NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

DIGITAL SATELLITE COMMUNICATION

Graduation Project
EE- 400

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I will always be grateful and thankful to all who taught, guided, and instructed me in my academic life.

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"GOD BLESS YOU ALL"

ABSTRACT

A communications satellite is a spacecraft that carries aboard communications equipment, enabling a communications link to be established between distant points. Satellites are hanged on their orbits as a result of the balance between centrifugal gravitational forces.

A communication satellite permits two or more points on the ground (earth stations) to send messages one to another over great distances using radio waves.

Hundreds of active communications satellites are now in orbit. They receive signals from one ground station, amplify them, and then retransmit them at a different frequency to another station. Satellites use ranges of different frequencies, measured in hertz (Hz) or cycles per second, for receiving and transmitting signals.

The main objective of this Thesis is to represent basic elements of satellite communication systems, including *Frequency Allocation, Earth Station, Transponder, Methods of Access* and some of *Satellite Applications.*

The described topics give the reader enough information for understanding the architecture and principle of *Satellite Communication Systems.*

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INTRODUCTION

Satellite communication has evolved into an everyday, commonplace thing. Most television coverage travels by satellite, even reaching directly to the home from space. No longer is it a novelty to see that a telecast has been carried by satellite (in fact, it would be novel to see something delivered by other means). The bulk of transoceanic telephone and data communication also travels by satellite. For countries such as Indonesia, domestic satellite have greatly improved the quality of service from the public telephone system and brought nations more tightly together.

Some of the first communications satellites were designed to operate in a passive mode. Instead of actively transmitting radio signals, they served merely to reflect signals that were beamed up to them by transmitting stations on the ground. Signals were reflected in all directions, so receiving stations around the world could pick them up.

This project consists of four chapters;

Chapter one is Introduction to Satellite Communication; in this chapter, we presented an introduction to small satellite, application, and new technologies.

Chapter two Satellite Communication; here we gave a description for the Satellite Systems and Services, presenting the Satellite Frequency Bands, Orbits, Construction, Launching And Earth Station substructure.

Chapter three Satellite Orbit Choice; the inter satellite and the choice of the orbit which explained in this chapter, satellite node, satellite path, what is the path, minimum path and shape of the path, the Seamless Assumption.

Chapter four Digital satellite communications the first part of this chapter discuses the connectivity, the quality, reliability, flexibility digital audio sampling, compression, satellite video applications, and the advantage of digital transmission.

CHAPTER ONE

INTRODUCTION TO SATELLITE COMMUNICATION

1.1 Introduction to small satellite

Small satellites have literally been around since the dawn of the Space Age. But the success of trunk communications via satellite, coupled with manned exploration of space has forced the space industry towards ever larger and more expensive missions. Small, cheap satellites used to be the exclusive domain of scientific and amateur groups. Now major advances in microelectronics, in particular microprocessors, have made smaller satellites a viable alternative. They provide cost-effective solutions to traditional problems at a time when space budgets are decreasing.

Interest in small satellites is growing fast world-wide. Businesses, governments, universities and other organisations around the world are starting their own small satellite programmes. But what are the benefits to be gained from using small satellites? Traditionally satellites have become ever larger and more powerful. INTELSAT-6, a trunk communications satellite, has a design life of 10-14 years, weighs 4600kg at launch, and has deployed dimensions of 6.4 x 3.6 x 11.8m. It generates 2600W, and can support up to 120,000 two way telephone channels, and three TV channels. Consequently development times and satellite costs have been rising, and a single in-orbit failure can be costly. A typical modern micro-satellite weighs 50kg, has dimensions 0.6m x 0.4 x 0.3m, and generates 30W. Smaller satellites offer shorter development times, on smaller budgets and can fulfill many of the functions of their larger counterparts. As micro-satellites can benefit from leading edge technology, their design life time is often more limited by the rapid advances in technology rather than failure of the on-board systems. A perfect example of this is the Digital Store and Forward satellite UoSAT-2 launched in 1984, which is still operational in 1995. It carries an 128kbytes on-board message store and operates at 1200bps data rate, but was superceded by UoSAT-3 in 1990 with 16MByte message store, operating at 9600bps. The current satellite in this series, FASat-Alfa (1995) has 300MBytes of solid state message store, and operates at 76,800bps. The significant reductions in costs make many new applications feasible. Recently it has been recognised that small satellites can complement the services provided by the existing larger satellites, by providing cost effective solutions to specialist communications, remote sensing, rapid response science and military missions, and technology demonstrators.

Recently constellations of satellites have been proposed to provide voice and data communications to mobile users world-wide. These systems are divided into "Little LEO's" and "Big LEO's and MEO's". The latter offer a real time mobile voice communication systems and require medium sized and powerful satellites, but the little LEO's will provide data services, and can be successfully implemented by small satellites. These systems no doubt will establish the small satellite in the marketplace.

After a spate of high profile failures of faster better cheaper missions, NASA reports have added "smarter" to the mantra. It was concluded that the cost may have been taken to limits where reliability was significantly affected.

1.2.1 Mass distribution

The mass distribution of small satellite (<500kg mass) is plotted below for the period 1980-1999. The trend line shows an upward trend, but this is deceptive. It can be seen that the number of minisatellites in the 100-500kg mass class has increased, and that their trend is towards lighter spacecraft. It could be argued that technology has permitted larger spacecraft to be built smaller making the minisatellite class spacecraft more popular.

For microsatellites the trend is also towards smaller satellites, and the first modern nanosatellites have been launched towards the end of the 1990's. The general trend is also marginally downwards, although statistics are distorted by the early Soviet military constellations and communications satellite constellations of the 1990's

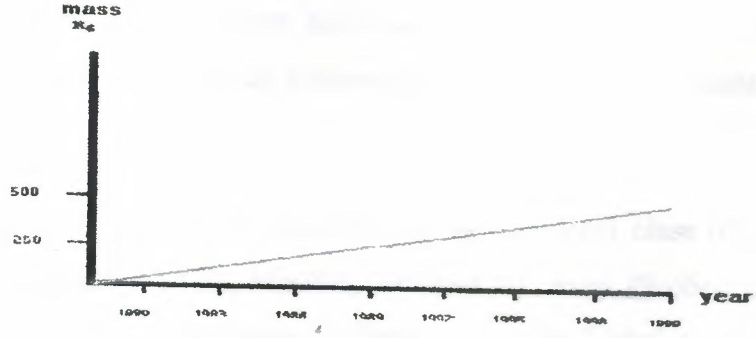


Figure 1.1 Mass Distribution

1.2.2 Applications

The applications are plotted for the period 1980-1999, as well as the yearly distribution over this period as shown in the figure 1.2 .

Figure 1.2 Application of small satellite

1.3 Satellite Classification

First of all, it is worth defining what we mean by a small satellite. The spirit of the current small satellite world is encompassed by the slogan "Faster, Better, Smaller Cheaper". Small satellite projects are characterised by rapid development scales when compared with the conventional space industry, often ranging from six to thirty-six months. Leading-edge technology is routinely included in order to provide innovative solutions, permitting lighter satellite systems to be designed inside smaller volumes. Frequently, traditonal procedures, with roots in the military and manned space programmes, can no longer be justified, and low cost solutions are favoured to match the reducing space budgets. So in many ways it is the philosophy, and not the size or mass of the satellite that matters.

Many terms are used to describe this rediscovered class of satellites, including SmallSat, Cheapsat, MicroSat, MiniSat, NanoSat and even PicoSat! The US Deference Advanced Research Projects Agency referes to these as LightSats, the U.S. Naval Space Command as SPINSat's (Single Purpose Inexpensive Satellite Systems), and the U.S. Air Force as TACSat's (Tactical Satellites). Nevertheless, in recent years a general method of classifying satellites in terms of deployed mass has been generally adopted. The boundaries of these classes are an indication of where launcher or cost tradeoffs are typically made, which is also why the mass is defined including fuel ('Wet mass ').

Table 1.1 Classification of small satellite mass distribution

Large satellite	>1000kg	
Medium sized satellite	500-1000kg	
Mini satellite	100-500kg	Small Satellites
Micro satellite	10-100kg	Small Satellites
Nano satellite	1-10kg	Small Satellites
Pico satellite	0.1-1kg	Small Satellites
Femto satellite	<100g	Small Satellites

The classification above which shown in table 1.1 is slightly different from the one seen traditionally, and reflect my personal views. Satellites in the 500-1000kg are typically designated as a "small satellite", however I feel this causes confusion and until a better term appears I will define it as a medium sized satellite here. Furthermore, I have added a class termed "Pico-satellite" and "Femto-satellite", as interest in this area seems to be growing. The small satellites we are concerned with throughout these pages are therefore satellites weighing approximately *less* than 500kg.

The mass distribution for small satellites illustrates that there are no clear mass boundaries, although there is a general lack of spacecraft in the 100-200kg class.

1.4 Introduction To Traffic Capacity

The demand for personal communications has led to research and development efforts towards a new generation of PCS (Personal Communication Systems). Several MSSs (Mobile Satellite Systems) for personal communications like *Iridium, Globalstar, Odyssey* and *ICO* are being developed and will be able to provide mobile services (i.e. voice, data and paging) on world-wide bases.

In the first phase, MSSs will be a complementary component to terrestrial cellular networks like GSM (Global System for Mobile Communications). MSSs will provide mobile communication services in areas where terrestrial infrastructure is not available, and provide an additional layer of coverage in areas already covered by terrestrial mobile networks. Beyond 2000 an integration of future MSSs in UMTS (Universal Mobile Telecommunication System) and FPLMTS (Future Public Land Mobile Telecommunication System) is envisaged].

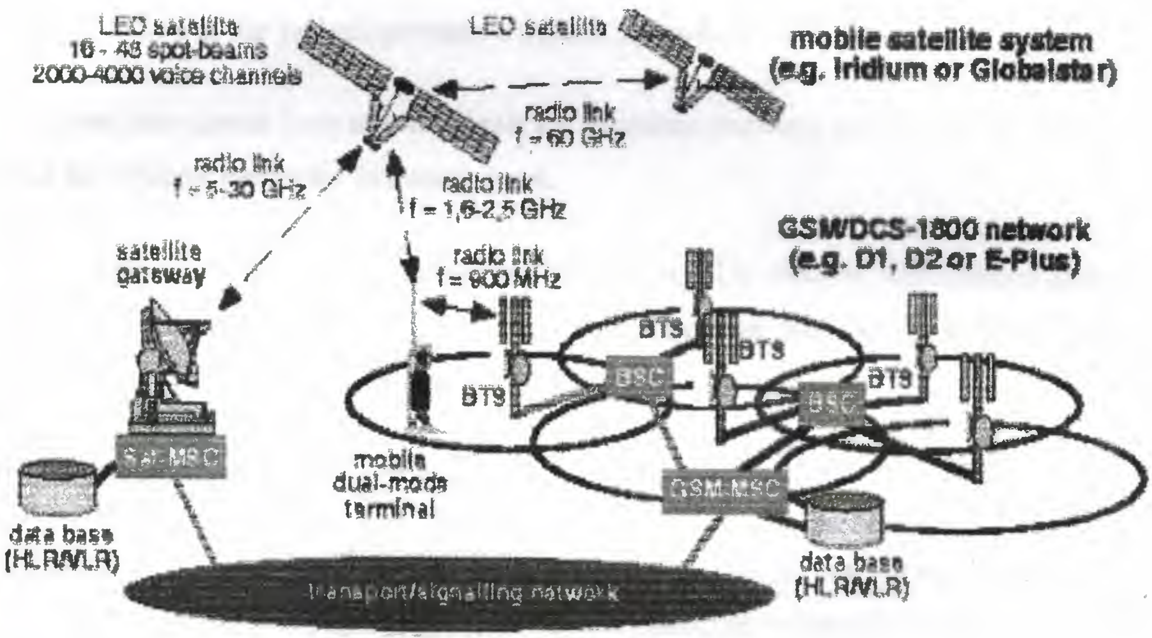


Figure 13 Integrated satellite and terrestrial mobile network

1.5 Next Generation Satellite Communication Technology

1.5.1 New services utilizing the advantages of satellite communication

New satellite communication system and fundamental technologies for realizing next generation satellite services are researched to contribute to the evolution of multimedia communication society.

1.5.1.1 Bi-directional multimedia satellite communication system

NTT had developed first generation multimedia satellite communication system and started providing service from 1998. It provides a medium for Internet access and video program delivery. This system uses a hybrid network of a high-speed satellite forward link and terrestrial access links. To meet the increasing demand for low-cost and ubiquitous access links, a second generation system with satellite transmitting functions is currently under development.

The features of the second-generation system are as follows;

1. The access link signals from user terminals are superimposed onto the forward link signal for efficient use of the frequency band.

2. The requirements for the user terminal are few, i.e., a DTH receiver size antenna and less than 0.1W transmission power. Therefore, low-cost and space saving user terminals that will fit into private house, small offices are available.

3. Even portable terminals will be attainable.

4. The forward link signal is completely compatible with the first generation system, and the data rate is about 30Mbit/s. Consequently, the system can accommodate both first and second-generation users.

The configuration of the system is shown in figure 1.4

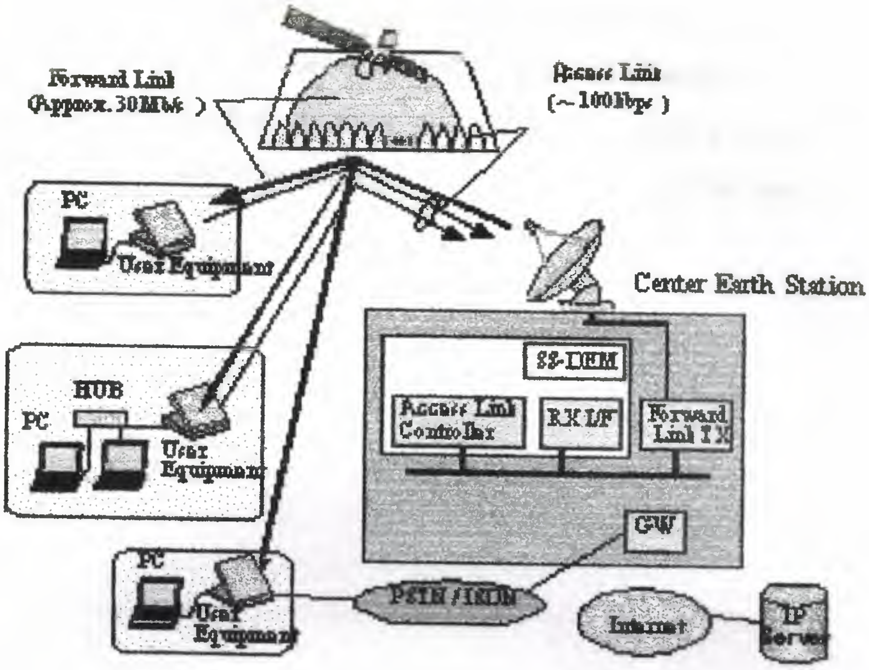


Figure 1.4 Configuration of bi-directional multimedia satellite communication system

1.5.1.2 Mobile Multimedia Satellite Communication System

Mobile communication systems such as PDC (Personal Digital Cellular) has spread rapidly, and multimedia communication in mobile environment is required for next stage. One of the features of multimedia communication system is that uplink signal such as request signal is low capacity and downlink signal including pictures is high capacity. The basic configuration of developing mobile multimedia satellite communication system is composed of satellite tracking antenna that receives high speed signal from communication satellite and ground mobile terminals for uplink signals. This system provides the high speed mobile multimedia communication environment. System architecture including satellite tracking antenna and mobile network is now under development.

1.5.1.3 On board digital signal processing technology

In the satellite communication systems in the future, many users will communicate by suitable user terminals such as small handsets, portable earth stations and fixed earth stations. In the systems, the multi-media contents that are the text, the voice, the image, and the movie, etc. will be transmitted at a variety of transmission speed. Our study group research and develop several key techniques, multi rate filtering technique, on-board regenerative relaying technique and an on-board digital signal processing technique, for the high performance transponder in order to achieve such the above systems.

1.6 Satellite System Architectures

Supported services satellite systems can complement terrestrial systems, as they are particularly suitable for covering sparsely populated areas. In other areas they can support emerging networks such as the broadband (B)-ISDN or mobile systems Satellite systems can support a wide set of interactive and distributive services that, according to ITUR (the successor to the CCIR), are divided into three categories; conversion, control and management of the satellite transmission resources.

(a) Fixed Satellite Services: concerning communication services between earth station at given positions. Video and sound transmissions are included, primarily point-to-point basis, but these services also extended to some broadcasting applications.

(b) Broadcast Satellite Services: principally comprising direct reception of video and sound by the general public.

(c) Mobile Satellite Services: including communications between a mobile earth station and a fixed station, or between mobile stations

Each of these services groups are defined for a different satellite environment and technology, but they cover the whole range of B-ISDN interactive and distributive services defined in ITU-T (formerly CCITT) recommendation. These satellite services are designed for provision by both geostationary orbit (LEO) satellite systems essentially include the following elements:

. 1.7.1 Wireless Networking

Networking that uses electromagnetic waves traveling through free space to connect stations on a network. Wireless transmission is said to use unguided media, as opposed to the guided media of copper cabling and fiber-optic cabling used in traditional wired networks. Wireless networking is typically used for :

- Communication with mobile stations, which precludes the use of fixed cabling, or for mobile users who roam over large distances, such as sales reps with laptops that have cellular modems.

- Work areas in which it is impractical or expensive to run cabling, such as older buildings that are costly to renovate. In this case, two solutions are possible:

  1-Create a wireless LAN (WLAN) that uses no cabling between stations.

  2-Create a combination of traditional wired local area networks (LANs) and as many wireless stations as needed.

- Networking buildings on a campus using a wireless bridge or router. You can typically use wireless bridges or routers over distances up to 25 miles. They might support point-to-point or multipoint connections and often support Internet Protocol (IP) or Internetwork Packet Exchange (IPX) routing using static routing or the Routing Information Protocol (RIP).

Wireless networking suffers somewhat from lower data transmission rates (the maximum is currently about 10 Mbps), greater susceptibility to electromagnetic interference (EMI), and greater risk of eavesdropping than transmission over guided media. You can largely solve the security issue by using secure network protocols, but you should be sure to isolate wireless stations from sources of EMI in the operating frequency range of the network. A microwave oven, for example, can degrade wireless communication that is based on the microwave portion of the electromagnetic spectrum.

1.7.2 How It Works

In the broadest sense, wireless networking is composed of all forms of network communication that use electromagnetic waves of any wavelength or frequency, which includes the following portions of the electromagnetic spectrum:

(1) Infrared (IR) :Ranges from frequencies of about 300 GHz to 200 THz and is used primarily in confined areas where line-of-sight communication is possible. IR cannot penetrate buildings or structures, but it can reflect off light-colored surfaces. **(2) Microwave:** Ranges from 2 GHz to 40 GHz and is used for both point-to-point terrestrial communication and satellite communication. Microwave suffers from signal degradation when weather conditions are poor (for example, in fog or rain) . **(3) Broadcast radio:** Ranges from 30 MHz to 1 GHz, is less affected by poor atmospheric conditions than microwave, and can travel through most buildings and structures, but suffers from multipath interference over long distances.

1.7.3 Satellite Orbits

When a satellite is launched, it is placed in orbit around the earth. The earth's gravity holds the satellite in a certain path as it goes around the earth, and that path is called an "orbit." There are several kinds of orbits. Here are three of them.

A) LEO , or Low Earth Orbit

A satellite in low earth orbit circles the earth 100 to 300 miles above the earth's surface. Because it is close to the earth, it must travel very fast to avoid being pulled out of orbit by gravity and crashing into the earth. Satellites in low earth orbit travel about 17,500 miles per hour. These satellites can circle the whole earth in about an hour and a half.

B) MEO , or Medium Earth Orbit

Communications satellites that cover the North Pole and the South Pole are placed in a medium altitude, oval orbit. Instead of making circles around the earth, these satellites make ovals. Receivers on the ground must track these satellites. Because their orbits are larger than LEOs, they stay in sight of the ground receiving stations for a longer time. They orbit 6,000 to 12,000 miles above the earth.

C) GEO, or Geostationary Earth Orbit

A satellite in geosynchronous orbit circles the earth in 24 hours—the same time it takes the earth to rotate one time. If these satellites are positioned over the equator and travel in the same direction as the earth rotates, they appear "fixed" with respect to a given spot on earth—that is, they hang like lanterns over the same spot on the earth all the time. Satellites in GEO orbit 22,282 miles above the earth. In this high orbit, GEO satellites are always able to "see" the receiving stations below, and their signals can cover a large part of the planet. Three GEO satellites can cover the globe, except for the parts at the North and South poles.

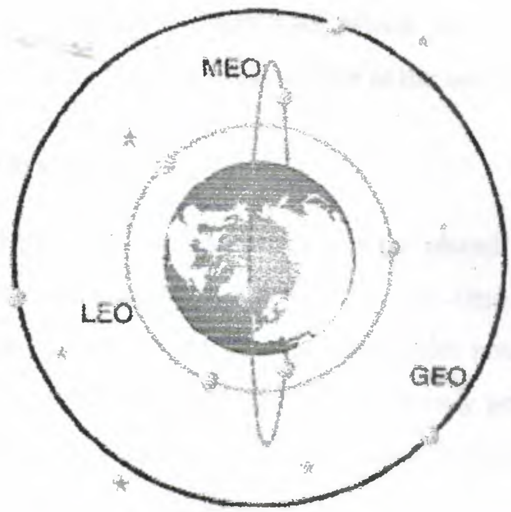


Figure 1.5 Satellite Orbits

1.7.3.1 The LEO Systems

Cellular telephony has brought us a new technological "system"-- the personal communications system (PCS). In the fully developed PCS, the individual would carry his telephone with him. This telephone could be used for voice or data and would be usable anywhere. Several companies have committed themselves to providing a version of this system using satellites in low earth orbits (LEO). These orbits are significantly lower than the TELSTAR/RELAY orbits of the early 1960s. The early "low-orbit" satellites were in elliptical orbits that took them through the lower van Allen radiation belt. The new systems will be in orbits at about 500 miles, below the belt.

The most ambitious of these LEO systems is Iridium, sponsored by Motorola. Iridium plans to launch 66 satellites into polar orbit at altitudes of about 400 miles. Each of six orbital planes, separated by 30 degrees around the equator, will contain eleven satellites. Iridium originally planned to have 77 satellites-- hence its name. Element 66 has the less pleasant name Dysprosium. Iridium expects to be providing communications services to hand- held telephones in 1998. The total cost of the Iridium system is well in excess of three billion dollars.

In addition to the "Big LEOS" such as Iridium and Globalstar, there are several "little leos." These companies plan to offer more limited services, typically data and radio determination. Typical of these is ORBCOM, which has already launched an experimental satellite and expects to offer limited service in the very near future.

1.7.3.2The GEO-LEO transition

At the beginning of the space age, all satellites were placed in low earth orbit, due to the limitations of the launch technology of the time. However, rapid improvement in rocketry, and the wide earth coverage and stable positioning offered by the geostationary equatorial orbit soon made this orbit extremely popular for satellite-based transponders amplifying and returning signals passed between geographically-distant ground stations.

The geostationary orbit soon dominated long-distance civilian communications, as the wide land area coverage it offered made it convenient for connecting distant telephone exchanges to provide international telephony, particularly for trans-Atlantic calls, and for the real-time broadcast to many nations of television events of international interest, for immediate terrestrial rebroadcast. (Demand for satellite capacity for television increases dramatically each time the Olympics are held, for example.)

The increase in capacity of terrestrial land and undersea links, thanks primarily to improvements in fibre-optic and switching technology, has decreased the importance of this orbit's role in linking land-based telephone exchanges for international calls. Instead, satellite communication is now useful as a backup for ground links, while the popularity of television, desire for programme choice, and lack of available spectrum for additional terrestrial analogue television channels has given the orbit a new purpose in the broadcasting of television channels direct-to-home. Syndicated radio programmes are also broadcast to terrestrial radio stations, via satellites in geostationary orbit, for rebroadcasting to listeners. Linking physically-remote computer terminals on a timesharing basis by VSAT is possible via geostationary orbit.

There is a proven demand for mobile communication in remote areas that lack the land-based telephony infrastructure found in developed countries (and that also lack the associated ground-based mobile cellular networks!), as shown by the success of Inmarsat's services for marine communications and, later, their transportable mobile telephone sets of various sizes (the size being largely determined by the requirements of the antenna and the weight largely by useful battery life). However, the propagation delay, resulting from the signal travelling to geostationary orbit and back, when combined with the land-network transmission, switching delays and processing delays needed to complete a call, significantly degrades the perceived quality of real-time two-way telephone communication. Interactive video links via geostationary orbit suffer the same way, as interviews 'live by satellite' demonstrate with their awkward pauses .

Geostationary orbit can now be seen as better suited to wide-area non-interactive broadcast applications, rather than the two-way communication that initially dominated it. However, there is a demand for mobile two-way interactive communication that this orbit cannot easily.

CHAPTER TWO

SATELLITE COMMUNICATION

2.1 Satellite system

A satellite system consists basically of a satellite in space which links many earth stations on the ground, as shown schematically in Fig. 2.1 The user generates the base-band signal which is routed to the earth station through the terrestrial network. The terrestrial network can be a telephone switch or a dedicated link to the earth station. At the earth station the base-band signal is processed and transmitted by a modulated radio frequency (RF) carrier to the satellite. The satellite can be thought of as a large repeater in space. it receives the modulated RF carriers in its uplink (earth-to-space) frequency spectrum from all the earth stations in the network, amplifies these carriers, and retransmits them back to earth in the downlink (space-to-earth) frequency spectrum which is different from the uplink frequency spectrum in order to avoid interference. The receiving earth station processes the modulated RF carrier down to the base-band signal which is sent through the terrestrial network to the user.

Satellite system essentially include the following elements

2.1.1 Ground Segment

Which includes traffic interfaces, gateway function for traffic adaptation, protocol conversion, control and management of the satellite transmission resources a space segment comprising the satellite (s). Two main types of satellites are considered; transparent and future on-board processing (OBP) of the many types of OBP satellite, those that include switching function (e.g. ATM local connection switching functions) .

2.1.2 Earth Station:

The initially small number of earth station has now increased considerably, with operation on all continents. Typical earth station characteristic is 5 to 10 kW of transmitter power radiation from an antenna having a reflector between 10 and 32 m in temperature is between 50 and 200 K at 5°elevation angle. A very suitable characteristic indicative of the quality of receiving system in the merit G/T, that is the ratio of the receiving antenna gain to the system noise temperature in Kelvin's, expressed in dB/K. A large earth station, having an antenna diameter about 25m and a system noise temperature of 50 K, operating at 4 GHZ has a G/T figure of about 41 dB/K.In smaller earth station the G/T figure decreases.

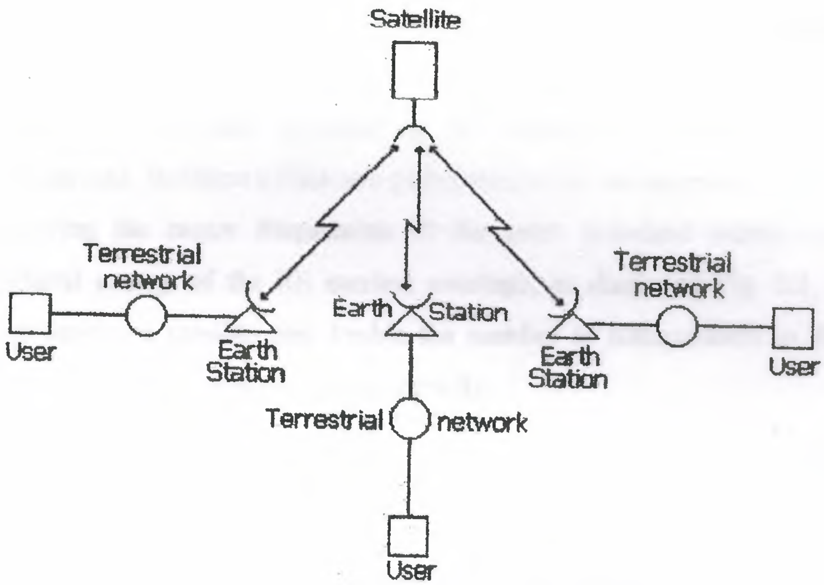


Figure 2.1 Satellite system

Most commercial communications satellites today utilize a 500-MHz bandwidth on the uplink and a 500-MHz bandwidth on the downlink. The most widely used frequency spectrum is the 6/4-GHz band, with an uplink of 5.725 t&7.075 GHz and a downlink of 3.4 to 4.8 G1-Iz. The 6/4-GHz band for geostationary satellites is becoming overcrowded because it is also used by common carriers for terrestrial microwave links. Satellites are now being operated in the 14/12-GHz band using an uplink of 12.75 to 14.8 GHz and a downlink of either 10.7 to 12.3 GHz or 12.5 to 12.7 GHz. The 14/12-GHz band will be used extensively in the future and is not yet congested, but one problem exists rain, which attenuates 14/12-0Hz signals much more than it does those at 6/4 GHz. The frequency spectrum in the 30/20-0Hz bands has also been set aside for Commercial satellite communications, with a downlink of 18.1 to 21.2 GHz and an uplink of 27.5 to 31 GHz. Equipment for the 30/20-GHz band is still in the experimental stage and is expensive.

The typical 500-MHz satellite bandwidth at the 6/4 and 14/12-GHz bands can be segmented into many satellite transponder bandwidths. For example, eight transponders can be provided, each with a nominal bandwidth of 54 MHz and a center-to-center frequency spacing of 61 MHz. Modem communications satellites also employ frequency reuse to increase the number of transponders in the 500 MHz allocated to them. Frequency reuse can be accomplished through orthogonal polarizations where one transponder operates in one polarization (e.g., vertical polarization) and a cross-polarized transponder operates in the orthogonal polarization (e.g., horizontal polarization). Isolation of the two polarizations can be maintained at3O dB or more by staggering the center frequencies of the cross polarized transponders so that only sideband energy of the RE carriers overlaps, as shown in Fig. 2.2. With orthogonal polarizations a satellite can double the number of transponders in the available 500-MHz bandwidth, hence double its capacity.

With this brief discussion of a general satellite system we will now take a look at an earth station that transmits information to and receives information from a satellite. Fig 2.3 shows the functional elements of a digital earth station. Digital information in the form of binary digits from the terrestrial network enters the transmit side of the earth station and is then processed (buffered, multiplexed, formatted. etc.) by the base-band equipment so that these forms of information can be sent to the appropriate destinations. The presence of noise and the nonideal nature of any communication channel introduce errors in the information being sent and thus limit the rate at which it can be transmitted between the source and the destination. Users generally establish an error rate above which the received information is not usable. If the received information does not meet the error rate requirement, error-correction coding performed by the encoder can often be used to reduce the error rate to the acceptable level by inserting extra digits into the digital stream from the output of the base-band equipment. These extra digits carry no information, but are used to accentuate the uniqueness of each information message. They are always chosen so as to make it unlikely that the channel disturbance will corrupt enough digits in a message to destroy its uniqueness.

corrupt enough digits in a message to destroy its uniqueness.

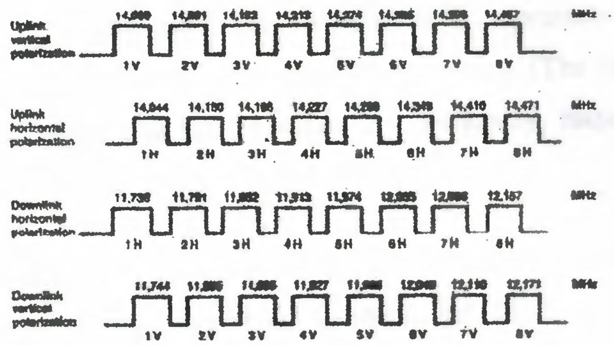


Figure 2.2 Staggering Frequency Resue Ku-band transponders

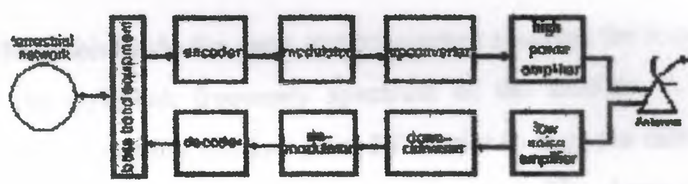


Figure 2.3 Functional Block Diagram of a Digital Earth Station

In order to transmit the base-band digital information over a satellite channel that is a band-pass channel, it is necessary to transfer the digital information to a carrier wave at the appropriate band-pass channel frequency.

This technique is called digital carrier modulation. The function of the modulator is to accept the symbol stream from the encoder and use it to modulate an intermediate frequency (IF) carrier. in satellite communications, the IF carrier frequency is chosen at 70 MHz for a communication channel using a 36-MHz transponder bandwidth and at 140 MHz for a channel using a transponder bandwidth of 54 or 72 MHz. A carrier wave at an intermediate frequency rather than at the satellite RF uplink frequency is chosen because it is difficult to design a modulator that works at the uplink frequency spectrum (6 or 14 0Hz, as discussed previously).

For binary modulation schemes, each output digit from the encoder is used to select one of two possible waveforms. For M-ary modulation schemes, the output of the encoder is segmented into sets of k digits, where $M = k^2$ and each k-digit set or symbol is used to select one of the M waveforms. For example, in one particular binary modulation scheme called phase-shift keying (PSK), the digit 1 is represented by the waveform $s_1(t) = A \cos \omega_0 t$ and the digit 0 is represented by the waveform $s_0(t) = -A \cos \omega_0 t$, where ω_0 is the intermediate frequency. (The letter symbols ω and f will be used to denote angular frequency and frequency, respectively, and will be referred to both of them as "frequency.")

The modulated IF carrier from the modulator is fed to the up-converter, where its intermediate frequency ω_0 is translated to the uplink RF frequency w. in the uplink frequency spectrum of the satellite. This modulated RF carrier is then amplified by the high-power amplifier .(HPA) to a suitable level for transmission to the satellite by the antenna.

On the receive side the earth station antenna receives the low-level modulated RF carrier in the downlink frequency spectrum of the satellite. A low-noise amplifier (LNA) is used to amplify this low-level RF carrier to keep the carrier-to-noise ratio at a level necessary to meet the error rate requirement. The down-converter accepts the amplified RF carrier from the output of the low-noise amplifier and translates the downlink frequency ω_d to the intermediate frequency ω_0. The reason for down-converting the RF frequency of the received carrier wave to the intermediate frequency is that it is much easier to design the demodulator to work at 70 or 140 MHz than at a downlink frequency of 4 or 12 GHz. The modulated IF carrier is fed to the demodulator, where the information is extracted. The demodulator estimates which of the possible symbols was transmitted based on observation of the received IF carrier. The probability that a symbol will be correctly detected depends on the carrier-to-noise ratio of the modulated carrier, the characteristics of the satellite channel, and the detection scheme employed. The decoder performs a function opposite that of the encoder. Because the sequence of symbols recovered by the demodulator may contain errors, the decoder must use the uniqueness of the redundant digits introduced by the encoder to correct the errors and .recover information-bearing digits. The information stream is fed to the base-band equipment for processing for delivery to the terrestrial network.

In the United States the Federal Communications Commission (FCC) assigns orbital positions for all communications satellites to avoid interference between adjacent satellite systems operating at the same .frequency. Before 1983 the spacing was established at 4° of the equatorial arc, and the smallest earth station antenna for a simultaneous transmit-receive operation allowed by the FCC is 5 m in diameter.

In 1983, the FCC ruled that fixed service communications satellites in the geostationary orbit should be spaced every 2° along the equatorial arc instead of 4°. This closer spacing allows twice as many satellites to occupy the same orbital arc.

The FCC ruling poses a major challenge to antenna engineers to design a directional feed for controlling the amount of energy received off-axis by the antenna feed, thus reducing interference from an adjacent satellite. This challenge is especially great because the trend in earth stations is toward smaller antennas, but smaller antennas .have a wider beam-width and thus look at a wider angle in the sky.

The FCC ruling specified that, as of July 1, 1984, all new satellite earth station antennas had to be manufactured to accommodate the spacing of 20 and that, as of January 1, 1987. all existing antennas must be modified to conform to the new standards.

2.2 Spectrum

2.2.1 Satellite Frequency Bands

The frequencies used for satellite communications are allocated in super-high frequency (SHF) and extremely-high frequency (EHF) bands which are broken down into sub-bands as summarized in Table 2.1. Spectrum management is an important activity that facilitates the orderly use of the electromagnetic frequency spectrum not only for satellite-communications but for other telecommunications applications as well.

Table 2.1 Satellite Frequency Spectrum

Frequency Band	Range (GHz)
L	1 – 2
S	2 – 4
C	4 – 8
X	8 - 12
Ku	12 - 18
K	18 - 27
Ka	27 - 40
Millimeter	40 - 300

2.2.2 Capacity

The approximate bandwidths available for satellite services in the different frequency bands are listed in Table 2.2:

Table2.2 Satellite Bandwidth Spectrum

NAME	TOTAL BANDWIDTH
Below 1 GHz (MSS)	161MHz
L and S Bands(MSS)	168 MHz
C Band (FSS)	1750 MHz
Ku Band(FSS)	2250 MHz for GSO 3750 MHz for NGSO
Ka Band	7000 MHz
V Band	A lot

It should be noted, that Table 3 includes primary and secondary allocations (for further details and restrictions see [1], [6] and [7])

The MSS bandwidth below 1 GHz is fragmented in many narrowband pieces and they are the L and S bands cannot offer broadband mainly used by store and forward NGSO systems.

services because the total available bandwidth is limited to about 168.5 MHz. Therefore GSO and NGSO systems can only offer narrowband mobile services.

Due to the lack of spectrum, they cannot replace or compete with the terrestrial cellular networks.

Only terrestrial networks have the possibility to offer the necessary capacity due to the in little cells. The satellite component must be a complement and cover rural frequency reuse areas or areas not covered by the terrestrial cellular networks (e.g. navigation). The L/S bands are used for mobile services because of the propagation properties: there is little long term variation of the propagation lose

(robustness to rain), allowing handheld terminals to operate within the admitted maximal emission power. The C/Ku/Ka/V-bands offer much more and less fragmented bandwidths for satellite communications, permitting broadband services. The C and Ku band are already extensively used and therefore not very attractive for new GSO projects. The Ka band offers a lot of bandwidth and is therefore suited for broadband services. The V band is almost a virgin area and offers a huge capacity. However, the technology necessary to use it is not yet mature. This band will be used once the Ka band is full.

2.3.1 The Anatomy of Satellite

Satellites have only a few basic parts : a satellite housing , a power system ,an antenna system , a command and control system, a station keeping system, and transpoders.

2.3.2 Satellite Housing

The configuration of the satellite housing is determined by the system employed to stabilize the attitude of the sattelite in its orbital slot. Three-axis-stabilized satellites use internal gyrosccopes rotating at 4,000 to 6,000 revolutions per minute (RPM). The housing is rectangular with external features as shown bellow.

2.3.3 Power System

Satellites must have a continuous source of electrical power--24 hours a day, 365 days a year. The two most common power sources are high performance batteries and solar cells. Solar cells are an excellent power source for satellites. They are lightweight, resilient, and over the years have been steadily improving their efficiency in converting solar energy into electricity. Currently the best gallium arsenide cells have a solar to electrical energy conversion efficiency of 15-20%. There is however, one large problem with using solar energy. Twice a year a satellite in geosynchronous orbit will go into a series of eclipses where the sun is screened by the earth. If solar energy were the only source of power for the satellite, the satellite would not operate during these periods. To solve this problem, batteries are used as a supplemental on-board energy source. Initially, Nickel-Cadmium batteries were utilized, but more recently Nickel-Hydrogen batteries have proven to provide higher power, greater durability, and the important capability of being charged and discharged many times over the lifetime of a satellite mission.

2.3.4 Antenna System

A satellite's antennas have two basic missions. One is to receive and transmit the telecommunications signals to provide services to its users. The second is to provide Tracking, Telemetry, and Command (TT&C) functions to maintain the operation of the satellite in orbit. Of the two functions, TT&C must be considered the most vital. If telecommunications services are disrupted, users may experience a delay in services until the problem is repaired. However, if the TT&C function is disrupted, there is great danger that the satellite could be permanently lost--drifting out of control with no means of commandinu it.

2.3.5 Command and Control System

This control system includes tracking, telemetry & control (TT&C) systems for monitoring all the vital operating parameters of the satellite, telemetry circuits for relaying this information to the earth station, a system for receiving and interpreting commands sent to the satellite, and a command system for controlling the operation of the satellite.

2.3.6 Station Keeping

Although the forces on a satellite in orbit are in balance, there are minor disturbing forces that would cause a satellite to drift out of its orbital slot if left uncompensated. For example, the gravitational effect of the sun and moon exert enough significant force on the satellite to disturb its orbit. As well, the South American land mass tends to pull satellites southward.

Station keeping is the maintenance of a satellite in its assigned orbital slot and in its proper orientation. The physical mechanism for station keeping is the controlled ejection of hydrazine gas from thruster nozzles which portrude from the satellite housing. When a satellite is first deployed, it may have several hundred pounds of compressed hydrazine stored in propellant tanks. Typically, the useful life of a satellite ends when the hydrazine supply is exhausted--usually after ten years.

2.3.7 Transponders

A transponder is an electronic component of a satellite that shifts the frequency of an up-link signal and amplifies it for retransmission fo the earth in a down-link. Transponders have a typical output of 5 to 10 watts. Communications satellites typically have between 12 and 24 on-board transponders.

2.4 Gateway stations

Gateway Stations (GSs) act as the interface between the satellite constellation network and the terrestrial fixed network. They are likely to also act as the sources of control signals for the satellites for attitude control, station keeping, and internal housekeeping functions, but we will assume that this control traffic is small and negligible in comparison with the user traffic.

A GS will be able to see one or more satellites in the constellation at all times to ensure that it can pass connections between the terrestrial and space networks. A number of GSs, spread world-wide, are likely to be necessary to handle all of the inter-network load and to keep connections within delay budgets. Theoretically, a constellation network could be fully functional with only one GS, provided that the GS and ISLs had sufficient capacity

2.4.1 Mobile users

As with ground stations, we assume an even spread of mobile users world-wide, so that each satellite has the same amount of traffic coming from the mobile users in its footprint and the input to the network remains homogeneous.

This neglects a number of mobile issues, such as handover of mobile stations, the amount of mobile users active at any one time, capacity needed for tracking users and ringing handsets, and so on.

As we do for gateway stations, we will assume for convenience that the messages from the pool of mobile users related to a satellite follow the Poisson arrival distribution for network traffic.

2.4.2 Earth Station Antenna

The earth station antenna is one of the important subsystems of the RF terminal because it provides a means of transmitting the modulated RF carrier to the satellite within the uplink frequency spectrum and receiving the RF carrier from the satellite within the downlink frequency spectrum. The earth station antenna must meet three basic requirements:

1) The antenna must have a highly directive gain; that is, it must focus its radiated energy into a narrow beam to illuminate the satellite antenna in both the transmit and receive modes to provide the required uplink and downlink carrier power. Also, the antenna radiation pattern must have a low side-lobe level to reduce interference from unwanted signals and to minimize interference into other satellites and

terrestrial systems.

2) The antenna must have a low noise temperature so that the effective noise temperature of the receive side of the earth station, which is proportional to the antenna temperature, can be kept low to reduce the noise power within the downlink carrier bandwidth. To achieve a low noise characteristic, the antenna radiation pattern must be controlled in such a way as to minimize the energy radiated into sources other than the satellite. Also, the Ohmic losses of the antenna that contribute directly to its noise temperature must be minimized. This includes the Ohmic loss of the wave-guide that connects the low-noise amplifier to the antenna feed.

The antenna must be easily steered so that a tracking system (if required) can be employed to point the antenna beam accurately toward the satellite taking into account the satellite's drift in position. This is essential for minimizing antenna pointing loss.

A) Antenna Types

The two most popular earth station antennas that meet the above requirements are the paraboloid antenna with a focal point feed and the Cassegrain antenna.

A paraboloid antenna with a focal point feed is shown in Fig. 2.4 This type of antenna consists of a reflector which is a section of a surface formed by rotating a parabola about its axis, and a feed whose phase center is located at the focal point of the paraboloid reflector. The size of the antenna is represented by the diameter D of the reflector. The feed is connected to a high-power amplifier and a low-noise amplifier through an orthogonal mode transducer (OMT) which is a three-port network. The inherent isolation of the OMT is normally better than 40 dB. On the transmit side the signal energy from the output of the high-power amplifier is radiated at the focal point by the feed and illuminates the reflector which reflects and focuses the signal energy into a narrow beam. On the receive side the signal energy captured by the reflector converges on the focal point and is received by the feed which is then routed to the input of the low-noise amplifier. This type of antenna is easily steered and offers reasonable gain efficiency in the range of 50 to 60%. The disadvantage occurs when the antenna points to the satellite at a high elevation angle. In this case, the feed radiation which spills over the edge of the reflector (spillover energy) illuminates the ground whose noise temperature can be as high as 2900 K and results in a high antenna noise contribution. Paraboloid antennas with a focal point feed are most often employed in the United States for receive-only applications.

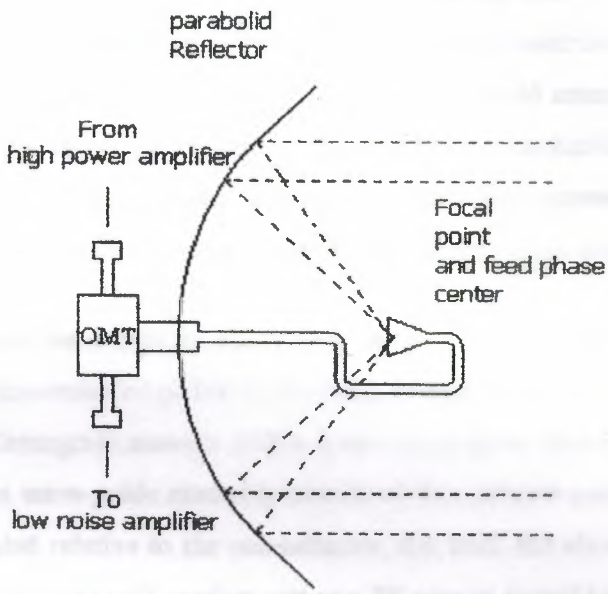


Figure 2.4 parabolic Antenna

A Cassegrain antenna is a dual-reflector antenna which consists of a paraboloid main reflector, whose focal point is coincident with the virtual focal point of a hyperboloid sub-reflector, and a feed, whose phase center is at the real focal point of the sub-reflector, as shown in Fig. 2.5. On the transmit side, the signal energy from the output of the high-power amplifier is radiated at the real focal point by the feed and illuminates the convex surface of the sub-reflector which reflects the signal energy back as if it were incident from a feed whose phase center is located at the common focal point of the main reflector and sub-reflector. The reflected energy is reflected again by the main reflector to form the antenna beam. On the receive side, the signal energy captured by the main reflector is directed toward its focal point. However, the sub-reflector reflects the signal energy back to its real focal point where the phase center of the feed is located. The feed therefore receives the incoming energy and routes it to the input of the low-noise amplifier through the OMT. A Cassegrain antenna is more expensive than a paraboloid antenna because of the addition of the sub-reflector and the integration of the three antenna elements -the main reflector, sub-reflector, and feed- to produce an optimum antenna system. However, the Cassegrain antenna offers many advantages over the paraboloid antenna: low noise temperature, pointing accuracy, and flexibility in feed design. Since the spillover energy from the feed is directed toward the sky whose noise temperature is typically less than 3O° K, its contribution to the antenna noise temperature is small compared to that of the paraboloid antenna. Also, with the feed located near the vertex of the main reflector, greater mechanical stability can be achieved than with the focal point feed in the paraboloid antenna. This increased stability permits very accurate pointing of high-gain narrow-beam antennas.

To minimize the losses in the transmission lines connecting the high-power amplifier and the low-noise amplifier to the feed, a beam wave-guide feed system may be employed. A Cassegrain antenna with a beam wave-guide feed system is shown in Fig. 2.6. The beam wave-guide assembly consist of four mirrors supported by a shroud and precisely located relative to the sub-reflector, the feed, the elevation axis, and the azimuth axis. This mirror configuration acts as a RF energy funnel between the feed and the sub-reflector and, as such, must be designed to achieve minimum loss while allowing the feed to be mounted in the concrete foundation at ground level. The shroud assembly acts as a shield against ground noise and provides

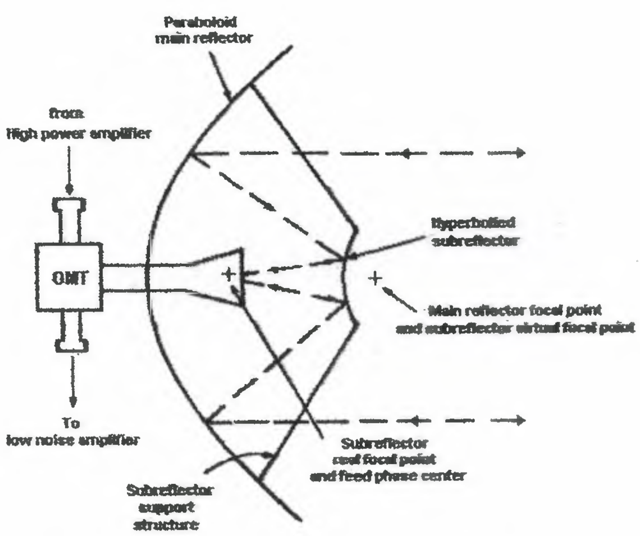
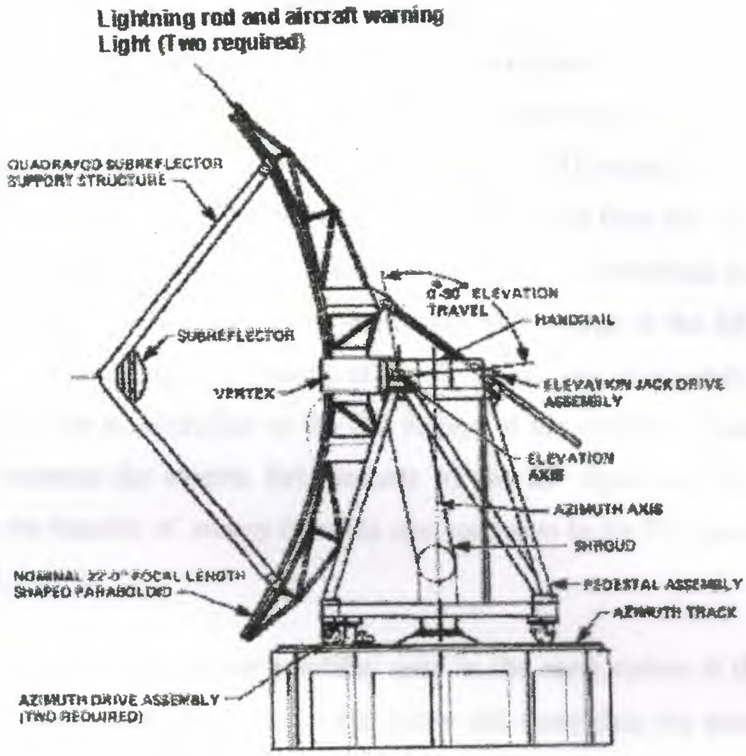


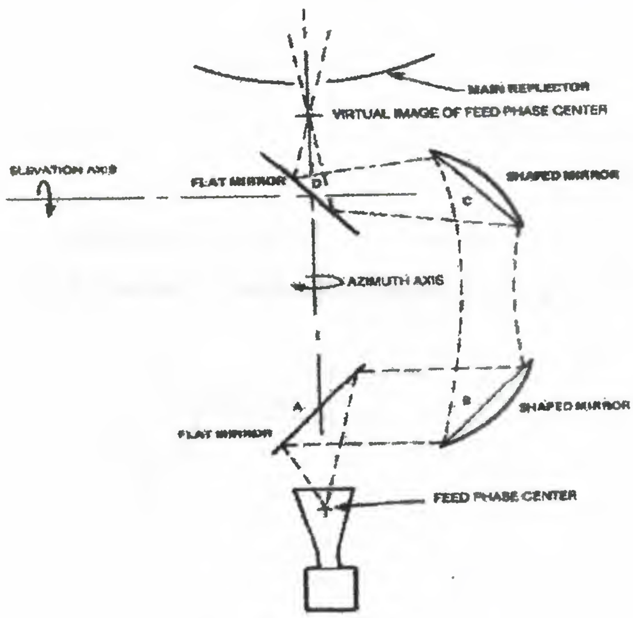
Figure 2.5 Cass grain Antenna

a rigid structure which maintains the mounting integrity of the mirrors when the antenna is subjected to wind, thermal, or other external loading conditions. The lower section of the shroud assembly is supported by the pedestal and rotates about the azimuth axis. The upper section of the shroud assembly is supported by the main reflector support structure and rotates about the elevation axis. The beam wave-guide mirror system directs the energy to and from the feed and the reflectors. The configuration utilized is based on optics, though a correction is made for diffraction effects by using slightly elliptical curved mirrors. For proper shaping and positioning of the beam Wave-guide mirrors, the energy from the feed located in the equipment room is refocused so that the feed phase center appears to be at the sub-reflector's real focal point. In operation, mirrors A, B, C, and D move as a unit when the azimuth platform rotates. Mirror D is on the elevation axis and rotates also when the main reflector is steered during elevation. In this way, the energy to and from the beam wave-guide system is always directed through the opening in the main reflector vertex.

As mentioned previously, modern communications satellites often employ dual polarizations to allow two independent carriers to be sent in the same frequency band, thus permitting frequency reuse and doubling the satellite capacity.



(a)



(b)

Figure 2.6 (a) a complete structure of cassegrain antenna (b) beam wave-guide feed

2.4.3 High Power Amplifier

One of the most widely used high power amplifiers in earth stations, the traveling wave tube amplifier. The traveling wave tube employs the principle of velocity modulation in the form of traveling waves. The RF signal to be amplified travels down a periodic structure called helix. Electrons emitted from the cathode of the tube are focused into a beam along the axis of the helix by cylindrical magnets and removed at the end by the collector after delivering their energy to the RF field. The helix slows down the propagation velocity of the RF signal (the velocity) to that of the electron beam , which is controlled by the DC voltage at the cathode. Those results in an interaction between the electric field include by the RF signal and the electrons, which result in the transfer of energy from the electron beam to the RF signal causing it to be amplified.

Another type of high power amplifier used in the earth station is the Klystron amplifier, which can provide higher gain and better efficiency than the traveling wave tube amplifier but a much smaller bandwidth. For low power amplification GaAs FET amplifiers are used. These are solid state amplifiers and offer much efficiancy than the above two types of amplifiers.

2.4.3.1 Up-converter

The Up converter accept the modulated IF carrier and translate its frequency ω_0 to the uplink frequency ω_u by mixing ω_0 with a local oscillator frequency ω_1.

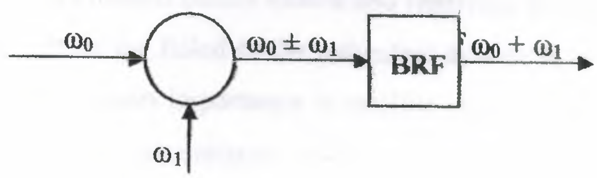


Figure2.7 Function of up-converter

The up conversion may be accomplished by with a single or double conversion preprocess.

2.4.3.2 Down-converter

The down-converter receives the modulated RF carrier from the low noise amplifier and translates its radio frequency ω_d in the down-link frequency spectrum of the satellite to the intermediate frequency ω_0. Like up-conversion, down-conversion may be achieved with a signal conversion process or with a dual conversion process using mixer.

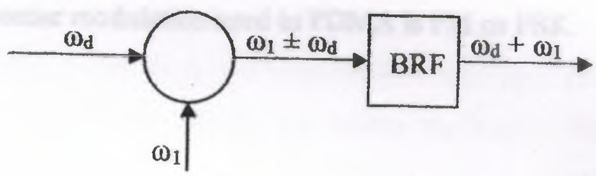


Figure 2.8 function of down converter

2.4.3.3 Redundancy Configuration

As we have seen in previous sections, except for the antenna all earth stations systems namely, the high-power amplifier, the up-converter, and the down-converter, must employ some sort of redundancy to maintain high reliability which is of utmost importance. When the on-line equipment in the redundancy configuration fails The standby equipment is automatically switched over and becomes the on-line equipment .The process of detecting critical failure modes and resolving all these failure modes by automatic switchover from the failed to the redundant system is called monitoring and control. Reliability is of utmost importance in satellite communications. When a single high-power amplifier is used, transmission will stop upon its failure. Therefore the high-power amplifier in earth stations always employs some sort of redundancy configuration.

2.5.1 Frequency Division Multiple Access

FDMA has been used since the inception of satellite communication. Here each earth station in the community of earth stations that share the transponder capacity transmits one or more carriers to the satellite transponder at different center frequencies. Each carrier is assigned a frequency band in the transponder bandwidth, along with a small guard band to avoid interference between adjacent carriers. The satellite transponder receives all the carriers in its bandwidth, amplifies them, and retransmits them back to earth. The earth station in the satellite antenna beam served by the transponder can select the carrier that contains the messages intended for it. FDMA is illustrated in Fig. 2.9 The carrier modulation used in FDMA is FM or PSK.

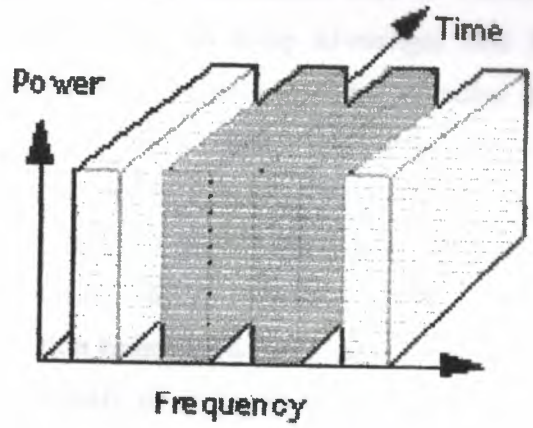


Figure 2.9 Concept of FDMA

The following are the features of FDMA:

1) If channel not in use, sits idle
2) Channel bandwidth relatively narrow (30kHz), ie, usually narrowband systems
3) Symbol time >> average delay spread .little or no equalization required
4) Best suited for analogue links bits needed

5) Requires tight filtering to minimize interference
6) Usually combined with FDD for duplexing

2.5.2 Time Division Multiple Access

In TDMA the earth stations that share the satellite transponder use a carrier at the same center frequency for transmission on a time division basis. Earth stations are allowed to transmit traffic bursts in a periodic time frame called the TDMA frames During the burst, an earth station has the entire transponder bandwidth available to it for transmission. The transmit timing of the bursts is carefully synchronized so that all the bursts arriving at the satellite transponder are closely spaced in time but do not overlap. The satellite transponder receives one burst at a time, amplifies it, and retransmits it back to earth. Thus every earth station in the satellite beam served by the transponder can receive the entire burst stream and extract the bursts intended for it. TDMA is illustrated in Fig. 2.10 The carrier modulation used in TDMA is always a digital modulation scheme. TDMA possesses many advantages over FDMA, especially in medium to heavy traffic networks, because there are a number of efficient techniques such as demand assignment and digital speech interpolation that are inherently suitable for TDMA and can maximize the amount of terrestrial traffic that can be handled by a satellite transponder. For example, a 72-MHz transponder can handle about 1781 satellite PCM voice channels or 3562 32-kbps adaptive differential PCM channels. With a digital speech interpolation technique it can handle about twice this number, 3562 terrestrial PCM voice channels or 7124 32-kbps adaptive differential PCM voice channels. In many TDMA networks employing demand assignment the amount of terrestrial traffic handled by the transponder can be increased many times. Of course these efficient techniques depend on the terrestrial traffic distribution in the network and must be used in situations that are suited to the characteristics of the technique. Although TDMA has many advantages, this does not mean that FDMA has no advantages over TDMA. Indeed, in networks with many links of low traffic, FDMA with demand assignment is overwhelmingly preferred to TDMA because of the low cost of equipment.

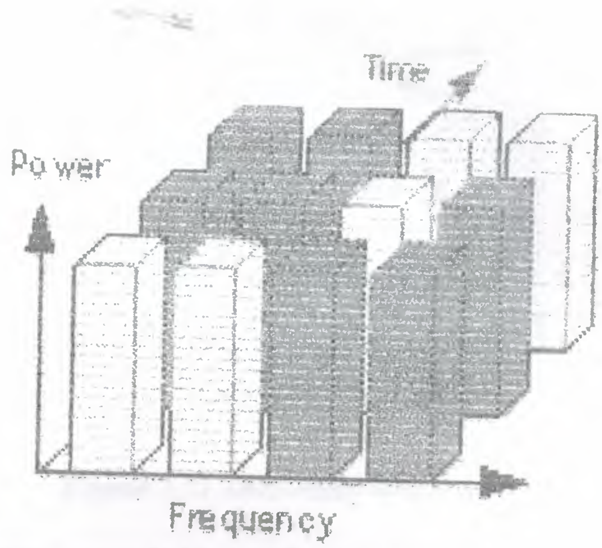


Figure 2.10 Concept of TDMA

Besides FDMA and TDMA, a satellite system may also employ random multiple access schemes to serve a large population of users with bursty (low duty cycle) traffic. Here each user transmits at will and, if a collision (two users transmitting at the same time, causing severe interference that destroys their data) occurs, retransmits at a randomly selected time to avoid repeated collisions. Another type of multiple access scheme is code division multiple access, where each user employs a particular code address to spread the carrier bandwidth over a much larger bandwidth so that the earth station community can transmit simultaneously without frequency or time separation and with low interference.

TDMA has some advantages that are, In addition to increasing the efficiency of transmission, TDMA offers a number of other advantages over standard cellular technologies. First and foremost, it can be easily adapted to the transmission of data as well as voice communication. TDMA offers the ability to carry data rates of 64 kbps to 120 Mbps (expandable in multiples of 64 kbps). This enables operators to offer personal communication-like services including fax and voiceband data, as well as bandwidth-intensive applications such as multimedia and videoconferencing.

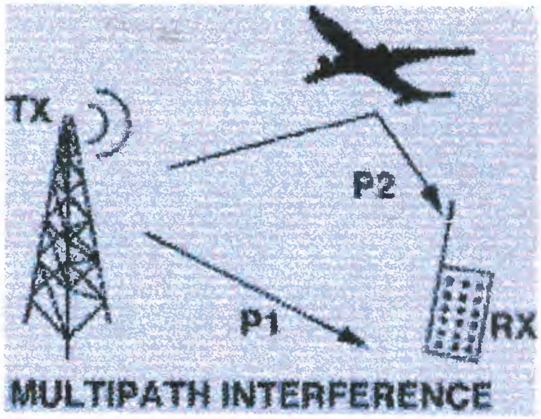


Figure 2.11 Multi-Path Inter-Face

One way of getting around this interference is to put a time limit on the system. The system will be designed to receive, treat, and process a signal within a certain time limit. After the time limit has expired, the system ignores signals. The sensitivity of the system depends on how far it processes the multipath frequencies. Even at thousandths of seconds, these multipath signals cause problems.

2.5.3 Code Division Multiple Access

Code division multiple access (CDMA) is actually a hybrid combination of the use of FDMA and TDMA. Users are assigned to different codes which govern the time slot and frequency band for the signal transmission, see Fig. 2.12. At one instant (time slot), a user is only allowed to use one of the frequency bands which is unoccupied by the others. By this scheme, the channel capacity can greatly increase with the minimum degree of interference by the other users.

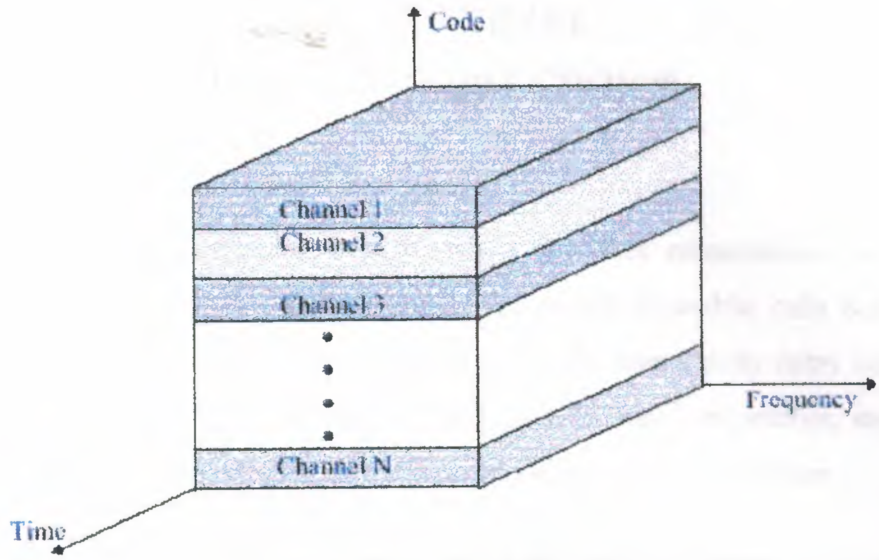


Figure 2.12 Concept of CDMA

CDMA is an application of spread spectrum (SS) techniques which can increase the channel capacity for signal transmission and reduce interference by the other users.

CHAPTER THREE

SATELLITE ORBIT CHOICE

3.1 Intersatellite links

The intersatellite-link (ISL) approach, where satellites communicate directly with each other by line of sight, makes support for mobile-to-mobile calls between different satellite footprints, within the constraints of a tight interactivity delay budget, far easier than the GEO approach (despite introducing additional complexities, such as handover between satellites), and removes traffic from the ground infrastructure.

Adding ISLs also introduces flexibility in routing, builds inherent redundancy into the network, and avoids the need for visibility of both user and gateway by each satellite in the constellation.

One of the consequences of having ISLs is that, for ease of construction of the satellites, fixed intersatellite link antennas are preferable. This may not be possible in the interplane case between satellites in different orbits, as the line-of-sight paths between these satellites will change angle and length as the orbits separate and converge between orbit crossings, giving rise to:

- high relative velocities between the satellites
- tracking control problems as antennas must slew around
- Doppler shift

However, fixed antennas are possible in the intra-plane case, i.e. between satellites at different phases on the same orbital path, provided that the orbits are circular.

This can be considered a result of Kepler's second law, where equal areas of arc of the orbital plane are swept out in equal times. With elliptical orbits, a satellite would see the relative positions of satellites 'ahead' and 'behind' appear to rise or fall considerably throughout the orbit, and controlled pointing of the fore and aft intraplane link antennas would be required to compensate for this. Choosing circular orbits avoids this technical complication.

The choice of circular orbits also has the advantage of allowing a relatively constant ground footprint size and shape with constant link and delay budgets (albeit with some variation due to the oblate ness of the earth and other perturbing factors), avoiding the problem of *zooming*. As a result of this, most proposed satellite constellations adopt circular orbits.

(The exception to this rule is *Ellipso*, where worldwide coverage is foregone in favour of the apparently-hanging-in-the-sky effect at high latitudes of certain elliptical orbits where is 63.4°. Other orbits with this inclination but different periods are the Molnya (12-hour) and Tundra (24-hour) orbits; Ellipso uses 3-hour retrograde sun-synchronous orbits and an additional equatorial orbit. These inclined orbits allow increased coverage of more profitable densely-populated regions, at the expense of no coverage of regions considered unprofital

3.2 Choice of orbit

Now we have decided upon circular orbits, we can consider the following cases:

3.2.1The star pattern

Here, the inclination of the orbits to the equator, δ, is a constant 90°, so that all of the orbits cross at the poles, and if viewed from one of the poles the orbital planes intersect to make a star.

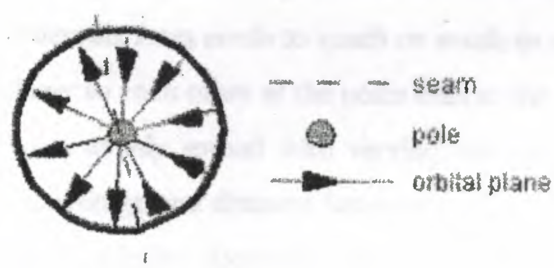


Figure3.1: Polar view of star pattern

The right ascensions of the ascending nodes of the p orbital planes $\Omega_1 .. \Omega_p$ are such that they are approximately evenly spaced, with the exception of the two contra-rotating planes at the ring edges, where there cannot be ISLs due to the high relative speed (twice the orbital speed) of the satellites moving in opposite directions. Here the separation between the contra-rotating planes is slightly less than between other planes, to ensure full, overlapping, ground coverage.

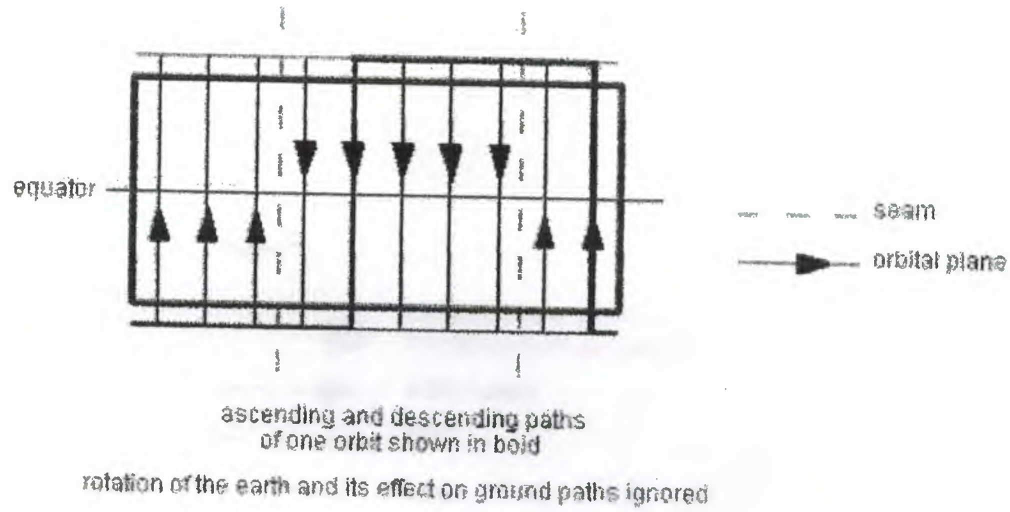


Figure 3.2 Mercator projection of constellation

Figure 3.2 ignores the effect on the orbital paths of the earth's rotation. The effect of the earth's rotation on orbital paths is shown in Appendix

With the exception of the poles, any point on the earth's surface will see satellites moving at even intervals from north to south or south to north. As satellites in neighbouring planes are closer to each other at the poles than at the equator, coverage of the polar constellation is not evenly spread with varying latitude. The equator is the largest separation that the coverage and distance between orbits must be defined for. At the poles, the overlapping of satellite footprints will cause interference and multiple coverage, requiring some footprints to be disabled, and the high relative velocities of satellites traveling in neighboring planes will make maintaining ISLs very difficult due to Doppler shift and the need to slew antennas around 180° to track satellites continuously across the pole.

To get an idea of the network shape, we can take the network off the earth, breaking the ring formed by the orbital planes, and lay it flat Figure 3.3.

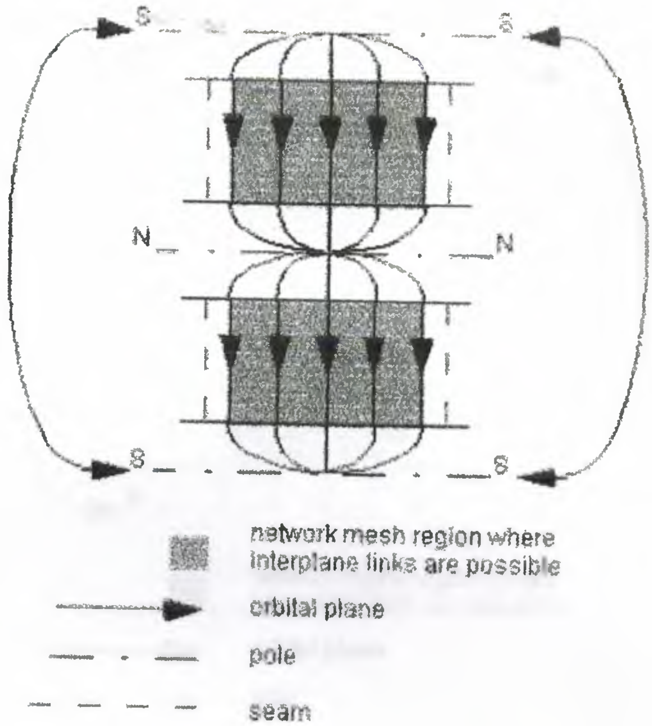


Figure 3.3:Flattening the network

Join one pole to itself (SS to SS) and stretch the network around so that the seams are adjacent, and the sphere returns.

We can simplify this diagram still further by saying that it is topologically equivalent to the same diagram with the half-twists, caused by orbits crossing each other at the poles, and removed; giving us an easier-to-visualize rectangle Figure 3.4.This assumes that there are no ISLs near the poles when we do this.

Our constellation network has the topology of a ring, whose edges are formed by the seam. (Strictly speaking, now we have untwisted it is a cylinder, as a ring is really an orbital plane with no thickness. However, we will stick with the 'ring' notation to remind us of the untwisting, as uniform cylinders are rarely twisted in this manner. Even when simulating uniform cylinders later, the 'ring' notation will be used.)

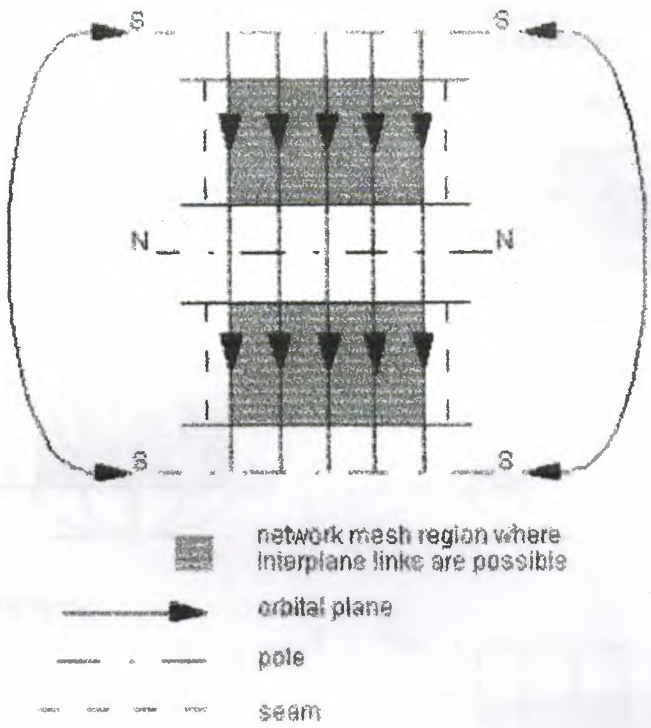


Figure 3.4 Untwisting the network

The seam imposed by the contra-rotating planes, where there are no ISLs, can make routing longer because traffic between opposite parts of the earth must be passed via intra-plane links over the poles. The distance in the network between two ground stations on the earth will vary, depending on where the seam is, and the communication time between them will vary as a result of this [Figure 3.5]. Although the ground stations are always the same physical distance apart on the earth's surface, the apparent network distance between them changes with time in a seamed network.

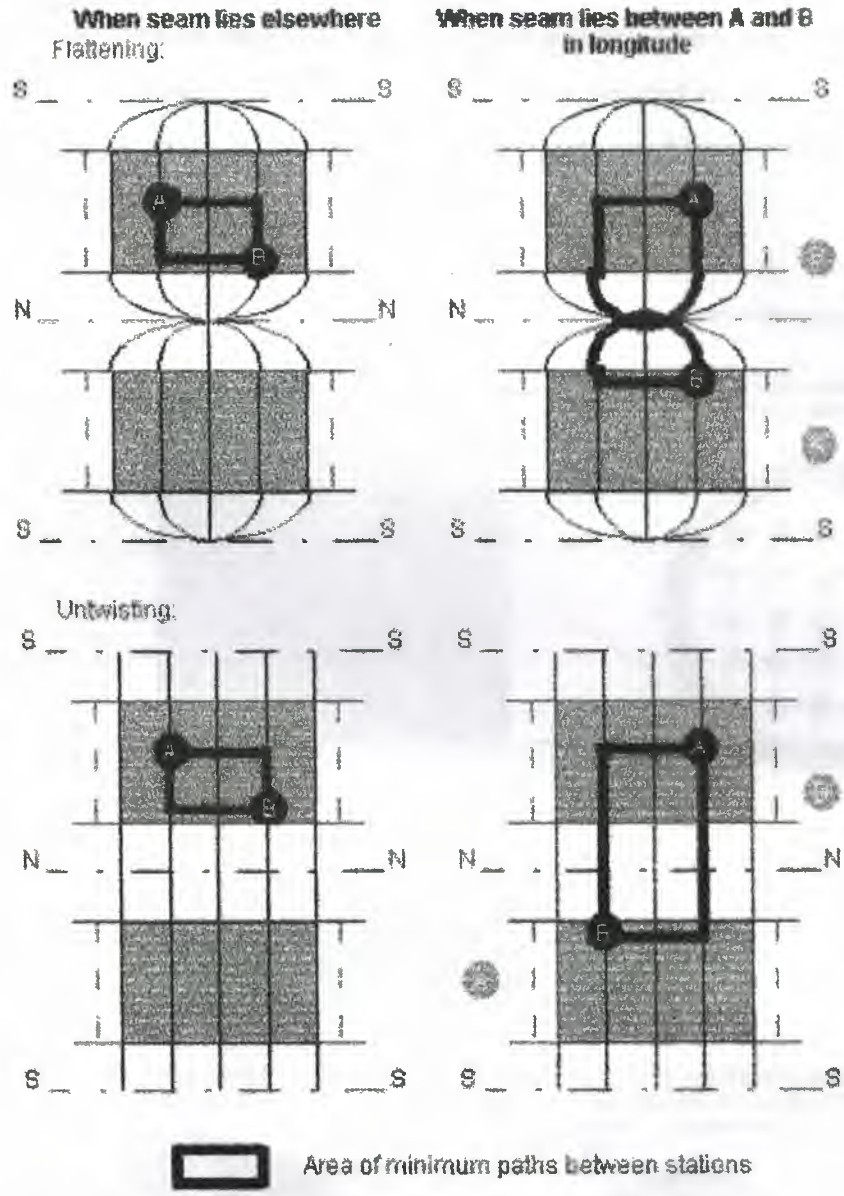


Figure 3.5 How seam position varies apparent network distance

If we double the number of orbital planes, so that each plane overlaps entirely with its retrograde, we can eliminate this seam. However, we then use double the number of satellites, and we have two planes of satellites at any point. This is *double network coverage*, so that any point on the ground has not just one, but two distinct and widely separated areas of the network that it can see and communicate with. (This network coverage is a somewhat different and separate concept to the *double global coverage* detailed in *AdRid87*, which is concerned with seeing two satellites at a time from any point within given latitudes on the earth.)

The ring has been widened so that its longitudinal seam edges now wrap over and touch themselves. With all edges touching, you have a torus. This torus maps onto a sphere. To do that, the diameter of the axis of the torus is reduced to zero, so that the two 'sides' of the torus coincide. We can obtain the same double-network-coverage sphere from a square mesh [Figure3.6].

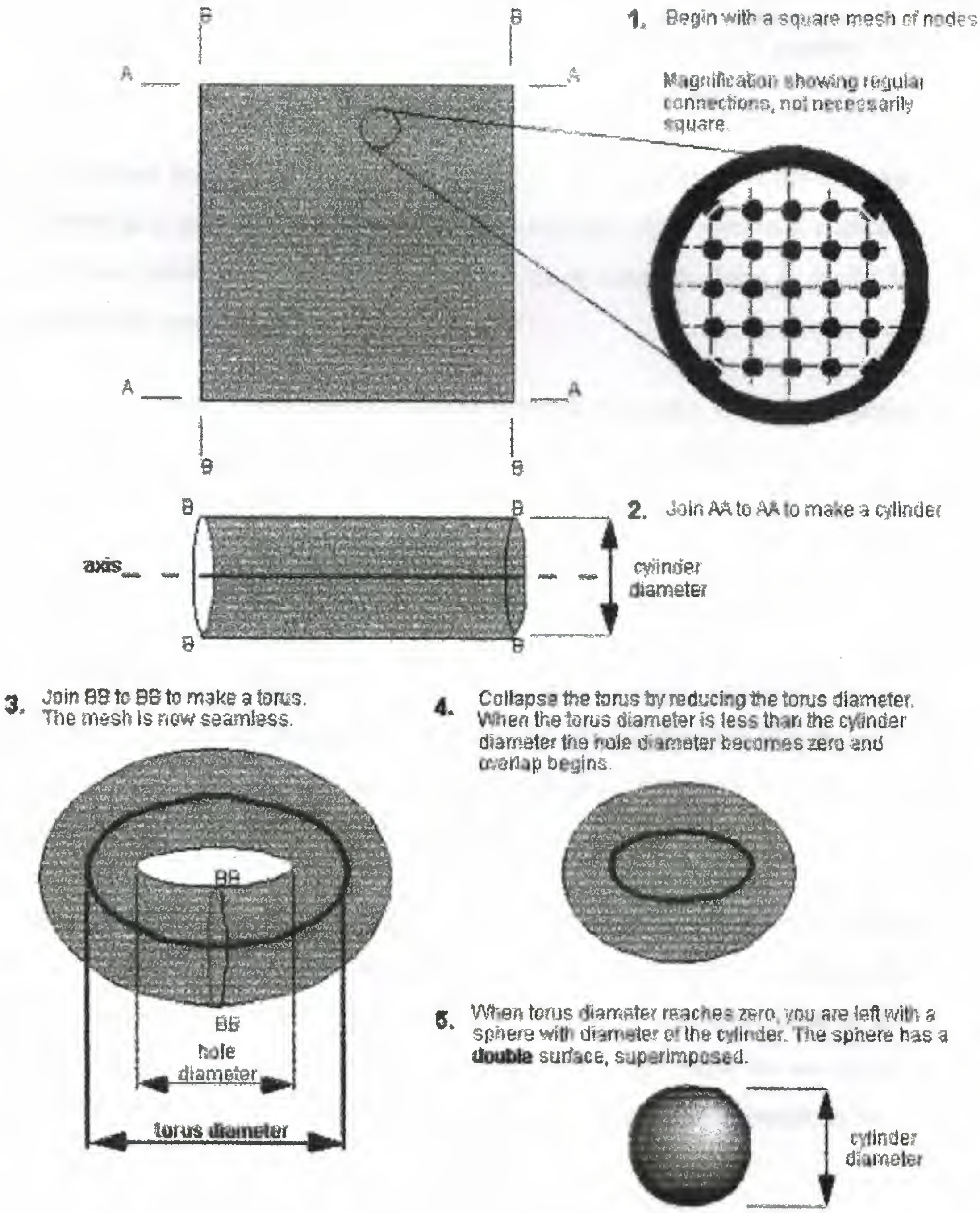


Figure3.6 Constructing your own seamless mesh thought model

In shrinking the model, there is a change in surface area by altering sizes of links. Let the original square grid be size n by n. Then the cylinder is length n and circumference $n=2\pi r$, and the torus diameter is also r, as the circle cut by that diameter is again $n=2\pi r$, from the cylinder length. The torus is then shrunk to give a double-surface sphere of radius r, surface area $2 \times 4\pi r^2 = 8\pi r^2$.

We began with a grid of area of $n^2=(2\pi r)^2=4\pi^2 r^2$, or a factor of $\frac{\pi}{2}$ greater. We still have the same number of nodes; all the shrinkage has been in the links.

(Here, as there is no seam, there is no change in the network distance between two points, which is a constant. A seamless network can therefore give us a constant delay between two points, which may be important as a constant delay is useful in interactive multimedia applications.)

This double-surface sphere gives us double network coverage, where each point on the ground sees two planes of network and two widely-separated points in the network, one in each plane. If a station on the ground can see two points, it can communicate with those points. If those points are in different planes, the point on the ground is communicating with two distinct and separate parts of the network.

Such a double-plane constellation cannot be conveniently described by the number of satellites/number of planes/number of distinct phases notation introduced in *Walker71*. This notation does not fully indicate the topology or size of the network, and so is not really suitable for satellite networks.

Being able to put traffic into the mesh network at more than one point, or visible node, from one point on the ground, complicates analysis. The wide separation and relationship of the two input points raises a number of analysis problems. What is the network diameter? Does the independence assumption still hold? How do we decide which point the traffic will use to enter the network at any time? These questions need to be investigated.

Wange95 discusses seamless network coverage, but does not appear to realize that double network coverage is a result of any seamless network, that twice the number of satellites is needed for the seamless networks that he attempts to analyse, and that ignoring this invalidates his analysis.

The case of single network coverage with seam, giving the network topology of an equatorial-axis twisted ring, is much more likely to be implemented, as in *Iridium* and in *Teledesic*, and therefore of more interest to us.

3.2.2 Reducing double network coverage - polar cut

With double network coverage in a star constellation, it would be feasible for the satellites to be carrying traffic for only half of their orbits, so that, around the globe, the functioning network is seen as a flow of satellites from one pole to the other, and we have reduced seamless double coverage to single coverage with a polar-axis cylinder, with unidirectional flow across the cylinder and with no longitudinal seam. Satellites in the network reaching a pole fall out of the network and are silent while they come back in the opposite direction to the in-network satellites, and are then enabled as part of the network when they return to the first pole.

This makes full inter-plane communication with single, rather than double, network coverage possible, at the expense of intra-orbit communication over the poles, where communication between the different orbits in different directions is not possible.

However, as this polar-cut single network coverage requires half the network doing nothing at any one time, and doubles the number of satellites to be launched and operated, this approach is both expensive and inefficient, although splitting a seamless double network coverage torus into two polar-cut single-network-coverage polar-axis cylindrical networks is interesting.

3.2.2.1 Reducing double network coverage - Manhattan

There is a way to resolve the problem of double network coverage and yet still be seamless. This involves using the Manhattan network, a computer network based upon the surface of a torus, as the basis for our satellite constellation.

In the Manhattan network, each node or computer lies on two rings in orthogonal directions. Data travels around these rings in one direction only, so that each computer has two network inputs and two network outputs. If the data can travel either way around the ring, we have a bi-directional Manhattan network.

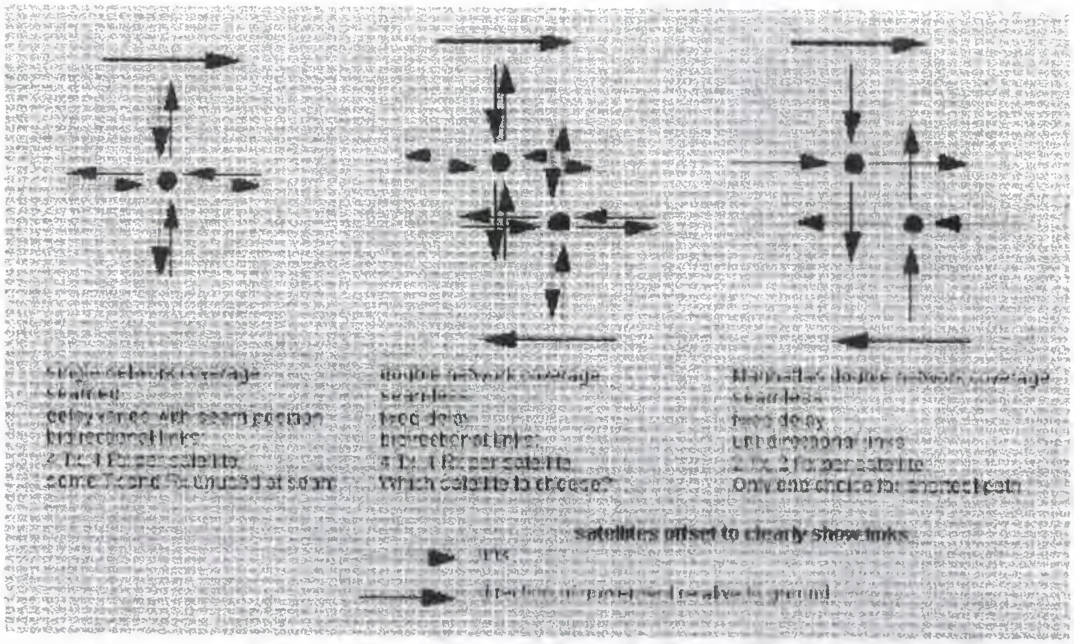


Figure3.7 Single, double and Manhattan network coverage

In assuming that each satellite communicates with all its neighbors by sending and receiving information directly, we are assuming a form of bi-directional Manhattan network. This gives us the double network coverage and seeing two planes of the network from the ground that wrapping a torus onto a sphere implies, along with the resulting redundancy.

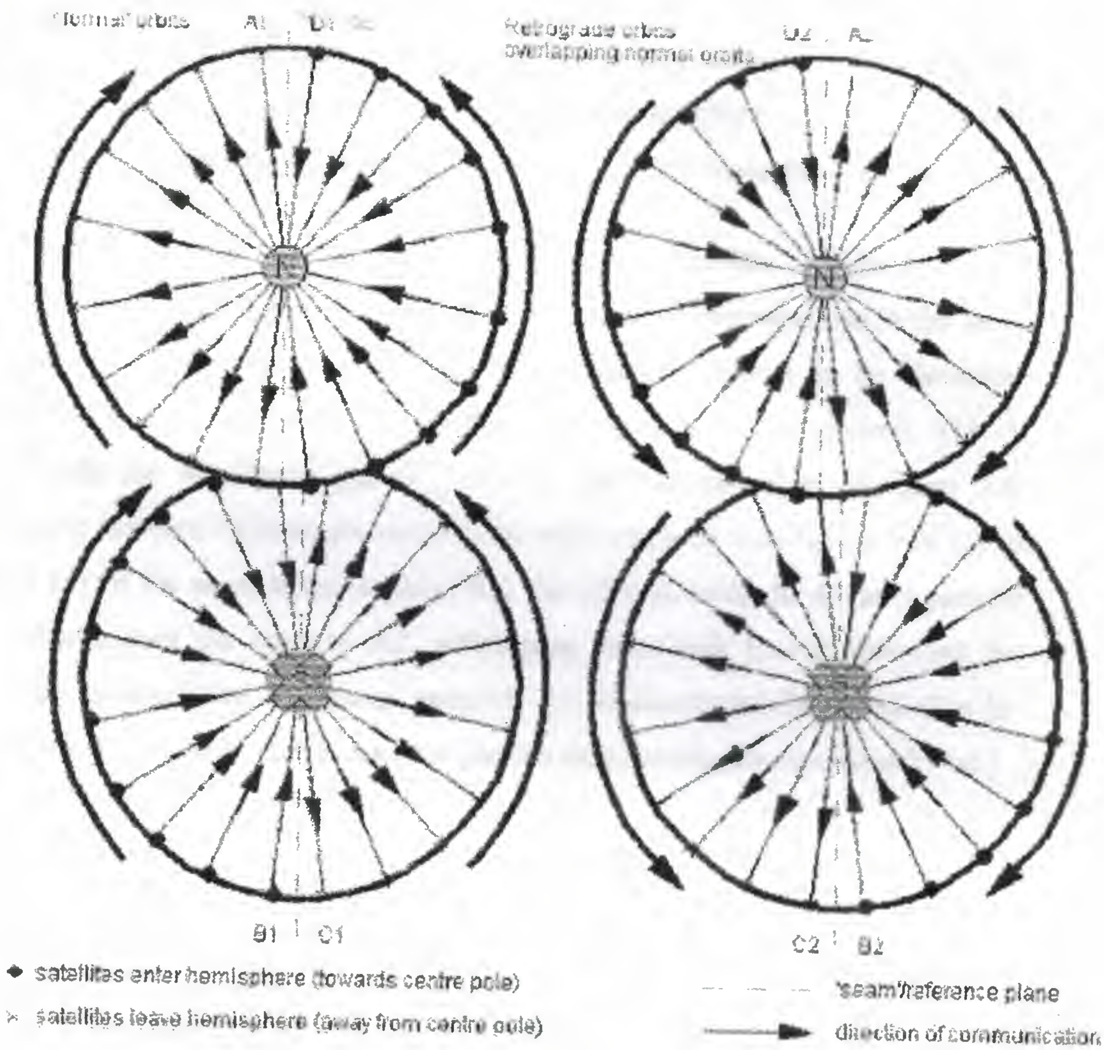


Figure 3.8 A seamless Manhattan satellite constellation with fewer ISLs

However, this need not be the case. If we have double network coverage or bi-directional Manhattan, we have more links than we need to ensure full communication. By reducing the links to the Manhattan case, as shown in Figure 3.7, we still have a fully-connected constellation network, and the ground station chooses the satellite it wishes to send to depending on where it wants to communicate with in order to obtain the shortest route.

A full seamless Manhattan constellation is shown in Figure 3.8. This shows all hemispheres as viewed from the North Pole. The southern hemispheres are inverted and viewed through the earth, as if the earth was made of glass, as indicated by the dots and crosses at the poles. This allows a satellite's path to be followed off the edge of one hemisphere by moving to the same position on the touching hemisphere, although this viewing approach means that forward-and-right in one hemisphere is seen as forward-and-left in the other, as we switch between viewing the satellite from above and below.

In both the normal (1) and retrograde (2) orbits, a satellite or node will travel between half-hemispheres in the order ABCDA, as will all communications in the same orbital plane. (In Figure 3.7 we chose intraplane communications to be 'forwards' instead of 'backwards' relative to the satellites' movement over the ground. This is arbitrary.) With the Manhattan two T_x, two R_x satellites described in figure 3.6, communication between different planes over the seam can pass from hemisphere (1) to hemisphere (2) of the same letter or back. So, the 'normal' orbits in A1 pass packets round clockwise over the seam to A2, which pass them back to A1, following the arrows. (The bi-directional Manhattan network has bi-directional links and thus bi-directional arrows indicating that it can pass packets either clockwise or anticlockwise.)

Figure 3.9 Cross-section through the equator

The seam is no longer really a seam, since communications pass over it due to the nature of double coverage. In fact, the seam is now simply a reference plane the orbits are placed relative to, and this reference plane can be at any longitude.

If we look at the equator and plot both normal and retrograde orbits' hemisphere entry/exit points, we can see the wrapped torus discussed in Figure 3.6 clearly. [Figure 3.9].

Seamless networks allow fixed-delay communication between two ground stations, as there is no seam changing position relative to the ground stations. The bi-directional Manhattan network, or double-network-coverage constellation, offers the ground station a choice of satellites for paths of the same delay length.

The Manhattan network, which has fewer links, offers the ground station the choice of a long path and a short path (not necessarily as short as in the bi-directional case) via different satellites in different network planes. However, for shortest-path communications between two ground stations, this means that a ground station must receive from one network plane and send to the other plane. (Overlap of spot beams of satellites traveling in different directions makes this difficult, but use of ground-fixed cells, as in *Teledesic*, should simplify the implementation.) Provided that delays of equal length both ways are not needed, only one overhead satellite can be used for both sending and receiving.

Manhattan networks are extensively discussed in computing literature [e.g. GoodGreen86, Maxemchuk87], and recognizing that the satellite network constellation can be a bi-directional or unidirectional Manhattan network allows this literature to be applied in modeling the network performance.

The lack of redundancy in the Manhattan constellation network means that a single link failure can increase delay times considerably. This, coupled with the problems of technical implementation for satellite diversity, so that shortest network paths can be achieved by sending to one network layer and receiving from the other, makes implementing the Manhattan constellation network technically difficult.

The number of satellites that must be launched for a seamless network, and the problem of double network coverage, make building any form of seamless constellation network of little benefit unless fixed delay between ground stations is essential.

However, this does not invalidate the seamless network as a starting point for analysis, provided that we are aware of the limitations of the assumptions we make.

3.2.2.2 The Delta Pattern

The delta pattern, as discussed in detail in Walker71, is a more general constellation case than the polar case. The orbits are inclined with constant inclination δ, and the even spacing of the right angles of the ascending nodes $\Omega_1 .. \Omega_p$ ensures full ground coverage. There is no coverage above a certain latitude depending upon the size of δ, and to ensure that there is no break in the ground coverage below that latitude it is necessary to add more orbital planes and adjust orbital spacing until each direction wraps around to join itself, giving the *double network coverage* discussed above.

The delta pattern can be thought of as equivalent to the double-coverage star, but for a narrower band of latitudes about the equator. Again, it would be possible for satellites traveling towards one pole to 'drop out' of the network, effectively giving the topology of a polar-axis single-coverage cylinder, or for the double-coverage delta pattern to be split into two single-coverage networks in this way.

The delta pattern with a very high inclination and the extra orbits giving double network coverage removed is very similar to a star pattern. For *Iridium*, δ=86.4°, and the problem of maintaining ISLs at high latitudes and high relative velocities is simply avoided by having only three lines of interplane ISLs around the equator, where the relative velocities of satellites in different orbital planes are low.

A seamless delta network gives double network coverage of each point on the ground under the network, leading to complex ground-space analysis or simply turning the satellites off for half the time, just as previously discussed for the double-network-coverage star network.

It would be possible to place our orbits with constant inclination to any reference plane, which does not have to be the equator. However, if we place the orbits with constant inclination to a plane other than the equator, we complicate the ground paths, and the varying action of precession due to the oblate ness of the earth will act to distort the network, making controlling ground coverage and maintaining ISLs via pointing much more complex. As a result, the equator is the only reference plane we consider.

3.2.2.3 Other Great-Circle Patterns

These are circular orbits of varying inclination δ and spacing Ω that attempt to distribute orbital coverage in all dimensions. A large number of different constellations are possible. However, varying inclinations result in varying precessions due to the oblate ness of the earth, making it difficult to maintain relative orbital positions between orbital planes and thus the network topology via ISLs.

Clare87 details the constellations where the satellites are placed at the vertices of Platonic solids centered on the earth to ensure even coverage (effectively a subset of the delta network with the addition of an equatorial orbit), provides diagrams showing orbital positions, and does some traffic analysis of the resulting ISL networks. The differential precession problem caused by varying inclination is avoided as all orbits are at the same inclination, with the exception of the equatorial orbit, which is completely unaffected by precession. However, the large angles between orbital planes for the simple Platonic solids (which must also be Archimedean solids for even ground coverage) make maintaining ISLs difficult, as satellites in neighboring planes have large relative speeds with increased Doppler shifts, and pointing is difficult. The lack of precession of the equatorial orbit will cause equatorial satellites to fall out of sync with the other satellites.

Ballard80 concentrates on the bounds of multiple satellite visibility by interleaving low-inclination multiple planes containing few satellites and using careful phasing to fill in the gaps between satellite footprints in the same plane. This does not use the 'street of coverage' approach (required for near-polar constellations with near-parallel planes) that is assumed by Walker and detailed in Rider85. Although interleaving and careful phase alignment of planes for coverage is adopted by *Globalstar* to decrease the number of satellites required, it places severe constraints on inter-satellite networking, and we will not consider it further here.

Like the other constellation patterns outlined earlier, these orbital patterns will repeat at regular intervals, so analysis of a quasi-stationary constellation is possible. Despite their even ground coverage, these patterns pose difficulties for ISLs, with disadvantages that the delta and star configurations do not have. We will not examine these patterns further here.

3.3 The Seamless Assumption

So far, we have decided upon a seamed star or near-polar delta single-network-coverage satellite constellation network consisting of a number of inclined circular near-polar orbit planes in which the satellites travel. However, a seamed network is difficult to analyze.

Provided that we account for the effects of double network coverage, we can begin analysis with a seamless, truly homogeneous network where every satellite node is identical, sees the same network in the same way, and considers itself to be the centre of the network. This ***homogeneous network*** is a useful starting point for mathematical analysis, from which we can approach the much more likely seamed case with single coverage, provided we remember the differences between seamed and seamless networks and do not equate single and double network coverage.

3.4 The Satellite Node

Each one of the satellites in the constellation network, which communicates with other, neighboring, satellites via ISLs, and communicates with its associated ground station and associated pool of mobile users, is a ***node*** in the constellation network .

A node will have a number of connecting ISLs, or just links, to neighboring nodes in the network. Traffic can pass either way between nodes connected via a link in this way. KleSil83 defines the degree of a node, N, to be the number of nodes in the network the node can communicate with, including itself. However, when we look at a network, we can easily count the number of connections to other nodes a node has. As in Wang94, let's call this number N_c , and then

$$N_c = N - 1 \qquad \textit{Equation } \textbf{(3.1)}$$

Since we are initially considering a homogeneous mesh network, N and N_c will have constant values for each node in the network.

Packets arriving and leaving a node via ISLs can consider being within the constellation network. However, packets originating from the earth - either the associated ground station or the mobile users - are entering the network at this node. As far as the rest of the constellation network is concerned, the node is the *source* of these packets. Similarly, packets exiting the constellation network at a node to the ground station or mobile users leave the network at this node, and the network considers the node to *sink* these packets. During a two-way interactive connection sending packets across the network, there will be two nodes both *sourcing* and *sinking* packets entering and leaving the network.

We will ignore traffic generated at a node within the network, say for network control purposes, as this should be very small compared to the traffic travelling through the network from the earth. However, a node can act as both source and sink at once, in the case of mobile users communicating with the local ground station in the satellite footprint.

In graph theory terms, our satellite *nodes*, where *links* intersect, are described as *vertices*, where *edges* intersect. We are considering bi-directional communication, so that each line we draw on a graph of a network is really two links or edges in opposite directions between common vertices or nodes. This gives us a specific form of a digraph. We will adopt the notation of nodes (from computer networking) and links (from the satellite field) in the hope that these are more familiar to the reader.

3.5 The Orbital Plane

To ensure continuous ground coverage we put more than one node in the same circular orbit. Let the number of nodes in an orbit be n. It is sensible to space these nodes evenly around the circular orbit, so the phase separation between each node is $(360/n)^\circ$.

Since we want ISLs between nodes, n must be sufficient to allow line-of-sight communication between the nodes without blockage by the earth. Each of the n nodes will communicate with the neighboring node ahead of it (the previous node relative to the ground) and behind it (the next node relative to the ground), forming a ring of communication in the ring of the orbit [Figure 3.10]. We can see that this is the case $N_c = 2$.

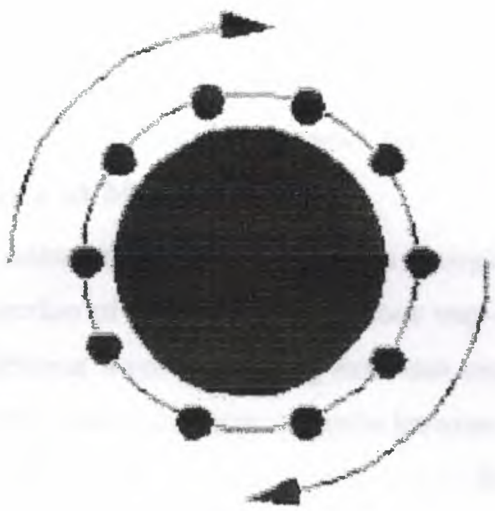


Figure 3.10: Single orbital plane

All of the nodes in the same orbit are on the same orbital plane, and we will call communication with nodes ahead and behind *intraplane* (within the plane) communication. For a circular orbit, this intraplane communication can be by fixed antennae or by optical link, as the nodes will always be in the same position relative to one another.

3.6 The Minimum Path

3.6.1 The Path

We can define a *path* as a series of connected links between a source node and a sink node. These nodes will communicate with each other via one or more paths made up of one or more links between neighboring nodes. How the paths are used is up to the routing strategy. Datagram traffic might select individual links at random and pass traffic in the direction of the sink node, or use deflection routing, while wormhole routing and circuit-switched connections such as ATM will be concerned with choosing and using a set of paths between source and sink.

3.6.2 The Minimum Path

A *minimum path* is the shortest possible path between two communicating nodes, and is determined simply by counting the links in possible paths and taking the least number to get from source to sink. (We are not considering length of links, or propagation delay, at this point. This can be introduced later as *link weighting.)* In the meshes that we are considering, there is one minimum path between neighboring nodes, and more than one minimum path between nodes that are not neighbors.

3.6.3 Number of Minimum Paths

Two communicating nodes can be thought of as sitting at the corners of a rectangular section of mesh made up of four way-connected nodes, or a *grid*, and the number of different ways of traveling from one terminating node to the other, in either direction, is the number of minimum paths between those two nodes. (When $N_c = 4$ and the edges of the grid are joined to each other to form a torus, this is generally called a *bidirectional Manhattan network*. The Manhattan network is a two-dimensional arrangement of uni-directional ring networks named after the rectangular one-way street pattern in that part of New York. The Manhattan network itself is discussed in 3.2.2.1.)

This number of minimum paths in the grid can be found by superimposing Pascal's triangle upon the grid. As we move out from the source node across the grid, we can sum the number of ways to get to an intermediate node, which is the number of distinct minimum paths to that node, as the sum of the number of ways we got to nodes neighboring that node. This simple summation builds up Pascal's triangle, which shows us that there are more minimum paths, and thus more traffic, passing through the centre of the grid [Figure 3.11].

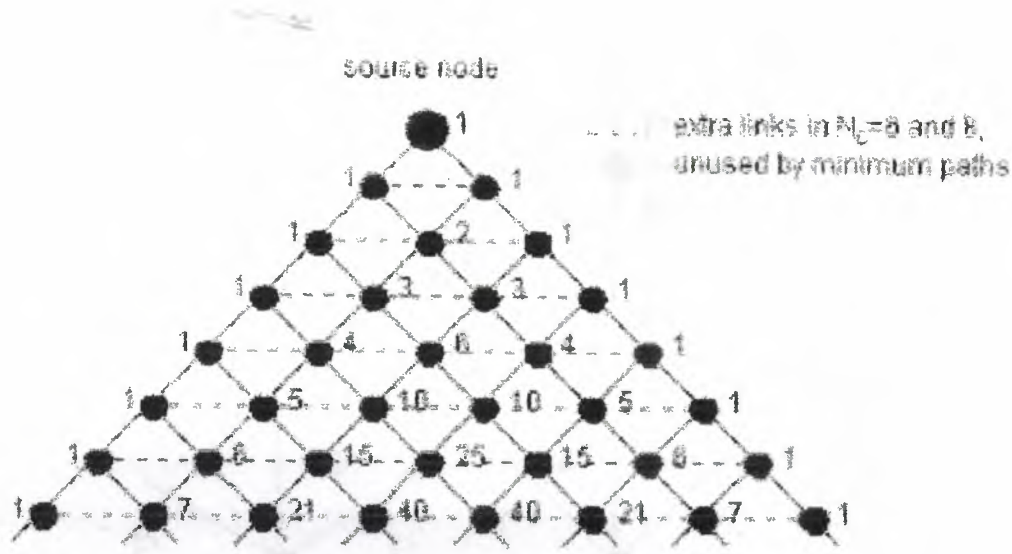


Figure 3.11 Pascal's triangle for minimum paths

At each point in Pascal's triangle, the number of paths you can take from the topmost node to a destination node is given by the sum of the numbers of paths to the last nodes you could have passed through on your way down.

This applies to the cases $N_c = 2$ (although analyzing a one-dimensional grid in this way is overkill, since you simply travel down one edge of Pascal's triangle and are forever 1-1-1-1), and the cases $N_c = 4$, 6 and 8, where N_c Pascal's triangles are joined edge-to-edge around the node of interest [Figure 3.12].

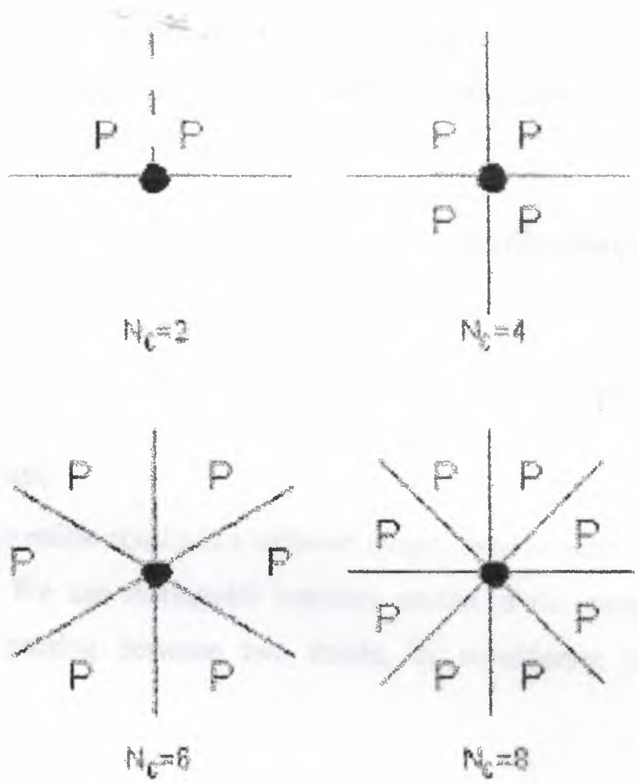


Figure 3.12 Mapping Pascal's triangle around the source node

In the cases of $N_c = 6$ and 8 we are actually viewing a sheared grid of squares, and the additional links in these cases point away from the sink node and cannot form part of a minimum path. These extra links are shown in Figure 3.11; the only difference between the six way and eight way cases is the acuteness of the triangle. The shearing and rotation of the girded Pascal's triangle needed to get the six way and eight way cases is shown more clearly below [Figure 3.13].

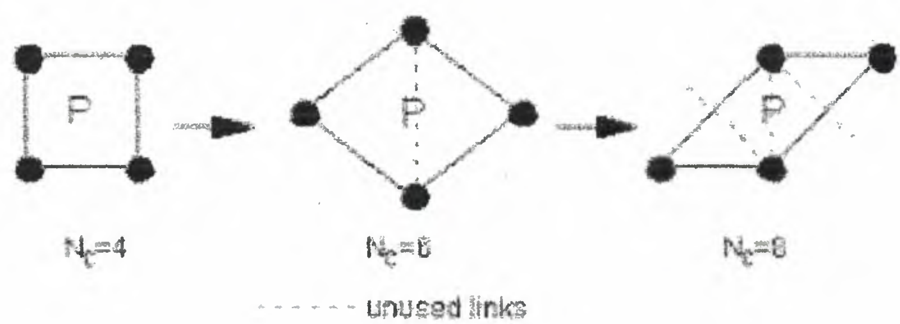


Figure 3.13 Shearing the Pascal's grid

To maintain the same plane orientation, necessary rotation of the six way case is included here. Pascal's triangle, and thus the number of minimum paths *Np* between two nodes, is generated by the formula:

Where we travel x links from the source node in one direction, and y links in the orthogonal direction, down to the sink node.

For $N_c = 3$, symmetry is lost, and Pascal's triangle does not apply.

3.6.4 Shape of a Path

Each of these possible routes is a different *shape*, even though the lengths of the routes are the same. We can distinguish between routes of the same length passing through a node, or passing between two nodes, by considering their unique and individual shapes.

Shapes of paths of a set length can be defined by passing through a constraining anchor node, where the node is fixed in both space and on the path so that that all the shapes of the path are split into two distinct sections of fixed lengths. Alternatively, the node can be unconstraining, where the anchoring node is fixed in space but the path can slide through the node and the lengths of the sections either side of the node are not fixed.

In the rectangular grid, we have two constraining anchors at opposing corners of the grid, and shapes of paths of fixed length between them.

CHAPTER FOUR

DIGITAL SATELLITE COMUNICATION

4.1 Overview

The purpose of operating a satellite in orbits is clearly to provide connections between earth stations, which in turn deliver or originate various types of communications service. Application of such satellite networks, are broken down into the broad categories of video, telephone, and data. The first part of this chapter reviews the features and generic arrangements of networks independent of the specific use. This provides a cross reference with regard to the applications which are reviewed in detail at the end of this chapter.

4.2 Connectivity

The manner in which points on the earth are linked between each other is called "connectivity". There are three generic forms of connectivity: point-to-point, point-to-multi point, and multipoint –to-point. Each of these connectivities, reviewed in the following paragraphs, can be established through one satellite and two or more earth stations. Comparisons are made with implementations of the same connectivities using terrestrial communications technology .It is shown that while terrestrial systems compete favorably on a point-to-point basis, satellite networks have a decided advantage whenever a multipoint connectivity is needed.

4.2.1 Point –to- Point

The simplest type connectivity is point-to-point, illustrated in Figure 4.1 with two earth stations both transmitting simultaneously to the satellite .A pair of earth stations transmit RF carriers one to another (and receive each others carriers), creating what is called a duplex link. The parties being served can thereby talk or transmit information in both directions at the same time the uplink sections of the satellite repeater receives both transmissions and after translation to the downlink frequency range, transmits them back toward the ground. Reception by and earth station of the opposite ends transmission completes the link. In most cases, transmission between earth stations through the satellite repeater are continues in time. If the satellite provides a single footprint covering both earth stations, then a given station can receive in the downlink its own information as well as that of its communicating partner. This supplementary ability provides a unique way for stations to verify the content and equality of satellite transmission.

Atypical network of several earth stations and a satellite provides many duplex point-to-point links to interconnects the locations on the ground. There are many possible circuit routings between the locations. In a fully interconnected "mesh" network. The maximum number of possible links between N earth stations is equal to N(N-1)/2.To prevent harmful RF interference; all stations cannot be on the same frequency at the same time. The technology which allows the needed simultaneous transmission without RFI through the satellite repeater is called multiple access.

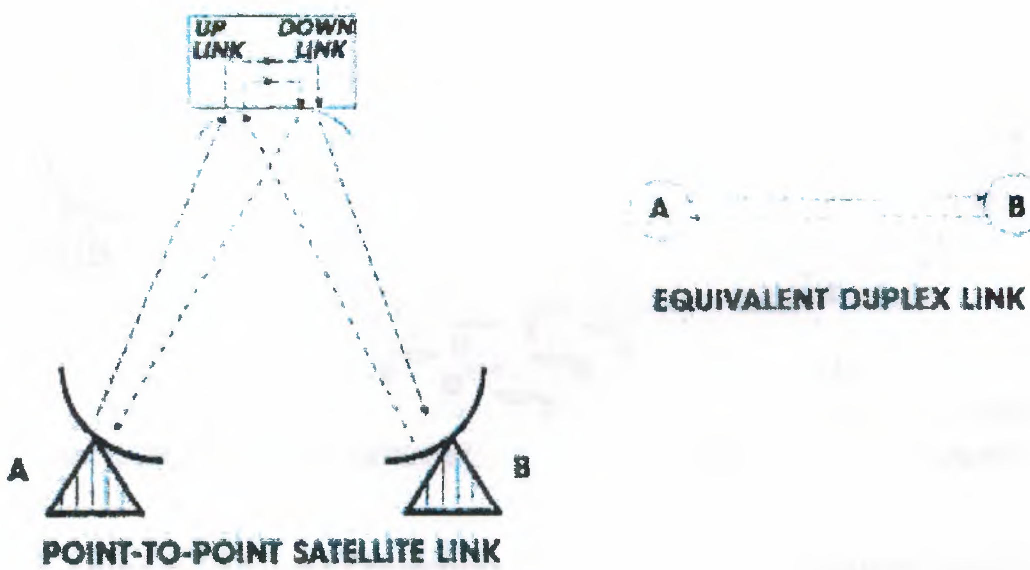


Figure 4.1 Point-to-Point Connectivity Using Full Duplex Satellite Link

4.2.2 Point-to-Multipoint

While point-to-point links are easily achieved by satellite, it is the point –to-multipoint link which takes full advantage of the wide area coverage of the satellites footprint. Figure 4.2 indicates how satellite broadcasting is accomplished with one transmitting earth station (called the uplink in common practice) and many receives – only (RO) earth stations. The satellite repeater retransmits the single RF carrier containing the information to be distributed. It is usually advantageous to use the highest satellite transmit power possible, because this allows the use of smaller diameter (less expensive) RO antennas on the ground. As the number of RO s increase in to hundreds of thousands or millions, the optimum transmitter power to use in space becomes much larger than that permitted at C band by the ITU. BSS segment of Ku band is available for such high-power broadcast applications. The cost of the more expensive BSS satellite is shared among more and more users, who than saves substantial amounts on the cost of their ground equipment. This is an economic tradeoff between the cost of the satellite and that of the ground segment.

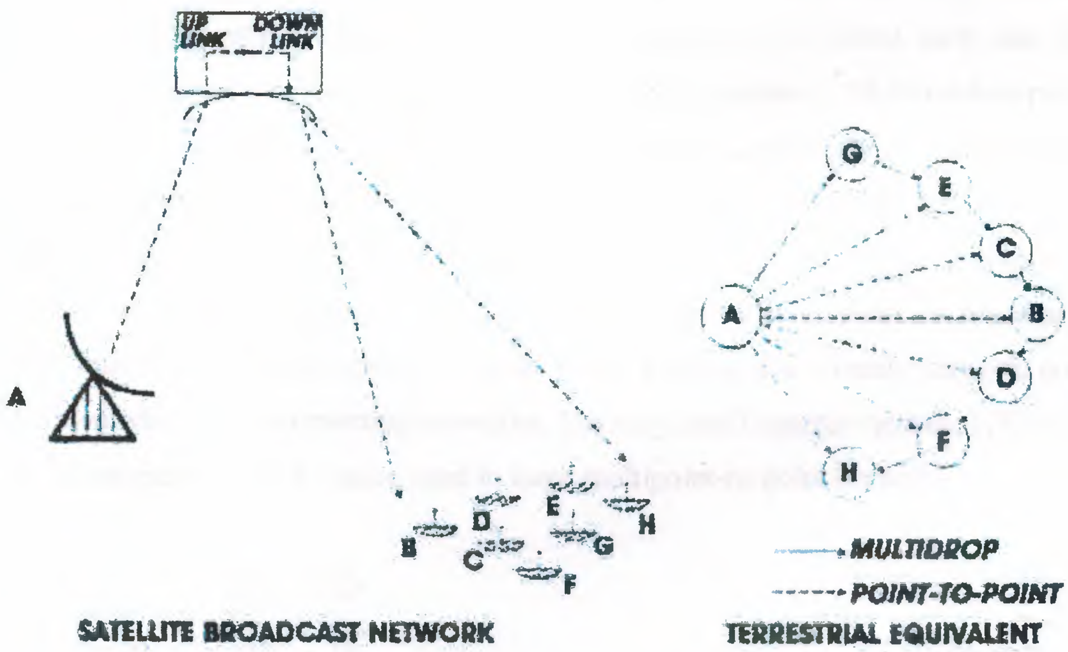


Figure4 .2 point-to-Multipoint Connectivity Providing a one-way Broadcast Capability.

Achieving point-to-multipoint connectivity with a terrestrial network is extremely expensive, since the cost of adding cable or microwave facilities to reach service points is roughly proportional to the number of points. In contrast to satellite broadcasting, there is usually no economy on scale in delivering broadcast information terrestrially. There is a terrestrial approach, wherein the receiving points are chained together. This tends to be less reliable on an overall basis because users are delivered the signal along the route of the system (i.e., a chain is no stronger than its weakest link). The first use of terrestrial microwave for TV distribution was accomplished in this manner. In data communication, a terrestrial chain of this type using telephone circuits is called a multidrop line.

4.2.3 Multipoint-to-Point

A multipoint-to-point satellite network compliments the broadcast approach by allowing remote stations to send information back to the central station. As shown in figure 3.3, this type of connectivity provides two-way communication because the remotes receive the broadcast from the central station and can transmit back over the same satellite. It is different from a point-to-point network because the remote stations cannot communicate directly with one another but must do so through the central station, commonly referred to as the hub. In figure 4.3, the remotes efficiently transmit packets of data toward the satellite on the same frequency but timed such that the packets do not overlap when they enter the satellite repeater. Multipoint-to-point networks are an important extension of point-to-point because of the relatively small antenna size and simplicity of the remote station. These are afforded by using a more sophisticated hub station with a large-diameter antenna. Many commercial applications can effectively use this type of connectivity where subscriber response is necessary. Modern intelligence to the remote stations while keeping the overall network cost competitive with modern terrestrial networks. The very small aperture terminal (VSAT) is type of inexpensive earth station used in large multipoint-to-point networks.

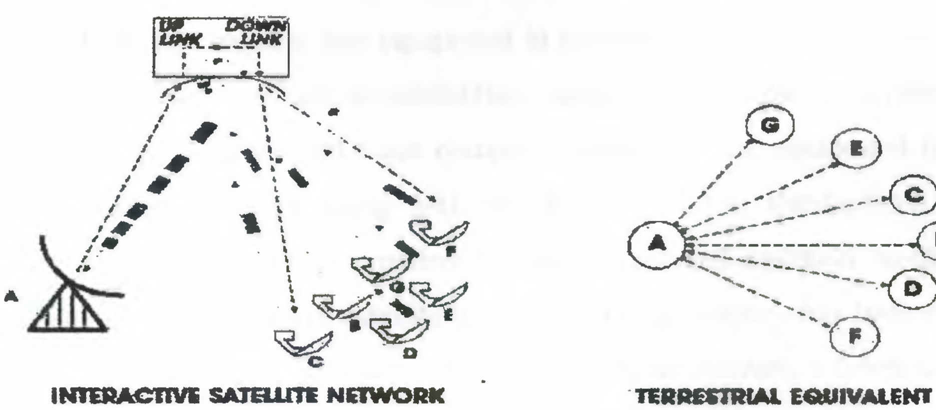


Figure 4.3 Interactive Satellite Network Using Multipoint-to-Point Connectivity.

4.3 Flexibility

A satellite-based network is inherently very flexible from a number of perspectives, which are described in the following paragraphs.

4.3.1 Implementation of Satellite Networks

To begin with, the implementation of the ground segment of a satellite network is relatively simple primarily because the number of physical installations is minimal. To put in a satellite network, a planner need only consider the sites where service is required.

Installation of a fiber optic cable system requires first that the right-of-way be secured from organizations such as governments, utility companies, and railroads. Hundreds or even thousands of sites must be provided with shelter and power (and even access roads in the case of terrestrial microwave). After the entire system is installed and tested, all of the equipment must be maintained to assure continuous service. Even still, one outage along the route will probably put the entire chain out of services until a crew and equipment can arrive on the scene to effect repair.

In contrast, the time to install an earth station network is relatively short, particularly if the sites are close to where service is provided. This assumes that a space a space segment already exists. In the past, implementation times for earth stations were lengthened, not because of sites construction, but rather because electronic equipment had to be special ordered and then manufactured. The low production volumes (because satellite communication requires less equipment in general than terrestrial) discouraged manufacturers from mass production standardized equipment and holding inventory for future sales. In today's larger and more competitive earth station equipment marked, higher manufacturing volumes along with the arrival of more standardized digital systems have allowed equipment suppliers to reduce cost and maintain on-the-shelf inventory. The time to implement satellite networks and add stations has been reduced from one to two years down to from one to two months. In contrast, a terrestrial fiber network is like a major highway project and will take years to design and construct.

4.3.2 Expansion of the Network

With a proper network architecture, new earth stations can be added without affecting the existing stations. This reduces the expansion timeframe to a few months or weeks, since all that needs to be done is to purchase the equipment, prepare the site, and then install the stations. Increasing the number of ROs is particularly easy and economical, and operation of existing stations is not affected. Satellite networks of the 1970s providing point-to-point links could not be modified easily because of the old, inflexible analog technology employed.

To add an earth station to an old analog point-to point network would require dismantling the equipment at each station to be linked with the new station. This major drawback of the older system has been eliminated with programmable digital technology. These more flexible digital approaches, can now be assumed in virtually every future application involving two-way communication.

4.3.3 Simplification of Network Routing

Rather than purchasing new long distance facilities for their exclusive use, many users lease voice and data circuit from terrestrial network operation (called *common carries* in North America). Therefore, the "backbone" network would already exist, and the only time necessary for implementation of such a private network is that needed to run local cable loops or to make appropriate wiring changes in the telephone offices. Time delays of many weeks month or still involved, however, beginning from the moment when service order are placed. The common carrier must then perform the network engineering install equipment if necessary and make the required wiring change. And then test the resulting circuit for proper operation. If the circuit or circuits cross the bond-aries between the terrestrial networks of different providers, then the process must be run simultaneously by the various organizations and coordination between them must be handled in some manner. In a modern satellite network, only the end connections are involved, because the satellite itself provides all of the intermediate routing.

Terrestrial networks must deliver multipoint connectivity by extending terrestrial links to each and every point to be served. There are terrestrial radio techniques which limit satellites by placing omnidirectional (i.e., wide, circular area coverage) repeaters on tours or mounting tops. Broadcast radio and TV work on a point-to-multipoint basis, and cellular mobile telephone is an excellent multipoint-to-point system. All such terrestrial techniques, however, are severely restricted as to range because of light-of-sight radio propagation. To extend will beyond this geographical limitation, less reliable point-to-point links must be established between the radio tours to change the broadcast of cellular stations together.

4.3.4 Introduction to Services

Expansion of a satellite network can add new services, many of which can not currently be accommodated terrestrial. Perhaps clearest example is the long distance transmission of full motion color television, which, as noted earlier, could not be carried over transoceanic telephone cables. It was until the advent of terrestrial microwave radio in North America that cost-to-cost TV transmission was possible. Satellite repeaters in the FSS have sufficient bandwidth to carry several TV channels along with an array of voice and data traffic. On a local level, the local telephone loops which bring voice and low-speed data services into the office and home are currently very limited in their capacity. Home cable television service is made possible only with a separate coaxial cable, and interactive two-way video teleconferencing is only provided on a very limited basis over terrestrial systems. Any and all of these services can be included in, or added to, the current generation of small earth station, particularly the VSAT operating at Ku band. Therefore, flexibility of satellite communication takes on added dimensions with new services which can not currently be offered on a single terrestrial network.

The three generic types of connectivity were covered in the previous section. It is very noteworthy that a given satellite network can achieve these connectivities individually or simultaneously. While a terrestrial network is usually restricted to a point-to-point capability. It is not uncommon for a user to implement a point-to-point satellite network involving from 10 to 50 earth stations and then add a broadcast capability to extend the network to hundreds or even thousands of receiving points. Any one of the point-to-point stations could then be used as an uplink site to broadcast digital information or video programming on an occasional basis. The multipoint-to-point capability can be installed in the future by adding transmit "retrofit" package to many of the smaller receive only stations.

4.4 Reliability

The remaining features to be described are more difficult to explain and quantify: they can, however, ultimately be the factors, which decide in favor of satellite transmission over terrestrial. The mere fact that a satellite link requires only one repeater hop, or a maximum of two in the case of international services, tends to make the satellite connection extremely reliable. The engineering of the link, must properly take into account the frequency band and fade margin requirements. When this is done and an establish satellite is employed, the link will be up and usable for well in excess of 99% of the time. In fact, satellite engineers normally talk of the link reliabilities of 99.99%, which equates to an outage or downtime of nine hours in an entire year. Normally, this outage is segmented into duration's of a few minutes distributed mainly through the rainiest months.

Long distance terrestrial systems normally provide reliabilities in the range of from 95 to 98%, where outage can be produced by fades on any of its radio paths (in the case of terrestrial microwave) and by equipment outage at any of the hundreds of repeater sites along the route. Cable systems are susceptible to accidental breakage or detection of the cable itself, and outages of several hours or even days at a time do occur. A single buried cable or microwave system is relatively unreliable due to the inevitable breakage or failure. Therefore reliable means of communication, although the cost of implementation would only be within the range of relatively wealthy organizations (AT&T. govern- ments , and major industrial corporations).

Equipment failures on satellite links do occur, and for that the reason backup systems are provided. A communication satellite contain essentially 100% backup for all of its critical subsystem to prevent a catastrophic failure. The individual transponders to transmitters within the repeater section will usually not be speared 100%, so that a fractional loss of capacity is possible at some time in the useful orbital life. Experience with modern commercial satellite ahs been excellent, and users have come to except near perfection in the reliability of these spacecraft. The principle cause of communication outage is not failure of satellite hardware but rather is due to double illumination problem described in chapter1 Harmful radio frequency interference (RFI) is a fairly routine occurrence and satellite operators are reasonably well equipped respond to and identify the source of the problem (which is almost always accidental and of short duration).

The reliability of satellite communication is enhanced by the fact that virtually all of the ground facilities can be under direct control of one using organization. If a problem occurs with equipment or its interface with other facilities such as telephone switches or computer, the user's technical support personnel can easily identify and reach the trouble spot. Restoration of service can thus be accomplished conveniently and quickly, Terrestrial linkups can involved many organizations which provide services in section of the country or city, complicating the necessary troubleshooting and follow-up. For example, the former AT and T Bell System was broken up in the United State in 1983, resulting in the creating of seven independent corporation, each controlling roughly one-seventh of the local telephone service of the country. AT and T continues to be the largest long distance service provided as the regional Bell companies are currently restricted from this type of business. To reach customer location in two different regions requires that he facilities of three different companies be used: two regional Bell companies and AT and T. A competing long distance company such as MCI may provide a more advantageous service at perhaps a lower coast and can be used in lieu of AT and T. The facilities of the regional Bell companies, however, must still be arranged for the end-to-end service will be amplified in time duration as three entities work to locate and rectify the problem.

4.5 Quality

The following paragraphs identify different approaches to measuring quality of transmission. Emphasis is usually placed on human perception, which is particularly valid for analog signals such as voice and video. Quality in data communication boils down to the quantity of valid data, which reaches the distant end.

4.5.1 Signal Reproduction

For a signal of transmission. A satellite is nearly ideal for delivering a signal of the highest quality. Modern satellite system radiate sufficient power into the geographical footprint to be received by ground antenna of diameters in the range of 0.8 to 10 meter (3 to 32 feet). Because satellite use line-of-sight transmission in direction nearly perpendicular to the atmosphere, the frequency and duration of link fades are reduced as compared to terrestrial microwave, many terrestrial network suffer from man-made noise and various kinds of short interruptions (glitches), while satellite links experience primarily receive noise which is constant and easily compensated for with power. All of these factors allow the satellite communication engineer to design link of the highest possible circuit quality and to select equipment, which will provide this quality with confidence. The communication application where these aspects of quality play the greatest role is in point-to-point and point-to-multipoint video. Essentially all video programming destined to North American homes is carried long distance by satellite the perceived quality of the delivered video signal is for all practical purposes identical to that of the signal created at the studio or played from the originating video tape machine.

4.5.2 Voice Quality and Echo

The issue of quality of voice transmission has received a lot attention. Particularly in the United States where many large communication companies compete for customers. The use of the GEO for the communication relays was controversial to pick prior to the first use of SYNCOM in 1962 because of the delay of one-quarter second introduced by the long transmission path. The impact of this delay on voice communication continues to be debated even today; particularly as high-capacity fiber optic systems are installed in the developed world. Voice communication over satellite can be made acceptable to over 90% of telephone subscribers, as has been proven by numerous quality surveys. Terrestrial systems do not suffer as much from delay and hence are potentially more desirable, other factors being equal.

The mechanism that produces echo, Which can be the most objectionable result of delays illustrated in figure 3.4 echo is present in any terrestrial or satellite telephone link, because electrical signals are waves and thus are reflected by the far end back over the return path. Echo becomes objectionable, however, when the talker hears his own speech delayed by more than a few milliseconds. Shorter delays produce a hollow sound, like that heard in a long hallway or tunnel. At the left of figure 3.4 speech from a female talker is converted into electrical energy in the voice frequency rang (300 to 3400 Hz) by the handset and passes over the signal pair of wires to the telephone equipment used to connect to a long distance circuit. The same pair of wires allows the speech from distant end (where the male talker is listening at the moment) to reach the female talker. In contrast, the long distance circuit breaks the two directions in half, segregating the sending and receiving wire pairs. The device that routes the energy properly between the two wire (local loop) and four wire (trunk) lines is called a hybrid. The typical configuration has hybrid on each end: figure 4.4 however; show that the male talker is connected through an undefined terrestrial network within which several hybrids could exits. The echo path is produced within one or more of these unseen hybrids, allowing some of the female talker's speech energy to make a U-turn and head back towards the female talker. Since the echo is the result of uncontrollable factors in the terrestrial network. It must be actively blocked or else a negative impact on quality will result. Obviously, a satellite circuit with its one-quarter second (250ms) delay is subject to her first word.

The simplest and most effective type of echo control is to use a voice activated switch. As shown in figure 4.4. Whenever the female talker is speaking, the control circuits of the switching detect the presence of the incoming speech on the upper wire pair, and the switch on the lower wire pair opened. When she stops talking, however, the switch closes automatically. And the male talker is free to speak and be heard by the female talker. A similar switching would have to be placed on the basic type of echo control device is called an echo suppressor and has been on terrestrial and satellite circuit for decades. Other features are necessary to make the switch respond to characteristics of human conversation, such as when one party needs to interrupt the other, One of the biggest problems with satellite voice circuit of past years has been the difficulty of getting these old-fashioned echo suppressor to work correctly.

With the advent of high-speed digital circuit and microprocessors, a much superior echo control device has appeared. This is the echo canceller, which works the way the name implies, instead of switching in or out, an echo canceller works with digitalized version of the speech and mathematically eliminates the echo from it, It is an active control device and has the ability to

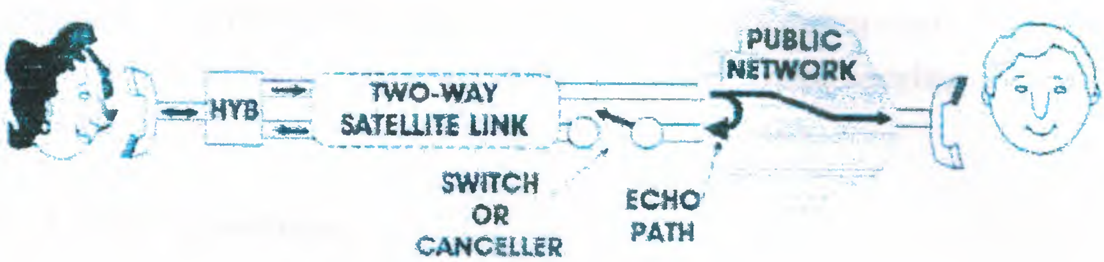


Figure 4.4 Telephone Echo a Satellite Is Caused By Electrical Reflection at the End where it can Be Eliminated by an Echo Canceller.

Characterize the echo path through the hybrid or terrestrial network. From this information, the canceller determines how to abstract a sample of the incoming speech from the return path to the distant talker. The details of how this technology works are beyond the scope of this chapter. The important point, however, is that there is strong evidence that an advance digital voice communication link with modern echo cancellation will be rated higher in quality by telephone subscribers than a traditional analog voice link on a long distance terrestrial network.

4.6 Digital Audio Data:

Digital audio data is usually described using the following three parameters: sampling rate, bits per sample, and number of channels. The sampling rate is the number of samples per second. Bits per sample is the number of bits used to represent each sample value. Number of channels is one for mono, two for stereo, etc.

4.6.1 Audio Sampling

An analog audio signal has amplitude values that continuously vary with time. To encode this signal digitally, the amplitude value of the signal is measured at regular intervals. This is called sampling. According to the Nyquist theory of signal processing, to faithfully represent a signal of a certain frequency, the sampling rate must be at least twice that of the highest frequency present in the signal . Using this theory, sampling is lossless since the original signal can be reconstructed based on the samples. To avoid aliasing distortion, the signal is low-pass filtered to remove any high frequencies that can not be represented by the sampling rate.

Using Nyquist's theory, 8 kHz is a sufficient sampling rate to capture the range of human voice (40 Hz to 4 kHz) and 40 kHz is a sufficient sampling rate to capture the range of human hearing (20 Hz and 20 kHz). In practice, typical sampling rates range from 8 kHz to 48 kHz

4.6.2 Audio Quantizing

Sampled values representing the amplitude of the signal at the sample time are quantized into a discrete number of levels. The number of levels depends on how many bits are used to store the sample value. For digital audio, this precision usually ranges from 8 bits per sample (256 levels) to 16 bits per sample (65536 levels). Quantization induces error into the data because no matter how many bits of precision are used, it is impossible to represent an infinite number of amplitude values with a finite number of increments. Uniform pulse code modulation (PCM) encoding is an encoding method where the quantizer values are uniformly spaced. Uniform PCM is an uncompressed audio encoding format, however some other PCM formats such as mu-law or A-law PCM use quantizer values that are logarithmically spaced, effectively achieving a degree of compression .

4.6.2.1 Digital Audio Compression Techniques

Uncompressed digital audio can require a large amount of bandwidth to transmit. There are many techniques used to compress digital audio. Some of the techniques commonly used in desktop videoconferencing systems are described below. Typically these are techniques that can achieve real-time compression and decompression in software or inexpensive hardware. Some techniques apply to general audio signals and some are designed specifically for speech signals.

4.6.2.2 mu-law and A-law PCM

With PCM encoding methods, each sample is represented by a code word. Uniform PCM uses a uniform quantizer step spacing. By performing a transformation, the quantizer step spacing can be changed to be logarithmic, allowing a larger range of values to be covered with the same number of bits. There are two commonly used transformations: mu-law and A-law. These transformations allow 8 bits per sample to represent the same range of values that would be achieved with 14 bits per sample uniform PCM. This translates into a compression ratio of 1.75:1 (original amount of information:compressed amount of information). Because of the logarithmic nature of the transform, low amplitude samples are encoded with greater accuracy than high amplitude samples.The mu-law and A-law PCM encoding methods are formally specified in the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) Recommendation G.711, "Pulse Code Modulation (PCM) of voice frequencies." The mu-law PCM encoding format is common in North America and Japan for digital telephony with the Integrated Services Digital Network (ISDN). The A-law PCM encoding format is common with ISDN in other countries. G.711 is one of the audio standards specified in H.320 Note that at 8 kHz, 8 bits per sample, and 1 channel, mu-law or A-law PCM requires a bandwidth of 64 kbps.

4.6.2.3 ADPCM

PCM encoding methods encode each audio sample independently from adjacent samples. However, usually adjacent samples are similar to each other and the value of a sample can be predicted with some accuracy using the value of adjacent samples. For example, one simple prediction method is to assume that the next sample will be the same as the current sample. The ADPCM (Adaptive Differential Pulse Code Modulation) encoding method computes the difference between each sample and its predicted value and encodes the difference (hence the term "differential"). Fewer bits (typically 4) are needed to encode the difference than the complete sample value. Encoders can adapt to signal characteristics by changing quantizing or prediction parameters (hence the term "adaptive"). ADPCM typically achieves compression ratios of 2:1 when compared to mu-law or A-law PCM. Differences among different flavors of ADPCM encoders include the way the predicted value is calculated and how the predictor or quantizer adapts to signal characteristics. Many desktop videoconferencing systems use ADPCM encoding methods. The ITU-T has several recommendations defining different ADPCM methods (G.721, G.722, G.723, G.726, G.727). One of the audio encoding methods specified by H.320 is G.722, "7 kHz Audio-coding within 64 kbit/s," which uses SB-ADPCM encoding (Sub-Band ADPCM). The G.722 encoder samples at a rate of 16 kHz with 14 bits precision. With the SB-ADPCM method, the frequency band is split into two sub-bands (higher and lower) and the signals in each sub-band are encoded using ADPCM. G.722 has three modes of operation: 64, 56 and 48 kbps. With the 56 or 48 kbps modes, the additional 8 or 16 kbps of bandwidth (assuming a 64 kbps communication channel) can be used for other data.

4.6.2.4 LPC And CELP

There are some encoding methods designed specifically for speech. By using models of the characteristics of speech signals, these encoding methods can achieve good results for speech data. However, these methods usually do not work well for non-speech audio signals two encoding methods designed for speech signals are LPC and CELP.

A LPC (Linear Predictive Coding) encoder fits speech signals to a simple analytic model of the vocal tract. The best-fit parameters are transmitted and used by the decoder to generate synthetic speech that is similar to the original. A standard that utilizes simple LPC encoding is U.S. Federal Standard 1015 which requires a bandwidth of 2.4 kbps. Also, GSM (Groupe Speciale Mobile) encoding uses a variation of LPC called RPE-LPC (Regular Pulse Excited - Linear Predictive Coder with a Long Term Predictor Loop). GSM began as a European cellular phone speech encoding standard. GSM compresses 160 13-bit samples (2080 bits) to 260 bits which is an 8:1 compression ratio. For 8 kHz sampling, this means GSM encoded speech requires a bandwidth of 13 kbps. A CELP (Code Excited Linear Prediction) encoder does the same vocal tract modeling as an LPC encoder. In addition, it computes the error between the input speech data and the model and transmits the model parameters and a representation of the errors. The errors are represented as indicies into a common code book shared between encoders and decoders. This is where the name "Code Excited" comes from. The extra data and computations produce a higher quality encoding than simple LPC encoding. A standard that utilizes simple CELP encoding is U.S. Federal Standard 1016 which requires a bandwidth of 4.8 kbps. Also, ITU-T Recommendation G.728, which is one of the audio encoding formats specified by H.320 .uses a variation of CELP, LD-CELP (Low Delay CELP). G.728 requires a bandwidth of 16 kbps and is quite computationally complex, requiring special hardware.

4.6.3 Circuit-Switched Communication Channels

Circuit-switched communication is a method of data transfer where a path of communication is established and kept open for the duration of the session. A dedicated amount of bandwidth is allocated for the exclusive use by the session. When the session is completed, the bandwidth is freed and becomes available for other sessions. Advantages of circuit-switched communication for desktop videoconferencing are that dedicated bandwidth is available and the timing of the data delivery is predictable. A disadvantage of circuit-switched communication for desktop videoconferencing is that sessions are primarily point-to-point and require expensive multi-conferencing units (MCUs) to accomodate multipoint conferences. Also, dedicated bandwidth is wasteful during periods of limited activity in a conference session.

4.6.3.1 Packet-Switched Communication Channels

Packet-switched communication is a method of data transfer where the information is divided into packets, each of which has an identification and destination address. Packets are sent individually through a network and, depending on network conditions, may take different routes and arrive at their destination at different times and out-of-order. No dedicated bandwidth circuit is set up as with circuit-switched communication. Bandwidth must be shared with whomever else is on the network.

An advantage of packet-switched communication for desktop videoconferencing is the capability to more easily accomodate multipoint conferences. A disadvantage is the unpredictable timing of data delivery, which can cause problems for delay sensitive data types such as voice and video. Video packets received out-of-order may have to be discarded. Audio packets can be buffered at the receiver, re-ordered, and played out at a constant rate, however this induces a delay which can be detrimental to interactive communication.

4.6.3.2 Broadband ISDN

Broadband ISDN (BISDN) has the potential to solve the problems encountered with circuit-switched and packet-switched communication. Asynchronous Transfer Mode (ATM) is the data link layer protocol that is commonly associated with BISDN. ATM combines the best qualities of circuit-switched and packet-switched communication. ATM can support different data transmission speeds, multiplex signals of different data types, and provide different classes of service. [14] These capabilities will satisfy the service requirements of the different types of data possible with desktop videoconferencing. BISDN and ATM show great promise for the future, but their deployment at this time is limited.

4.7 Satellite Video Applications

Television or video services, which are one and the same, is perhaps the most popular source of entertainment and information for the public. The broadcasting industry has embraced satellite communication as the primary means of carrying programming from the program originator (TV Networks, cable TV programmers, and program syndicators) to the final point of distribution (broadcast TV station, cable TV system operators, and home dishes) in this section, the way in which programmers and distributors use satellite in there business is explained in some detailed

4.8 TV Broadcasting

To explain the importance of the current role of satellites, this section begins with review of the general characteristics of the TV broadcasting industry as it exists in North America. Table 4.1 summarizes the participants in the US broadcasting industry. Broadcasting is the commonplace medium whereby local TV stations employ VHF or UHF frequencies to transmit programming to the community. The range of reception is usually limited by line-of-sight propagation to approximately 50 to 100 miles. To conserve frequency channels, the same channel is assigned by the government to another station some safe distance away. Individuals use directional antenna (yagis and reflectors dipoles) to maximize signal strength and to suppress reception of unwanted distant stations operating on the same or adjacent channels. A given station only transmits a single channel and hints are constrained to offer only on program at a time.

TABEL 4.1 Comparison of Programming Services in Use for Over-the-Air Television in the United States

PART OF INDUSTRY	EXAMPLES
COMMRECIAL NETWORK	ABC, CBS, NBC, FOX
NETWORK AFFILIATE STATION	WABC, KCBS, KNBC, KTTV
INDEPNDENT STATION	WWOR, KTLA, WGN
PUBLIC BOADCASTING NETWORK	PUBLIC BROADCASTING SERVIC
PUBLIC BOADCASTING STATION	WNET, KCET, WGBH
SYNDICATION COMPANY	BUENA VISTA TELEVISION
SYNDICATED PROGRAMMING DELIVERY	WOLD, SYNSAT

4.8.1 Networks, Affiliates, and Independent Stations

There are national television network (ABC, CBS, NBC, and FOX in the US) to provide programs to affiliated TV station for broadcasting over their assigned frequency channel either in real time or by replay from video tape. The term "NETWORK" in the context is capitalized to distinguish it from the generic term. Independent station (i.e., those not affiliated with network) can also obtain programming from the outside from syndication companies, which sell programs either individually or as packages. While most syndicated programs are in fact old network programs (reruns), syndicators often deliver now programs and movies. For example "Wheel of Fortune" and "Entertainment Tonight" are two very popular syndicated programs not offered by the networks. Networks affiliates also obtain much of their programming from syndicators.

All station operates their own studios so that they too can originate programs, particularly local news, special events, and most importantly to the success of the station, advertising. In North America, the revenues of the stations and the Networks are derived from the sale of advertising, because individual viewers do not pay for the right to watch over-the-air television (except of course when they buy the advertised product or service). Subscription television (STV), an exception to this rule, employed scrambling to control viewing of broadcasts and assures that monthly fees were paid. In the United States, however, STV was only successful for a short while between 1980 and 1982 until competition from videocassettes recorders and cable television undermined their profitability.

Networks offer the advertiser the important advantage over the local station of being able to deliver a nation wide audience. Which is important to products link GM Automobiles and Time Magazine the revenues of the station and Networks are tied to relative size of their respective audience, which is evaluated by respected polling organizations such as A. C. Nielsen Company. Therefore the programmers need to deliver programming of sufficiently high quality to attract the largest possible audience. Their profitability is constrained "however" by the cost of producing this programming and of delivering it to the affiliated stations.

4.8.2 Satellite Program Distribution

This then brings us to the importance of satellite in providing the needed low cost and highly reliable means of delivering the programming. A single satellite can employ point-to-multipoint connectivity to perform this function on a routine basis. To receive programming, every TV station in the United States owns and operates at least one receiving earth station and many own stations usable as uplinks. To achieve very high reliability during an extremely high value (in terms of advertising dollars) event such as the Olympics or the Super Bowl, a Network will "double feed" the program on two different satellites at the same time.

In the United States, there exist public television stations, which are neither operated for a profit nor obtain income from advertising. The Public Broadcasting Service (PBS) is nonprofit television Network that distributes programming to these public television stations. Most of the funds for PBS and the stations raised through individual and corporate contributions rather than advertising. Stations also PBS and ach other for program production and rights for broadcasting. This has allowed the development of a narrower slice of programming (i.e., not of mss appeal) which caters to an audience more interested in education, public affairs, and classical culture.

Because of budget constraints, PBS was the first to adopt satellite delivery in 1976, using the Westar 1 satellite.

The benefits of satellite delivery having been demonstrated, the commercial Network then began of moving quickly in the same direction during the following years. As indicated previously. By 1984 all Network programming and most syndicated programming was being delivered by satellite links over the INTELSAT system for providing coverage of overseas events.

The technical means by which the TV broadcast industry uses satellite is illustrated in figure 3.5 predominant frequency band employed is C band for the simple reason that more ground antennas and satellites are available than at Ku band. The program distribution satellite shone on the left is used to broadcast the edited program feed on a point –to –multipoint basis. The downlink is received at each TV station by its own receive-only earth station and from there it is either transmitted over the local TV channel or stored on videotape. In the case of live broadcast from the network studio, the signal is connected from the camera to the uplink earth station and over the program distribution satellite. A video switching capability in the studio and t each TV station allows technicians to insert taped advertising and computer-generated graphics. Even though most programs are played from videotape, it is generally more economical to distribute tape programs by satellite to the TV stations where they are again recorded rather than mailing the tape (process called bicycling) around the country. Whether the programs are live or taped, the local TV stations are able to insert their own paid advertising in time slots left for that purpose by the network or syndicator

4.8.3 Backhaul of Event Coverage

All sports events and much news coverage is brought to the studio over separate point-to-point satellite link called a "backhaul". In the case of football games, for example, stadiums in North America have access via terrestrial microwave to a local earth station which c uplink the telecast to the backhaul satellite, illustrated in Figure 4.5. The Network or stations pay for the use of satellite and uplinking earth station by the minute or hour. The galaxy satellite system, owned and operated by Hughes Communications, Inc., is used extensively for this purpose and calls its occasional use business the Video Timesharing Service. Anyone with a receiving earth station can pick up the backhaul, which does not yet include the "commentary" and advertising spots that are interested at the studio prior to reuplinking to the program distribution satellite.

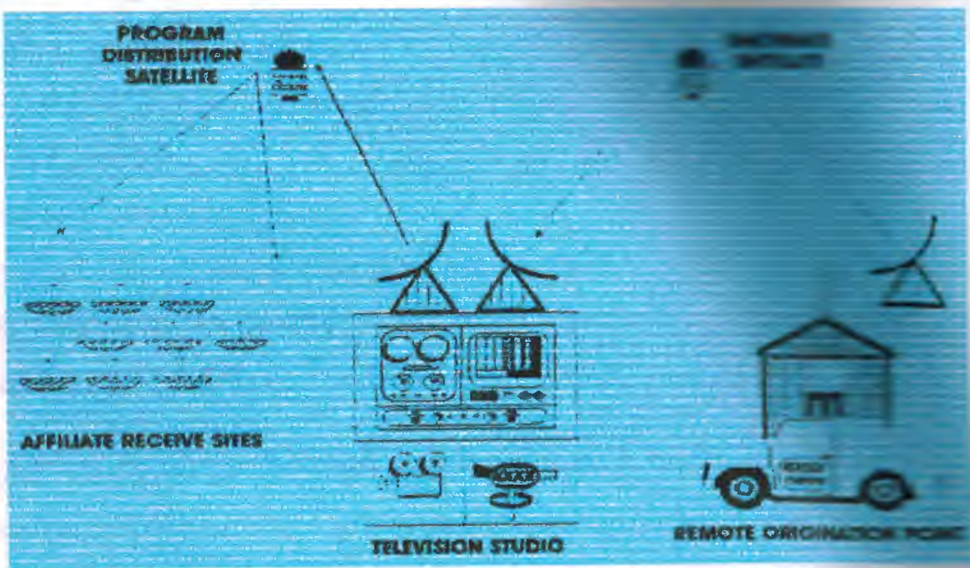


Figure 4.5 The Use of Satellite Transmission in the Commercial Television Industry for Backhaul of Event Coverage and Program Distribution to Affiliates

If coverage is of a one-time even such as a natural disaster or Olympic race. Then a truck-mounted transportable earth station is driven to the site and erected prior to Transmission. The use of a KU-band (14/12 GHz) backhaul has become particularly attractive for this type of rapid deployment service, and is called station news gathering (SNG). A KU-band SNG transportable is much more compact and mobile than its C-band equivalent and can be operated almost immediately after it has been parked on location. In addition, the use of non-shared KU-band frequencies eliminates any need for prior frequency coordination. Whether C or KU band, the time demands an economics of even converge can mean that backhaul satellite link will be attractive where the distance to the studio is anywhere from 50 to 5000 miles. For example, a backhaul was used during the Los Angeles Olympics of 1984 to reach from Lake Casts to Hollywood, a distance of approximately 60 miles.

4.9 Advantages Of Digital Transmission

Communications by digital signaling is an increasingly important technique for radio communication by satellite relay and other means. Digital transmission has a number of advantages over other techniques. These include:

1) the ease and efficiency of multiplexing multiple signals or handling digital messages in "packets" for convenient switching;
2) The relative insensitivity of digital circuits to retransmission noise, commonly a problem with analogue systems;
3) potential for extremely low error rates and high fidelity through error detection and correction;
4) communications privacy;
5) the flexibility of digital hardware implementation, which permits the use of microprocessors and miniprrocessor, digital switching, and the use of large scale integrated (LSI) circuits.

Digital transmission techniques are gaining increased usage for satellite communication, microwave relay, and cable or wave-guide transmission. However, the original and final forms of the information transmitted by the digital link may be analogue voice or video and therefore the analogue/digital interface is an important element of the communications system.

Most satellite communication is at microwave frequencies largely because the available bandwidth is substantial. However, transmission in the UHF frequency band has important application to relatively low data rate mobile users where near-omni directional antennas are employed.

CONCLUSION

Satellite communication is a very important technology, now a days it had been used in large area of the community, especially in Europe and America .

A communication satellite permits two or more points on the ground (earth stations) to send messages to one another over great distances using radio waves. The class of earth-orbiting satellites that is the subject of this section consists of those satellites located in the geostationary orbit, a satellite in the geostationary earth orbit (GEO) revolves around the earth in the plan of the equator once in 24 hours.

Geostationary advantages:

- The laying and maintenance of intercontinental cable is difficult and expensive.
- The heavy usage of intercontinental traffic makes the satellite commercially attractive.

Satellites can cover large areas of the Earth. This is particularly useful for sparsely populated areas; Satellite communications employ electromagnetic waves to carry information between ground and space

Satellite communication has evolved into an everyday, commonplace thing. Most television coverage travels by satellite, even reaching directly to the home from space. No longer is it a novelty to see that a telecast has been carried by satellite (in fact, it would be novel to see something delivered by other means). The bulk of transoceanic telephone and data communication also travels by satellite

Satellite communication today's is very important in wars to know any thing about the enemy, when or how they will attack, these information is very important in such situations , some hospitals in western country use satellite communications in there amp lance to determine the way they will go , from all this we can say that Satellite communication is very important and very useful .

REFERENCE

1. www.Google.com

2. Richaria, M.,"Satellite Communication System, Design Principles", Mac Milan Pres LTD., 1995

3. J.J. Spikier, Jr., Digital Communication by Satellite. Englewood Cliffs, NJ: Prentice-Hall, 1997.

4. Proof. Dr. FAKHREDDIN MAMEDOV ,Telecommunication . Near East University .2000