CHAPTER 1

INTRODUCTION

This chapter presents general background information for those who are unfamiliar with the field of satellite communications. Fundamental features are discussed in this chapter with more detailed treatment reserved for the following chapter.

1.1 WHY SATELLITE COMMUNICATIONS

Communication via satellite is a natural outgrowth of modern technology and the continuing demand for greater capacity and higher quality communications. Relatively recent technical developments have made satellite communications possible. The pressure of near saturation usage of conventional transmission media has caused this new capability to be eagerly sought.

Although the communications facilities of the various military departments have generally been able to support their requirements in the past, predictable requirements indicate that large-scale improvements will have to be made to satisfy future needs of the Department of Defense. The usage rate of both commercial and military systems has increased by at least ten percent per year over the past fifteen years, and there appears to be general agreement that this trend will continue at an accelerated rate. Centralized control of military operations, with its accompanying reliability and security requirements, has generated demands for communications with greater capacity and for long-haul communications to previously inaccessible areas. Some of these requirements can be met only by sophisticated modulation techniques and wide-band, long-distance transmissions for which satellite communication is the most promising means.

1.2 SIMPLIFIED DESCRIPTION

A satellite communication system is one that uses earth-orbiting vehicles, or satellites, to relay radio transmissions between earth terminals. There are two types of communication satellites: active and passive. A passive satellite merely reflects radio signals back to earth. An active satellite, on the other hand, acts as a repeater; it amplifies signals received and then re-transmits them back to earth. This increases the signal strength at the receiving terminal compared to that available from a passive satellite.

A typical operational link involves an active satellite and two earth terminals. One station transmits to the satellite on a frequency called the up-link frequency; the satellite amplifies the signal, translates it to the down-link frequency, and then transmits it back to earth where the signal is picked up by the receiving terminal. This basic concept is illustrated by figure 1-1.

The basic design of a satellite communication system depends to a great degree upon the parameters of the satellite's orbit. By convention an orbit is identified by its

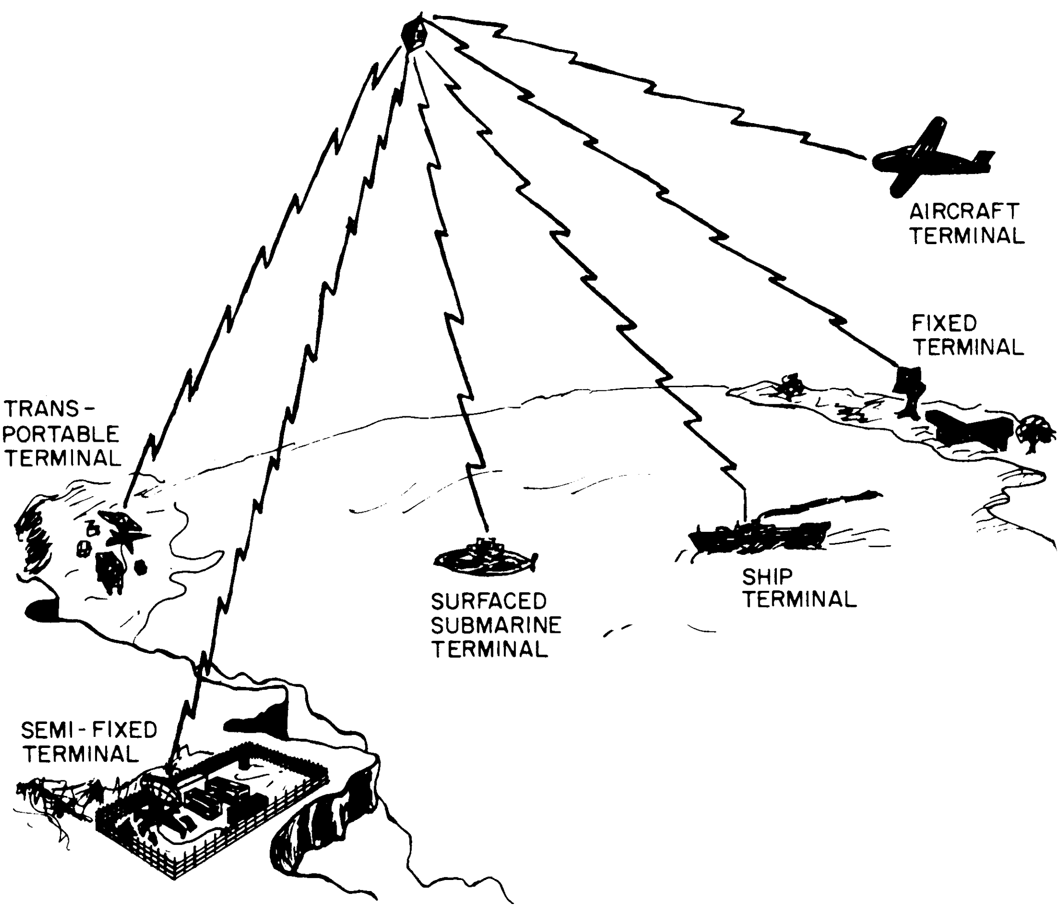

Figure 1-1. Satellite Communication System

shape and the inclination of its orbital plane in relation to the earth's equatorial plane. In general terms an orbit is either elliptical or circular and its inclination is classified as inclined, polar or equatorial. A special type of orbit is a synchronous orbit, one in which the period of the orbit is the same as that of the earth. An orbit which is not synchronous is called asynchronous, with a further subidentification of a near synchronous type in which the period of orbit approaches that of the earth. Orbits are discussed further in section 2.2.

1.3 THE ROLE OF SATELLITE COMMUNICATIONS

In the context of a global military communications network, satellite communication systems become subsystems adding sorely needed capacity or additional alternate routing for communications traffic. A satellite link is just one of several kinds of long-distance links that interconnect switching centers located strategically around the world to comprise the Defense Communications System (DCS) network. Satellite links are usually in parallel with links that employ the more conventional means of communication — HF radio, tropospheric scatter, ionospheric scatter, line-of-sight, microwave, and landline. Satellite links provide added capacity between various points in the network; and, since these links continue in operation under conditions that render other media inoperable, they make a significant contribution to the improvement of reliability.

The primary purpose of the DCS is to provide long-haul, point-to-point communications capabilities to Department of Defense users. Users need only establish communications with the nearest switching center to become network subscribers and to have access to the entire system. Beyond the point-to-point communications requirements there are the tactical communications requirements of the individual services. For the Navy, the potential of satellite communications for tactical (non-DCS) service is most encouraging.

1.4 TYPES OF COMMUNICATION SERVICE

The following types of service are within the capability of present satellite communication systems and either are, or will be, available to the Defense Satellite Communications System (DSCS):

a. Wide-band. This service provides the capability for high-speed data and computer-to-computer transmission. It also provides the capability for relaying television and graphics.

b. Secure-Voice. This service provides the capability for secure-voice conferencing. Alternatively, it can transmit data at 50 kbps.

c. Voice/Data (4 kHz). This service provides for non-secure-analog voice, 2400-bps vocoded voice, 2400-bps data or record traffic transmission, or multiplexed teletype channels.

d. Teleprinter. This service can provide 75-baud record traffic.

1.5 TYPICAL APPLICATIONS

In the application of satellite communication resources to military communications, certain typical deployments will exploit to the maximum extent their versatility and capacity. Some such applications are:

a. DCS Long-Distance, Common-User Communication. This type of communication represents the normal employment of the satellite subsystem. This application provides additional high-capacity wide-band trunks for a variety of transmission modes and added flexibility for rerouting traffic.

b. DCS Area Common-User Communication. Area communication supports large concentrations of forces engaged in operations encompassing a discrete remote area. Such service extends high-capacity, long-distance DCS trunks to a high density of potential users engaged in fluid tactical situations.

c. Contingency Operation. In this application the DCS facilities are extended to support a military operation or humanitarian effort. In this connection, the capability of the satellite subsystem can be used to advantage to support rapid deployment and to furnish reliable long-distance trunking service within a minimum time.

d. Command and Control of Widely Deployed Forces. HF communication to elements of widely deployed forces is difficult even under ideal propagation conditions. On the other hand, the capabilities of a satellite subsystem offer rapid, reliable communication between and among mutually supporting theater and fleet commanders.

A satellite subsystem also possesses the necessary flexibility for system reconfiguration without loss of contact during sudden or frequent headquarters displacement.

e. Tactical Communications. With the development of suitable antennas and equipments that can be installed in most types of ships and aircraft, satellite communications will be able to fill the requirements for various tactical communications, such as ship-to-ship, ship-to-aircraft, ship-to-shore-to-ship, and aircraft-to-ship. This type of communications will be more reliable and less subject to detection than methods presently in use.

f. Fleet Broadcast and Ship-to-Shore. Present fleet broadcasts and ship-to-shore communications rely heavily upon HF for communication over extended distances. As with tactical communications, a satellite subsystem will be more reliable and less subject to detection. This will ensure reliable long-range links between major fleet units and naval communication stations ashore and will simultaneously enhance fleet security.

1.6 ADVANTAGES OF SATELLITE COMMUNICATIONS

Satellite communications offer unique advantages over conventional transmission for long-distance service. Satellite links are unaffected by the propagation anomalies that interfere with HF radio, are free from the high attenuation of wire or cable facilities, and are capable of spanning long distances without the numerous intervening repeater stations which are required for line-of-sight or troposcatter links. They can furnish the greater reliability and flexibility of service needed to support a military operation.

1.6.1 Capacity

Although existing commercial satellite communication systems are capable of handling hundreds of voice-frequency channels, the present operational military communication satellite system, the Phase I Initial Defense Satellite Communications System (IDSCS), is limited to less than a dozen voice channels per earth terminal. Four separately assigned channels, each capable of handling eleven voice channels, are available in each IDSCS satellite on both the up link and down link; however, the power limitations of the Phase I satellite on the down link prevents the use of more than two RF channels simultaneously (one full duplex circuit). In the antijam spread-spectrum mode an RF bandwidth of 40 MHz is used. The Phase II DSCS satellites, now under contract, will have considerably greater channel capability with a considerably wider RF bandwidth.

1.6.2 Reliability

Since propagation of communication satellite frequencies is not dependent upon reflection or refraction and is affected only slightly by atmospheric phenomena, the reliability of active satellite communication systems is limited, essentially, only by the reliability of the equipment employed and the skill of the operating and maintenance personnel. This improvement in reliability is a remarkable advantage for Navy communications, so long dependent upon unreliable HF propagation for most tactical communications.

1. 6. 3 Vulnerability

Within the present state of the art in rocketry, destruction of an orbiting vehicle is possible; however, destruction of a single communication satellite would be quite difficult and expensive. The cost would be exorbitant compared to the tactical advantage gained. It would be particularly difficult to destroy an entire multiple-satellite system such as the twenty-six random-orbit satellite system currently in use in the IDSCS. The earth terminals offer a more attractive target for physical destruction, but they can be protected by the same measures that are taken to protect other vital installations.

A high degree of invulnerability to jamming is afforded by the highly directional antennas at the earth terminals and by the wide bandwidth system which can accommodate sophisticated antijam modulation techniques such as spread spectrum and frequency hopping.

1. 6. 4 Flexibility

Almost all of the existing operational military satellite earth terminals are housed in transportable vans that can be loaded into large cargo planes and flown to remote areas. With trained crews these terminals can be put into operation in a matter of hours. Therefore, direct long-haul communications can be established quickly to remote areas nearly anywhere in the free world. (The present and proposed DSCS satellites provide slight coverage in the polar regions at latitudes greater than 70 degrees.)

1. 7 LIMITATIONS

Limitations of a satellite communications system are determined by the satellite's technical characteristics and its orbital parameters. Active communication satellite systems are limited by satellite transmitter power on the down links and to a lesser extent by satellite receiver sensitivity on the up links. Early communication satellites have also been limited by low gain antennas.

1. 7. 1 Satellite Transmitter Power Limitations

The amount of power available in an active satellite is limited by the weight restrictions imposed on the satellite. Early communication satellites were limited to a few hundred pounds because of launch-vehicle payload restraints. The only feasible power source consistent with the above weight limitation is the inefficient solar cell. (Total power generation in the Phase I IDSCS satellites is less than 50 watts.) Thus the RF power output is severely limited and a relatively weak signal is transmitted by the satellite on the down link. The weak transmitted signal, further diminished by propagation losses, results in a very weak signal being available at the earth terminals. The level of signals received from a satellite is comparable to the combination of external atmospheric noise and internal noise of standard receivers. Consequently, special techniques must be used to permit extraction of the desired communication information from the received signal. Large, high gain antennas and special types of preamplifiers solve this problem but add complexity and size to the earth terminal. (The smallest terminal in the IDSCS has an 18-foot antenna and weighs 19, 500 pounds.) Development of more efficient power sources and relaxation of weight restrictions will permit improved satellite performance and increased capacity.

1.7.2 Satellite Receiver Sensitivity

Although powerful transmitters and highly directional antennas can be used at an earth station, the spherical wavefront of the radiated signal spreads as it travels through space. The satellite antenna intercepts only a small amount of the transmitted signal power and, because of its low gain, a relatively weak signal is received at the satellite receiver. Although the strength of the signal received on the up link is not as critical as that received on the down link, careful design of the RF stage of satellite receivers is required to achieve satisfactory operations. Development of stabilized high gain antennas and improved RF input stages in the receiver will make this problem less critical.

1.7.3 Satellite Availability

The availability of a satellite to act as a relay station between two earth terminals depends on the locations of the earth terminals and the orbital parameters of the satellite. All satellites, except those in a synchronous orbit, will be in view of any given pair of earth stations only part of the time. The length of time that a nonsynchronous satellite in a circular orbit will be in the zone of mutual visibility depends upon the height at which the satellite is circling. Elliptical orbits cause the satellite zone of mutual visibility between any two earth terminals to vary from orbit to orbit, but the times of mutual visibility are predictable. See figure 1-2 for an illustration of the zone of mutual visibility.

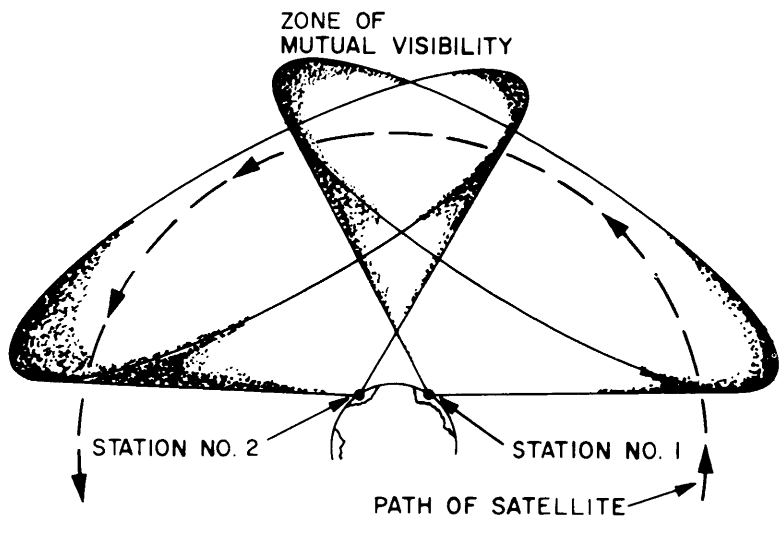

Figure 1-2. Zone of Mutual Visibility

1.8 SATELLITE PROJECTS

The tremendous potential of satellite communications has long been realized. As early as October 1945, long before the Russian SPUTNIK of October 1957, Arthur C. Clarke, a former chairman of the British Interplanetary Society, writing in Wireless World, discussed the potential of synchronous satellite communications.

The first successful satellite communications utilized the earth's natural satellite, the moon. In November 1955, almost two years before SPUTNIK was launched, the moon was used as a passive satellite to establish a teletype link between Washington, D. C. and Hawaii. Later, in 1960, successful communications were conducted with an artificial passive satellite, ECHO. This was a large, highly reflective, inflated balloon which had been injected into a near circular inclined orbit about 1000 miles high with an inclination of 47 degrees.

SCORE, launched in December 1958, was the first active communication satellite. SCORE was injected into an inclined elliptical orbit and broadcast for thirteen days President Eisenhower's recorded Christmas message. TELSTAR 1 was launched into an inclined elliptical orbit in July 1962 and became the first high-capacity communication satellite.

All of the above communication satellites advanced the state of the art, but all were of limited usefulness because their orbital geometry made them visible to earth terminals only part of the time. The state of the art in rocketry had not advanced sufficiently to permit injection of a satellite into a synchronous equatorial orbit. In such an orbit the satellite would appear motionless to any earth terminal within the satellite's area of visibility.

1.8.1 SYNCOM Project

Successful injection of a satellite into a quasi-synchronous, nearly circular, inclined orbit occurred with the first SYNCOM satellite, launched in February 1963. Although the communication package of this SYNCOM satellite was destroyed by an explosion that occurred when the satellite was injected into its final orbit, the SYNCOM 1 launch was the first demonstration of a new method to inject a payload into a synchronous orbit.

SYNCOM 2, launched in July 1963, also achieved a quasi-synchronous, near circular, inclined orbit and its communication package operated properly. NASA conducted a number of tests and then turned over the operation of the satellite to the Department of Defense.

SYNCOM 3, launched in August 1964, was injected into a synchronous, circular, equatorial orbit. To an observer on earth, SYNCOM 3 appeared to be suspended and motionless over the equator. After some experimentation with SYNCOM 3, NASA turned over the operation of the satellite to the Department of Defense.

The SYNCOM launches were the forerunners of the commercial EARLY BIRD and INTELSAT communication satellites and the Initial Defense Communications Satellite Program (IDCSP) satellites.

1.8.2 Defense Satellite Communications System (DSCS)

The IDSCS, under the direction of the DCA, consists of twenty-six, equatorially positioned, randomly spaced, near synchronous satellites. These active satellites, which are part of the DSCS, have a limited capacity at the present time. Subsequent phases of this project, when implemented, will produce an increased wide-band digital communication capability by employing satellites with increased power and capacity. The DSCS is presently programmed in three phases:

a. Phase I. - This phase evolved from the use of the SYNCOM and IDCSP satellites. (The SYNCOM satellites have deteriorated and are no longer used.) The Advanced Defense Communication Satellite Project, scheduled to follow the IDCSP, has given way to a more evolutionary phased approach. Subsequent phases will employ synchronous equatorial satellites with increased radiated power and controllable high gain antennas.

b. Phase II. - The primary objective of Phase II is to achieve an enhanced communication capability during the 1971 to 1975 period. The plan is to add synchronous equatorial, station-kept, medium-power satellites to increase system capability. Earth terminals will also be modified in three stages to increase bandwidth and to improve modulation techniques. This, in turn, will increase channel capacity and protect the communication service.

c. Phase III. - During Phase III, the modulation method will be changed, higher powered satellites will be added, and the earth subsystem will be expanded to include airborne and smaller ground terminals. This phase, which should provide greater survivability, flexibility, availability and capacity than Phase II, is planned for implementation during the post-1975 time period. The earth terminals will include second generation equipment, retaining the most desirable features of the Phase II equipment and incorporating subsequent improvements in the state of the art.

1.8.3 TACSATCOM

Supported by data obtained from the Lincoln Experimental Satellite (LES) series of experimental satellites (particularly LES-5 and LES-6), an inter-service developmental Tactical Satellite Communication (TACSATCOM) Program was established under the direction of a steering group composed of Army, Navy, Air Force and Marine Corps representatives. The TACSATCOM satellite, launched in February 1969 into a synchronous equatorial orbit, operates in the UHF and SHF bands. Two similar families of terminal equipments, one using UHF and one using SHF, are designed for a wide spread of tactical uses, ranging from a one-man pack warning and alerting receiver to transceivers for a two- or three-man pack or for jeep mounting or shelter mounting. Airborne, surface ship and submarine terminals are included in the program.

All the transceivers can transmit and receive on at least one voice (or teletype) channel. Other versions can handle up to 6 full duplex voice channels, including some vocoded voice, and the largest version can handle high-speed data through either a differential phase-shift keyer modem or the tactical transmission system (TATS) bandspread multiple frequency modem.