Satellite Communication

Subject Code : 10EC662	IA Marks : 25
No. of Lecture Hrs/Week : 04	Exam Hours : 03
Total no. of Lecture Hrs. : 52	Exam Marks : 100

PART - A

Unit - 1
Over view of Satellite Systems: Introduction, frequency allocation, INTEL Sat.

3 Hours

Unit - 2
Orbits: Introduction, Kepler laws, definitions, orbital element, apogee and perigee heights, orbit perturbations, inclined orbits, calendars, universal time, sidereal time, orbital plane, local mean time and sun synchronous orbits, Geostationary orbit: Introduction, antenna, look angles, polar mix antenna, limits of visibility, earth eclipse of satellite, sun transit outage, leandiag orbits.

10 Hours

Unit - 3
Propagation impairments and space link: Introduction, atmospheric loss, ionospheric effects, rain attenuation, other impairments.
Space link: Introduction, EIRP, transmission losses, link power budget, system noise, CNR, uplink, down link, effects of rain, combined CNR.

8 Hours

Unit - 4
Space Segment: Introduction, power supply units, altitude control, station keeping, thermal control, TT&C, transponders, antenna subsystem.

6 Hours

PART - B

Unit - 5 & 6
Earth Segement: Introduction, receive only home TV system, out door unit, indoor unit, MATV, CATV, Tx – Rx earth station.

6 Hours

Interference and Satellite access: Introduction, interference between satellite circuits, satellite access, single access, pre-assigned FDMA, SCPC (spade system), TDMA, pre-assigned TDMA, demand assigned TDMA, down link analysis, comparison of uplink power requirements for TDMA & FDMA, on board signal processing satellite switched TDMA.

9 Hours

Unit - 7 & 8

DBS, Satellite mobile and specialized services: Introduction, orbital spacing, power ratio, frequency and polarization, transponder capacity, bit rates for digital TV, satellite mobile services, USAT, RadarSat, GPS, orb communication and iridium.

10 Hours

Text Book:

1. **Satellite Communications**, Dennis Roddy, 4th Edition, McGraw-Hill International edition, 2006.

References books:

1. **Satellite Communications**, Timothy Pratt, Charles Bostian and Jeremy Allnutt, 2nd Edition, John Wiley & Sons, 2003.
2. **Satellite Communication Systems Engineering**, W. L. Pitchand, H. L. Suyderhoud, R. A. Nelson, 2nd Ed., Pearson Education., 2007.

INDEX SHEET

Unit – 1
Over view of Satellite Systems

Introduction, frequency allocation, INTEL Sat.

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1.1 Introduction

Features offered by satellite communications

- Large areas of the earth are visible from the satellite, thus the satellite can form the star point of a communications net linking together many users simultaneously, users who may be widely separated geographically.

- Provide communications links to remote communities.

- Remote sensing detection of pollution, weather conditions, search and rescue operations.

1.2 Frequency allocations

International Telecommunication Union (ITU) coordination and planning World divided into three regions:

Region 1: Europe, Africa, formerly Soviet Union, Mongolia

Region 2: North and South America, Greenland

Region 3: Asia (excluding region 1), Australia, south west Pacific

Within regions, frequency bands are allocated to various satellite services:

- Fixed satellite service (FSS)

  Telephone networks, television signals to cable

- Broadcasting satellite service (BSS)

  Direct broadcast to home Astro is a subscription-based direct broadcast satellite (DBS) or direct-to-home satellite television and radio service in Malaysia and Brunei

- Mobile satellite service

  Land mobile, maritime mobile, aeronautical mobile

- Navigational satellite service

  Global positioning system

- Meteorological satellite service

Frequency band designations in common use for satellite service

TABLE 1.1 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

1.3 Intelsat

- International Telecommunications Satellite
- Created in 1964, now has 140 member countries, >40 investing entities
- Geostationary orbit ----orbits earth`s equitorial plane.
- Atlantic ocean Region (AOR), Indian Ocean Region (IOR), Pacific Ocean Region. education, interactive video and multimedia
- Latest INTELSAT IX satellites wider range of service such as internet, Direct to home TV, telemedicine, tele- education, interactive video and multimedia

Recommended Questions:

1. Explain briefly various services provided by a satellite .
2. What is the frequency bands allocated to various satellite services?

Unit – 2

Orbits

Introduction, Kepler laws, definitions, orbital element, apogee and perigee heights, orbit perturbations, inclined orbits, calendars, universal time, sidereal time, orbital plane, local mean time and sun synchronous orbits, Geostationary orbit: Introduction, antenna, look angles, polar mix antenna, limits of visibility, earth eclipse of satellite, sun transit outage, leandiag orbits.

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2.1 Intoduction

- Johannes Kepler (1571 ±1630) derive empirically three laws describing planetary motion.
- Kepler's laws apply quite generally to any two bodies in space which interact through gravitation.
- The more massive of the two bodies is referred to as the primary, the other, the secondary, or satellite.

2.2 Kepler's first law:

It states that the path followed by a satellite around the primary will be an ellipse. An ellipse has two focal points shown as F1 and F2

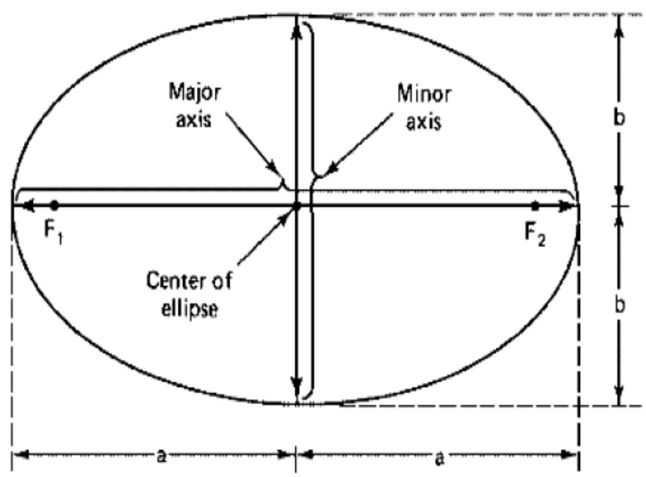

Figure 2.1 The foci F_1 and F_2, the semimajor axis a, and the semiminor axis b of an ellipse.

The center of mass of the two-body system, termed the barycenter, is always centered on one of the foci.

- In our specific case, because of the enormous difference between the masses of the earth and the satellite, the center of mass coincides with the center of the earth, which is therefore always at one of the foci.
- The semimajor axis of the ellipse is denoted by a, and the semiminor axis, by b. The eccentricity e is given by

$$e = \frac{\sqrt{a^2 - b^2}}{a}$$

For an elliptical orbit, 0 < e < 1. When e = 0, the orbit becomes circular.

2.3 Kepler`s Second Law:

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.

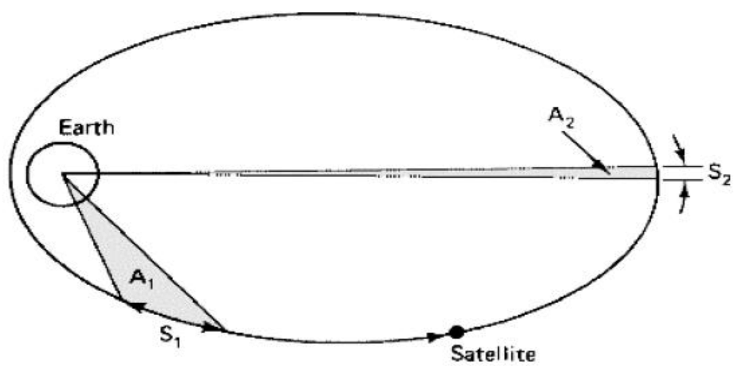

Figure 2.2 Kepler's second law. The areas A_1 and A_2 swept out in unit time are equal.

Thus the farther the satellite from earth, the longer it takes to travel a given distance

2.4 Kepler's Third Law:

It states that the square of the periodic time of orbit is proportional to the cube of the mean distance between the two bodies.

The mean distance is equal to the semimajor axis a.

For the artificial satellites orbiting the earth, Kepler's third law can be written in the form

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

a = semimajor axis (meters)
n = mean motion of the satellite (radians per second)
Q = earth's geocentric gravitational constant. = 3.986005 v 1014 m3/sec2

This equation applies only to ideal situation satellite rbiting a perfectly spherical earth of uniform mass, with no pertubing forces acting, such as atmospheric drag.

Example 2.1:

Calculate the radius of a circular orbit for which the period is 1day.
Solution:
The mean motion, in rad/ day, is

$$n := \frac{2 \cdot \pi}{1 day}$$

Thus, $$n = 7.272 \times 10^{-5} \cdot \frac{rad}{\sec}$$

Also, $$\mu := 3.986005 \times 10^{14} \cdot m^3 \cdot \sec^{-2}$$

Kepler`s 3rd Law gives $$a := \left(\frac{\mu}{n^2} \right)^{1/3}$$

$$a = 42241 km$$

2.5 Definitions of Terms for Earth-Orbiting Satellites

For the particular case of earth-orbiting satellites, certain terms are used to describe the position of the orbit with respect to the earth.

Apogee: The point farthest from earth. Apogee height is shown as ha in Fig. 2.3.

Perigee: The point of closest approach to earth. The perigee height is shown as hp in Fig. 2.3.

Line of apsides: The line joining the perigee and apogee through the center of the earth.

Ascending node: The point where the orbit crosses the equatorial plane going from south to north.

Descending node: The point where the orbit crosses the equatorial plane going from north to south.

Line of nodes: The line joining the ascending and descending nodes through the center of the earth.

Inclination: The angle between the orbital plane and the earth¶s equatorial plane. It is measured at the ascending node from the equator to the orbit, going from east to north. The inclination is shown as i in Fig. 2.3.

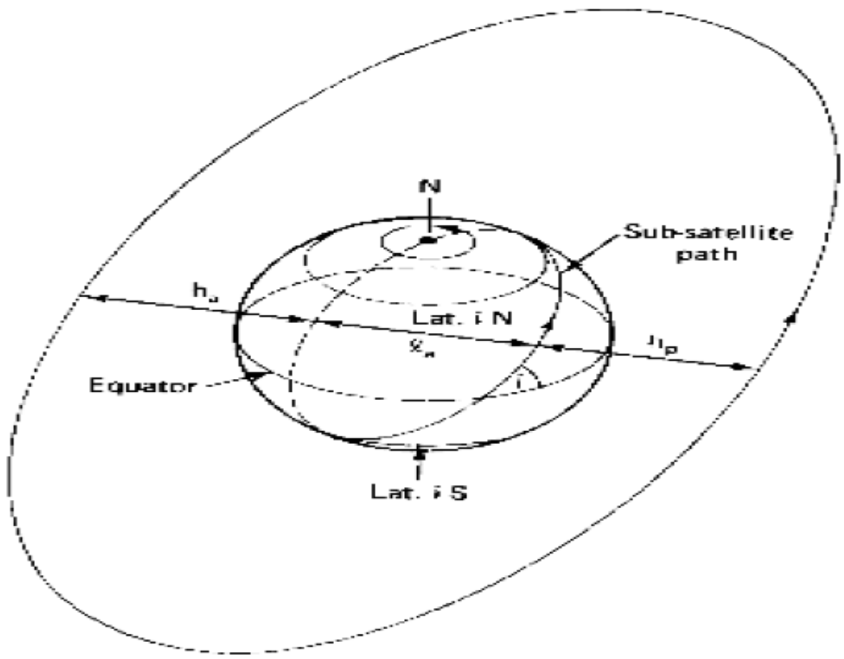

Figure 2.3 Apogee height h_a, perigee height h_p, and inclination i. l_a is the line of apsides.

Prograde orbit: An orbit in which the satellite moves in the same direction as the earth's rotation. Also known as a direct orbit. The inclination of a prograde orbit always lies between 0 and 90°.

Retrograde orbit :An orbit in which the satellite moves in a direction counter to the earth's rotation. The inclination of a retrograde orbit always lies between 90 and 180°.

Argument of perigee :The angle from ascending node to perigee, measured in the orbital plane at the earth's center, in the direction of satellite motion.

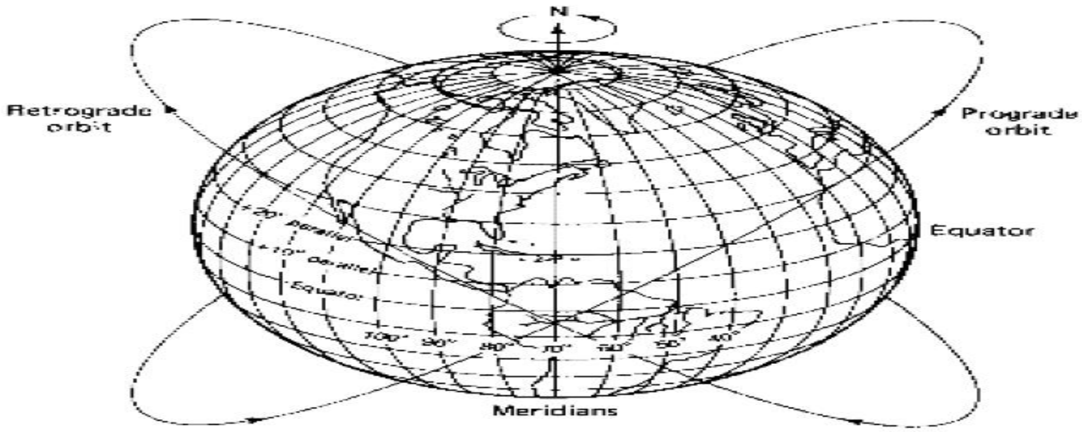

Figure 2.4 Prograde and retrograde orbits.

2.6 Inclined Orbits

A study of the general situation of a satellite in an inclined elliptical orbit is complicated by the
A tropical year contains 365.2422 days. In order to make the calendar year, also referred to as the civil year, more easily usable, it is normally divided into 365 days. The extra 0.2422 of a day is significant and for example, after 100 years, there would be a discrepancy of 24 days between the calendar year .
Fact that different parameters are referred to different reference frames.

The orbital elements are known with reference to the plane of the orbit, the position of which is fixed (or slowly varying) in space, while the location of the earth station is usually given in terms of the local geographic coordinates which rotate with the earth.

Rectangular coordinate systems are generally used in calculations of satellite position and velocity in space, while the earth station quantities of interest may be the azimuth and elevation angles and range.
Transformations between coordinate systems are therefore required.

Determination of the look angles and range involves the following quantities and concepts:

1. The orbital elements, as published in the NASA bulletins and described in Sec. 2.6

2. Various measures of time

3. The perifocal coordinate system, which is based on the orbital plane

4. The geocentric-equatorial coordinate system, which is based on the earth's equatorial plane
5. The topocentric-horizon coordinate system, which is based on the observer's horizon plane

The two major coordinate transformations needed are:

- The satellite position measured in the perifocal system is transformed to the geocentric-horizon system in which the earth¶s rotation is measured, thus enabling the satellite position and the earth station location to be coordinated.

- The satellite-to-earth station position vector is transformed to the topocentric-horizon system, which enables the look angles and range to be calculated

2.7 Calendars

The mean sun does move at a uniform speed but otherwise requires the same time as the real sun to complete one orbit of the earth, this time being the tropical year. A day measured relative to this mean sun is termed a mean solar day. Calendar days are mean solar days, and generally they are just referred to as days.

A tropical year contains 365.2422 days. In order to make the calendar year, also referred to as the civil year, more easily usable, it is normally divided into 365 days. The extra 0.2422 of a day is significant and for example, after 100 years, there would be a discrepancy of 24 days between the calendar year and the tropical year.

Julius Caesar made the first attempt to correct for the discrepancy by introducing the leap year, in which an extra day is added to February whenever the year number is divisible by four. This gave the Julian calendar, in which the civil year was 365.25 days on average, a reasonable approximation to the tropical year.

By the year 1582, an appreciable discrepancy once again existed between the civil and tropical years. Pope Gregory XIII took matters in hand by abolishing the days October 5 through October 14, 1582, to bring the civil and tropical years into line and by placing an additional constraint on the leap year in that years ending in two zeros must be divisible by 400 to be reckoned as leap years.

This dodge was used to miss out Gregorian calendar 3 days every 400 years. The resulting calendar is the, which is the one in use today.

2.8 Universal Time

Universal time coordinated (UTC) is the time used for all civil timekeeping purposes, and as a standard for setting clocks.

The fundamental unit for UTC is the mean solar day.

The mean solar day is divided into 24 hours, an hour into 60 minutes, and a minute into 60 seconds.

Thus there are 86,400 ³clock seconds´ in a mean solar day.

Satellite-orbit epoch time is given in terms of UTC. Universal time coordinated is equivalent to Greenwich mean time (GMT), as well as Zulu (Z) time.

Distinction between system is not critical, the term universal time (UT) will be used.
Given UT in the normal form of hours, minutes, and seconds, it is converted to fractional days as

$$UT_{day} = \frac{1}{24}\left(hours + \frac{minutes}{24} + \frac{seconds}{3600}\right)$$

This is converted to degrees as

$$UT^{o} = 360 \times UT_{day}$$

2.9 Sidereal time

Sidereal time is time measured relative to the fixed stars. It will be seen that one complete rotation of the earth relative to the fixed stars is not a complete rotation relative to the sun.

2.10 The orbital Plane

In the orbital plane, the position vector r and the velocity vector v specify the motion of the satellite

2.11 The Geostationary Orbit

A satellite in a geostationary orbit appears to be stationary with respect to the earth.

Three conditions are required for an orbit to be geostationary:

1. The satellite must travel eastward at the same rotational speed as the earth.
    a. If the satellite is to appear stationary it must rotate at the same speed as the earth, which is constant
2. The orbit must be circular.
    a. Constant speed means that equal areas must be swept out in equal times, and this can only occur with a circular orbit
3. The inclination of the orbit must be zero.
    any inclination would have the satellite moving north and south, and hence it would not be geostationary. Movement north and south can be avoided only with zero inclination

2.12 Antenna Look Angles

The look angles for the ground station antenna are the azimuth and elevation angles required at the antenna so that it points directly at the satellite.

The three pieces of information that are needed to determine the look angles for the geostationary orbit are

1. The earth station latitude, denoted here by PE
2. The earth station longitude, denoted here by JE
3. The longitude of the subsatellite point, denoted here by JSS (often referred to as the satellite longitude)

2.13 Polar Mount Antenna

Polar mount is a piece of equipment installed into geostationary satellites to be accessed by swinging the satellite dish around one axis. This allows one positioned only to be used to remotely point the antenna at any satellite.

2.14 Limits of Visibility

There will be east and west limits on the geostationary arc visible from any given earth station. The limits will be set by the geographic coordinates of the earth station and the antenna elevation. The lowest elevation in theory is zero, when the antenna is pointing along the horizontal.

Recommended Questions

1. State Keplers laws of elementary motion, with the help of a neat diagram and give necessary equations.
2. Deine apogee and perigee.
3. Define the terms (a) Prograde orbit (b) Apogee (c) Argument of perigee)d) Ascending node.
4. An earth station is located at latitude 30 degree S and longitude 65degree E. Calculate the antenna look qngles for satellite at 156 degree E.
5. Explain briefly launching orbit, close to the geosynchronous attitude. Its orbitalperiod is exactly 24 hours one solar day. Calculate
   (a) The radius of the earth.
   (b) The rate of drift around the equator of the subsatellite point in degree/solar day. An observer on the earth sees that the satellite is drifting across the sky.
   (c) Is the satellite moving towards east or west

Unit – 3
Propagation impairments and space link

Introduction, atmospheric loss, ionospheric effects, rain attenuation, other impairments.

Space link

Introduction, EIRP, transmission losses, link power budget, system noise, CNR, uplink, down link, effects of rain, combined CNR.

8 Hours

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3.1 Introduction

A signal traveling between an earth station and a satellite must pass through the earth's atmosphere, including the ionosphere.

3.2 Atmospheric Losses

Losses occur in the earth's atmosphere as a result of energy absorption by the atmospheric gases. These losses are treated quite separately from those which result from adverse weather conditions, which of course are also atmospheric losses. To distinguish between these, the weather-related losses are referred to as atmospheric attenuation and the absorption losses simply as atmospheric absorption.

3.3 Ionospheric Effects

Radio waves traveling between satellites and earth stations must pass through the ionosphere. The ionosphere has been ionized, mainly by solar radiation. The free electrons in the ionosphere are not uniformly distributed but form in layers. Clouds of electrons may travel through the ionosphere and give rise to fluctuations in the signal.
The effects include scintillation, absorption, variation in the direction of arrival, propagation delay, dispersion, frequency change, and polarization rotation.

Ionospheric scintillations:

- Are variations in the amplitude, phase, polarization, or angle of arrival of radio waves.
- Caused by irregularities in the ionosphere which changes with time.
- Effect of scintillations is fading of the signal. Severe fades may last up to several minutes.

Polarization rotation:

- porduce rotation of the polarization of a signal (Faraday rotation)
- When linearly polarized wave traverses in the ionosphere, free electrons in the ionosphere are sets in motion a force is experienced, which shift the polarization of the wave.
- Inversely proportional to frequency squared.
- Not a problem for frequencies above 10 GHz.

3.4 Rain Attenuation

Rain attenuation is a function of rain rate.

Rain rate, Rp = the rate at which rainwater would accumulate in a rain gauge situated at the ground in the region of interest (e. g., at an earth station). The rain rate is measured in millimeters per hour.

Of interest is the percentage of time that specified values are exceeded. The time percentage is usually that of a year; for example, a rain rate of 0.001 percent means that the rain rate would be exceeded for 0.001 percent of a year, or about 5.3 min during any one year.

3.5 Introduction

This chapter describes how the link-power budget calculations are made. These calculations basically relate two quantities, the transmit power and the receive power, and show in detail how the difference between these two powers is accounted for.

3.6 Equivalent Isotropic Radiated Power

A key parameter in link budget calculations is the equivalent isotropic radiated power, conventionally denoted as EIRP. The Maximum power flux density at some distance r
from a transmitting antenna of gain G is

$$\psi_M = \frac{GP_S}{4\pi r^2}$$

An isotropic radiator with an input power equal to GPS would produce the same flux density. Hence this product is referred to as the equivalent isotropic radiated power, or

$$EIRP = GP_S$$

EIRP is often expressed in decibels relative to one watt, or dBW. Let PS be in watts; then

$$[EIRP] = [P_S] + [G]\ dBW$$

where [PS] is also in dBW and [G] is in dB.

The isotropic gain for a paraboloidal antenna is

$$G = \eta(10.472 fD)^2$$

Where,

f is the carrier frequency
D is the reflector diameter
n is the aperture efficiency

3.7 Transmisssion losses

The [EIRP] is the power input to one end of the transmission link, and the problem is to find the power received at the other end.

Losses will occur along the way, some of which are constant. Other losses can only be estimated from statistical data, and some of these are dependent on weather conditions, especially on rainfall.

The first step in the calculations is to determine the losses for clear weather, or clear-sky, conditions. These calculations take into account the losses, including those calculated on a statistical basis, which do not vary significantly with time. Losses which are weather-related, and other losses which fluctuate with time, are then allowed for by introducing appropriate fade margins into the transmission equation.

3.8 The Link-Power Budget Estimation

Losses for clear sky conditions are

$$[LOSSES] = [FSL] + [RFL] + [AML] + [AA] + [PL]$$

The decibel equation for the received power is

$$[P_R] = [EIRP] + [G_R] - [LOSSES]$$

where

[PR] = received power, dBW
[EIRP] = equivalent isotropic radiated power, dBW

[FSL] = free-space spreading loss, dB
[RFL] = receiver feeder loss, dB
[AML] = antenna misalignment loss, dB
[AA] = atmospheric absorption loss, dB
[PL] = polarization mismatch loss, dB

3.9 System Noise

The major source of electrical noise in equipment is from the random thermal motion of electrons in various resistive and active devices in the receiver.

Thermal noise is also generated in the lossy components of antennas, and thermal-like noise is picked up by the antennas as radiation.

The available noise power from a thermal noise source is given by

$$P_N = kT_N B_N$$

Where

T_N = equivalent noise temperature (K)

B_N = equivalent noise bandwidth (Hz)

k = 1.38×10^{-23} (Boltzmann's constant)

For thermal noise, noise power per unit bandwidth, N0, is constant (a.k.a noise energy)

$$N_0 = \frac{P_N}{B_N} = kT_N \ joules$$

In addition to thermal noise, intermodulation distortion in high-power amplifiers result in signal products which appear as noise, that is intermodulation noise.

3.10 Carrier-to-Noise Ratio

A measure of the performance of a satellite link is the ratio of carrier power to noise power at the receiver input.

Conventionally, the ratio is denoted by C/ N (or CNR), which is equivalent to PR/PN.
In terms of decibels,

$$\left[\frac{C}{N}\right] = [P_R] - [P_N]$$

Equations (12.17) and (12.18) may be used for [PR] and [PN], resulting in

$$\left[\frac{C}{N}\right] = [EIRP] + [G_R] - [LOSSES] - [k] - [T_S] - [B_N]$$

The G/ T ratio is a key parameter in specifying the receiving system performance

$$\left[\frac{G}{T}\right] = [G_R] - [T_S]\, dBK^{-1}$$

Since $P_N = kT_N B_N = N_o B_N$, then

$$\left[\frac{C}{N}\right] = \left[\frac{C}{N_o B_N}\right]$$

$$= \left[\frac{C}{N_o}\right] - [B_N]$$

therefore

$$\left[\frac{C}{N_o}\right] = \left[\frac{C}{N}\right] + [B_N]$$

The final expresion is

$$\left[\frac{C}{N_0}\right] = [EIRP] + \left[\frac{G}{T}\right] - [LOSSES] - [k]\ dBHz \quad \text{---(1)}$$

3.11 The Uplink

The uplink earth station is transmitting the signal and the satellite is receiving it. Equation (1) can be applied to the uplink, but with subscript U denotes that the uplink is being considered.

$$\left[\frac{C}{N_0}\right]_U = [EIRP]_U + \left[\frac{G}{T}\right]_U - [LOSSES]_U - [k] \quad \text{--(2)}$$

Eq (2) contains: the earth station EIRP, the satellite receiver feeder losses, and satellite receiver G/T. The freespace loss and other losses which are frequency-dependent are calculated for the uplink frequency. The resulting carrier-to-noise density ratio given by Eq. (2) is that which appears at the satellite receiver.

3.12 Downlink

The downlink the satellite is transmitting the signal and the earth station is receiving it. Equation (1) can be applied to the downlink, but with subscript D to denote that the downlink is being considered.

$$\left[\frac{C}{N_0}\right]_D = [EIRP]_D + \left[\frac{G}{T}\right]_D - [LOSSES]_D - [k] \quad \text{--(3)}$$

Eq. (3) contains: the satellite EIRP, the earth station receiver feeder losses, and the earth station

receiver G/T. The free-space and other losses are calculated for the downlink frequency.
The resulting carrier-to-noise density ratio given by Eq. (3) is that which appears at the detector of the earth station receiver.

Where the carrier-to-noise ratio is the specified quantity rather than carrier-to-noise density ratio, Eq. (1) is used. On assuming that the signal bandwidth B is equal to the noise bandwidth BN, we obtain:

$$\left[\frac{C}{N}\right]_D = [EIRP]_D + \left[\frac{G}{T}\right]_D - [LOSSES]_D - [k] - [B] \quad \text{--(4)}$$

3.13 Combined Uplink and Downlink C/N Ratio

The complete satellite circuit consists of an uplink and a downlink, as sketched in Fig.3.1

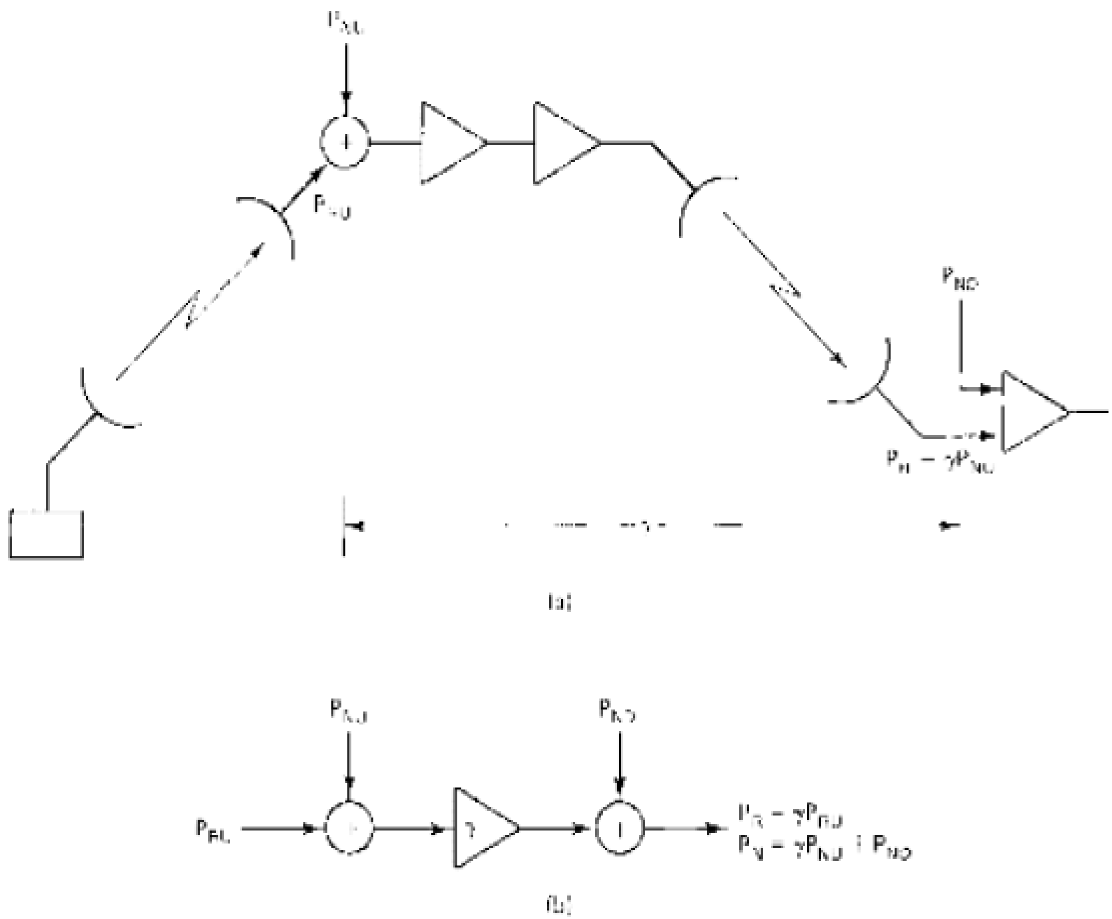


Fig 3.1 (a) combined uplink and downlink

(b) power flow diagram

Noise will be introduced on the uplink at the satellite receiver input.

PNU = noise power per unit bandwidth
PRU = average carrier at the same point
The carrier-to-noise ratio on the uplink is

$$(C/\ N_o)_U = (P_{RU}/P_{NU}).$$

Note that power levels, and not decibels, are being used.

PR = carrier power at the end of the space link
= the received carrier power for the downlink.
= K x the carrier power input at the satellite
Where
K = the system power gain from satellite input to earth station input. This includes the satellite transponder and transmit antenna gains, the downlink losses, and the earth station receive antenna gain and feeder losses.

The noise at the satellite input also appears at the earth station input multiplied by K, and in addition, the earth station introduces its own noise, denoted by PND. Thus the end-of-link noise is KPNU + PND.

The C/No ratio for the downlink alone, not counting the KPNU contribution, is PR/PND, and the combined C/No ratio at the ground receiver is PR/(KPNU + PND). The power flow diagram is shown in Fig. 3.1 b.

The combined carrier-to-noise ratio can be determined in terms of the individual link values. To show this, it is more convenient to work with the noise-to-carrier ratios rather than the carrier-to-noise ratios, and these must be expressed as power ratios, not decibels.

Denoting the combined noise-to-carrier ratio value by No/C, the uplink value by (No/C)U, and the downlink value by (No/C)D then,

$$\frac{N_o}{C} = \frac{P_N}{P_R}$$

$$= \frac{\gamma P_{NU} + P_{ND}}{P_R}$$

$$= \frac{\gamma P_{NU}}{P_R} + \frac{P_{ND}}{P_R}$$

$$= \frac{\gamma P_{NU}}{} + \frac{P_{ND}}{P_R}$$

$$= \left(\frac{N_o}{C}\right)_U + \left(\frac{N_o}{C}\right)_D \qquad \text{--(4)}$$

Equation (4) shows that to obtain the combined value of C/N0, the reciprocals of the individual values must be added to obtain the N0/C ratio and then the reciprocal of this taken to get C/N0. The reason for this reciprocal of the sum of the reciprocals method is that a single signal power is being transferred through the system, while the various noise powers which are present are additive.

Similar reasoning applies to the carrier-to-noise ratio, C/ N.

Recommended Questions:

1. The noised figure for a system is 12dB, the cable loss is 5dB, the LNA gain is 50d and its noise temperature is 150 K. The antenna noise temperature is 35 K. calculate the noise temperature reffered to the input.
2. Explain combined uplink and downlink C/N ratio.
3. Explain the different transmission losses in a satellite link
4. Define saturation flux density. Obtain the equation for saturation EIRP for uplink

Unit – 4
Space Segment

Introduction, power supply units, altitude control, station keeping, thermal control, TT&C, transponders, antenna subsystem.

6 Hours

Text Book:

1. **Satellite Communications**, Dennis Roddy, 4th Edition, McGraw-Hill International edition, 2006.

References books:

1. **Satellite Communications**, Timothy Pratt, Charles Bostian and Jeremy Allnutt, 2nd Edition, John Wiley & Sons, 2003.
2. **Satellite Communication Systems Engineering**, W. L. Pitchand, H. L. Suyderhoud, R. A. Nelson, 2nd Ed., Pearson Education., 2007.

4.1 Introduction

A satellite communications system can be broadly divided into two segments, a ground segment and a space segment. The space segment will obviously include the satellites, but it also includes the ground facilities needed to keep the satellites operational, these being referred to as the tracking, telemetry, and command (TT&C) facilities. In many networks it is common practice to employ a ground station solely for the purpose of TT&C.

The equipment carried aboard the satellite also can be classified according to function. The payload refers to the equipment used to provide the service for which the satellite has been launched. The bus refers not only to the vehicle which carries the payload but also to the various subsystems which provide the power, attitude control, orbital control, thermal control, and command and telemetry functions required to service the payload.

In a communications satellite, the equipment which provides the connecting link between the satellite's transmit and receive antennas is referred to as the transponder. The transponder forms one of the main sections of the payload, the other being the antenna subsystems.

4.2 The Power Supply

The primary electrical power for operating the electronic equipment is obtained from solar cells. Individual cells can generate only small amounts of power, and therefore, arrays of cells in series-parallel connection are required.

For the HS376 satellite manufactured by Hughes Space and Communications Company. The spacecraft is 216 cm in diameter and 660 cm long when fully deployed in orbit. During the launch sequence, the outer cylinder is telescoped over the inner one, to reduce the overall length. Only the outer panel generates electrical power during this phase. In geostationary orbit the telescoped panel is fully extended so that both are exposed to sunlight. At the beginning of life, the panels produce 940 W dc power, which may drop to 760 W at the end of 10 years. During eclipse, power is provided by two nickel-cadmium long-life batteries, which will deliver 830 W. At the end of life, battery recharge time is less than 16 h.

4.3 Attitude Control

The attitude of a satellite refers to its orientation in space. Much of the equipment carried aboard a satellite is there for the purpose of controlling its attitude. Attitude control is necessary. To exercise attitude control, there must be available some measure of a satellite's orientation in space and of any tendency for this to shift. In one method, infrared sensors, referred to as horizon detectors, are used to detect the rim of the earth against the background of space. With the use of four such sensors, one for each quadrant, the center of the earth can be readily established as a reference point. Any shift in orientation is detected by one or other of the sensors, and a corresponding control signal is generated which activates a restoring torque. Usually, the attitude-control process takes place aboard the satellite, but it is also possible for control signals to be transmitted from earth, based on attitude data obtained from the satellite. Also, where a shift in attitude is desired, an attitude maneuver is executed. The control signals needed to achieve this maneuver may be transmitted from an earth station.

4.4 Station Keeping

In addition to having its attitude controlled, it is important that a geostationary satellite be kept in its correct orbital slot. The equatorial ellipticity of the earth causes geostationary satellites to drift slowly along the orbit, to one of two stable points, at 75°E and 105°W. To counter this drift, an oppositely directed velocity component is imparted to the satellite by means of jets, which are pulsed once every 2 or 3 weeks. This results in the satellite drifting back through its nominal station position, coming to a stop, and recommencing the drift along the orbit until the jets are pulsed once again.

These maneuvers are termed east-west station-keeping maneuvers. Satellites in the 6/4-GHz band must be kept within ±0.1° of the designnated longitude, and in the 14/12-GHz band, within ±0.05°. A satellite which is nominally geostationary also will drift in latitude, the main perturbing forces being the gravitational pull of the sun and the moon. These forces cause the inclination to change at a rate of about 0.85°/year. If left uncorrected, the drift would result in a cyclic change in the inclination, going from 0 to 14.67° in 26.6 years (Spilker, 1977) and back to zero, at which the cycle is repeated. To prevent the shift in inclination from exceeding specified limits, jets may be pulsed at the appropriate time to return the inclination to zero. Counteracting jets must be pulsed when the inclination is at zero to halt the change in inclination. These maneuvers are termed north-south station-keeping maneuvers, and they are much more expensive in fuel than are east-west station-keeping maneuvers. The north-south station-keeping tolerances are the same as those for east-west station keeping, ±0.1° in the C band and ±0.05° in the Ku band.

4.5 Thermal Control

Satellites are subject to large thermal gradients, receiving the sun’s radiation on one side while the other side faces into space. In addition, thermal radiation from the earth and the earth’s albedo, which is the fraction of the radiation falling on earth which is reflected, can be significant for low-altitude earth-orbiting satellites, although it is negligible for geostationary satellites. Equipment in the satellite also generates heat which has to be removed. The most important consideration is that the satellite’s equipment should operate as nearly as possible in a stable temperature environment. often used to remove heat from the communications payload In order to maintain constant temperature conditions, heaters may be switched on (usually on command from ground) to make up for the heat reduction which occurs when transponders are switched off. In INTELSAT VI, heaters are used to maintain propulsion thrusters and line temperatures (Pilcher, 1982).

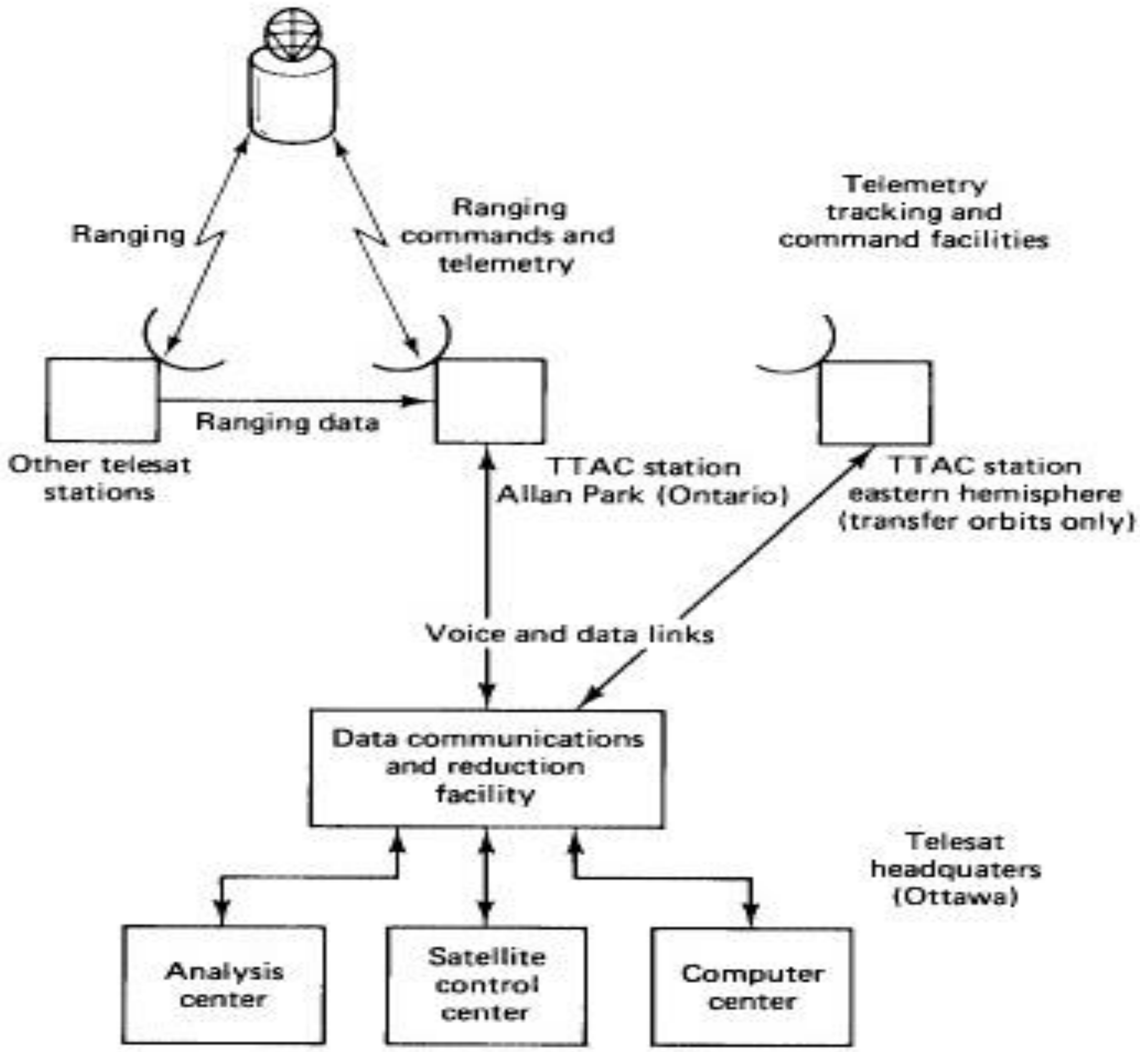
4.6 TT&C Subsystem

The telemetry, tracking, and command subsystem performs several routine functions aboard the spacecraft. The telemetry, or telemetering, function could be interpreted as measurement at a distance. Specifically, it refers to the overall operation of generating an electrical signal proportional to the quantity being measured and encoding and transmitting this to a distant station, which for the satellite is one of the earth stations. Data which are transmitted as telemetry signals include attitude information such as that obtained from sun and earth sensors; environmental information such as the magnetic field intensity and direction, the frequency of meteorite impact, and so on; and spacecraft information such as temperatures, power supply voltages, and stored-fuel pressure. Certain frequencies have been designated by international agreement for satellite telemetry trans missions. During the transfer and drift orbital phases of the satellite launch, a special channel is used along with an omnidirectional antenna. Once the satellite is on station, one of the normal communications transponders may be used along with its directional antenna, unless some emergency arises which makes it necessary to switch back to the special channel used during the transfer orbit.

Telemetry and command may be thought of as complementary functions. The telemetry subsystem transmits information about the satellite to the earth station, while the command subsystem receives command signals from the earth station, often in response to telemetered information. The command subsystem demodulates and, if necessary, decodes the command signals and routes these to the appropriate equipment needed to execute the necessary action. Thus attitude changes may be made, communication transponders switched in and out of circuits, antennas redirected, and station keeping maneuvers carried out on command. It is clearly important to prevent unauthorized commands from being received and decoded, and for this reason, the command signals are often encrypted. Encrypt is derived from a Greek word kryptein, meaning to hide, and represents the process of concealing the command signals in a secure code. This differs from the normal process of encoding, which is one of converting characters in the command signal into a code suitable for transmission. Tracking of the satellite is accomplished by having the satellite transmit beacon signals which are received at the TT&C earth stations. Tracking is obviously important during the transfer and drift orbital phases of the satellite launch. Once it is on station, the position of a geostationary satellite will tend to be shifted as a result of the various disturbing forces, as described previously. Therefore, it is necessary to be able to track the satellite's movement and send correction signals as required. Tracking beacons may be transmitted in the telemetry channel, or by pilot carriers at frequencies in one of the main communications channels, or by special tracking antennas. Satellite range from the ground station is also required from time to time. This can be determined by measurement of the propagation delay of signals especially transmitted for ranging purposes.

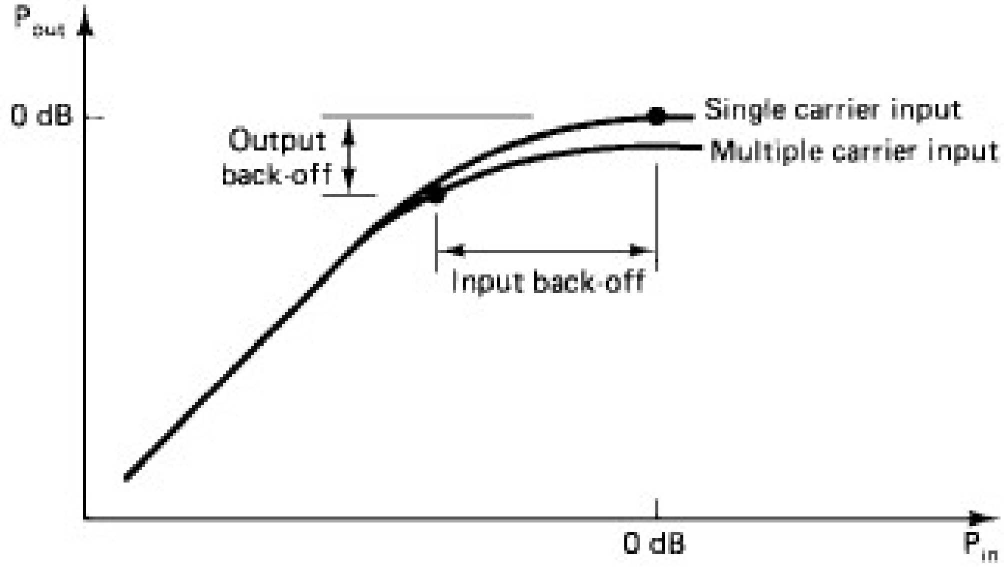
4.7 Transponders

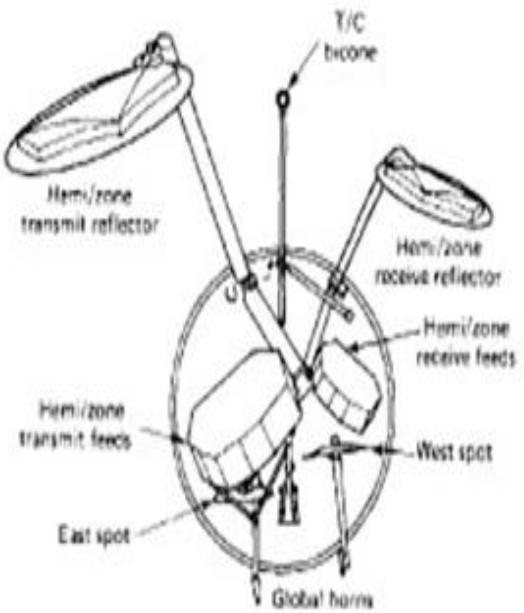
A transponder is the series of interconnected units which forms a single communications channel between the receive and transmit antennas in a communications satellite. Some of the units utilized by a transponder in a given channel may be common to a number of transponders. Thus, although reference may be made to a specific transponder, this must be thought of as an equipment channel rather than a single item of equipment.

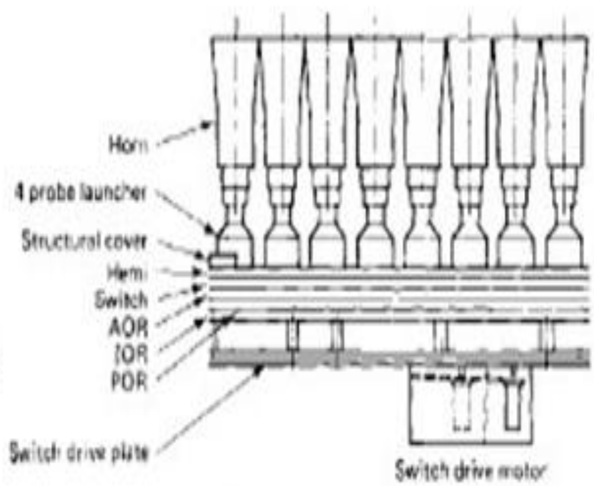


4.8 The Antenna Subsystem

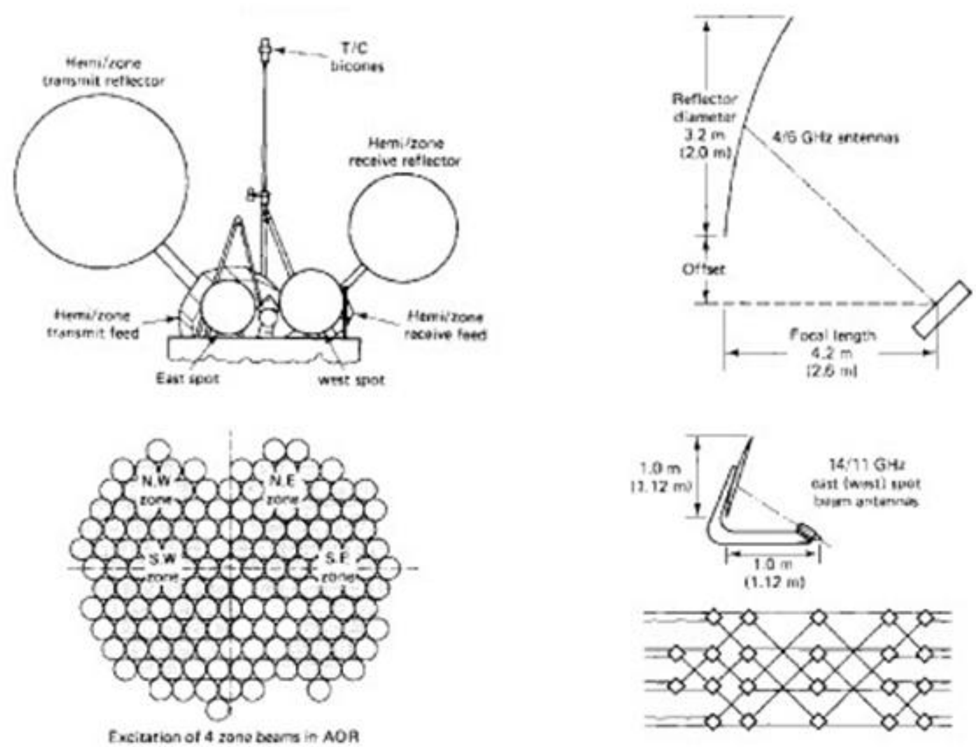
The antennas carried aboard a satellite provide the dual functions of receiving the uplink and transmitting the downlink signals. They range from dipole-type antennas where omnidirectional characteristics are required to the highly directional antennas required for telecommunications purposes and TV relay and broadcast. Directional beams are usually produced by means of reflector-type antennas, the paraboloidal reflector being the most common.







Section through part of the feed array



Recommended Questions:

1. Explain (a) the power supply subsystem (b) thermal control subsystem
2. With a neat diagram explain satellite altitude Explain 3 axis methods of satellite stabilization
3. What is meant by satellite reuse? Briefly describe the working of a wide band receiver

Unit - 5 & 6
Earth Segment

Introduction, receive only home TV system, out door unit, indoor unit, MATV, CATV, Tx – Rx earth station.

6 Hours

Interference and Satellite access

Introduction, interference between satellite circuits, satellite access, single access, pre-assigned FDMA, SCPC (spade system), TDMA, pre-assigned TDMA, demand assigned TDMA, down link analysis, comparison of uplink power requirements for TDMA & FDMA, on board signal processing satellite switched TDMA.

9 Hours

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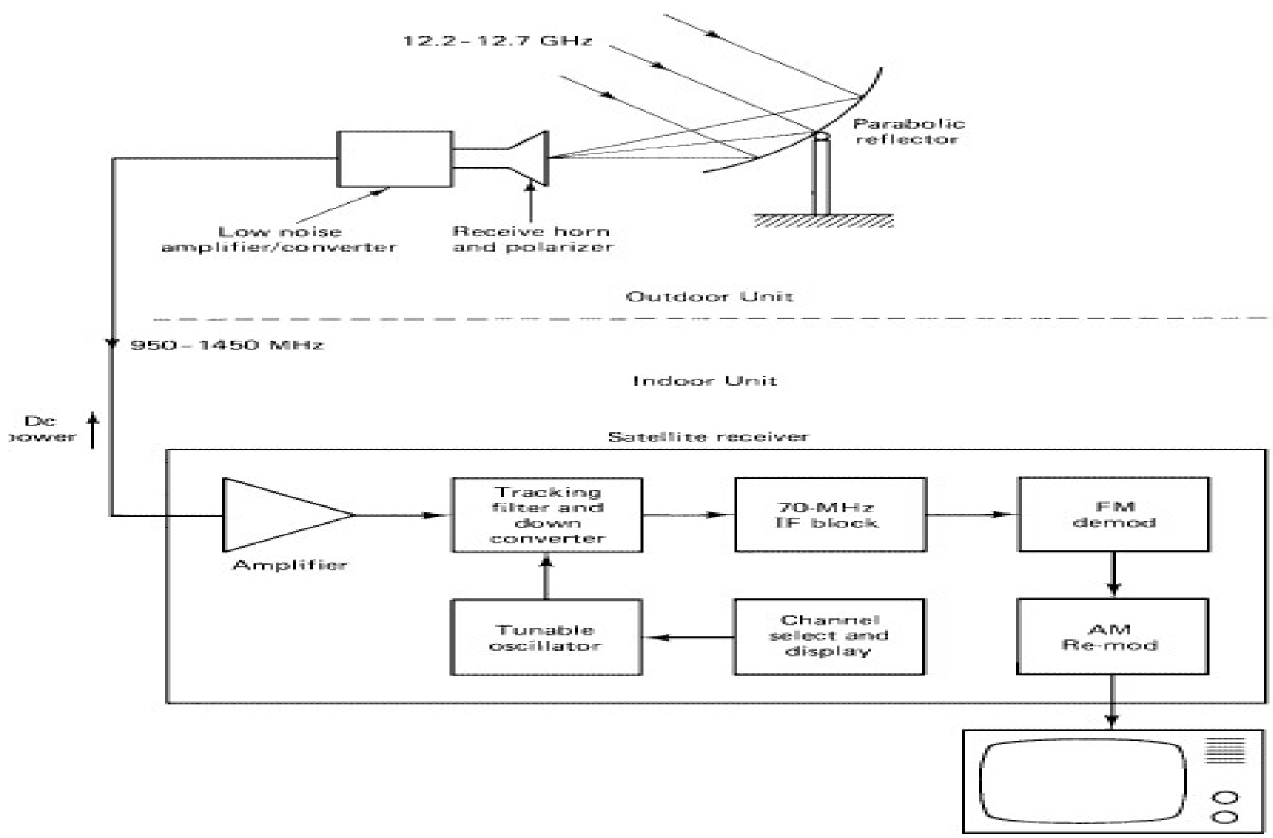
5.1 Introduction

The earth segment of a satellite communications system consists of the transmit and receive earth stations. The simplest of these are the home TV receive-only (TVRO) systems, and the most complex are the terminal stations used for international communications networks. Also included in the earth segment are those stations which are on ships at sea, and commercial and military land and aeronautical mobile stations.

5.2 Receive-Only Home TV Systems

Planned broadcasting directly to home TV receivers takes place in the Ku (12-GHz) band. This service is known as direct broadcast satellite (DBS) service. There is some variation in the frequency bands assigned to different geographic regions. The comparatively large satellite receiving dishes (about 3-m diameter) which are a familiar sight around many homes are used to receive downlink TV signals at C band (4 GHz). Such downlink signals were never intended for home reception but for network relay to commercial TV outlets (VHF and UHF TV broadcast stations and cable TV "head end" studios). Although the practice of intercepting these signals seems to be well established at present, various technical and commercial and legal factors are combining to deter their direct reception. The major differences between the Ku-band and the C-band receive-only systems lies in the frequency of operation of the outdoor unit and the fact that satellites intended for DBS have much higher EIRP.



5.3The outdoor unit

This consists of a low noise amplifer/converter combination. A parabolic reflector is used along with horn mounted at focus.

The downlink frequency band of 12.2 to 12.7 GHz spans a range of 500 MHz, which accommodates 32 TV/FM channels, each of which is 24 MHz wide. Obviously, some overlap occurs between channels, but these are alternately polarized left-hand circular (LHC) and right-hand circular (RHC) or vertical/horizontal, to reduce interference to acceptable levels. This is referred to as polarization interleaving. A polarizer that may be switched to the desired polarization from the indoor control unit is required at the receiving horn. The receiving horn feeds into a low-noise converter (LNC) or possibly a combination unit consisting of a low-noise amplifier (LNA) followed by a converter. The combination is referred to as an LNB, for low-noise block. The LNB provides gain for the broadband 12-GHz signal and then converts the signal to a lower frequency range so that a low-cost coaxial cable can be used as feeder to the indoor unit. The standard frequency range of this downconverted signal is 950 to 1450 MHz. The coaxial cable, or an auxiliary wire pair, is used to carry dc power to the outdoor unit. Polarization-switching control wires are also required.

The low-noise amplification must be provided at the cable input in order to maintain a satisfactory signal-to-noise ratio. A low-noise amplifier at the indoor end of the cable would be of little use, because it would also amplify the cable thermal noise. Of course, having to mount the LNB outside means that it must be able to operate over a wide range of climatic conditions, and homeowners may have to contend with the added problems of vandalism and theft.

5.4 The indoor unit for analog (FM) TV

The signal fed to the indoor unit is normally a wideband signal covering the range 950 to 1450 MHz. This is amplified and passed to a tracking filter which selects the desired channel. As previously mentioned, polarization interleaving is used, and only half the 32 channels will be present at the input of the indoor unit for any one setting of the antenna polarizer. This eases the job of the tracking filter, since alternate channels are well separated in frequency.
The selected channel is again downconverted, this time from the 950- to 1450-MHz range to a fixed intermediate frequency, usually 70 MHz although other values in the VHF range are also used. The 70-MHz amplifier amplifies the signal up to the levels required for demodulation. A major difference between DBS TV and conventional TV is that with DBS, frequency modulation is used, whereas with conventional TV, amplitude modulation in the form of vestigial single sideband (VSSB) is used. The 70-MHz, frequency-modulated IF carrier therefore must be demodulated, and the baseband information used to generate a VSSB signal which is fed into one of the VHF/UHF channels of a standard TV set.

5.5 Master Antenna TV System

A master antenna TV (MATV) system is used to provide reception of DBS TV/FM channels to a small group of users, for example, to the tenants in an apartment building. It consists of a single outdoor unit (antenna and LNA/C) feeding a number of indoor units. It is basically similar to the home system already described, but with each user having access to all the channels independently of the other users. The advantage is that only one outdoor unit is required, but as shown, separate LNA/Cs and feeder cables are required for each sense of polarization. Compared with the single-user system, a larger antenna is also required (2- to 3-m diameter) in order to maintain a good signal-to-noise ratio at all the indoor units.

Where more than a few subscribers are involved, the distribution system used is similar to the CATV system described in the next section.

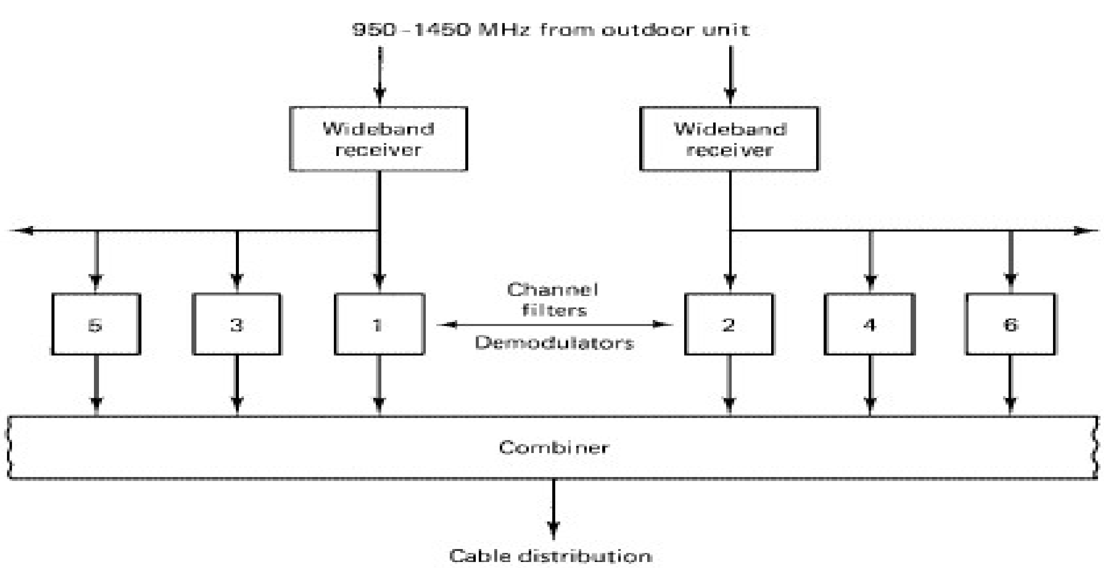
5.6 Community Antenna TV System

The community antenna TV system employs a single outdoor unit, with separate feeds available for each sense of polarization, like the MATV system, so that all channels are made available simultaneously at the indoor receiver. Instead of having a separate receiver for each user, all the carriers are demodulated in a common receiver-filter system. The channels are then combined into a standard multiplexed signal for transmission over cable to the subscribers.

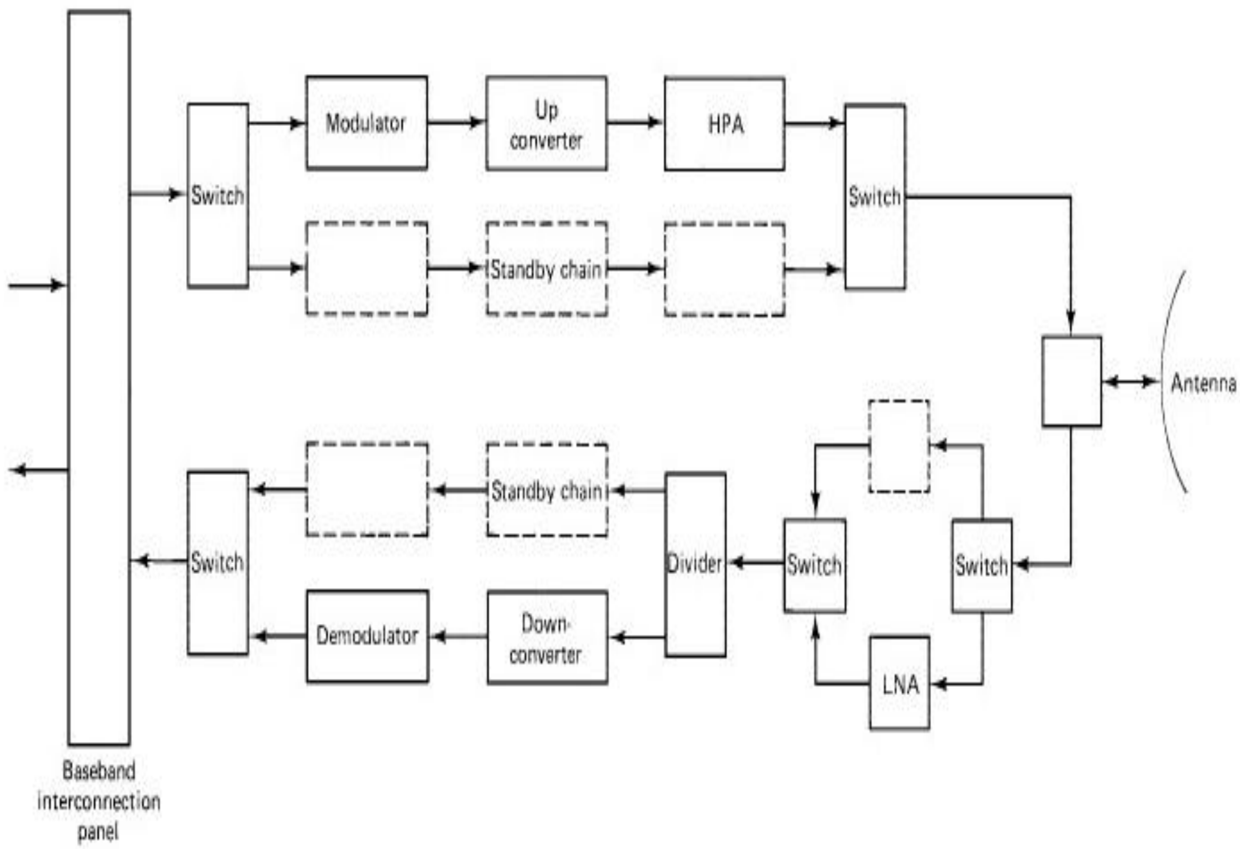
In remote areas where a cable distribution system may not be installed, the signal can be rebroadcast from a low-power VHF TV transmitter.

With the CATV system, local programming material also may be distributed to subscribers, an option which is not permitted in the MATV system.

5.7 Transmit-Receive Earth Stations



In some situations, a transmit-only station is required,for example, in relaying TV signals to the remote TV receive-only stations already described. Transmit-receive stations provide both functions and are required for telecommunications traffic generally, including network TV.



It may be that groupings different from those used in the terrestrial network are required for satellite transmission, and the next block shows the multiplexing equipment in which the reformatting is carried out. Following along the transmit chain, the multiplexed signal is modulated onto a carrier wave at an intermediate frequency, usually 70 MHz. Parallel IF stages are required, one for each microwave carrier to be transmitted. After amplification at the 70-MHz IF, the modulated signal is then upconverted to the required microwave carrier frequency. A number of carriers may be transmitted simultaneously, and although these are at different frequencies they are generally specified by their nominal frequency, for example, as 6-GHz or 14-GHz carriers.

It should be noted that the individual carriers may be multi destination carriers. This means that they carry traffic destined for different stations. For example, as part of its load, a microwave

carrier may have telephone traffic for Boston and New York. The same carrier is received at both places, and the designated traffic sorted out by filters at the receiving earth station.
The station's antenna functions in both the transmit and receive modes, but at different frequencies. In the C band, the nominal uplink, or transmit, frequency is 6 GHz and the downlink, or receive, frequency is nominally 4 GHz. In the Ku band, the uplink frequency is nominally 14 GHz, and the downlink, 12 GHz. High-gain antennas are employed in both bands, which also means narrow antenna beams. A narrow beam is necessary to prevent interference between neighboring satellite links. In the case of C band, interference to and from terrestrial microwave links also must be avoided. Terrestrial microwave links do not operate at Ku-band frequencies.

In the receive branch, the incoming wide-band signal is amplified in a low-noise amplifier and passed to a divider network, which separates out the individual microwave carriers. These are each down converted to an IF band and passed on to the multiplex block, where the multiplexed signals are reformatted as required by the terrestrial network. It should be noted that, in general, the signal traffic flow on the receive side will differ from that on the transmit side. The incoming microwave carriers will be different in number and in the amount of traffic carried, and the multiplexed output will carry telephone circuits not necessarily carried on the transmit side.
A number of different classes of earth stations are available, depending on the service requirements. Traffic can be broadly classified as heavy route, medium route, and thin route. In a thin-route circuit, a transponder channel (36 MHz) may be occupied by a number of single carriers, each associated with its own voice circuit. This mode of operation is known as single carrier per channel (SCPC), a multiple-access mode which is discussed further in Chap. 14. Antenna sizes range from 3.6 m (11.8 ft) for transportable stations up to 30 m (98.4 ft) for a main terminal.

A medium-route circuit also provides multiple access, either on the basis of frequency-division multiple access (FDMA) or time-division multiple access (TDMA), multiplexed baseband signals being carried in either case.

Antenna sizes range from 30 m (89.4 ft) for a main station to 10 m (32.8 ft) for a remote station.

Interferance and satellite acess

Interference may be considered as a form of noise, and as with noise, system performance is determined by the ratio of wanted to interfering powers, in this case the wanted carrier to the interfering carrier power or C/I ratio. The single most important factor controlling interference is the radiation pattern of the earth station antenna.

Comparatively large-diameter reflectors can be used with earth station antennas, and hence narrow beamwidths can be achieved. For example, a 10-m antenna at 14 GHz has a 3-dB beamwidth of about 0.15°. This is very much narrower than the 2° to 4° orbital spacing allocated to satellites. To relate the C/I ratio to the antenna radiation pattern, it is necessary first to define the geometry involved.
The orbital separation is defined as the angle subtended at the center of the earth, known as the geocentric angle. However, from an earth station at point P the satellites would appear to subtend

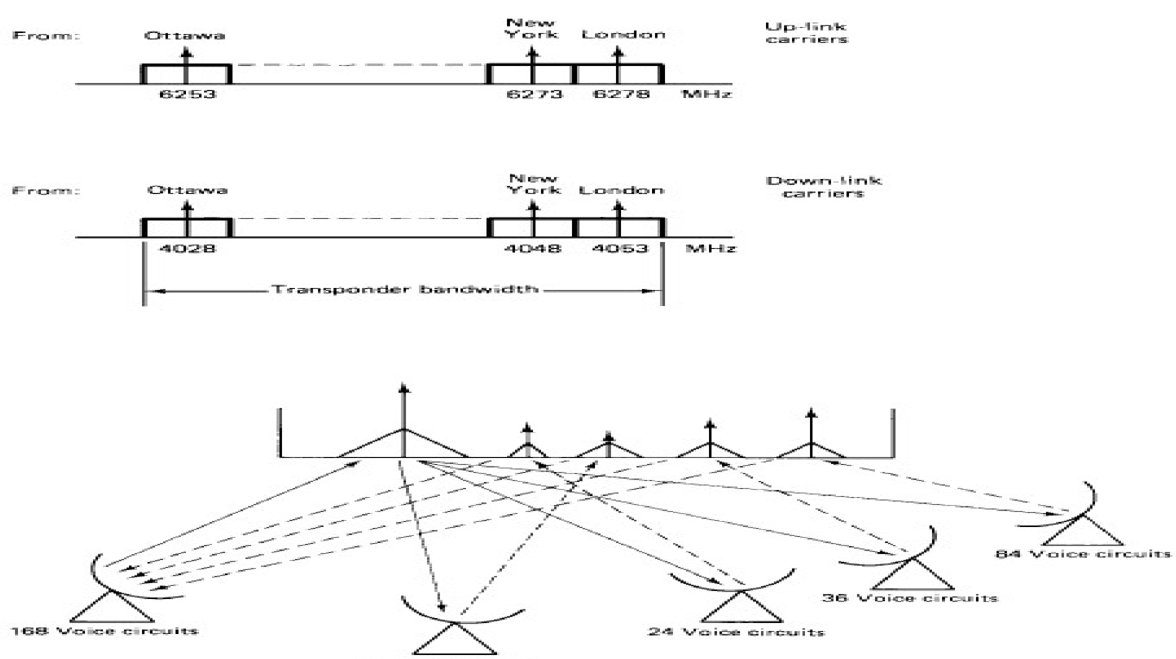
an angle ß. Angle ß is referred to as the topocentric angle. In all practical situations relating to satellite interference, the topocentric and geocentric angles may be assumed equal, and in fact, making this assumption leads to an overestimate of the interference (Sharp, 1983).

6.1 Single Access

With single access, a single modulated carrier occupies the whole of the available bandwidth of a transponder. Single-access operation is used on heavy-traffic routes and requires large earth station antennas such as the class A antenna. As an example, Telesat Canada provides heavy route message facilities, with each transponder channel being capable of carrying 960 one-way voice circuits on an FDM/FM carrier. The earth station employs a 30-m-diameter antenna and a parametric amplifier, which together provide a minimum [G/T] of 37.5 dB/K.

6.2Preassigned FDMA

Frequency slots may be preassigned to analog and digital signals, and to illustrate the method, analog signals in the FDM/FM/FDMA format ill be considered first. As the acronyms indicate, the signals are frequency-division multiplexed, frequency modulated (FM), with frequency-division multiple access to the satellite. In Chap. 9, FDM/FM signals are discussed. It will be recalled that the voice-frequency (telephone) signals are first SSBSC amplitude modulated onto voice carriers in order to generate the single sidebands needed for the frequency-division multiplexing. For the purpose of illustration, each earth station will be assumed to transmit a 60-channel supergroup. Each 60-channel supergroup is then frequency modulated onto a carrier which is then upconverted to a frequency in the satellite uplink band.



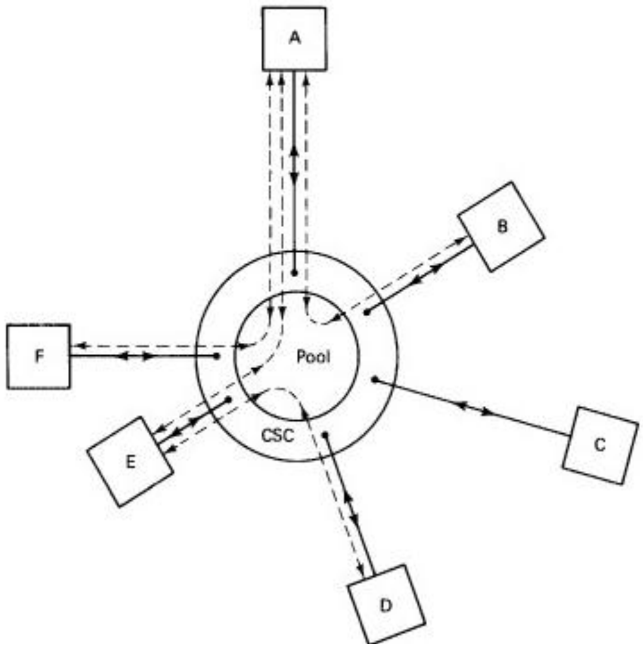
6.3 Spade System

The word Spade is a loose acronym for single-channel-per-carrier pulse-code-modulated multiple-access demand-assignment equipment. Spade was developed by Comsat for use on the INTELSAT satellites (see, e.g.,Martin, 1978). However, the distributed-demand assignment facility requires a common signaling channel (CSC). The CSC bandwidth is 160 kHz, and its center frequency is 18.045 MHz below the pilot frequency. To avoid interference with the CSC, voice channels 1 and 2 are left vacant, and to maintain duplex matching, the corresponding channels 1′ and 2′ are also left vacant. Recalling from Fig. 14.5 that channel 400 also must be left vacant, this requires that channel 800 be left vacant for duplex matching. Thus six channels are removed from the total of 800, leaving a total of 794 one-way or 397 full-duplex voice circuits, the frequencies in any pair being separated by 18.045 MHz.(An alternative arrangement is shown in Freeman, 1981).

All the earth stations are permanently connected through the common signaling channel (CSC). This is shown diagrammatically in Fig. for six earth stations A, B, C, D, E, and F. Each earth station has the facility for generating any one of the 794 carrier frequencies using frequency synthesizers. Furthermore, each earth station has a memory containing a list of the frequencies currently available, and this list is continuously updated through the CSC. To illustrate the procedure, suppose that a call to station F is initiated from station C in Fig. Station C will first select a frequency pair at random from those currently available on the list and signal this information to station F through the CSC. Station F must acknowledge, through the CSC, that it can complete the circuit. Once the circuit is established, the other earth stations are instructed, through the CSC, to remove this frequency pair from the list.

Cities chosen at station C may be assigned to another circuit. In this event, station C will receive the information on the CSC update and will immediately choose another pair at random, even before hearing back from station F. Once a call has been completed and the circuit disconnected, the two frequencies are returned to the pool, the information again being transmitted through the CSC to all the earth stations. As well as establishing the connection through the satellite, the CSC passes signaling information from the calling station to the destination station, in the example above from station C to station F. Signaling information in the Spade system is routed through the CSC rather than being sent over a voice channel. Each earth station has equipment called the demand assignment signaling and switching (DASS) unit which performs the functions required by the CSC.

Some type of multiple access to the CSC must be provided for all the earth stations using the Spade system. This is quite separate from the SCPC multiple access of the network's voice circuits. Time division multiple access, described in Sec. 14.7.8, is used for this purpose, allowing up to 49 earth stations to access the common signaling channel.



6.4 TDMA

With time-division multiple access, only one carrier uses the transponder at any one time, and therefore, inter modulation products, which result from the nonlinear amplification of multiple carriers, are absent. This leads to one of the most significant advantages of TDMA, which is that the transponder traveling-wave tube (TWT) can be operated at maximum power output or saturation level. Because the signal information is transmitted in bursts, TDMA is only suited to digital signals. Digital data can be assembled into burst format for transmission and reassembled from the received bursts through the use of digital buffer memories. Figure 1 illustrates the basic TDMA concept, in which the stations transmit bursts in sequence. Burst synchronization is required, and in the system illustrated in Fig. 1, one station is assigned solely for the purpose of transmitting reference bursts to which the others can be synchronized. The time interval from the start of one reference burst to the next is termed a frame. A frame contains the reference burst R and the bursts from the other earth stations, these being shown as A, B, and C in Fig. 1.

Figure 2 illustrates the basic principles of burst transmission for a single channel. Overall, the transmission appears continuous because the input and output bit rates are continuous and equal. However, within the transmission channel, input bits are temporarily stored and transmitted in bursts.

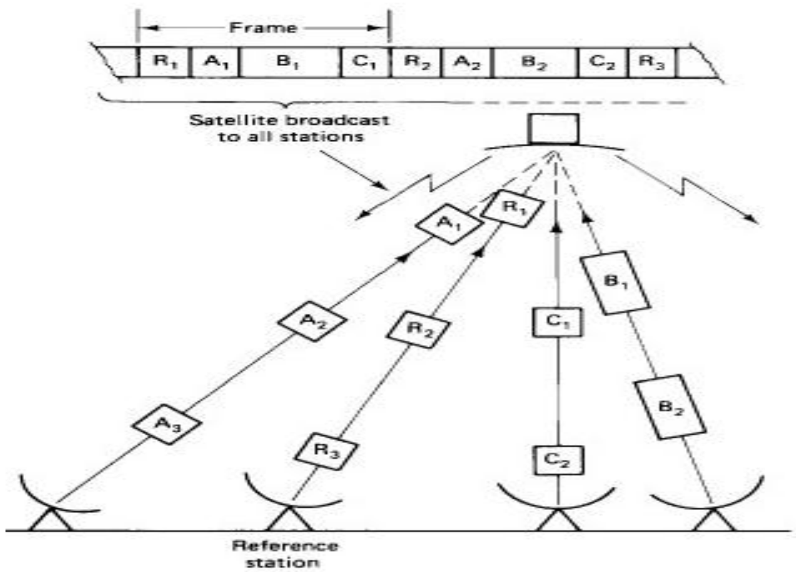


Fig 1

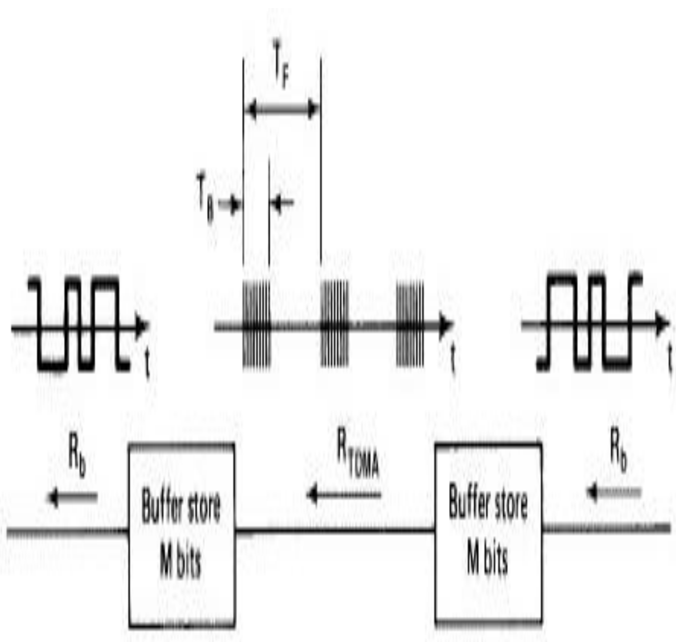


Fig2

Figure 3 shows some of the basic units in a TDMA ground station, which for discussion purposes is labeled earth station A. Terrestrial links coming into earth station A carry digital traffic addressed to destination stations, labeled B, C, X. It is assumed that the bit rate is the same for the digital traffic on each terrestrial link. In the units labeled terrestrial interface modules (TIMs), the incoming continuous-bit-rate signals are converted into the intermittent-burst-rate mode. These individual burst-mode signals are time-division multiplexed in the time- division multiplexer (MUX) so that the traffic for each destination station appears in its assigned time slot within a burst.

Certain time slots at the beginning of each burst are used to carry timing and synchronizing information. These time slots collectively are referred to as the preamble. The complete burst containing the preamble and the traffic data is used to phase modulate the radiofrequency (rf) carrier. Thus the composite burst which is transmitted at rf consists of a number of time slots, as shown in Fig. 4. These will be described in more detail shortly. The received signal at an earth station consists of bursts from all transmitting stations arranged in the frame format shown in Fig. 4. The rf carrier is converted to intermediate frequency (IF), which is then demodulated. A separate preamble detector provides timing information for transmitter and receiver along with a carrier synchronizing signal for the phase demodulator, as described in the next section. In many systems, a station receives its own transmission along with the others in the frame, which can then be used for burst-timing purposes.

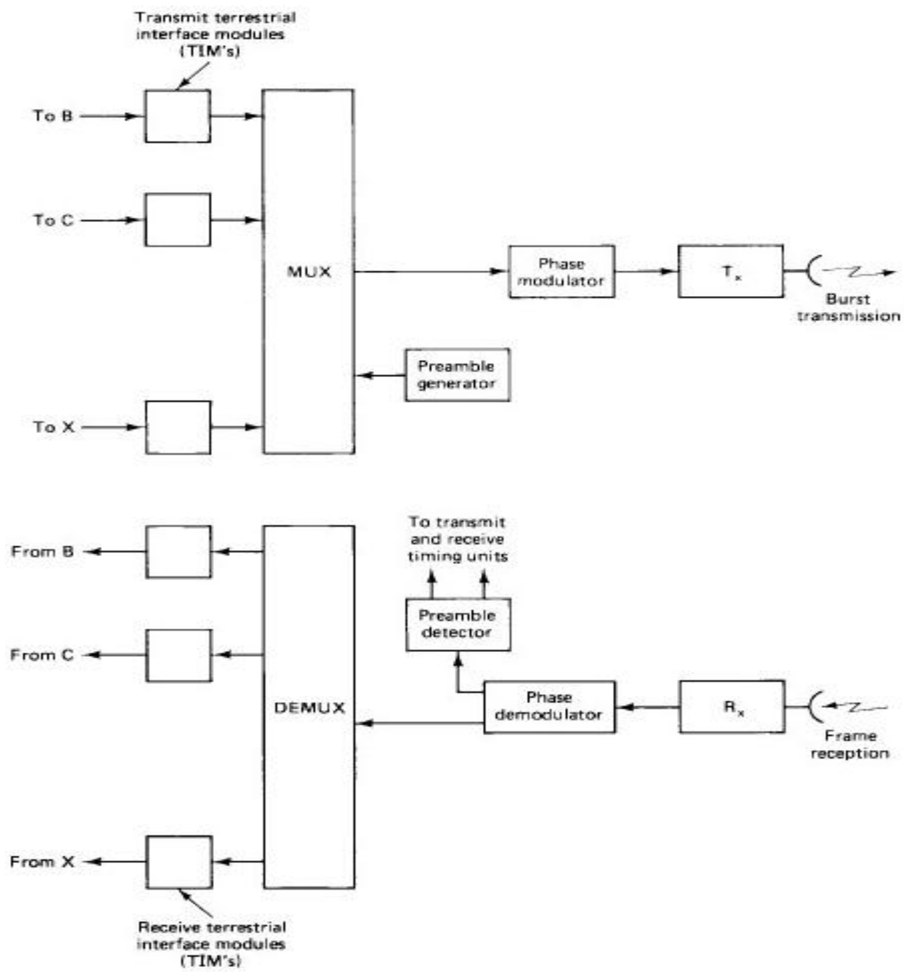


Fig 3

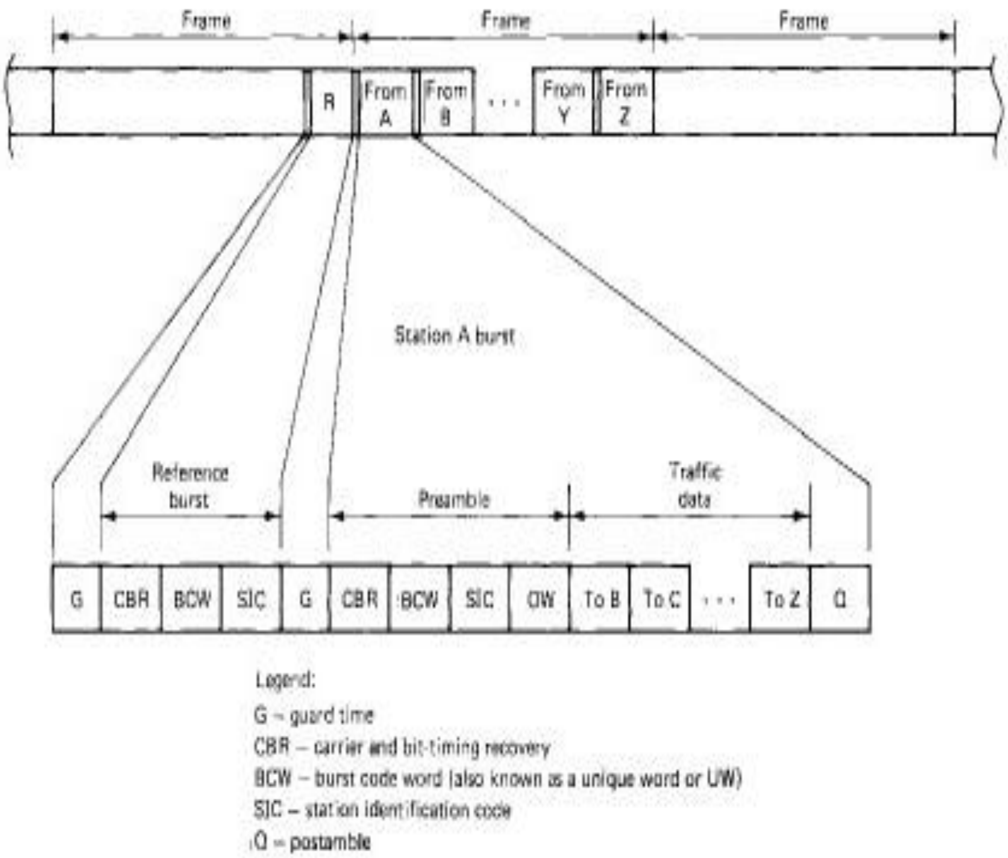


Fig 4

Recommended Questions:

1. Explain a MATV system, with a neat diagram
2. With a neat block diagram explain the outdoor and indoor unit for a analog FM TV
3. A FM/TV carrier is specified as having a modulation index of 2.571 and top modulating frequency of 4.2MHz. Calculate theprotection ratio required to give a quality impairment factor of (a) 4.2 (b) 4.5
4. Explain possible interference nodes between satellite circuits and a terrestrial station. Explain spade system.
5. With a neat block diagram explain frame and burst formats for a TDMA system
6. Explain carrier recovery circuit with single tuned circuit having AFC.

Unit - 7 & 8
DBS, Satellite mobile and specialized services

Introduction, orbital spacing, power ratio, frequency and polarization, transponder capacity, bit rates for digital TV, satellite mobile services, USAT, RadarSat, GPS, orb communication and iridium.

10 Hours

Text Book:

1. **Satellite Communications**, Dennis Roddy, 4th Edition, McGraw-Hill International edition, 2006.

References books:

1. **Satellite Communications**, Timothy Pratt, Charles Bostian and Jeremy Allnutt, 2nd Edition, John Wiley & Sons, 2003.
2. **Satellite Communication Systems Engineering**, W. L. Pitchand, H. L. Suyderhoud, R. A. Nelson, 2nd Ed., Pearson Education., 2007.

7.1 Introduction

Satellites provide broadcast transmissions in the fullest sense of the word, since antenna footprints can be made to cover large areas of the earth. The idea of using satellites to provide direct transmissions into the home has been around for many years, and the services provided are known generally as direct broadcast satellite (DBS) services. Broadcast services include audio, television, and Internet services.

7.2 Orbital Spacing's

Orbital spacing is 9° for the high-power satellites, so adjacent satellite interference is considered nonexistent.

It should be noted that although the DBS services are spaced by 9°, clusters of satellites occupy the nominal orbital positions. For example, the following satellites are located at 119°W longitude.

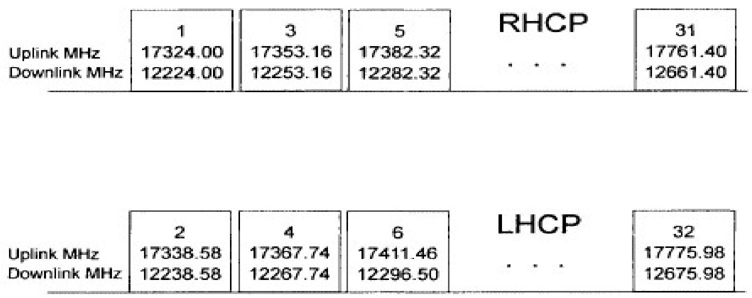
7.3 Power Rating

Satellites primarily intended for DBS have a higher [EIRP] than for the other categories, being in the range 51 to 60 dBW. At a Regional Administrative Radio Council (RARC) meeting in 1983, the value established for DBS was 57 dBW (Mead, 2000). Transponders are rated by the power output of their high-power amplifiers. Typically, a satellite may carry 32 transponders. If all 32 are in use, each will operate at the lower power rating of 120 W. By doubling up the high-power amplifiers, the number of transponders is reduced by half to 16, but each transponder operates at the higher power rating of 240 W.

7.4 Frequencies and Polarization

The requencies for DBS varies from region to region throughout the world.

The available bandwidth (uplink and downlink) is seen to be 500 MHz. A total number of 32 transponder channels, each of bandwidth 24 MHz, can be accommodated. The bandwidth is sometimes specified as 27 MHz, but this includes a 3-MHz guard band allowance. Therefore, when calculating bit-rate capacity, the 24 MHz value is used. The total of 32 transponders requires the use of both right-hand circular polarization (RHCP) and left-hand circular frequency plan for Region 2.

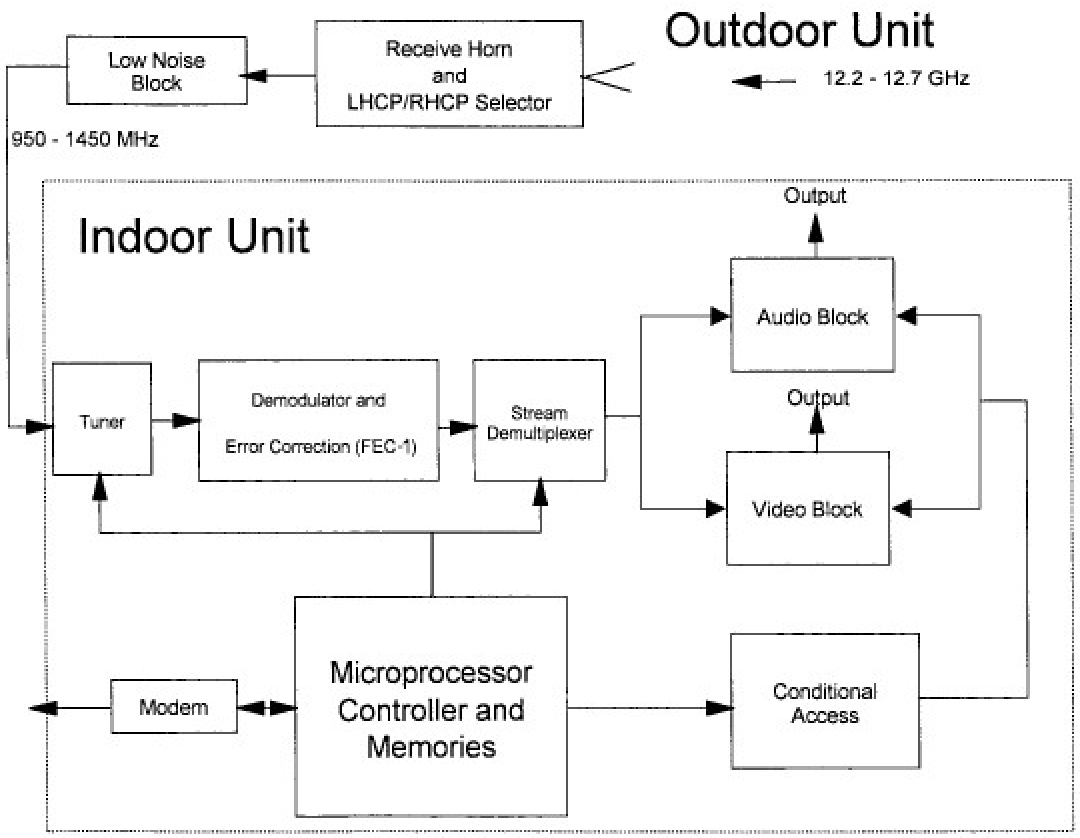


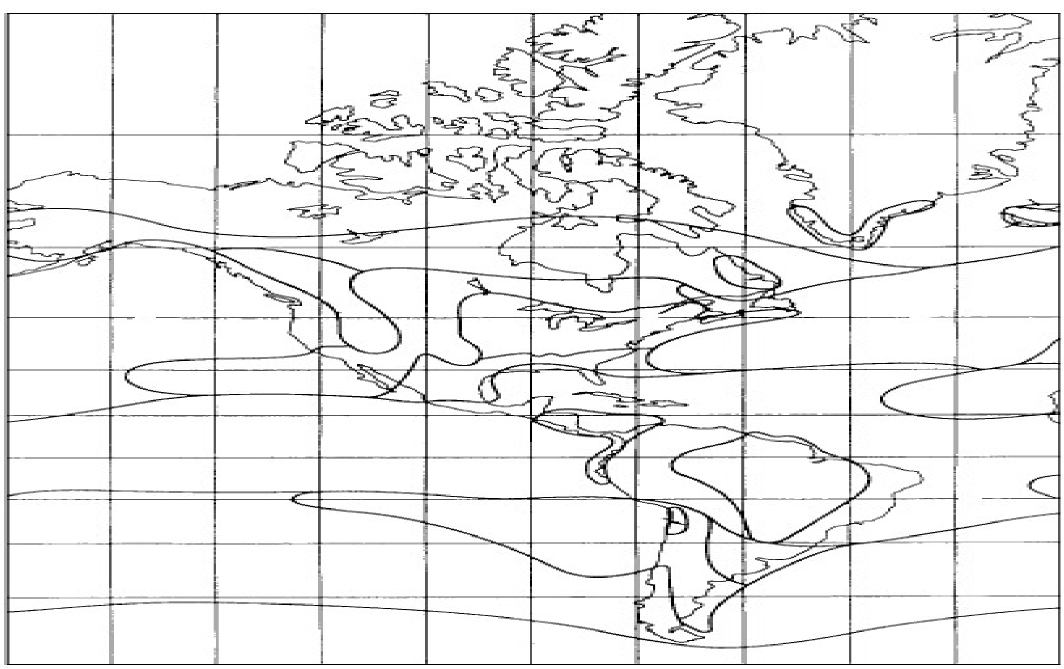
7.5 Transponder Capacity

The 24-MHz bandwidth of a transponder is capable of carrying one analog television channel. To be commercially viable, direct broad- cast satellite (DBS) television [also known as direct-to-home (DTH) television] requires many more channels, and this requires a move from analog to digital television. Digitizing the audio and video components of a television program allows signal compression to be applied, which greatly reduces the bandwidth required. The signal compression used in DBS is a highly complex process, and only a brief overview will be given here of the process. Before doing this, an estimate of the bit rate that can be carried in a 24-MHz transponder will be made.

7.6 The Home Receiver Indoor Unit (IDU)

The block schematic for the indoor unit (IDU) is shown in Fig1. The transponder frequency bands shown in Fig2 are down converted to be in the range 950 to 1450 MHz, but of course, each transponder retains its 24-MHz bandwidth. The IDU must be able to receive any of the 32 transponders, although only 16 of these will be available for a single polarization. The tuner selects the desired transponder. It should be recalled that the carrier at the center frequency of the transponder is QPSK modulated by the bit stream, which itself may consist of four to eight TV programs time-division multiplexed. Following the tuner, the carrier is demodulated, the QPSK modulation being converted to a bit stream. Error correction is carried out in the decoder block labeled FEC 1. The demultiplexer following the FEC 1 block separates out the individual programs, which are then stored in buffer memories for further processing (not shown in the diagram). This further processing would include such things as conditional access, viewing history of pay per-view (PPV) usage, and connection through a modem to the service provider (for PPV billing purposes). A detailed description of the IRD will be found in Mead (2000).


Outdoor Unit
Low Noise Block
Receive Horn and LHCP/RHCP Selector
12.2 - 12.7 GHz
950 - 1450 MHz
Indoor Unit
Output
Audio Block
Output
Tuner
Demodulator and Error Correction (FEC-1)
Stream Demultiplexer
Video Block
Microprocessor Controller and Memories
Modem
Conditional Access



7.7 Uplink

Ground stations that provide the uplink signals to the satellites in a DBS system are highly complex systems in themselves, utilizing a wide range of receiving, recording, encoding, and transmission equipment. Signals will originate from many sources. Some will be analog TV received from satellite broadcasts. Others will originate in a studio, others from video cassette recordings, and some will be brought in on cable or optical fiber. Data signals and audio broadcast material also may be included. All of these must be converted to a uniform digital format, compressed, and time-division multiplexed (TDM). Necessary service additions which must be part of the multiplexed stream are the program guide and conditional access. Forward error correction (FEC) is added to the bit stream, which is then used to QPSK modulate the carrier for a given transponder. The whole process, of course, is duplicated for each transponder carrier. Because of the complexity, the uplink facilities are concentrated at single locations specific to each broadcast company.

8.1 Mobile Satellite System Architecture

A mobile satellite system (MSS) is a system that provides radio communication services between

1. Mobile earth stations and one or more satellite stations
2. Mobile earth stations by means of one or more satellites
3. Satellites.

Figure 8.1 shows the basic architecture of a mobile satellite system (MSS) with a land-based digital switched network (LDSN) and inter-satellite cross link. Assuming that a new-generation mobile satellite is being designed for Fig. 8.1, the total spacecraft system such as power, guidance and control, and data handling would have advanced-technology components. The satellite would contain onboard digital signal processors (DSP) and memory for onboard data processing capability and onboard fast packet switches. The onboard fast packet switches would be capable of supporting space-optimized traffic from multiple earth stations.

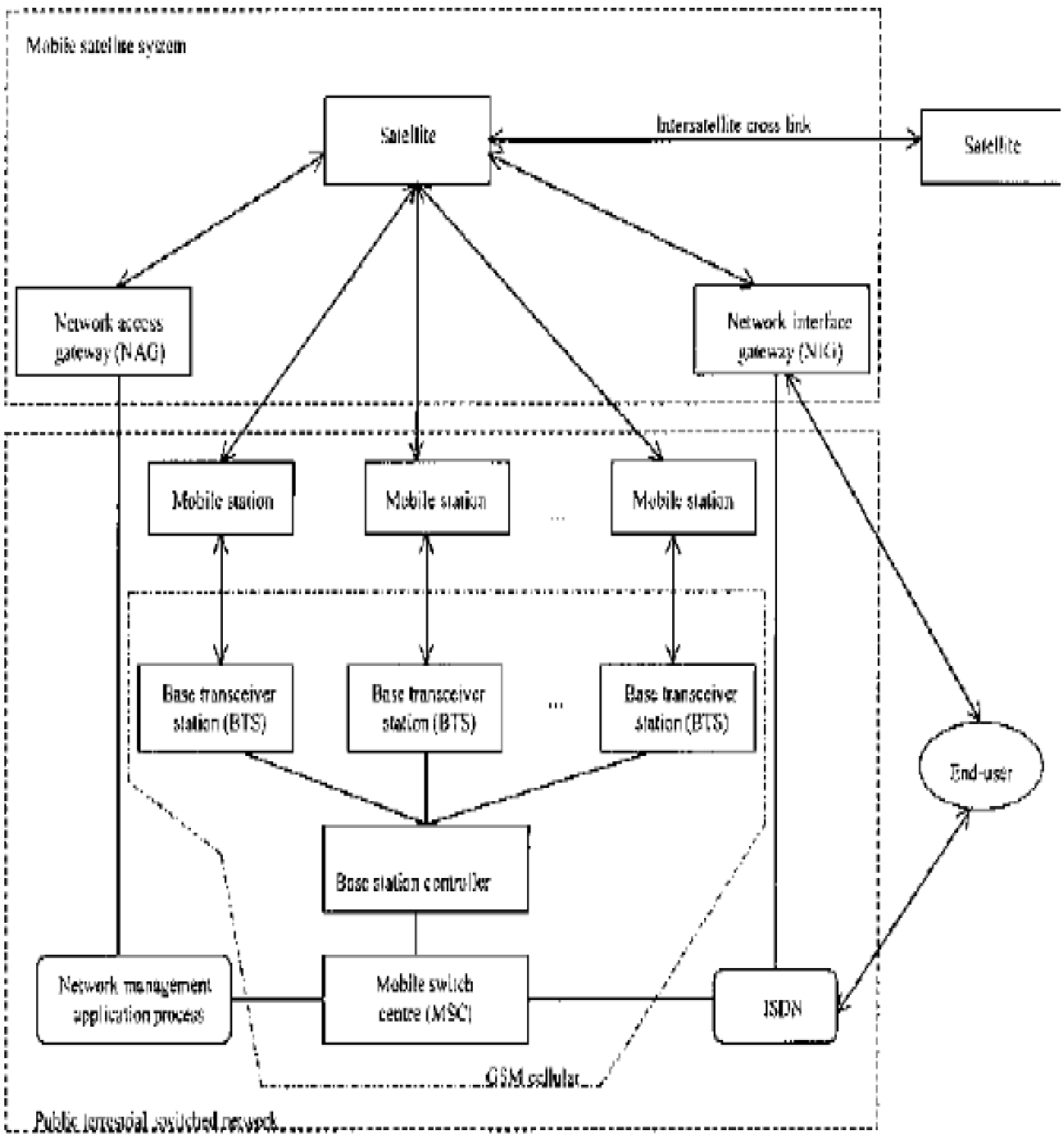


FIG 8.1 Block diagram of a mobile satellite system with terrestrial switched network and Inter-satellite cross link.

The DSP will be responsible for resource management and control including encryption/decryption, channelization, demodulation, and decoding/encoding. This functionality has been discussed in the previous chapters. As stated earlier, since most, if not all, of the services covered by the MSS are, in principle, provided by terrestrial switched digital networks

(e.g. ISDN) we will attempt to explain some the concepts applicable to ISDN that have not been previously dealt with in previous chapters.
The network routers (gateways) allow:
Seamless inter-satellite cross link; that is, direct data transfers from one satellite to another,
Seamless connectivity for users anywhere in the world through mobile=fixed earth stations and public-switched digital networks
Traffic shaping, resource accounting, cache for traffic redirection and load sharing, and integrated network management to support a myriad of simultaneous connections per satellite

Any mobile station registered on the mobile satellite network is interconnected to any available channel of the network interface gateway (NIG) through proper channel assignments issued by the network access gateway (NAG).
When the satellite illuminates a particular area or region, the mobile satellite system routes intended messages (e.g., telephone calls, data, etc.) through the ground networks (e.g., ISDN), ground stations, or directly to the user terminals. User terminals can be personal terminals for individual subscribers or multiuser terminals for corporate (e.g., Internet providers, communication resellers, etc) and communal residential subscribers.
The public terrestrial switched networks, called in this text Land-based Digital Switched Network (LDSN), contain the integrated services digital network (ISDN) and mobile communications systems to provide end users with efficient communication services between fixed and fixed terminals, fixed and mobile terminals, and mobile and mobile terminals. In the network arrangement shown in Fig. 8.1, any mobile stations using the services of PLSN can communicate both signaling and bearer traffic to the base transceiver station (BTS) that provides the most favorable radiofrequency (RF) signal. This establishes an association between the mobile station's geographic location and the closest BTS. As the mobile station moves from the coverage area of one BTS to another, the first association is released and a new one is formed. This procedure is called handover. The base station controller (BSC) and mobile switching center (MSC) manage radio resources, channel assignments, and handover services. A single BSC can control multiple BTS's. A single MSC can control multiple BSCs. Multiple MSCs may reside within a single LDSN. The network management application process (MAP) defines services for signaling among several MSCs. In principle, all the services MAP defines and provides are applicable to the MSS.

Recommended Questions:

1. Write short notes on (a) INTELSAT (b) Radarsat (c) Polar mount antenna (d) Irridium.
2. Explain global positioning system in detail
3. Write short notes on (a) system noise temperature (b) Preassigned FDMA