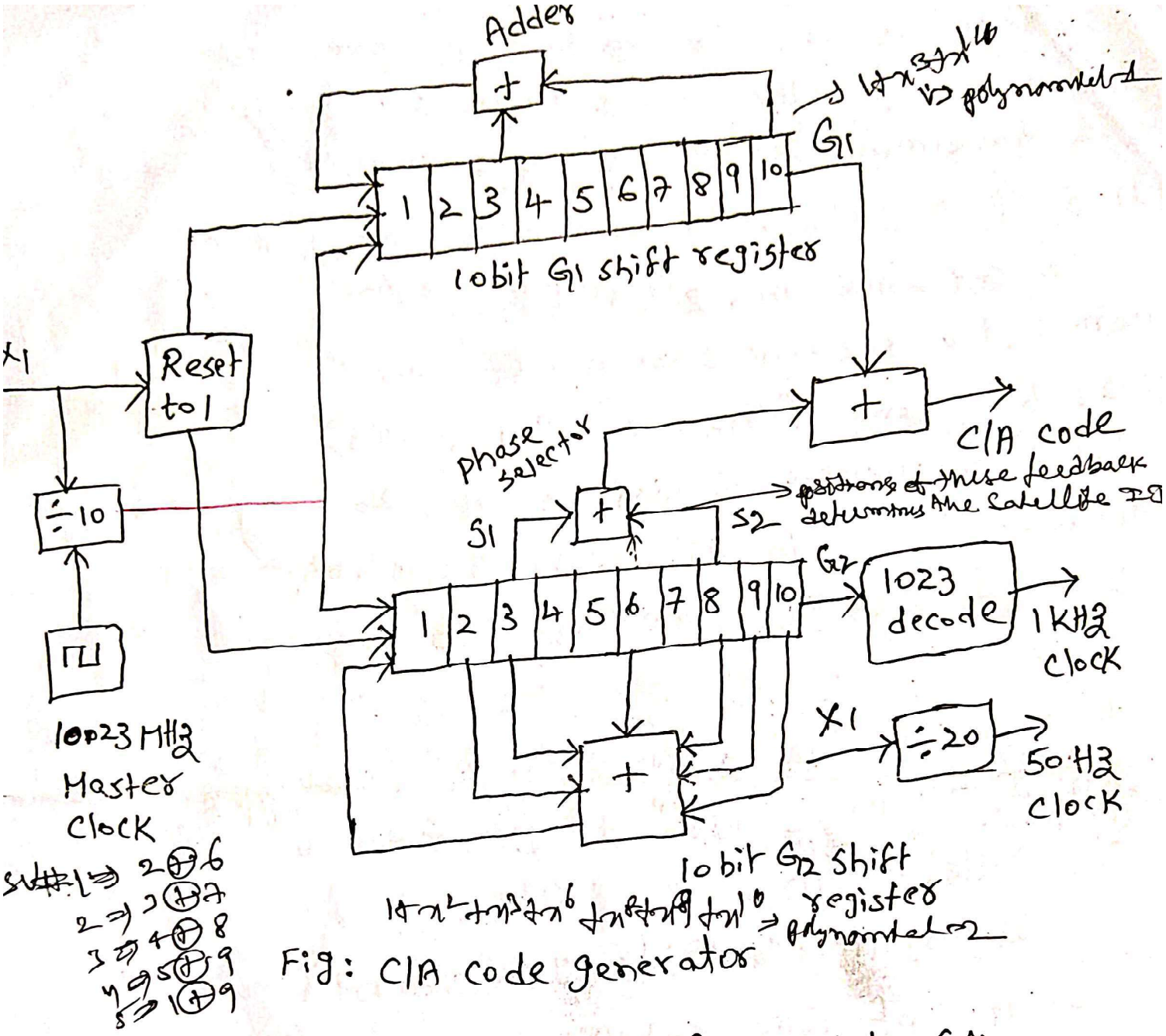


Fig: C/A code generator

→ For satellites numbered from 1 to 64 have 64 gold sequences. By using this algorithm in equation ① an overall of 100 gold sequences can be generated.

→ The required sequences must have low cross correlation properties. Hence only the frequencies which are having this property are selected for a satellite.

→ Among the 64 gold sequences, the correlator should select one sequence. and reject all others.

→ Two C/A code sequences with zero cross-correlation, will have a rejection ratio of 1023, but not all the 64 sequences will have zero cross correlation

→ The 37 gold sequences will posses low cross correlation properties.

only 32 are actually used in GPS.

P-code :-

→ The P-code (precise code) is one of the pseudorandom codes, which is employed by the GPS satellites for transmitting the data information.

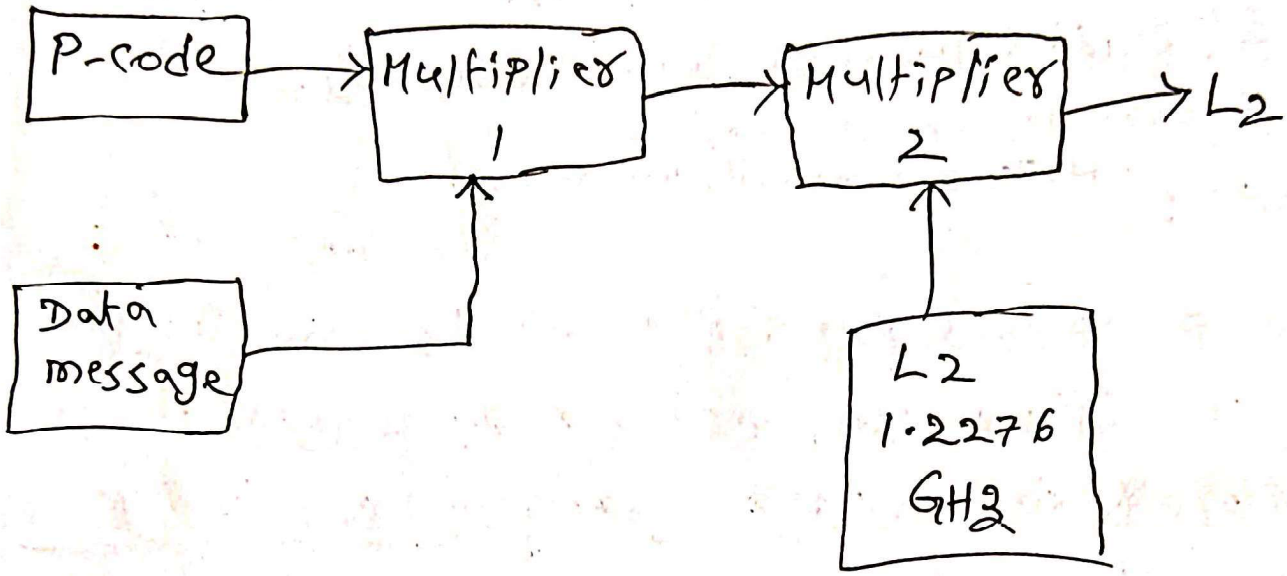
→ All the GPS satellites perform BPSK modulation of the P-code at a carrier frequency of 10.23 MBPS (i.e 1.2276 GHz, L_2 frequency) and then transmit it. Then the GPS receiver receives, demodulate and uses them.

→ The P-code is used for military purposes because they support encryption

→ The encripted P-code is called Y-code.

7 But encrypted data can not be properly read by the receivers, unless they have the corresponding decryption algorithm.

The disadvantage of P-code over C/A code is it's complexity.



→ The navigation message is the information to be transmitted that is spread using P-code in the multiplier-1

→ The output of multiplier-1 is then used to modulate the carrier frequency 1.2276 GHz in the multiplier-2 and generates L_2 signal.



Satellite signal acquisition:

→ The GPS receiver must find the starting time of the unique C/A code for each of four satellites

> This is done by correlating the received signal with stored C/A codes, as in any direct sequence spread spectrum system. (DS-SS system)

> A DS-SS receiver locks to a given code by matching the locally generated code to the code received from the wanted satellite.

> The locally generated code is compared to the received code bit by bit (i.e all 1023 bits of sequence), untill either lock is found, or the receiver concludes that this is not the correct code for the satellite signal it is receiving.

> If the starting time for the locally generated code was not selected correctly, correlation will not be obtained immediately. The locally generated code is then moved forward one bit in time, and correlation is attempted again.

> This process is continued 1023 times untill all possible starting times for the locally generated code have been tried.

→ If the satellite with that particular ~~code~~ C/A code is not visible, then no correlation will occur and lock will not be achieved.

- It takes a minimum of 1 sec to search all 1023 bit positions of a 1023 bit C/A code. So in a typical case, it will take atleast 15 sec to acquire the first satellite.

→ once one C/A code is found, the remaining satellites can then be acquired in a few seconds because their ID's are known from the data transmitted in the navigation message of each.

→ once any of the GPS satellites has been acquired, the navigation message provides sufficient information about the adjacent satellites for the remaining visible satellites to be acquired quickly.

GPS Navigation Message:

→ A key feature of the GPS C/A code is the navigation message

→ The navigation message contains a large amount of information

that is used by GPS receivers to optimize the acquisition of satellite signals and calculate position.

→ The navigation message is sent at 50 bPS by BPSK modulation of the C/A and P-codes; ~~effectively~~

→ 20 C/A code sequences form one navigation message bit.

Header	Telemetry message: health of satellite, handover word.
Subframe1	satellite clock correction data. Age of transmitted data
subframe 2 and 3	Ephemeris for this satellite.
Subframe4	Almanac data for satellites 25 and higher. Ionospheric Model data
Subframe 5.	Almanac data for satellites 1-24. Health data for satellites 1-24

fig: GPS Navigation message: subframe details

→ The phase of 20 sequences is inverted between the '1' and '0' bits of the message by modulo-2 addition of the navigation message data to the C/A and P-code sequences.

→ The navigation ~~message is~~ signal is extracted by a 50 bps BPSK demodulator that follows the C/A or P-code correlator.

→ The narrow bandwidth of the navigation message ensures a high S/N ratio at the demodulator input and correspondingly low probability of bit errors in the navigation message.

→ The complete navigation message is 1500 bits, sent as a 30-s frame with 5 subframes.

→ However some information is contained in a sequence of frames, and the complete dataset requires 12.5 min for transmission.

GPS signal levels:

→ GPS receiver antennas have low gain because they must be omnidirectional

→ The C/A code transmitted by the satellite is a direct sequence spread spectrum signal.

→ So the C/N ratio in the C/A code's RF bandwidth will be ~~Les~~ less than 0 dB. (i.e low C/N ratio)

→ The low C/N ratio of the spread spectrum signal is converted to a usable S/N by correlation of the code sequences, which adds a de-spreading (processing) gain to the C/N ratio.

→ The theoretical processing gain of a direct sequence spread spectrum signal is equal to the ratio of the chip rate to the bit rate in the spreading sequence, but losses in the correlation process always make practical gains a little lower.

→ The navigation message has a 50-bps bit rate, and each bit extends over 20 C/A code correlation periods.

→ The C/A code correlator output is passed through a 50-Hz band-width filter which integrates the 20 pulses from the correlator to give a single message

bit, in the form of a 50 bps BPSK signal.

→ The S/N ratio of the BPSK message signal will theoretically be be 13 dB higher than the S/N at the correlator output, at 23.3 dB. However, the correlation and filtering processes are not perfect and an implementation margin of several dB must be allowed.

→ The S/N ratio of the BPSK signal will be above 20 dB in most cases (i.e it shows it is an error free detection of the navigation message.

Timing Accuracy:

→ The position location process requires an accurate mesurement of time of arrival of the code sequence at the receiver.

→ The output of the C/A code correlator is 1 μs wide pulse that repeats every millisecond.

→ The accuracy with which a timing measurement can be made on a single pulse is given by approximate relationship

$$\delta t \approx \frac{1}{[B_n \sqrt{S/N}]} \text{ seconds}$$

where δt = rms timing error

B_n = Noise Bandwidth of the RF channel

and S/N ratio is the signal-to-Noise power ratio (not in dB) for the pulse in the noise bandwidth B_n

- The S/N ratio after the correlator is

$$S/N = C/N + G_p - \text{losses}$$

where G_p = Correlator processing gain

For C/A code $G_p = 1023 = 30.1$ dB and

~~S/N~~ if $C/N = -18.4$ dB

then $S/N = -18.4\text{dB} + 30.1\text{dB} - \text{losses}$

$S/N = 11.7\text{dB} - \text{losses}$

→ If we assume losses = ~~1~~ 1.7 dB

then S/N = 10 dB, a power ratio of 10

→ The theoretical noise bandwidth of the correlator is $B_n = 1$ MHz (i.e 10^6 Hz)

so $\delta t \approx \left[\frac{1}{10^6\sqrt{10}}\right]$ sec = 0.316 μs

→ A typical GPS receiver will update the display no more than twice a second, so the pulse from the correlator can be averaged over a period of half a second which will decrease the rms error by $\sqrt{500} = 22.4$ to an rms value of 14 ns, assuming randomly distributed errors.

GPS C/A code Accuracy:

→ Major sources of errors in a GPS receiver that calculates it's position are

(i) satellite clock and ephemeris errors
(ii) selective availability (when switched on)
(iii) Ionospheric delay (advance)
(iv) Tropospheric delay
(v) Receiver Noise
(vi) Multipath.

Differential GPS (DGPS)
Accuracy of GPS measurement can be increased by using DGPS. A 2nd GPS receiver at a reference station is required in DGPS system

→ Accuracy with GPS C/A code receiver can be found by a range error budget

→ DOP (Dilution of precision factors):

This is the different levels of errors in the receiver position

Ephemeris data: It is used to calculate the position of each satellite in the orbit

Almanac data: It is the information about the time and status of entire ~~const~~ satellite constellation

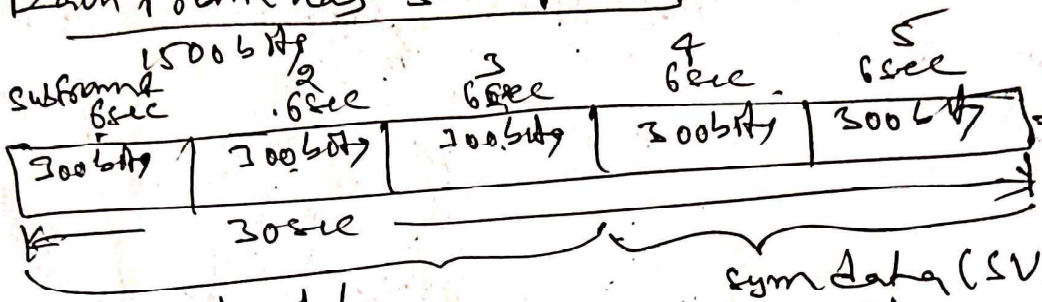
Differential GPS [DGPS]:

→ The accuracy of GPS measurements can be increased by using DGPS.

→ A second, GPS receiver at a reference station is required in DGPS system.

25 Frames = 1 navigation msg → 12.5 min

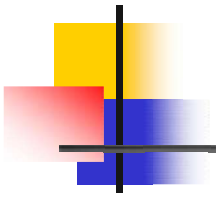
Each Frame has 5 subframes:



Sat. data
↓
Contains Ephemeris & clock corrections
(updated every 30 sec)

Sys data (SV: 1 to 32)
Almanac
+ Ionospheric data
+ UTC data (universal time coordinated)
(updated every 12.5 min)

5 subframes = 1 Frame, 25 Frames = 1 nav msg



Satellite Communication

Presented
by
Mr.P.Rangappa
Assistant Professor
Department of ECE
RGMCET,NANDYAL.

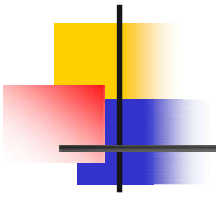
OBJECTIVES

- To introduce the basic principles of Satellite Communication systems, orbital mechanics, launchers.
- To know the different subsystems of satellites.
- To introduce the basic concepts and designing of Satellite links.
- To introduce the basic concepts of earth station transceiver.
- To know the basics of direct broadcast satellite television
- To know the basic concepts of various multiple access techniques and GPS systems.

UNIT-I:INTRODUCTION

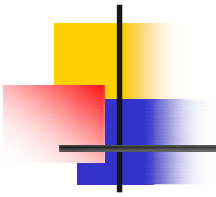
- Communication satellites
- Introduction and Historical Background





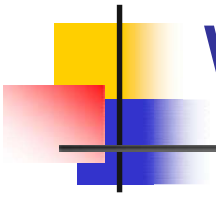
Satellite Introduction

- **Satellite:** In **astronomical terms**, a satellite is a celestial body that orbits around a planet.
  - **Example:** The moon is a satellite of Earth.
- In **aerospace terms**, a satellite is a space vehicle launched by humans and orbits around Earth or another celestial body.



Introduction

- **Communications Satellite:** It is a microwave repeater in the sky that consists of a diverse combination of one or more components including transmitter, receiver, amplifier, regenerator, filter onboard computer, multiplexer, demultiplexer, antenna, waveguide etc.
- A satellite radio repeater is also called **transponder.** This is usually a combination of transmitter and receiver.



What is a satellite system?

- A **satellite system** consists of one or more satellites, a ground-based station to control the operation of the system, and a user network earth stations that provides the interface facilities for the transmission and reception of terrestrial communications traffic.

How a satellite works?

- A satellite stays in orbit because the gravitational pull of the earth is balanced by the centripetal force of the revolving satellite.
- One Earth station transmits the signals to the satellite at **Up link frequency.** Up link frequency is the frequency at which Earth station is communicating with a satellite.
- The satellite transponder process the signal and sends it to the second Earth station at another frequency called **downlink frequency.**

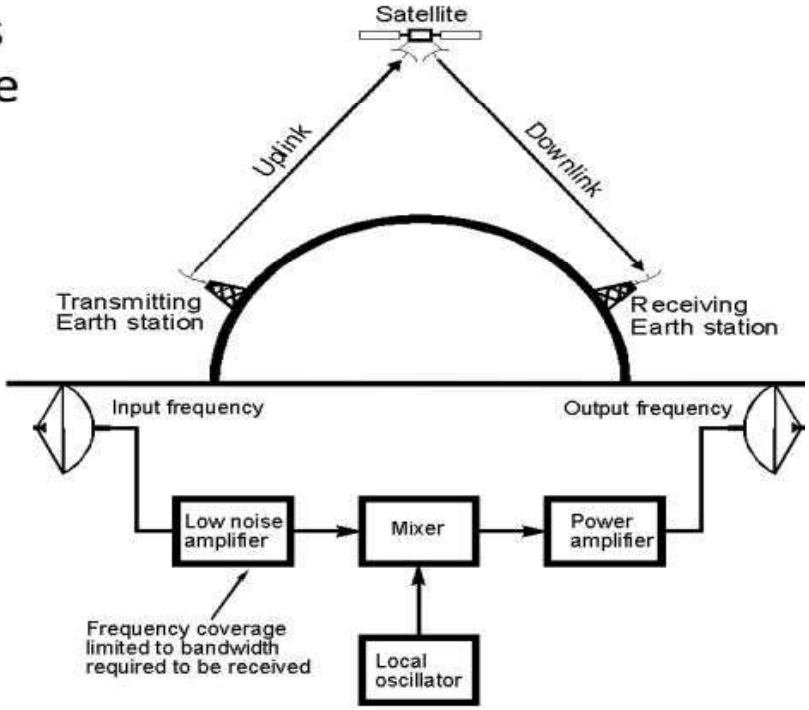
➢HOW SATELLITES WORK :

I. A Earth Station sends message in GHz range (Uplink).

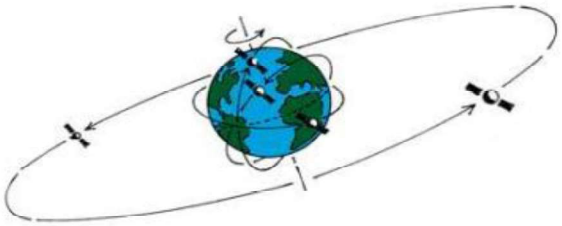
II. Satellite Receive and retransmit signals back. (Downlink)

III. Difference between Downlink and Uplink frequency is

2 GHz.



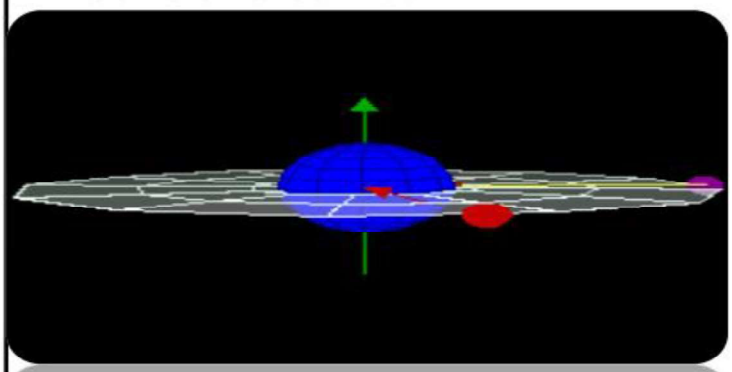
➢HOW DO SATELLITES STAY IN ORBIT?



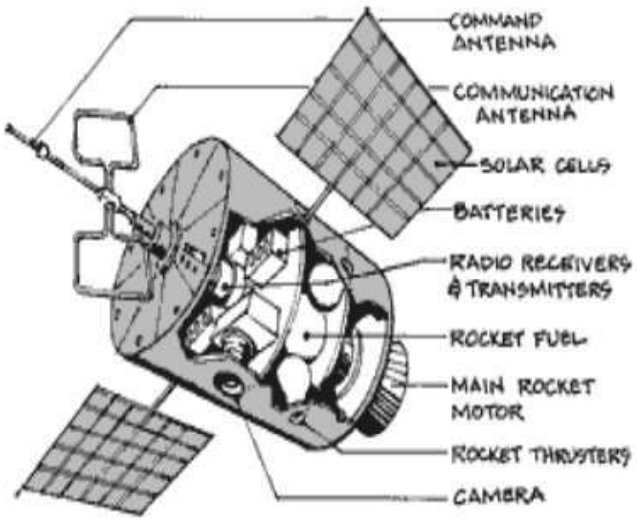
▪Satellites stay in orbit due to the balance of two factors:

i. Velocity and
ii. Gravitational pull between the Earth and the satellite.

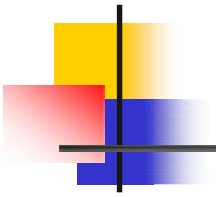
✓ Satellites never fall into the Earth this because Earth is round and curves.



➢WHAT ARE THE COMPONENTS OF A SATELLITE?

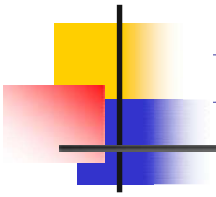


- **Many satellites are powered by rechargeable batteries.**
- **Small thrusters provide attitude i.e. stabilize the satellite's position in space.**



Advantages of Satellite Communications over Terrestrial Communications

- The coverage area greatly exceeds.
- Transmission cost of a satellite is independent of the distance from the center of the coverage area.
- Satellite-to-satellite communication is very precise.
- Higher bandwidths are available for use.



Disadvantages of Satellite Communications

- Launching satellites into orbits is costly.
- Satellite bandwidth is gradually becoming used up.
- The propagation delay is larger.

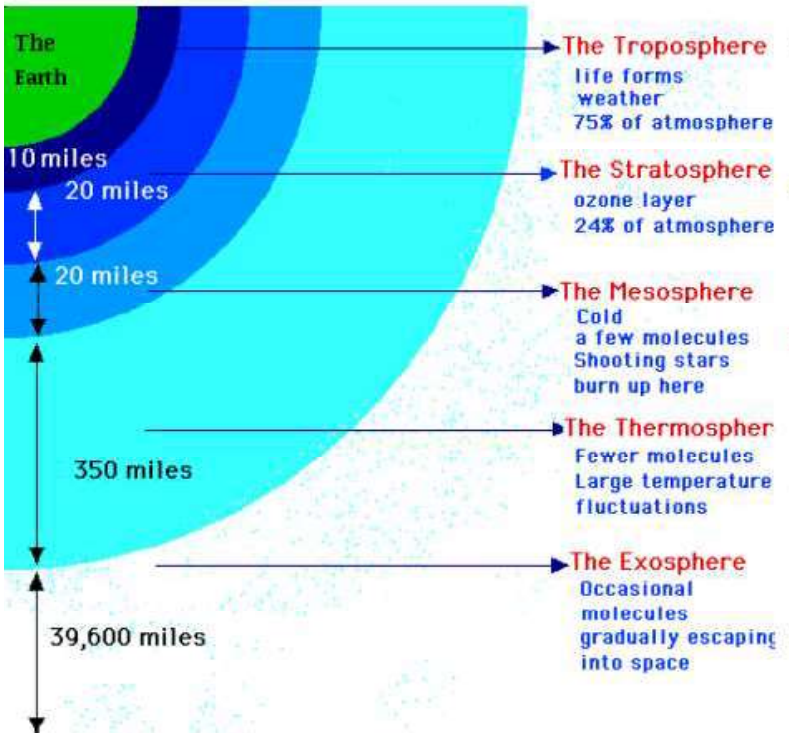
➢USES OF SATELLITE:

- IT IS USED FOR **LONG DISTANCE COMMUNICATION.**
- IT IS **SPEEDY AND RELIABLE.**
- IT IS USED FOR **WEATHER FORECASTING.**

(study of atmosphere ,rain ,sunshine at any place at perticular time)

- IT IS USED FOR **TRANSMIT T.V. SIGNAL OVER LARGE DISTANCE COMMUNICATION.**
- POLAR SATELLITE IS USED FOR **REMOTE SENSING.**

➢LAYER OF ATMOSPHERE :



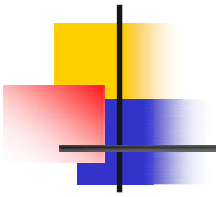
❖ **TROPOSPHERE :**

❖ **STRATOSPHERE :**

❖ **MESOSPHERE :**

❖ **THERMOSPHERE :**

❖ **EXOSPHERE :**



Regions of Space

- Space is defined as a place *free from obstacles*

It can be divided into three regions:

- Air Space -> region below 100 km from earth's surface
- Outer Space -> also called cosmic space and ranges from 100 km up till 42, 000 km. It is mostly used by communication satellites.
- Deep Space -> Regions beyond 42,000 km fall in this category

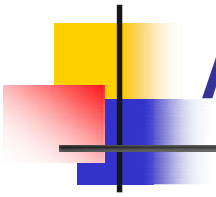
ITU Regions

Region 1: Europe, Africa, what was formerly the Soviet Union, and Mongolia

Region 2: North and South America and Greenland

Region 3: Asia, Australia, and the southwest Pacific





Active and Passive Satellites

→Active satellites are used for linking and also for processing the signals.

The linkage is known as bent pipe technology where processing like frequency translation, power amplification etc take place.

•Active satellites employ 'Regenerative Technology' which consists of demodulation, processing, frequency translation, switching and power amplification are carried out. Block used for this purpose is called transponder.

→ Passive satellites do-not have on-board processing and are just used to link two stations through space.

Low cost - Loss of power – not useful for communication applications.

Active and Passive Satellites

✓ There are two major classes of communications satellites, *passive* and *active*.

✓Passive satellites only reflect the signal coming from the source, toward the direction of the receiver.

With passive satellites, the reflected signal is not amplified at the satellite, and only a very small amount of the transmitted energy actually reaches the receiver. Since the satellite is so far above Earth, the radio signal is attenuated due to free-space path loss, so the signal received on Earth is very, very weak.

✓Active satellites, on the other hand, amplify the received signal before retransmitting it to the receiver on the ground.

✓Passive satellites were the first communications satellites, but are little used now. Telstar was the second active, direct relay communications satellite

- Satellites can be classified by their function since they are launched into space to do a specific job.
- The satellite must be designed specifically to fulfill its role. There are nine different types of satellites i.e. Communications Satellite, Remote Sensing Satellite, Navigation Satellite, LEO, MEO, HEO, GPS, GEOs, Drone Satellite, Ground Satellite, Polar Satellite.
- Communications satellites are artificial satellites that relay receive signals from an earth station and then retransmit the signal to other earth stations. They commonly move in a geostationary orbit.
- A remote Sensing instrument collects information about an object

TYPES OF SATELLITES

- Communications Satellite
- Remote Sensing Satellite
- Navigation Satellite
- Geocentric Orbit type staellies - LEO, MEO, HEO
- Global Positioning System (GPS)
- Geostationary Satellites (GEOs)
- Drone Satellite
- Ground Satellite
- Polar Satellite
- Nano Satellites, CubeSats and SmallSats

➢SATELLITE FREQUENCY BANDS :

- Different kinds of satellites use different frequency bands.
- L–Band: 1 to 2 GHz,
- S-Band: 2 to 4 GHz
- C-Band: 4 to 8 GHz
- X-Band: 8 to 13 GHz
- Ku-Band: 13 to 18 GHz
- K-Band: 18 to 28 GHz
- Ka-Band: 28 to 40 GHz

❑ There is a inverse relationshi between frequency and wavelength.

❑ As wavelength increases (and frequency decreases), larger antennas (satellite dishes) are necessary to gather the signal.

➢C-BAND



common frequency spectrums used by today's satellite.

- C-band satellite transmissions occupy the 4 to 8 GHz frequency range.
- C-band antenna is approximately 2-3 meters in diameter

➢KU-BAND :



- **Ku-band satellite transmissions occupy the 13 to 18 GHz frequency range.**
- **Ku-band antennas can be as small as 18 inches in diameter**
- **These very high frequency transmissions mean very small wavelengths and very small diameter receiving antennas.**

Frequency Band Designations

Frequency range, GHz	Band designation
0.1–0.3	VHF
0.3–1.0	UHF
1.0–2.0	L
2.0–4.0	S
4.0–8.0	C
8.0–12.0	X
12.0–18.0	Ku
18.0–27.0	K
27.0–40.0	Ka
40.0–75	V
75–110	W
110–300	mm
300–3000	μm

used for mobile and navigational services and for data transfer from weather satellites.

used for mobile satellite services and navigation systems.

used for FSS and no direct broadcast services are allowed (6/4 GHz)

used at present for DBS, and it is also used for certain fixed satellite services. (14/12 GHz)

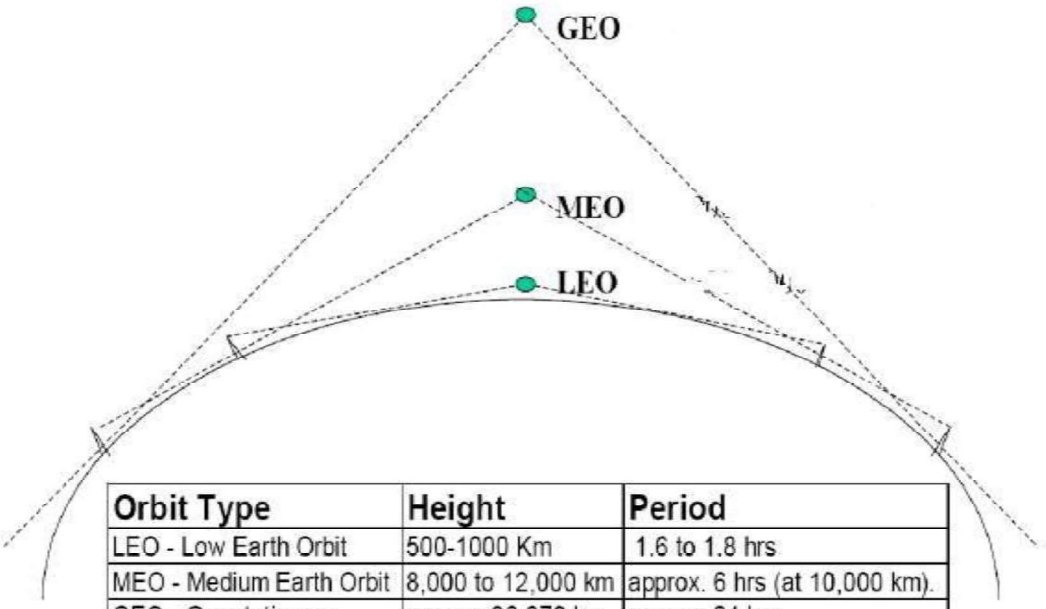
Services provided by satellites

Name of the satellite	Services
Fixed satellite service	• Telephone Networks • Transmitting TV signals to cable companies
Broadcasting satellite service	Direct Broad cast service or DTH
Mobile satellite services	• Land Mobile • Maritime mobile • Aeronautical Mobile
Navigational satellite services	GPS
Meteorological satellite services	Search and rescue services

➢TYPES OF ORBITS

- ❑LOW-EARTH-ORBIT (LEOS)
- ❑MEDIUM-EARTH-ORBIT (MEOS)
- ❑GEOSTATIONARY (GEOS)

Orbital Types



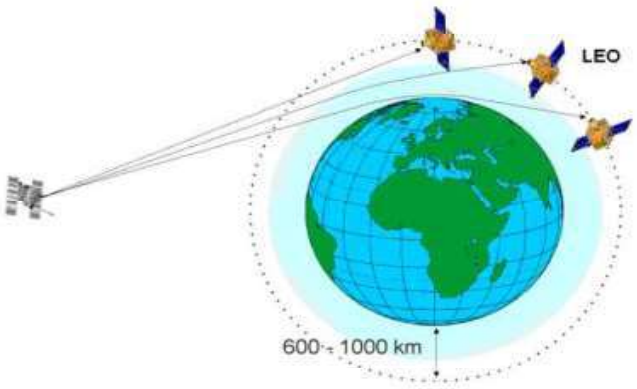
Orbit Type	Height	Period
LEO - Low Earth Orbit	500-1000 Km	1.6 to 1.8 hrs
MEO - Medium Earth Orbit	8,000 to 12,000 km	approx. 6 hrs (at 10,000 km).
GEO - Geostationary	approx. 36,870 km	approx. 24 hrs

➢LOW-EARTH-ORBIT (LEO)

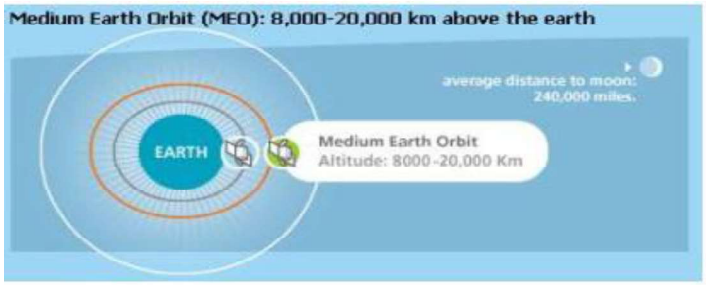
- ❑ Altitude (600-1000 KM)
- ❑ satellite gives it a better signal strength

- ❑ **Advantages:**
  - ❑ Reduces transmission delay

- ❑ **Disadvantages:**
  - ❑ Smaller coverage area.
  - ❑ Shorter life span (5-8 yrs.)



➢MIDDLE-EARTH-ORBITING (MEO)



➢MEOs orbits between the altitudes of 8,000 - 20,000 km above the earth.

➢MEO satellites have a larger coverage.

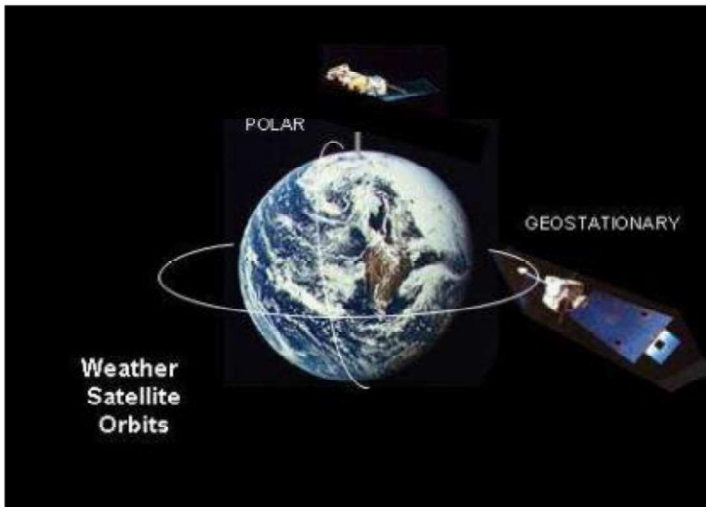
➢These orbits are primarily reserved for communications satellites that cover the North and South Pole.

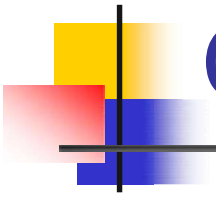
➢ MEOs are placed in an elliptical (oval-shaped) orbit.



GEOSYNCHRONOUS-EARTH-ORBIT (GEO)

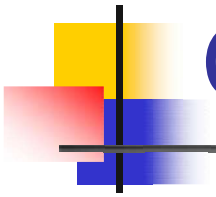
- From the ground level the satellite appears fixed.
- GEO satellites have a 24 hour view of a particular area.
- Coverage to 40% of area Of planet by this satellite





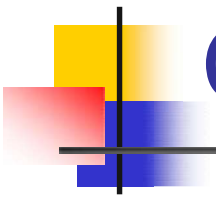
GEOs

- Originally proposed by Arthur C. Clarke
- Circular orbits above the equator
- Angular separation about 2 degrees - allows 180 satellites
- Orbital height above the earth about 23000 miles/35000km
- Round trip time to satellite about 0.24 seconds



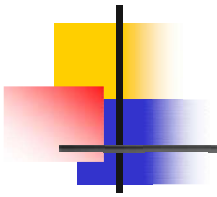
GEOs (2)

- GEO satellites require more power for communications
- The signal to noise ratio for GEOs is worse because of the distances involved
- A few GEOs can cover most of the surface of the earth
- Note that polar regions cannot be “seen” by GEOs



GEOs (3)

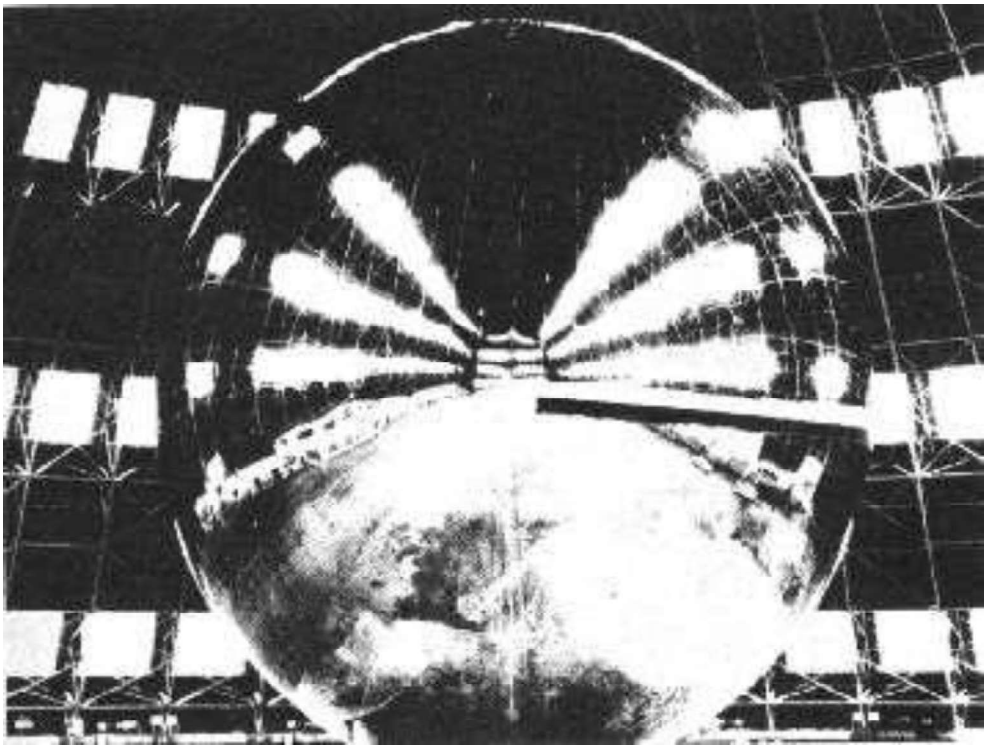
- Since they appear stationary, GEOs do not require tracking
- GEOs are good for broadcasting to wide areas



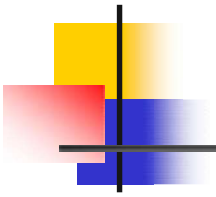
Early experiments

- US Navy bounced messages off the moon
- ECHO 1 “balloon” satellite - passive
- ECHO 2 - 2nd passive satellite
- All subsequent satellites used active communications

ECHO 1



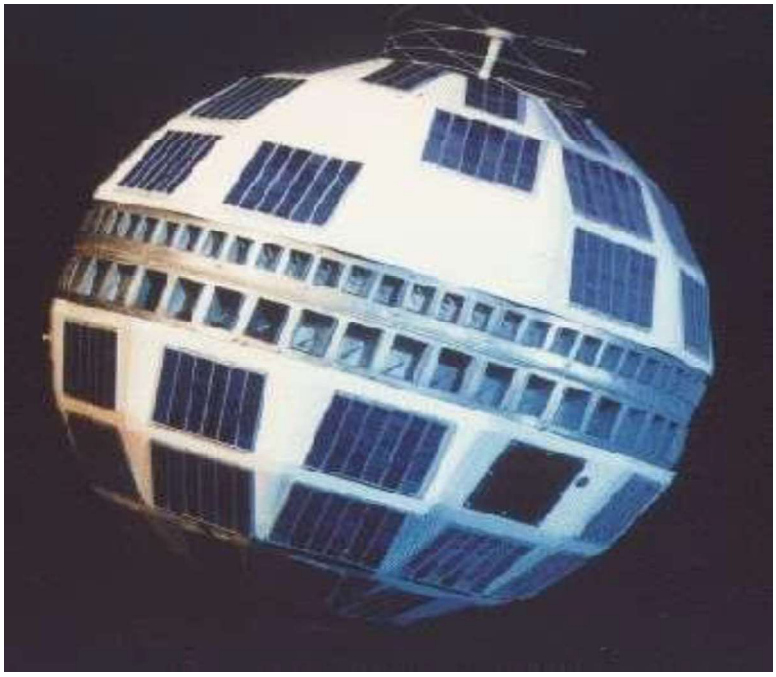
- Photo from NASA



Early satellites

- Relay
  - 4000 miles orbit
- Telstar
  - Allowed live transmission across the Atlantic
- Syncom 2
  - First Geosynchronous satellite

TELSTAR



- Picture from NASA

SYNCOM 2



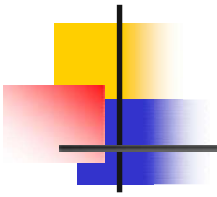
- Picture from NASA

➢HISTORY OF SATELLITES :

❑The world's first artificial satellite is the Sputnik 1 was launched in 1957



- First satellite that was used for communication purpose in INDIA was - **ARYABHATTA (19 April 1975)**
- The first geostationary communication satellite - **SYNCOM 3(19 Aug 1963).**
- Father of geostationary communication satellite is **-HAROLD ROSEN (Aircraft engineer)**



Historical Overview

- 1945 → Theorist named Clarke studied that satellite orbiting in equatorial orbit at radius of approx. 42,000 km would look as if stationary if moving at a specific speed. 3 satellites at a space of 120 degree apart can cover the whole world. Evolution of the concept of *GEO*

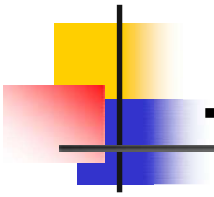
1950's –Putting the pieces together:

- 1956 -Trans-Atlantic cable opened (about 12 telephone channels per operator).
- 1957 First man-made satellite launched by former USSR (Sputnik-1, LEO). It was used to identify atmospheric density of various orbital layers. It provided data about radio signal distribution in ionosphere.
- 1958 First US satellite launched (SCORE). First voice communication established via satellite (LEO, lasted 35 days in orbit).



1960's –First satellite communications:

- 1960 First passive communication satellite (Large balloons, Echo I and II).
- 1962: First active communication satellite (Telstar I , MEO).
- 1963: First satellite into geostationary (GEO) orbit (Syncom1, communication failed).
- 1964: International Telecomm. Satellite Organization (INTELSAT) created.
- 1965 First successful communications GEO (Early Bird / INTELSAT 1).



1970's –GEO Applications Development,

DBS:

- 1972 First domestic satellite system operational (Canada).
- 1975 First successful direct broadcast experiment (USA-India).
- 1977 A plan for direct broadcast satellites (DBS) assigned by the ITU
- 1979 International Mobile Satellite Organization (Inmarsat) established.



1980's –GEO Applications Expanded, Mobile:

- 1981 First reusable launch vehicle flight.
- 1982 International maritime communications made operational.
- 1984 First direct-to-home broadcast system operational (Japan).
- 1987 Successful trials of land-mobile communications (Inmarsat).
- 1989-90 Global mobile communication service extended to land mobile and aeronautical use (Inmarsat)



- **1990+'s NGSO applications development and GEO expansion**

1990-95:

- Proposals of non-geostationary (NGSO) systems for mobile communications.
- Continuing growth of VSATs around the world
- Spectrum allocation for non-GEO systems.
- Continuing growth of DBS. DirectTV created.

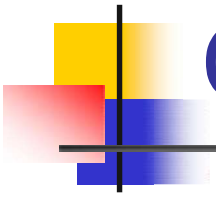
1997:

Launch of first batch of LEO for hand-held terminals (Iridium).

Voice-service portables and paging-service pocket size mobile terminals launched (Inmarsat).

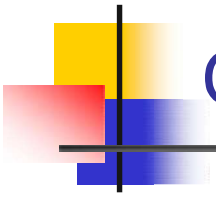
1998-2000:

Mobile LEO systems initiate service and fail afterwards (Iridium,Globalstar).



Chronology

- 1945 Arthur C. Clarke Article: "Extra-Terrestrial Relays"
- 1955 John R. Pierce Article: "Orbital Radio Relays"
- 1956 First Trans-Atlantic Telephone Cable: TAT-1
- 1957 Sputnik: Russia launches the first earth satellite.
- 1962 TELSTAR and RELAY launched
- 1962 Communications Satellite Act (U.S.)
- 1963 SYNCOM launched
- 1965 COMSAT's EARLY BIRD: 1st commercial communications satellite
- 1969 INTELSAT-III series provides global coverage



Chronology (2)

- 1972 ANIK: 1st Domestic Communications Satellite (Canada)
- 1974 WESTAR: 1st U.S. Domestic Communications Satellite
- 1975 RCA SATCOM: 1st operational body-stabilized comm. satellite
- 1976 MARISAT: 1st mobile communications satellite
- 1988 TAT-8: 1st Fiber-Optic Trans-Atlantic telephone cable
- 1994 GPS system deployed by USAF
- 1998-2001 Iridium

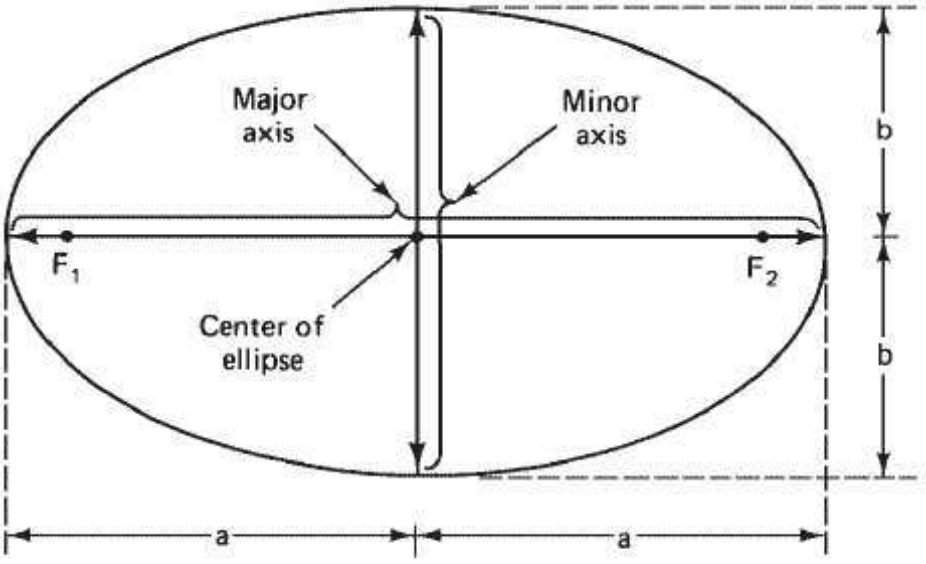
Kepler's three Law



1. The orbit of a planet is an ellipse with the Sun at one of the two foci.
2. A line segment joining a planet and the Sun sweeps out equal areas during equal intervals of time.
3. The square of the orbital period of a planet is proportional to the cube of the semi-major axis of its orbit.

Kepler's First Law

States that the path followed by a satellite around the primary will be an ellipse.



The foci F_1 and F_2, the semimajor axis a, and the semiminor axis b of an ellipse.

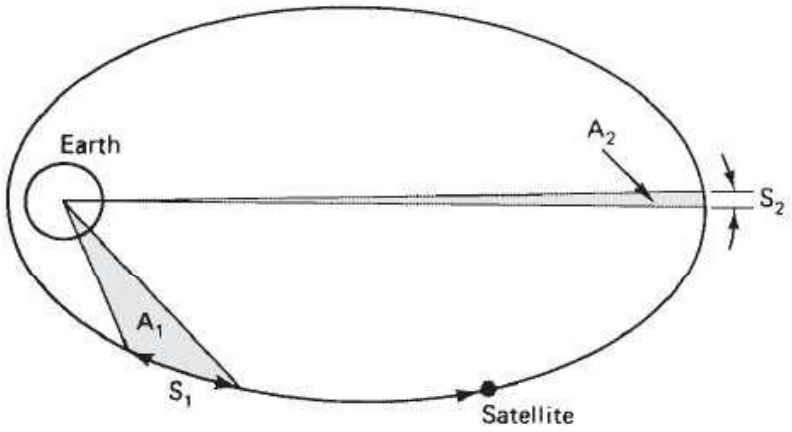
Eccentricity

- The **eccentricity** is defined as $e = \sqrt{a^2 - b^2}$

- For a circle, **e = 0**
  - The range of values of the eccentricity for ellipses is **0 < e < 1**
  - The higher the value of **e**, the longer and thinner the ellipse

Kepler's second law

States that, for equal time intervals, a satellite will sweep out equal areas in its orbital plane, focused at the barycenter.



Kepler's second law. The areas A_1 and A_2 swept out in unit time are equal.

Kepler's Third Law

States that the square of the periodic time of orbit is proportional to the cube of the mean distance between the two bodies.

Comparison between multiple orbiting objects

$$(Ta/Tb)^2 = (rA/rB)^3$$

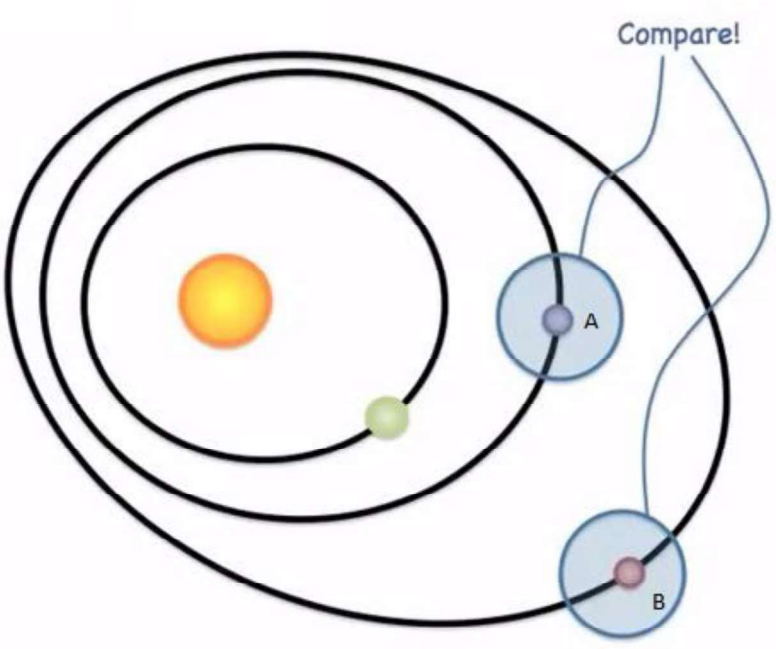
Where

T – stands for orbital period units of time but no sec. Could be like days , months or years

r - Average orbital radius of satellite

Subscripts are the objects that are to be compared.

Kepler's Third Law





Example

Average orbital radius

Earth = $1.5X10^8$ m

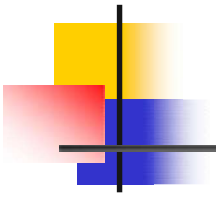
Jupiter = $7.8 X 10^8$ m

Orbital period

Earth = 1.0 years

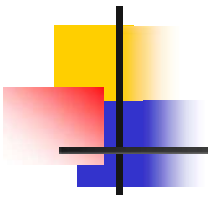
Jupiter = ??

Ans = 11.9 Years



Major problems for satellites

- Positioning in orbit
- Stability
- Power
- Communications
- Harsh environment



Satellite Communications

Orbital Mechanics

Newton's **Laws of Motion**

s = Distance traveled in time, t

u = Initial Velocity at $t = 0$

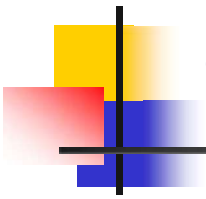
v = Final Velocity at time = t

a = Acceleration

F = Force acting on the object

This is the Key equation

- $s = ut + (1/2)at^2$
- $v^2 = u^2 + 2at$
- $v = u + at$
- $F = ma$



Concept of Force

- Force (F) = Mass(m) × Acceleration(a)
  - ***m*** is the mass of the satellite
  - Unit of Force is a ***Newton***
  - A ***Newton*** is the force required to accelerate 1 kg by 1 m/s^2
  - Underlying units of a ***Newton*** are therefore (kg) × (m/s^2)
  - In Imperial Units 1 ***Newton*** = 0.2248 ft lb.

Acceleration Inwards

a_{IN} = *acceleration due to gravity* = μ / r^2

- r = radius from center of earth to satellite
- μ = G* M_E , is the Kepler's Constant

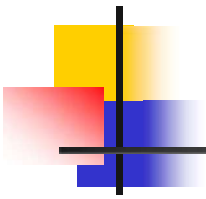
  $\mu = 3.9861352 \times 10^5 \text{ km}^3/\text{s}^2$
- G = Universal Gravitational Constant

  $G = 6.672 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$

  $= 6.672 \times 10^{-20} \text{ km}^3/(\text{kg s}^2)$ (other units)
- M_E = Mass of the earth

  $M_E = 5.9733 \times 10^{24} \text{ kg}$

Note: An object near the earth's surface accelerates at a rate of 9.811 m/s²



Acceleration Outwards

$$a_{OUT} = centrifugal\ acceleration = v^2 / r$$

Where:

- r = radius from center of Earth to satellite
- v = speed component on a direction perpendicular to rotation.

Forces on a Satellite

- Force **inwards** due to gravity (i.e.centripetal force) is:

$$F_{IN} = m \times (\mu / r^2) = m \times (GM_E / r^2)$$

- Force **outwards** (i.e. ***centrifugal force):***

$$F_{OUT} = m \times (v^2 / r)$$

Balancing the Forces

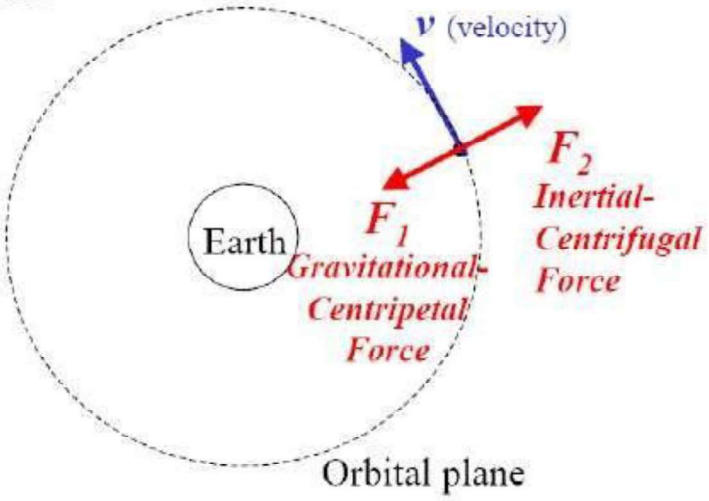
- For the satellite to stay in orbit, the forces must balance; set $F_{IN} = F_{OUT}$, solve for the required speed v

$$v = (\mu / r)^{1/2}$$

- If circular orbit:

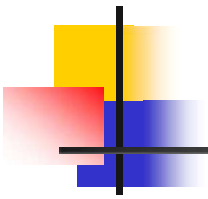
$$T = 2\pi r / v$$

$$T = 2\pi r^{3/2} / \mu^{1/2}$$



Example Circular Orbits

Satellite System	Orbital Height (km)	Orbital Velocity (km/s)	Orbital Period hr. min. sec.
INTELSAT	35,786.43	3.0747	23 56 4.091
ICO-Global	10,255	4.8954	5 55 48.4
Skybridge	1,469	7.1272	1 55 17.8
Iridium	780	7.4624	1 40 27.0



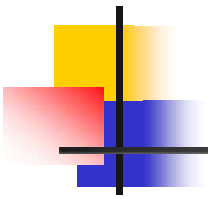
Orbit Limits

- There must be a balance between inward gravitational (centripetal) forces and outward centrifugal forces
- Must not be too close to the earth as it will be slowed down by the atmosphere
- Velocity must be in the **right direction** (parallel to earth surface).



Orbital Mechanics:
Kepler's Laws

Developing Equations of the Orbit



- Solving the differential equation leads to three laws of orbits (***Kepler's Laws of Motion)*** and six constants (***the orbital constants/ephemeris data***) which define the orbit
  - ***Kepler's Laws of Planetary Motion*** govern motion of satellite around earth and planets around sun
- Johann Kepler (1571 - 1630) was a German astronomer and scientist who derived the laws empirically by observation only.
- Isaac Newton (1642-1724) was a British astronomer who calculated these relationships **50 years later**.

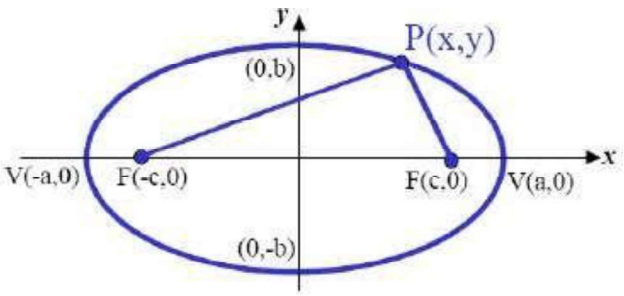
Kepler's Three Laws

- **First Law:** Orbit is an *ellipse* with the larger body (earth) at one focus
- **Second Law:** The satellite sweeps out *equal arcs* in *equal time* (*NOTE*: for an ellipse, this means that the orbital speed varies around the orbit)
- **Third Law:** The square of the period of revolution equals a *constant* × the *third power* of the *semi-major axis* of the ellipse

We'll look at each of these next



Review of Ellipse Geometry



- Points (-c,0) and (c,0) are the **foci**.
- Points (-a,0) and (a,0) are the **vertices**.
- Line between vertices is the **major axis**.
- ***a*** is the length of the ***semi-major axis.***
- Line between (0,b) and (0,-b) is the **minor axis**.
- ***b*** is the length of the ***semi-minor axis.***

Important Relationships:

$$a^2 = b^2 + c^2$$

Standard Equation:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

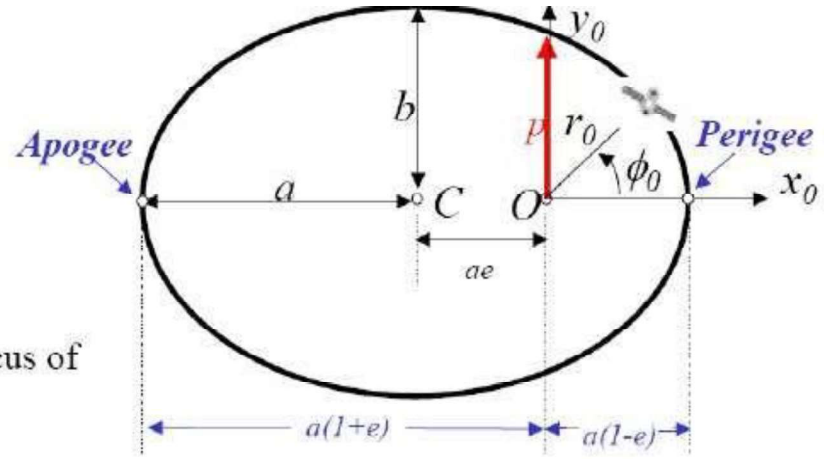
Area of ellipse:

$$A = \pi ab$$

Kepler's First Law: Elliptical Orbits

Important Definitions:

- e = ellipse's eccentricity
  $0 < e < 1 \Rightarrow$ ellipse
  $e = 0 \Rightarrow$ circle
- O = center of earth (one focus of ellipse)
- C = center of ellipse
- Perigee = Point closest to earth
- Apogee = Point furthest from earth
- a = length of semi-major axis
  = (perigee + apogee)/2
- b = length of semi-minor axis



- p = width of ellipse at focus = $a(1-e^2)$
- r_0 = distance earth's center to satellite
- φ_0 = angle between r_0 and the perigee (the true anomaly)

Orbit Eccentricity

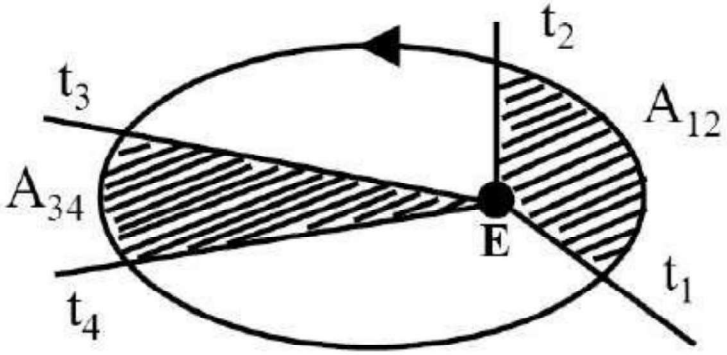
- If a = semi-major axis,
  b = semi-minor axis, and
  e = eccentricity of the orbit ellipse,
  then

$$e = \frac{a - b}{a + b}$$

NOTE: For a circular orbit, $a = b$ and $e = 0$

Kepler's Second Law: Equal Area Arcs

- **If $t_2 - t_1 = t_4 - t_3$, then $A_{12} = A_{34}$**
- **Velocity of satellite is *slowest at apogee and fastest at perigee***



Kepler's Third Law: Orbital Period

- Orbital period and the Ellipse are related by:

$$T^2 = (4\,\pi^2\,a^3) / \mu$$

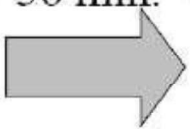
μ = **Kepler's Constant** = GM_E

IMPORTANT: Period of revolution is referenced to inertial space, i.e., to the galactic background, NOT to an observer on the surface of one of the bodies (earth).

– For a GEO, for instance, ***T*** is the sidereal day…

Solar vs. Sidereal Day -1

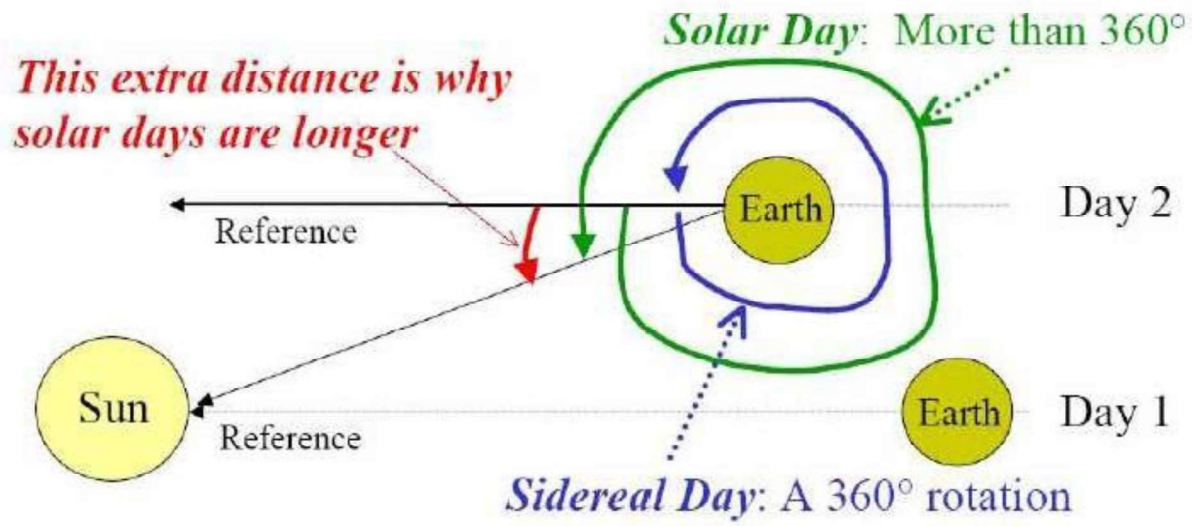
- A ***sidereal day*** is the time between consecutive crossings of any particular longitude on the earth with reference to inertial space (or it's own axis); I.e., in practice, with reference to any star other than the sun. This corresponds to a 360 degree rotation.
- A ***solar say*** is the time between consecutive crossings of any particular longitude of the earth by the sun-earth axis. This corresponds to more than 360 degrees.
  - Solar day = EXACTLY 24 hrs
  - Sidereal day = 23 h 56 min. 4.091 s
- Why the difference?



Solar vs. Sidereal Day -2

- Why the difference?
  - By the time the Earth completes a full rotation with respect to an external point (not the sun), it has already moved its center position with respect to the sun.
  - The extra time it takes to cross the sun-earth axis, averaged over 4 full years (because every 4 years one has 366 deays) is of about 3.93 minutes per day.

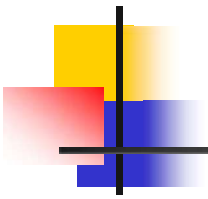
Solar vs. Sidereal Day -3





Satellite Communication

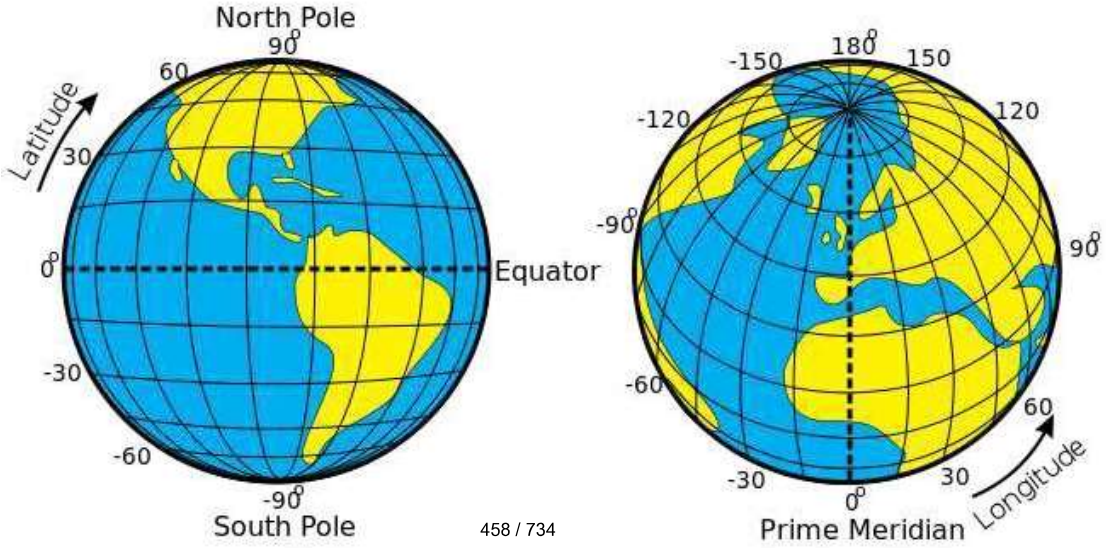
Location on earth & look angle determination



Location on Earth

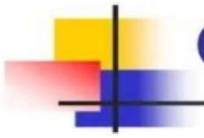
- The earth is effectively a sphere, so how do we describe where a point is on its surface?
- The most common way to locate points on the surface of the Earth is by standard, geographic coordinates called latitude and longitude. These coordinates values are measured in degrees, and represent angular distances calculated from the center of the Earth.

- **Equator**—The line which encircles the Earth at an equal distance from the North and South Poles.
- **Geographic coordinates**—Coordinate values given as latitude and longitude



Look Angle Determination

Slides:



Coordinate System

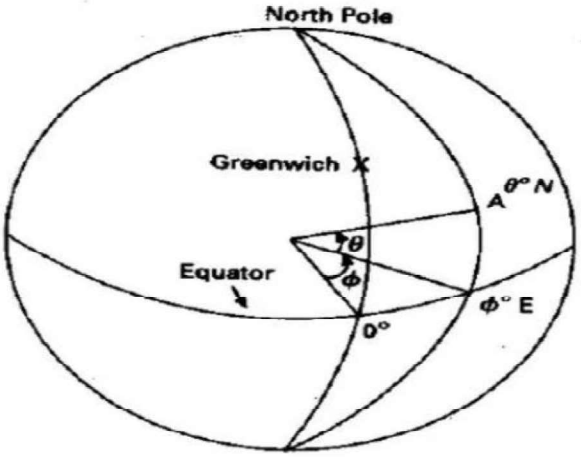
- **Latitude:** Angular distance, measured in degrees, north or south of the equator.

  L from -90 to +90 (or from 90S to 90N)
- **Longitude:** Angular distance, measured in degrees, from a given reference longitudinal line (Greenwich, London).

  l from 0 to 360E (or 180W to 180E)

Look Angle Determination Slides:

Coordinate System



Latitude (θ°N) and longitude (ϕ°E) of a point A.

Coordinate System 1
Geocentric Equatorial Coordinates

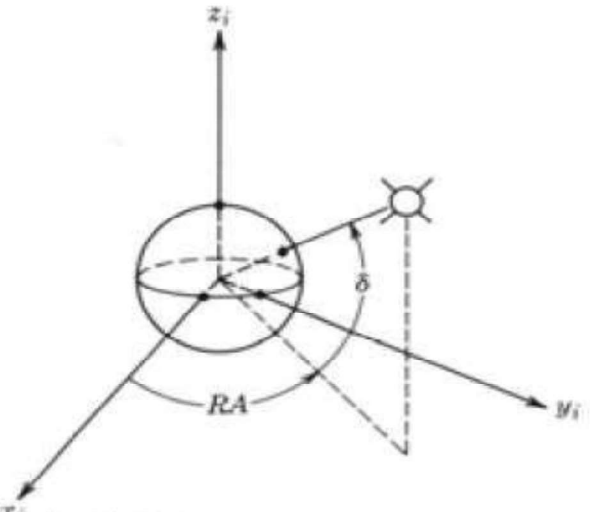
- $\mathbf{z_i}$ axis — Earth's rotational axis (N-S poles with N as positive z)
- $\mathbf{x_i}$ axis — In equatorial plane towards **FIRST POINT OF ARIES**
- $\mathbf{y_i}$ axis — Orthogonal to $\mathbf{z_i}$ and $\mathbf{x_i}$

NOTE: The ***First Point of Aries*** is a line from the center of the earth through the center of the sun at the vernal equinox (spring) in the northern hemisphere

Geocentric Equatorial Coordinates

RA = Right Ascension (in the x_i,y_i plane)

δ = Declination (the angle from the x_i,y_i plane to the satellite radius)



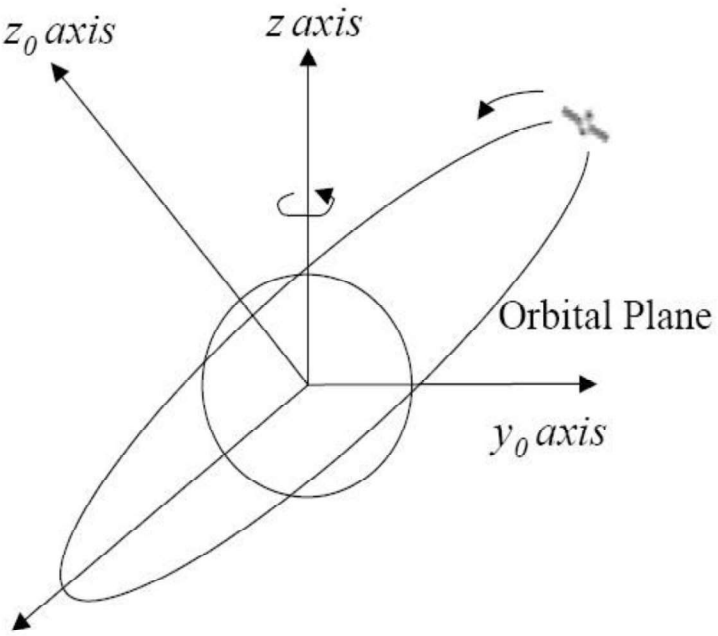
To ***First Point of Aries***

NOTE: Direction to ***First Point of Aries*** does **NOT** rotate with earth's motion around; the direction only ***translates***

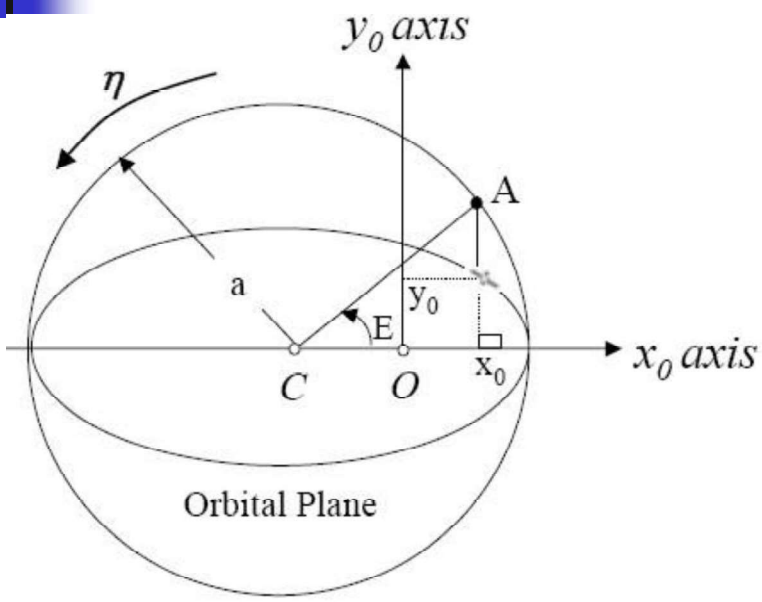
40

Coordinate System 2 – Orbital Plane Coordinate System

- The earth is at the center of the coordinate system
- Reference plane coincides with orbital plane of satellite



Locating a Satellite in its Orbit

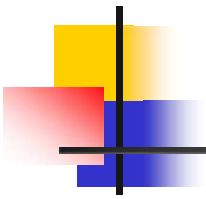


Circumscribed Circle

- η = Average angular velocity
- ***M*** = **Mean Anomaly** = Arc length (in radians) that the satellite would have traversed since perigee passage if it were moving around the circumscribed circle with average angular velocity η
- ***E*** = **Eccentric anomaly** = Angle between the orbit center and the intersection between the vertical line from the satellite to the circumscribed circle

Locating a Satellite in its Orbit

- **Given the time of perigee t_p, the eccentricity e, and the length of the semi-major axis a**
  - $\mathbf{t_p}$ Time of Perigee = time the satellite is crossing the x_0 axis, according to the reference used.
  - t- $\mathbf{t_p}$ = time elapsed since satellite last passed the perigee.
- **Calculate the orbital constants to locate the satellite in the orbital plane at time t**



Steps of Procedure

- η Average angular velocity

  $\eta = (\mu^{1/2})/(a^{3/2})$

- **M** Mean anomaly

  $M = \eta(t - t_p)$

- **E** Eccentric anomaly

  $M = E - esin(E)$

- $\mathbf{r_o}$ Radius from orbit center

  $r_0 = a - aecos(E)$

Orbital Description

- ϕ_o True anomaly

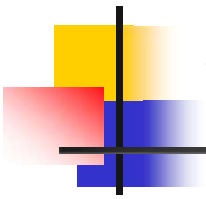
$$r_0 = \frac{a(1-e^2)}{1+e\cos(\phi_0)} \qquad \text{(solve for } \phi_0\text{)}$$

- $\mathbf{x_0}$ and $\mathbf{y_0}$

$$x_0 = r_0\cos(\phi_0) \qquad y_0 = r_0\sin(\phi_0)$$

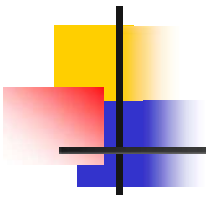
(polar to cartesian coordinate transform)

Now, we have the coordinates of the satellite, (r_o, ϕ_o) or (x_o, y_o), in the orbital plane at time t



Orbital Description

- The ***Orbital Constants*** allow you to determine coordinates (r_o, φ_o) and (x_o, y_o) in the orbital plane
- Now need to locate the orbital plane with respect to the earth
- More specifically: need to locate the orbital location with respect to a **point on the surface of the earth**

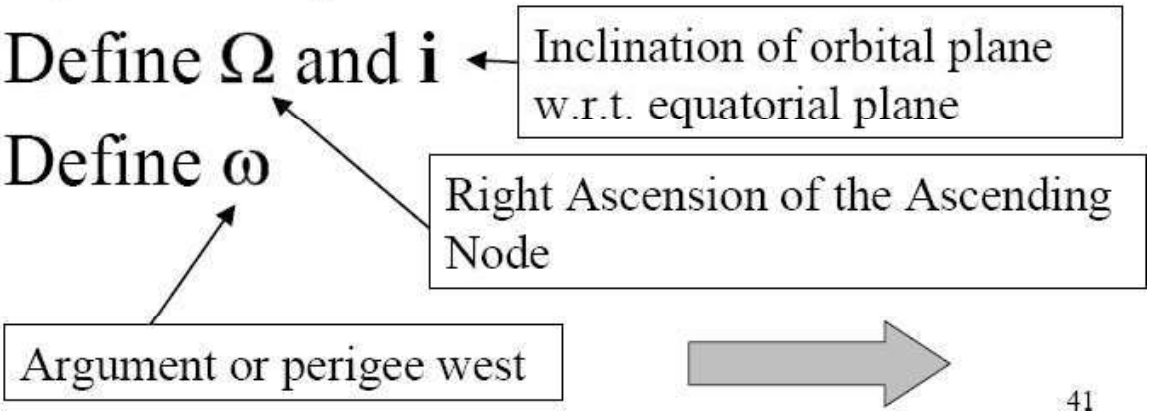


Locating Satellite with respect to Earth

- The orbital constants define the orbit of the satellite with respect to the **CENTER** of the earth
- To know where to look for the satellite in space, we must relate the orbital plane and time of perigee to the earth's axis

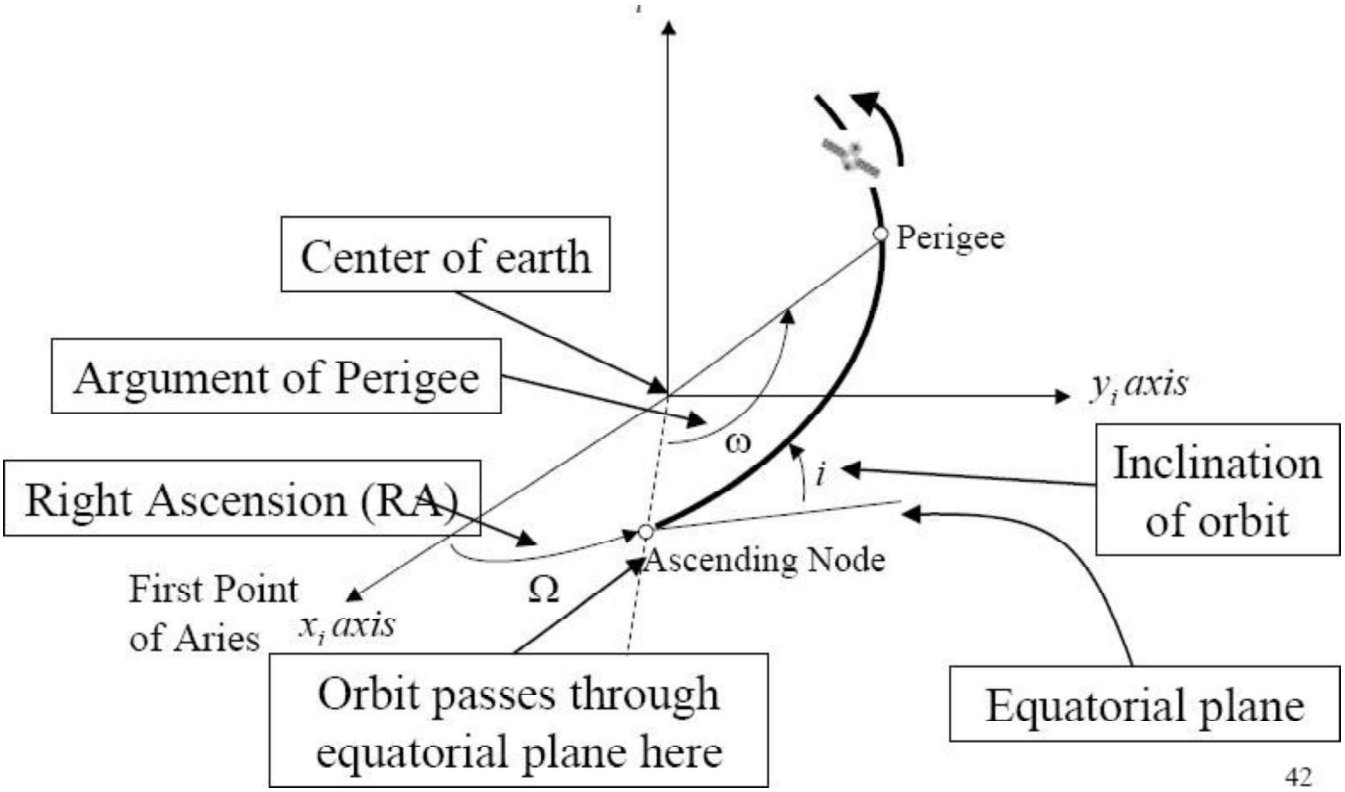
Defining Parameters

- Find the ***Ascending Node***
  - Point where the satellite crosses the equatorial plane from South to North
  - Define Ω and **i**
  - Define ω



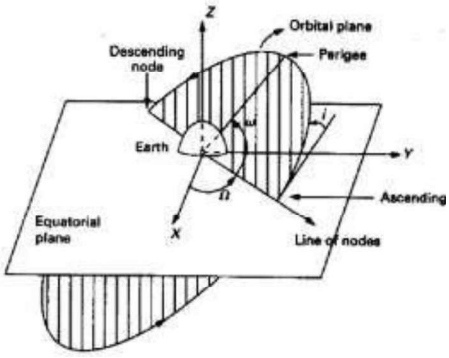
41

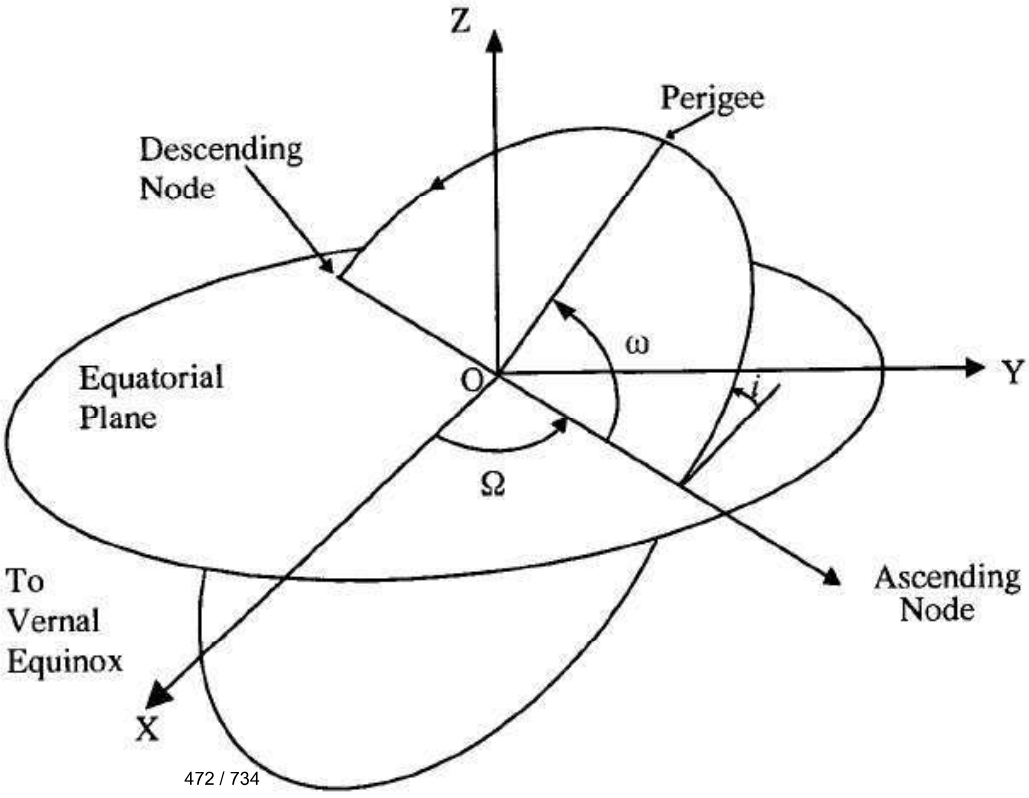
Defining Parameters



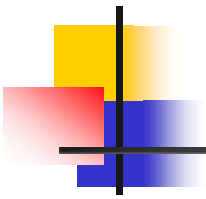
42

Locating Satellite with respect to Earth

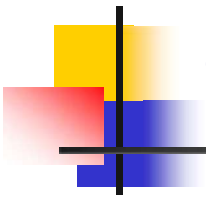




Locating Satellite with respect to Earth



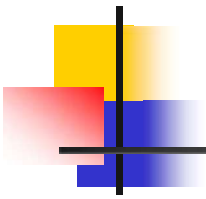
- Ω and **i** together locate the Orbital plane with respect to the Equatorial plane.
- ω locates the Orbital coordinate system with respect to the Equatorial coordinate system.



Complete Satellite Location

To specify the exact position of an orbiting satellite at a given instant, we need the <u>Orbital Elements:</u>

- Ω Right Ascension of the Ascending Node
- **i** Inclination of the orbit
- ω Argument of Perigee
- $\mathbf{t_p}$ Time of Perigee
- **e** Eccentricity of the elliptical orbit
- **a** Semi-major axis of the orbit ellipse

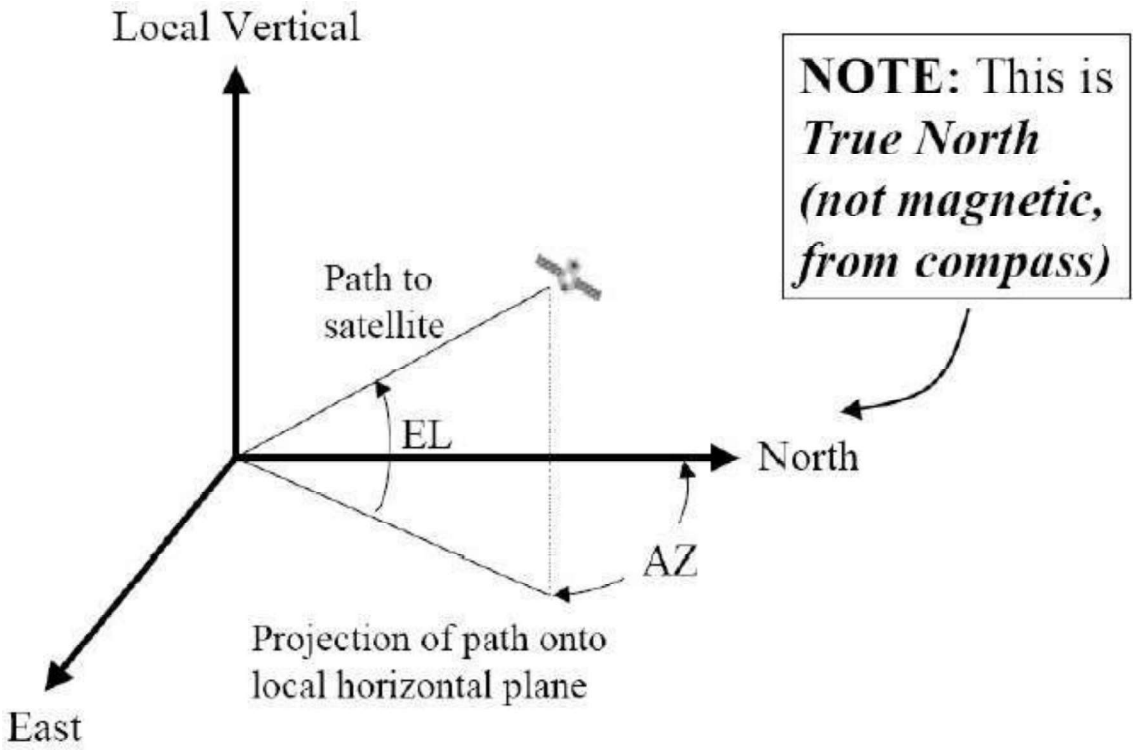


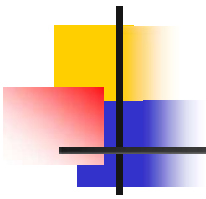
Look Angle determination

Look angles: The coordinates to which an ES must point to communicate with a satellite. These are *azimuth* (AZ) and *elevation angle* (EL)

- AZ: The angle measured from N to E to projection of satellite path onto horizontal plane
- EL: The angle measured from the horizontal plane to the orbit plane

The *subsatellite point*: The point, on the earth's surface, of intersection between a line from the earth's center to the satellite

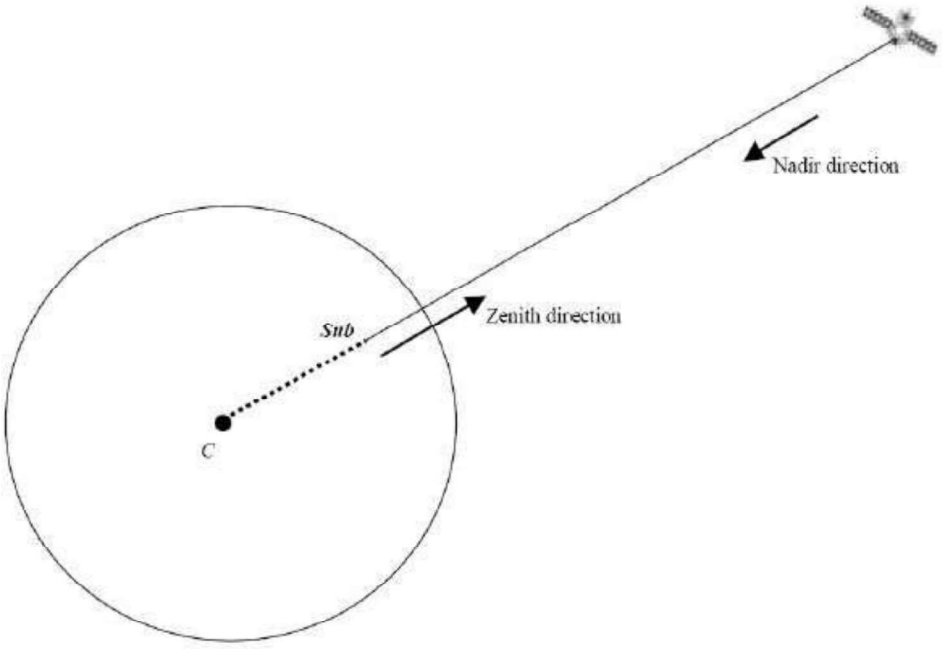

Local Vertical
NOTE: This is True North (not magnetic, from compass)
Path to satellite
EL
North
AZ
Projection of path onto local horizontal plane
East



Look Angles

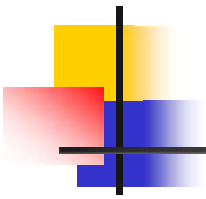
- **Azimuth:** Measured eastward (clockwise) from geographic north to the projection of the satellite path on a (locally) horizontal plane at the earth station.
- **Elevation Angle:** Measured upward from the local horizontal plane at the earth station to the satellite path.

SUBSATELLITE POINT



Calculating the look Angle

- ***Need*** six Orbital Elements
- ***Calculate*** the orbit from these Orbital Elements
- ***Define*** the orbital plane
- ***Locate*** satellite at time ***t*** with respect to the ***First Point of Aries***
- ***Find location*** of the Greenwich Meridian relative to the first point of Aries
- ***Use Spherical Trigonometry*** to find the position of the satellite relative to a point on the earth's surface



Satellite Coordinates

- SUB-SATELLITE POINT
  - Latitude $\mathbf{L_s}$
  - Longitude $\mathbf{l_s}$
- EARTH STATION LOCATION
  - Latitude $\mathbf{L_e}$
  - Longitude $\mathbf{l_e}$
- Calculate γ, ANGLE AT EARTH CENTER

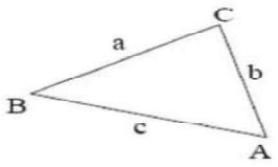
Between the line that connects the earth-center to the satellite and the line from the earth-center to the earth station.

Look Angle Determination

Slides:

Review of Geometry

- Review of plane trigonometry
  - Law of Sines
  - Law of Cosines
  - Law of Tangents



$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

$$c^2 = a^2 + b^2 - 2ab\cos C$$

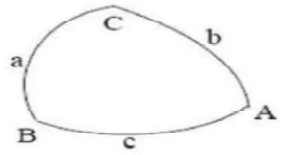
$$\tan\frac{C}{2} = \sqrt{\frac{(d-a)(d-b)}{d(d-c)}}, d = \frac{a+b+c}{2}$$

- Review of spherical trigonometry
  - Law of Sines
  - Law of Cosines for angles
  - Law of Cosines for sides

$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

$$\cos a = \cos b\cos c + \sin b\sin c\cos A$$

$$\cos A = -\cos B\cos C + \sin B\sin C\cos a$$



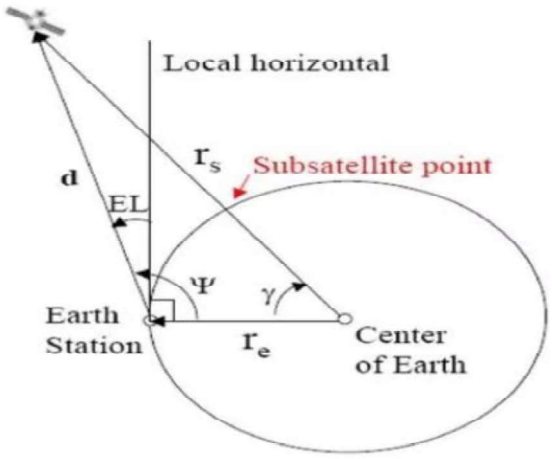
59

Look Angle Determination

Slides:

Geometry of Elevation Angle

- Plane in picture is the one that includes center of the earth, Earth Station and Satellite.
- Subsatellite point will also be on the same plane.



$El = \psi - 90^o$

γ = central angle

r_s = radius to the satellite

r_e = radius of the earth

Look Angle Determination

Slides:

Central Angle

γ is defined so that it is non-negative and

$$\cos(\gamma) = \cos(Le)\cos(L_s)\cos(l_s - l_e) + \sin(L_e)\sin(L_s)$$

The magnitude of the vectors joining the center of the earth, the satellite and the earth station are related by the law of cosine:

$$d = r_s\left[1+\left(\frac{r_e}{r_s}\right)^2 - 2\left(\frac{r_e}{r_s}\right)\cos(\gamma)\right]^{1/2}$$

Look Angle Determination

Slides:

Elevation Angle Calculation

By the sine law we have

$$\frac{r_s}{\sin(\psi)} = \frac{d}{\sin(\gamma)}$$

Which yields

$$\cos(El) = \frac{\sin(\gamma)}{\left[1+\left(\frac{r_e}{r_s}\right)^2 - 2\left(\frac{r_e}{r_s}\right)\cos(\gamma)\right]^{1/2}}$$

Look Angle Determination

Slides:

Example: Elevation Angle for GEO Satellite

Using r_s = 42,164 km and r_e = 6,378.14 km gives

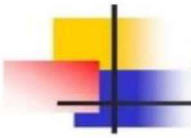
d = 42,164 [1.0228826 -0.3025396 cos(γ)]$^{1/2}$ km

Which finally gives the elevation angle

$$\cos(El) = \frac{\sin(\gamma)}{[1.0228826 - 0.3025396\cos(\gamma)]^{1/2}}$$

Look Angle Determination

Slides:



Azimuth Angle Calculation

- More complex approach for non-geo satellites.
- Different formulas and corrections apply depending on the combination of positions of the earth station and subsatellite point with relation to each of the four quadrants (NW, NE, SW, SE).
- Its calculation is simple for GEO satellites

Look Angle Determination

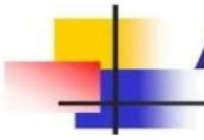
Slides:

Azimuth Angle Calculation for GEO Satellites

- SUB-SATELLITE POINT
  - Equatorial plane, Latitude **Ls = 0o**
  - Longitude **ls**
- EARTH STATION LOCATION
  - Latitude **Le**
  - Longitude **le**

Look Angle Determination

Slides:



Azimuth Angle for GEO sat.

The original calculation previously shown:

$$\cos(\gamma) = \cos(Le)\cos(L_s)\cos(l_s - l_e) + \sin(L_e)\sin(L_s)$$

Simplifies using $L_s = 0^o$ since the satellite is over the equator:

$$\boxed{\cos(\gamma) = \cos(Le)\cos(l_s - l_e)}$$

Look Angle Determination

Slides:

Azimuth Angle for GEO sat.

To find the azimuth angle, an ***intermediate angle,*** α, must first be found. The intermediate angle allows the correct quadrant (see Figs. 2.10 & 2.13) to be found since the azimuthal direction can lie anywhere between 0° (true North) and clockwise through 360° (back to true North again). The intermediate angle is found from

$$\alpha = \tan^{-1}\left[\frac{\tan|(l_s - l_e)|}{\sin(L_e)}\right]$$

Look Angle Determination

Slides:



Azimuth Angle for GEO sat.

Case 1: Earth station in the Northern Hemisphere with

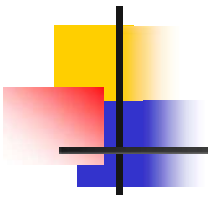
(a) Satellite to the SE of the earth station: $Az = 180^o - \alpha$

(b) Satellite to the SW of the earth station: $Az = 180^o + \alpha$

Case 2: Earth station in the Southern Hemisphere with

(c) Satellite to the NE of the earth station: $Az = \alpha$

(d) Satellite to the NW of the earth station: $Az = 360^o - \alpha$



EXAMPLE LOOK ANGLES

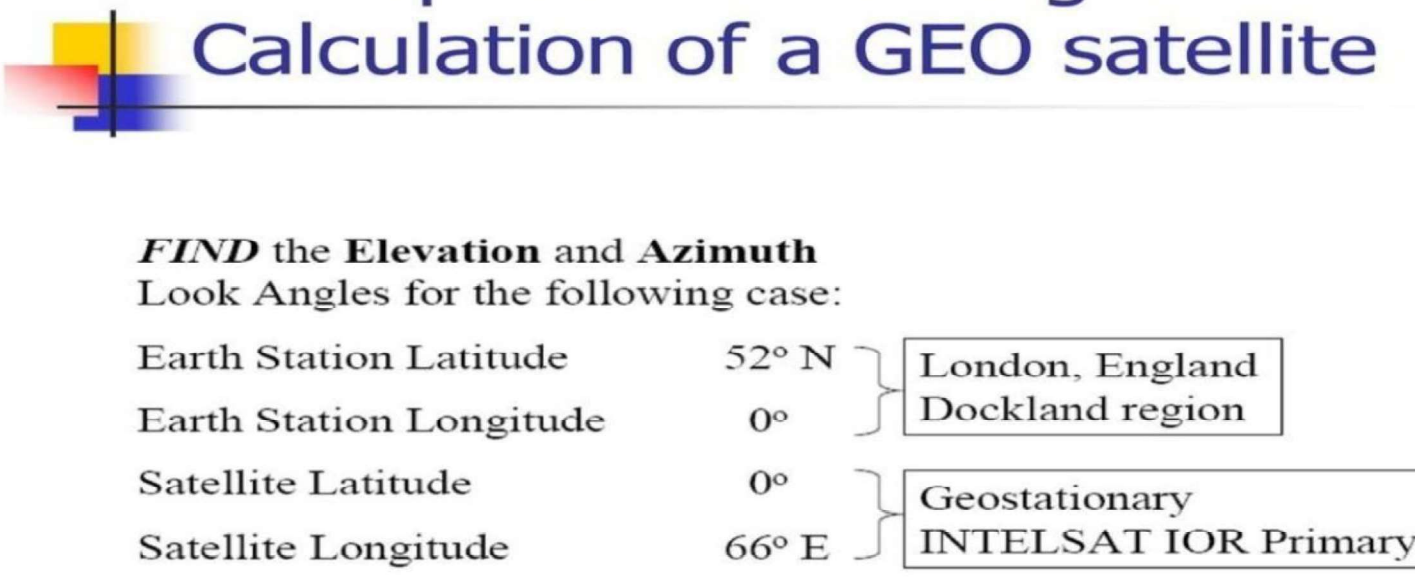
An earth station is situated at Docklands of Londan,England.Then calculate the look angles of that earth station to a geostationary satellite in the Indian ocean operated by Intelsat. The details of the earth station site and the satellite are as follows.

Earth station latitude and longitude are 52.0^0 N and 0^0.

Satellite longitude(subsatellite point)is 66^0E.

Look Angle Determination

Slides:



Look Angle Determination

Slides:

Example (Contd.)

Step 1. Find the central angle γ

$$\cos(\gamma) = \cos(L_e)\cos(l_s - l_e)$$
$$= \cos(52)\cos(66)$$
$$= 0.2504$$

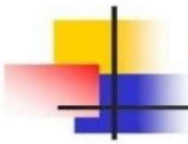
yielding $\gamma = 75.4981°$

Step 2. Find the elevation angle El

$$\cos(El) = \frac{\sin(\gamma)}{[1.0228826 - 0.3025396\cos(\gamma)]^{1/2}}$$

El=5.85°

Look Angle Determination Slides:



Example (Contd.)

Step 3. Find the intermediate angle, α

$$\alpha = \tan^{-1}\left[\frac{\tan\left|(l_s - l_e)\right|}{\sin(L_e)}\right]$$

$$= \tan^{-1}\left[\left(\tan(66 - 0)\right) / \sin(52)\right]$$

$$= 70.6668$$

Look Angle Determination

Slides:



Example (Contd.)

The earth station is in the Northern hemisphere and the satellite is to the South East of the earth station. This gives

$$Az = 180^\circ - \alpha$$
$$= 180 - 70.6668 = 109.333^\circ \text{ (clockwise from true North)}$$

ANSWER: The look-angles to the satellite are

Elevation Angle = 5.85°

Azimuth Angle = 109.33°

Look Angle Determination

Slides:

LIMITS OF VISIBILITY

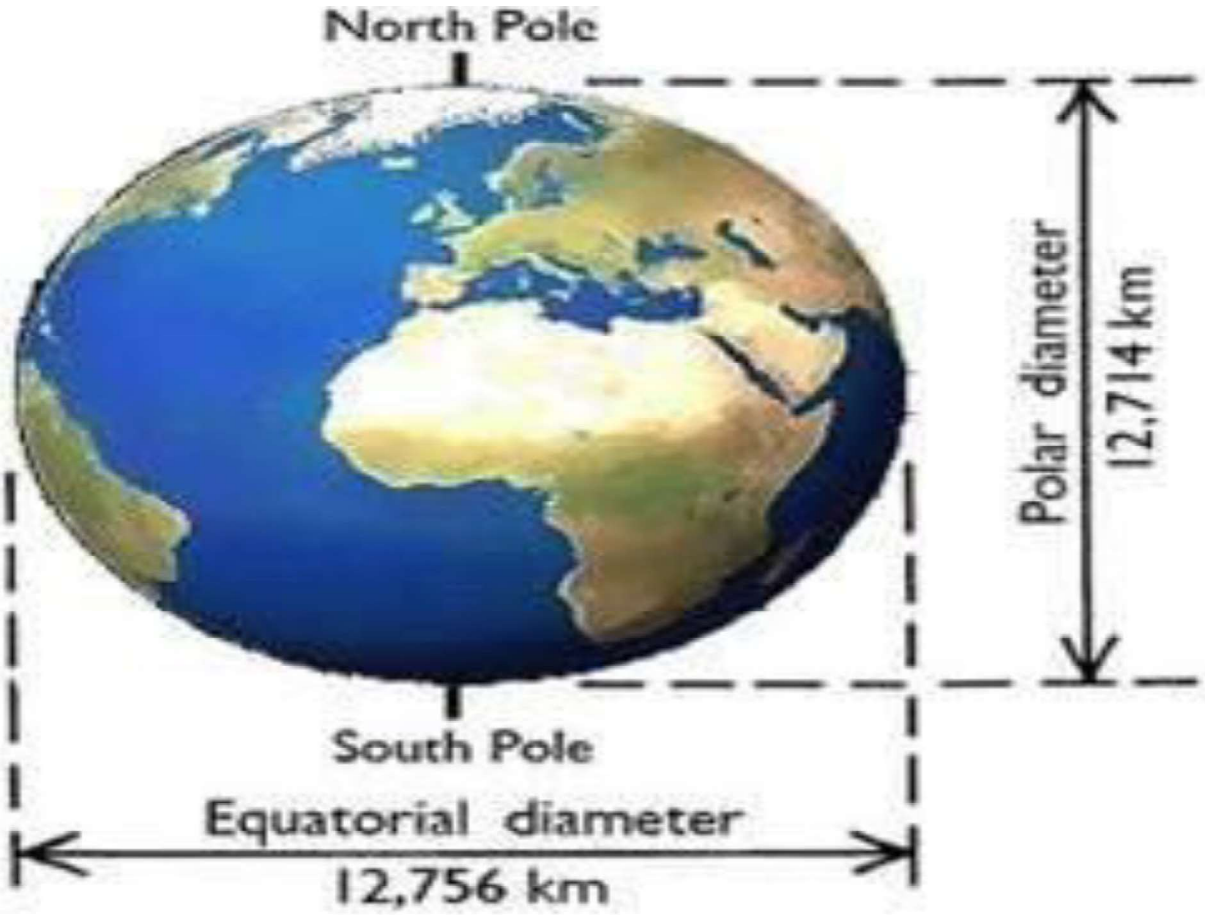
- There are a number of perturbing forces that cause an orbit to depart from the ideal keplerian orbit.
- The period for a geostationary satellite is 23 h, 56 min, 4 s, or 86,164 s.
- The reciprocal of this is 1.00273896 rev/day,
- The east and west limits of geostationary are visible from any given Earth station.
- These limits are set by the geographic coordinates of the Earth station and antenna elevation.
- The lowest elevation is zero (in theory) but in practice, to avoid reception of excess noise from Earth some finite minimum value of elevation is issued.
- The earth station can see a satellite over a geostationary arc bounded by **+/- (81.3⁰)** about the earth station's longitude.

ORBITAL PERTURBATIONS:

- Under ideal conditions, we consider the orbit as an ellipse whose properties are constant with time.
- In practice, the satellite and the earth respond to many other influences including asymmetry of earth“s gravitational field, thegravitational fields of sun and moon, and solar radiation pressure.
- For LEO satellites, atmospheric drag can also be important.
- All of these interfering forces cause the true orbit to be different from ellipse.
- The perturbations are assumed to cause the orbital elements to
  vary with time.

LONGITUDINAL CHANGES: EFFECTS OF EARTH'S OBLATNESS:

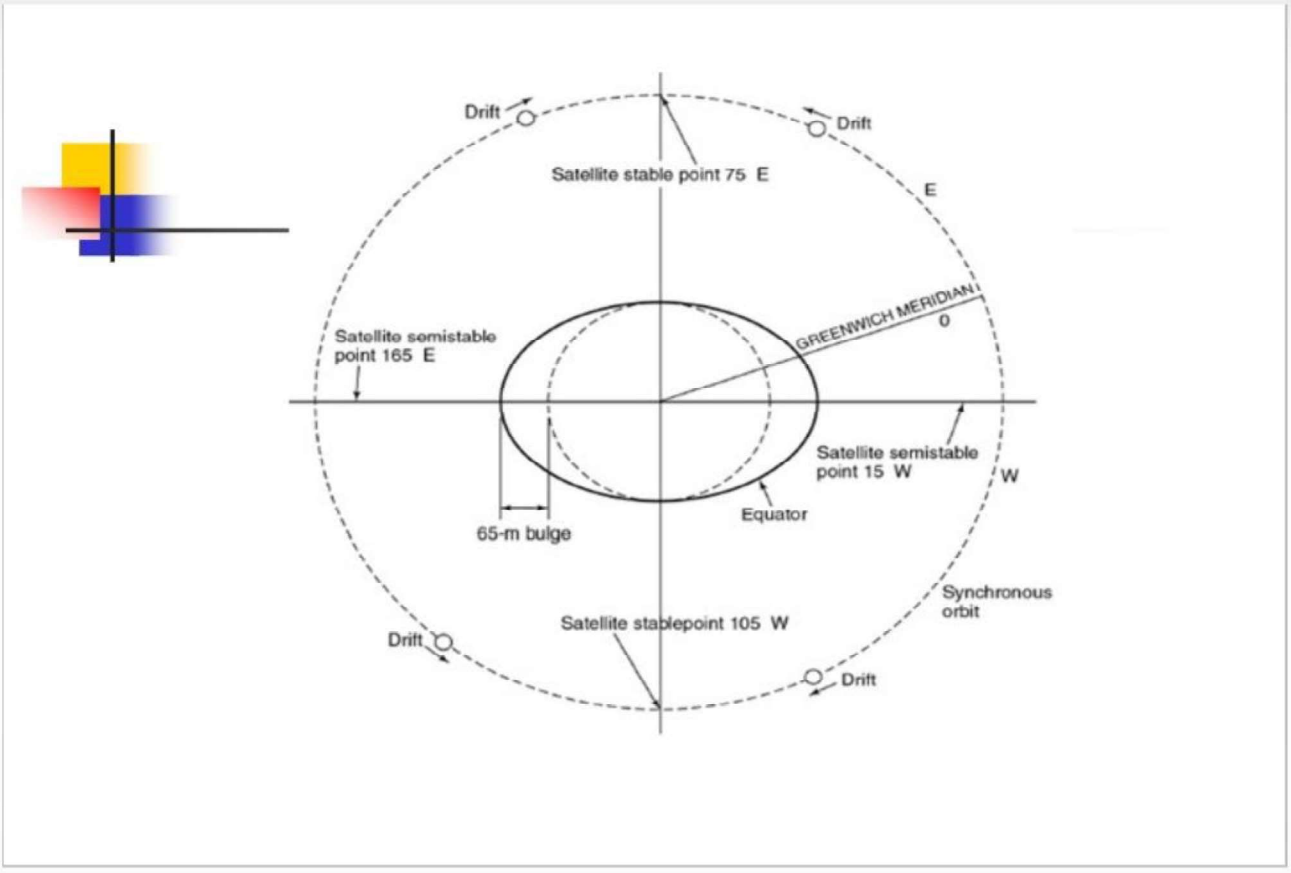
- The earth is neither a perfect sphere nor a perfect ellipse.
- The earth is flattened at the poles; the equatorial diameter is
  about 20 km more than average polar diameter.
- The equatorial radius is not constant (does not vary more than 100m around equator)
- There are some regions on earth where the gravitational attraction is higher, referred as regions of mass concentration or MASCONS.
- These nonregular features of the earth lead to nonuniform gravitational field around earth. The force on an orbiting satellite will vary with position.


North Pole
Polar diameter
12,714 km
South Pole
Equatorial diameter
12,756 km

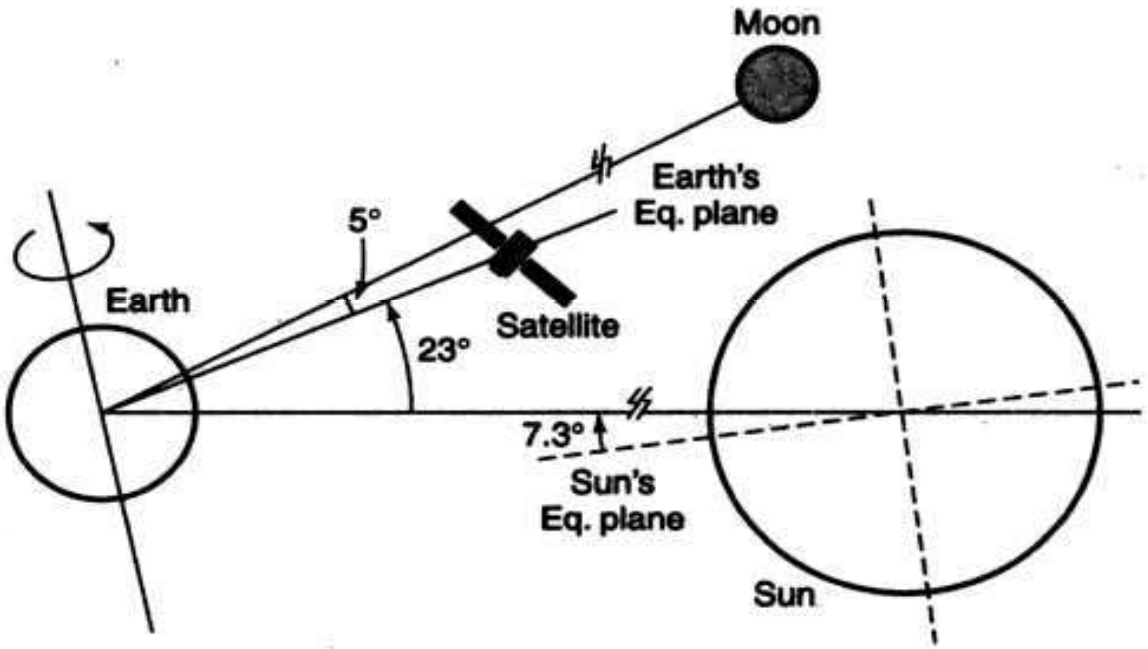
- A GEO satellite is weightless when it is in orbit. The smallest force on satellite will cause it to accelerate and then drift away from its nominal location.

- There will generally be an additional force toward the nearest equatorial bulge in either an eastward or westward direction along orbital plane.

- Due to position of Mascons & equatorial bulges, there are four equilibrium points in the geostationary orbit: two stable and two unstable.
- Stable points-> 75° E & 252° E, Unstable points-> 162° E & 348° E
- The satellite at an unstable orbital location is at top of a gravity hill. Given a small force, it will drift down the gravity slope into gravity well(valley) and finally stay there, at the stable position.
- If a satellite is perturbed slightly from one of the stable points, it will tend to drift back to the stable point without any thruster firings required.
- If a satellite is perturbed slightly from one of the unstable points, it will immediately begin to accelerate its drift toward nearer stable point and once it reaches this point, it will oscillate in longitudinal position about this point until it stabilizes at that point.
- These stable points are called graveyard geosynchronous orbit locations.


Drift
Drift
Satellite stable point 75 E
E
GREENWICH MERIDIAN
0
Satellite semistable
point 165 E
Satellite semistable
point 15 W
W
Equator
65-m bulge
Synchronous
orbit
Satellite stablepoint 105 W
Drift
Drift

INCLINATION CHANGES: EFFECTS OF SUN & MOON



- The plane of the earth“s orbit around the sun– the ecliptic - is at an inclination of 7.3° to the equatorial plane of the sun.
- The earth is tilted about 23° away from the normal to the ecliptic.
- The moon circles the earth with an inclination of around 5° to the equatorial plane of the earth.
- Due to the sun“s equator, the ecliptic, the earth“s equator and moon“s orbital plane around earth – are all different, a satellite in orbit around the earth will be subjected to a variety of out-of- plane forces.
- This will tend to try to change the inclination of the satellite“s orbit from its initial inclination.

- The mass of sun is significantly larger than that of the moon but the moon is considerably closer to the earth than the sun. For this reason, the acceleration force induced by the moon on a geostationary satellite is about twice as large as that of the sun.
- The net effect of the acceleration forces induced by the moon and sun on a geostationary satellite is to change the plane of the orbit at an initial average rate of change of 0.85°/year from the equatorial plane.
- When both the sun and moon are acting on the same side of satellite"s orbit, the rate of change of plane of geostationary satellite"s orbit will be higher than average. When both the sun and moon are acting on the opposite side of satellite"s orbit, the rate of change of plane of geostationary satellite"s orbit will be less than average.

- To increase the orbital maneuver lifetime of a satellite for a given fuel load, mission planners deliberately place a satellite planned for geostationary orbit into an initial orbit with an inclination.

ORBIT DETERMINATION:

- Orbit determination requires that sufficient measurements be made to determine uniquely the six orbital elements needed to calculate the future orbit of the satellite.
- Hence calculate the required changes that need to be made to the orbit to keep it within nominal orbital location.
- The control earth station use to measure the angular position of
  the satellites.
- These earth station are generally referred to as TTC&M (Telemetry, Tracking, Command and Monitoring) stations of the satellite network.

- Major satellite networks maintain their own TTC&M stations around the world.
- Smaller satellite systems generally contact for such TTC&M functions from spacecraft manufacturer or from the large satellite system operators, as it is generally uneconomic to build advanced TTC&M stations with fewer than 3 satellites to control.

ORBITAL EFFECTS IN COMMUNICATIONS SYSTEMS PERFORMANCE:

1. Doppler shift ->

- For stationary observer, the frequency of moving radio transmitter varies with transmitter"s velocity relative to the observer.
- If „Ft" is true transmitter frequency (i.e. frequency of signal when transmitter is at rest) and „Fr" is received frequency then „Fr" is greater than „Ft" when transmitter is moving towards the receiver and „Fr" lower than „Ft" when transmitter is moving away from receiver.

$$\frac{F_r - F_t}{F_t} = \frac{\Delta f}{F_t} = \frac{V_t}{V_p}$$

$$\Delta f = \frac{V_t . F_t}{C} = \frac{V_t}{\lambda}$$

Where,

V_t = Component of transmitter velocity towards receiver.

V_p = Component of phase velocity of light.

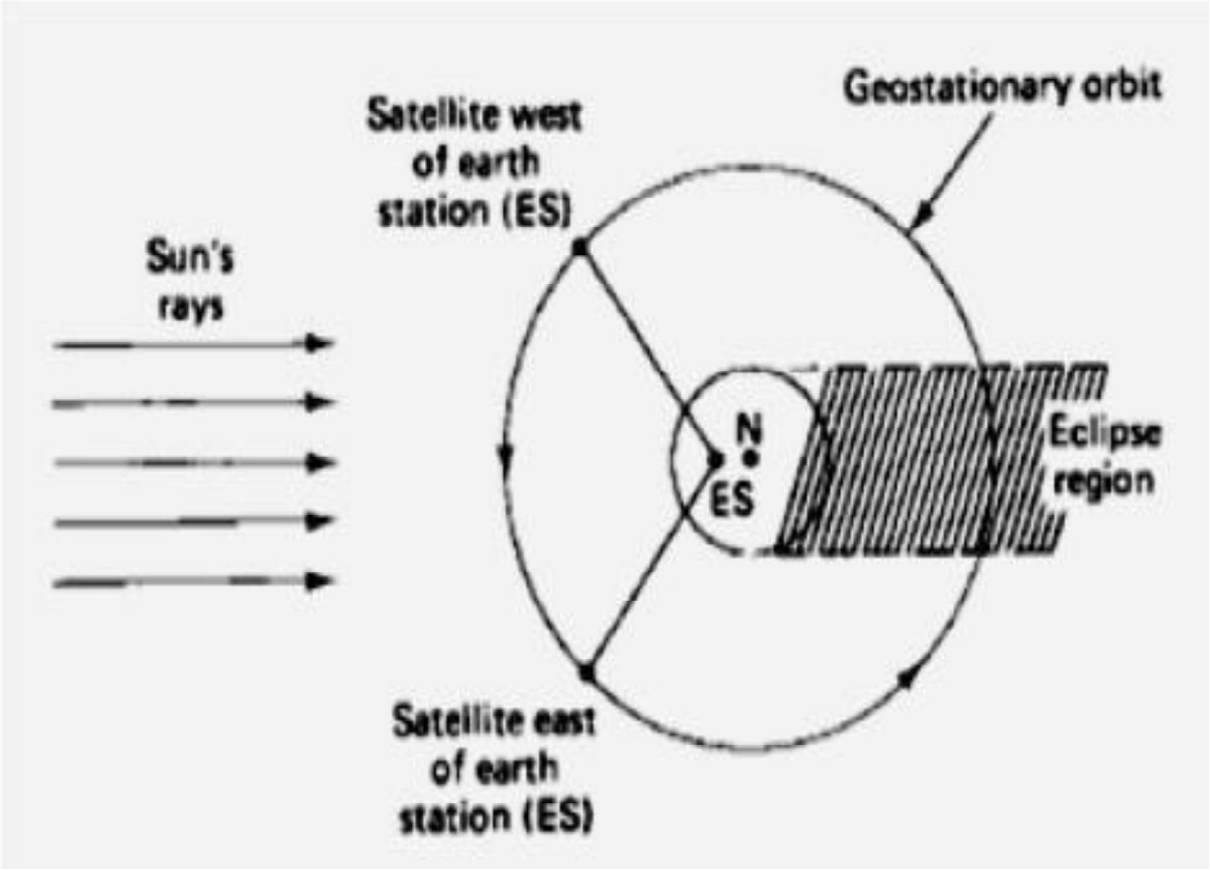
λ = wavelength of transmitted signal.

RANGE VARIATIONS:

- Generally when satellite revolves around the earth, it undergoes some form of variation in its position during a cyclic daily variation.
- This variation in the position heads to the variation in the range between satellites and user terminal.

SOLAR ECLIPSE:

- A satellite is said to be in eclipse when the earth prevents sunlight from reaching it, that is, when the satellite is in the shadow of the earth.
- For geostationary satellites, eclipses occur during two periods that begin 23 days before the equinoxes(March 21 & September 23) and end 23 days after equinox periods.
- Eclipse occur close to equinoxes, as these are the times when the sun, the earth, and the satellite are all nearly in the same plane.


Geostationary orbit
Satellite west of earth station (ES)
Sun's rays
N
ES
Eclipse region
Satellite east of earth station (ES)

- During full eclipse, a satellite receives no power from its solar
  array and it must operate entirely from its batteries.
- Batteries are designed to operate with a maximum depth of discharge.
- Nickel-Hydrogen batteries, can operate at about 70% depth of
  discharge and recover fully once recharged.
- Ground controllers perform battery-conditioning routines prior to eclipse operation.
- The routines consist of deliberately discharging the batteries until they are close to their maximum depth of discharge, and then fully recharging the batteries before eclipse season begins.

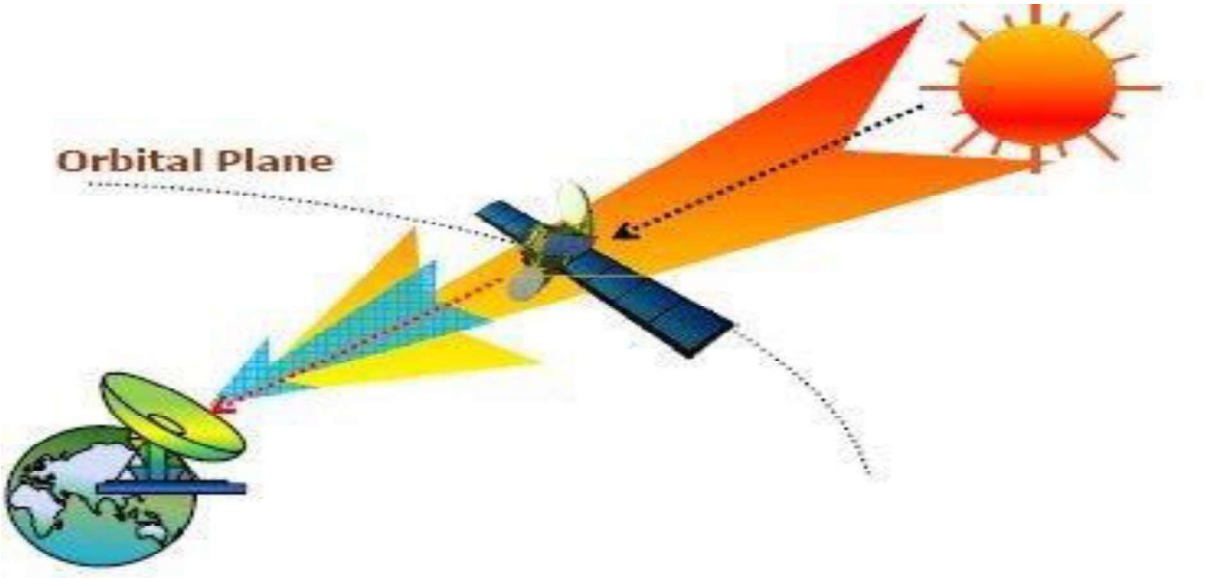
- The eclipse season is design challenge for spacecraft builders.
- Rapidity with which the satellite enters and exits the shadow can cause extreme changes in both power and heating effects over relative short periods.
- Eclipse periods are therefore monitored carefully by ground controllers, as this when most of the equipment failures are likely to occur.

SUN TRANSIT OUTAGE:

- During the equinox periods, not only does the satellite pass through the earth“s shadow on the dark side of the earth, but theorbit of the satellite will also pass directly in front of the sun.

- The sun is a “hot” microwave source with an equivalent temperature of about 6000 to 10000k.

- The earth station antenna will therefore receive not only the signal from the satellite but also the noise temperature transmitted by sun.



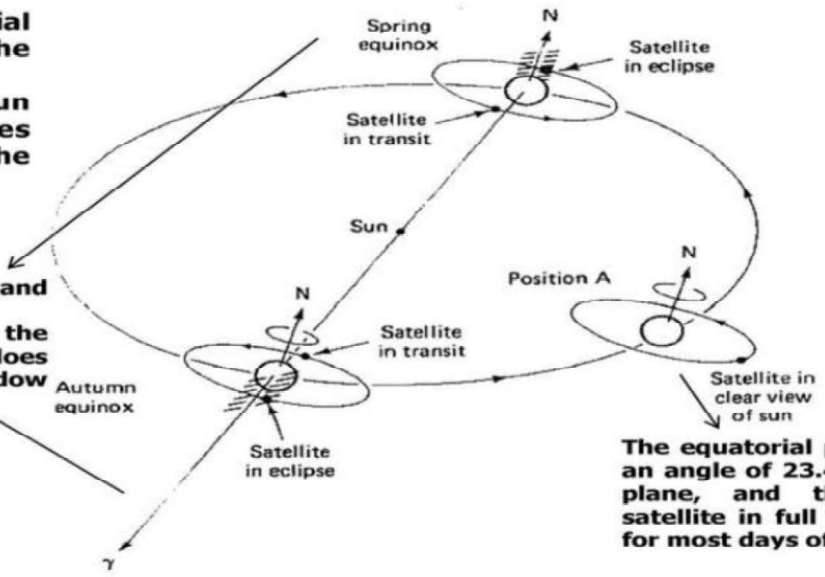
- For satellite system operators with more than one satellite at their disposal, traffic can be off-loaded to satellites that are just out of , or are yet to enter, a sun outage.

Look Angle Determination

Slides:

EARTH ECLIPSE OF A SATELLITE

If the earth's equatorial plane coincided with the plane of the earth's orbit around the sun geostationary satellites would be eclipsed by the earth once each day.



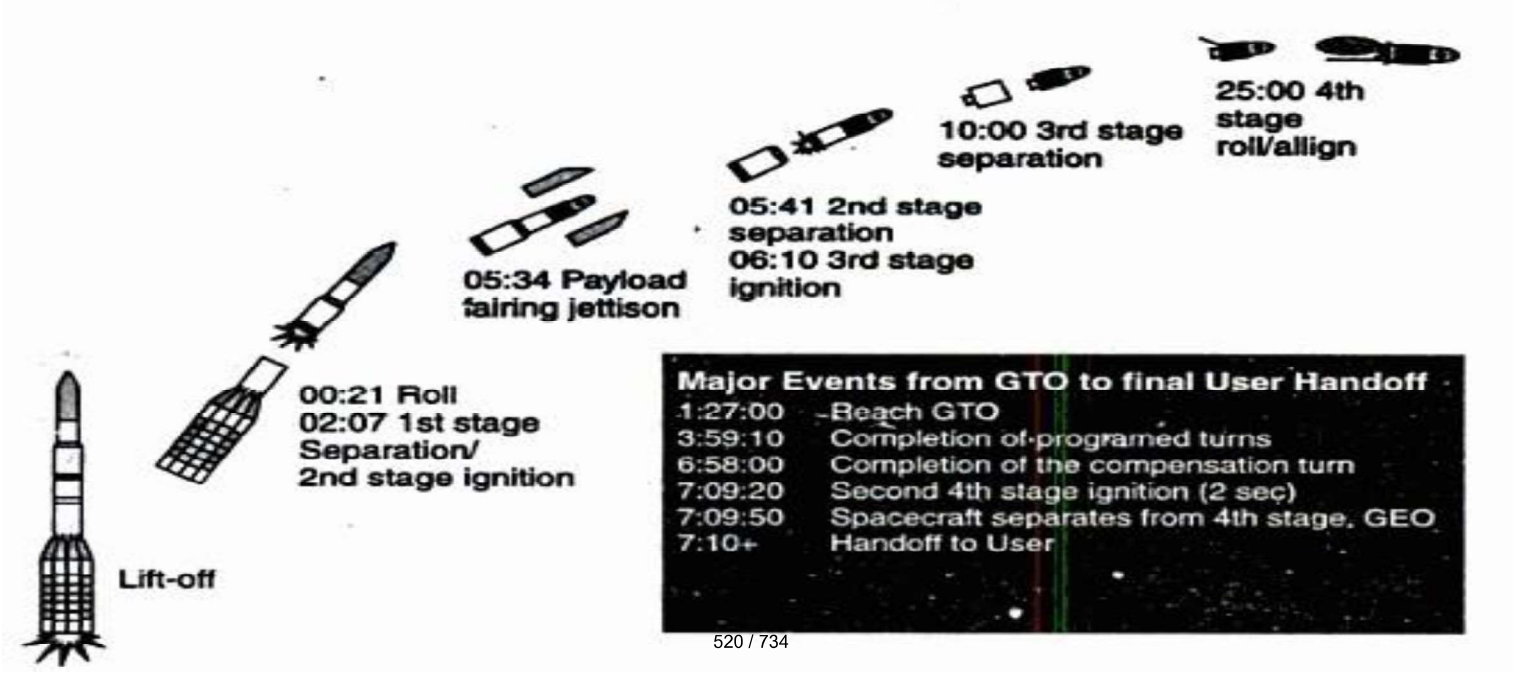
Around the spring and autumnal equinoxes, when the sun is crossing the equator, the satellite does pass into the earth's shadow at certain periods

The equatorial plane is tilted at an angle of 23.4° to the ecliptic plane, and this keeps the satellite in full view of the sun for most days of the year

LAUNCH & LAUNCH VEHICLES:

- A Satellite cannot be placed into a stable orbit unless two parameters that are uniquely coupled together – the velocity vector and the orbit height – are simultaneously correct.
- A geo-stationary satellite, must be in orbit at a height of 35,786.03 km above the surface of the earth (42,164.17 km radius from center of the earth) with an inclination of zero degrees, an elliptically of zero, and a velocity of 3074.7 m/s tangential to earth in the plane of the orbit, which is the earth's equatorial plane.
- The further out from the earth orbit is, the greater the energy
  required from launch vehicle to reach that orbit.

- In any earth satellite launch, the largest fraction of energy expended by rocket is used to accelerate the vehicle from rest until it is about 20 miles (32 Km) above the earth.
- To make the most efficient use of the fuel, it is common to shed excess mass from launcher as it moves upward on launch; this is called staging.



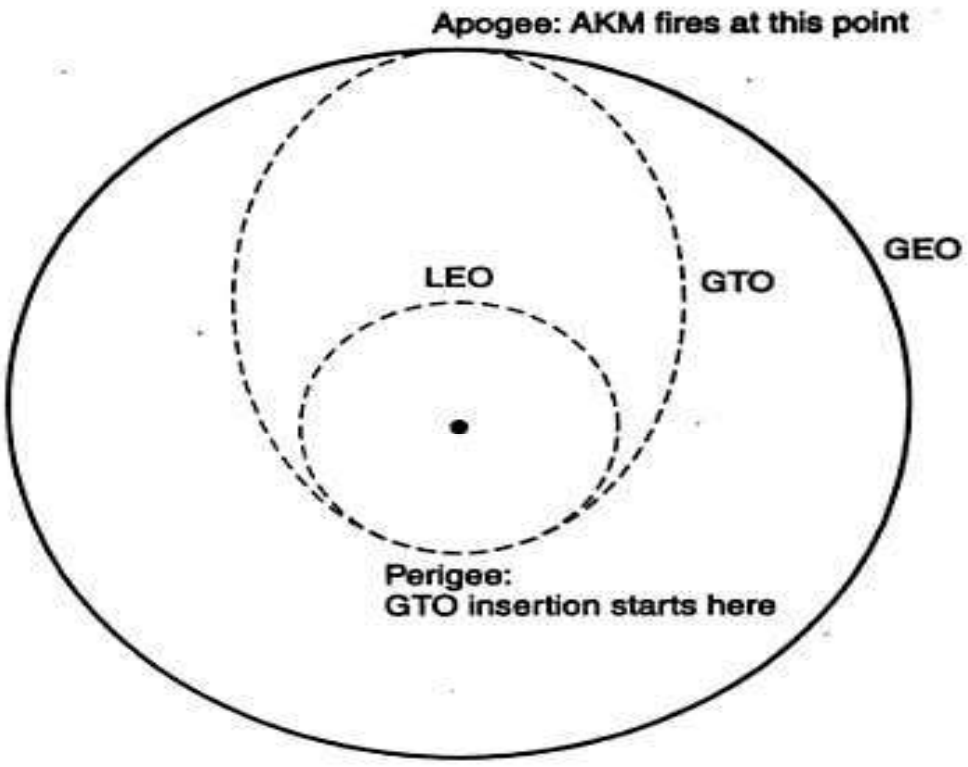
- Most launch vehicles have multiple stages and, as each stage is completed, that portion of launcher is expended until final stage places the satellite into desired trajectory. Hence the term: Expendable Launch Vehicle (ELV).

- The Space Shuttle, called the Space Transportation System (STS) by NASA, is partially reusable.

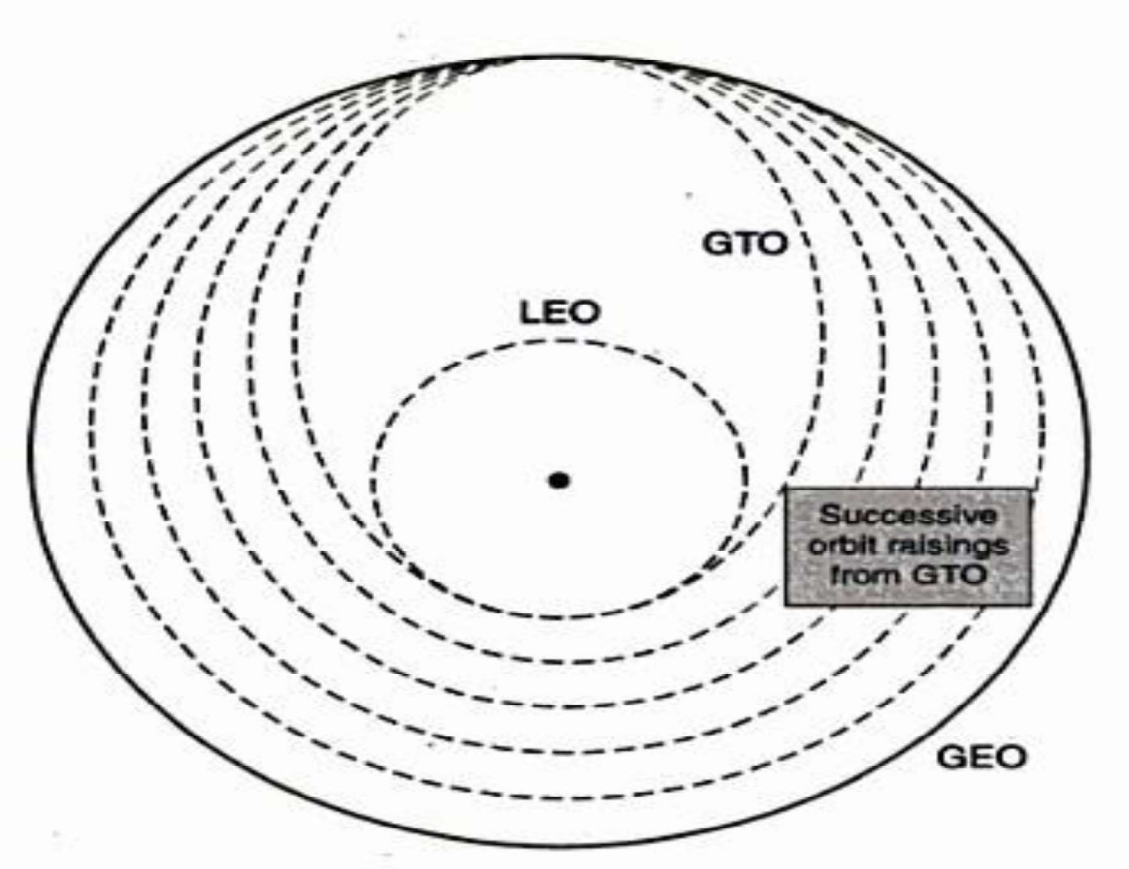
- The solid rocket boosters are recovered and refurbished for future missions and the shuttle vehicle itself is flown back to earth for refurbishment and reuse. Hence the term: Reusable Launch Vehicle (RLV).

PLACING SATELLITE IN GEOSTATIONARY ORBIT:

1.GTO WITH AKM



2.GTO with Slow orbit raising



UNIT-II
SATELLITE SUBSYSTEMS

CONTENTS:

- Attitude & Orbit control system
- TTC&M system
- Power system
- Communication subsystems
- Satellite Antennas
- Space Qualification
- Equipment Reliability

Attitude & Orbit Control System(AOCS):

- This subsystem consists of rocket motors that are used to move the satellite back to the correct orbit when external forces cause it to drift off station
- Gas jets are used to control the attitude of the satellite.
- The attitude and orbit of a satellite must be controlled so that the satellite's antennas point toward the earth and so that user knows where in the sky to look for the satellite.

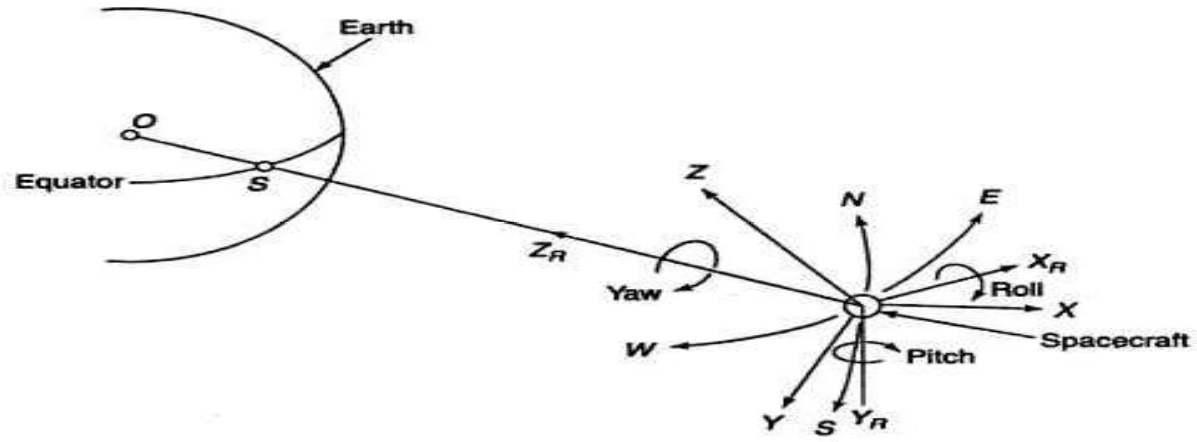
Attitude control system:

- There are two ways to make a satellite stable in orbit.
- The body of the satellite can be rotated at rate between 30 & 100 rpm, that provides stability of the spin axis & keeps it pointing in the same direction, such satellites are known as spinners.
- Alternatively, the satellite can be stabilized by the one or more momentum wheels, called as three-axis stabilized satellite.

- The momentum wheel is usually a solid metal disk driven by an electric motor.
- There must be one momentum wheel for each of the three axes of the satellite and rotated to provide a rotational force about any of the three axes.
- There are two types of rocket motors used on satellite 1. Bipropellant thrusters 2. arc jets or ion thrusters

- In three-axis stabilized satellite, one pair of gas jets is needed for each axis to provide rotation in both direction.
- When motion required along particular axis , the appropriate gas jets is operated for a specific period of time.

- The satellite attitude is defined in terms of three axis - **ROLL , PITCH, YAW**
- Roll axis is towards the velocity vector of the satellite as the satellite moves in orbit.
- Yaw axis is towards the earth center.
- Pitch axis is mutually perpendicular to both these two axis.
- They are called earth oriented co-ordinate axes.



(a)

- The satellite attitude is defined in terms of three axis - **ROLL , PITCH, YAW**
- Roll axis is towards the velocity vector of the satellite as the satellite moves in orbit.
- Yaw axis is towards the earth center.
- Pitch axis is mutually perpendicular to both these two axis.
- They are called earth oriented co-ordinate axes.

- Any perturbing force about a particular axis can cause a slight rotation about that axis.

- The zero error attitude is defined when the satellite antenna radiation beam point to the required direction.

- With this zero error attitude, the solar panels also will be able to track the sun properly.

- Error in attitude is determined by attitude error detection sensors(Infra red earth sensors) attached to the satellite.
- Any object which is above absolute zero degree Kelvin radiates energy & earth at 300 degree kelvin radiates infrared energy more compared to other wavelength bands.

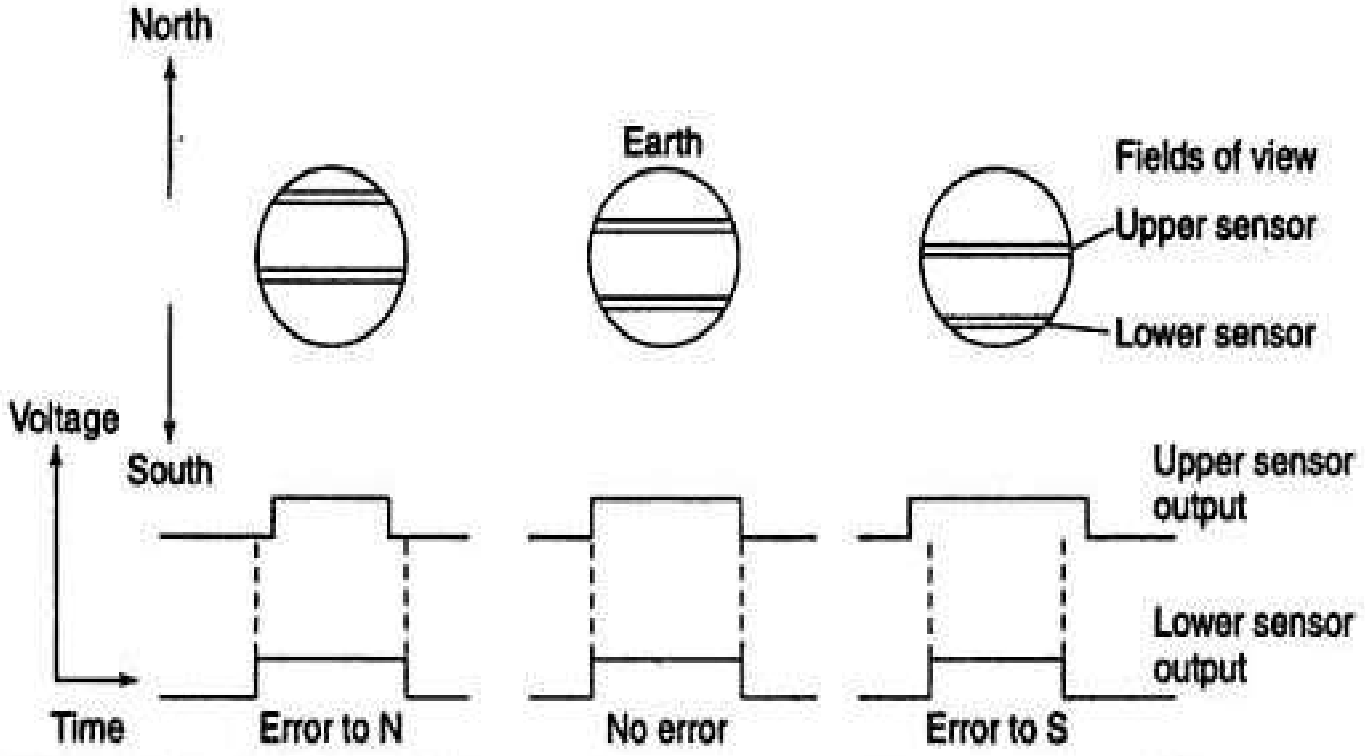
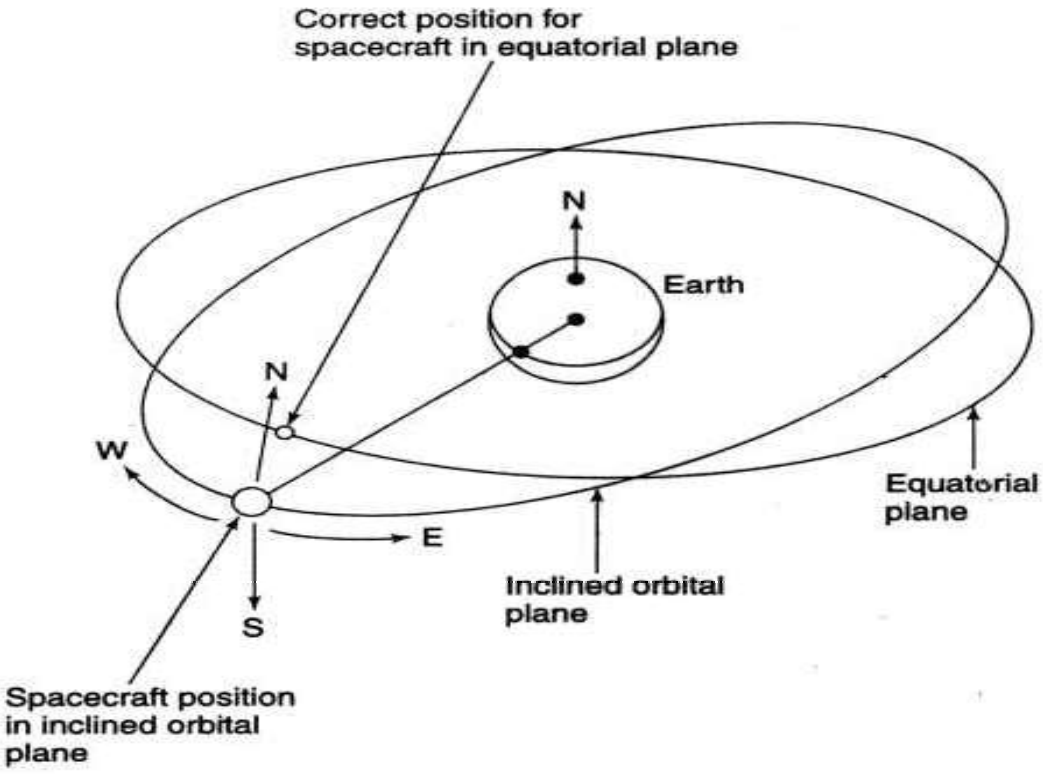


FIGURE 3.5 Principle of N–S control of a spinner satellite using infrared Earth sensors.

- By processing the pulse width generated by sensors, it is possible to measure the attitude error about Roll & Pitch axes.

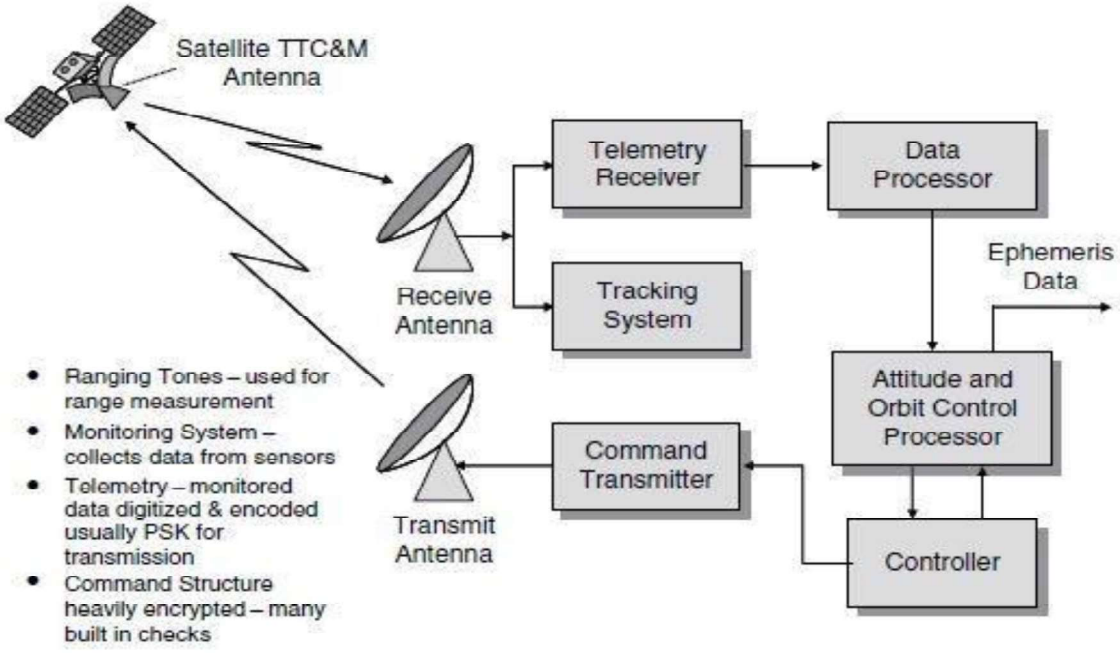
Orbit control:

- The gravitation forces of moon & the sun cause inclination of orbital plane.
- There are many other smaller forces that act on satellite causing the orbit to change.
- For the orbit to be truly geostationary, it must lie in equatorial plane, be circular and have correct altitude.


Correct position for
spacecraft in equatorial plane
N
Earth
N
W
E
S
Equatorial
plane
Inclined orbital
plane
Spacecraft position
in inclined orbital
plane

- The various forces acting on the satellite will steadily pull it out of the correct orbit; it is the function of the orbit control system to return it to the correct orbit.
- Gas jets that can impart velocity changes along three reference axes of satellite are used.
- Correcting the inclination of a satellite orbit requires more fuel to expended than for any other orbital correction.
- This places a weight penalty on those satellites that must maintain accurate station keeping & reduces communication payload they can carry.

Telemetry, Tracking, Command & Monitoring(TTC&M)



Telemetry & Monitoring System:

- It collects data from many sensors within satellite & send these data to the controlling earth station.
- Several hundred of sensors are located on satellite to monitor pressure in the fuel tanks, voltage & current in power conditioning unit, current drawn by each subsystem , & critical voltages & current in communications electronics.

- Temperature of many subsystem must be kept within predetermined limits, so many temp. sensors are fitted.
- The sensor data, the status of each subsystem are reported back to the earth by telemetry system.
- Telemetry data are digitized and transmitted as phase shift keying(PSK) of low- power telemetry carrier using time division techniques.

- At controlling earth station a computer can be used to monitor, store, and decode telemetry data so that status of any system or sensors on the satellite can be determined immediately.
- Alarms can also be sounded if any vital parameter goes outside allowable limits.

Tracking:

- A no. of techniques can be used to determine current orbit of satellite.
- Velocity & acceleration sensors on satellite can be used to establish the change in orbit from last known position, by integration of data.
- The earth station controlling satellite can observe the Doppler shift of telemetry carrier to determine rate at which range is changing.
- Active determination of range can be achieved by transmitting a pulse, or sequence of pulses, to the satellite and observing the time delay before pulse is received again.

Command:

- A secure and effective command structure is required for successful launch and operation any communications satellite
- The command system is used to make changes in attitude and corrections to the orbit and to control communication system.
- During launch, it is used to control firing of AKM & to spin up spinner or extend solar sails & antennas of 3-axis stabilized satellite.

- The command structure must posses safeguards against unauthorized attempts to make changes to satellite's operation.

- Encryption of commands & responses is used to provide security in command system.

- After monitoring all the data, commands are generated at the control terminal of computer.

- The command word is sent in a TDM frame to the satellite.
- After checking for validity in satellite, command word is sent back to the control station via telemetry link where it is checked again in the computer.
- If it found correctly, an **execute** instruction will sent to satellite.
- The entire process may take 5 0r 10s, but minimizes the risk of erroneous commands causing satellite malfunction.

Power System:

- All communication satellites obtain their electrical power from solar cells, which converts incident sunlight into electrical energy.
- Some deep space planetary research satellites have used thermonuclear generators.
- Communication satellite have not used nuclear generators.

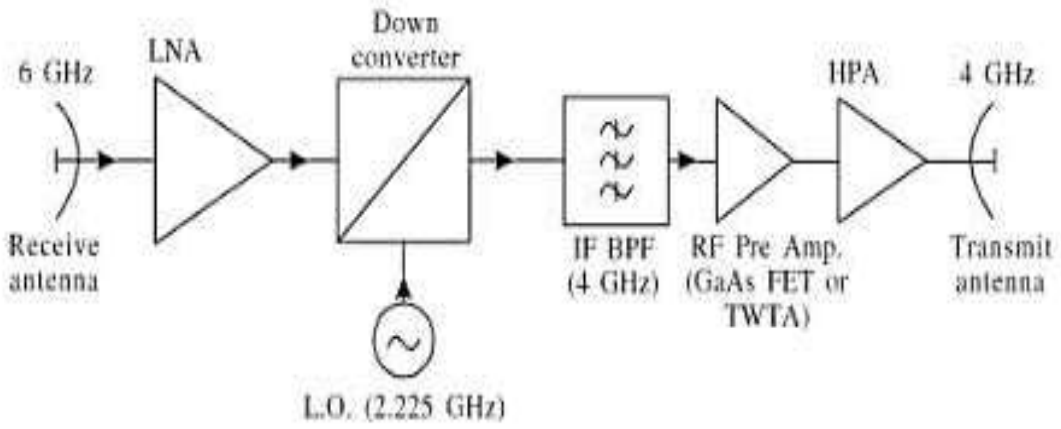
- Sun is a powerful source of energy.
- At geostationary altitude, the radiation falling on a satellite has an intensity of 1.39kW/m^2.
- Solar cells do not convert all incident energy into electrical power; their efficiency is typically 20 to 25% at beginning of life(BOL) but falls with the time because of aging of the cells.
- Since sufficient power must be available at the end of life(EOL) of satellite to supply all the systems on board, about 15% extra area of solar cells is usually provided as an allowance for aging.

- A spin stabilized satellite usually has a cylindrical body covered in solar cells.
- Because solar cells are on cylindrical surface, half of the cells are not illuminated at all, which results little electrical power being generated.
- The cells that are not illuminated by sunlight face cold space, which cause them to cool down.
- More recently, large communication satellites for direct broadcast operation generate up to 6kW from solar power.

- A three- axis stabilized satellite can make better use of its solar cell area, since the cells can be arranged on flat panels that can be rotated to maintain normal incidence of the sunlight.
- A primary advantage is that by unfurling a folded solar array when the satellite reaches geostationary orbit, power in excess of 10kW can be generated with large array.
- To obtain 10kW from a spinner requires a very large body as compared to three-axis stabilized body.

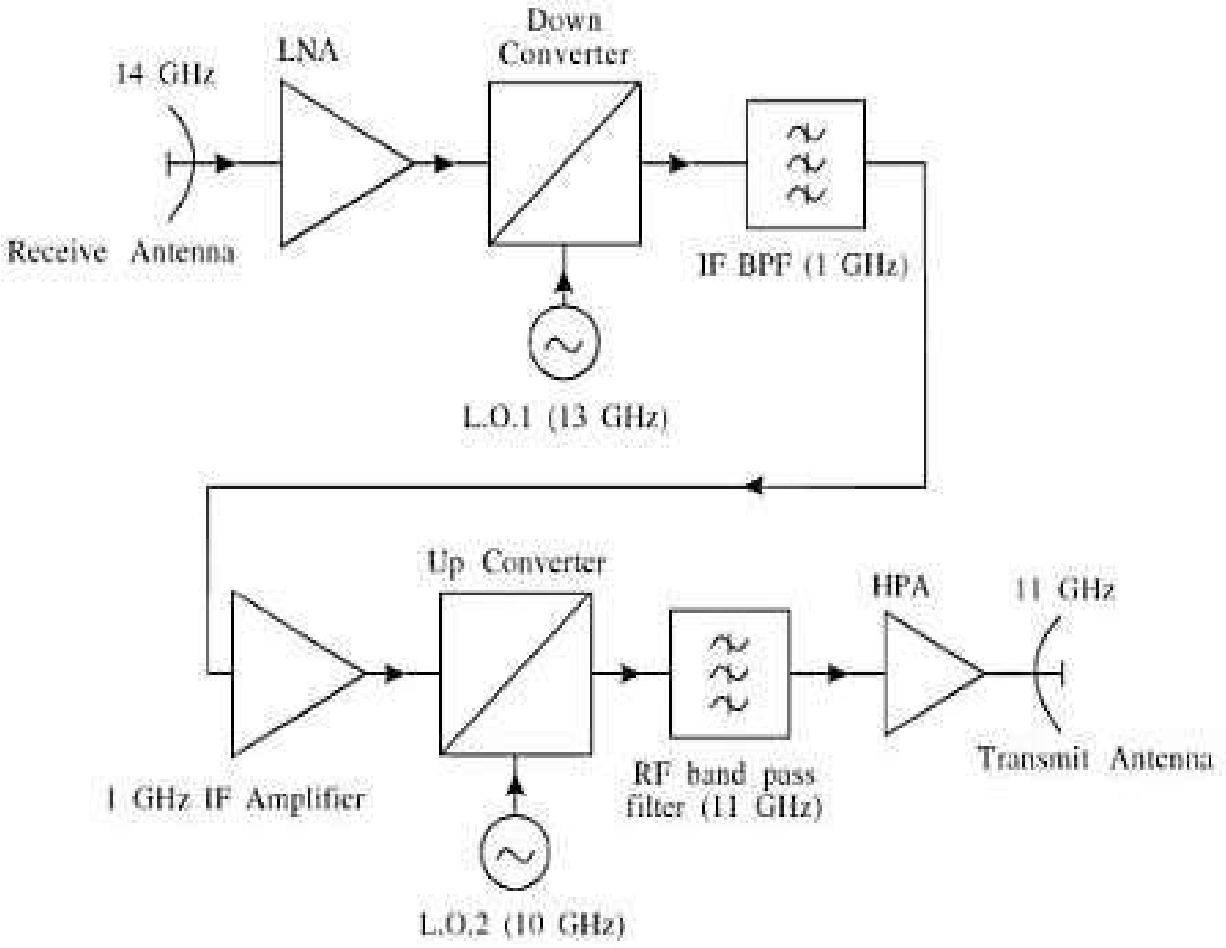
Communication Subsystems

- **Transponders-**
  - A transponder consists of BPF to select the particular channel's band of frequency, a downconverter & an output amplifier.



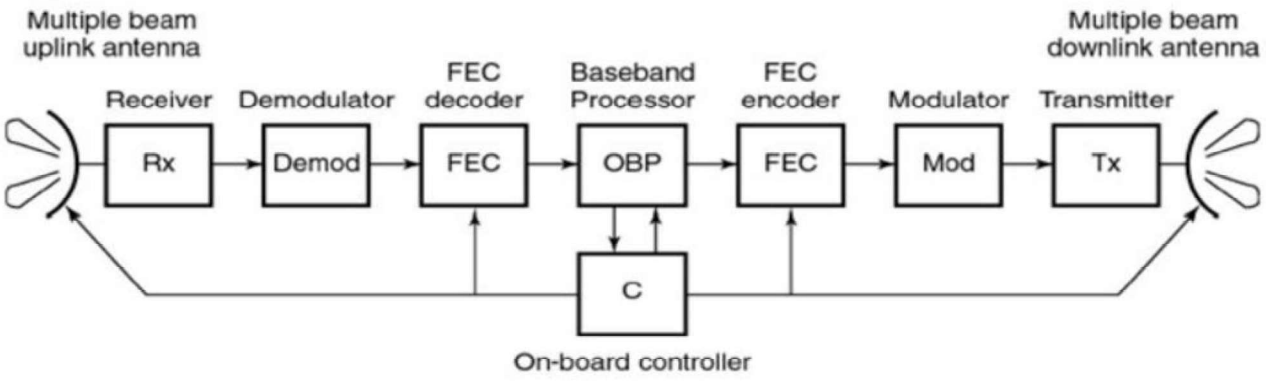
- Fig. shows a typical single conversion bent pipe transponder used on many satellites for 6/4 GHz band.
- The local oscillator is at 2225 MHz to provide the appropriate shift in frequency from 6 GHz to 4 GHz.
- Band pass filter after the mixer removes unwanted frequencies.
- The output power amplifier is usually a solid state power amplifier(SSPA)unless a very high output power is required.

- Redundancy is provided for high-power amplifiers in each transponder by including a spare TWTA(travelling Wave tube amplifier) or solid-state amplifier(SSPA) that can be switched if primary power amplifiers fail.
- The lifetime of high power amplifier's is limited and they represent least reliable component in most transponders.
- Providing a spare HPA in each transponder increases the probability that the satellite will reach the end of its working life with all its transponders working.


14 GHz
LNA
Down
Converter
Receive Antenna
IF BPF (1 GHz)
L.O.1 (13 GHz)
Up Converter
HPA
11 GHz
1 GHz IF Amplifier
RF band pass
filter (11 GHz)
Transmit Antenna
L.O.2 (10 GHz)

- Transponders for use in the 14/11-GHz bands normally employ a double frequency conversion scheme
- Incoming 14-GHz carrier is translated to an IF around 1GHz.
- The amplification & filtering are performed at 1 GHz & a relatively high-level carrier is translated back to 11 GHz for amplification by HPA.

Figure 3.14 (p. 79)
Onboard processing transponder.



Satellite Antennas:

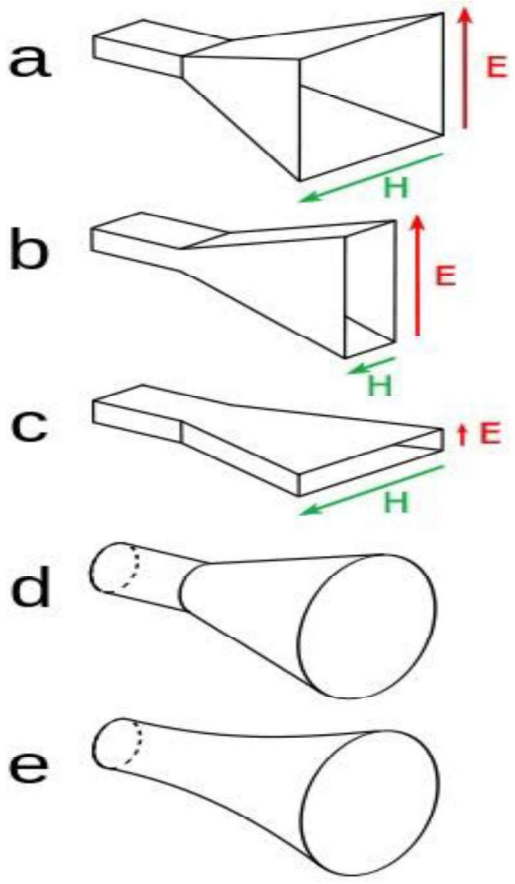
- Wire Antennas: Monopole & Dipole
- Horn Antennas
- Reflector Antennas
- Array Antennas

Wire Antennas:

- These are used primarily at VHF & UHF to provide communications for the TTC&M systems.
- They are positioned with great care on the body of the satellite in an attempt to provide **omnidirectional** coverage.
- An **antenna pattern** is a plot of the field strength in far field on antenna.
- It is usually measured in decibels(dB).

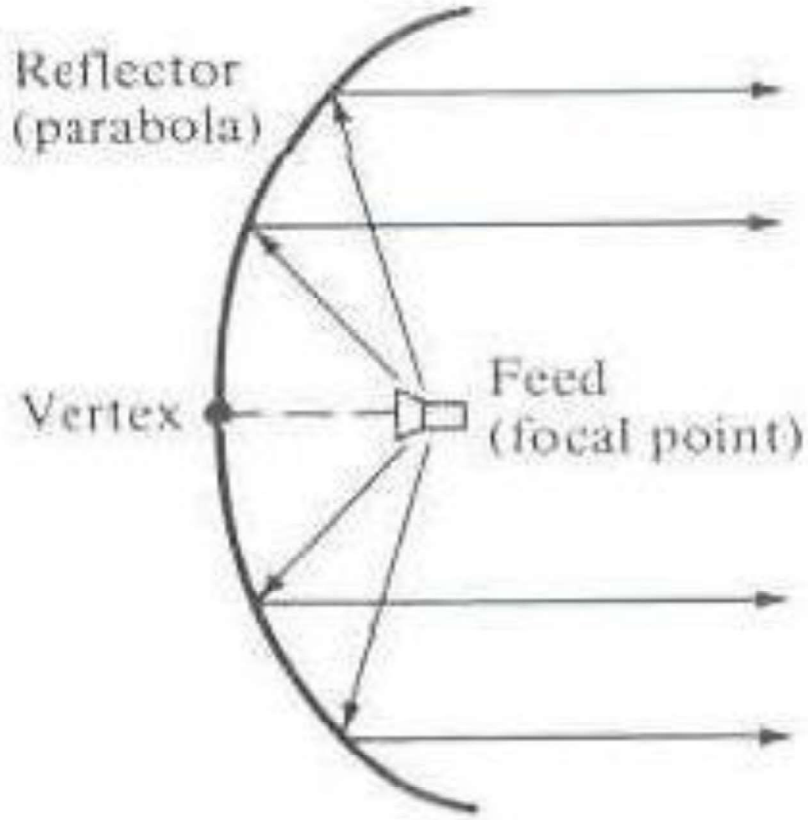
Horn Antennas:

- These are used at microwave frequencies when relatively wide beams are required, as for global coverage.
- A horn is a flared section of waveguide that provides an aperture several wavelengths wide and a good match between the waveguide impedance and free space.
  - Horns are also used as feeds for reflectors


a
E
H
b
E
H
c
E
H
d
e

Reflector Antennas:

- The most often used antenna for satellite systems, particularly for those operating above 10 GHz, is the ***parabolic reflector antenna***.
- These are usually illuminated by one or more horns and provide a lager aperture compared to horn antenna.
- Parabolic reflectors offer a much higher gain than that achievable by the horn antenna alone.


Reflector
(parabola)
Vertex
Feed
(focal point)

Array Antennas:

- Array antennas are also used on satellites to create multiple beams from a single aperture.
- Multiple beams are formed by combining the radiation from several small elements made up of dipoles, horns etc.
- Iridium and Globalstar used these kind of antennas to generate up to 16 beams from a single aperture for their LEO mobile telephone systems.

Equipment Reliability & Space qualification:

- Once satellite is in geostationary orbit, there is little possibility of repairing components that fail or adding more fuel for station keeping.
- The component that make up the satellite must therefore have very high reliability.
- Two approaches are used: **Space qualification** of every part of the satellite to ensure that it has a long life expectancy in orbit & **redundancy** of most critical components to provide continued operation when one component fails.

Space Qualification:

- Outer space, at geostationary orbit distances, is a harsh environment.
- The sun irradiates the satellite with 1.4 kW of heat and light on each square meter of exposed surface.
- When surfaces are in shadow, surface temperature will fall toward absolute zero.
- Electronic equipment can't operate at such extremes of temperature & heated or cooled so that it's temp. stays within the range 0˚ to 75 ˚C. This requires a thermal control system.

- The first stage in ensuring high reliability in a satellite is by selection and screening of every component used.
- Past operational & test experience of components indicates which components can be expected to have good reliability.
- Each component is tested individually to ensure that it meets its specification. This process is known as quality control or quality assurance & is vital in building any equipment that is to be reliable.
- Once individual components and subsystems have been space qualified, the complete satellite must be tested as a system to ensure that its many systems are reliable.
- When a satellite is designed, three prototype models are often build and tested.

- **Mechanical model-** It contains all the structural & mechanical parts that will be included in the satellite & is tested to ensure that all moving parts operate correctly in vacuum, over a wide temperature range. It also subjected to vibration & shock testing.
- **Thermal model-** It contains all electronics packages and other components that must be maintained at the correct temperature.
- **Electrical model-** contains all the electronic parts of the satellite and is tested for correct electrical performance under total vacuum and a wide range of temperatures.

- Testing carried out on models is designed to overstress the system and induce failure in any weak components.
- Temperature cycling will be carried out to 10% beyond expected extremes; structural loads 50% above those expected may be applied.
- Electrical equipment will be subjected to excess voltage and current drain to test for food electronic and thermal reliability.

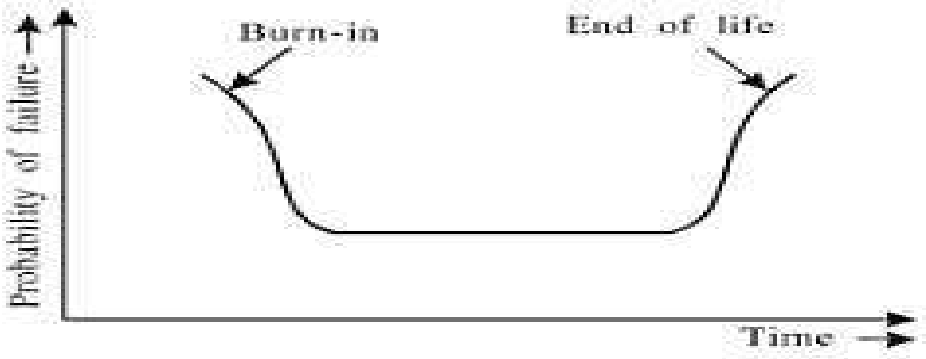
Reliability:

- We need to be able to calculate reliability for two reasons:

1.We want to know what the probability is that subsystem will still be working after a given time period, &

2.we need to provide redundant components or subsystems where probability of failure is too great to be accepted.

- Reliability is a mathematical technique which gives an idea about the probability of failure.



- The reliability of a component can be expressed in terms of probability of failure after time t.
- For most electronic equipment, probability of failure is higher at beginning of life- the burn – in period.
- As the component ages, failure becomes more likely.
- Mathematically reliability of device or sub-system is defined as,

$$R_t = \frac{N_s(t)}{N_o} = \frac{(number\ of\ surviving\ components\ at\ time\ t)}{(number\ of\ components\ at\ start\ of\ test\ procedure)}$$

- The other improvement parameter in reliability study is the meantime before failure (MTBF) and is given by

$$\text{MTBF} = m = \frac{\sum t_i}{N_o}$$

Where t_i = time after which ith device fails.

- MTBF is related to average failure by

$$\lambda = \frac{1}{MTBF}$$

- The failure rate λ is often given as average failure rate per 10^9 hours. In terms of reliability of subsystem or device it is given by

$$R = e^{-\lambda t}$$

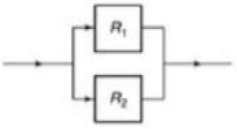
Redundancy:

- By using redundant components, reliability of subsystem can be increased.
- The redundant device can incorporate with the existing operating devices/ components either in series or in parallel or may be mixed.

Redundancy

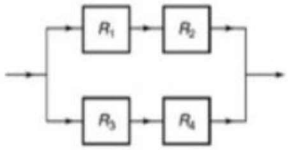


(a)



(b)

Figure 3.21 (p. 91)
Redundancy connections. (*a*) Series connection. (*b*) Parallel connection. (*c*) Series/parallel connection. (*d*) Switched connection.



(c)

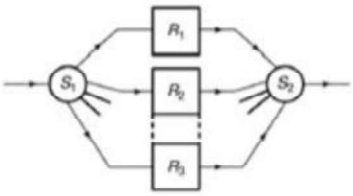
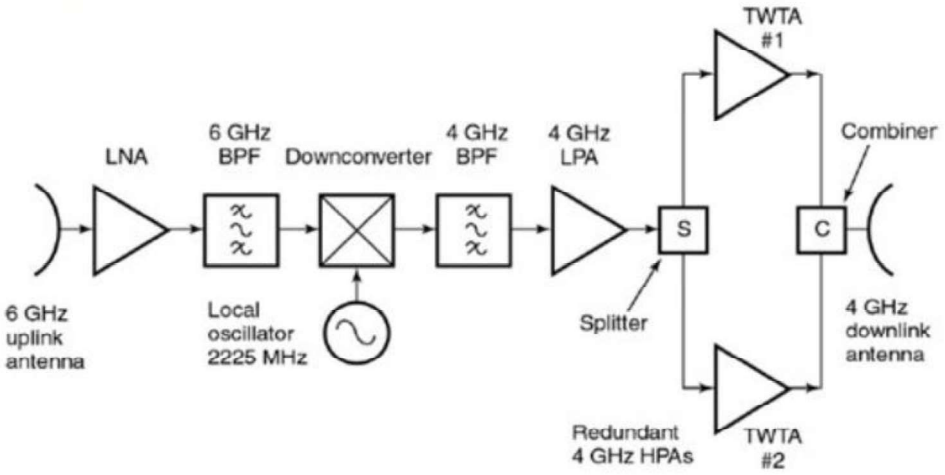
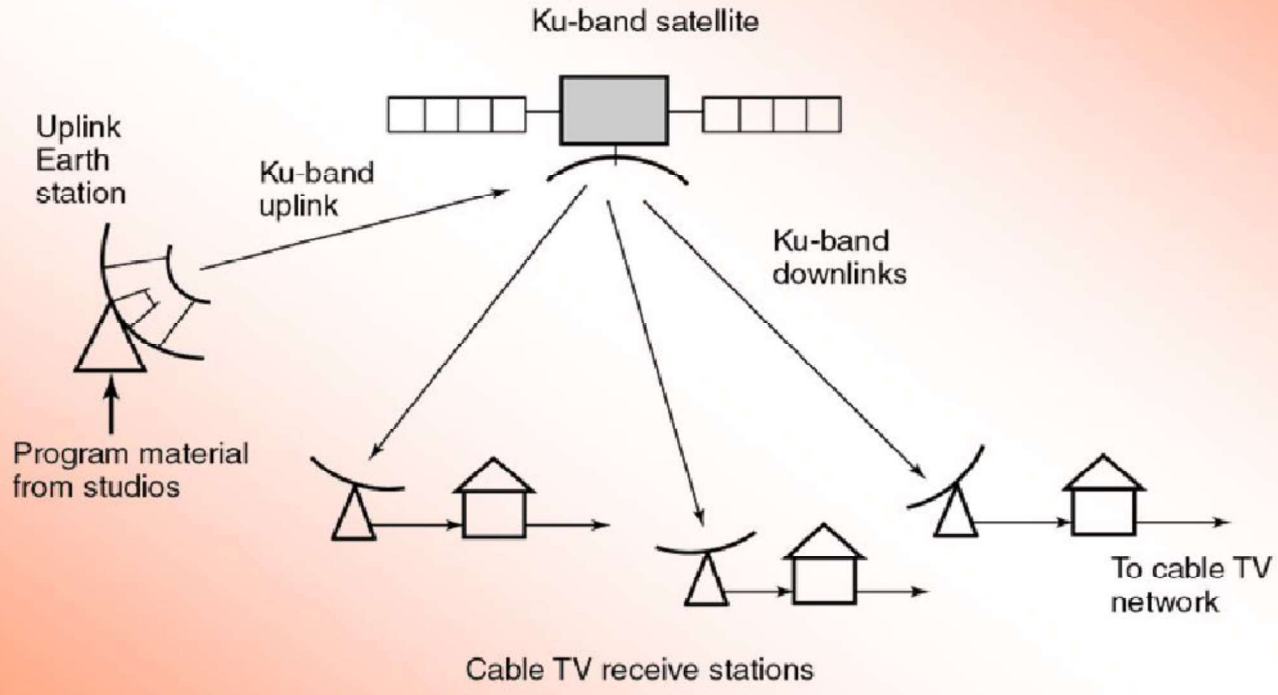


Figure 3.22 (p. 92)
Redundant W/TA configuration in HPA of a 6/4 GHz bent pipe transponder.



UNIT-III
SATELLITE LINK DESIGN

Chapter 4 Satellite Link Design



- **This chapter is about**
- (1).The basic transmission theory
- (2).The basic procedures for the design of satellite communication links
- (3).Design examples

4.1 Introduction

1.Critical factor in the design of any satellite

(1) weight

- The number and output power of transponders on the satellites
- The weight of station-keeping fuel

(2) overall dimension

(3) antenna

(4) three other factors:

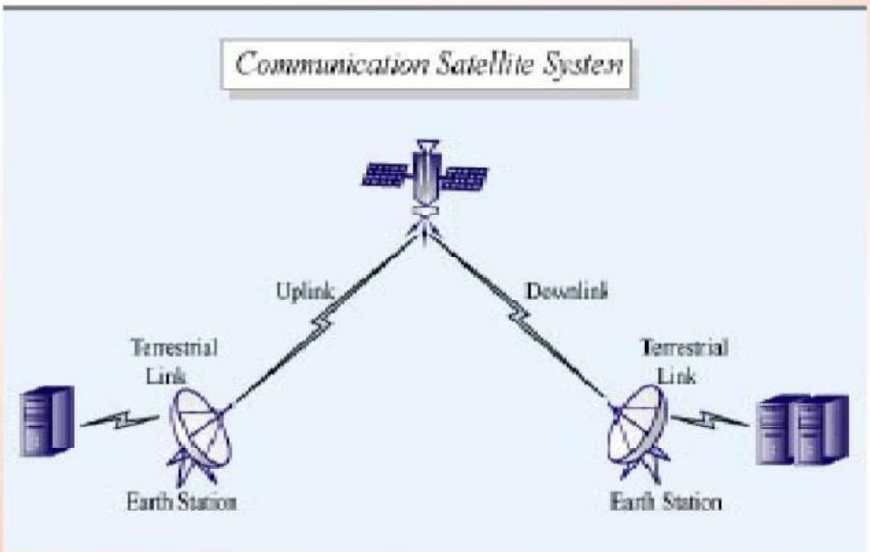
- The choice of frequency band
- Atmospheric propagation effects
- Multiple access technique

2. Performance objectives

- (1) a bit error rate (BER)
- (2) a signal to noise ratio (S/N)
- BER or S/N is determined by the carrier-to-noise ratio (C/N)

3. Carrier-to-Noise ratio (C/N)

- (1).The C/N ratio is calculated at the input of the receiver, at the output terminals (or port) of the receiving antenna.
- (2).Two signal paths:
- uplink
- downlink



- (3). The overall C/N at the earth station receiver depends on both links and both must achieve the required performance for a specified percentage.

4. Designing a satellite system requires knowledge of :

(1) The required performance of the uplink and downlink

(2) The propagation characteristics

(3) Rain attenuation for frequency band being used at the earth station location

(4) The parameters of the satellite

(5) The parameters of the earth station

4.2 Basic Transmission Theory

- Consider a transmitting source in free, radiating a total power P_t watts uniformly in all direction as show in Figure 4.2. such a source is called isotropic;

- At a distance R meters from the hypothetical isotropic source transmitting RF power P_t,watts, the flux density crossing the surface of a sphere with radius R is given by

$$F = \frac{P_t}{4\pi R^2} W / m^2$$

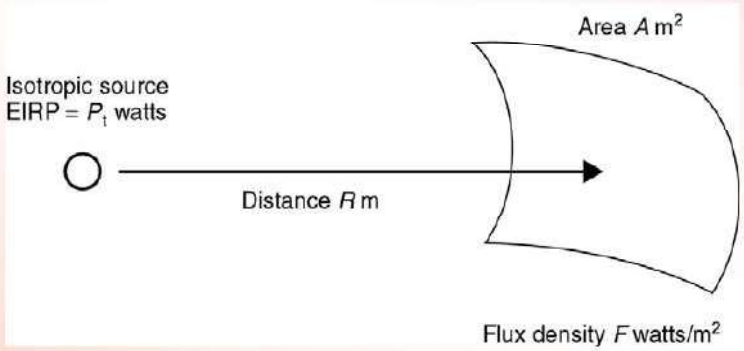


 Figure 4.2 Flux density produced by an isotropic source.

- For a transmitter with output P_t watts driving a lossless antenna with gain G_t, the flux density in the direction of the antenna boresight at distance R meters is

$$F = \frac{P_t G_t}{4\pi R^2} W / m^2$$

- The product $P_t G_t$, is often called the effective isotropically radiated power or EIRP,
- and it describes the combination of transmitter power and antenna gain in terms of an equivalent isotropic source with power $P_t G_t$, watts, radiating uniformly in all directions.

- If we had an ideal receiving antenna with an aperture area of A m^2, we would collect power P_r watts given by
- $$P_r = F \times A \text{ watts}$$

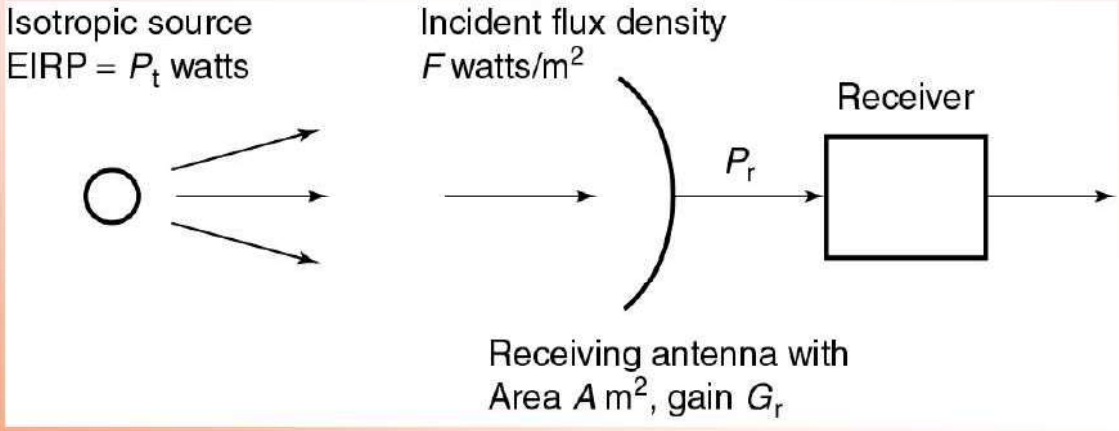


Figure 4.3 Power received by an ideal antenna with area A m^2. Incident flux density is $F = P_t/4\pi R^2$ W/m^2. Received power is $P_r = F \times A = P_t A/4\pi R^2$ W.

- A Practical antenna uses an effective aperture A_e where:

$$A_e = \eta_A A_r$$

- and η_A is the aperture efficiency of the antenna.
- Thus the power received by a real antenna with a physical receiving area A_r , and effective aperture area A_e m^2 is:

$$p_r = \frac{P_t G_t A_e}{4\pi R^2} watts$$

- A fundamental relationship in antenna theory is that the gain and area of an antenna are related by

$$G = 4\pi A_e / \lambda^2$$

- where λ is the wavelength (in meters) at the frequency of operation.

$$p_r = \frac{P_t G_t A_e}{4\pi R^2} watts$$

$$G = 4\pi A_e / \lambda^2$$

substituting for A_e in Eq(4.6) gives: $$p_r = \frac{P_t G_t G_r}{(4\pi R / \lambda)^2} watts$$

The expression is known as the link equation, and it is essential in the calculation of power received in any radio link.

- Collecting the various factors, we can write

$$\text{Power received} = \frac{\text{EIRP} \times \text{Receiving antenna gain}}{\text{Path loss}} \text{ watts}$$

- In decibel terms, we have

$$P_r = \text{EIRP} + G_r - L_p \text{ dBW}$$

where，$\text{EIRP} = 10\log_{10}(P_t G_t) dBW$

$$G = 10\log_{10}(4\pi A_e / \lambda^2) dBW$$

$$L_p = 10\log_{10}(4\pi R / \lambda)^2 = 20\lg(4\pi R / \lambda) dBW$$

- In practice
- P_r =EIRP+ G_r- L_p -L_a -L_{ta} -L_{ra} dBW
- L_a = attenuation in atmosphere
- L_{ta} = losses associated with transmitting antenna
- L_{ra} = losses associated with receiving antenna

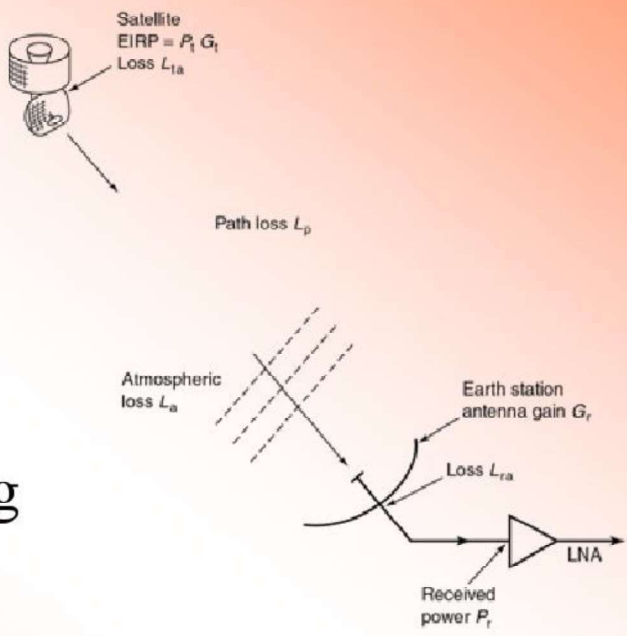


Figure 4.4 (p. 104)
A satellite link. LNA, low noise amplifier.

- EXAMPLE 4.2.1
- A satellite at a distance of 40,000 km from a point on the earth's surface radiates a power of l0 W from an antenna with a gain of l7 dB in the direction of the observer. Find the flux density at the receiving point, and the power received by an antenna at this point with an effective area of l0 m^2.
- **Answer:**
- (1).Using Eq. (4.3) $F = \frac{P_t G_t}{4\pi R^2} W/m^2$
- P_t=10 W
- G_t=17dB=50
- R=4× 10^7m

- $F = 10 \times 50/(4 \times 3.14 \times (4 \times 10^7)^2) = 2.49 \times 10^{-14}$ w
- The power received with an effective collecting area of 10 m^2 is therefore
- $$P_r = F \times A = 2.49 \times 10^{-13} \text{ w}$$

- (2)The calculation is more easily handled using decibels.

- F in dB units = $10\log_{10}(P_tG_t) - 20\ 1\log_{10}(R) - 10 \log_{10} 4\ \pi$

- Noting that
- $10 \log_{10} 4\ \pi = 11.0$ dB

- $F = 27.0 - l52.0 - l1.0$
- $= -136.0 dB(W/m^2)$
- Then, $Pr = -l36.0 + l0.0 = -l26 dBw.$
- $(10\ m^2 = 10\ \log_{10} 10 = 10\ dB)$

- Example 4.2.2
- The satellite in Example 4.2.1 operates at a frequency of 11GHz. The receiving antenna has a gain or 52.3 dB. Find the received power.
- **Answer:**
- P_r =EIRP+ G_r- L_p dBW
- EIRP=27.0dBW
- G_r=52.3dB

  $L_p = 10\log_{10}(4\pi R/\lambda)^2 = 20\lg(4\pi R/\lambda) dBW$
- =-205.3dB
- P_r=27.0+52.3-205.3=-126.0 dBW

4.3 System Noise Temperature and G/T Ratio

4.3.1 Noise Temperature

1. Noise temperature is useful concept in communications receivers, since it provides a way of determining how much thermal noise is generated by active and passive devices in the receiving system.
2. In electronics, noise temperature is a temperature (in kelvins) assigned to a component such that the noise power delivered by the noisy component to a noiseless matched resistor is given by $P_n = k\, T_p\, B_n$

   它等于一个电阻在与这个噪声源相同的带宽内，给出相同的功率时，所具有的绝对温度

$P_n = k T_p B_n$

where

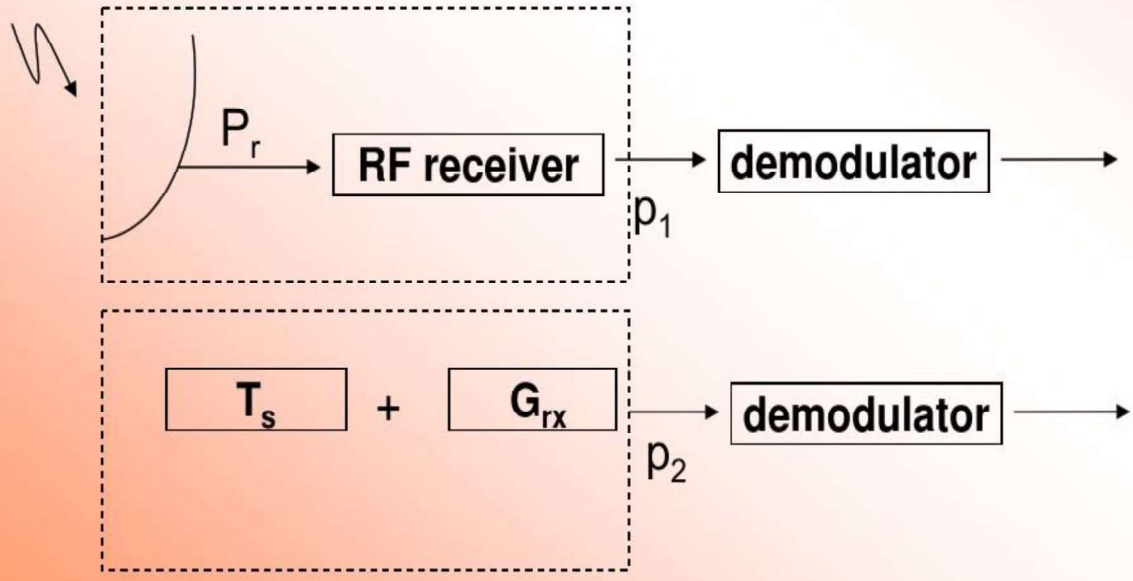
- P_n =the available noise power (in watts) and will be delivered only to a load that is impendence matched to the noise source.
- k = Boltzmann's constant = 1.39×10^{-23} J/K =-228.6 dBW/K/Hz
- T_P=Physical temperature of source in Kelvin degrees
- kT_p = a noise power spectral density in watts per hertz. The density is constant for all radio frequency up to 300 GHz.
- B_n = noise bandwidth in which the noise power is measured, in hertz.

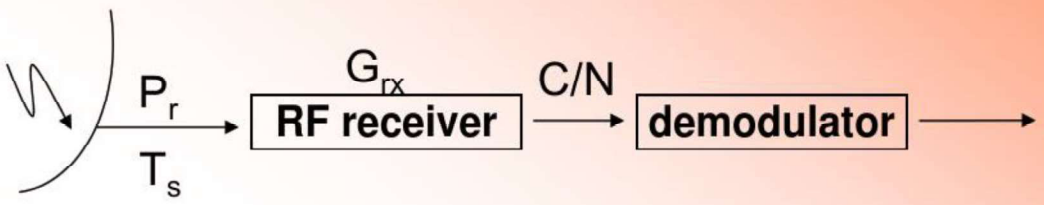
3. why do we need noise temperature ?

- We need a way to describe the noise produced by the components of a low noise receiver. This can be done by equating the component to a black body radiator with an equivalent noise temperature, T_n Kelvin.

4.system noise temperature T_s

- T_s is the noise temperature of a noise source, located at the input of a noiseless receiver, which gives the same noise power as the original receiver measured at the output of the receiver and usually includes noise from the antenna.





(1) The noise power referred to the input of the receiver is P_n ,Where $P_n = k\,T_s\,B_n$ watts

(2)The overall end- to-end gain of the receiver is G_{rx}

- The noise power at the demodulator input is $P_{no} = kT_sB_nG_{rx}$ watts

- where G_{rx} is the gain of the receiver from RF input to demodulator input.
- The narrowest bandwidth is B_n Hz,

- (3) Let the antenna deliver a signal power P_r watts to the receiver RF input. The signal power at the demodulator input is $P_r G_{rx}$ watts, representing the power contained in the carrier and sidebands after amplification and frequency conversion within the receiver.
- (4)Hence, the carrier- to- noise ratio at the demodulator is given by

$$\frac{C}{N} = \frac{P_r G_{rx}}{kT_s B_n G_{rx}} = \frac{P_r}{kT_s B_n}$$

4.3.2 Calculation of System Noise Temperature

1. The superhet receiver (has three main subsystems):

- a front end (RF amplifier, mixer and local oscillator)
- and IF amplifier (IF amplifier and filters),
- and a demodulator and baseband section.

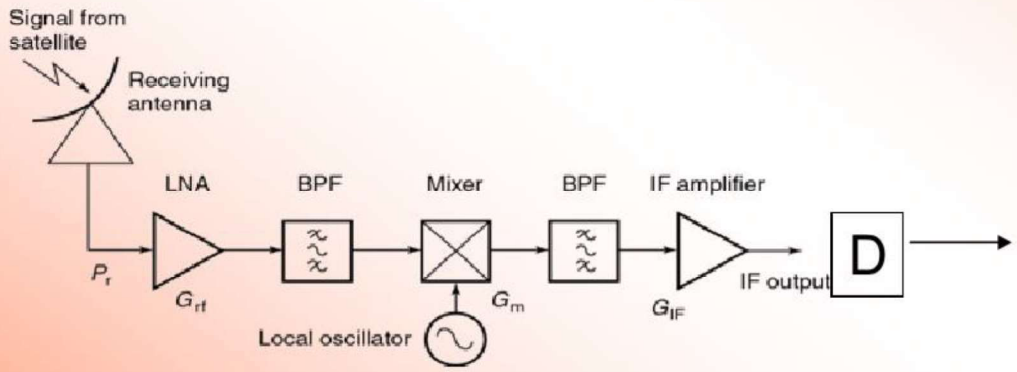


Figure 4.5 Simplified earth station receiver. BPF, bandpass filter.

2. A low noise amplifier or LNA.

- The RF amplifier in a satellite communication receiver must generate as little noise as possible, so it is called a low noise amplifier or LNA.
- The mixer and local oscillator form a frequency conversion stage that down converts the RF signal to a fixed intermediate frequency (IF), where the signal can be amplified and filtered accurately.

3. Double conversion earth station receiver.

- The first downconversion shifts signals in a 500-MHz band to the first IF range 900-1400 MHz.
- The second downconverter has a tunable local oscillator and channel selection filter to select the wanted transponder signal in the second IF centered at 70 MHz.

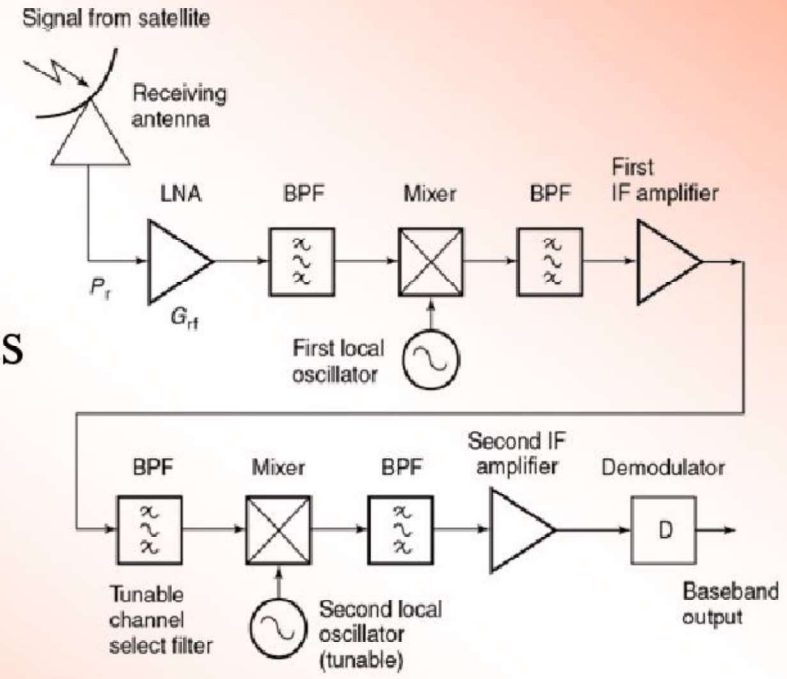


Figure 4.6 Double conversion earth station receiver.

4. Noise model of receiver

(1) The noisy amplifiers and downconverter have been replaced by noiseless units, with equivalent noise generators at their inputs.

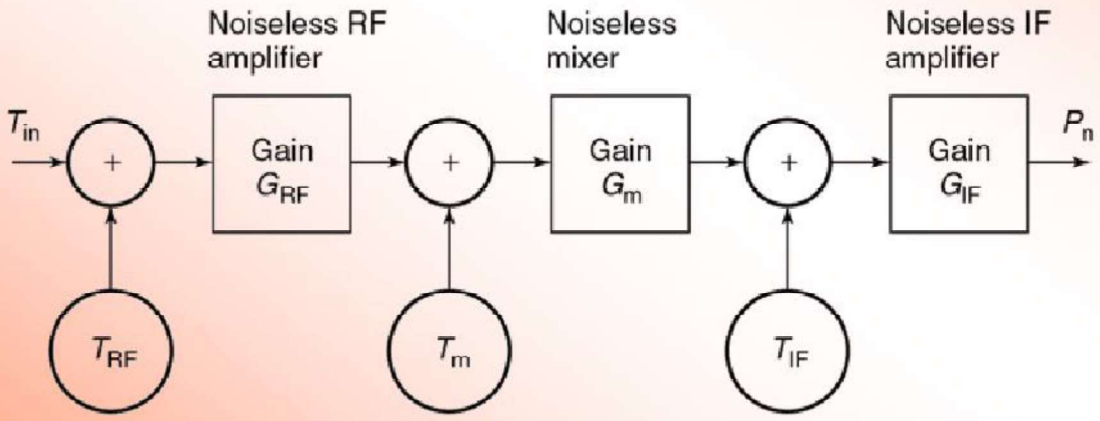


Figure 4.7a (*a*) Noise model of receiver.

- The noisy devices in the receiver are replaced by equivalent noiseless blocks with the same gain and noise generators at the input to each block such that the block produces the same noise at its output as the device it replaces.

power that device with a noise temperature of T_n Kelvin produces	=	Noise power that black body at temperature T_n degrees Kelvin produces	+	power that noiseless amplifier with the same gain produces

(2) All noisy units have been replaced by one noiseless amplifier, with a single noise source Ts as its input.

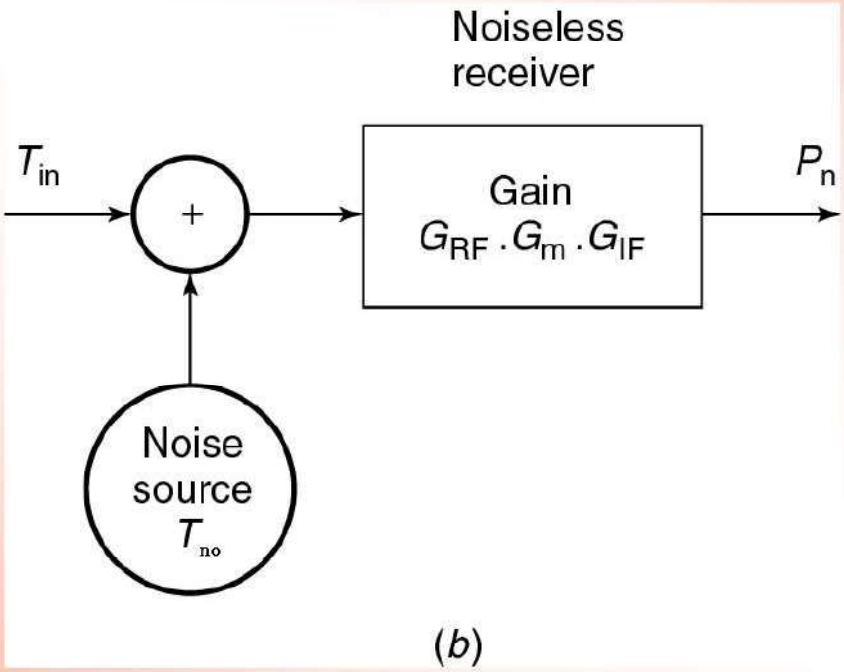


Figure 4.7b (*b*) Noise model of receiver.

(3) The lossy device has been replaced by a lossless device, with a single noise source T_{no} at its output.

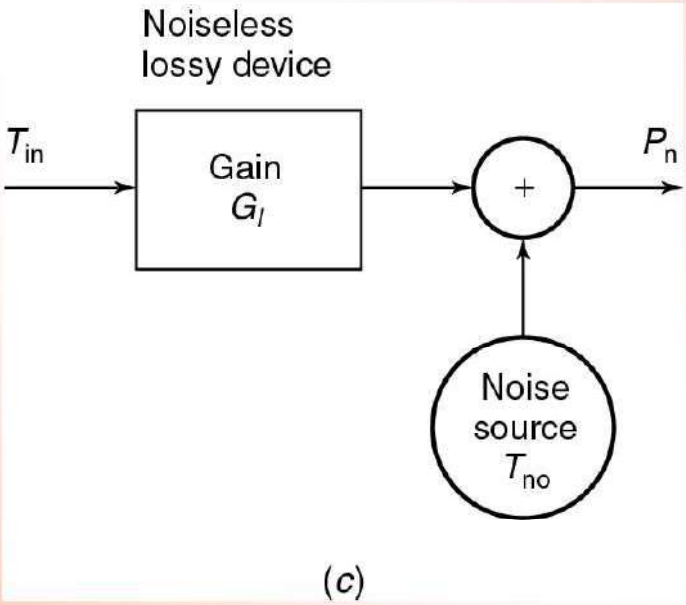
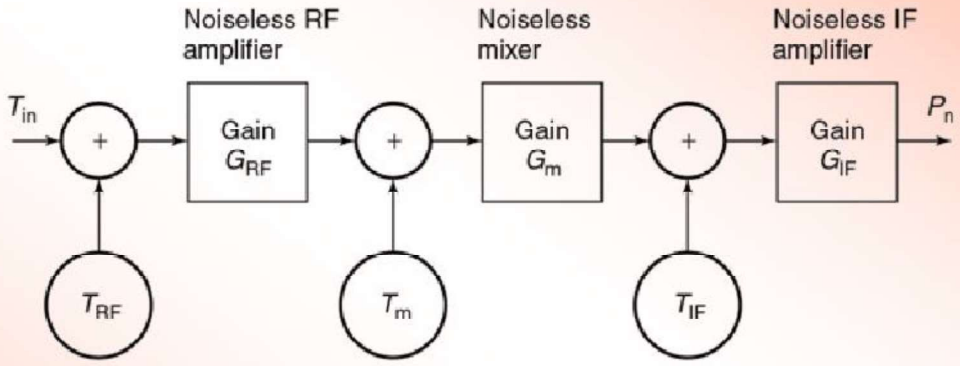


Figure 4.7c (*c*) Noise model for a lossy device.

5. The system noise temperature T_s



(1) The total noise power of the receiver

- $P_n = G_{IF}kT_{IF}B_n + G_{IF}G_mkT_mB_n + G_{IF}G_mG_{RF}kB_n\,(T_{RF} + T_{in})$

- $P_n = G_{IF}G_mG_{RF}kB_n\,[T_{RF} + T_{in} + T_m/G_{RF} + T_{IF}/(G_{RF}G_m)]$

- Where
- G_{RF}, G_m, and G_{IF} are the gains of the RF amplifier mixer and IF amplifier andT_{RF}, T_m, and T_{IF} are their equivalent noise temperatures.
- T_{in} is the noise temperature of the antenna, measured at its output port.

(2). the single source of noise temperature T_s generates:

$$P_n = G_{IF}G_mG_{RF}kT_SB_n$$

(3) T_s

- total noise power
- $P_n = G_{IF}G_mG_{RF}kB_n\,[T_{RF} + T_{in} + T_m/G_{RF} + T_{IF}/(G_{RF}G_m)]$
- $kT_SB_n = kB_n\,[T_{RF} + T_{in} + T_m/G_{RF} + T_{IF}/(G_{RF}G_m)]$
- $T_S = [T_{RF} + T_{in} + T_m/G_{RF} + T_{IF}/(G_{RF}G_m)]$
- When the RF amplifier in the receiver front end has a high gain
- $T_S = T_{antenna} + T_{LNA}$

Example 4.3.1

- Suppose we have a 4-GHz receiver with the following gains and noise temperatures:
- $T_{in} = 25$ K $G_{RF} = 23$ dB
- $T_{RF} = 50$ K $G_{IF}=30$ dB
- $T_{IF}=1000$ K
- $T_m = 500$ K
- Calculate the system noise temperature assuming that the mixer has a gain $G_m = 0$ dB.
- Recalculate the system noise temperature when the mixer has a -l0dB loss.How can the noise temperature of the receiver be minimized when the mixer has a loss of l0 dB?

- The system noise temperature is given by Eq. (4.l8)
- $T_{S=} [T_{RF} + T_{in} + T_m /G_{RF} + T_{IF}/(G_{RF}G_m)]$
- $T_s = [25 + 50 + (500/200) + (l000/200)] = 87.5$ K
- If the mixer had a loss, as is usually the case, the effect of the IF amplifier would be greater for G_m = - l0 dB, the linear value is $G_m = 0.l$ as a ratio.
- Then $T_s = [25 + 50 + (500/200) + (1000/20)] = l37.5$ K
- The lowest system noise temperatures are obtained by using a high gain LNA.

- Suppose we increase the LNA gain in this example to $G_{RF} = 50$ dB, giving ratio $G_{RF} = 10^5$
- $T_s = [25 + 50 + (500/10^5) + (1000/10^4)] = 75.1$ K

- The high gain of the RF LNA amplifier has made the system noise temperature almost as low as it can go: $T_s = T_{in} + T_{RF} = 75$ K in these example. LNAs for use in satellite receivers usually have gains in the range 40 dB~45 dB.

6. the noise passing through a lossy medium

$T_{no}=T_p(1-G_1)$

Where

G_1 is the linear gain (less than unity not in decibels) of the attenuating device or medium,

T_p is the Physical temperature in degrees kelvin of the device or medium.

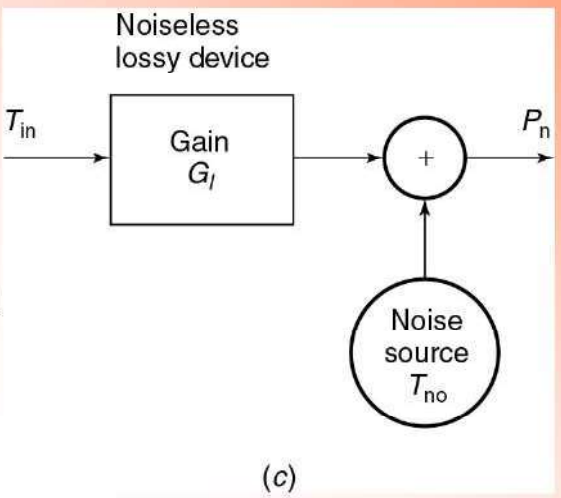
- For an attenuation of A dB, the value of G_1 is given by
- $G_1=10^{A/10}$
- Note that A is a negative value

Example 4.3.2

- The system illustrates in Example 4.3.1 has an LNA With a gain of 50 dB. A section of lossy waveguide with an attenuation of 2 dB is inserted between the antenna and the RF amplifier Find the new system noise temperature for a waveguide temperature of 300^0K.
- The waveguide loss of 2 dB (ratio 1.58) can be treated as a gain, G_1, that is 1ess than unity:
- ($G_1 = 10^{-2/10} = 0.631$).

- $T_{wg} = T_p(1 - G_1) = 300(1 - 0.631) = 110.7\ K$
- The waveguide attenuate the noise from the antenna, so
- $T_{in} = 0.63 \times 25 = 15.8\ K$
- The new system noise temperature, referred to the input of the LNA, is
- $T_s = [15.8 + 110.7 + 50 + (500)/10^5) + (1000/10^4)]$
- $= 176.6\ K$

- We can refer the system noise temperature to the antenna Output port by dividing the above by G_1. This transfer the noise source from the LNA input to the waveguide input.
- $T_s = 176.6/0.631 = 279.9$ K
- The new system noise temperature is 5.7 dB higher than the system noise temperature without the lossy waveguide.



- Note that when the system noise temperature is low ,each 0. 1 dB of attenuation ahead of the RF amplifier will add approximately 6.6 K to the system noise temperature. (Using the formula in Example 4.3.2 with $T_n = 290^0$K, G_1 = -0.1 dB = 0.977
- and $T_{no} = 290 \times 0.023 = 6.6$ K)
- This is the reason for placing the front end of the receiver at the output of the antenna feed. Waveguide losses ahead of the LNA can have a disastrous effect on the system noise temperature of low noise receiving systems.

4.3.3Noise Figure and Noise Temperature

- 1. Noise figure
- Noise figure is frequently used to specify the noise generate within a device.
- The operational noise figure (NF) is defined by the following formula:
- $$NF = \frac{(S/N)_{in}}{(S/N)_{out}}$$
- 2. The relationship between noise figure and noise temperature
- Because noise temperature is mere useful in satellite communication systems, it is best to convert noise figure to noise temperature T_d.

- The relationship is
- $T_d = T_0(NF - 1)$
- where the noise figure is a linear ratio, not in decibels, and where T_0 is the reference temperature used to calculate the standard noise figure usually 290 K.
- NF is frequently given in decibels and must be converted to a ratio before being used in Eq.(4.l8).

- EXAMPLE 4.3.3
- An amplifier has a quoted noise figure of 2.5 dB. What is its equivalent noise temperature?
- Answer :
- 2.5 dB=1.78
- $T_d = 290(1.78 - 1) = 226$ K
- this value of noise temperature could then be used in Eq. (4.17), with other appropriate data, to calculate system noise temperature.

4.3.4 G/T Ratio for Earth Station

$$\because p_r = \frac{P_t G_t G_r}{(4\pi R/\lambda)^2} \qquad N = kT_s B_n$$

$$\therefore \frac{C}{N} = [\frac{P_t G_t G_r}{kT_s B_n}][\frac{\lambda}{4\pi R}]^2 = [\frac{P_t G_t}{kB_n}][\frac{\lambda}{4\pi R}]^2[\frac{G_r}{T_s}]$$

$$\therefore \frac{C}{N} \propto \frac{G_r}{T_s}$$

G_r/T_s or G/T can be used to specify the quality of a receiving earth station or a satellite receiving system,

- EXAMPLE 4.3.4
- An earth station antenna has a diameter of 30 m, has an overall efficiency of 68%, and is used to receive a signal at 4150 MHz. At this frequency the system noise temperature is 79 K When the antenna points at the satellite at an elevation angle of 28^0. What is the earth station G/T ratio under these conditions? If heavy rain causes the sky temperature to increase so that the system noise temperature rises to 88 K what is the new G/T value?

- First calculate the antenna gain. For a circular aperture:

$$G_r = \eta_A 4\pi A / \lambda^2 = \eta_A (\pi D / \lambda)^2$$

- At 4150 MHz, λ = 0.0723 m. Then
- G = 0.68 x$(3.14 \times 30/0.0723)^2$ = 1.16 x 10^6 or 60.6 dB
- Converting T_s into dBK
- T_s = 10lg79 = 19.0 dBK
- G/T = 60.6 - 19.0 = 41.6 dBK
- If T_s = 88 K in heavy rain, G/T = 60.6 - 19.4 = 41.2 dB/K.

4.4 Design of Downlinks

1. The design of any satellite communication is based on two objectives:

(1). meeting a minimum C/N ratio for a specified percentage of time,

(2). and carrying the maximum revenue earning traffic at minimum cost

2. All satellite connections links are affected by rain attenuation.

(1). In the 6/4 GHz band the effect of rain on the link is small.

(2). In the l4/11GHz (Ku) band, and even more so in the 30/20 GHz (Ka) band, rain attenuation becomes all important.

(3). C band or Ku band is used for Voice channels with sufficient link margin that outage times are small. Internet transmissions are less affected by short outages and generally do not require a real-time channel, making Ka band better suited for Internet access.

4.4.1 Link Budgets

1. link budget

- C/N ratio calculation is simplified by the use of link budgets.

- A link budget is a tabular method for evaluating the received power and noise power in a radio link.

- Link budgets invariably use decibel units for all quantities so that signal and noise powers can be calculated by addition and subtraction.

2. Worst case scenario

Link budgets are usually calculated for a worst case, the one in which the link will have the lowest C/N ratio. Factors which contribute to a worst case scenario include:

(1). An earth station located at the edge of the satellite coverage zone where the received signal is typically 3 dB lower than in the center of the zone because of the satellite antenna pattern,

(2).maximum path length from the satellite to the earth station,

(3).a low elevation angle at the earth station giving the highest atmospheric path attenuation in clear air

(4). and maximum rain attenuation on the link causing loss of received signal power and an increase in receiving system noise temperature.

- *The edge of the coverage pattern of the satellite antenna and the longest path usually go together.*

3. The calculation of carrier to noise ratio in a satellite link

(1). The received carrier power in dB watts

- $P_r = EIRP + G_r - L_p - L_a - L_r - L_t$

(2). A receiving terminal with a system noise temperature T_sK and a noise bandwidth B_n Hz has a noise power P_n ,referred to the output terminals of the antenna where

- $P_n = kT_s B_n$

The receiving system noise power is usually written in decibel units as

- $N = k + T_s + B_n$

4.4.2 Link Budget Example:C-Band Downlink for Earth Coverage Beam

(1). The satellite used in this example (see Tables 4.4a and 4.4b) is in geostationary earth orbit

(2). The C/N ratio for the downlinks calculated in clear air conditions and also in heavy rain.

1. in clear air

(1). P_t

- The saturated output power of the transponder is 20 W = l3 dBW.
- We assume an output back-off of 2 dB,
- the power transmitted by the transponder is P_t=13-2=11 dBW

(2). G_t

- The satellite provides coverage of the visible earth, which subtends an angle of approximately 17^0 from a satellite in a geostationary orbit, by using a global beam antenna.
- $G_t=33000/17^2=20dB$
- $ERIP=P_t+G_t=11+20=31$ dBW

(3). G_r

- the receiving earth station has an antenna with an aperture diameter of 9 m and gain of 49.7 dB at 4GHz

$$G_r = \eta_A(\pi D/\lambda)^2 = 49.7dB, \qquad \eta_A = 66\%$$

(4). L

- The maximum path length of a GEO satellite link is 40,000 km, which gives a path loss of l96.5 dB at 4GHz

$$L_p = 10\log_{10}(4\pi R/\lambda)^2 = 10\log(4\pi \times 4000 \times 10^3/0.075) = 196.5dB$$

- 3 dB for losses at the edge of coverage zone of the satellite.
- L_{ant} =3 dB
- 0.2 dB for propagation losses in clear air
- L_a =0.2 dB
- 0.5dB for miscellaneous losses such as antenna mispointing, polarization mismatch and antenna degradation
- L_m =0.5dB

(5). P_r

- Received power at earth station P_r =ERIP+ G_r-L_{all}
- P_r =31+49.7-196.5-3-0.2-0.5=-119.5 dBW

(6). N

- Receiver noise power
- k = BoItymann's constant , -228.6 dBW
- T_s = System noise temperature, 75 K=18.8 dBK
- B_n = Noise bandwidth, 27 MHz =74.3 dBHz
- N=k+T_s+B_n =-135.5 dBW

(7). C/N

- $C/N = P_r - N = -119.5 - (-135.5) = 16.0$ dB

(8). link margin

- The minimum permitted overall C/N ratio for this link is 9.5 dB, corresponding to the FM threshold of an analog satellite TV receiver.
- link margin=16-9.5=6.5 dB
- This link margin is available in clear air conditions, but will be reduced when there is rain in the slant path.

2. in heavy rain

(1).Heavy rain in the slant path can cause up to 1 dB of attenuation at 4 GHz, which reduces the received power by 1 dB

- P_{rain} =-119.5-1=120.5 dBW

(2) and increases the noise temperature of the receiving system. this is an increase in system noise temperature of 2.3 dB.

N_{rain}=-135.5+2.3=133.3 dBW

(3)The recalculated C/N ratio

- $(C/N)_{rain} = P_{rain} - N_{rain}$=120.5-133.3 =12.7dB

TABLE 4.4b, C-Band Downlink Budget in Rain

P_{fca}	= Received power at earth Station in clear air	-119.5 dBW
A	= Rain attenuation	-1.0 dB
P_{rai}	= Received power at earth station in rain	-120.5 dBW
$N_{c\,a}$	=Receiver noise power in clear air	-135.5 dBW
$\triangle N_{rain}$	= Increase in noise temperature due to rain	2.3 dB
N_{rain}	= Receiver noise power in rain	-133.2 dBW

C/N ratio in receiver in rain

$C/N = P_{rain} - N_{rain}$ = -120.5 dBW - (-133.2 dBW) =12.7 dB

(8). link margin

- The minimum permitted overall C/N ratio for this link is 9.5 dB, link margin=12.7-9.5=3.2 dB
- We Should always leave a small margin for unexpected losses if we want to guarantee a particular level of reliability in the link. In this case, we will use a 2dB margin and examine how the remaining link margin can be traded against other parameters in the system.

① For diameter of the earth station antenna

G'_r=1.2dB=1.32

G_r=49.7-1.32=48.5dB

$G_r = \eta(\pi D / \lambda)^2$ η=66% λ=0.075 $\Rightarrow D = 7.8m$

diameter of the earth station antenna can be reduced from 9m to 7.8m

②.Change Global beam antenna to regional antenna

- Global beam $6^0 \times 3^0$,which is l2.0 dB higher than the on-axis gain of a global beam.
- Using the link budget in Tables 4.4a and 4.4b, we can trade the extra 12dB gain of a regional coverage satellite antenna for a reduction in earth station antenna dimensions.
- For the example of a 9.0m antenna receiving analog FM-TV, we could reduce the antenna diameter by a factor of 4 to 2.25m. This is the smallest size of antenna used by home satellite TV systems operating in C band.

4.5 Satellite System Using Small Earth Station

4.5.1 Domestic satellite link to the Continental United States

4.5.2 Direct Broadcast TV

4.5.1 Domestic satellite link to the Continental United States

- Viewed from a geostationary orbit, at a longitude of around 100^0W the continental United State approximately subtends an angle of $6^\circ \times 3^\circ$

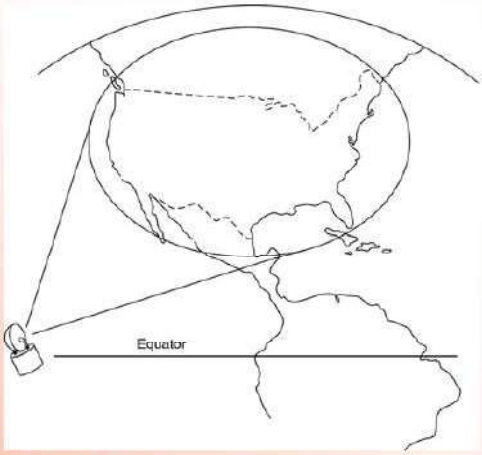


Figure 4.8 Domestic satellite link to the Continental United States viewed from geostationary orbit

(1) P_t

- Output power of 5 W, transmitting a single carrier
- P_t=10log5=7.0dBW

(2)G_t

- An Aperture antenna to Produce a single beam with 3dB beamwidths of 6^0 by 3^0 has dimensions approximately 13 λ by 26 λ , and a gain of 32 dB.
- G_t=33000/(3×6) =32dBW
- For a receiving earth station at the edge of the coverage zone, the gain of the satellite antenna in that direction is typically 3 dB lower or
- G_t=32-3 =29dBW

(3) G_r

- For the GEO satellite system shown in Figure 4.8,the received carrier level and C/N ratio can readily be calculated for an earth station with a 3-m antenna at the edge of the coverage zone, using a transponder with an output power of 5 W at 4 GHz, transmitting a single carrier, ignoring all losses, and using a receiving antenna gain of 40.0 dB(63% efficiency)
- $G_r = 63\% \ (3 \times 3.14/0.075)^2 = 40.0$ dB

(4)L_p

$$L_p = 10\log_{10}(4\pi R/\lambda)^2 = 10\log(4\pi \times 4000 \times 10^3 / 0.075) = 196.5dB$$

- $P_r = P_t + G_t + G_r - L_p = 7.0 + 29.0 + 40.0 - 196.5$
- $= -120.5$dBW

(5) The noise power at the input to low noise receiver with noise bandwidth of 30 MHz and system noise temperature of 100K is

- $N = k\,T_s\,B_n = -228.6 + 20.0 + 74.8 = -133.8$ dBW

(6)C/N

- $C/N = P_r - N = -120.5 - (-133.8) = 13.3$dB
- This is 3.8dB above an FM threshold of 9.5dB

4.5.2 Direct Broadcast TV

Direct broadcast satellite television (DBS-TV) originally started in Europe in the 1980s using analogy FM transmission in Ku band.

1. in clear air

(1) In Table 4.5 a transponder output power of 160 W is used

- P_t= 160 W =22.0 dB W

(2) The satellite antenna gain is 34.3 dB on axis

- G_t=34.3 dB

(3) The receiving antenna is a high efficiency design with a fronted offset parabolic reflector 0.45m in diameter

- The gain of this antenna is ? dB at 12.0 GHz with an aperture efficiency of 67%.
- G_r=33.3 dB

(4)path loss at 12.2 GHz,38000m path

$$L_p = 10\log_{10}(4\pi R/\lambda)^2 = 10\log(4\pi \times 38000/0.025) = 205.7dB$$

- The receiver is located at the -3dB contour of the transmitting antenna.
- and miscellaneous losses of 0.4dB for clear sky attenuation at 12 GHz
- and 0.4 dB for receive antenna mispointing and other losses are allowed

- (5) received carrier power is ? dBW in clear sky conditions
- $P_r = P_t + G_t + G_r - L_p$
- $= 22.0 + 34.3 + 33.3 - 205.7 - 3 - 0.4 - 0.4$
- $= -119.6\text{dBW}$

2. in heavy rain

(1). The first step ,determine the total path attenuation, A

- $A=A_{ca}+A_{rain}$ dB
- A_{ca} is the clear sky path attenuation due to atmospheric gaseous absorption,
- A_{rain} is attenuation due to rain

(2). The sky noise temperature resulting from a path attenuation A_{total} dB is

- $T_{sky}=270\times(1-10^{-A/10})K$
- *using an assumed medium temperature of 270 K for the rain*

(3). antenna noise temperature may be calculated as

- $$T_A = \eta_c \times T_{sky} K$$

- *The antenna noise temperature may be assumed to be equal to the sky noise temperature, although in Practice not all of the incident noise. energy from the sky is output by the antenna , and a coupling coefficient, of 90 to 95%; is often used when calculating antenna noise temperature in rain.*

(4). System noise temperature is then given by:

- $T_{s\ rain}=T_{LNA}+T_A$ K

- *almost all satellite receivers use a high gain LNA as the first element in the receiver front end. This makes the contribution of all later parts of the receiver to the system noise temperature negligible.*

(5)The increase in noise power, ΔN_{rain} dB, caused by the increase in sky noise temperature is given by

- $$\Delta N_{rain} = 10\log[\frac{kT_{srain}B_n}{kT_{sca}B_n}] = 10\log[\frac{T_{srain}}{T_{sca}}]dB$$

- where T_{sca} is the system noise temperature in clear sky conditions.

(6). in rain the value of carrier power is C_{rain}

- $C_{rain} = C_{ca} - A_{rain}$ dB
- *The received power is reduced by the attenuation caused by the rain in the slant path*

(7). The resulting $(C/N)_{dn}$ rain value when rain intersects the downlink is given by

- $(C/N)_{dn\ rain} = (C/N)_{dn\ ca} - A_{rain} - \Delta N_{rain}$ dB
- *where* $(C/N)_{dn\ ca}$ *is the downlink C/N ratio in clear sky conditions.*
- *If a linear (bent pipe) transponder is used, the* $(C/N)_{up}$ *ratio must be combined with* $(C/N)_{dnrain}$ *to yield overall* $(C/N)_0$ *ratio for the link.*

4.6 uplink design

- The uplink design is easier than the downlink in many cases:

  (1)since an accurately specified carrier power must be presented at the satellite transponder

  (2)and it is often feasible to use much higher power transmitter at earth stations than can be used on a satellite.

- However, VSAT systems use earth stations with small antennas and transmitter powers below 5 W, giving low uplink EIRP.
- Satellite telephone handsets are restricted to transmitting at power levels below 1 W because of the risk of EM radiation hazards. In mobile systems the uplink from the satellite telephone is usually the link with the lowest C/N ratio.

(1)the power received at the input to the transponder is P_{rxp} where

- $P_{rxp} = P_t + G_t + G_r - L_p - L_{up}$
- *Where $P_t G_t$ is the uplink earth station EIRP in dBW, G_r is the satellite antenna gain in dB.*
- (2)The noise power referred to the transponder input is N_{xp} W where
- $N_{xp} = k + T_{xp} + B_n$
- *The bandwidth B_n is the band width of the bandpass filter in the IF stage of the earth station receiver for which the uplink signal is intended.*

(3)the value of $(C/N)_{up}$ at the LNA input of the satellite receiver is given by

- $C/N=10\log_{10}[P_r/(kT_sB_n)]=P_{rxp}-N_{xp}$ dB

(4) $P_{rxp}=N+C/N$ dBW

(5)The P_{rxp} can be calculated from the output power of the transponder and transponder gain when these parameters are known and a bent pipe transponder is used.

$$P_{rxp}=P_{sat}-B_{O0}-G_{xp}$$

Where P_{rxp} is the saturated power output of the transponder in dBW,

B_{O0} is the output backoff in dB,

and G_{xp} is the gain of the transponder in dB.

EXAMPLE 4.6.1

- A transponder of a Ku-band satellite has a linear gain of 127 dB and a nominal output power at saturation of 5W. The satellite's 14-GHz receiving antenna has a gain of 26 dB on axis, and the beam covers western Europe.
- Calculate the power output of an uplink transmitter that gives an output power of 1W from the satellite transponder at a frequency of 14.45 GHz when the earth station antenna has a gain of 50 dB and there is a 1.5-dB loss in the waveguide run between the transmitter and antenna. Assume that the atmosphere introduces a lossof 0.5 dB under clear sky conditions and that the earth station is located on the -2 dB

- contour of the satellite's receiving antenna. If rain in the path causes attenuation of 7dB for 0.01% of the year, what output power rating is required for the transmitter to guarantee that a 1W output can be obtained from the satellite transponder for 99.99% of the year if uplink power control is used.

EXAMPLE 4.6.1

- G_{xp}=127dB
- G_r=26dB
- G_t=50dB
- 转发器输入功率＋转发器增益＝转发器输入功率
- P_{in}=0dB-127dB=-127dB
- P_{rxp}=EIRP+ G_{rxp}- L_p- L_{at}- L_{ta}- L_{ra}
- P_t=P_{rxp}- G_t - G_{rxp} + L_p+ L_{at} + L_{ta}+ L_{ra}
- P_t=-127-50-26+207.2+1.5+0.5+2.0=7.2dBW

4.7 Design for Specified C/N: Combining C/N and C/I Values in Satellite Links

So far in our analysis of uplinks and downlink we have considered only

(1) the receiver thermal noise

(2) and noise radiated by atmospheric gases

(3) and rain in the slant path.

- When a complete satellite link is engineered, the noise in the earth station IF amplifier will have contributions from

(1) the receiver itself,

(2) the receiving antenna ,

(3) sky noise,

(4) the satellite transponder from which it received the signal and adjacent satellites

(5) and terrestrial transmitters which share the same frequency band

- When more than one C/N ratio is Present in the link, we can add the individual C/N ratio to obtain an overall C/N ratio .
- $(C/N)_0=1/[1/(C/N)_1 +1/(C/N)_2+1/(C/N)_3+\dots]$

- EXAMPLE 4.7.1
- Thermal noise in an earth station receiver result in a $(C/N)_{dn}$ ratio of 20.0dB. A signal is received from a bent pipe transponder with a carrier to noise ratio $(C/N)_{up}$=20.0 dB. What is the value of overall $(C/N)_0$, at the earth station? If the transponder introduces intermodulation products with (C/I) ratio = 24 dB, what is the overall $(C/N)_o$ ratio at the receiving earth station?

$$(C/N)_0 = \left[\frac{1}{1/(C/N)_{up} + 1/(C/N)_{dn}}\right] = \left[\frac{1}{0.01 + 0.01}\right] = 50 \quad \text{or} \quad 17.0\,\text{dB}$$

The intermodulation (C/I) value of 24.0 dB corresponds to a ratio of 0.004. The overall $(C/N)_0$ value is then

$$(C/N)_0 = \left[\frac{1}{0.01 + 0.01 + 0.004}\right] = 41.7 \quad \text{or} \quad 16.2\,\text{dB}$$

■

4.7.1 Overall $(C/N)_o$ with Uplink and Downlink Attenuation

- Most satellite links are designed with link margins to allow for attenuation that may occur in the link or increase in noise power caused by interference.
- There are three different transponder types or operating modes:
- Linear transponder $P_{out} = P_{in} + G_{xp}$ dBW.
- Nonlinear transponder: $P_{out} = P_{in} + G_{xp} - \triangle G$ dBW
- regenerative transponder: P_{out}=constant dBW

- where
- P_{in} is the power delivered by the satellite's receiving antenna to the input of the transponder.
- P_{out} is the power delivered by the transponder HPA to the input of the satellite's transmitting antenna,
- G_{xp} is the gain of the transponder and all parameters are in decibel units.

4.7.2 Uplink and Downlink Attenuation in rain

- rain attenuation affects uplinks and downlinks differently. we usually assume the rain attenuation is occurring on either uplink or downlink, but not on both at the same time.

1. Uplink Attenuation and $(C/N)_{up}$

- Rain attenuation on the uplink path to the satellite reduces the power at the satellite receiver input, and thus reduces $(C/N)_{up}$ in direct proportion to 'the attenuation on the slant path.

(1) for the case of a linear transponder and rain attenuation in the uplink of A_{up} dB

- $(C/N)_{o\ uplink\ rain} = (C/N)_{o\ clear\ air} - A_{up}$ dB
- *If the transponder is operating in a linear mode the output power will be reduced by the same amount, which will cause $(C/N)_{dn}$ to fall attenuation on the uplink. When both $(C/N)_{up}$ and $(C/N)_{dn}$ are reduced by A_{up} dB, the value of $(C/N)_o$ is reduced by exactly the same amount, A_{up} dB.*

(2) If the transponder is nonlinear, the reduction in input power caused by uplink attenuation of A_{up} dB results in a smaller reduction in output Power by an amount $\triangle G$.

- $(C/N)_{o\ uplink\ rain} = (C/N)_{o\ clear\ air} - A_{up} + \triangle G$ dB

(3) If the transponder is digital and regenerative, or incorporates an Automatic Gain Control (AGC) system to maintain a constant output power level.

- $(C/N)_{o\ uplink\ rain} = (C/N)_{o\ clear\ air}$

2.Downlink Attenuation and $(C/N)_{down}$

- $(C/N)_{dn\ rain} = (C/N)_{dn\ clear\ air} - A_{rain} - \triangle N_{rain}$ dB
- $(C/N)_0 = 1/[1/(C/N)_{dn\ rain} + 1/(C/N)_{up}]$

4.7.3 Satellite Communication Link Design

A typical two-way satellite communication link consists of four separate path:

(1).an outbound uplink path from one terminal to the satellite

(2).and outbound downlink to the second terminal;

(3).and an inbound uplink from the second terminal to the satellite

(4).and an inbound downlink to the first terminal.

- The design procedure

1. Determine the frequency band in which the system must operate. Comparative designs may be required to help make the selection.
2. Determine the communications parameters of the satellite. estimate any values that are not known.
3. Determine the parameters of the transmitting and receiving earth stations.
4. start at the transmitting earth station. establish an uplink budget and a transponder noise Power budget to find $(C/N)_{up}$ in the transponder.

5. Find the output power of the transponder based on transponder gain or output backoff
6. Establish a 'downlink Power and noise budget for the receiving earth station. Calculate $(C/N)_{dn}$ and $(C/N)_o$ for a station at the edge of the coverage zone (worst case).
7. calculate S/N or BER in the baseband channel. Find the link margins.
8. Evaluate the result and compare with the specification requirements. change parameter Of the system as required to obtain acceptable $(C/N)_o$, or S/N or BER values. this may require several trial designs.

9 determine the propagation conditions under which the link must operate. Calculate outage time for the uplinks and downlinks.

10. redesign the system by changing some parameters if the link margins are inadequate check that all parameters are reasonable, and that the design can be implemented.

UNIT-IV

MULTIPLE ACCESS

Multiple Access
Why and What ?

- Radio frequency is a ***shared*** medium
  - Multiple users are using the same spectrum (e.g. 800-825MHz)
  - How to allocate communications channels?
- Multiple access protocols govern how radio frequency medium are allocated to each channel
  - *Fixed allocation access protocols* are conflict free
  - *Random access protocols* allow users to share access statistically with conflict resolution

MULTIPLE ACCESS

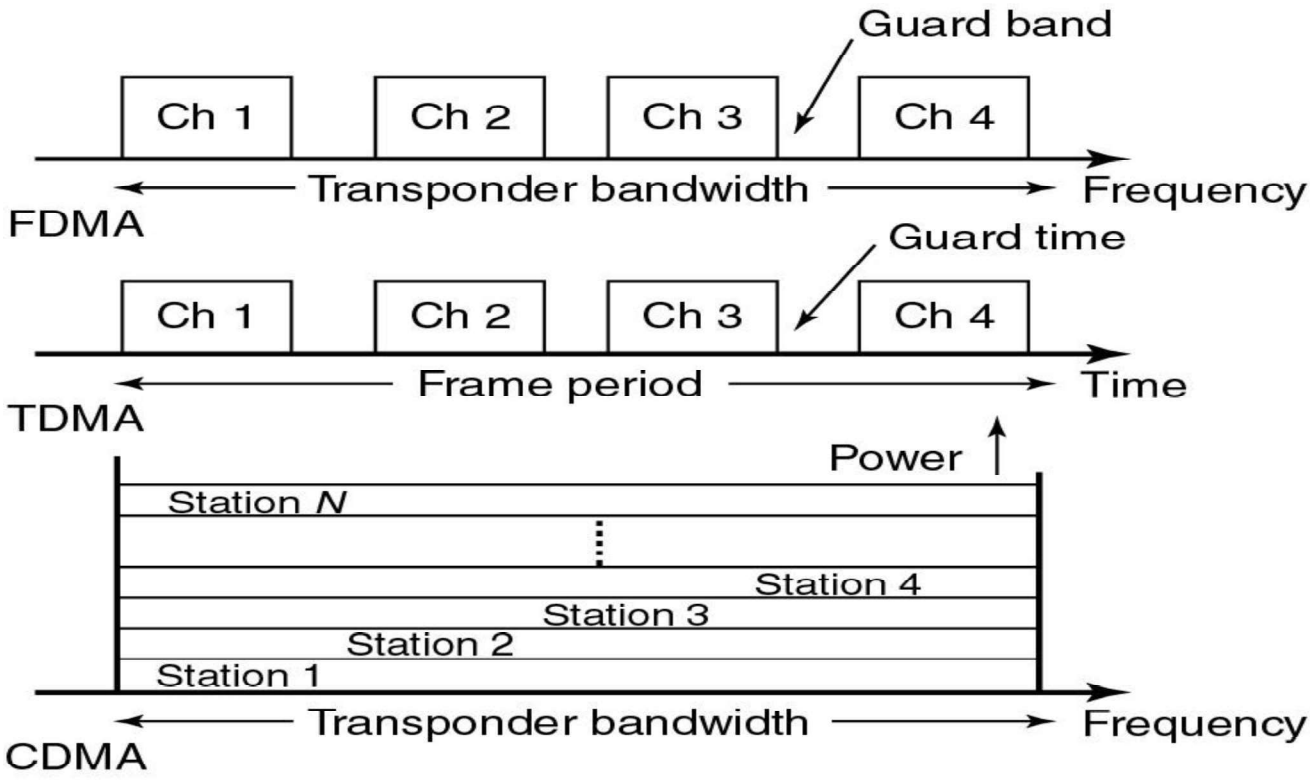
- Multiple access is the "**ability of a large number of earth stations to simultaneously interconnect their respective voice, data, teletype, facsimile, and television links through a satellite**"
- The basic problem involved is how to permit a changing group of earth stations to share a satellite in a way that optimizes the
  - satellite capacity - adaptability to multimedia traffic
  - spectrum utilization - cost
  - satellite power - user acceptability
  - interconnectivity - flexibility
- There are three basic techniques: **FDMA, TDMA, CDMA**

Need of Multiple Access:

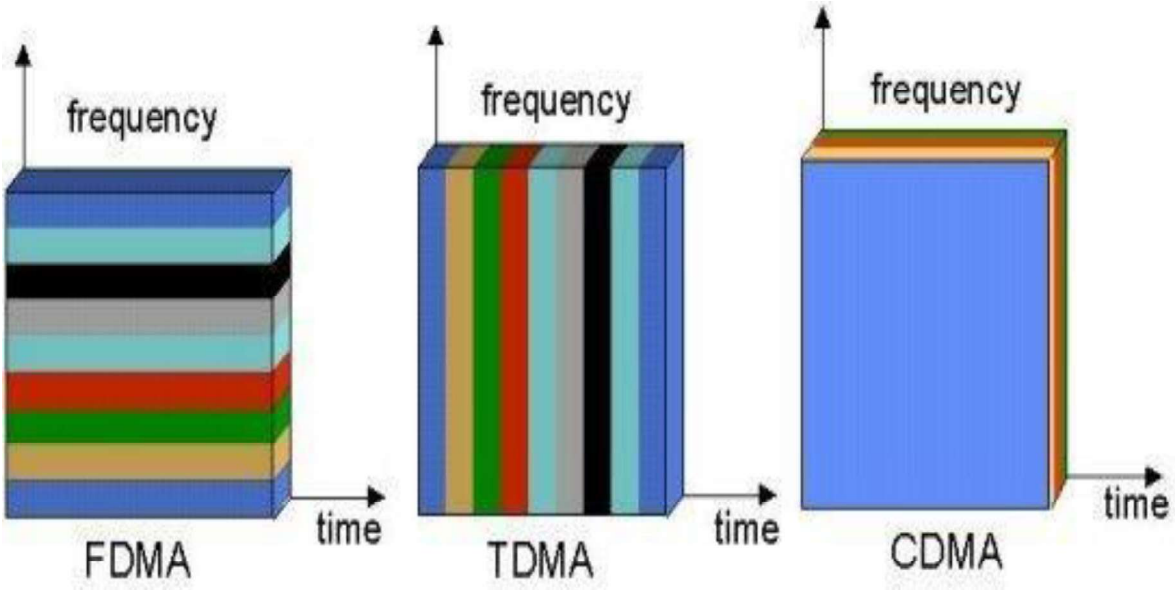
- Satellites are usually built and employed for the common good of one or more regions.
- This means a lot of people needs to send and receive data through a satellite without major mishaps.
- For this purpose, we may use one of the several multiple access techniques.
- Mentioned here are FDMA, TDMA, CDMA and DAMA.

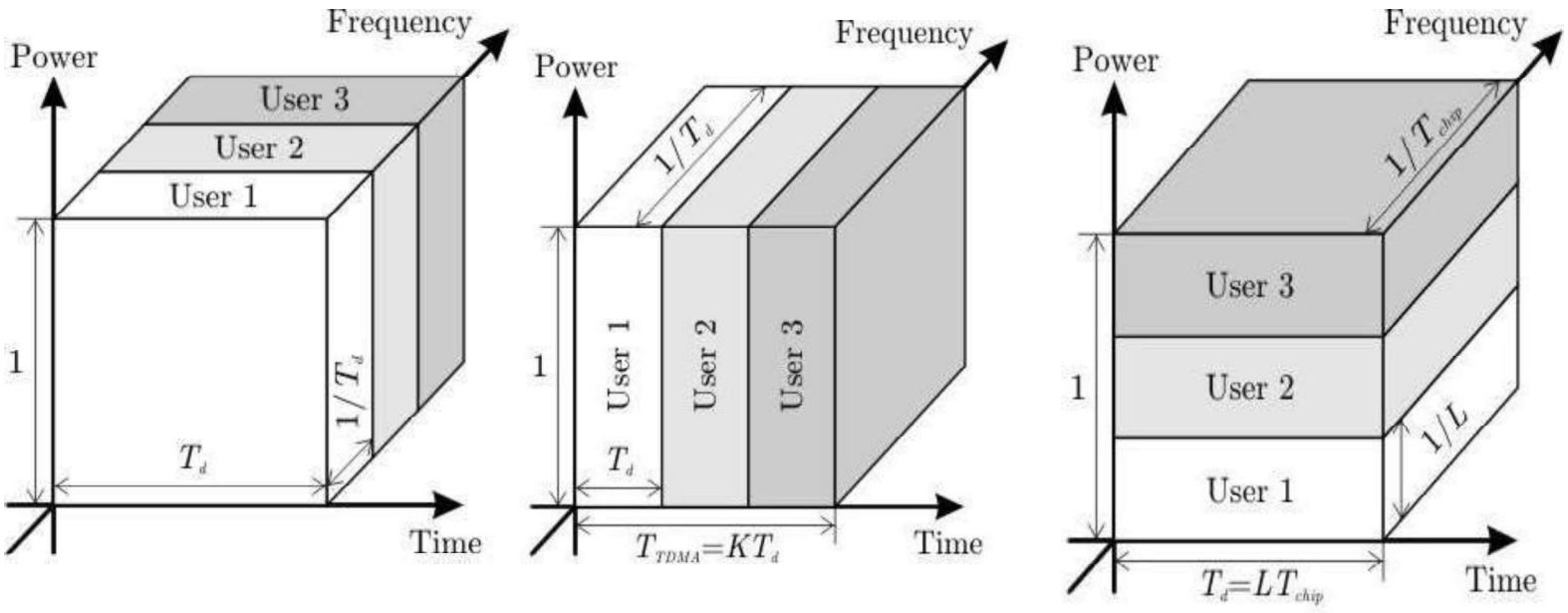
- FDMA - *Frequency Division Multiple Access*
  - Channels are allocated to non-overlapping frequency bands
- TDMA - *Time Division Multiple Access*
  - Non-overlapping time slots are allocated to channels
- CDMA - *Code Division Multiple Access*
  - Channels are differentiated via codes
  - A class of spread spectrum communications

Multiple access techniques: FDMA, TDMA, and CDMA. Note that in the direct sequence form of CDMA shown here, all the channels overlap in both time and frequency.



- If the proportion of the resource (frequency, time, code) is allocated in advance, it is called ***PRE-ASSIGNED*** **MULTIPLE ACCESS** or ***FIXED*** **MULTIPLE ACCESS**
- If the proportion of the resource is allocated in response to traffic conditions in a dynamic manner it is called ***DEMAND ASSIGNED*** **MULTIPLE ACCESS - DAMA**


frequency
time
FDMA
frequency
time
TDMA
frequency
time
CDMA



3-dimensional plot showing:
(a) FDMA technique
(b) TDMA technique.
(c) CDMA technique.

Frequency Division Multiple Access (FDMA):

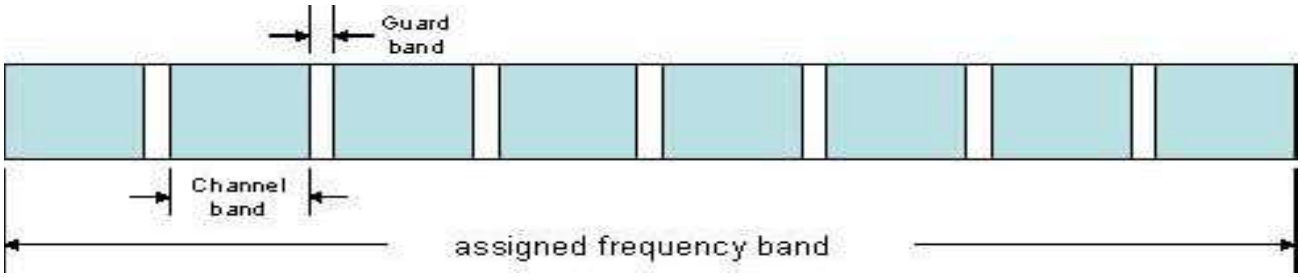
- Frequency division, as the name suggests, operates by dividing the available bandwidth between users on the basis of frequency.
- A group of users maybe allotted a range of frequencies and each individual user can use a limited frequency shifted channels, within that range.
- Earlier analogue FDMA used FM waves with slightly different carrier frequencies to get the job done.

Frequency Division Multiple Access(FDMA):

- First multiple access technique used in satellite communication systems.
- Available frequency band is divided into N non – overlapping channels.
- Guard band minimize interference between channels.
- FDM- FM RF carrier is used to transmit data to the satellite.
- The main advantage of FDMA is that filters can be used to separate signals.

How it works

- FDM-FM was transmitted to satellite from ESs.
- These were received by a common transponder.
- Microwave filters were used in ESs to separate signals within the transponder.
- The corresponding ESs received data back from the transponder and the data get demuxed.
- If the frequency assignment has to be changed, all the ESs' filters must be retuned.
- This can cause long idle times too.



FDMA Frequency sharing in FDMA

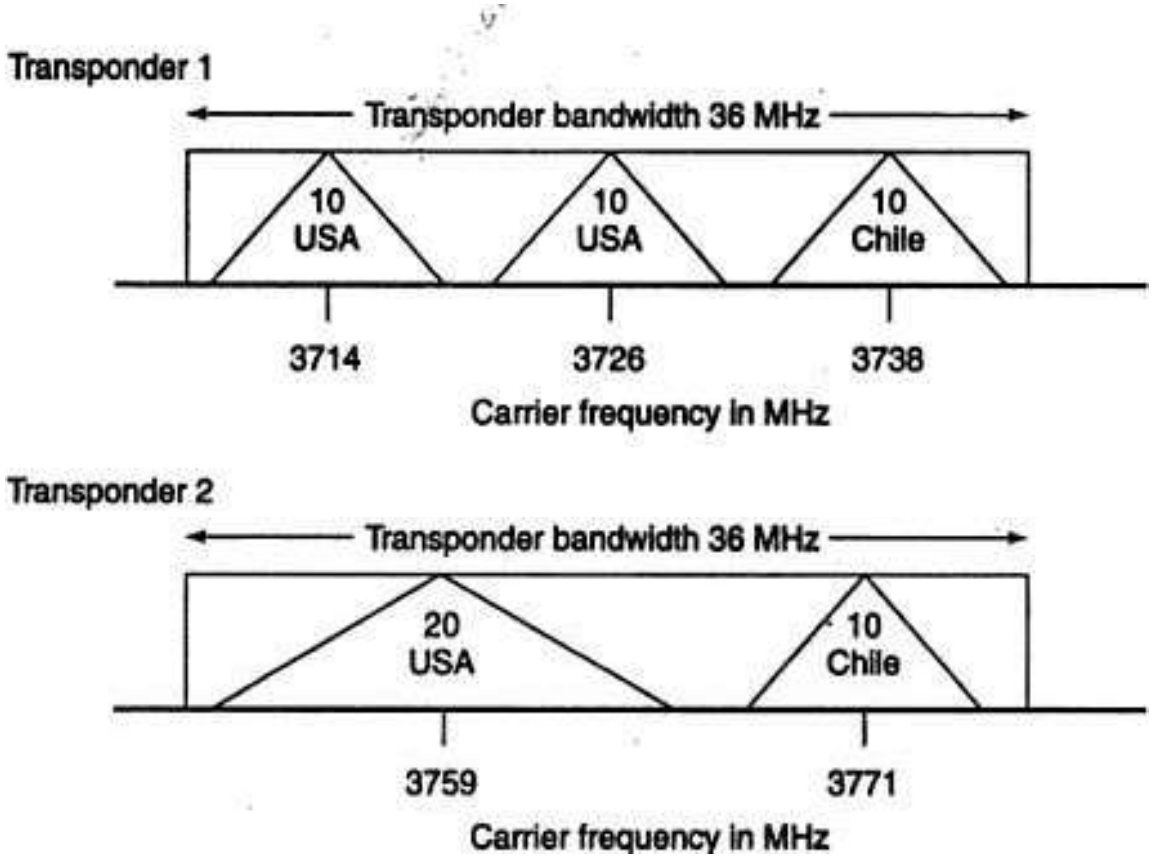
Improving on it

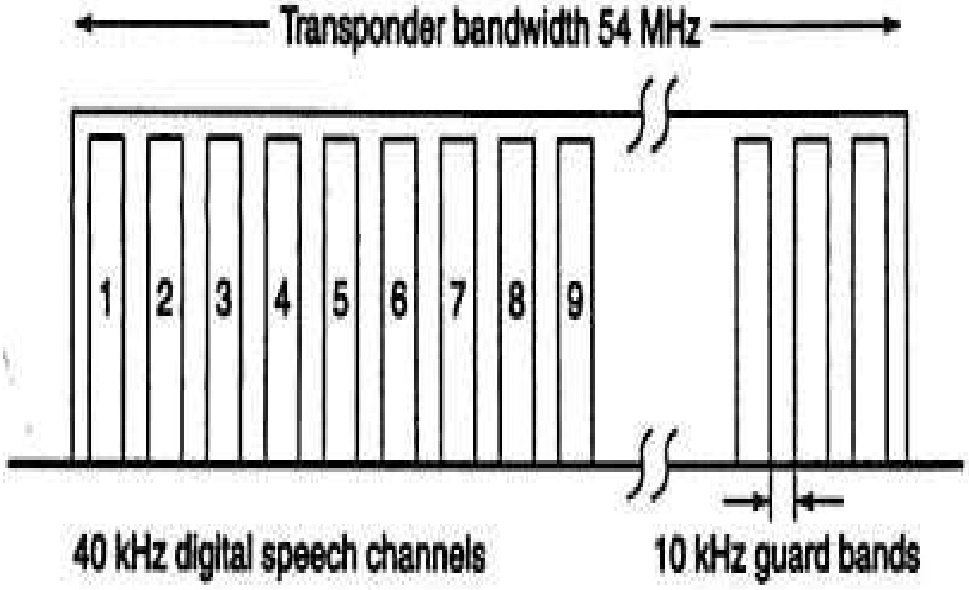
- Single Channel Per Carrier (SCPC) technique means a number of small mobile earth stations can transmit and receive data over a single transponder.
- This can enable satellite telephony
- This can also help utilize the whole wide bandwidth of the transponders

What can go wrong

- High power amplifiers used in transponders can have non-linear operation near saturation.
- Travelling Wave Tube Amplifier can have more susceptibility to this than a Solid State High Power Amplifier.

- This can cause reduced ratio.$(C/N)_0$
- Equalization at the Earth station can mask this effect to a certain extent.


Transponder 1
Transponder bandwidth 36 MHz
10
USA
10
USA
10
Chile
3714
3726
3738
Carrier frequency in MHz
Transponder 2
Transponder bandwidth 36 MHz
20
USA
10
Chile
3759
3771
Carrier frequency in MHz


Transponder bandwidth 54 MHz
1
2
3
4
5
6
7
8
9
40 kHz digital speech channels
10 kHz guard bands

Advantages:

- If channel is not in use, it sits idle
- Fairly efficient when the number of stations is small and the traffic is uniformly constant
- No need for network timing.
- No restriction regarding the type of baseband or type of modulation.

Disadvantages:

- The presence of guard bands.

Requires right RF filtering to minimize adjacent channel interference

Intermodulation:

- Intermodulation products are generated whenever more than one signal is carried by a nonlinear device.
- The characteristics of a transponder can be modeled by a cubic curve to illustrate the generation of third – order intermodulation.
- Third – order intermodulation is important because third- order IM products often have frequencies close to the signals that generate the intermodulation.
- To illustrate the generation of third- order IM products, we will model nonlinear characteristics of the transponder HPA with cubic voltage relationship and apply two unmodulated carriers at frequencies f1 & f2 at the input of the amplifier.

$V_{out} = A\, v_{in} + b(V_{in})^3$ where $A >> b$

The amplifier input signal is

$V_1 \cos w_1 t + V_2 \cos w_2 t$

The amplifier output signal is

$$\begin{aligned} V_{out} &= AV_{in} + b(V_{in})^3 \\ &= AV_1 \cos\omega_1 t + AV_2 \cos\omega_2 t + b(V_1 \cos\omega_1 t + V_2 \cos\omega_2 t)^3 \end{aligned} \tag{6.3}$$

linear term — cubic term

The linear term simply amplifies the input signal by a voltage gain A. The cubic term, which will be denoted as V_{3out}, can be expanded as

$$\begin{aligned} V_{3out} &= (V_1 \cos\omega_1 t + V_2 \cos\omega_2 t)^3 \\ &= b[V_1^3 \cos^3\omega_1 t + V_2^3 \cos^3\omega_2 t + \\ &\quad 2V_2^2 \cos^2\omega_2 t \times V_2 \cos\omega_2 t + 2V_2^2 \cos^2\omega_2 t \times V_1 \cos\omega_1 t] \end{aligned} \tag{6.4}$$

The first two terms contain frequencies f_1, f_2, $3f_1$, and $3f_2$. The triple-frequency components can be removed from the amplifier output with band-pass filters. The second two terms generate the third-order IM frequency components.

We can expand the cosine squared terms using the trig identity $\cos^2 x = \frac{1}{2}[\cos 2x + 1]$. Hence the IM terms of interest become

$$\begin{aligned} V_{IM} &= bV_1^2 \times V_2[\cos\omega_2 t \times (\cos 2\omega_1 t + 1)] + \\ &\quad bV_2^2 \times V_1[\cos\omega_1 t \times (\cos 2\omega_2 t + 1)] \\ &= bV_1^2 \times V_2[\cos\omega_2 t \cos 2\omega_1 t + \cos\omega_2 t] + \\ &\quad bV_2^2 \times V_1[\cos\omega_1 t \cos 2\omega_2 t + \cos\omega_1 t] \end{aligned} \tag{6.5}$$

The terms at frequencies f_1 and f_2 add to the wanted output of the amplifier, so the third-order intermodulation products are generated by the $f_1 \times 2f_2$ and $f_2 \times 2f_1$ terms.

Using another trig identity

$$\cos x \cos y = \cos(x + y) + \cos(x - y)$$

The output of the amplifier contains IM frequency components given by

$$\begin{aligned} V'_{IM} = {} & bV_1^2 \times V_2[\cos(2\omega_1 t + \omega_2 t) + \cos(2\omega_1 t - \omega_2 t)] \\ & + bV_2^2 \times V_1[\cos(2\omega_2 t + \omega_1 t) + \cos(2\omega_2 t - \omega_1 t)] \end{aligned} \tag{6.6}$$

We can filter out the sum terms in Eq. (6.6), but the difference terms, with frequencies $2f_1 - f_2$ and $2f_2 - f_1$ may fall within the transponder bandwidth. These two terms are known as the third-order intermodulation products of the high-power amplifier, because they are the only ones likely to be present at the output of a transponder which incorporates a narrow bandpass filter at its output. Thus the third-order intermodulation products that are of concern are given by V_{3IM} where

$$V_{3IM} = bV_1^2 V_2 \cos(2\omega_1 t - \omega_2 t) + bV_2^2 V_1 \cos(2\omega_2 t - \omega_1 t) \tag{6.7}$$

The magnitude of the IM products depends on the parameter b, which describes the nonlinearity of the transponder, and the magnitude of the signals. The wanted signals at the transponder output, at frequencies f_1 and f_2, have magnitudes AV_1 and AV_2. The wanted output from the amplifier is

$$V_{out} = AV_1 \cos\omega_1 t + AV_2 \cos\omega_2 t$$

The total power of the wanted output from the HPA, referenced to a 1 ohm load, is therefore

$$P_{out} = \tfrac{1}{2}A^2V_1^2 + \tfrac{1}{2}A^2V_2^2 = A^2(P_1 + P_2)\ \text{W} \tag{6.8}$$

The power of the IM products at the output of HPA is

$P_{IM} = b^2 (P_1^3 + P_2^3)$

Calculation of C/N with intermodulation:

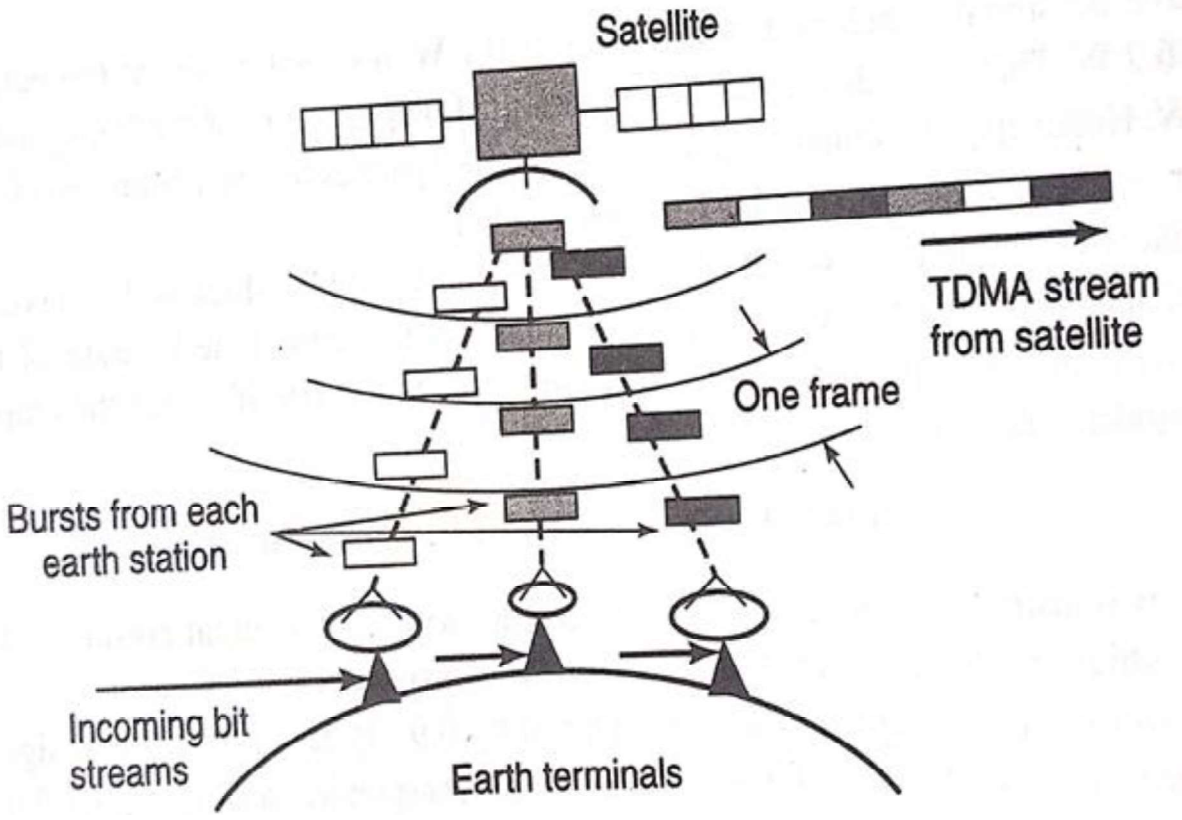
- $(C/N)_o = 1/[1/(C/N)_{up} + 1/(C/N)_{dn} + 1/(C/N)_{IM}]$

Time Division Multiple Access (TDMA)

- In TDMA, ideally, the whole bandwidth is used by a user for a fixed amount of time.
- All practical TDMA signals are digital and hence are advantageous over traditional FDMA system.
- Problems of non-linearity are not present here as at a time the whole bandwidth of a transponder is used only by a single signal.
- However, need for higher bitrates (requires more energy) and presence of ISI can be a problem.

Time Division Multiple Access(TDMA):

- In TDMA a no. of earth stations take turns transmitting bursts of RF signals through a transponder.
- All practical TDMA systems are digital.
- TDMA is an RF multiple access technique that allows a single transponder to be shared in time between RF carriers from different earth stations.
- The RF carrier from each earth station sharing a transponder is sent as burst at a specific time.
- At satellite, bursts from different earth stations arrive sequentially, so transponder carries a near continuous signal.


Satellite
TDMA stream
from satellite
One frame
Bursts from each
earth station
Incoming bit
streams
Earth terminals

How it works

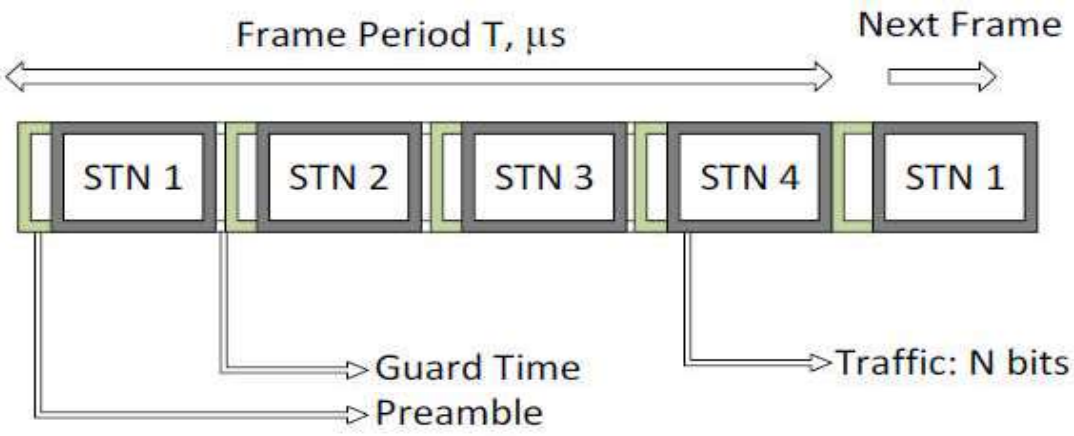
- Multiple ESs transmits data in short bursts so they reach the transponder in a sequence
- The transponder simply outputs all the incoming data into a continuous stream of serial data with short guard times.
- All ESs must be synced for their signals to arrive within the positions allotted to them in a frame.
- The received serial data can be recovered using sync attained between transmitter

Bits and pieces…

- Digital data is often broken down into bits.
- Symbols are representations of data in a bit.
- Bitrate is the number of its transferred per second.
- Baud rate is the number of symbols transferred.
- For BPSK, the former and later are same.
- Baud rate determines the bandwidth of a signal.
- QAM can be used for transmission, if a higher than usual $(C/N)_0$ is available.

Being framed

- A TDMA frame contains all data from all ESs in a TDMA network.



Bursting with data

- Data in a TDMA network is sent as bursts.
- Proper synchronization of bursts is required for it to be framed properly.
- A master station transmits a reference burst on which the rest of the earth stations start transmitting.
- Each frame has one, and it's a preamble, of the incoming data traffic.
- Reducing this overhead can improve efficiency.

Guardians…

- Guard times small empty slots between traffic
- They are important to avoid crashing of multiple data bits.
- If a collision occurs, multiple data is lost.
- Longer guard times can affect efficiency, but improve reliability and safety.
- Typical guard times range from 1-5 µs.

Time Division Multiple Access:

- The time T_d available in each station burst for transmission of data bits

$T_d = [T_{frame} – N(t_g + t_{pre})]/N$ seconds

- In 1 s, the total no. of bits , C_b , transmitted by each earth station is

$C_b = [T_{frame} – N(t_g + t_{pre})]* R_b /T_{frame} *N$

- The no. of speech channel that can be carried by each earth station is

$n= [T_{frame} – N(t_g + t_{pre})] * R_b /(T_{frame} * r_{sp})*N$

Reference Burst

- A reference burst is a preamble followed by no traffic bits.
- In some systems , a separate reference burst may be transmitted by one of the station, designated as master station.

Synchronization

•Earth stations operating in a TDMA network must transmit their RF bursts at precisely controlled times such that bursts from each of the earth stations arrive at the satellite in the correct sequence.

•One station is designated as the master station, & may generate a reference burst to mark the start of the frame.(SOTF= Start of transmit frame)

•Each of the station within the network has a time slot within the frame and must maintain its transmission within that time slot.

There are guard times at each end of each station's burst, which define the accuracy that burst timing must achieve.

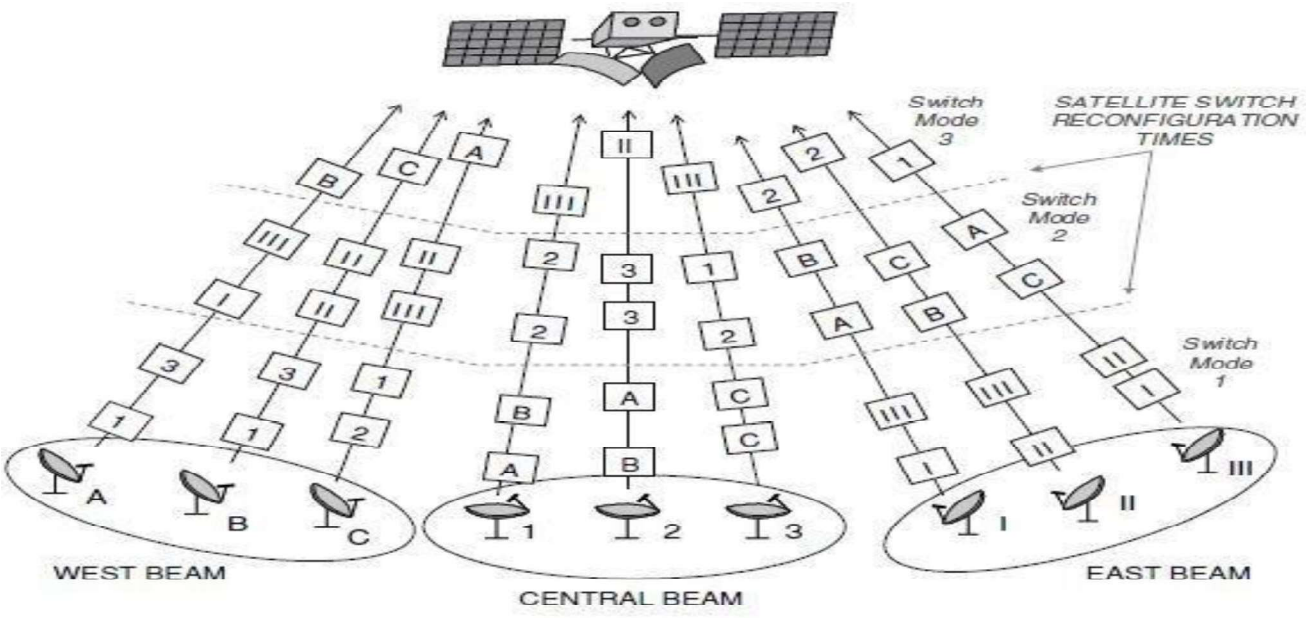
Satellite switched TDMA

•Instead of using a single antenna beam to maintain continuous communication with its entire coverage zone, the satellite has a number of narrow antenna beams that can be used sequentially to cover the zone.

•A narrow antenna beam has a higher gain than a broad beam, which increases the satellite EIRP and therefore increases capacity of downlink.

•Uplink signals received by satellite are demodulated to recover the bit streams, which are structured as sequence of packets are addressed to different receiving earth stations.

The satellite creates TDMA frames of data that contain packets addressed to specific earth stations, and switches its transit beams to the direction of receiving earth station as packets are transmitted.



Advantages of TDMA

- Flexible bit rate
- No frequency guard band required
- No need for precise narrowband filters
- Extended battery life.
- The most cost-effective technology for upgrading a current analog system to digital

Disadvantages:

- Requires timing synchronization
- Demand high peak power on uplink

Onboard Processing:

•Generally satellite use bent pipe transponder which simply amplifies a signal received from earth and retransmits it back to earth and retransmits it back to earth.

•The disadvantage of the bent pipe transponder is that it is not well suited to uplinks from small earth stations, especially in Ka band.

•The solution is baseband processing transponder or onboard processing.

Baseband Processing Transponder

- It has a receiver and transmitter similar to those found in an earth station.
- The received signal from the uplink is converted to an intermediate frequency and demodulated to recover the baseband signal, which is then processed.
- The baseband signal is modulated onto a carrier at downlink frequency and transmitted back to earth.
- The advantage of this process is that uplink and downlink signal format need not to be the same and the C/N ratios of the uplink and downlink are not tied together through reciprocal formula.
- Separation of the uplink and downlink signals allows different modulation methods to be used, as well as flexible error correction codes.

Demand Assigned Multiple Access (DAMA)

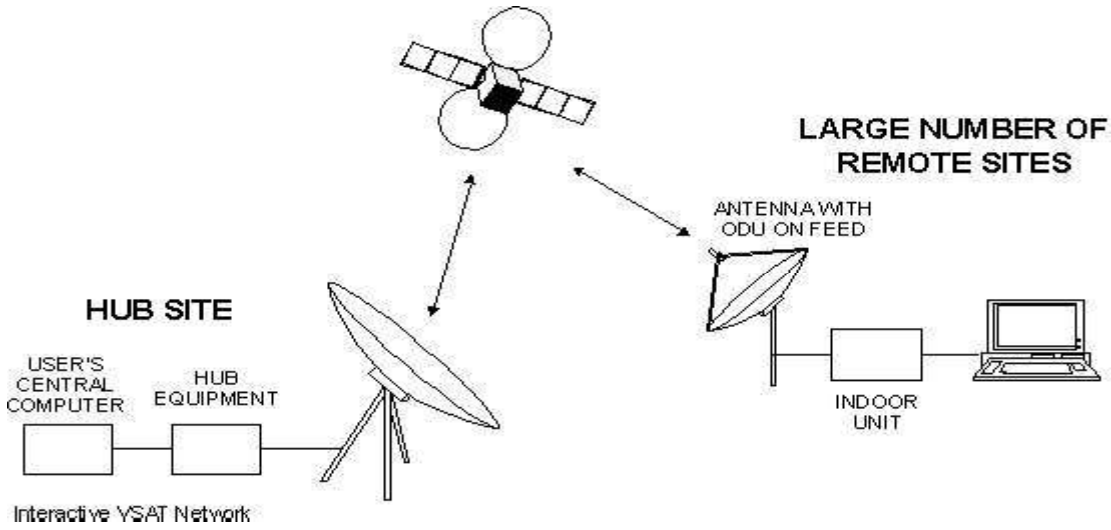
- This technique is used when the link between the station and satellite is not a constant one.
- This helps assign bandwidth according to demand.
- This can be implemented on TDMA, or as a combination with FDMA and TDMA.
- Commonly used in VSAT (Very Small Aperture Terminal) systems.

Demand Access Multiple Access(DAMA):

•DAMA can be used in any satellite communication link where traffic from an earth station is intermittent.

•Demand access allows a satellite channel to be allocated to a user on demand, rather than continuously, which greatly increases the no. of simultaneous users who can be served by the system.

•Most SCPC – FDMA system uses demand access to ensure that the available bandwidth in a transponder is used as fully as possible.



DAMA Depiction of a DAMA System

How it works

- There are two different types of channels in DAMA
- A Common Signalling Channel (CSC)
- And a Communication Channel (CC)
- A user wishing to enter the CC first calls the controlling ES using CSC.
- Bent pipe transponders then accept the data and retransmits.
- Receivers should listen in sync continuously to retrieve the data.

Demand access systems require two types of a channel: a common signaling channel(CSC) and a communication channel.

•A user wishing to enter the communication network first calls the controlling earth station using the CSC, and the controller then allocates a pair of channels to that user.

•The CSC is operated in RA mode.

•The CSC are located at the ends of the transponder bandwidth.

•When earth station wants to access the satellite, it transmits a control packet to satellite on the CSC Frequency & waits for a reply.

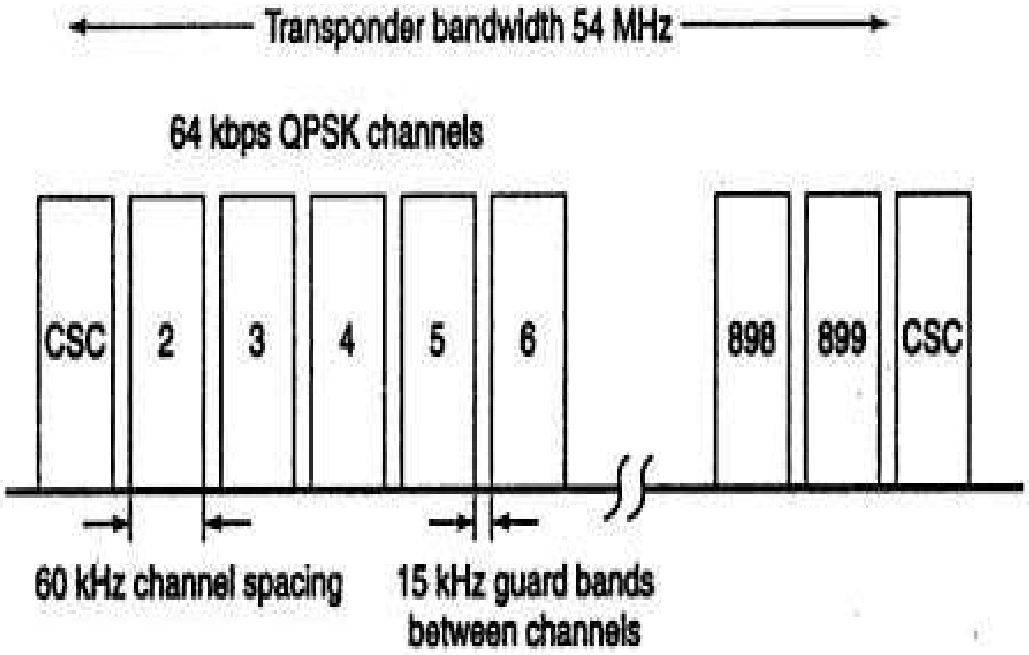


FIGURE 6.11 Frequency plan for a 54-MHz transponder carrying 900 demand access channels. Each channel has an occupied RF bandwidth of 45 kHz and carries one 64-kbps signal. Channel 1 and channel 900 are common signaling channels (CSC) used by the demand assignment system to set up access to the other 898 channels.

The control packet is received by the hub earth station and decoded.

- The control packet contains source address & destination address., also it includes cyclic redundancy check (CRC).
- The control station measures duration of the connection in order to generate billing data.

Where it is used

- DAMA is often used in military environments due to the relative simplicity of implementation and ease of modelling
- It can operate with bent pipe transponders and thus require no security on the satellite side.
- The master and slave stations can upgrade compressions without expensive satellite replacements.

Code Division Multiple Access (CDMA)

- In CDMA, all users can use the whole bandwidth, all the time.
- The data need not be synced or be filtered.
- It can allow users with more needs utilize the bandwidth more, while conserving it when idled.
- Transmission times or frequencies are irrelevant here, and there is hardly any spectrum allocation.
- Currently used method is Direct Sequence Spread Spectrum.

Code Division Multiple Access(CDMA):

- CDMA is a scheme in which a no. of users can occupy all of the transponder bandwidth all of the time.
- CDMA signals are encoded such that information from an individual transmitter can be recovered by a receiving station that knows the code being used.
- Each receiving station is allocated a CDMA code; any transmitting station that wants to send data to earth station must use the correct code.
- CDMA codes are typically 16 bits to many thousands of bits in length, and bits of a CDMA are called **chips.**

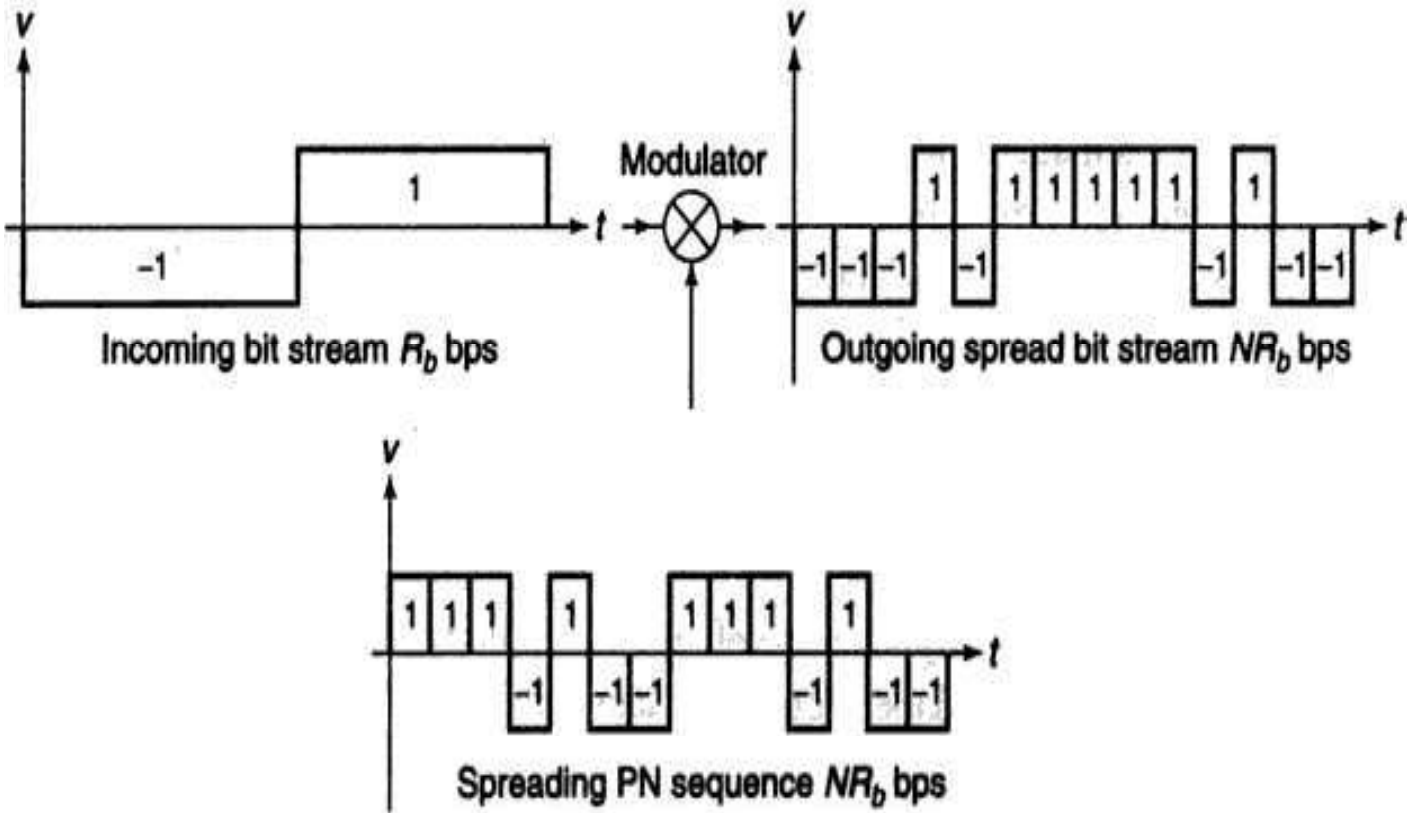
How it works

- Any earth station can code their data based on a CDMA code, obeying a set of rules defined by an organization.
- This code can be 16 bits to several thousand bits long.
- Since multiple stations can saturate the bandwidth without much effort, this system is highly efficient.
- The receiver needs the same code used by the transmitter.

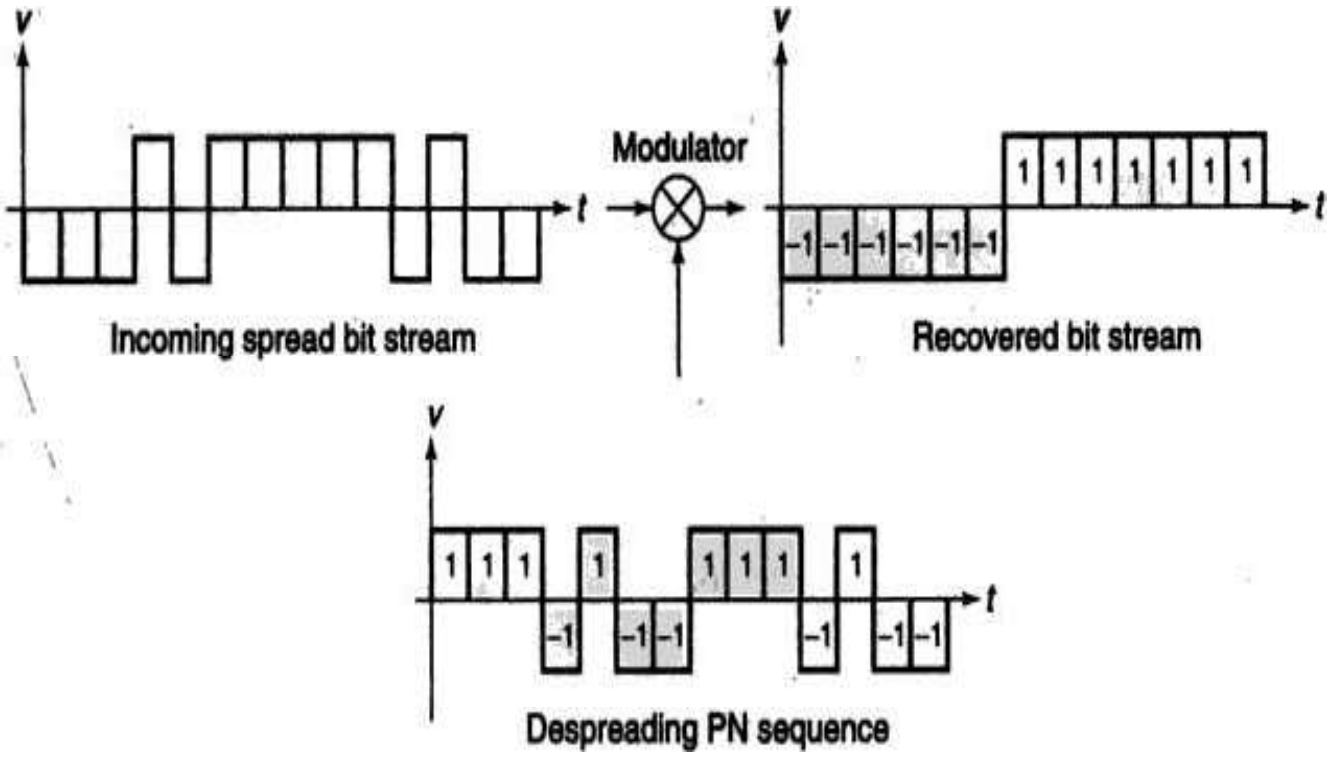
CDMA chip sequence modulates the data bits of original message and chip rate is always much greater than the data rate.

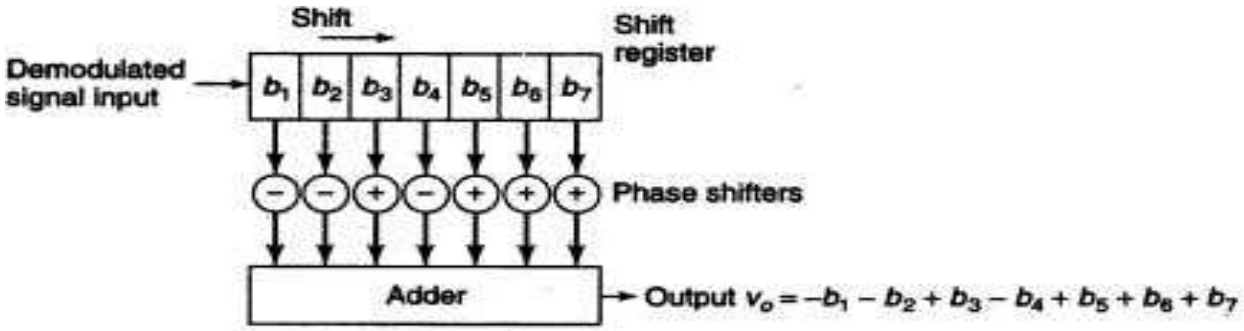
- This greatly increases the speed of digital transmission.
- CDMA is also known as spread spectrum.
- Direct sequence spread spectrum (DS-SS) is the only current type used in satellite communication.

Transmitting Side



Receiving Side





Bits clocked in	Register contents	Output
0	1 1 1 1 1 1 1	$v_o = 1$
1	−1 | 1 1 1 1 1 1	$v_o = 3$
2	−1 −1 | 1 1 1 1 1	$v_o = 5$
3	−1 −1 −1 | 1 1 1 1	$v_o = 3$
4	1 −1 −1 −1 | 1 1 1	$v_o = 3$
5	−1 1 −1 −1 −1 | 1 1	$v_o = 1$
6	1 −1 1 −1 −1 −1 | 1	$v_o = -1$
7	1 1 −1 1 −1 −1 −1	$v_o = -7$

Bits clocked in	Register contents	Output
8	1 | 1 1 −1 1 −1 −1	$v_o = 1$
9	1 1 | 1 1 −1 1 −1	$v_o = 3$
10	1 1 1 | 1 1 −1 1	$v_o = 1$
11	−1 1 1 1 | 1 1 −1	$v_o = 1$
12	1 −1 1 1 1 | 1 1	$v_o = 3$
13	−1 1 −1 1 1 1 | 1	$v_o = 1$
14	−1 −1 1 −1 1 1 1	$v_o = 7$

Topics covered beyond the syllabus of SC:

1. Multi-frequency TDMA (MF-TDMA)

2. High-Throughput Satellite (HTS)

3. “Starlink” satellite internet constellation system.

Rajeev Gandhi Memorial College of Engineering & Technology

Autonomous
NANDYAL-518501

Department of Electronics & Communication Engineering

Academic Year: 2022-23

Subject: Satellite Communication (SC)

Class: IV B.Tech, II Sem

Faculty member taught earlier: Dr.Kethepalli Mallikarjuna, Mr.M.V.Rajasekhar

Suggestions:

As per the course structure of the UG (R19), SC subject is completely based on the study of orbital mechanics, satellite subsystems, satellite link design, different multiple access techniques used in satellite communication and also the GPS and satellite navigation systems. So, this subject covers the importance of global coverage using satellite communication along with satellite link design. Hence, following suggestions are made by subject experts:

1. As the subject comprises of theory and quantitative analysis design earlier overall pass percentage was 85%. So, it is required to discuss more about designing problems to improve overall percentage further.
2. To improve the subject knowledge, this subject is to be demonstrated with prototype design models.
3. To improve the results, to take care of slow learners by taking extra classes and make them to practice more from previous year question papers as assignments.
4. Regular counseling and motivation should be given to the students to avoid the lacking in the subject knowledge.
5. The environment of the class should be interactive with respect to the subject discussion so that students can understand elaborately and may ask more questions.

Signature of the subject expert-1
Dr.Kethepalli Mallikarjuna
Professor and HOD
Dept.of ECE

Signature of the subject expert-2
Mr.M.V.Rajasekhar
Assistant Professor
Dept.of ECE

Rajeev Gandhi Memorial College of Engineering & Technology
(Autonomous Institution | Approved by AICTE New Delhi | Affiliated to JNTU Anantapur)
Address : Nerawada 'X' Roads,Nandyal,Kurnool Dist,Andhra Pradesh,India
Counselling Code : RGIT
(ESTD-1995)
NAAC A+ GRADE
NBA NATIONAL BOARD OF ACCREDITATION

P.Rangappa
Asst. Prof.
Dept. of ECE
Phone: 9966393750
Email: palle.ranga@gmail.com

S.No.	Year (Batch)	Section	Subject	Branch	Registered	Appeared	Failed	Pass(%)	Highest
1	II B.Tech. II Sem. & 2021	B	ARMP Lab	ECE	73	72	5	93.06	10
2	IV B.Tech. II Sem. & 2019	D	SC	ECE	64	62	1	98.39	9
3	IV B.Tech. II Sem. & 2019	A	SC	ECE	71	70	0	100.00	9
4	IV B.Tech. I Sem. & 2019	B	DIP Lab	ECE	70	70	1	98.57	10
5	IV B.Tech. I Sem. & 2019	C	DDV (SDC)	ECE	69	69	7	89.86	9
6	IV B.Tech. I Sem. & 2019	B	DDV (SDC)	ECE	70	69	1	98.55	9
7	III B.Tech. II Sem. & 2019	A	ARMP Lab	ECE	70	70	0	100.00	10
8	III B.Tech. II Sem. & 2019	D	AMII	ECE	62	62	6	90.32	7
9	III B.Tech. II Sem. & 2019	A	AMII	ECE	70	70	0	100.00	9
10	IV B.Tech. I Sem. & 2018	A	DSP&IP Lab	ECE	67	67	0	100.00	10
11	IV B.Tech. I Sem. & 2018	D	SC	ECE	60	55	4	92.73	9
12	IV B.Tech. I Sem. & 2018	A	SC	ECE	67	67	0	100.00	10
13	III B.Tech. II Sem. & 2018	A	MPMC Lab	ECE	68	67	0	100.00	10
14	III B.Tech. II Sem. & 2018	A	MPMC	ECE	68	67	0	100.00	10
15	IV B.Tech. I Sem. & 2017	D	SC	ECE	51	48	6	87.50	9
16	IV B.Tech. I Sem. & 2017	A	SC	ECE	57	57	0	100.00	9
17	III B.Tech. II Sem. & 2017	C	DSP	ECE	52	52	12	76.92	8
18	IV B.Tech. II Sem. & 2016	C	WCN	ECE	55	55	2	96.36	8
19	IV B.Tech. I Sem. & 2016	D	MP	ECE	55	51	0	100.00	10
20	IV B.Tech. I Sem. & 2016	D	DSP&IP Lab	ECE	55	51	0	100.00	10
21	IV B.Tech. I Sem. & 2016	D	SC	ECE	55	55	2	96.36	9
22	IV B.Tech. I Sem. & 2016	C	SC	ECE	55	55	6	89.09	9

S.No.	Year (Batch)	Section	Subject	Branch	Registered	Appeared	Failed	Pass(%)	Highest
23	IV B.Tech. II Sem. & 2015	B	SEM	ECE	60	60	0	100.00	10
24	IV B.Tech. II Sem. & 2015	C	WCN	ECE	61	61	5	91.80	8
25	IV B.Tech. II Sem. & 2015	B	WCN	ECE	60	59	8	86.44	8
26	IV B.Tech. I Sem. & 2015	D	DSP&IP Lab	ECE	59	57	3	94.74	10
27	IV B.Tech. I Sem. & 2015	A	DSP&IP Lab	ECE	64	61	4	93.44	10
28	IV B.Tech. I Sem. & 2015	D	SC	ECE	59	59	5	91.53	10
29	IV B.Tech. I Sem. & 2015	C	SC	ECE	61	61	4	93.44	9
30	M.Tech. I Sem. & 2017	A	MC&I Lab	ES	6	6	0	100.00	10
31	M.Tech. I Sem. & 2017	A	MC&I Lab	ES	6	6	0	100.00	10
32	III B.Tech. II Sem. & 2015	B	MPMC Lab	ECE	60	59	0	100.00	10
33	III B.Tech. II Sem. & 2015	B	DSP	ECE	60	58	5	91.38	10
34	III B.Tech. I Sem. & 2015	C	CS	ECE	62	62	4	93.55	10
35	III B.Tech. II Sem. & 2014	C	MP & MC Lab	EEE	70	69	5	92.75	69
36	M.Tech. II Sem. & 2016	A	NNM Lab	DSCE	1	1	0	100.00	9
37	M.Tech. II Sem. & 2016	A	NN&A	DSCE	1	1	0	100.00	8
38	IV B.Tech. II Sem. & 2013	C	CN	ECE	62	60	8	86.67	71
39	M.Tech. I Sem. & 2016	A	IP Lab	DSCE	1	1	0	100.00	9
40	M.Tech. I Sem. & 2016	A	IVP	DSCE	1	1	0	100.00	7
41	IV B.Tech. I Sem. & 2013	C	DS&IP Lab	ECE	62	60	2	96.67	73
42	III B.Tech. I Sem. & 2014	C	MP &MC	EEE	70	67	19	71.64	78
43	IV B.Tech. I Sem. & 2013	B	DSP	EEE	62	62	7	88.71	91

Copyright © 2021 RGMCET. All rights reserved.

Developed by Suresh Babu J