NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

SATELLITE COMMUNICATIONS

Graduation Project
EE-400

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ABSTRACT

A communications satellite is a spacecraft that carries aboard communications equipment, enabling a communications link to be established between distant points.Satellite that orbit the earth do so 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 to one 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.Many satellites use a band of frequencies of about 6 billion hertz, or 6 gig hertz (GHz) for upward

This project is about the technologies that comprise the field of commercial satellite communication, intending to provide bridge between those who need a practical understanding and those whose business *it is* to develop and operate these systems.

One of the main objectives in writing this project is to give the reader enough of this understanding to allow him or her to ask the right questions. The explanations and factual material provided here are directed toward that objective rather than offering a technical or historical reference. Within the context of this chapter, the term satellite means the actual communication spacecraft in orbit which relays radio signals between earth stations on the ground. Unfortunately, in the United States, common vernacular among telecommunication consumers applies the term satellite to service rendered by the satellite in conjunction with the accessing earth stations.

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.

However. In the project consists of three chapters;

Chapter one is introduction to satellite communication in this chapter we presented the history, development and new technology.

Chapter two is satellite communication; it presents in detail an analysis of basic characteristics of satellite, Kepler's laws and it has three laws, also we talked about satellite orbits, Ended this chapter by addressing frequency band because it is very important section in communication.

Chapter three application of satellite networks 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.

CHAPTER!

INTRODUCTION TO SATELLITE COMMUNICATION

1.1 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. A unique benefit has appeared in the area of emergency preparedness and response. For example, when the devastating earthquake of September 1985 hit till Mexico City, the newly launched Morelos satellite maintained a reliable television transmission around the nation even though all terrestrial long distance lines out of the city stopped working.

This chapter is about the technologies that comprise the field of commercial satellite communication, intending to provide bridge between those who need a practical understanding and those whose business it is to develop and operate these systems. One of the main objectives in writing this chapter is to give the reader enough of this understanding to allow him or her to ask the right questions. The explanations and factual material provided here are directed toward that objective rather than offering a technical or historical reference. Within the context of this chapter, the term satellite means the actual communication spacecraft in orbit, which relays radio signals between earth stations on the ground. Unfortunately, in the United States, common vernacular among telecommunication consumers applies the term satellite to service rendered by the satellite in conjunction with the accessing earth stations.

1.2 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:

1.2.1 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), will be designated here as switching satellites.

1.2.2 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 min diameter. Reception is by the same antenna. The overall receiving system noise temperature is between 50 and 200 Kat 5°elevation angle. A very suitable characteristic indicative of the quality of receiving system in the merit *GIT,* that is the ratio of the receiving antenna gain to the system noise temperature in Kelvin's, expressed in *dBIK.* A large earth station, having an antenna diameter about 25m and a system noise temperature of 50 K, operating at 4 GHZ has a *GIT* figure of about 41 dB/K. In smaller earth station the *GIT* figure decreases.

1.3 Dedicated Satellite

Specific national requirements have promoted several countries to start dedicated satellite for their own domestic systems. Dedicated satellite offers technical advantages whereby it is possible either to increase the transponder traffic capacity or to reduce the cost of the earth segment by simplifying the earth station with the use of smaller antennas.

1.3.1 lnmarsat

An international marine satellite communication system, Inmarsat is also in operation. A European consortium has proposed the Marots system as the first stage of Inmarsat, interfacing with Marisat. Inmarsat has 53 members' nations future Intelsat and satellite may include maritime communications capability.

1.3.2 Aerosat

Clearly there are other potential mobile users for satellite communications besides ships. US, CANADA and several European countries had planed an aeronautical satellite system. Although the project came to standstill because of economic and institutional obstacles, considerable work has been done on defining the Aerosat system and this may eventually bear fruit.

1.4 International Telecommunication Satellite Organization

INTELSAT was established in 1964, whereby it became possible for all nations to use and share in the development of one satellite system. Its prime objective is to provide on a commercial basis the space segment for International Public Telecommunications Services of high quality and reliability. To be available to all areas of the world where the INTELSAT organization had grown to 114 investor members as of February 1988. Communication is the American signatory of INTELSAT. A part from its global system, INTELSAT is currently leasing satellite transponders to European PTT authorities for their domestic communication. And now we are going to see on this chapter some information about what are we going to study so as:

1. **Power Supply:**

All working satellites need power to operate. The sun provides power to most of the satellite orbiting earth. This power system uses solar arrays to make electricity from sunlight, batteries to store the electricity, and distribution units that send the power to all the satellite's instruments.

2. **Command and data:**

The Command and Data Handing system controls all the functions of the spacecraft. It's like the satellite brain. The heart of this is the Flight computer. There is also an input /output processor that directs all the control data that moves to and from the Flight Computer.

3. **Communications**

The communications system has a transmitter, a receiver, and various antennas to relay messages between the satellite and earth. Ground control uses it to send operating instructions to the satellite's computer. This system also sends pictures and other data captured by the satellite back to engineers on earth.

4. Pointing Control

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1.5 Histories and Development

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transmitting ground station. These messages were retransmitted when the satellite passed over a receiving station. *Telstar 1,* launched by American Telephone and Telegraph Company in 1962, provided direct television transmission between the United States, Europe, and Japan and could also relay several hundred-voice channels. Launched into an elliptical orbit inclined 45° to the equatorial plane, *Telstar* could only relay signals between two ground stations for a short period during each revolution, when both stations were in its line of sight.

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. Many satellites use a band of frequencies of about 6 billion hertz, or 6 gig hertz (GHz) for upward, or uplink, transmission and 4 GHZ for downward, or downlink:, transmission. Another band at 14 GHZ (uplink) and 11 or 12 GHZ (downlink:)is also much in use, mostly with fixed (nonmobile) ground stations. A band at about 1.5 GHZ (for both uplink and downlink:)is used with small, mobile ground stations (ships, land vehicles, and aircraft). Solar energy cells mounted on large panels attached to the satellite provide power for reception and transmission. In 500 years, when humankind looks back at the dawn of space travel, Apollo's landing on the Moon in 1969 may be the only event remembered. At the same time, however, Lyndon B. Johnson, himself an avid promoter of the space program, felt that reconnaissance satellites alone justified every penny spent on space. Weather forecasting has undergone a revolution because of the availability of pictures from geostationary meteorological satellites--pictures we see every day on television. All of these are important aspects of the space age, but satellite communications has probably had more effect than any of the rest on the average person. Satellite communications is also the only truly commercial space technology- -generating billions of dollars annually in sales of products and services.

1.5.1 The Billion Dollar Technology

In fall of 1945 an RAF electronics officer and member of the British Interplanetary Society, Arthur C. Clarke, wrote a short article in *Wireless World* that described the use of manned satellites in 24-hour orbits high above the world's land masses to distribute television programs. His article apparently had little lasting effect in spite of Clarke's repeating the story in his 1951/52 *The Exploration of Space.* Perhaps the first person to carefully evaluate the various technical options in satellite communications *and* evaluate the financial prospects was John R. Pierce of AT&T's Bell Telephone Laboratories who, in a 1954 speech and 1955 article, elaborated the utility of a communications "mirror" in space, a medium-orbit "repeater" and a 24-hour-orbit "repeater." In comparing the communications capacity of a satellite, which he estimated at 1,000 simultaneous telephone calls, and the communications capacity of the first trans-Atlantic telephone cable (TAT-1), which could carry 36 simultaneous telephone calls at a cost of 30-50 million dollars, Pierce wondered if a satellite would be worth a billion dollars.

After the 1957 launch of Sputnik I, many considered the benefits, profits, and prestige associated with satellite communications. Because of Congressional fears of "duplication," NASA confined itself to experiments with "mirrors" or "passive" communications satellites (ECHO), while the Department of Defense was responsible for "repeater" or "active" satellites which amplify the received signal at the satellite--providing much higher quality communications. In 1960 AT&T filed with the Federal Communications Commission (FCC) for permission to launch an experimental communications satellite with a view to rapidly implementing an operational system. The U.S. government reacted with surprise-- there was no policy in place to help execute the many decisions related to the AT&T proposal. By the middle of 1961, NASA had awarded a competitive contract to RCA to build a medium-orbit (4,000 miles high) active communication satellite (RELAY); AT&T was building its own medium-orbit satellite (TELSTAR) which NASA would launch on a cost-reimbursable basis; and NASA had awarded a sole- source contract to Hughes Aircraft Company to build a 24-hour (20,000 mile high) satellite (SYNCOM). The military program, ADVENT, was cancelled a year later due to complexity of the spacecraft, delay in launcher availability,and cost over-runs.

By 1964, two TELSTARs, two RELAYs, and two SYNCOMs had operated successfully in space. This timing was fortunate because the Communications Satellite Corporation (COMSAT), formed as a result of the Communications Satellite Act of 1962, was in the process of contracting for their first satellite. COMSAT's initial capitalization of 200 million dollars was considered sufficient to build a system of dozens of medium-orbit satellites. For a variety of reasons, including costs, COMSAT ultimately chose to reject the joint AT&T/RCA offer of a medium-orbit satellite incorporating the best of TELSTAR and RELAY. They chose the 24-hour-orbit (geosynchronous) satellite offered by Hughes Aircraft Company for their first two systems and a TRW geosynchronous satellite for their third system. On April 6, 1965 COMSAT's first satellite, EARLY BIRD, was launched from Cape Canaveral. Global satellite communications had begun.

1.5.2The Global Village: International Communications

Some glimpses of the Global Village had already been provided during experiments with TELSTAR, RELAY, and SYNCOM. These had included televising parts of the 1964 Tokyo Olympics. Although COMSAT and the initial launch vehicles and satellites were American, other countries had been involved from the beginning. AT&T had initially negotiated with its European telephone cable "partners" to build earth stations for TELSTAR experimentation. NASA had expanded these negotiations to include RELAY and SYNCOM experimentation. By the time EARLY BIRD was launched, communications earth stations already existed in the United Kingdom, France, Germany, Italy, Brazil, and Japan. Further negotiations in 1963 and 1964 resulted in a new international organization, which would ultimately assume ownership of the satellites and responsibility for management of the global system. On August 20, 1964, agreements were signed which created the International Telecommunications Satellite Organization (INTELSAT).

By the end of 1965, EARLY BIRD had provided 150 telephone "half- circuits" and 80 hours of television service. The INTELSAT II series was a slightly more capable and longer-lived version of EARLY BIRD. Much of the early use of the COMSAT/INTELSAT system was to provide circuits for the NASA Communications Network (NASCOM). The INTELSAT III series was the first to provide Indian Ocean coverage to complete the global network. This coverage was completed just days before one half billion people watched APOLLO 11 land on the moon on July 20, 1969.

From a few hundred-telephone circuits and a handful of members in 1965, INTELSAT has grown to a present-day system with more members than the United Nations and the capability of providing hundreds of thousands of telephone circuits.

Cost to carriers per circuit has gone from almost $100,000 to a few thousand dollars. Cost to consumers has gone from over $10 per minute to less than $1 per minute. If the effects of inflation are included, this is a tremendous decrease! INTELSAT provides services to the entire globe, not just the industrialized nations.

1.5.3 Hello Guam: Domestic Communications

In 1965, ABC proposed a domestic satellite system to distribute television signals. The proposal sank into temporary oblivion, but in 1972 TELESAT CANADA launched the first domestic communications satellite, ANIK, to serve the vast Canadian continental area. RCA promptly leased circuits on the Canadian satellite until they could launch their own satellite. The first U.S. domestic communications satellite was Western Union's WESTAR I, launched on April 13, 1974. In December of the following year RCA launched their RCA SATCOM F- 1. In early 1976 AT&T and COMSAT launched the first of the COMSTAR series. These satellites were used for voice and data, but very quickly television became a major user. By the end of 1976 there were 120 transponders available over the U.S., each capable of providing 1500 telephone channels or one TV channel. Very quickly the "movie channels" and "super stations" were available to most Americans. The dramatic growth in cable TV would not have been possible without an inexpensive method of distributing video.

The ensuing two decades have seen some changes: Western Union is no more; Hughes is now a satellite operator as well as a manufacturer; AT&T is still a satellite operator, but no longer in partnership with COMSAT; GTE, originally teaming with Hughes in the early 1960s to build and operate a global system is now a major domestic satellite operator. Television still dominates domestic satellite communications, but data has grown tremendously with the advent of very small aperture terminals (VSATs). Small antennas, whether TV-Receive Only (TVRO) or VSAT are a commonplace sight all over the country.

1.5.4 New Technology

The first major geosynchronous satellite project was the Defense Department's ADVENT communications satellite. It was three-axis stabilized rather than spinning. It had an antenna that directed its radio energy at the earth. It was rather sophisticated and heavy. At 500-1000 pounds it could only be launched by the ATLAS- CENTAUR launch vehicle. ADVENT never flew, primarily because the CENTAUR stage was not fully reliable until 1968, but also because of problems with the satellite. When the program was canceled in 1962 it was seen as the death knell for geosynchronous satellites, three-axis stabilization, the ATLAS-CENTAUR, and complex communications satellites generally. Geosynchronous satellites became a reality in 1963, and became the only choice in 1965. The other ADVENT characteristics also became commonplace in the years to follow.

In the early 1960s, converted intercontinental ballistic missiles (ICBMs) and intermediate range ballistic missiles (IRBMs) were used as launch vehicles. These all had a common problem: they were designed to deliver an object to the earth's surface, not to place an object in orbit. Upper stages had to be designed to provide a delta-Vee (velocity change) at apogee to circularize the orbit. The DELTA launch vehicles, which placed all of the early communications satellites in orbit, were THOR IRBMs that used the VANGUARD upper stage to provide this delta-Vee. It was recognized that the DELTA was relatively small and a project to develop CENTAUR, a high-energy upper stage for the ATLAS ICBM, was begun. ATLAS-CENTAUR became reliable in 1968 and the fourth generation of INTELSAT satellites used this launch vehicle. The fifth generation used ATLAS-CENTAUR and a new launch-vehicle, the European ARIANE. Since that time other entries, including the Russian PROTON launch vehicle and the Chinese LONG MARCH have entered the market. All are capable of launching satellites almost thirty times the weight of EARLY BIRD. In the mid-1970s several satellites were built using three-axis stabilization. They were more complex than the spinners, but they provided more despun surface to mount antennas and they made it possible to deploy very large solar arrays. The greater the mass and power, the greater the advantage of three-axis stabilization appears to be. Perhaps the surest indication of the success of this form of stabilization was the switch of Hughes, closely identified with spinning satellites, to this form of stabilization in the early 1990s. The latest products from the manufacturers of SYNCOM look quite similar to the discredited ADVENT design of the late 1950s.

Much of the technology for communications satellites existed in 1960, but would be improved with time. The basic communications component of the satellite was the traveling-wave-tube (TWT). These had been invented in England by Rudoph Kompfner, but they had been perfected at Bell Labs by Kompfner and J. R. Pierce. All three early satellites used TWTs built by a Bell Labs alumnus. These early tubes had power outputs as low as 1 watt. Higher- power (50-300 watts) TWTs is available today for standard satellite services and for direct-broadcast applications. An even more important improvement was the use of high-gain antennas. Focusing the energy from a I-watt transmitter on the surface of the earth is equivalent to having a 100-watt transmitter radiating in all directions. Focusing this energy on the Eastern U.S. is like having a 1000-watt transmitter radiating in all directions. The principal effect of this increase in actual and effective power is that earth stations are no longer 100-foot dish reflectors with cryogenically-cooled maser amplifiers costing as much as $10 million (1960 dollars) to build. Antennas for normal satellite services are typically 15-foot dish reflectors costing $30,000 (1990 dollars). Direct-broadcast antennas will be only a foot in diameter and cost a few hundred dollars.

1.5.5 Mobile Services

In February of 1976 COMSAT launched a new kind of satellite, MARISAT, to provide mobile services to the United States Navy and other maritime customers. In the early 1980s the Europeans launched the MARECS series to provide the same services. In 1979 the UN International Maritime Organization sponsored the establishment of the International Maritime Satellite Organization (INMARSAT) in a manner similar to INTELSAT. INMARSAT initially leased the MARISAT and MARECS satellite transponders, but in October of 1990 it launched the first of its own satellites, INMARSAT II F-1. The third generation, INMARSAT III, has already been launched. An aeronautical satellite was proposed in the mid-1970s. A contract was awarded to General Electric to build the satellite, but it was canceled--INMARSAT now provides this service. Although INMARSAT was initially conceived as a method of providing telephone service and traffic-monitoring services on ships at sea, it has provided much more. The journalist with a briefcase phone has been ubiquitous for some time, but the Gulf War brought this technology to the public eye.

The United States and Canada discussed a North American Mobile Satellite for some time. In the next year the first MSAT satellite, in which AMSC (U.S.) and TMI

(Canada) cooperate, will be launched providing mobile telephone service via satellite to all of North America.

In 1965, when EARLY BIRD was launched, the satellite provided almost 10 times the capacity of the submarine telephone cables for almost 1110th the price. This price-differential was maintained until the laying of TAT-8 in the late 1980s. TAT-8 was the first fiber-optic cable laid across the Atlantic. Satellites are still competitive with cable for point-to-point communications, but the future advantage may lie with fiber-optic cable. Satellites still maintain two advantages over cable: they are more reliable and they can be used point-to-multi-point (broadcasting).

Cellular telephone systems have risen as challenges to all other types of telephony. It is possible to place a cellular system in a developing country at a very reasonable price. Long-distance calls require some other technology, but this can be either satellites or fiber-optic cable.

1.6 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 TELSTARIRELAY 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.

CHAPTER2

SATELLITE COMMUNICATIONS

2.1 Overview

A communications satellite is a spacecraft that carries aboard communications equipment, enabling a communications link to be established between distant points. Satellite that orbit the earth do so a result of the balance between centrifugal gravitational forces. Johannes Kepler (1571-1630) discovered the laws that govern satellite motion. Although Kepler was investigating the motion in planets and their moons (so-called heavenly bodies), the same laws apply the artificial satellites launched for communications purposes. Before examining the role of these satellites play in telecommunications, a brief intruding to Kepler's laws will be presented as they apply to such satellites. Kepler's laws apply to any two bodies in space that interact through gravitation. The more massive of the bodies is called the primary end the other secondary or satellite.

2.2 Basic Characteristics of Satellites

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 consist 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, maintaining precise synchronization with the earth's rotation. It is well known that a system of three satellites in GEO, each separated by 120 degrees oflongitude, as shown in figure 2.1, can receive and send radio signals over the entire globe except for the polar regions. A given satellite has a coverage region, illustrated by the shaded oval, within which earth stations can communicate with and be linked by the satellite.

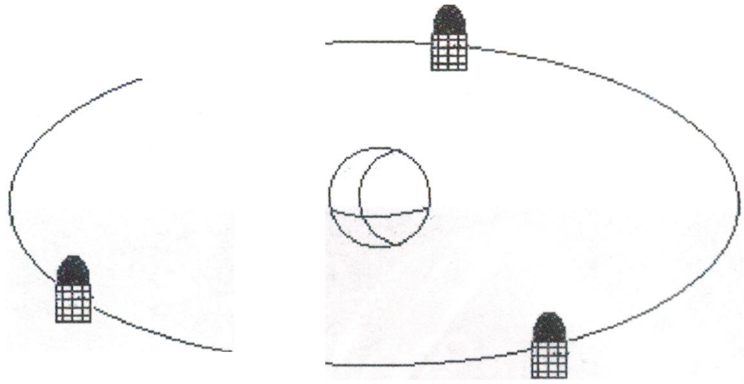


Figure 2.1 A System of Three Geostationary Communications Satellites Provides Nearly Worldwide Coverage.

The GEO (also referred to as the Geostationary satellite orbit (GSO)) is the idea case of the entire class of geosynchronous (synchronous) orbits, which all have a 24-hour period of revolution but are typically inclined with respect to the equator. As viewed from the earth, asynchronous satellite in an inclined orbit will appear to drift during a day about it's normal position in the sky. The GEO is not a stable arrangement and inclination naturally increases in time. Inclination is controlled by the use of an onboard propulsion system which enough fuel for corrections during the entire life time of the satellite. Asynchronous satellite not intended for GEO operation can be lunched with considerably less auxiliary fuel for this purpose. Orbit inclination of greater than 0.1 degrees is usually not acceptable for commercial service unless the earth station antennas can automatically repaint toward the satellite as it appears to move.

The key dimension of the geostationary satellite is its ability to provide coverage of an entire hemisphere at one time. A large contiguous land area, as well as offshore location can simultaneously access a ingle satellite. If the satellite has specially design communication beam focused on these areas. Then any receiving antennas within the footprint of the beam (the area of coverage) will receive precisely the same transmission. Locations well outside the footprint will generally not be able to use the satellite effectively. The typical example in north America is the galaxy I satellite see figure 2.2 which has 24 television channels with coverage throughout the 50 united states. These 24 channels are broadcast to more than 15000 cable television systems and to over two million home backyard and roof top antennas. In general, two-way (full duplex) communications is possible because the satellite receiving beam will provide thsamefootprint.

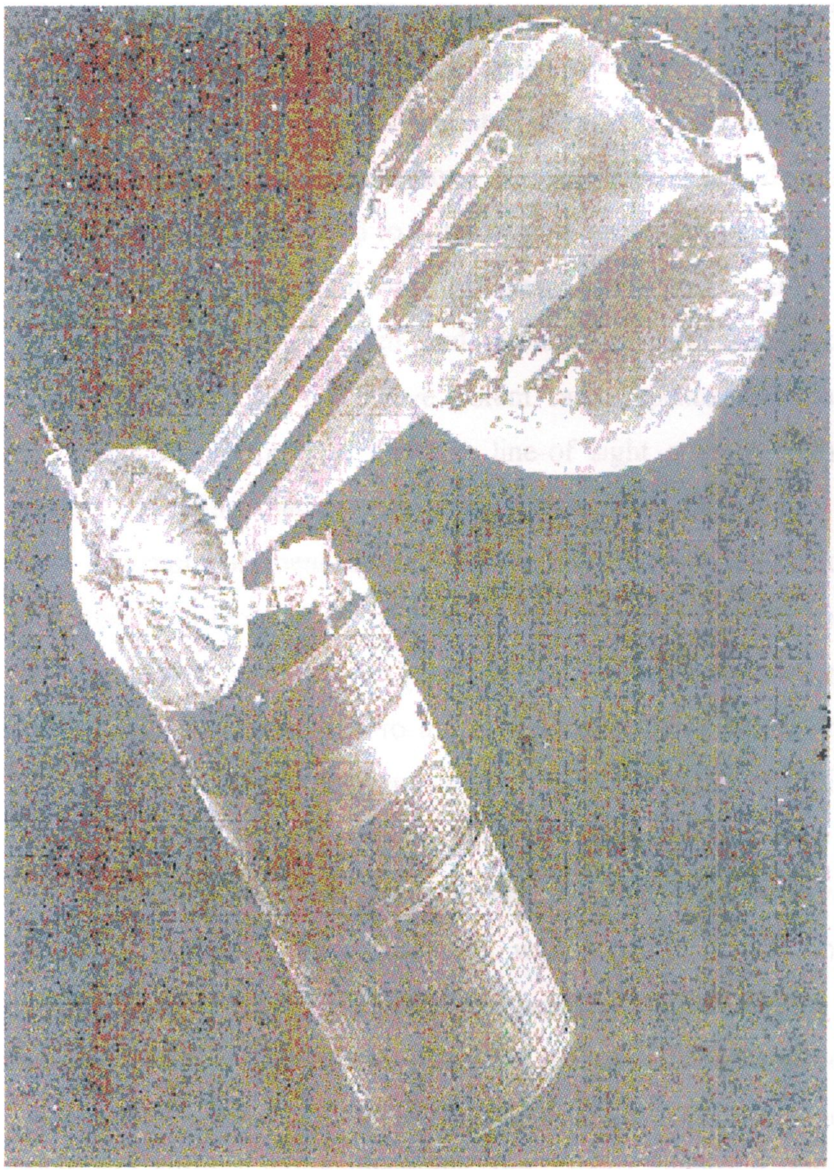


Figure 2.2 Typical footprint of a geostationary satellite.

The expansion in the use of satellites for communication has not occurred in a vacuum. Terrestrial communication system, which include cable and point-to-point microwave radio, where around before satellites, are still around, and will be around long into the future (as will satellites). Technology is always advancing, and satellite terrestrial communication will improve in quality, capability, and economy. Terrestrial systems must spread out over a land mass like a highway network in order to reach the points of access in cities. The time, difficulty, and expense incurred are extensive; but once established, a terrestrial infrastructure can last a lifeteam. Satellites, on the other hand, designed to last about ten years in orbit due to the practical inability to service a satellite in GEO and replenish consumables (fuel, battery cells, and degraded or failed components). The term bypass is often used to refer to the ability of satellite links to step over the existing terrestrial network and thus avoid the installation problem and service delays associated with local telephone service. Figure 2.3 depicts the three means of long hole communication used to connect two user location. Using the satellite in a duplex mode (i.e., allowing simultaneous twoway interactive communication), the user can employ earth stations at each end, eliminating any connection with the terrestrial network. In a terrestrial microwave system, radio repeaters must be positioned at intermediate points along route to maintain line-of sight contact. This is because microwave energy., including that on terrestrial and satellite radio links, travels in a straight line with minimum of bending over or around obstacles. In the case of long distance cable system, a different form of repeater is needed to amplify the signals and compensate for changes in cable characteristic. Therefore cable systems (coaxial and fiber optic) are probably the mot costly to install and maintain. Only providers of local and long distance telephone service and major users of communication services (government agencies, multinational corporations, railroads, utilities, etc.) are able to justify the expense of operating their own terrestrial cable or microwave networks. Satellite network, on the other hand, are well within the reach of much smaller organizations, since satellite capacity can be purchased or rented from a much large company or agency. Examples of satellite operators include international consortia like INTELSAT, government-owned communications companies, and privet companies like TELSAT Canada and Hughes communications, Inc., which construct the systems and operate them as a business. The availability of small, low-cost earth stations which take advantage of more sophisticated satellites has allowed the smallest potential users to apply satellite bypass networks to achieve economies and save time. The idea of a satellite dish on every roof top is now possible.

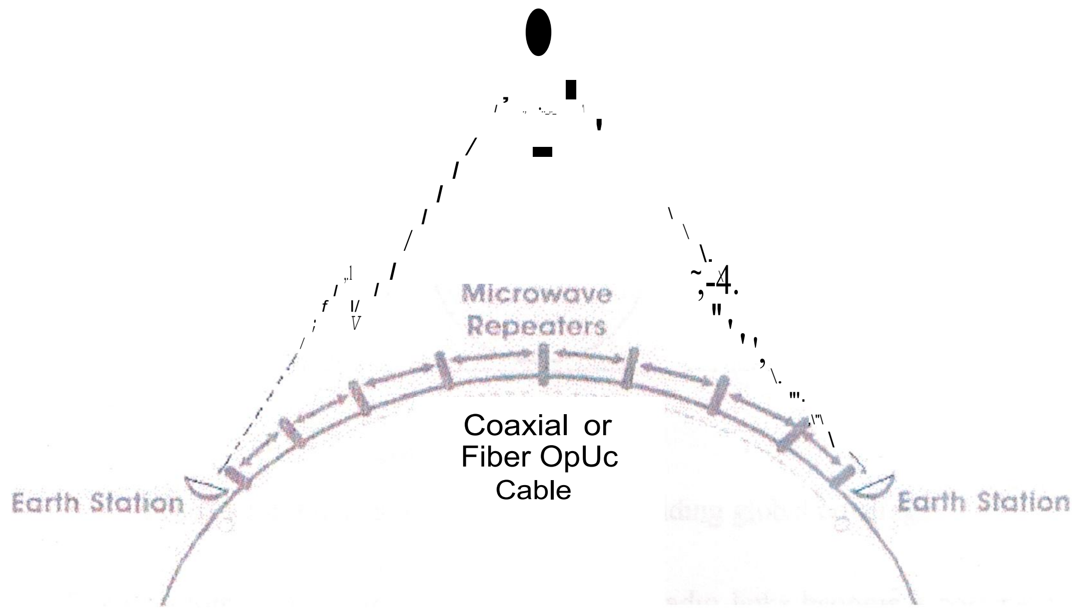


Figure 2.3 Terrestrial Microwave and Cable Systems Require Multiple Hops while A Satellite System Provide the same Capability with Single Hop.

2.3 Satellite communication

Satellite communication became a possibility when it was realised (by the science fiction writer, Arthur C. Clarke) that a satellite orbiting at a distance of 36000Km from the Earth would be geostationary, i.e. would have an angular orbital velocity equal to the Earth's own orbital velocity. It would thus appear to remain stationary relative to the Earth if placed in an equatorial orbit. This is a consequence of Kepler's law that the period of rotation T of a satellite around the Earth was given by:

T = **2r.r:1/ı**

,f{gsR")

Where **r** is the orbit radius, **R** is the Earth's radius and $gs=9.81ms_2$ is the acceleration due to gravity at the Earth's surface. As the orbit increases in radius, the angular velocity reduces, until it is coincident with the Earth's at a radius of **36000Km.** In principle, three geostationary satellites correctly placed can provide complete coverage of the Earth's surface (Figure 2.4).

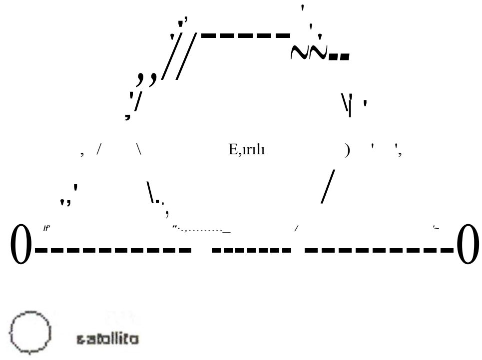


Figure 2.4 Geostationary satellites providing global coverage

For intercontinental communication, satellite radio links become a commercially attractive proposition. Space communication showed phenomenal growth in the 1970s, and will continue to grow for some years to come. The growth has been so rapid that there is now danger of overcrowding the geostationary orbit. Satellite communication has a number of advantages:

- The laying and maintenance of intercontinental cable is difficult and exp~nsive.
- 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 communication is limited by four factors:

- Technological limitations preventing the deployment of large, high gam antennas on the satellite platform.
- Over-crowding of available bandwidths due to low antenna gains.
- The high investment cost and insurance cost associated with significant probability of failure.
- High atmospheric losses above 30GHz limit carrier frequencies.

A microwave antenna has two functions. It provides **gain** (i.e. amplification). It also directs the radiation into confined regions of space: the **antenna beam.** These properties are largely dependent on the antenna size. For a circular, dish antenna, the gain G is related to the antenna area A by the formula:

$$G = 4\pi A/\lambda^2$$

where >1.is the wavelength of the transmitted carrier. The angular width of the antenna beam 0is related to the antenna radius **R** by:

H - .0,6L\/ *R*

Thus, large antennas have high gains and narrow beams (Figure 2.5).

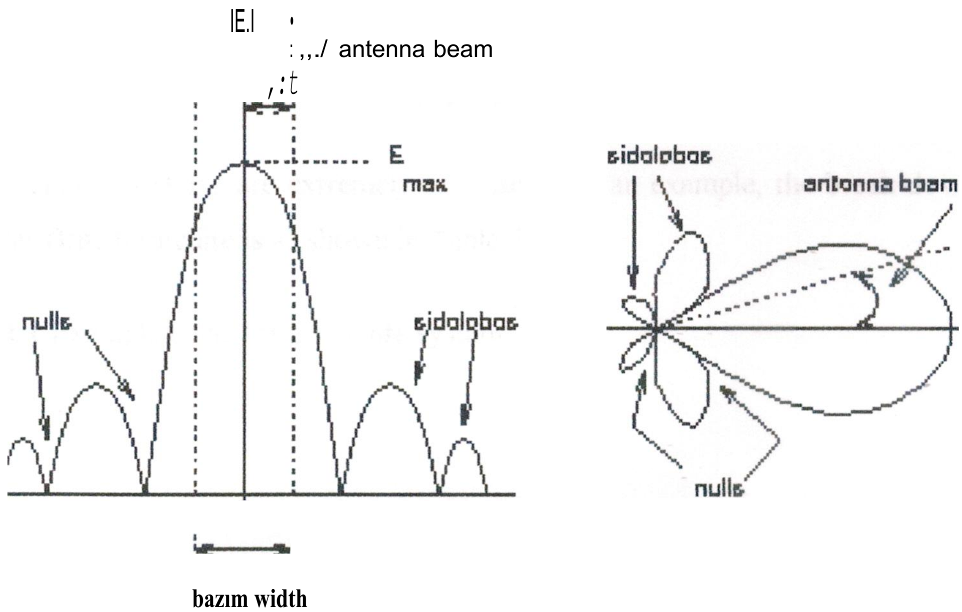


Figure 2.5 A typical antenna beam profile of a dish antenna

The cost of constructing an antenna is a strong function of its size. A rough rule of thumb is the cost is proportional to the diameter cubed. Thus a doubling of the antenna size will result in the satellite cost increasing eight times. As a result, antenna sizes are limited. The limitation in antenna size means that the satellite beam is wide. In order to prevent electromagnetic interference with terrestrial stations, the power radiated by the satellite is limited by international convention. In any event power is severely limited on a satellite platform.

Because the radiated power is low, large receiving antennas are required. The larger the receiver antenna, the larger the antenna gain, and hence the better the receiver SNR. The SNR is a function of the bandwidth, and the atmospheric attenuation. Ground stations close to the poles of the Earth have low elevation **look angles,** and signals have to pass through a thicker section of atmosphere. The size of receiver antenna is determined by the two requirements; 500MHz receive bandwidth and full capability at $\pm 80°$ of latitude.

A standard INTELSAT receiver is 30m in diameter. An antenna this large has a very narrow beam, typically 0.01^{0}. A geostationary satellite is not truly stationary; it wanders slightly in the sky. The very narrow beam width of the receiver requires automatic tracking of the satellite, and continuous pointing of the receiver antenna. An INTELSAT ground station is thus a large, expensive piece of equipment.

Satellite systems are extremely expensive. As an example, the break down for a particular British satellite is as shown in Table 2.1.

Table 2.1 Example costs for a satellite system

Item	**Cost [$Million]**
Satcllitc construction	300
lnv-catmcn t finance	300
Insur;;1.ncc	3UO
Launch	100
	1000

The use of satellites for regional communication is possible if there is sufficient demand for traffic. By reducing the range of latitudes down to $\pm 60°$, and reducing the bandwidth down to 50MHz, large reductions in satellite and ground station receiver costs are possible. One such direct-to-user (DTU) system is the Satellite Business System (SBS) covering a range of business and governments users with a demand for high speed data links in the US. The region is split into areas, roughly coincident with the satellite antenna gain contours, denoting increased cost of receiver technology. It is important to realize that the economies of satellite communication only make this regional communication possible if the system is heavily used (Figure 2.6).

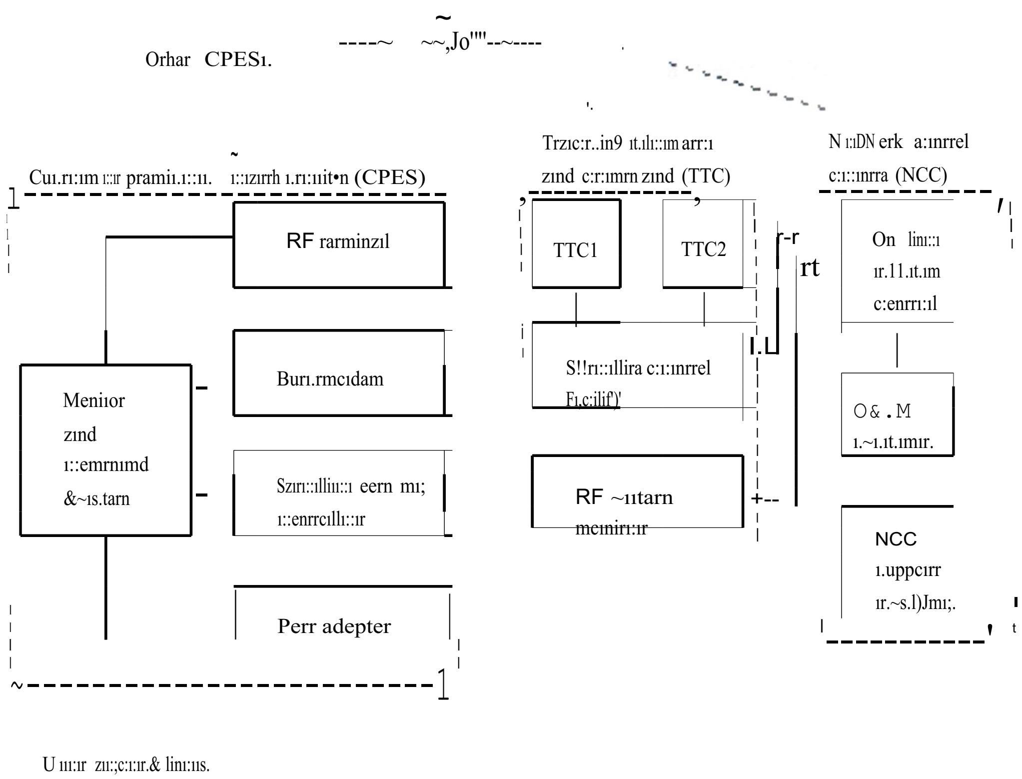


Figure 2.6 The Satellite Business System operational schematic

Improvements in satellite receiver technology have permitted smaller antennas to be used as ground station receivers. However, antennas are reciprocal. They have the same directional characteristics in transmit and receive. The use of low gain, wide beam earth stations for DTU systems has contributed considerably to the bandwidth overcrowding problem, particularly in the US.

Recently there has been interest in low-earth orbiting (LEO) satellites. Here, a satellite placed in a 1000Km orbit has an orbital time of 1 hour. These satellites can be operated in a store-and-forward mode, picking up data at one part of the globe and physically transferring it to another. Because the data-rates and orbit radius are greatly reduced, small, low-cost satellites and ground stations are possible. However, such satellites have yet to demonstrate any commercial success.

2.3.1 Satellite Communications The Birth Of A Global Footprint

A host of potential satellite-based communication services may finally do away with the disadvantages of conventional wireline and wireless technology. Satellite communications technology may be that last link in the evolution of a truly networked global community. According to reports published by a panel study commissioned by NASA and the National Science Foundation in the US, despite growing use of fibre optic cables, nearly 60 percent of all overseas communications is routed through satellites. It is estimated that more than 200 countries use about 200 satellites for "domestic, regional and/or global linkages, Defence communications, direct broadcast services, navigation, data collection, and mobile communications". Satellite communication is, currently, a $15 billion per year business and is looking at a 100 percent growth scenario in the next 10 years.

Later this month, a low earth orbit satellite will ride into space on a McDonnell Douglas Delta rocket. This will be the first of the Motorola-led Iridium consortium's planned 66 satellites. It marks an important step in realizing true world-wide communication linkage.

Basic telephony at affordable rates, through fixed-site and mobile satellite telephones, will be available for the first time to countries across the world. A new era in satellite communication will usher in multiple attempts to link the globe in a spidery web of satellite footprints and gateways. Space-based telecommunication systems, based on wireless personal communications network, will allow global telephone transmission of all types, including voice, data, fax, and paging. Various consortiums are feverishly working towards a 1998 implementation of networks of low-earth-orbiting satellite-based digital telecommunications systems that will offer wireless telephone and other telecom services.

The advantages are numerous from providing low-cost, high-quality telephony to other communications possibilities such as data transmission, paging, facsimile, and position location to geographically diverse areas. The obvious commercial advantage lies in offering these services in places not linked by current wire or wireless technology 24 hours a day, asked by the reliability of a bottom line driven commercial entity. As of now, there are several visible competitors vying with Motorola-led consortium-Iridium-for frequency, sponsorship, and subscribers; Globalstar-the Loral-Qualcomm venture; Odyssey (TRW), ICO, Elipso 1 and 2, Teledesic, and Aries are some of the names on

Strategies vary, but casing Iridum with Globalstar provides an interesting overview of the battle for positional supremacy. Motorola, for instance, is looking to put up a "network of networks" in space to provide world-wide, on-demand, voice and data communications services. The $3.8 billion network will run through 66 low-orbit satellites that web the globe. Naturally, to make the satellite control system work-and work well-Iridium's network management systems will have to be really sophisticated.

Globalstar is also trying to achieve world-wide penetration through a series of strategic link ups with regional service providers. A limited partnership between Loral Space & Communications Ltd and Qualcomm Inc., California, it now includes 10 strategic partners like Dacom/Hyundai and France Telecom/Alcatel acting as Globalstar service providers in over 100 countries. Each service provider will exclusively offer Globalstar services in its earmarked area and will thus market and distribute Globalstar service and be responsible for all necessary regulatory approvals. In addition, it will also own and operate the necessary gateways.

Global star will begin launching satellites in the second half of 1997 and will commence initial commercial operations via a 32-satellite constellation in 1998. Full 48-satellite coverage will occur in the first half of 1999. Globalstar expects to begin generating positive cash flow in 1999. As versus this, Iridium wants to put up a constellation of 66 satellites which would be the foundation of its global telecommunications network. Lockheed Missiles & Space Co.'s $700 million contract with Motorola Satellite Communications Division (SATCOM) for Iridium TM/SM is a prime example of how Motorola has brought in Defense technology and development to its commercial activity.

By the scheme of things, it appears that in remote areas with little or no existing wire line telephony, users will essentially make or receive calls through fixed-site telephones, similar either to phone booths or ordinary wire line telephones. Each subscriber terminal will communicate through a satellite to a local Globalstar gateway.

The net for the target customer is large and versatile. For hand-held and mobile services, users will include international travelers in areas where cellular coverage is poor or non-existent. Hospitals in remote areas, government and Defense posts in hitherto inaccessible areas, commercial vehicle operations, both national and international, such as ships, commercial trawlers, and aircrafts. Field-based activity is bound to give tremendous fillip to the concept, even if volumes are not dramatic in percentage terms. Archeology, geologists, and civil engineers could all make use of satellite phones.

Each of the many ventures is looking to be different. Teledesic, for instance, plans to use 840 refrigerato-sized, cross-linked satellites for broadband services such as videoconferencing and real-time imaging. It plans to support up to 20 million users over 95 percent of earth's surface. Aries, a 300 million dollar venture, will put 48 satellites in polar orbits. Elipso 1 and 2 estimated to be about $ 180 million conceives 6-18 satellites in two planes for US domestic service only, but is now in court with Qualcomm over patenting issues.

They will all target the mid-range, relatively, wire line-based communication economy that lacks adequate communication infrastructure. Iridium, for instance, has the participation of 47 countries, many of which have poor networks. It is this market that will offer a sustainable growth if pricing and service formulae are planned right. Based on a need-based structure, offering a package-based service should prove to be an advantage. To penetrate this market, the system must ensure optimum connectivity and promise low-cost, high quality system to users and to prevailing basic service providers.

To this end, strategic local tie-ups can only help. In India, for example, designing should allow for the routing of all calls, including international calls, through the service provider's present network from the local gateway, rather than ignoring it altogether. This gives the satellite service provider leverage for costing, and the advantage of existing infrastructure and additional revenue opportunities, while permitting local regulatory authorities to maintain supervision over the content and quality of service, ensuring optimum service to the customer.

2.4 Kepler's Law

We can mint this keplers law in its three laws.

2.4.1 Kepler's First law

Kepler's first law, states that the satellite will follow an elliptical path its orbit around the primary body. An ellipse has two focal points or (foci). The center of mass of two -bodies systems, termed the barycenter, is always center on one of the foci. In our specific case, because of the enormous difference between the masses of the earth and satellites, the center of mass always coincides with the center of the earth, which is therefore at one of the foci. This is an important point because the geometric properties of the ellipse are normally made with reference to one of the foci that can be selected to be one centered in the earth.

2.4.2 Kepler's Second Law

Kepler's second law state that for equal time intervals the satellite sweeps out equal areas in the orbital plane, focused at the barycenter. Referring to assuming that the satellite travels distance Sland S2 meters in 1 s, the areas Al&A2 will be equal. The average velocities are S1 and S2 mis. Because of the equal area law, it is obvious that distance S1 is greater than distance S2, and hence the velocity S1 is greater than velocity S2 generalizing. It can be said that the velocity will be greatest at the point of closest approach the earth (termed the perigee) and will be at least the farthest. Point from the earth (termed the Pogee).

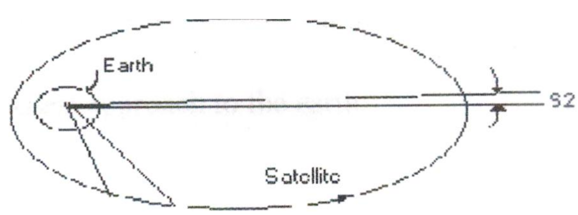


Figure 2.7 Kepler's Second Law

2.4.3 Kepler's Third Law

Kepler's third law states that the square of the periodic time of orbit is promotional to the cube of the mean distance between the two bodies. The mean distance as used by Kepler can be shown to be equal to the semimajor axis, and the third law can be stated in mathematical form as:

$$a = Ap^{\frac{2}{3}}$$

Where A is a constant. With a in Km and P in mean solar days, the constant A for earth evaluates to A= 42241.0979

These equations apply for the ideal cases of a satellite orbiting a perfectly spherical earth with no disturbing forces.

In reality, the earth's equatorial bulge and external disturbing forces will result deviations in the satellite motion from the idea. Fortunately the major deviations can be calculated and allowed for satellite that orbit close to the earth (coming within several hundred kilometers) will be affected by atmospheric drag and by the earth's magnetic field. For the more distant satellites, the main disturbing forces are the gravitational fields of the sun and the moon.

2.5 Satellite Orbits

Although an infinite numbers of orbits are possible, only a very limited number of these are of use for satellite communications. Some of the terms used in describing an orbits are

Apogee. The point farthest from the earth.

Perigee. The point of closest approach to the earth.

Ascending node, the point where the orbit crosses the equatorial plane going from south to north and the angle from the earth's equatorial plane to the orbital plane measured counterclockwise at the ascending node

2.5.1 Geostationary Orbit

A geostationary satellite is one that appears to be stationary relative to the earth. There is only one geostationary orbit, but this occupied by a large number of satellites. It is most widely used orbit by far, for the very practical reason that the earth station antennas don't needs to track geostationary satellites. The first and obvious requirements for a geostationary satellite is that it must have zero inclination. Any other inclination would carry the satellite over some range of latitudes and hence would not be geostationary.

Thus the geostationary orbit must lie in the earth equatorial plane. The second obvious requirements are that geostationary satellites should travel eastward at the same rotational velocity as the earth. Sincere this velocity is constant, then from Kepler's second law.

2.5.2 Geo-synchronous Orbit

a) Basic Orbital Characteristics

The earth's period of rotation, that is, the time taken for one complete rotation about its center of mass relative to the stellar background is one sidereal day, approximately 23hours 6 minutes 4 seconds. If a satellite has a direct, circular orbit and its period of revolution measured as above, it is a geo-synchronous satellite. The radius of its orbit (Rg) will be 42164km and its height above the earth's surface will be about 35786km. If this satellite daily Earth track (that is, the locus of the points on the points on the earth's surface that are vertically below the satellite at any instant) is traced, the maximum extent of the pattern in degrees of latitude, north and south of the equator, is equal to the angle of inclination of the orbit. Provided that the orbit is indeed circular, the north-going track crosses-over point of the north-going tracks is no longer located in the equatorial plane and the pattern becomes asymmetrical.

b) Advantages

The GSO is better for the most communication systems than any other orbit. The reasons are:

One satellite can provide continuous links between earth stations. An inclined gee-synchronous satellite can do this also, although the gee-graphical area that can be served is more limited if the angle of inclination is large, and the disadvantages of using satellite with an orbital period of less than one siderial day for systems that are required to provide continuous connections.

The gain and radiation pattern of satellite antennas can be optimized, so that the gee-graphical area illuminated by the beam, called the footprint that can be matched accurately to the service area, yielding significantbenefits.

The gee-graphical area visible from the satellite, and therefore potentially accessible for communication, is very large, as showing in the figure (2.4) below the diameter of the area with in which the angle of elevation a of gee-stationary satellite is greater than 5° is about 19960 km.

If the orbit is accurately gee-stationary, earth station antennas of considerable gain can be used without automatic satellite tracking equipment cost and minimizingthe operational attenuation required.

The assignment used in different gee-stationary satellite networks can be coordinated efficiently, the satellite footprints can be matched to the service area, and earth station antennas usually have high again.

c) Disadvantage

1. A satellite link from earth to station via gee-stationary satellite is very long.
2. The angle of elevation of the satellite as seen from earth station in high latitudes is quite low, leading at times to degraded radio propagation and possible obstruction by hills, buildings, and so on.

2.5.3 Inclined Elliptical Orbits

a) Basic orbital

The shape of an ellipse is characterized by its eccentricity ε, where:

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

a and **b** are the semi-major and semi-minor axes of the ellipse. There are two foci located on the major axis and separated from the origin ellipse by distance c, where

C=&a

For an earth satellite with an elliptical of the earth. The points on the orbit where the satellite is most and least distance from the earth are called the apogee and the perigee respectively. The greatest and least distances from the surface of the earth, the altitudes of apogee and perigee ha and hp given by

$$h_a = a(1+ \in) - R_E$$

$$h_p = a(1- \in) - R_E$$

a, b are semi-major and semi-minor axes of the ellipse. These various terms are illustrated in Figure (2.8)

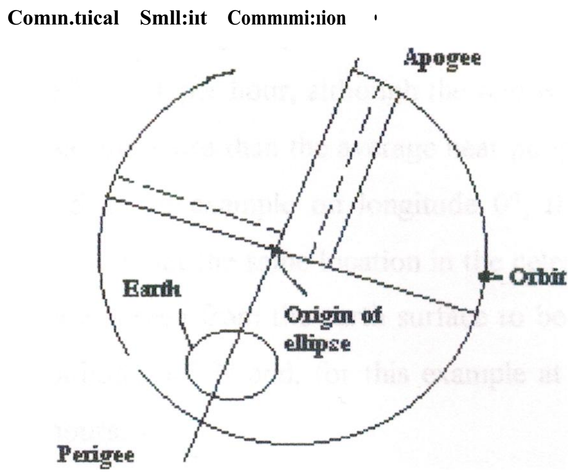


Figure 2.8 Semi major and semi manor axis of the ellipse

A satellite is perfectly circular orbit has uniform speed round that orbit, but the speed of motion a satellite in an elliptical orbit varies. As the satellite moves from apogee to perigee its potential energy falls and its kinetic energy, as reeled by its speed, rises. Correspondingly, the potential energy rises and the speed fails as the satellite moves from perigee to apogee. This variation of speed is convent ally expressed in the form of Kepler's second law of planetary motion.

b) The Earth Coverage Of Satellite In Elliptical Orbits

Satellite in orbits of substantial eccentricity spend most of each orbital period at a high altitude, close to the height of their apogee, from which they can cover a large footprint. In general they are of little use at low altitude, near to perigee. The systems that might find such orbits of value are national or regional in coverage rather than global. Thus it is necessary to stabilize the Earth track, to ensure that the point on the earth directly beneath the apogee should be consistently located at an appropriate point in the services area.

c) High Latitude Coverage

A point on the surface of the earth sweeps through right ascension at a constant rate of approximately 3600/24=15° per hour. A satellite in a direct elliptical orbit with period of T (hours) sweeps through right ascension in the same direction as the earth and at an average rate 360°/ T per hour, although the rate will be considerably less than the average near apogee and more than the average near perigee. The Earth track of the Molniya orbit, centered as an example on longitude 0°, the satellite passes through apogee twice each day, at about the same location in the celestial frame of reference. At each apogee the satellite is seen from the earth surface to be within a few degrees of a central point around latitude 60° N and, for this example at longitude 0°or 180° for a period of about eight hours.

d) Short Orbital Period

Satellite in circular orbits with height above the earth of 8000 km have an orbital period of 4.7 hours; 12 satellite in phased orbits might be needed to provide continuous coverage of a service area that is continental in extent. A satellite with an elliptical orbit having a period of two hours might also have a height above the earth's surface at apogee of 8000 km, depending on the eccentricity of its orbits.

e) Medium-Altitude Orbits

Geo-stationary satellite has great advantages for communications applications where polar coverage is not required. In the early days of satellite communication, it was fered that one- way transmission times exceeding 250 ms might be an unacceptable impediment to telephone conversation. Geo-stationary satellite seems likely to continue to dominate satellite communications with high- capacity links between fixed points. However, there has recently been a revival of interest in using medium- altitude orbits for serving mobile earth stations, because compared with the GSO, the transmission loss is lower.

2.5.4 The Global Star System

Loral Qualcomm Satellite Services Company develop the Global-Star at 1944.the first group is supposed launched in mid 1997, service will begin in mid 1998, and full service will be in 1999. Global-Star use of :M:MA technology allows users to connect multiple satellite, improves single quality, eliminates interference, and disconnects cross talk and loss of data.

2.5.5 The Orboccomm System

The orbital communication co-operation (Orboccomm) is a law earth orbital (LEO) satellite system intended to provide two way message and data communication services and position determination. The first two satellite of (Orboccomm) launched at April 1995. In Febl996 the production subscriber communication equipment became available. Orboccomm covers 67 countries and about two-third of the earth's population. This is served by launched by the end of 1997. During the interval until the constellation is completed, the licenses will be building their own ground stations, and beginning their own service. Offered in Europe and most of Latin, American beginning in 1997. Full global availabilityis projected for 1999.

2.6 Frequency Bands

Satellite communications employ electromagnetic waves to carry information between ground and space. The frequency of an electromagnetic wave is the rate of reversal of its polarity in cycles per second (now defined to be units of Hertz). Alternating current in a copper wire also has this frequency property, and if the frequency sufficiently high, the wire will become an antenna, radiating electromagnetic energy the same frequency. Recall that wavelength is inversely proportional to frequency, with the proportionality constant being the speed of light (i.e., 300000000 meters per second in a vacuum).

A particular range of frequencies is called a frequency band, while the full extant of all frequencies for zero to infinity is called the spectrum. In particular, the radio frequency (RF) part of the electromagnetic spectrum permits the efficient generation of signal power, its radiation into free space, and reception at a distant point. The most useful RF frequencies lie in the microwave bands (between approximately 300 MHz and 300000 MHz) although lower frequencies (longer wavelengths) are attractive for certain applications.

An RF signal on one frequency is called a carrier and the actual information that it carries (voice, video, or data) is called modulation. A carrier with modulation occupies a certain amount of RF bandwidth within the frequency band of interest. If two carriers are either on the same frequency or have overlapping bandwidths, then radio frequency interference (RFI) may occur. To the user, RFI can look or sound like background noise (which is neither intelligible nor particularly distressful), or it could produce an annoying effect like herringbone patterns on a TV monitor. When the interference affect would be classed as harmful, a condition similar to the radio-jamming encounter in the short-wave broadcast band.

Frequency bands are allocated for various purposes by the International Telecommunication Union (ITU), a United Nations agency which is located in Geneva, Switzerland. Members of the ITU include essentially every government on the planet, who in turn are responsible for making specific assignments of RF carriers to frequencies within the allocated bands to domestic users. The ITU has allocated the same parts of the spectrum to many users and for many purposes around the world because of the fixed nature of the resource . The consequence of this is that users of radio communication always allow for limited amounts of RFI and must prepared to deal with harmful interference if and when it occurs . When there are disputes between countries over RFI or frequency as-signments, the ITU often plays the role of mediator or judge.

The spectrum of RF frequencies is depicted in figure 2.9, which indicates a logarithmic scale the abbreviations that are in common usage . The bottom end of the spectrum from 0.1 to 100 MHz has been applied to the various radio broadcasting services and is not used for space communication . The frequency bands of interest for satellites lie above 100 MHz . Where we find the VHF (very high frequency) , UHF (ultra high frequency) and SHF (super high frequency) bands . The SHF range has been broken down further by common usage into sub-bands with letter designations , the familiar C and Ku bands being include . It is interesting to note that these letter designations are of historical interest , since they formerly were classified designations for the microwave bands used for radar and other military or government purpose . today they are simply shorthand named for the more popular satellite bands , all lying in the range of 1 GHz (1.000 MHz) to 30 GHz.

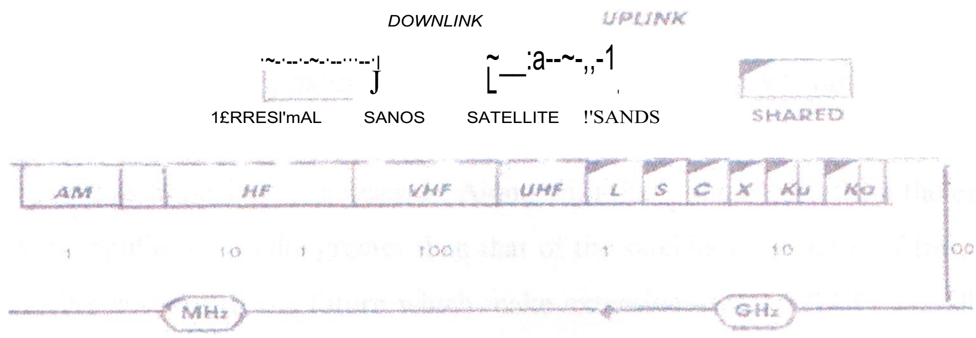


Figure. 2.9 The Radio Frequency Spectrum Identifying Commonly Used Frequency Bands and Their Designations

An important consideration in the used of microwave frequency for satellite communication is the matter of sharing . Figure 2.9 indicated that most of the satellite bands (light shading) are "shared," which means that the same frequencies are used by terrestrial microwave links . Parts of the Ku and Ka bands , on the other band , are not shared with terrestrial so that only satellite links are permitted . In most instance , the tow service must coexist by virtue of a process called frequency coordination , where users who plan to use a given band for a given purpose work with current users to assure that harmful RFI will be avoided . A band which is not shared , therefore , is particularly valuable to satellite communication , since terrestrial microwave system can be totally ignored . Frequency coordination , however , is often necessary to control interference among satellite system which use the same frequency band and operate in adjacent orbit positions .

A typical satellite band is divided into separate halves , one for ground to space links (the uplink) and one for space to ground links (the downlink) . This separate is reflected in the design of the satellite microwave repeater to minimize the chance of downlink signals being re-received and thereby jamming the operation of the satellite. By way of contrast , such a division is not provided for terrestrial system , but considerable care must be exercised in assignment frequencies , since links can run in any direction between micorwave relay towers .

Uplink frequency bands allocated by the ITU are typically slightly above the corresponding downlink: frequency band to take advantage of the fact that it is easier to generate RF power within an earth station than it is on-board a satellite , where weight and power are limited . It is a natural characteristic of the type of RF power amplifier used in both location that the efficiency of conversion from ac power into RF power tends to decrease as frequency is increased . Along with this , the output from the earth station power amplifier is usually greater than that of the satellite by a factor of from 10 to 100 . Satellite systems of the future which make extensive use of VSATs will allow less uplink power , so that the cost of the earth station can be minimize .

2.6.1 C Band

The frequency band known as C band was the the first part of the microwave spectrum to be used extensively for commercial satellite communication . Another common designation which we will use is 6/4 GHz, which identifies the nominal center of the uplink frequency band (5.925 to 6.425 GHz) followed after the slash mark(/) by the nominal center of the downlink:frequency band (3.700to 4.200 GHz). (The uplink-downlink convention is not industry standard and others have reversed the order to express the number in ascending order .) To this day , C band remains the dominate frequency band for commerical satellite communication ,even as the higher bands (i.e.,Ku) come into greater use . What were the reason for the selection of C band in the first place , and why does it remain so popular?

C band at the outset a principal advantage over bands which are either higher or lower in frequency-hence , it represent an optimum . Figure 2.10 identifies the factor dealing with the level of radio noise which can distrub reseption at a distance point . The simplest means of overcoming this noise is to increase the level of received signal power from the radio link , either by transmitting more power towards the receiving antenna or by increasing the size of the receiving antenna . As shown in figure 2.10 , C band lies in a range of frequency near 1 GHz where the combination of natural and manmade noise sources is a minimum.

Hence , all other things being equal , C band requires less signal level to provide good quality communication . Lower frequencies toward 100 MHz suffer from a high level of man-made radio noise due to electrical equipment , automobile ignition system , and the like . Another dis-advantage of lower frequencies is the meager bandwidth that is available (Figure 2.10 has a logarithmic scale , magnifying the width at lower end) . For example , assuming that a 10% block of bandwidth is being allocated , the corresponding available bandwidth at 0.1 GHz and 4 GHz are 10 MHz and 400 MHz , respectively .

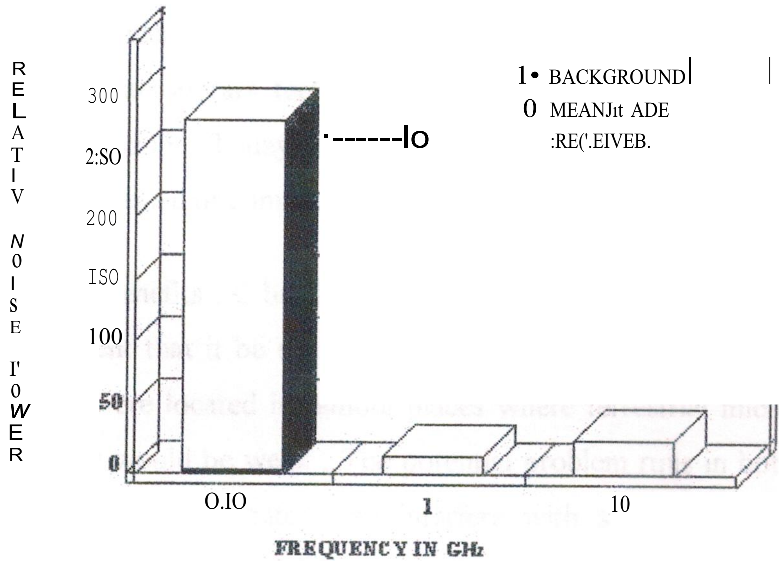


Figure. 2.10 RF Noise Power in a Receiving System as Function of frequency from Background, Man-Made, and Internal Sources.

As one moves well above 1 GHz , the radio receiver itself produced the bulk of the noise which the signal must overcome . This type of noise can be heard in a TV set or FM receiver without an antenna connected (this demonstrates that the noise is in fact generated inside receiver) . Receiver noise increases in intensity as frequency is increased but is not the main determent to operation at frequencies above 10 GHz , as is explaned in the following paragraphs .

The principle factor which affect the performance of satellite links at frequencies above 10 GHz is the absorption of the RF carrier power by the atmosphere . The most detrimental atmosphere effect is rain attenuation , which is a decrease of signal level due to absorption of microwave energy by water droplet in a rainstorm . Due to the relationship between the size of droplets relative to the wavelength of the radio signal , microwave energy at higher frequencies is more heavily absorbed than that at lower frequencies . The following section on Ku and Ka bands will provide more background . Rain attenuation is particularly a problem in tropical regions of the world with heavy thunderstorm activity , as these storms contain intense rain cells .

Equipment technology and availablilitywere factors in the favor of C band . In the early years (1965 to 1970) , C band microwave hardware was obtainable from other application such as terrestrial microwave , troposphere scatter communication system (which use high power microwave beams to achieve over-the-horizon link), and radar. No breakthrough in contemporary technology was necessary to take advantage of the technical feature of C band . Today , the equipment has been made very inexpensive (relatively speaking) because of competition and high-volume production .

With all of the benefits , C band is still constrained in some ways because of the international requirement that it be shared with terrestrial radio services . Traditionally C band earth station were located in remote places where terrestrial microwave signal on the same frequency would be weak . The potential problem runs in both direction - the terrestrial microwave transmitter can interfere with satellite reception (i.e.,the downlink) at the earth station , and RF energy from an earth station uplink can leak rowards a terrestrial microwave receive and distrub its operation .

Shielding , illustrated in Figure 2.11 , is the technique by which sharing can be made to work . A natural or man-made obstacle is located near the earth station antenna , but between it and the terrestrial microwave station exiting approximately within a 50-mile radius . As was stated in the beginning of this chapter , microwave signal travel in straight line , and one would expect that an obstacle would block them entirely . Microwave energy energy will experience diffraction , how-ever , since it is an electromagnetic wave . What diffraction does is to cause the wave to bend over (or around) an obstacle and thereby potentially interfere with reception on the other side . The amount of bending can be predicted and is a function of the distance between the source , obstacle , and receiver , as well as

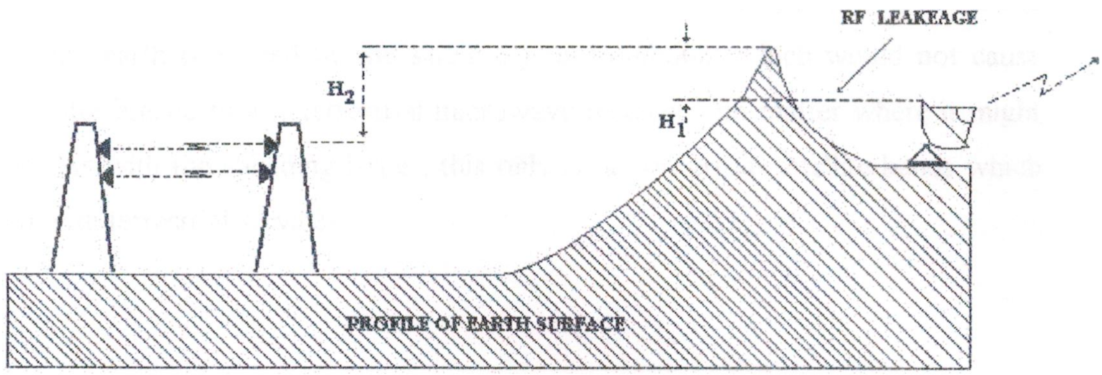


Figure. 2.11 The Use of Terrain Shieldingto Block Radio Frequency Interference Between a Microwave Link and a Earth Station

Of the height difference (indicated in Figure 2.11 by Hl and H2) . If the height differences are large , causing all antennas to lie well below the top of the obstacle , then little signal will search the receiver and good shielding is therefore achieved . Note that shielding is equal for both direction of propagation (i,e., from earth station to terrestrial microwave tower and vise versa) .

A distance of greater than 50 miles usually provides natural shielding from the curvature of the earth augmented by foliage and man-made structures . Obviously , if the microwave station is on top of a high building or mountain , then the earth station siting engineering will have to look long and hard for adequate natural shielding . Man-made shielding in the form of 30 to 60-foot metal or concrete walls has proven effective in such difficult situations.

Yet another aspect of sharing has to do with the ITU regulation which attempts to protect terrestrial radio receivers from direct satellite radiated signals . The level of such signals is low relative to that emanating from another line-of sight microwave station ; if satellite power is allowed to increase without bound , however , then it is theoretically possible to produce measurable interference into a terrestrial receiver . Figure 2.12 depicts the situation which has the greatest potential for such interference , i.e, where the antenna of the terrestrial station is pointing at another terrestrial station along the horizon but on a direct path to a satellite in orbit . To deal with this potential problem , the regulations limit the power flux density (power per unit area on the surface of the earth produced by the satellite) to an amount which would not cause significant interference to any terrestrial microwave receiver , no matter where it might be located .As with the shielding issue , this only is a concern in satellite bands which are shared with terrestrial services .

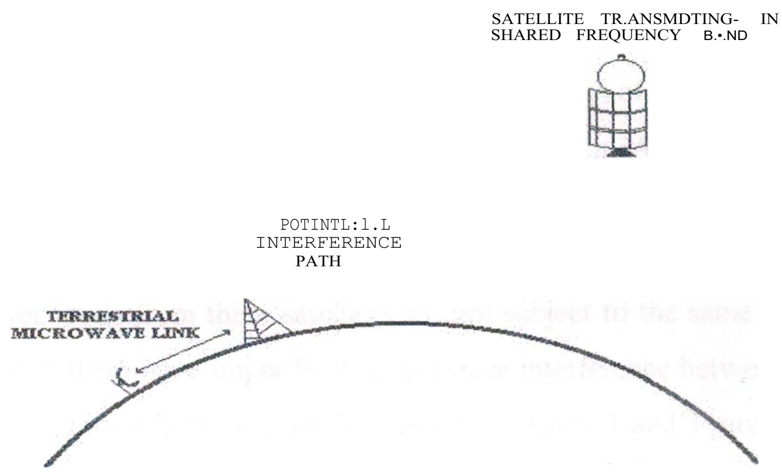


Figure 2.12 The Potential for Direct Radio Frequency Interference from a Satellite into a Terrestrial Microwave Receiver Where The Frequency Band is Shared

2.6.2 Ku Band

The frequency band that has done more to interest new users of satellite communication is Ku band . A part of the spectrum lying just above 10 GHz (see Figure 2.9) . Portions of Ku band are not shared with terrestrial radio , which has some advantages over C band , particularly for direct services using earth stations with small diameter antennas . The precise uplink and downlink frequency ranges allocated by the ITU vary to some degree with the region of the world .There are effectively three sections of Ku band which have been allocated to different services on an international or domestic basis . The most prevalent is the fixed satellite service (FSS), which is the service intended for one or tow way communication between fixed point on the ground . All of C band and the bulk of Ku band are allocated to the FSS for wide application in international and domestic communication . Sharing of these frequencies with terrestrial radio services is mandated by ITU regulation , however , and consequently part of Ku band is subject to the same coordination and siting difficulties as C band . The particular part of Ku band thusly affected is referred to as 14/11 GHz , where the uplink range is 14. 00 to 14. 500 GHz and the downlink range is 10. 95 to 11. 7 GHz (minus a gap of 0.25 GHz in the center). Only the downlink part of the allocation is actually subject to sharing .

A portion of the Ku allocation for FSS which is not shared with terrestrial services is referred to as 14/12 GHz (uplink range again is 14.00 to 14.50 GHz and downlink range is 11.70 to 12.20 GHz). The availability of14/12 GHz is limited to region 2, which is composed of north and South America. And can only be used for domestic communication services. North America, in particular, has been wide introduction of 14/12 GHz, while no such satellites are currently serving South America. Power levels from these satellites are not subject to the same restrictions as at C band, although there is an upper limit to minimize interference between satellites. Ku-band satellite operations in the rest of the world (i.e. region 1 and 3) are restricted to the 14/11 GHz shared allocation. In some instances, a region 1 (Europe and Africa) or region 3 (Asia) country can make 14/11 GHz appear like 14/12 GHz simply by precluding domestic terrestrial services from the band. Terrestrial radio services in adjacent countries are not under their control, however, and therefore international coordination must still be dealt with in border areas.

There is third segment of Ku band, referred to as 18/12 GHz, which is allocated strictly to the broadcasting satellite service (BBS). As with the 14/12 FSS band in region 2. The BSS band is not shared with terrestrial services. Its intended purpose is to allow television and other direct-to-home transmissions from the satellite. There are two regulatory features of this band, which make direct broadcasting to small antennas feasible. The first is that, without sharing, the satellite power level can be set at the highest possible level. Adjacent satellite interference could be a problem in a common coverage area. But this is precluded by the second feature: BSS satellites are to be spaced a comfortable nine degrees apart. In comparison, while there is no mandated separation between FSS satellites, a two-degree spacing has become the standard in the crowded North American orbital arc.

The operational advantages of 14/12 and 18/12 GHz lie with the simplicity of locating earth station sites (without regard for terrestrial radio stations) and the higher satellite downlink power levels permitted. The later results in smaller ground antenna diameters than at C band, All other things being equal. As was discussed in the section on C band, however, Ku band is subject to higher rain attenuation which can increase the incidents and duration of loss of an acceptable signal, figure 2.13 gives an indication of the relative amounts of extra downlink power, measured in dB of margin, needed to reduce the outage time to a few hours a month. Ka Band (30/20 GHz) is included for completeness, and is discussed later in this chapter. As shown in figure 2.13, the amount of margin to overcome a fade is also a strong function of the elevation angle from the earth station to the satellite in orbit. A rain cell exists as an atmospheric volume, which is wider than it is high; therefore low elevation angles force the radio signal to pass through a greater thickness of rainfall. Elevation angles of forty degrees or greater are consequently preferred for Ku-band frequencies and higher.

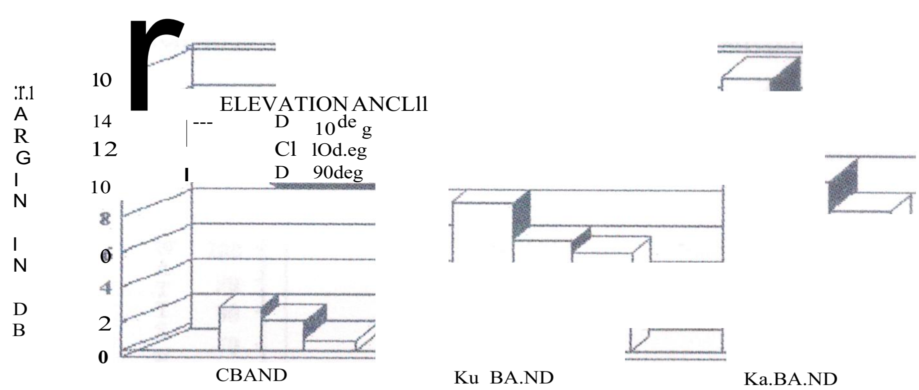


Figure 2.13 Link Margin in dB Required in C, Ku, and Ka Bands for Satellite Links as a Function of Earth Station Antenna Elevation Angle

Another important variable is the climate, where desert regions are less affected than tropical. In general, the need for greater power margin at Ku band tends to reduce some of the benefits obtainable by virtue of the higher satellite powers that are permitted by the international regulations.

2.6.3 UHF and L Band

Even through the amount of available band width below C band is diminished, these frequency bands are effective for providing rapid communication by way of mobile and transportable earth stations. With lower frequency of operation, the receiving antenna can be as simple as a small Yagi (TV type antenna) or wide helix. This is because the effective receiving area of a wire or rod antenna is inversely proportional to frequency. The use of relatively high power for each individual channel of communication (voice or data) also helps to reduce the size and cost of the receiving terminal. The tradeoff is in the number of voice channels per satellite: instead of being measured in the thousands for C-and Ku-band satellites, capacity of such lower frequency satellites ranges from tens to hundreds of channels. Figure 2.14 gives this tradeoff for a simple example of a relatively small satellite capable of delivering a total of 100 watts of RF power to its downlink antenna. At UHF or L band, ten watts per voice channel provides satisfactory reception by the type of antenna found on a ship or aircraft, but only ten such channels can be supported by this satellite at one time. A C-hand satellite can deliver perhaps 10,000 voice channels because 0.01 watts per channel can be received properly by a fixed antenna as large as ten meters in diameter.

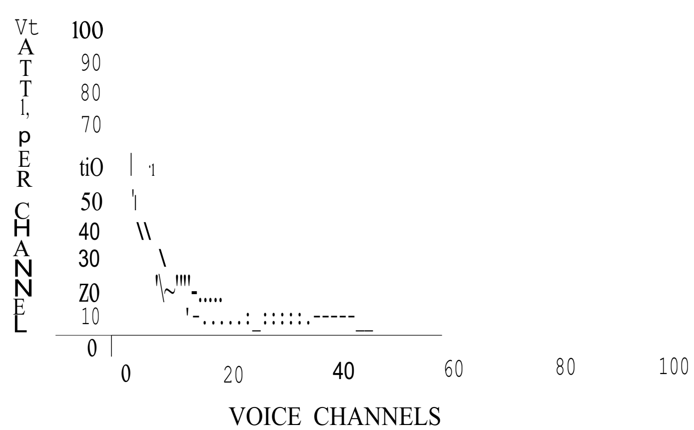


Figure 2.14 Satellite Channel Capacity versus RF Power per Channel

The use of such simple antennas on the ground, taking advantage of high power per channel in the satellite, also tends to restrict the total capacity of GEO in terms of the number of satellites that can operate at the same time. An earth station antenna has an angular range of operation, measured in azimuth and elevation, over which RF pass through at effectively its maximum level. In figure 2_15 for a low frequency satellite system, satellite A is at the center (peak) of the oval-shaped antenna beam emanating from an earth station. Operation at a relatively low frequency causes this beam to be broad enough to interfere with the operation of closely-spaced satellite at position B. the chords drawn within the beam show that the strength of the antenna beam (gain) in the direction of A is greater than in the direction of B, indicating that RFI would probably be harmful but not the maximum possible. A simple way to control RFI under this condition would be to use nonoverlapping bandwidths for the RF carriers of the respective satellite systems. More complex techniques which can "isolate" beams without separating the carriers in frequency are discussed later in this chapter.

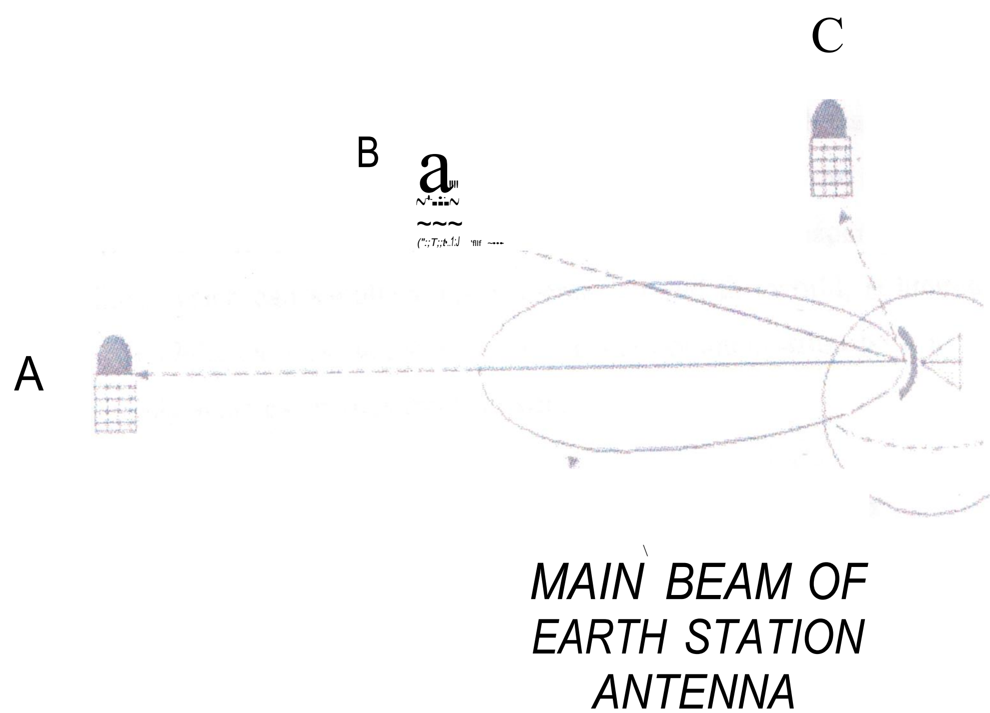


Figure 2.15 Effect of Wide Beam Earth Station Antenna on GEO Arc Utilization.

For the stellite at position C, the main beam of the ground antenna provides no measurable performance, and effective isolation is achieved. This means that satellite C can operate on the same frequencies as satellite A without causing or receiving harmful RFI. At higher frequencies and with higher gain ground antennas, illustrated in figure 2. 16, the main beam is significantly narrowed. This allows the three satellites to be moved closer together while maintaining the desired isolation, permitting more satellite to be accommodated in the orbit. Beam narrowing also happens when the diameter of the antenna is increased,

An example of a practical application of L-band ship-to-shore satellite communication is depicted in figure 2.17. A commercial passenger ship is shown with a compact antenna mounted on a mast. The satellite used in this example is Marisat, first launched in 1976. Ships at sea have always had limited communication and the most important consideration is that message delivery be very reliable. A Marisat terminal typically can pass a single Teletype channel along with a one-voice channel shared on a party line basis. The ship shown in the figure ahas a small directional antenna protected from the elements by an umbrella-shaped "radome". To compensate for rolling and pitching of the ship, the antenna is attached to a controlled mount, which keeps the satellite more or less at the center of the antenna beam. The satellite completes the link to the shore via C band, accessing to a conventional fixed earth station. Telephone calls and telex messages can then be routed to distant points over the public telephone and telex networks. The maritime mobile satellite system is being expanded, but the number of satellites, which can simultaneously operate around the world, is limited fewer than ten. Such mobile services would provide reliable communication with ships, airplanes, and eventually vehicles, as they move at will.

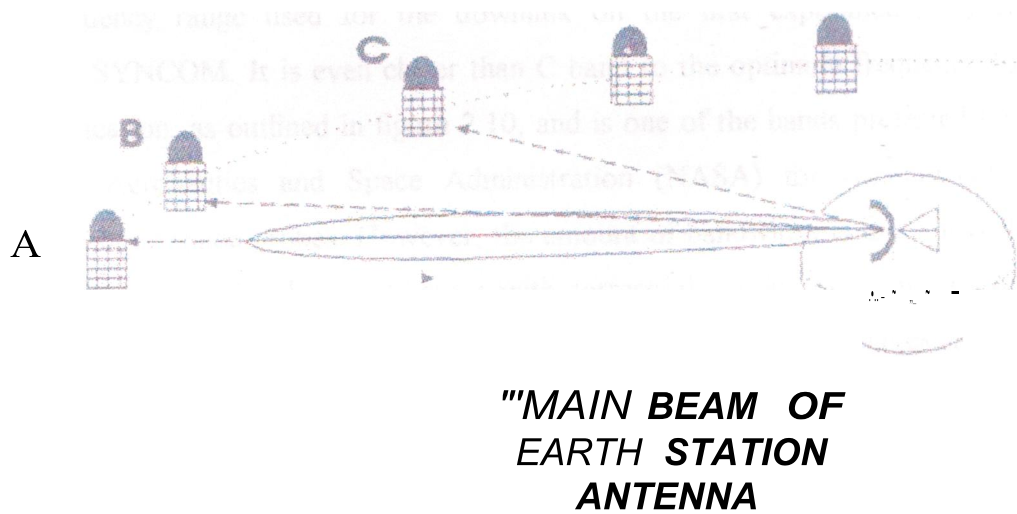


Figure 2.16 Improved GEO Arc Utilization from Narrow Earth Station Antenna Beams.

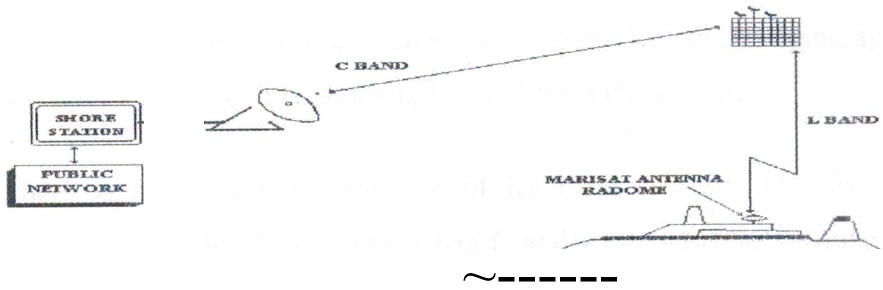


Figure 2.17 Example ofL-Band Service for Ship-to-Shore Communications Using the Marisat Satellite system.

2.6.4 S, X, and Ka Bands

The bands identified by S, X, and Ka in figure 2.9 have been applied to geostationary satellites in varying degrees but generally not for commercial purposes. In this section, the current and planned uses of these bands are briefly reviewed, but the reminder of the book will emphasize C and Ku bands, because of their widespread use around the world.

S band, nominally centered at 2 GHz, lies just below C band and was actually the frequency range used for the downlink on the first experimental synchronous satellite, SYNCOM. It is even closer than C band to the optimum frequency for space communication, as outlined in figure 2.1 0, and is one of the bands preferred by the US National Aeronautics and Space Administration (NASA) for communication with scientific deep space probes. However, the amount of bandwidth is much less than that offered by C and Ku bands. Sharing with terrestrial service such as industrial and educational television and studio-to-television transmitter links makes it extremely difficult to accomplish frequency coordination for earth stations. NASA, in fact, has had to place their deep space tracking stations and very remote parts of the country and the world. Broadcasting services from S-band satellite transmitters are used India and in the Arab countries, but there are currently no plans to do so in other parts of the world.

Government and military satellites communication systems of the United States and some other countries employ X band and, on an experimental basis, Ka band. With an uplink range of 7.90 to 8.40 GHz and a downlink range of7.25 to 7.75 GHz. X band is used extensively for military long- haul communication links much like C band is used on a commercial basis. In highly specialized cases, Ka band is being applied, since very narrow spot beams can be transmitted to and from the satellite.

There is a potential for the use of Ka band (30/20 GHz) for commercial applications in the decade of the 1990s when C and Ku bands may be fully occupied in some regions. During the 1970s, the japans space agency, NASDA, in conjunction with the government-owned Telecommunications Company, NTT, launched some experimental communication satellite, which operate in the Ka band frequency range.

The experimental links generally showed that the ample bandwidth that was allocated could in fact used under certain circumstances. Severe rain attenuation at these high frequencies would require that a given earth station include two receiving sites separated sufficiently so that only one is heavily affected at a time. Reception would then be switched to the site with the acceptable signal. This works because the most intense part of the storm is within the relatively small volume of a rain cell, whose dimensions are smaller than the spacing between receiving sites. In the United States, there are currently no plans to use Ka band for commercial communication services; NASA, however, has been pursuing a precursor 30/20 GHz program called the advanced communications technology satellite (ACTS) to advance the technology base.

2.7 ANTENNAS

2.7.1 Wire Antennas

Wire antennas are familiar to the layman because they are seen vertically everywhere. In automobiles, building ships aircraft, and so on. There are various shaes of wire antennas such as straight wire (dipole), loop, and helix, which are like the below

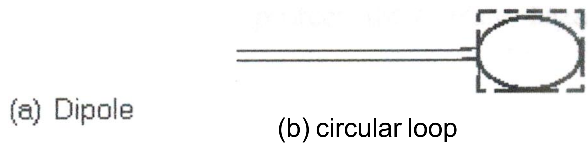


Figure 2.18 Straight wire Dipole

Loop antennas needs not only be circular. They may take the form of rectangular, square, ellipse, or any other configuration. The circular loop is the most common because of its simplicityin construction.

2.7.2 Aperture Antennas

Aperture Antennas may be more familiar to layman today then in the past because of the increasing demand for most sophisticated forms of antennas and utilization of higher frequencies. Some forms of aperture antennas of this type are very useful for aircraft or spacecraft applications, because they can be very conveniently

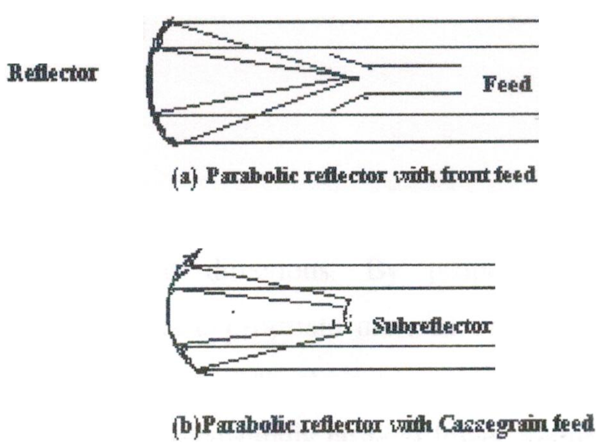


Figure 2.19 Parabolic Reflector

Flush monted on the skin of aircraft or spacecraft. In addition, they can be covered with a dielectric material to protect them from hazardous conditions of environment.

2.7.3 Array Antennas

Many applications require radiation characteristic that may not be achievable by a single element. It may, however, be possible that an aggregate of radiating elements in an electrical and geo-metrical arrangement (an array) will result in the desired radiation characteristics. The arrangement of the array may be such that the radiation from the element adds up to give a radiation maximum a particular directions, minimum in others as desired

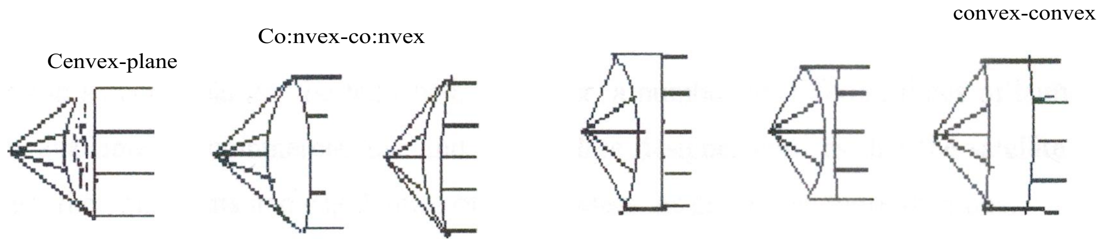
2.7.4 Reflector Antennas

The causes in the exploration of outer space has resulted in advancement of antenna theory, because of the need to communicate over great distance, sophisticated forms of antennas had to be used in order to trasmit and receive signals that had to travel millions of miles. A very common antenna form such in application is a parabolic reflector. Antennas of this type have beev built with diameter as large as 305 m. such large dimensions are needed to achieve the high gain required to transmit or receive after million of miles of travel.

2.7.5 Lens Antennas

Lenses are primarily used to collimate incident divergent energy to prevent it from spreading in undesired directions. By properly shaping the geo-metrical configuration and choosing the appropriate material of the lenses, they can transform various forms of divergent energy into plane waves. They can be used in most of the same applications as become execeedingly large at lower frequencies. Lens antennas are calssified according to the material forms are shown in figure bellows. In summary, an ideal antenna is one that will directions. In practice, however, such ideal performance cannot be achieved but may be closely approached.

Various typs of antennas are available and each type can take different forms in order too achieve the desired radiation characteristics for the particular application.



(a) Lens ıUt.tennawitk ıitd.ex of refraction >1 (b) Lens a:ntennas witk ıitd.ex of refraction <1

Figure 2.20 Lens antenna with index of refraction

2.8 Launchers And Launching

2.8.1 Introduction

A satellite may be launched into orbit a multi-stage expendable launch vehicle or a manned or unmanned reusable. The process of launching a satellite is based mainly on launching into equatorial circular orbits, and in particular the GSO, but broadly satellite into an orbit of the desired altitude, namely by direct ascet or by a Hohmann transfer ellipse. In the direct ascent method. The thrust of the launch vehicle is used to place the satellite in a trajectory, the turning point of which is marginally above the altitude of the direct orbit apogee kick motor (AKM) is often incorporated into the satellite itself, where other thrusters are also installed for adjusting the orbit or the satellite altitude throughout its operating lifetime in space. The Hohmann transfer ellipse trajectory that quires to be loced in an orbit at the desired altitude using the trajectory that quires the least energy. In practice it is usual for the direct ascent method to be used to inject a satellite into a LEO and for the Hohmann transfer ellipse method to be used for higher orbits.

2.8.2 Expandable Launch Vehicle:

a) Descreption And Capabilities:

Launch vehicle and their noise fairing impose mass and dimensional constrains on the satellite that can be launched. However, a number of different types of launcher are available for commercial use and the satellite designer ensures that the satellite will meet the constraints and capabilities of one of them, or preferably more than one.

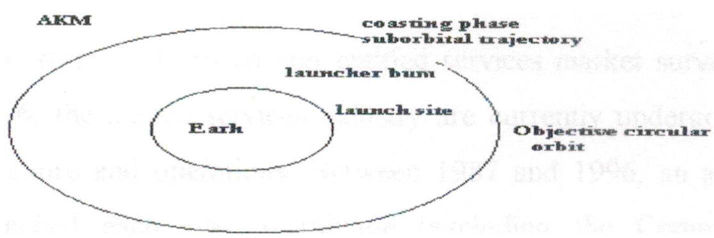


Figure 2.21 Launching Commerical Satellite

A brief description of the major expendable currently used for launching commercial satellite follows in this section. It should be noted that a few of them have the capability off placing satellite directly into a high circular orbit; with the others; use is made of a Hommann transfer elliptical orbit. When the objective is the GSO, the transfer orbit is called a Geo-synchronous or Geo-stationary transfer orbit (GTO). All of these vehicles consist of several stages, mostly fuelled by bi-properlane liquids, and solid racket boosters strapped on to the first assist some of them. The dimensional constraint on the launcher payload, consisting of one or more satellite, is determined by the size and shape of the nose fairing which protects the payload while the launcher is within the atmosphere. Several different fairing are available for most launchers, accommodating satellites of different size and shapes after they have been prepared for launching by folding back such structures as solar arrays and large antennas.

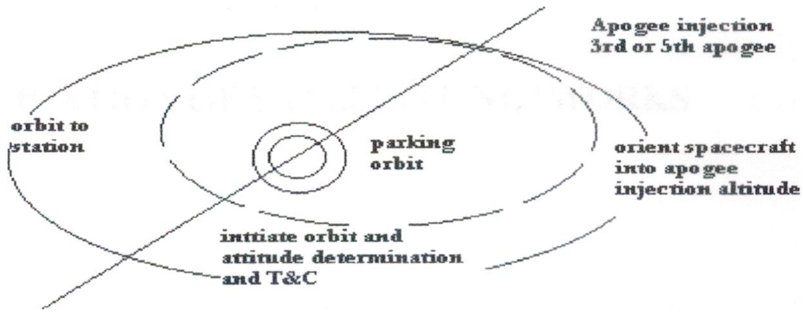


Figure 2.22 Solar Array of Launching Commerical

b) Satellite Launch Industry

According to study of Euro consult entitled services market survey worldwide prospects, 1996-2006, the launch services industry are currently undergoing a radical change in size. Structure and operations. Between 1987 and 1996, an average of 36 satellites were launched each year worldwide (excluding the Commonwealth of independent state CIS). At least three times more are scheduled per year over the next ten years. Similarlythe annual average mass launched into various orbits is expected to double from 69000 to 150000 kg whole demanded for both the Geo-stationary satellite orbit(GSO) and medium Earth Orbit (MEO)Low Earth Orbit(LEO) will peak over the next five years, potentially saturating launch capacities. This period will also see the commercial introduction of several new vehicle, therefore enlarging competition in the different market segments. As a result of growing competition and decreasing launch demand, anticipated around 2005, a buyer's market could well develop.

CHAPTER3

APPLICATION OF SATELLITE NETWORKS

3.1 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.

3.2 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.

3.2.1 Point –to- Point

The simplest type connectivity is point-to-point, illustrated in Figure 3.1 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.

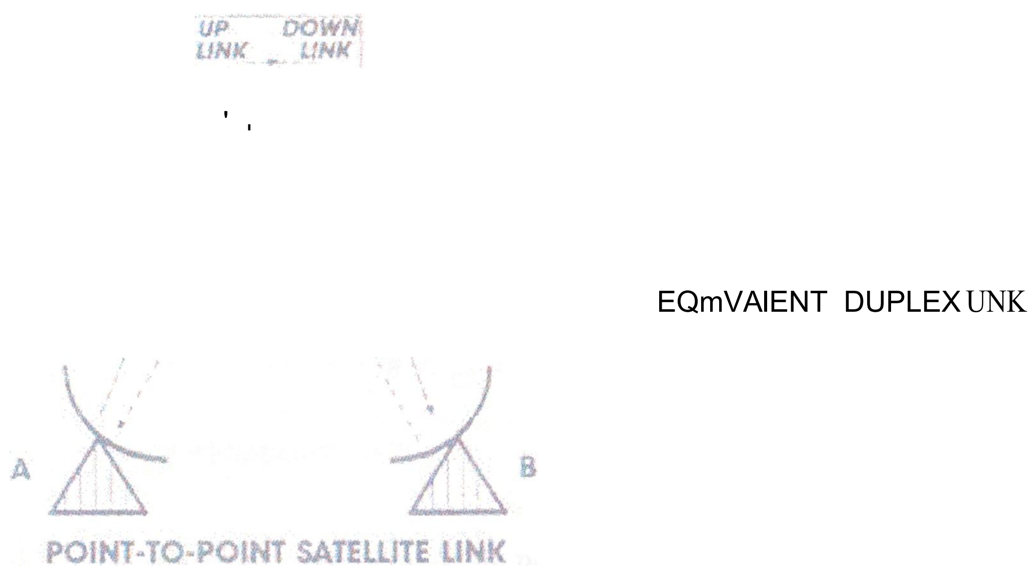


Figure 3.1 Point-to-Point Connectivity Using Full Duplex Satellite Link

3.2.2 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 3.2 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.

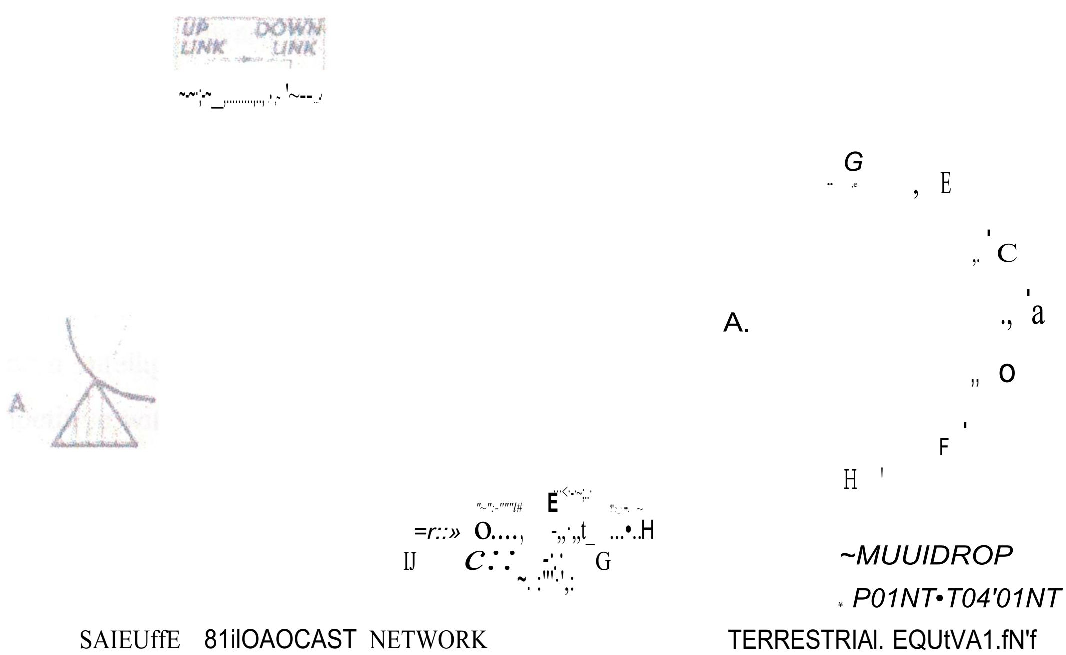


Figure 3.2 point-to-Multipoint Connectivity Providing a one-way Broadcast Capability.

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.

3.2.3 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 3.3, 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.

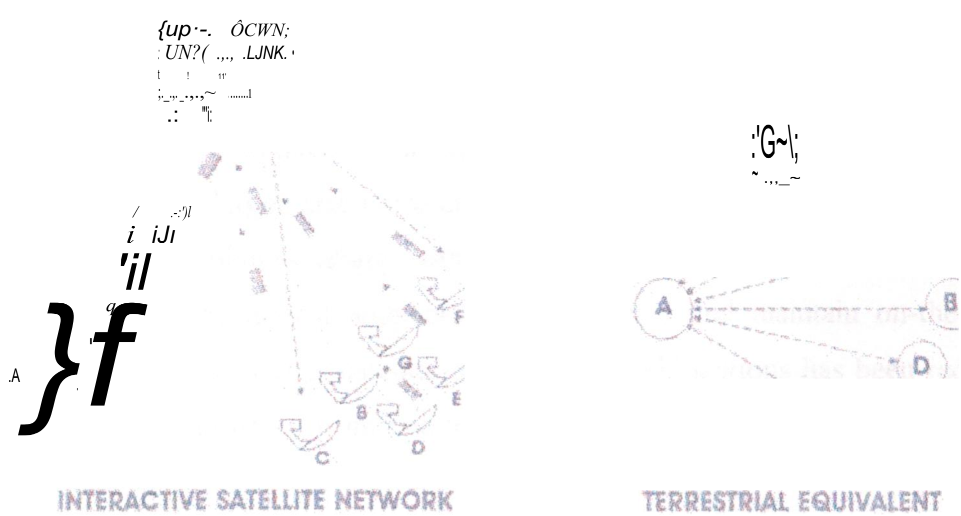


Figure 3.3 Interactive Satellite Network Using Multipoint-to-Point Connectivity.

3.3 Flexibility

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

3.3.1 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.

3.3.2 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, inflexibleanalog 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 involvingtwo-way communication.

3.3.3 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.

3.3.4 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.

3.4 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 chapter 1 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.

3.5 **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.

3.5.1 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.

3.5.2 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 3.4 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 3.4. 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

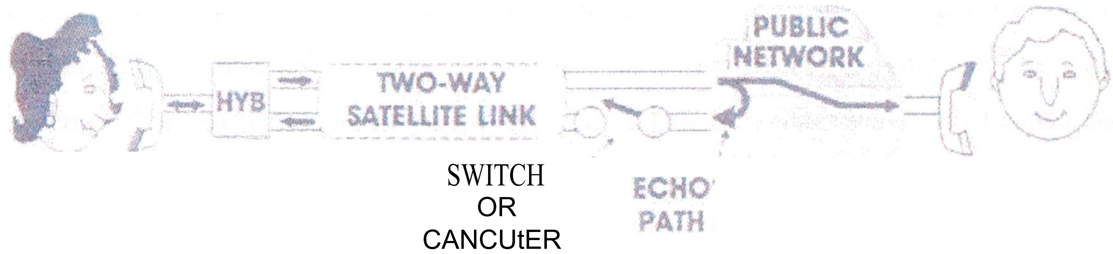


Figure 3.4 Telephone Echo a Satellite Is Caused By Electrical Reflection at the End where it can Be Eliminated by an Echo Canceller.

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.

3.6 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

3.6.1 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 3.1 summarizes the participants in the US broadcasting industry.

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 sufficientlyhigh 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.

3.6.3 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 station. 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

3.6.4 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 3.5. 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.

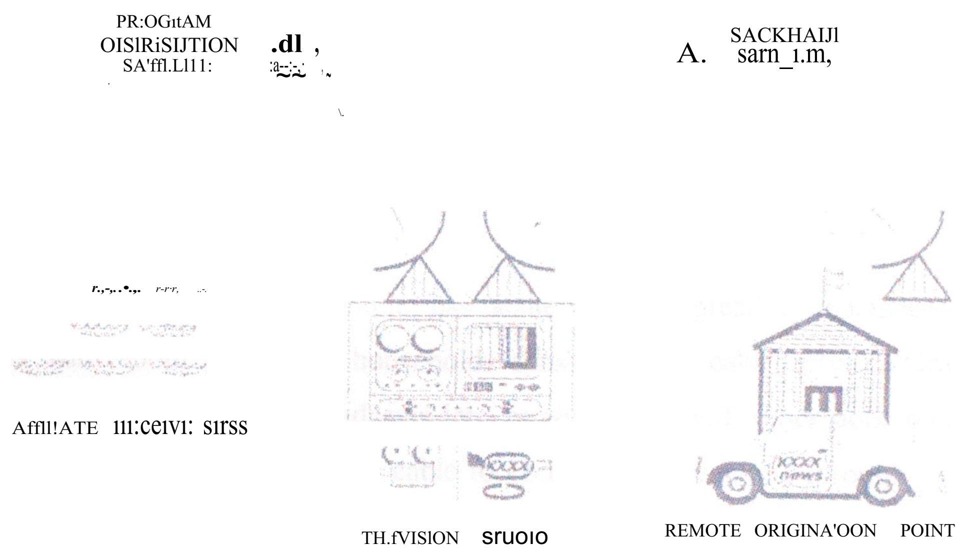


FIGURE 3.5 The Use of Satellite Transmission in the Commercial Television Industry for Backhaul of Event Coverage and Program Distribution to Affiliates

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-hand 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.

3.6.5 A Ground Antenna Utilization

A Network affiliated TV station will use one fixed-mounted earth station antenna to receive full-timeNetwork programming from the point-to-multipoint.

Program distribution satellite, some "roving" among other satellites can be done with a movable antenna to pick up special program provided by syndicated and to receive live coverage of sport events of interest only to the local community (for example, when the local baseball team is playing an away-from-home game in another city). Antennas used by the Network in backhaul service would therefore need to be movable, since events and satellite change from time to time.

3.7 Cable Television

The cable television medium has achieved widespread acceptance in North America with about half of all households subscribing to cable service. Originally a means to bring over-the-air broadcasts into remote areas with other poor reception, a local cable TV system uses coaxial cable to connect to each home through a point-to-multipoint distribution network. The programming material is collected at the "head end" which has the necessary high gain receiving antennas to pick up TV signals of reasonably good quality. In fact, the original name for cable TV was CATV, standing for community antenna television. A studio may be provided it a point between the head end and the cable distribution network. Unlike over-the-air broadcasting viewers. called subscribers. Pay a monthly fee for reception of the several TV channels delivered by the cable (many of which are "free" advertising-supported local and distant TV stations

In the mid-1970 Home Box Office (11130), a subsidiary of Time. Inc. experimented with a closed programming service which was made available to cable TV stations on a subscription basis. The key to the success has been the control that cable progarmmers and the cable system operators have over the delivery of the program "product" to the home. Satellite distribution was adopted because of its low cost of making the program channel available throughout the country. Today approximately one-third of all US domestic satellite transponders are employed for cable program distribution. which is by far the largest single application. Cable systems have their receiving earth stations located at the head end.

3.7.1 Classes of Cable Programming

There exist several classes of specialized cable programming, as summarized in Table 3 .2. The satellite-delivered channels are each focused into particular niches. HBO established the most lucrative niche, that of recent movies. In fact, prior to widespread use of VCRs, IIBO and Showtime, a service of Viacom International, provided the principal means to watch recent movies uninterrupted by commercials on home TV. To receive this service continuously Along with the regular channels, subscribers pay in additional monthly fee which is shared between the programmer and the cable system operator. The revenue *of* the programmer is then used like the advertising revenue s of a Network, paying for the acquisition of programming and for its distribution by satellite.

Table 3.2 Comparison of Cable TV Programming Services Available in North America

TYPE OF SERVICE	EXAMPLES
PAY MOVIE	HBO, SHOWTIME
SUPER STATION	WTBS, WWOR
NEWS	CNN,CSPAN
SPORTS	ESPN
MUSIC	MTV, NASHVILLE
CHILDREN	NICKLEODEON, DISNEY
RELIGIOUS	CBN, ETERNAL WORD
SCIENCE/EDUCATION	DISCOVERY
HOME SHOPPING	HOME SHOPPING NETWORK SKY MERCHANT
ADULT ENTERTAINMENT	PLAYBOY

Because of the marketing strategies of the movie studios which produce most of the product offered by the pay services (HBO. Showtime, etc.), there still exists a time delay (release window) of one year or more between when a movie is first shown in movie theaters and when it is made available to cable. Furthermore, the time delay is somewhat shorter with regard to the availability to the public of video tapes for home VCR usage. A new form of cable service called 'pay-per-view" has appeared, wherein the subscriber places an order to receive a specific movie broadcast at a scheduled time for a fee. The administration of this type of service is considerably more complicated, because the telephone order desk can anticipate thousands of calls for a particular movie. The delivery of the product into the home is controlled with decoders which will allow the scrambled picture to be received onlv when authorized.

In addition to the pay serv ices. there is a wide variety of "free" services which are delivered by satellite exclusively to cable systems. Ted Turner, chairman of Turner Broadcasting in Atlanta, Georgia, pioneered. two of these services. The first is called a super station, his SuperStation WTBS being the best known. A super station originates from a major independent over- the-air broadcas station in a large city and is uplinked to the cable distribution saıellite. This is useful to the TV station because it increases its audience in size and scope, making it more attractive to advertisers. The cable systems usually pay a relatively **low** fee per subscriber. The other service invented by Turner is the 24-hour news channel, exemplified by the highly successful Cable News Network (CNN). Essentially all of its zııdience is via cable systems. And it is supported both by advertising and small subscription fees.

Up until 1985, only independent TV stations were being used as super stations; however, a new cable programming service from Satellite Broadcast Networks has begun to uplink Network affiliated stzrions for reception primarily by home antennas. Called Prime Time 24. the service is scrambled and subscription fees are collected from individualswho wish to watch Ne pmgr":;:;rmin2 delivered by a C-band satellite.

Another innovative cable service is the ideo music channel. NITV, a very popular and successful music TV channel owned by Viacom International, is supported in the same manner as CNN and plays music videos 24 hours a day This type of programming is popular among young people (but probably witched by few people over the age of 30). The Disney Channel from Walt Disney Productions and Nickelodeon from Viacom have gained acceptance among the younger generation. Other cable channels suffer religious programming, science, education, Sports, Shopping and adult entertainment. The mix keeps changing all of the time in the United States as new programmers experiment with format and content. Many of these innovative concepts catch on and are adopted by the more established pay services and by the Networks. As a general comment, the audience enjoyed by the Networks has declined significantly in recent years due to inroads of cable TV and VCRs; the Networks, however, still attract the largest audiences for successful programs and earn many times the revenues of the cable programming services.

3.7.2 Satellite Utilization in Cable TV

The satellite delivery system used by cable is essentially identical to that employed by the Networks. As shown in Figure 3.5, program distribution satellites are used to carry the cable programming channels to the cable system head ends. A typical cable system head end in the United States will continuously receive from 10 to 30 satellite-delivered channels, coming from one to four different satellites. This means that multiple receiving antennas are usually required. The cost of the receiving antenna is relatively low because of the small reflector size required (12 to 18 feet). Expense can sometimes be minimized by using a single reflector with several feeds, each aligned for reception of a different satellite. In actually, it is the cost of the indoor receivers and considerations as to physical space for antennas that dominate the economics of the cable head end.

To control access to their product better, the cable programmers have begun to scramble the programming at the uplink using the Video Cipher II system developed by M/A-Com and sold by General Instruments. The receiving site at the cable head end then requires a descrambler for each channel being recovered. This approach allows the programmer to certify the particular down-link because the descramblers can be turned on (addressed) individually. The video part of the signal is distorted with a random sine wave while the audio is encrypted digitally. Scrambling also allows the programmer to reach the backyard dish owner and collect a monthly subscription fee as if he or she were connected to a cable system.

Some cable programming services cover remote events and therefore employ satellite backhaul just like the Networks. CNN relies heavily on backhaul to provide nearly around-the world news coverage. Also. WTBS broadcasts the away-from-home games of two of the main Atlanta professional sports teams and is a major user of backhaul links. An important requirement in the use of satellites for cable is that the backhaul (which is occasional) be separate from the program distribution, which is full time and continuous). Cable systems themselves generally do not after the programming coming from the satellite and many cannot handle a break in transmission the way TV stations are equipped to do.

3.7.3 Direct to Home

The Use of improved C-band satellites with increased downlink power like Galaxy I have reduced the size of the receiving antenna needed to obtain an acceptable picture. A new industry appeared in the early 1980s to manufacture and sell inexpensive receiving systems to the public. The attraction at the time was the cable programming available for free that the satellites delivered. By 1985, over one million "backyard dishes" were installed at homes, making the concept of direct broadcasting a reality. The pay cable services began to scramble their signals in 1986, and a new phase of industry development was underway. Individuals can buy a Video Cipher II decoder and pay a monthly or annual fee to the cable programmers so that their decoder would be authorized to unscramble the signals. By 1987, more than two million backyard dishes have been sold, and penetration of the home video Cipher II has accelerated. The development of this new market will be important, both to the near term success of Cable TV programming and also to the ultimate success of the direct broadcast satellite concept itself The succession to this "grass roots" service will be the ambitious direct broadcast satellite systems using the BBS allocation discussed before.

CONCLUSION

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 consist 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

To keep the satellite steady and pointing in the right direction we are using pointing control system. The system uses sensors, like eyes, so the satellite can see where it's pointing

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