# PREFACE

The *INTELSAT VSAT Handbook* was prepared by the INTELSAT Applications Support and Training department. The handbook is provided free of charge to INTELSAT signatories and users under INTELSAT's Assistance and Development Program (IADP) and INTELSAT Signatory Training Program (ISTP).

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First printed on: September 1998

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## INTELSAT, YOUR CONNECTION TO THE WORLD

Founded in 1964, INTELSAT is a global commercial cooperative of over 140 member countries providing advanced telecommunications services throughout the world on a nondiscriminatory basis.

INTELSAT's modern satellite fleet of high powered, technically advanced spacecraft in geostationary orbit provide telephone, television, and data distribution services to people around the world in over 200 countries, territories, and dependencies. (Refer to the above drawing.) Wherever your customers are located, INTELSAT is there.

### The INTELSAT Advantage

INTELSAT is the recognized leader in the satellite telecommunications industry. With a space segment reliability exceeding 99.999 percent, global connectivity, and a worldwide sales staff backed up by extensive customer training and engineering support, INTELSAT provides an unequaled standard of performance and customer support. New generations of high power satellites under construction demonstrate INTELSAT's commitment to serving the world's telecommunications requirements into the next century. Only INTELSAT can make that promise anywhere in the world.

### Our Customers

INTELSAT operates basically as a wholesale provider of satellite capacity with one or more authorized INTELSAT customers (Signatory or Duly Authorized Telecommunications Entity) in each country. Our customers are the major telecommunications providers and consumers throughout the world including:

- providers of basic long distance telephone services such as British Telecom, Cable and Wireless, AT&T, France Telecom, Deutsche Telekom, KDD;
- the world's major television broadcasters such as DBS, BBC, CNN, the European Broadcasting Union, depend on INTELSAT to transmit news, sports, and entertainment programming;
- airlines for transcontinental booking arrangements;
- international banks for credit verification and authorization;
- multinational manufacturers;
- petroleum companies;
- news and financial information services such as Reuters (U.K.), Agence France Presse (France), and ITAR Tass (Russia);
- international newspaper distributors such as the International Herald Tribune, the Financial Times, the Wall Street Journal, for simultaneous remote printing of daily editions on several continents; and
- disaster relief and health care agencies and organizations, regional economic organizations, national governments, and the United Nations, to foster human development and global interaction.

## GETTING ON LINE

The INTELSAT World Wide Web home page contains a wide variety of useful information concerning the INTELSAT system, including a description of the process of activating service. INTELSAT's home page is located at **http://www.intelsat.int.** The following sequence of links will access the information in the **Getting Connected** and **Going Operational** sections that fully describe the process of activating service in the INTELSAT network.

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# CHAPTER 1

## 1. INTRODUCTION TO VSAT NETWORKS VIA INTELSAT

***INTELSAT AND VERY SMALL APERTURE TERMINAL (VSAT) NETWORKS***

Very Small Aperture Terminal (VSAT) networks provide affordable access to communications services. INTELSAT has prepared this handbook to describe the technology, the planning process, and the applications and benefits of VSAT networks. INTELSAT's wide range of satellites and services are ready to tailor satellite capacity to meet all communications requirements for any VSAT operator on a non-discriminatory basis.

### 1.1 Introduction to VSAT Networks

Basic VSAT concepts defined in this chapter include VSAT terminology, the main components of a VSAT network, and the cost comparison between VSAT and terrestrial networks. This chapter shows the advantages of VSAT networks and the typical topologies used by VSAT operators.

## *1.2 What Is a VSAT?*

A Very Small Aperture Terminal (VSAT) is a micro-Earth station that uses the latest innovations in the field of satellite communications to allow user's access to reliable satellite communications. VSATs provide users with services comparable to large gateways and terrestrial networks, at a fraction of the cost. A typical VSAT consists of communications equipment and a small antenna with a diameter less than 3.5 meters.

VSAT networks provide users with simple equipment that requires minimal installation and repair. They are easy to operate and simple to troubleshoot. VSAT installations do not require staff with extensive expertise.

As depicted in Figure 1-1, a typical VSAT installation consists of an antenna, an outdoor unit (ODU), the interfacility link cable (IFL), and an indoor unit (IDU). The antenna and ODU provide the radio frequency conversion and amplification for the satellite uplink and downlink. The ODU is often called the transceiver because it includes the up converters (U/Cs); the Solid State Power Amplifier (SSPA); the Low Noise Amplifier (LNA), and the down converter (D/C). The IDU provides the baseband interfacing required to carry the user’s services. The power requirement for each VSAT is low and in some cases solar cells supply the power. Because of its simplicity, a VSAT installation takes only a few hours and the terminals are ready for service.

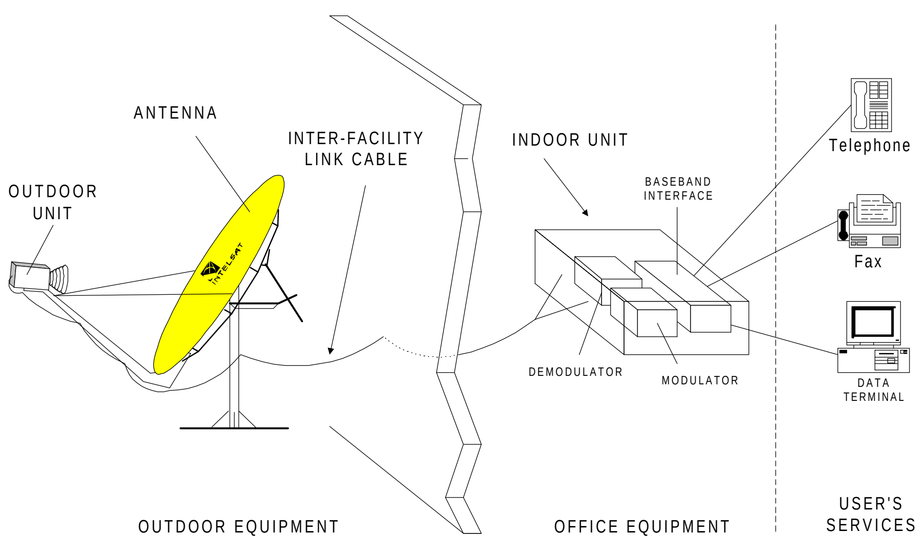


**Figure 1-1. Block Diagram of a Typical VSAT Terminal.**

VSAT terminals are generally part of a network, with a larger Earth station that serves as a network "*hub*". The hub contains the intelligence to control the network operation, configuration, and traffic. The hub also records the performance, status and activity levels of each VSAT terminal. Databases generated by the hub are also used for billing purposes. Hubs are usually located where the bulk of network traffic originates and/or terminates.

A hub consists of RF equipment, VSAT interface equipment, and user interfaces. (Refer to Figure 1-2.) The RF equipment consists of antenna, LNA, SSPA, and frequency converters. The RF equipment at the hub can be packaged in an outdoor unit to reduce the transmission line losses. If high reliability is needed, then indoor equipment with proper backup and switchover devices will be needed.

The VSAT interface equipment controls and supervises the network operation, and consists of modulators, demodulators, and baseband processors. The customer's baseband equipment interfaces the VSAT network's signal to the customer's terrestrial equipment.

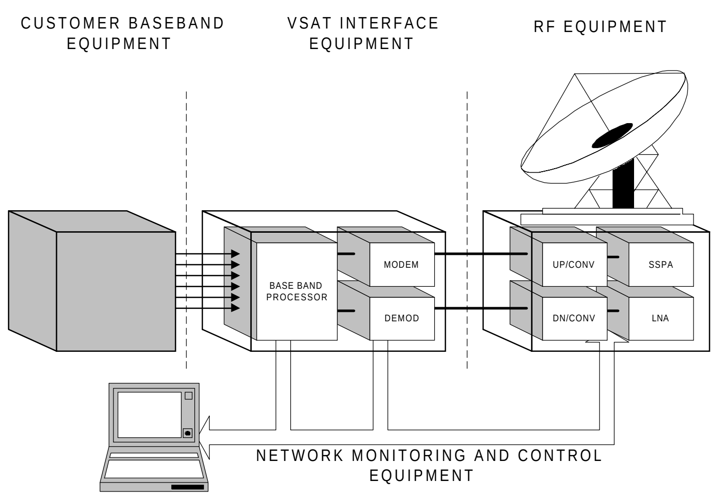


**Figure 1-2. Typical Block Diagram of a Hub Earth Station.**

VSAT technology used in the INTELSAT system offers high availability, service flexibility, high reliability, distance insensitivity, high traffic capacity, and powerful routing capabilities. The performance achieved by VSAT networks surpasses the performance of terrestrial networks in terms of availability and quality. Typical availability figures surpass 99.9 percent of the time for the satellite link, and 99.6 to 99.7 percent for the total VSAT network. BER performance is better than 1 error in 10 million transmitted bits (BER = $1 \times 10^{7}$).

## 1.3 VSAT Networks Versus Terrestrial Communications

Many potential users mistakenly hesitate to use VSATs because they fear that it will be an expensive means of telecommunications.

***To clarify the cost effectiveness of VSAT:***

Suppose that a corporation has a data network in which 150 branch offices, each with individual LANs, that are linked to a LAN at the corporation headquarters. The 150 branch offices are spread around the country and compose a network as shown in figure 1-3. Currently, they were using the Packet Switched Data Network (PSDN). The maximum data rate is 19.2 kbit/s in any connection between a branch and headquarters.

If the same corporation needs to upgrade the service by increasing the speed to 64 kbit/s, they could consider a dedicated line or satellite links as viable options.

When considering dedicated lines, the corporation found the following.

- The cost per lease line increases in proportion to the distance between the headquarters and the branches.
- The installation fee is directly related to the required data rate.
- The same data rate is not available at all the branches because the terrestrial network is not equally developed throughout the country.
- If a cable connection breaks, they have to rely on the phone company to fix the problem.

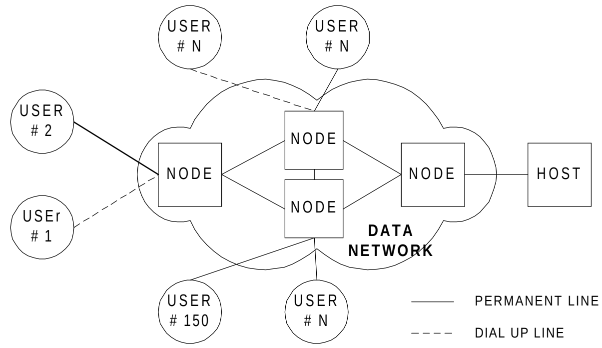


**Figure 1-3. Typical Terrestrial Network.**

By contrast, for a VSAT network, the corporation discovered the following.

- Long distance prices do not apply to VSAT networks.
- Each VSAT had a flat cost, independent of distance, making costs more predictable.
- The equipment and installation costs of VSATs is higher than terrestrial alternatives.
- A VSAT network can be managed independently of the terrestrial network.

They draw the comparison between dedicated lines and VSAT services by comparing the following costs:

**Cost of dedicated lines:**

- Monthly maintenance charges for a dedicated 64 kbit/s line = $_____
- Installation fee (nonrecurring) = $_____
- Equipment charges = $_____

**Cost of VSAT services:**

- Service charges = $_____
- VSAT network equipment cost = $_____ [1]
- Installation fee (nonrecurring) = $_____ [2]

The corporation concluded that VSAT networks are cost effective when compared to terrestrial alternatives. Figure 1-4 shows a specific example of cost comparison between VSAT services and the total cost of terrestrial alternatives. In this example, VSAT services are less expensive than dial up and dedicated lines. Moreover, after recovering the capital costs, the operational cost of VSATs shrinks to only satellite and staff expenses.

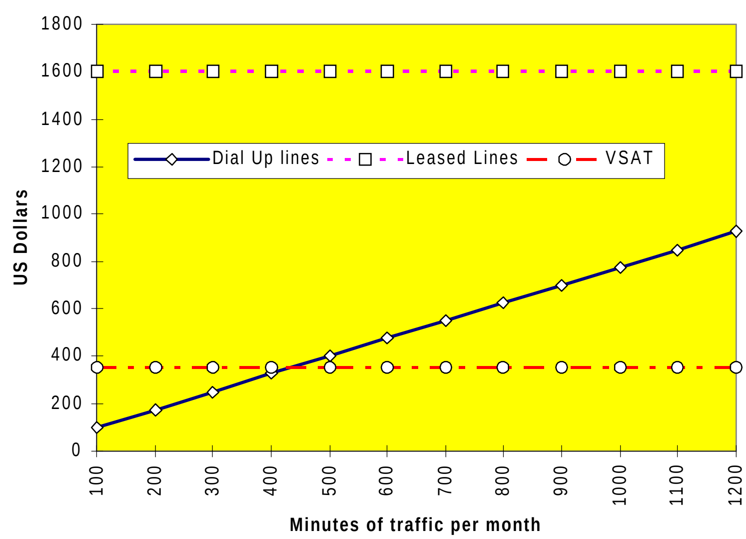


**Figure 1-4. Cost Comparison Between Terrestrial and VSAT Networks.**

In addition to cost savings, a VSAT network provides the customers with:

- full control over the entire communications network;
- insensitivity to the distance between nodes;
- faster data response time;

[1] *Hub equipment costs.*
[2] *This price includes VSAT terminal and installation.*

- higher grade of service and flexibility;
- shorter and fewer outages;
- equal access for all nodes in a network;
- possibility of transporting large flows of data at no extra cost;
- simple installation and maintenance; and
- fixed network costs, regardless of distance.

Users can accommodate virtually any service with confidence that, in the long term, the VSAT network will be more economic than existing terrestrial media.

## 1.4 VSAT Satellite Network Topology

There are three types of VSAT network topologies: star, mesh, and hybrid.

In star topology, each VSAT terminal transmits and receives only to the hub. (See Figure 1-5a.) This does not preclude the VSAT terminals from communicating among themselves, because VSAT-to-VSAT communication can be routed via the hub using a double satellite hop. The majority of VSAT networks use star topology because the large antenna gain at the hub optimizes the use of the space segment and minimizes the size of the VSAT terminal. The drawback of star topology is that the delay for VSAT to VSAT communication doubles in comparison to single hop transmission.

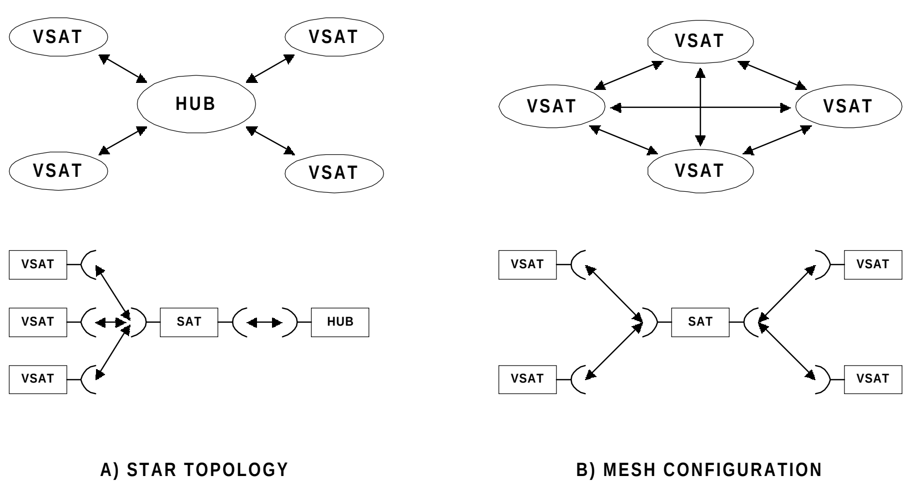


**Figure 1-5. Commonly Used VSAT Topologies.**

Mesh topology (Figure 1-5b) allows all terminals to communicate with each other directly. A hub must control the communication set up and tear down process, but need not be involved in carrying traffic. Sometimes, a VSAT terminal is equipped with the network management and control equipment, and the network is said to operate hublessly. Because each VSAT must have sufficient power and receive sensitivity (G/T) to communicate with every other VSAT, mesh topology requires larger antennas and SSPAs than star topology. Mesh technologies are well suited for applications such as voice that cannot tolerate delay.

Hybrid topology allows a group of VSAT terminals to communicate in mesh topology while others communicate only in star topology. This topology is useful for networks in which certain terminals have larger traffic demand between themselves than the other terminals. The terminals with higher traffic demand can be accommodated in mesh to reduce the expense of extra equipment at the hub, and satellite resources required for a double hop. The rest of the network can communicate with any of these larger terminals or each other via a star topology.

## *1.5 Satellite Frequency Bands*

Currently, in the INTELSAT system, two frequency bands are used for VSAT services, C-band and Ku-Band. For C-band operations, the antennas transmit at 6 GHz and receive at 4 GHz. Ku-band requires transmission at 14 GHz and reception at 11-12 GHz.

***Which frequency band is better?***

There is no direct answer to this question. The VSAT operator must decide the frequency band based on each band's different aspects listed in Table 1-1.

**Table 1-1. KU-Band vs. C-Band**

| KU-BAND | | C-BAND | |
|---|---|---|---|
| **BENEFITS** | **DRAWBACKS** | **BENEFITS** | **DRAWBACKS** |
| It allows the use of smaller dishes. | Signals susceptible to fading during rain. Attenuation range from 6 to 10 dB. | Signal less susceptible to rain fading.<br>Rain attenuation in the range of 0.4 to 1 dB. | Needs slightly larger dishes when compared to Ku-band. |
| Higher transponder power | Not available every where in the world | Widely available | Lower transponder power |
| | Narrower beam coverage | Wider and even global beam coverage | |
| Less terrestrial interference | | | Higher likelihood of terrestrial interference |

Proper network engineering can minimize the effects of Ku-band signal fading during rain. High network availability is available at both Ku- and C-band. VSAT operators prefer Ku-band to C-band because it allows them to reduce the capital investment by using smaller antennas. Nonetheless, INTELSAT portrays no distinction or preference for a particular frequency band because all INTELSAT satellites operate in both frequency bands.

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# CHAPTER 2

## 2. VSAT APPLICATIONS

***VSAT TECHNOLOGY FOR VOICE, DATA, AND VIDEO***

Regardless of whether VSATs are used for domestic, regional or international applications they offer a wide span of solutions for most telecommunications needs.

### 2.1 Overview of VSAT Applications

**VSATs are suited to many applications which broadly fall into two categories: broadcasting or one-way applications, and interactive or two-way applications**

***Broadcasting or one-way applications:*** Broadcasting represents one of the earliest and simplest applications for VSATs. Voice, video, or data is transmitted from a central station and broadcast to VSATs within the satellite beam coverage. It might seem that the signal is subject to access by unauthorized VSATs; however, the broadcaster can control access to the information to allow only the desired group of VSATs to receive the information. This access is often implemented in software and is often called "*narrow-casting*".

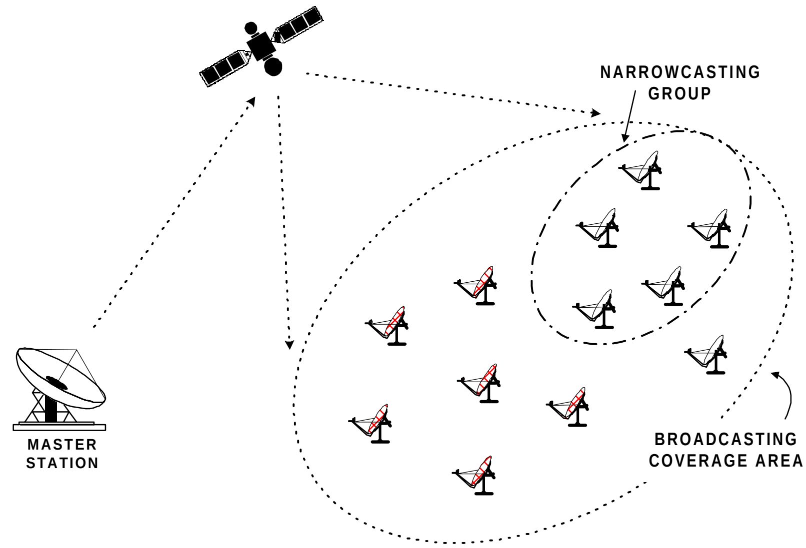


**Figure 2-1. Illustration of One-Way Applications.**

Examples of broadcasting applications include:

- price lists, inventory records;
- stock, bonds, and commodity information;
- weather bulletins, sports scores, news and press releases;
- sound broadcasting;
- digital video for conferencing or entertainment; and
- Internet distribution.

(See Figure 2-1.)

Often, broadcast VSAT applications use a return channel via the PSTN. For example, the entertainment industry uses pay-per-view (PPV) channels for special programs and events. Subscribers can see the program list and request, via the PSTN, access to a particular program. The program provider will download the access authorization to that user at the start of the requested program.

Internet broadcasting uses a similar approach to download information from web sites to end users. End-users dial Internet Service Providers (ISPs) using the PSTN to request access and information. Upon validation of the request, the ISP downloads the requested information via a high-speed satellite channel. The end-user receives the downloaded information using a receive-only VSAT. (See Figure 2-2.)

Internet applications via satellites benefit the ISP by avoiding the need for dedicated terrestrial high-speed lines. Furthermore, service providers can piggyback Internet traffic on to existing digital TV carriers, thereby cost effectively utilizing existing infrastructure.

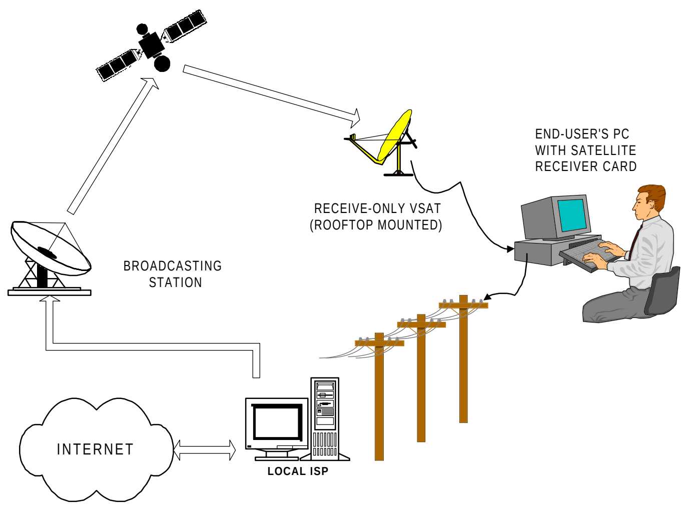


**Figure 2-2. Internet Broadcast with Terrestrial Return Link.**

***Interactive or two-way applications:*** Interactive applications allow two-way communication via the VSAT terminal. The carrier from the hub station to the VSAT is called *'outbound'*, while the carrier from the VSAT to the hub is called *'inbound'.* The applications can be bundled in four categories: interactive data service, interactive voice services, interactive video services, and high-speed, point-to- point services.

A. **Interactive data services**: This category consists of an application involving an inquiry from one terminal and a subsequent response from another terminal. (See Figure 2-3.) Some examples are**:**

- file and batch transfers for financial institutions, stock brokers, and banks (i.e., branch offices to headquarters;
- management of point-of-sale operations for supermarkets, retail shops, gas stations, fast food stores, for all types of payment terminals, including Automatic Teller Machines (ATMs) and credit card transactions;
- reservation requests and confirmations for airlines, hotels, car rentals, and travel agencies;

- data request retrieval from remote sensing on oil drillings, pipe lines, gas, electric, and transport industries; and
- remote processing and LAN extensions.


**Figure 2-3. Application Examples for Interactive VSAT Applications.**

B. **Interactive voice:** This category consists of the following voice services. (See Figure 2-4.):

- Voice services for private networks and corporations
- Voice services to extend the PSTN facilities to rural or remote areas

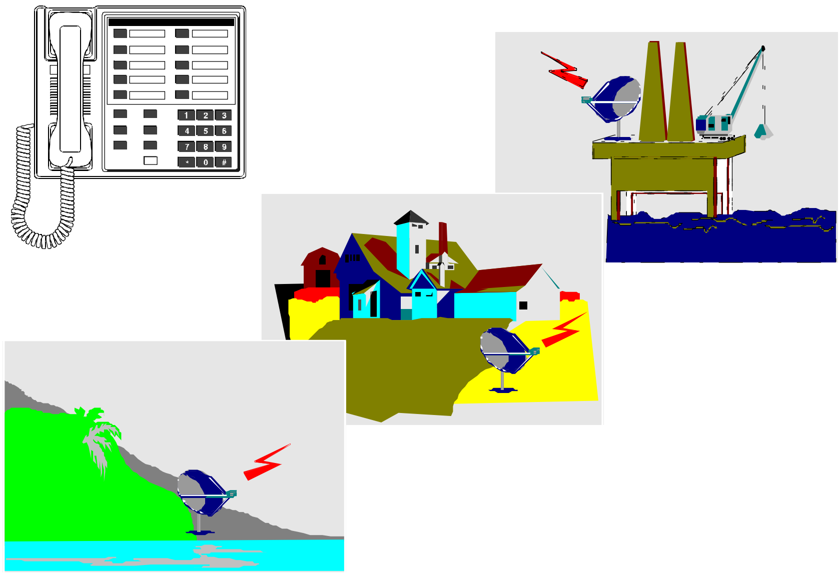

**Figure 2-4. Voice Applications Examples.**

A VSAT terminal is flexible enough to either handle a single telephone line for very low traffic levels, or several lines which, in turn, can be connected to a local PBX. Furthermore, a VSAT terminal can be connected to a base station to extend the service using Wireless Local Loop (WLL).

The combination of VSAT and WLL can extend the basic phone service to places where other technologies are not cost effective. For example, a VSAT equipped with 8 satellite channels and a WLL base station can serve a population of 500 telephones. The telephones can be wireless pay phones powered by solar cells or fixed wireless phones for domestic or business users. The coverage radius for the WLL unit is typically 12 to 20 miles. (Refer to Figure 2-5.) This application makes rural telephony affordable with per-line costs of about 1,000 to 1,500 dollars.

C. **Interactive video services:** Current compression rates enable video conferencing at data rates as low as 64 kbit/s. However, the best tradeoff between quality and cost is achieved at 384 kbit/s. VSAT users generally implement outbound video at 384 kbit/s and inbound video at 64 kbit/s. This configuration allows good quality in the outbound, and rate savings in the inbound. If the user needs symmetric quality, then the inbound needs the 384kbits/s, too.

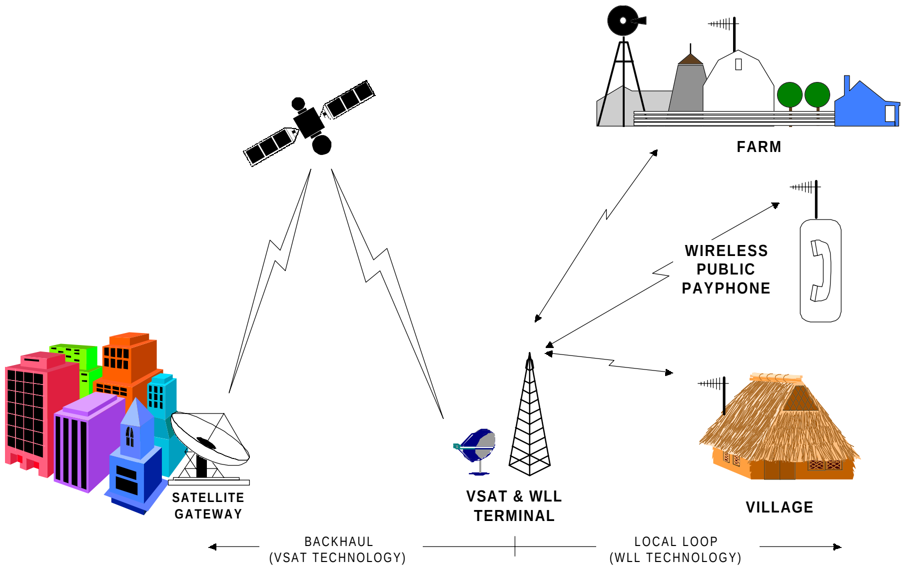


**Figure 2-5. VSAT-WLL Network Architecture Diagram.**

D. **High-speed, point-to-point services:** For reasons of availability, security, and/or economies, a customer may choose to use VSATs rather than terrestrial facilities for high-speed, point-to-point services. These networks typically have a small number of VSATs, in a point-to-point configuration, and can handle up to 1.544 Mbit/s (T1) or 2.048 Mbit/s (E1) carriers in a bidirectional fashion.

Regardless of the application, INTELSAT users can accommodate their VSAT services, using either tailored INTELNET leases or VSAT IBS services.

## 2.2 Benefits of VSAT Networks

From the application perspective, VSAT networks offer the following benefits:

- wide range of data, voice, and video applications;
- proven and robust technology, with high user satisfaction;
- quick network deployment;
- rapid and direct access to telecommunications;
- rapid response to market needs, because of ease of expansion;
- elimination of the *last mile* connection problem, because the satellite link is insensitive to the distance between nodes, and because the VSAT terminal can be collocated with the IDU equipment.
- reliability and ease of maintenance; and
- reliable operation with around-the-clock support from the INTELSAT Operations Center.

Taking the VSAT benefits into consideration, it is not surprising that VSAT networks are being installed to solve many telecommunications challenges. VSAT networks remain competitive and more effective than terrestrial solutions.

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# CHAPTER 3

## 3. MULTIPLE-ACCESS PROTOCOLS

### INTRODUCTION

In implementing VSAT networks, three different layers of protocols have to be considered: satellite access protocol, network access protocol, and user data protocols. (Refer to Figure 3-1.)

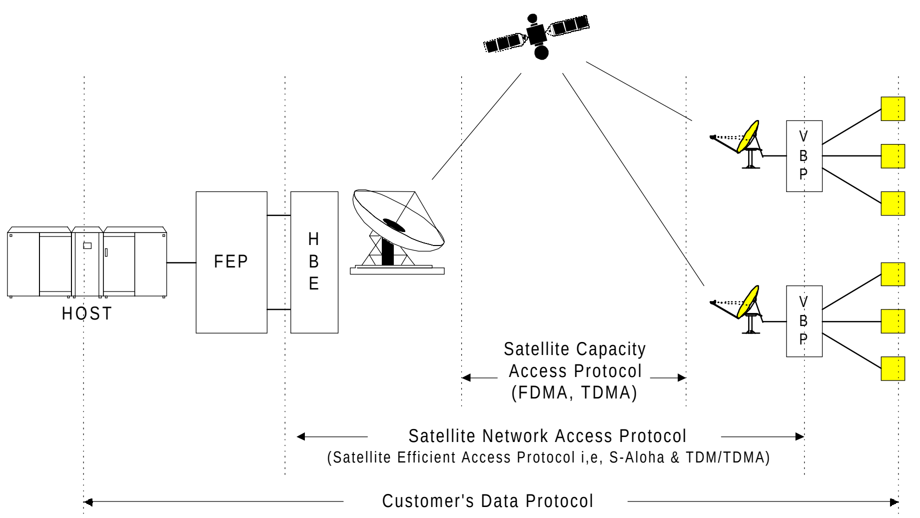


**Figure 3-1. Different Layers of Protocols Used in VSAT Networks.**

The performance of a network is directly affected by the protocol used, and a good network design will use protocols that achieve the highest network performance, for the specific application, while minimizing required satellite bandwidth.

### *3.1 Satellite Capacity Access Protocols*

A satellite access protocol describes the way in which multiple VSATs share the satellite bandwidth. There are only three techniques to divide satellite bandwidth among multiple users: Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), and Code Division Multiple Access (CDMA).

FDMA, the simplest access technique used by VSATs, allows the network to share satellite capacity by using a different frequency assignment for each carrier. As pictured in Figure 3-2a, VSAT terminals share the allocated capacity by transmitting their carriers at different frequencies. The carriers need not have the same power or bandwidth, but their sum must be within the allocated capacity.

TDMA, the second access technique, allows users to access the allocated capacity in a time-shared mode. Each VSAT transmits in bursts during set time slots. Once the allocated burst time is finished, the VSAT will cease its transmission and yield the capacity to other VSATs. As indicated in Figure 3.2b, at any given time, the entire allocated bandwidth and power are filled by one user.

Under CDMA, the third access technique, all VSATs transmit simultaneously in the same allocated frequency, bandwidth, and power. In CDMA, a pseudo-random sequence encodes the original signal by spreading the signal over a larger bandwidth. To restore the original signal, the receiver correlates the composite input with the original encoding sequence stored in its memory.

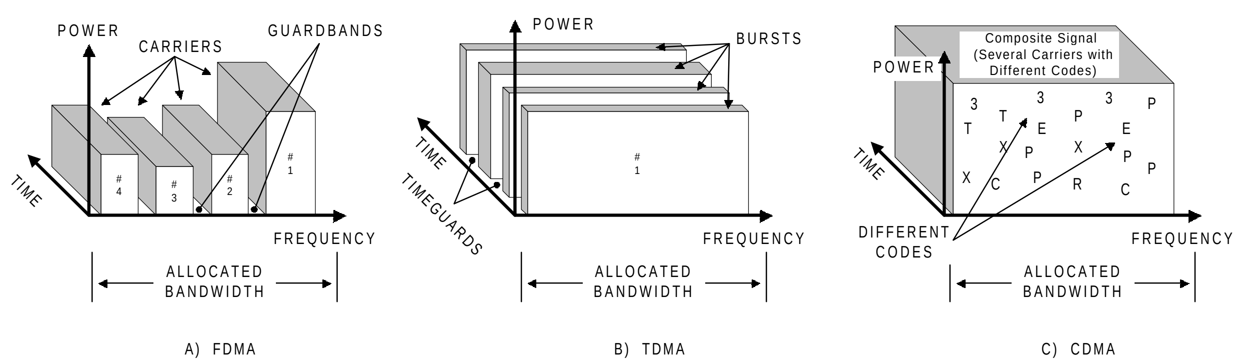


Figure 3-2. Basic Forms of Satellite Capacity Access Techniques.

## *3.2 Satellite Network Access Protocols*

Satellite network access protocols usually combine two satellites' capacity access techniques with some kind of traffic control. Most VSAT terminals carry thin traffic making it inefficient to permanently assign capacity to them. By using a network access protocol, efficiency improves. Network access protocols assign capacity to a particular terminal based on traffic demand. Capacity is requested by the VSATs and is assigned by the network controller at the hub, either on-demand, at random, or permanently.

In an on-demand assignment protocol, the VSAT requests the hub to dynamically pre-assign capacity, either time slots or carriers, before transmitting. This process implies a slower initial response time, but is highly efficient during data traffic transfer.

In a random assignment protocol, each VSAT transmits its traffic when it is received from one of its data ports. This mode offers a very short response time, but the traffic handling capability of a carrier is limited to avoid overloading the carrier.

In a permanent assignment protocol, the VSAT has permanent access to a small portion of the satellite capacity. In this case, the carrier rate limits the traffic a VSAT can carry.  However, when the carrier is not used by the VSAT to which it is assigned, the capacity is wasted.

There are two commonly used satellite access protocols that use a combination of on-demand assignments, random and permanent, assignments to improve the multiple-access efficiency.  These are Time Division Multiplex Time Division Multiple Access (TDM/TDMA) and Single Channel per Carrier Demand Assignment Multiple Access (SCPC/DAMA). TDM/TDMA uses a permanent TDM carrier for the outbound traffic to transmit information from the hub to the VSATs.  Information for many different VSATs is time division multiplexed onto a single outbound carrier. Multiple outbound carriers can be used for larger sized networks.

The VSATs use TDMA to access share inbound carriers. As depicted in Figure 3-3a, TDM/TDMA is a combination of FDMA and TDMA.

SCPC/DAMA uses a single channel per carrier to convey traffic. (See Figure 3-3b.)  When traffic exists, carriers are assigned in pairs, one from the hub to the VSAT and another from the VSAT to the hub, for the return channel.

TDM/TDMA and SCPC/DAMA handle voice and data with different efficiency. Both can operate with permanent or on-demand assignment, but only TDM/TDMA can access the satellite randomly.

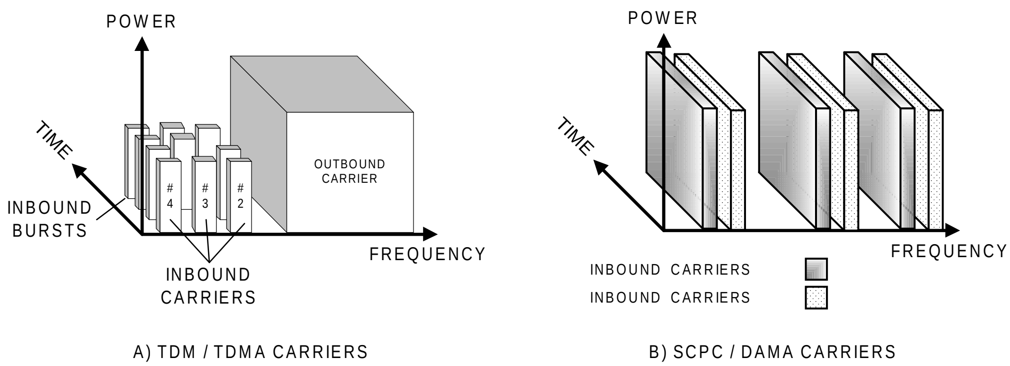


**Figure 3-3. Typical Multiple-Access Protocols from the Satellite Access Perspective.**

### *3.2.1.3 TDM/TDMA Networks*

TDM/TDMA protocols are very efficient and are used mostly in interactive data applications. Before data can be transported with these protocols, the data must be packetized. Each packet contains an address that identifies a data terminal within the VSAT network domain. A receiver, either the VSAT or the hub, acknowledges successful receipt of any packet. If noise, a collision or other impairment corrupts a packet, it will prevent the packet from reaching its destination. In this case, the receiver will not send an acknowledgment (ACK), and the same packet will be re-transmitted after a random time delay. The ACK mechanism ensures proper delivery and simplifies the data transport.

***Hub-to-VSAT link***: The outbound link is a single carrier, and is the result of multiplexing all the packets from different customers and directing them to the various VSATs in the network. The multiplexing is achieved at the front-end processor (FEP), which is connected to the customer’s host computers. Each VSAT listens to the entire traffic carried by the outbound carrier. However, each VSAT will only decode those packets containing control information or traffic packets addressed to one of its terrestrial interfaces.

***VSATs-to-hub link***: Depending on the size of the network, there will be one or several inbound carriers. The inbound carriers convey traffic from the VSAT to the hub. If a VSAT needs to communicate with a peer, it will transmit to the hub that will relay the packet to the other VSAT on a second satellite hop.

***Inbound-access protocols***: In a TDM/TDMA network, the access protocols are implemented in the inbound link from the VSAT to the hub. The protocols most commonly used are known as "random" or "***contention"*** protocols. The protocol is random because no central control determines which VSAT will transmit. This lack of central control lets the inbound capacity open for contention among the VSATs in the network. Each VSAT transmits data as packets at random times and contends with peers for capacity on the inbound carriers. The typical contention protocols are: ALOHA, Slotted ALOHA, Selective Reject ALOHA, and Demand Assignment TDMA with slotted ALOHA reservation access.

***Aloha*** is the earliest of the contention techniques and operates as follows. Whenever there are data to send, a packet will be created and transmitted. (See Figure 3-4a.) The VSAT will then wait for an ACK from the hub. If everything runs without interruption, the ACK should be received within the time comprising just over twice the round-trip delay. However, if another VSAT transmits a packet at about the same time and causes a collision, the hub will simply ignore the corrupted packets and will not send any ACKs. When the VSAT does not receive the ACK, it retransmits the packet after a random time delay. After several failed attempts the VSAT will inform the data terminal that the data channel failed.

An advantage of Aloha is the fast response as long as the shared access channels are operating at a throughput[3] lower than 18 percent. (Refer to Figure 3-4.) The penalty for the fast response and the operational simplicity is the low throughput achieved in the inbound carriers. If the offered traffic increases beyond 18 percent, the actual throughput decreases because of packet collisions, which in turn

3 *The term "throughput" describes the rate of data per second that a system processes, indicating the efficiency of a carrier. In Aloha or S-aloha, the percentage indicates the maximum user's data rate that any inbound carrier will convey. Contention protocols do not allow control in the transmission time of any VSAT. Therefore, a low throughput is purposefully selected to reduce the collision probability and improve the system performance. Thus a 64 kbit/s inbound carrier with 18 percent throughput conveys only 11.5 kbit/s as the average user's data. The actual data rate, and packet rate, in the carrier is 64 kbit/s, but the percentage of time that the VSAT's packets use the carrier is only 18 percent. (See Figure A.1.5.)*

degrades the response. This performance degradation occurs because collisions and lost packets (MSG 2 and 3 in Figure 3-4a) will require that packets be retransmitted in the same channel used for the new packets. Retransmission creates additional packet loading.

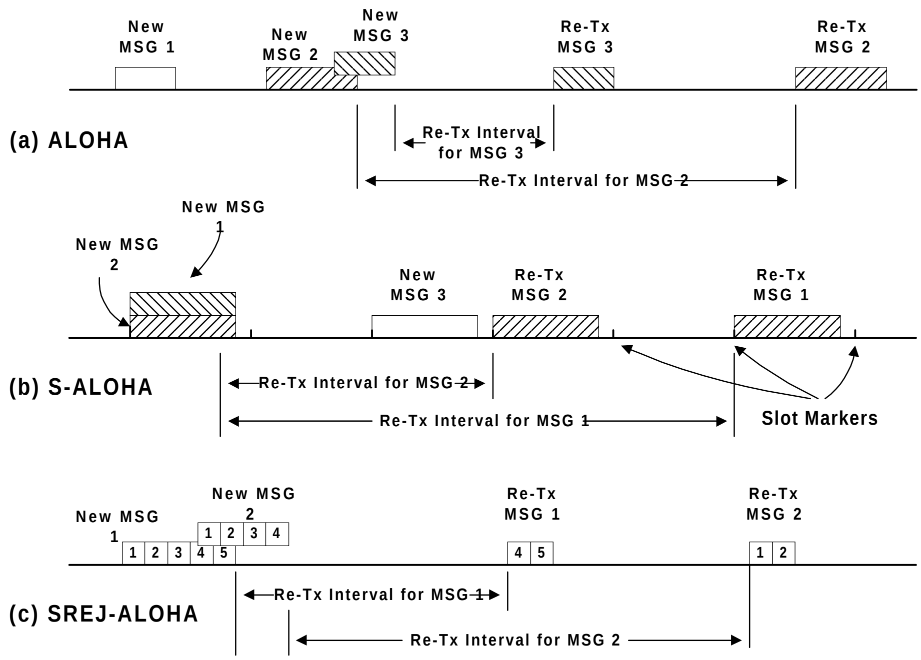


**Figure 3-4. Operation of multiple-access protocols.**

***Slotted Aloha*** (S-aloha) improves the throughput efficiency and lessens the likelihood of collision by inserting time slots in the inbound carrier. Each VSAT recreates the time slots by recovering timing information from the outbound carrier, so that each VSAT is synchronized to a master clock at the hub. This synchronization does not command any VSAT to transmit information in a cyclic way, but rather defines chunks of time slots. In this slotted environment, each VSAT will create fixed-length packets. The VSAT will start transmission only at the beginning of a time slot. Data Terminating Equipment (DTE) delivers an information string to the VSAT. The VSAT assembles the fixed-length packet or packets. The VSAT buffers its packet transmission until the start of the next time slot. (See Figure 3-4b.) The insertion of slots reduces the probability of packet collisions. S-aloha doubles the maximum carrier throughput of pure aloha to approximately 36 percent. (Refer to Figure 3-6.)

***Selective Reject Aloha*** (SREJ-Aloha) is a nonslotted, random-access protocol that achieves throughput almost equal to S-ALOHA without synchronization. (Refer to Figure 3-4c.) The SREJ-Aloha protocol formats a packet in subpackets. Each subpacket has its own header, acquisition preamble and trailer. The protocol exploits the fact that most collisions in an asynchronous system result in partial packet overlaps so that only the subpackets with conflict are actually retransmitted. Throughput for SREJ-ALOHA is in the range of 30 percent, and works well for variable length message scenarios.

***Demand Assignment TDMA with slotted ALOHA reservation*** (DA-TDMA) is a more sophisticated variation of S-aloha and SREJ-Aloha, and employs two levels of access depending upon the size of the packets. In the first level, when the information from the data terminal (DTE) to the VSAT fits within a packet and is within the inbound carrier slot size, then the network will operate as S-aloha. At the second level, when the information from the DTE is lengthy, the VSAT prepares a packet containing a short information field that requests a capacity reservation. The VSAT will transmit this packet to the hub using S-aloha. Upon successful reception at the hub station, the Hub Baseband Processor (HBP) will allocate several time slots for the requesting VSAT. The hub will then inform all the VSATs in the network of those slots and carriers set-aside for this user. Other VSATs will not contend for the capacity during that reserved period. This operation allows the VSAT to transmit in a conflict-free manner. (See Figure 3-5.) The rest of the VSATs will use the remaining inbound slots and carriers. The advantages of DA-TDMA are the high throughput and low delay. This performance is guaranteed even under high traffic loads.

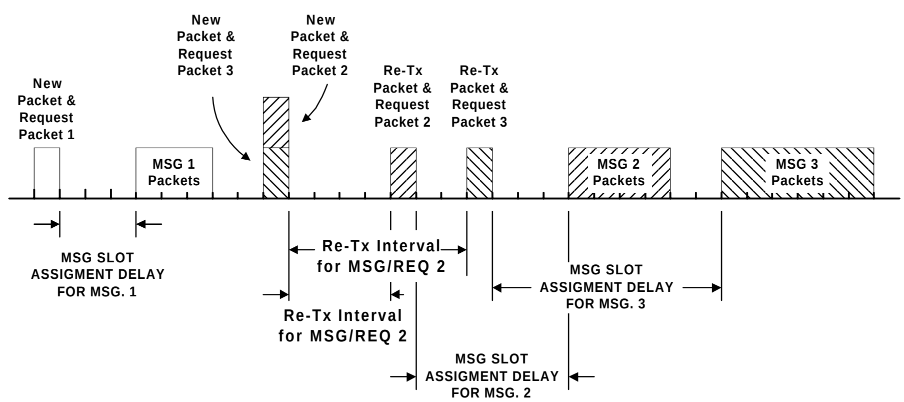


**Figure 3-5. Operation of DA-TDMA.**

Several manufacturers implement a DA-TDMA protocol with slight variations on how much capacity is permanently assigned to a VSAT. For example, if an inbound carrier operates at 128 kbit/s, then the group of VSATs accessing that carrier may have a permanent capacity of, for example, 2.4 kbit/s on average. Each VSAT will get a single time slot to transmit and the network will operate in TDMA. This permanent capacity improves the network performance because it improves the carrier efficiency and response time. The hub also reserves a certain capacity for S-aloha operation. This reserved capacity will serve as a buffer in case a VSAT terminal requests more capacity than its permanent allocation.  Such an arrangement improves the efficiency by minimizing collision problems. If an end user has only interactive applications with short packets then the permanent capacity will suffice. However, if at any time the application is more demanding and requires data rate increases,  the VSAT will request more capacity. The hub will assign capacity from the reserved S-aloha time slots that are available. This approach guarantees a fast response and high throughput with on-demand reservation. DA-TDMA is one of the most popular implementations of VSAT access methods.

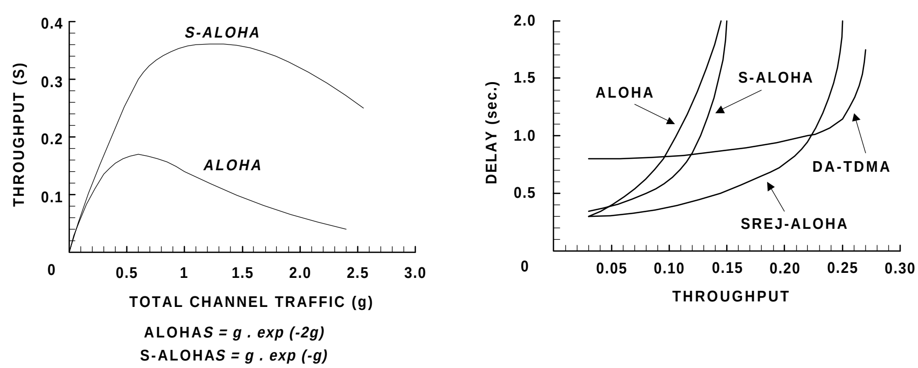


Figure 3-6.   Access Protocol Efficiency Comparison.

***Performance comparison:*** Maximizing throughput and minimizing delay are important characteristics in the selection of a network multiple-access protocol. Modern networks incorporate all the protocols discussed to ensure that the most suitable technique is available for each end user. This functionality allows the network to create Closed Users Groups (CUGs), where each group can use a different application and protocol without interfering with the rest of the network. Table 3.1 presents a performance summary for the four protocols already discussed.

**Table 3.1. Performance Comparison of Protocol Access Techniques.**

| TECHNIQUE | MAX. THROUGHPUT | TYPICAL DELAY | APPLICATION | REMARKS |
|---|---|---|---|---|
| Aloha | 13 ~18% | <0.5 sec. | Variable Length messages. | Timing not required. |
| S-aloha | 25 ~ 36% | <0.5 sec. | Fixed length messages. | |
| SREJ-Aloha | 20 ~ 30% | <0.5 sec. | Variable Length messages. | Capacity competitive with S-ALOHA. |
| DA-TDMA | 60 ~ 80% | <2 sec. | Variable Length messages. | Generally attractive for long messages (batch data, voice). |

### *3.2.2 SCPC/DAMA Networks*

Demand Assignment Multiple Access (DAMA) is an access protocol that allows each channel to use one carrier pair in a Single Channel Per Carrier (SCPC) mode to establish a link. (Refer to Figure 3-7.) These networks are used primarily for voice circuits.

***An SCPC/DAMA network is composed of three blocks:***

- Network Management and Control (NM&C)
- Traffic terminal at the hub
- Traffic terminal at the VSAT

The NM&C is responsible for controlling the network operations, assigning the satellite resources for each circuit, downloading channel configuration via control channels (CCs), and recording call records for billing.

The process of handling calls is as follows.

When a voice channel requests a circuit, by seizing a line, the VSAT will inform the hub of its identity and the dialed digits. The DAMA Network Controller (NCC) knows the origin and identifies the destination via the dialed digits. If the destination circuits are busy, the NCC instructs the originator to produce the busy tone. If the destination is not busy, the NCC provides the origin and destination channel units with the operating uplink and downlink frequencies. Once the channel units (CUs) tune to the assigned frequencies, the circuit is ready. The dialed digits are relayed over the satellite circuit to the PSTN at the destination CU for call completion. Upon termination of the call, the NCC is informed, the DAMA carriers are turned off, and the CUs return to an idle state to wait for a new call. The satellite frequencies return to a common pool of frequency for future use.

DAMA can operate in either star or mesh topology. Once the connection is established, the CUs carry the traffic through the assigned traffic carriers without intervention from the NCC. All DAMA channel units in a terminal share a common RF electronics and antenna facility.

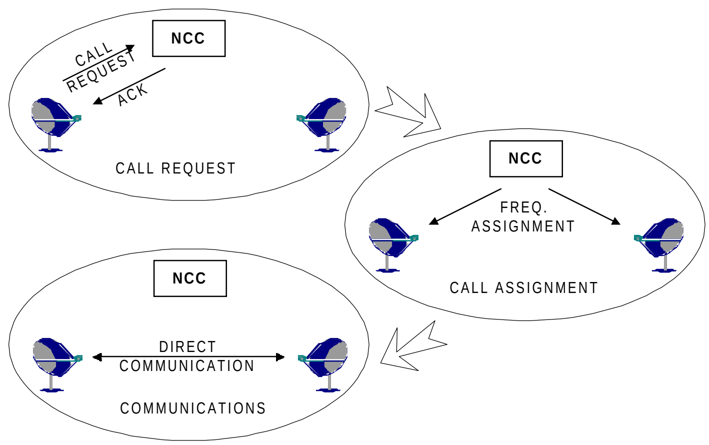


**Figure 3-7. Operation of SCPC/DAMA Protocol.**

Additional features in a SCPC/DAMA protocol are:

- **Voice compression.** To minimize the bandwidth requirements, SCPC/DAMA systems use voice compression. The modern compression algorithms operate at low rates (4.8 to 9.6 kbit/s) while maintaining a good voice quality. Compression rates at 4.8 kbit/s to 16 kbit/s per channel are available and provide bandwidth savings.

- **Voice activation.** SCPC/DAMA systems employ Voice Activation (VOX), which turns the carrier off during pauses of a conversation. VOX reduces the required satellite power. In pools of 100 channels or more, VOX provides a net reduction of satellite power utilization of up to 2.2 dB.

- **On-demand data channels.** If required, DAMA can offer clear channels at 64 kbit/s or higher on-demand. These clear channels can be used for data applications.

### 3.2.3 VSAT Protocol Implementation

To implement a VSAT protocol for data communications, at least three layers are needed, i.e., the network kernel, the communications gateway, and the user’s interface. (Refer to Figure 3-8.) The network kernel consists of the network multiple-access protocols. The network multiple-access protocol ensures the access to the satellite and a secure delivery of information while implementing functions such as packet congestion control and network management.

The communication gateway protocol interfaces the user's protocol to the network kernel. The gateway protocol operates as a packet assembler and disassembler (PAD). Its functions include packet addressing, routing, switching, and virtual circuit and flow control. The functions of the PAD are performed on the information transported in the kernel.

The user’s interface emulates the user protocols and locally terminates the user’s protocol. (Refer to Figure 3-8.) This is the performance of the data throughput over satellite.

In theory, a user’s host can bypass the user’s interface and PAD functions, and directly access the kernel. However, in practice, performance will be degraded because of satellite delay. It is preferred to terminate the user’s protocols locally, and take advantage of the PAD functions.

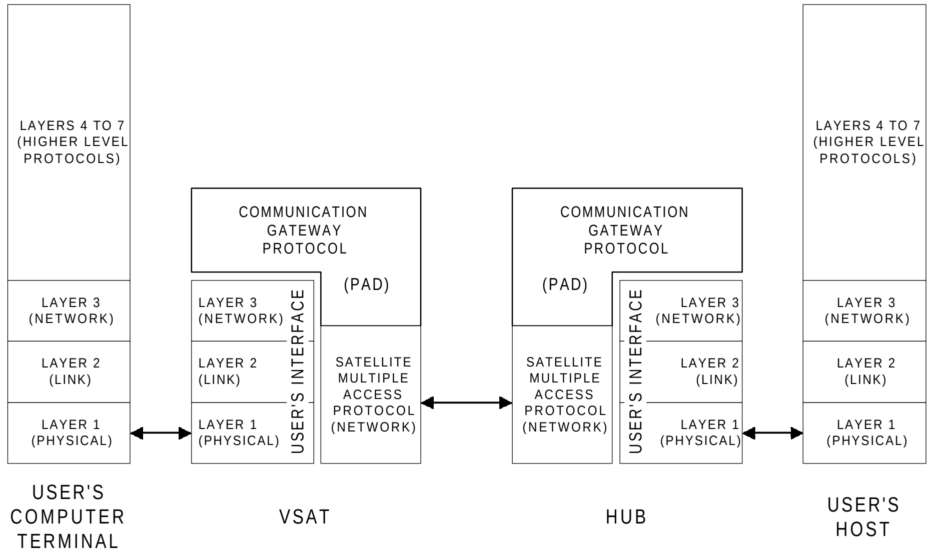


**Figure 3-8. General View of VSAT Protocols.**

## *3.3 User Protocols*

VSAT networks usually replace existing terrestrial data networks, and connect host computers with data terminals via a satellite. A terrestrial network generally low latency, circuit-based and therefore inherently transparent to the user host's protocol. Some of the user protocols used extensively include SNA/SDLC, X.25, BISYNC, ASYNC or TCP/IP. VSAT networks have inherent satellite latency and, consequently, utilize protocols optimized for this environment. VSAT networks, however, maintain transparency to the user host's protocols mentioned above.

This transparency is achieved by terminating the customer's protocol locally before entering the VSAT satellite link. (Refer to figure 3-9.) The satellite link then converts the customer's data to an efficient satellite protocol that ensures proper delivery and minimum delay.

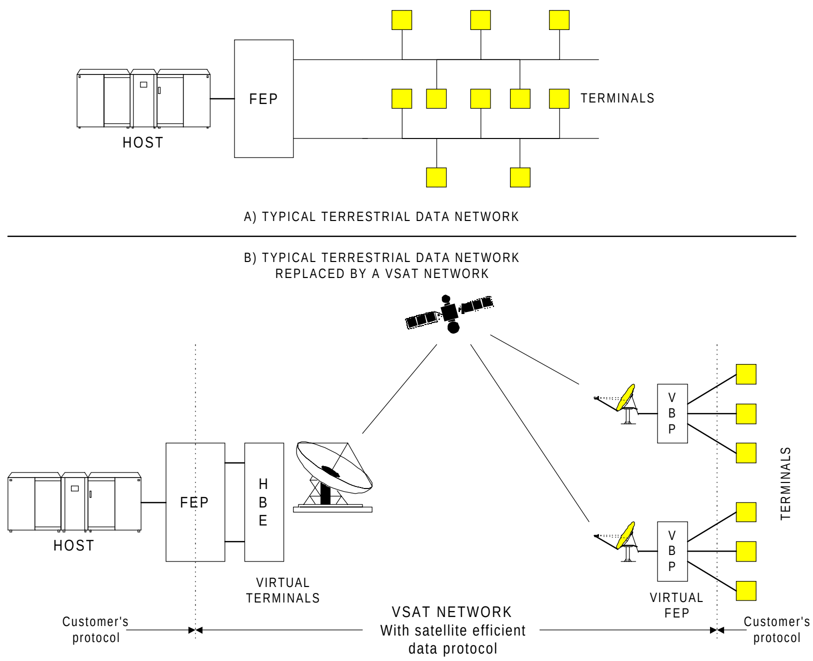


**Figure 3-9. Typical VSAT Emulating a Terrestrial Data Protocol.**

The system operates as follows.

1) Suppose a data terminal with a number 123 at the customer's headquarters sends data to terminal 456 in a branch office,
2) The host computer will route the packet from 123 to the FEP at the VSAT hub where terminal 456 virtually resides.
3) The FEP will acknowledge the information packet to the host and back to terminal 123, thus terminating the customer's protocol.
4) The FEP takes the information and assembles, or formats, a packet using its own satellite protocol.
5) When the packet is ready, the destination address is stamped to it to direct the information to the proper VSAT.
6) The satellite protocol transports the packet via the outbound satellite link and ensures data integrity and proper delivery.
7) All VSATs will listen to the information packets in the outbound carrier. Whenever a VSAT detects a packet containing an address, it will acknowledge it. The IDU will send an ACK message back to the hub. This is a short packet containing the received packet numbering, and is sent to the hub via the inbound carrier.
8) The hub, upon receiving the ACK, will know the packet was properly delivered and will erase the information from its buffers.

9) The VSAT will disassemble the packet, thus terminating the satellite protocol.
10) The IDU emulates the customer's protocol to deliver the information to terminal 456 in the expected protocol.

The satellite protocol, in most cases, is proprietary to the manufacturer. Therefore, the VSAT network must be capable of emulating locally all the user's protocols without the need to modify the configuration of existing equipment. The VSAT Baseband Processor (VBP) and the FEP at the hub are responsible for the user's data protocol processing. The interface cards usually implement the processing by software so that different protocols require different software versions. Therefore, the VBP should be able to download new versions or upgrades of software from the hub using the satellite channel.

The STAR topology of a VSAT network does not limit the traffic connectivity. If a service requires full-mesh connectivity, the hub will implement a virtual mesh connection by routing the VSAT-to-VSAT traffic using a double hop. In this case, to minimize delay, the FEP will not disassemble the packets, but it will route them out to the final destination. At the final destination, a VSAT, the VBP will disassemble the satellite protocol packets and reassemble the user's data protocol.

# CHAPTER 4

## PLANNING AND IMPLEMENTING VSAT NETWORKS VIA THE INTELSAT SYSTEM

***HOW TO CHOOSE A SUITABLE NETWORK CONFIGURATION***

Planning and implementing a VSAT network involves a decision making process. In some cases the process requires more than one iteration to reach to the most economic solution. The activities in the planning process include:

- defining the service requirements;
- defining expected network objectives in terms of performance, quality, and availability;
- defining the network size and design;
- comparing the design against available equipment, and analyzing the manufacturer's alternatives to fulfill the requirements and design;
- evaluating the costs;
- preparing an implementation plan;
- determining the space segment capacity required and reserving the capacity with INTELSAT;
- defining specification for procurements; and
- listing all postimplementation operational requirements.

### *4.1 Definition of Service Requirements*

Before planning begins, it is important to identify the menu of services that defines all the potential users that the VSAT network will require. An analysis of the current telecommunications infrastructure will also help to discover the niches not reached, and which the VSAT network can provide. This information will define ***what*** is needed, ***why*** it is needed and ***what*** *criteria* the clients will use to evaluate the results.

***The minimum information to gather includes:***

**A description of the client's service:** Different clients have different requirements, including voice, data, voice and data, interactive data, one-way broadcast, video-conferencing, or Internet. To determine what their evaluation criteria will be, the clients must reveal their expectations on quality and grade of service, throughput, response time, congestion, etc.

**Estimation of the traffic in the peak busy hour (PBH) for each service:** As realistic information as possible must be gathered on: Traffic erlangs, message sizes, call duration, service priority, response time, set-up time, application protocols (i.e., Ethernet, TCP/IP, etc.).

**The estimated traffic growth per year**: Number of new nodes per year, services per node, new services to existing nodes, priority of services per node.

**Any constraint in any site that may affect the VSAT operations:** Obstacles, building projects, roads, radio links operating in the same frequency, and zoning restrictions.

Collect the information in tabular form to define the initial service provisions, and use this as a road map for future upgrades and applications. The table might also suggest future enhancements that the VSAT will need to accommodate. In most cases, the initial service offering will define the network costs and feasibility. In some cases, it may be possible to implement the future enhancements solely through software upgrades.

### *4.1.1 Traffic Estimation*

Clients provide information that needs interpretation by the VSAT service provider. In most cases, clients have minimal knowledge of telecommunications or satellite jargon. Questionnaires to obtain a client's information should be written in plain language, avoiding technical jargon. Once the information is collected, the VSAT service provider and the client must discuss the implications of the questionnaire to assess the relevance of the client's requirements. This discussion will help clarify possible misunderstandings.

Next, the VSAT service provider must analyze the data to size the network. Voice and data traffic information are analyzed in different manners. Examples of both cases follow:

**Voice traffic:** For voice traffic, most of the information is given in the number of channels or phone extensions per site.

For example: Client A needs to provide voice services to 250 sites in a 3-year period. These sites will be part of a rural communications project. The project plan indicates that every year 85 sites will be added to the network. In the first year the client requires 2 trunk lines for 60 sites, and 4 trunk lines for the remaining 25 sites. The client provides the traffic as described in Table 4-1. The number of satellite channels needed to support this service can be determined from calculations based on Tables 4-1 and 4-2.

**Table 4-1. Summary of Requirements.**

| YEAR | 1 | 2 | 3 |
|---|---|---|---|
| Number of sites with 2 channels | 60 | 100 | 150 |
| Number of sites with 4 channels | 25 | 50 | 70 |
| Number of sites with 8 channels | | 20 | 30 |
| Total sites | 85 | 170 | 250 |
| Total number of channels | 220 | 560 | 820 |

The VSAT service provider needs to convert this number of channels to erlangs to derive the number of satellite channels. This is done by assigning a given traffic level to each line. For trunk lines, it is common to use a value between 0.1 to 0.25 erlangs[4] per line in the PBH. The total calculated traffic level for the network is shown in Table 4-2.

**Table 4-2. Calculated Traffic Intensity in Erlangs.**

| YEAR | 1 | 2 | 3 |
|---|---|---|---|
| Total number of channels | 220 | 560 | 820 |
| Traffic intensity with 0.1 Erlang per line | 22 | 56 | 82 |
| Traffic intensity with 0.25 Erlang per line | 55 | 140 | 205 |

4 *Erlang is the international unit of traffic intensity. One erlang represents a circuit occupied for 1 hour. It is used to calculate the number of channels needed to carry all calls. For more information of traffic calculations see Boucher, James, Traffic System Design Handbook. IEEE Press 1993.*

The number of satellite channels is the number of duplex channels needed to carry the entire network traffic, and is calculated using the erlang B tables and a probability of loss. The client must define the probability of loss. Typical values range from 1 percent to 5 percent [5]. Suppose the VSAT service provider chooses 0.1 erlang per line, and the client wants to use a 2 percent probability of loss. Table 4-3 shows the result of using these values.

**Table 4-3. Traffic Intensity and Calculated Number of Satellite Channels.**

| YEAR | 1 | 2 | 3 |
|---|---|---|---|
| Total number of channels | 220 | 560 | 820 |
| Traffic intensity with 0.1 Erlang per line | 22 | 56 | 82 |
| Number of satellite channels using 2 percent of probability of loss | 31 | 67 | 95 |

The number of channels in Table 4-3 will handle all the traffic in the network and will be the basis for calculating the required space segment at a later stage.[6]

The primary application of the network is to support voice traffic, and the assumed characteristics for the voice traffic include the following.

- Call duration is about 3 to 5 minutes.
- Call setup time is about 5 seconds.
- The voice calls are susceptible to changes in the connection delays, but are resilient to errors.

Therefore, the satellite access technique has to allocate a free voice channel in less than 5 seconds. Then it must run the channel over a permanent connection to avoid the changes in the connection delay, and must reduce the satellite bandwidth by allocating the calls on-demand. SCPC/DAMA is a technically feasible solution.

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*[5] The probability of loss is often called blockage probability. It represents a percentage of the call attempts in which a line, (in this case a satellite channel), will not be available for the user.*
*[6] The client can choose to provide very vague information like 'I would like to link the 15 telephone extensions in the branch offices to headquarters'. In this case the VSAT service provider has to assign traffic intensity, typically 0.0025 erlangs, per extension to calculate the branch office traffic intensity (0.0375 erlangs per branch). Then they will calculate the network traffic intensity and the number of channels.*

There may be instances in which the clients provide the traffic information in traffic minutes, and the information may be in the form indicated in Table 4-4.

**Table 4-4. Number of Minutes-Traffic Per Destination.**

| NODE | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | | 161943 | 150139 | 1295144 | 95713 | 395774 |
| 2 | 161943 | | 719180 | 40701 | 1891282 | 197720 |
| 3 | 150139 | 719180 | | 84565 | 831489 | 241145 |
| 4 | 1295144 | 40701 | 84565 | | 247042 | 111363 |
| 5 | 95713 | 1891282 | 831489 | 247042 | | 174757 |
| 6 | 395774 | 197720 | 241145 | 111363 | 174757 | |

Before any network sizing can take place, the information in Table 4-4 must be converted from traffic-minutes to erlangs. The conversion should follow the method indicated in ITU-T Recommendation E.506. This method recommends the use of the following formula to convert traffic-minutes information to erlangs:

$$A = \frac{Mdh}{60e}$$

Where:

- *A:* is the estimated mean traffic in erlangs carried in the busy hour
- *M:* is the total monthly paid minutes
- *d:* is the day/month ratio, i.e., the ratio of average weekday paid-time to the monthly paid time
- *h:* is the busy-hour/day ratio, i.e., the ratio of the busy-hour paid-time to the average daily paid-time
- *e:* is the efficiency factor , i.e., the ratio of busy-hour pad time to busy hour occupied time

INTELSAT recommends using the following values for the variables.

**d = 0.041**

This ratio relates the amount of traffic carried on a typical weekday compared with the total amount of traffic carried in a month. A typical weekday will carry 1/24$^{th}$ of the total monthly traffic. This value considers that the weekday/weekend traffic ratio is 0.8, meaning that the weekend traffic is only 20 percent lower than during the weekdays.

**h = 0.1**

This ratio depends primarily on the difference between local time at the origin and destination. In this example, a 2-hour time zone difference is assumed between the hub and the VSATs. Based on statistical measurements, ITU-T Recommendation E.523 proposes a busy-hour/daily traffic ratio of 10 percent for a 2-hour time zone difference.

**e = 0.97**

The efficiency factor converts paid-minutes into a measure of total circuit occupancy. ITU-T Rec. E.506 recommends values in the order of 90 percent or higher for automatic exchanges.

Considering these values, the number of erlangs per route is then calculated and the number of circuits can be derived. (See Tables 4-5 and 4-6.)

**Table 4-5. Calculated Number of Erlangs per Destination.**

| NODE | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | 0.0 | 1.0 | 0.9 | 7.6 | 0.6 | 2.3 |
| 2 | 1.0 | 0.0 | 4.2 | 0.2 | 11.1 | 1.2 |
| 3 | 0.9 | 4.2 | 0.0 | 0.5 | 4.9 | 1.4 |
| 4 | 7.6 | 0.2 | 0.5 | 0.0 | 1.5 | 0.7 |
| 5 | 0.6 | 11.1 | 4.9 | 1.5 | 0.0 | 1.0 |
| 6 | 2.3 | 1.2 | 1.4 | 0.7 | 1.0 | 0.0 |

**Table 4-6. Calculated Number of Channels per Destination (using Erlang B tables).**

| NODE | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | 0 | 5 | 5 | 15 | 4 | 7 |
| 2 | 5 | 0 | 10 | 3 | 19 | 5 |
| 3 | 5 | 10 | 0 | 4 | 11 | 6 |
| 4 | 15 | 3 | 4 | 0 | 6 | 4 |
| 5 | 4 | 19 | 11 | 6 | 0 | 5 |
| 6 | 7 | 5 | 6 | 4 | 5 | 0 |

**Data traffic:** Data traffic is more difficult to model because there are several different protocols with different characteristics. Suppose then, that as VSAT service provider, you collected the information in Table 4-7 from a group of clients.

**Table 4-7. Data Transaction and Character Traffic Estimate.**

| CLIENT | APPLICATION | T | $C_I$ | $C_O$ | $N_U$ | $N_{VSAT}$ | $T_M$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|
| ΩΣ; Bank | Account management and ATM transactions | 18000 | 100 | 400 | 5 | 75 | 4 | 2 |
| Insurance Co. | LAN to LAN interconnection [7] | 5800 | 60 | 300 | 25 | 15 | 3 | 2 |
| Manufacturing ABC, Inc. | Inventory control | 300 | 500 | 500 | 1 | 25 | 1 | 5 |
| Toys Retailers | Inventory control, Point-of-Sales (POS) operations | 15000 | 50 | 200 | 8 | 75 | 8 | 2 - 5 |
| Credits Unlimited | ATM and Credit Card verification points. | 50 | 40 | 100 | 10 | 50 | 0.5 | 2 - 5 |
| INTERNET Services Ltd. | Internet, Intranet for multi-users, corporations, and universities. | n/a | 60 | 600 | 15 | 25 | n/a | 2 |

Where:

T = Number of transactions per day

$C_I$ = Input characters per transaction in bytes

$C_O$ = Output characters per transaction in bytes

$N_u$ = Number of data terminals or end users per VSAT node

$N_{vsat}$ = Number of VSATs servicing the same application

$T_m$ = Transactions per minute in the Peak Busy Hour (PBH)

$R_T$ = Response time (in seconds)

To analyze this information, keep the following in mind.

- In each branch office there will be one or several data terminals that will offer traffic to the VSAT network (Nu),
- The number of transactions per minute, bytes per transaction, and response time ($T_m$, $C_I$, $C_O$ and $R_T$) depend on the client application,
- Internet is a special case because the number of transactions per day is not yet well characterized. To date, the manufacturers and Internet VSAT Service Providers (ISPs) use the following assumptions as conventions for Internet traffic
    - Most of the traffic is browsing traffic.
    - Of the registered users, only 10 percent are

[7] *The LAN-to-LAN interconnection can handle several protocols and services like TCP/IP for Internet, voice over IP, desktop videoconferencing.*

logged-in at any given time,

- Of the logged-in users only 20 percent are active at any given time, and most of these are reading received information or performing other short term tasks,
- The inbound to outbound traffic ratio is1/10.
- For browsing purposes, a minimum throughput of 9.6 kbit/s is required for the inbound channel.

It is worth noting that actual values could vary substantially variations from these typical numbers, rapid response time is commonly required by certain applications, and interactive data applications tend to be asymmetric with much less inbound data (VSAT-to-hub) than outbound data (hub-to-VSAT). Figure 4-1 depicts a block diagram with a typical configuration for the equipment and services that the network can provide.

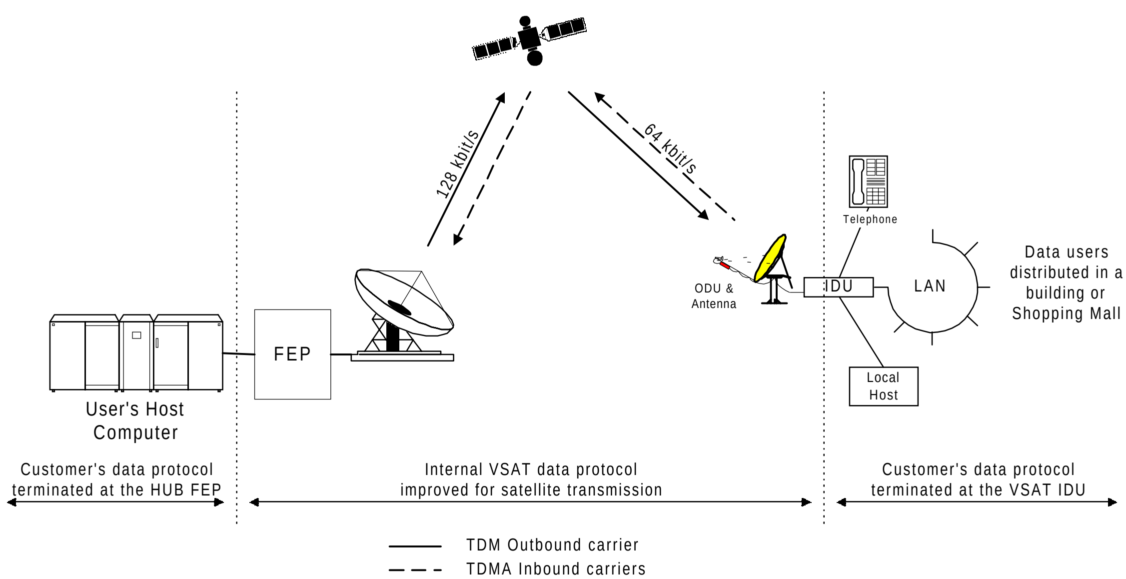


**Figure 4-1. Block Diagram of Network Equipment and Services.**

To calculate the number of carriers, the VSAT service provider must carefully evaluate the client’s applications. Each application defines how frequently a terminal will interact with the host and the average length of a message. Therefore, the client’s traffic profile, the number of sites, and the access techniques will define network sizing.

The number of carriers will then be defined by:

- the number of clients;
- the number of VSATs per client that simultaneously run an application;
- the number of data terminals per VSAT;
- the application and the number of interactions during the PBH;
- the number of of messages sent per transaction in each direction and the size of the messages;
- the satellite access protocol and overhead; and
- the required response time.

With the information in Table 4-7 as the basis, the following formula can be used to calculate the total traffic rate offered to the network:

$$T_r = \frac{N_u \times N_{vsat} \times P_L \times (8 \times P_T)}{\left( 60 / T_m \right)}$$

Where:

| | |
|---|---|
| $T_r$ | = Total rate offered to the network, in bit/second |
| $N_u$ | = Number of data terminals or end-users per VSAT node |
| $N_{vsat}$ | = Number of VSATs servicing the same application |
| $P_T$ | = Number of packets per transaction |
| $P_L$ | = Length of the packet in bytes, 100 and 200 for inbound and outbound traffic respectively |
| $T_m$ | = Number of transactions per hour (in PBH) |

Table 4-8 summarizes the result of applying the formula to the information of Table 4-7. Notice that the Internet traffic is treated differently in the sense that the minimum throughput in the inbound is 9.6 kbit/s.

**Table 4-8. Summary of the Network Traffic Calculation.**

| Client | Network Size | | | INBOUND TRAFFIC: PBL=100 BYTES | | | OUTBOUND TRAFFIC: PBL=200 BYTES | | |
|---|---|---|---|---|---|---|---|---|---|
| | $N_u$ | $N_{vsat}$ | $T_m$ | $C_i$ | $P_T$ | $T_r$ | $C_i$ | $P_T$ | $T_r$ |
| ΩΣ; Bank | 5 | 75 | 4 | 100 | 1 | 20,000 | 200 | 1 | 40,000 |
| Insurance Co. | 25 | 15 | 3 | 60 | 1 | 15,000 | 200 | 1 | 30,000 |
| Manufacturing ABC, Inc. | 1 | 25 | 1 | 500 | 5 | 1,667 | 500 | 3 | 1,667 |
| Toys Retailers | 8 | 75 | 8 | 50 | 1 | 64,000 | 100 | 1 | 128,000 |
| Credits Unlimited | 10 | 50 | 0.5 | 40 | 1 | 1,333 | 100 | 1 | 3,333 |
| INTERNET Services Ltd. | 15 | 25 | n/a | 60 | 1 | 72,000 | 300 | 2 | 360,000 |
| Total traffic (Tr) in bits/s during the PBH | | | | | | 174,000 | | | 563,000 |

From the total traffic (Tr) in Table 4-8, the VSAT service provider can calculate the number of carriers in the network. For this example, the calculation must consider the efficiency of the satellite access protocol as indicated in Table 3-1, and using the following formula:

$$C_r = \frac{T_r \times (1 + OH)}{\eta \times R}$$

Where:

- $C_r$ = Number of carriers at rate, R.
- $T_r$ = Total rate offered to the network, in bit/second
- OH = Traffic overhead, required for packet header and trailer, 20 percent for outbound (TDM) carrier and 40 percent for slotted ALOHA inbound carriers
- R = Information rate of the carriers. 64 kbit/s or 128 kbit/s for inbound and N x 64 kbit for the outbound ($N \leq 24$).
- $\eta$ = Efficiency of the access protocol. 23 percent for Slotted ALOHA and 90 percent for TDM (for inbound and outbound carriers respectively).

The result of applying the formula to the traffic in Table 4-7 is that the network will need 14 x 64 kbit/s inbound carriers, and one 768 kbit/s outbound carrier.[8]

[8] *Note: For outbound carriers use R=1 to allow $C_r$ to calculate the carrier rate for a single inbound carrier. Then round $C_r$ to the next multiple of Nx64 kbit.*

Before proceeding in the planning process, it is important to define the minimum performance expected from the network. This can be derived from the client's responses and must be defined in terms of:

## 4.2 Network Performance Definition

1) **Response time:** The elapsed time between the moment an inquiry is received from the user by the hub or VSAT and the moment when the response is delivered by the VSAT or hub to the user. In a data network, the response time will consist of the time it takes to get the data from a distant end.[9] For a voice network, the response time will consist of the setup time of a voice channel. When considering the response time, it is important to factor in the 520-msec. satellite round-trip propagation time.
2) **Throughput[10]:** For the clients, throughput represents time within which they expect their applications to achieve a given response. For VSAT service providers it indicates the efficiency of the network.
3) **Typical Bit Error Rate (BER):** The typical BER tolerated depends upon the application. Voice tolerates higher BER, while data need lower BER. Typical values are $10^{-5}$ to $10^{-7}$ for voice networks and $10^{-7}$ to $10^{-9}$ for data.
4) **Network availability**: Network availability is defined as the percentage of the time in which the network operates above the BER threshold. The availability of the ground equipment and the availability of the satellite link influence the total network availability.

A. **Equipment availability ($A_E$)** is defined by the ratio of the time the equipment operates properly to the total time. The time the equipment operates is indicated by the Mean Time Before Failure (MTBF). The total time is the addition of the time needed to repair a unit as indicated by the Mean Time To Repair (MTTR) plus the total operating time or MTBF. The formula to calculate $A_E$ is as follows:

$$A_E = \frac{MTBF}{MTBF + MTTR}$$

Typical values for AE are:

Hub = 99.995 percent to 99.999 percent

VSAT = 99.785 percent to 99.988 percent.

The value of $A_E$ is improved by providing some sort of redundancy to the equipment, however this increased the equipment costs.

B. **Link availability ($A_L$)** is defined as the ratio of the time the link is above the BER threshold to the total time. The link availability is influenced by the attenuation induced by the rain and other propagation effects together with outages caused by the sun interference[11]. The attenuation induced by the rain is higher at Ku-band than in C-band. The way to counter this attenuation is to introduce margins in the uplink and in the downlink. These so called ***rain margins*** must account for the following atmospheric impairments:

Gaseous absorption

Cloud attenuation

Melting layer attenuation

Rain attenuation

Tropospheric scintillation

Low-Angle fading

Ray bending

Defocusing

Cross-polar discrimination

The calculation of the total attenuation caused by these impairments requires Earth station parameters including meteorological and satellite-link parameters.

[9] *In a credit card verification network (which is a data network), the network response time will consist of the satellite round trip time and the processing time to get an authorization from the host computer.*

[10] *The term "throughput" describes the rate of data per second that a system processes. Throughput indicates the usage efficiency of a carrier. It is desirable to have a throughput of 100 percent, but due to the need for multi-access protocols like Aloha or S-Aloha, the 100 percent will never be achieved. The throughput percentage values for multi-access protocols indicate the maximum user's data rate that any inbound carrier will convey. Contention protocols do not allow control in the transmission time of any VSAT. Therefore, a low throughput is purposefully selected to reduce the collision probability and improve the system performance. Thus a 64 kbit/s inbound carrier with 18 percent throughput conveys only 11.5 kbit/s as the average user's data. The actual data rate, and packet rate, in the carrier is 64 kbit/s but the percentage of time that the VSAT's packets use the carrier is only 18 percent. (See Table 3.1.)*

[11] *The Sun interferes with normal communications when the antenna boresight is aligned with the Sun. The Sun's radiation during the solstices decreases the system G/T, disrupting the link. It happens twice a year during 3 to 5 days in the solstices and disrupts the services for no more than 3 minutes a day. The duration and occurrence dates vary with the location.*

There is a direct relation between link availability, satellite capacity, and the link cost. In some instances, the VSAT service provider must compromise the availability value to reduce the satellite capacity. Practical link availability values for VSAT networks range from 99.0 percent to 99.6 percent.

The rain margin calculations are discussed in Chapter 6.

## *4.3 Defining The Network Size And Design*

The network design will seek to balance the requirements in the Earth segment and space segment to find the, overall, cost-effective solution. Optimum network design minimizes the capital and operating costs while meeting all service requirements, and involves a tradeoff among available satellite capacity, antenna sizes, proposed connectivity, network topology, availability, quality, and growth over time.

**INTELSAT satellite and frequency band:** Determine which INTELSAT satellite covers the desired network geographical area. This is done after identifying the nodes and the physical locations for each. The planner will determine whether the appropriate INTELSAT satellite is C- or Ku-band, and the associated transponder characteristics. If both frequency bands provide suitable coverage, tradeoff analyses should be undertaken to determine which band better accommodates the network. The analysis must take into account both satellite characteristics, and propagation characteristics for the network's geographical area. In general, Ku-band antennas are smaller and less costly than C-band. In either case, INTELSAT has satellites providing continental and intercontinental service in every area of the world. Capacity is leased under flexible combinations of bandwidth and satellite power, and can be tailored to meet any VSAT service provider's needs.

**Topology and access alternatives:** The goal in defining the network topology is to balance the Earth segment costs with the required satellite resources. A star architecture allows use of a less expensive VSATs terminal. However, the connection between two nodes will require two hops (node A via satellite-to-hub station, and hub via satellite-to-node B). Direct connection between nodes, as in a mesh configuration, will not be possible. For node-to-node connection, the star architecture will result in 0.5 second of additional delay. If node-to-node connections are infrequent, double hop can be used because it reduces the cost of the VSAT equipment and satellite capacity.

Developing the most cost effective network design requires defining an initial topology that can be tested with link budgets. Various scenarios and iterations will help determine if the topology fits the service requirements. Some architecture choices will fall out naturally from the traffic requirements. For example, if the service requirement is for data distribution from one central site, then a star architecture should be considered. The star approach will also be suitable for inbound data collection systems. Many corporate networks are inherently suited to a star architecture because their information flow is primarily between corporate branches and a central headquarters facility.

**Link budgets:** Will be used to optimize network parameters. The aim is to get the smallest antenna size, the smallest power amplifier at the VSAT and utilize the smallest amount of space segment. Several iterations will be needed to find the best combination of antennas, satellite, and carrier characteristics for a given network. To assist its clients, INTELSAT has prepared the Lease and Sales Transmission Plan software (LST) version 4.3 (or later). This can be used to test various configurations and topologies and includes almost every possible modulation, coding, and satellite available in the INTELSAT system. It allows the user to check the impact of rain attenuation on the link and allows the user to test other operating conditions in a budget. The use of the LST is detailed in Chapter 6.

## *4.4 Network Design Versus Available Equipment*

Once a round of link budgets has been performed, the planner needs to compare the results with the available equipment. This must be done in terms of antenna, SSPA, carrier rates, coding, and modulation schemes. Although manufacturers can tailor equipment to meet a requirement, the cost is high. Therefore, it is better to match network requirements with the industry available equipment. If necessary, undertake additional iterations to see if an acceptable network design can be achieved using available equipment. If industry information is available, it should be used as reference for the link budget calculations. INTELSAT has prepared a vendor catalog, as an addendum to this handbook, that is available upon request. The information in the addendum can be used as a preliminary reference, but buyers must contact the manufacturer to get specific details on products, services, and costs.

## 4.5 Evaluation of Investment and Costs

The next step in the planning process is to evaluate the cost of a VSAT network.

### 4.5.1 Network Implementation Costs

The cost analysis starts with a summary of the capital costs. The following elements must be included.

**Equipment costs**: With the current competition among manufacturers, equipment costs are volatile, and negotiable. The VSAT units are likely to be the highest equipment cost, because there may be many VSATs in the network. Each remote site will include not only the VSAT itself, but the interfacility link and indoor equipment such as data subsystems and site management equipment. The hub facility and ancillary equipment should also be included.

**Staff and training:** Additional staff may be required to operate and maintain the VSAT network. Staff training on the new VSAT equipment will also be required.

**Local facilities**: Each site will require a site survey, local permit approval, and possibly frequency coordination[12], followed possibly by civil works, power, and air conditioning. Local conditions may indicate the need for additional heating, cooling, or dehumidifying equipment. Ancillary equipment such as power installations, and heating or air conditioners for the equipment can add to the cost.[13]

**Spare parts**: At he hub, it is typical to have 1 spare for each 10 items of online equipment (such as voice and data card units). For the remote VSAT terminals, it is typical to have 1 spare for every 20 items of the common equipment (such as SSPA and ODUs). Full redundancy would be likely for the hub station equipment, but is not required at the VSAT. The cost range for spare equipment would be 5 to 10 percent. (See Table 4-9.)

*[12] Ku-band sites often have blanket agreements and do not need frequency coordination.*
*[13] 1.2, 1.8, and sometimes 2.4m Ku-band VSATs often do not require any civil works, A/C, or special power. The IDU plugs into a wall outlet and powers the ODU. No electricity is run to the roof/antenna.*

### 4.5.2 Operational Costs

The next issue to consider is the operational costs of the VSAT network. The operational costs can be divided into satellite resources, staff, and facilities. Facilities operational costs consist of power, heat, and air conditioning costs.

**Space segment lease cost**: INTELSAT has a flexible tariff system, and a client can choose to either pay per carrier or to lease a portion of a transponder (INTELNET lease).

In carrier-based tariff, INTELSAT charges the client by the carrier size. The advantage of carrier-based tariff is that the service is pre-engineered and all the parameters are defined in the IESS documents. Capacity and quality of service are guaranteed by INTELSAT.

INTELNET leases provide the client with the highest flexibility possible. The client is free to define the service quality, availability, and any parameter affecting the network performance. The lease can start in bandwidths as small as 100 KHz with no limitations in the upper side of the scale. Prices are available from any INTELSAT sales representative or from the local INTELSAT Signatory.

**Staff costs**: Operational and maintenance staff will be needed to operate a VSAT network. The minimum staffing level at the hub can be considered to be one engineer, one technician, and one support staff. In addition, it can be assumed that one routine maintenance visit will be required each year for each VSAT site. Assume that each visit will take 4 hours, plus travel time, and per diem.

**Facilities' costs**: Facilities have ongoing expenses for such items as power, heat, and air conditioning. These costs are highly dependent on existing infrastructure and policies in the service area.

**Table 4-9. Example of Capital Cost Calculation for a VSAT System [14].**

| # | DESCRIPTION | PRICE | REMARKS |
|---|---|---|---|
| | **Hub station** | | |
| 1 | Equipment - fixed cost | $ 815,625 | This price depends on antenna size and hub sophistication. |
| 2 | Spares | $ 81,563 | 10 percent of spares for the hub. |
| 3 | Facilities - Land, building | $ 16,000 | |
| 4 | Hub station fixed costs | $ 913,188 | |
| 5 | Interfaces - one per VSAT | $ 250 | This is the additional cost to install each VSAT to the existing hub equipment. The application can be either voice or data. |
| 6 | Spares | $ 25 | |
| 7 | Hub station cost per VSAT | $ 275 | Multiply this value for the number of VSATs. |
| | **Operation's licensing** | | |
| 8 | Hub station | $ 2,500 | Licensing fee for the hub. |
| 9 | First VSAT | $ 750 | Licensing fee for the first VSAT terminals. |
| 10 | Total initial licensing | $ 3,250 | |
| | **VSAT station costs (each)** | | |
| 11 | VSAT terminal | $ 6,500 | Equipment in the range of $4,500 to $15,000 depending on capacity. Receive only terminals in the $1,200 to 2,500 range. |
| 12 | Spares | $ 325 | 5 percent for VSAT equipment. |
| 13 | Site Survey | $ 250 | To determine the antenna location and potential RF interference to/from the VSAT. |
| 14 | Site installation | $ 1,700 | Includes antenna mount, antenna assembly, power installation and intrasite cabling. Prices can range from $1,000 to $ 3,000 depending on VSAT antenna size. |
| 15 | Commissioning tests | $ 250 | Acceptance testing includes the transmission of a test signal from the VSAT and the testing of the interfaces. |
| 16 | Terminal licensing | $ 25 | Cost of individual VSAT license fee. |
| 17 | Total VSAT cost | $ 9,050 | Except the space segment. This price has to be multiplied by the number of VSATs. |
| 18 | Shipping handling and insurance | $ 160,718 | Estimated in 10 percent of the equipment cost and based on 100 VSAT terminals. |
| 19 | Documentation | $ 5,000 | |
| 20 | Training | $ 50,000 | Including travel, lodging, and per diem for 5 people. |
| 21 | Special items | $ 100,000 | |
| | **Total** | **$ 2,164,656** | |

[14] *These costs are given as example and it must be understood that the actual values vary from country to country.*

**Cost of future upgrades**: Given the competitive nature of the VSAT equipment business, the costs of upgrades are negotiable. Some vendors provide software updates freely (or at nominal charge). In doing so, they expect to keep the lines open to future business. Most, however, charge for updates, which can be purchased in packages or individually. It is important that a network has reasonably up-to-date software that is supported by the vendor. Hardware upgrades can require new hardware of modifications to existing modules. Some vendors will allow such upgrades and requisite training under a blanket agreement for a specified period.

Table 4-10 shows the calculated per VSAT monthly cost for the case study assumed in Chapter 8. This value includes the amortization of a $ 2 Million loan in 5 years at an 11 percent interest rate.

**Table 4-10. VSAT Monthly Cost.**

| # | DESCRIPTION | PRICE | REMARKS |
|---|---|---|---|
| 1 | Equipment costs | $ 432 | |
| 2 | Operation and maintenance cost | $ 33 | |
| 3 | Space segment cost | $ --- | Consult INTELSAT sales and marketing for details. |
| | Total VSAT monthly cost | $ --- | Excluding space segment |

The conclusions drawn from Table 4-10 are that the cost of services will be very low after the amortization period. Furthermore, the larger the number of VSAT nodes in the network, the lower the equipment cost per VSAT.

## 4.6 Implementation Plan

The implementation plan must cover several key aspects to ensure the successful completion of the project. The implementation plan must include the preparation of the following documents.

**The statement of work (SOW)[15]:** This is a written statement of the work required for the project. The SOW includes the objectives of the project, a brief description of the work, the financing, the technical constrains, if any, the specifications, and the schedule. The SOW must use plain language and must avoid the use of imprecise language, like "*optimum*" and "*approximately*".

**Project specifications and the Request for Proposal (RFP):** This section is often presented in a list form. The specifications may be separately identified or called out as part of the SOW. The specifications should stress the targeted quality and should not be loaded with outdated schematics or obsolete design. Refer to Section 4.7 for detailed information on a model RFP.

**The milestone schedule:** Must contain information such as, project start date, project end date, major milestones, expected deliverables and reports. Major milestones must include review meetings, factory tests, key deliverables, installation, commissioning, acceptance, training, warranty, etc.

The work breakdown structure (WBS), which defines the detailed tasks, effort required, and project timeline, is normally prepared by the contractor. It is a plan that defines all efforts to be expended in the project. The WBS establishes schedules for the accomplishment of a task and describes how the contractor has assigned the responsibilities. It will specify tasks to be subcontracted or outsourced. This document will be very useful when analyzing the proposals because it indicates the contractor's strength and weakness.

[15] *A good reference on SOW preparation is Statement of Work Handbook NHB5600.2, National Aeronautic and Space Administration, February 1975.*

### 4.7 Procurement Specification - The Request for Proposal (RFP)

With the availability of competitive VSAT products, open procurements have a wider scope to demand both price and service improvements. The RFP is important in describing exactly what is required from the network, and the division of responsibilities between the network provider and the contractor. The requirements need to be carefully established so that the service providers receive what is required and not what vendors wish to sell. The service provider must ensure that the RFP clearly outlines which entities are responsible for each task, and clearly indicate who is responsible for site licenses, site preparation [civil works, availability of power], frequency coordination, connection to user equipment, Earth station tests, taxes, license fees, and customs clearance. The service provider may prefer to contract out certain items such as site surveys or installation. There may be requirements for local procurement of certain equipment, and if so, these requirements should be included in the RFP.

Key aspects to consider for the procurement include:

- client's traffic profile;
- targeted BER and availability;
- service quality;
- application protocols;
- equipment location;
- test plan and expected results; (Acceptance Test Plan)
- criteria for network acceptance
- options needed for future expansion;
- schedule for deliverables;
- required technical support and response time from vendor;
- spare equipment;
- language for training; and
- ongoing technical support.

Contractual arrangements may vary with each network, as parties discuss the currency to be used for payment, the choice of which legal system will apply, or whether to stipulate arbitration for resolution of disputes. It is suggested that the RFP include a model contract, so that bidders are aware of the network contract requirements. The model RFP should include a description of the purchaser's organization and business plan for the network.

Finally, do not forget, if possible, to include a statement of the criteria that will be used for evaluation of proposals.

Appendix II contains a model specification for a VSAT network using the INTELSAT network, a table of contents for a model contract, and a sample of technical characteristics. This should be considered as a starting basis that can be modified and adapted for a specific requirement.

## *4.8 Post-Implementation Issues*

A new VSAT network represents a considerable capital investment, and provides an important user service. This investment needs to be protected by developing and implementing a maintenance plan even before the network becomes fully operational. At the beginning of the operation, little maintenance will be required. However, it is advisable to regularly inspect all equipment. Correcting adjustments or performing routine maintenance could prevent future problems. For example, while changes in voltage or signal levels may not be noticeable enough to register a service complaint, it is advisable to monitor these so as to detect any signs of performance deterioration. Equipment located outdoors should be inspected periodically for weather-related deterioration or other damage.

A spare parts system needs to be planned so that parts can be located and used when needed, and reordered as necessary. The manufacturer may recommend a minimum set that will support daily network operation. If some or all of the network management and maintenance are outsourced, then spare parts may be included in the contractor's responsibility.

Training should be provided to all staff who will be involved in operation and maintenance of the new equipment. This area is often overlooked. Training may be short, or require several days, and should be included in postimplementation plans. A plan for periodic training may be necessary to counter the effects of staff turnover.

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# CHAPTER 5

# VSAT NETWORK ARCHITECTURE AND TOP LEVEL SPECIFICATIONS

## 5.1 Analysis of Service Requirements

To define the top-level specifications, INTELSAT recommends starting the process by drawing a top-level diagram of the network. The diagram should indicate all the sites that will require services. Next, a matrix of traffic requirements must be prepared. This must contain data suitable for traffic analysis and link budget calculations. This traffic table can also form an integral part of the SOW or RFP documents.

Even though the proposed network may be simple or complex, the methods suggested for the  requirements document and the traffic matrix are similar.

**Map the physical area(s) to be served by the network.**  This may include existing terrestrial links as well as proposed new VSAT terminals.  Several maps may be needed depending on the size of the network and the number of regions, countries, or areas to be served.

**Prepare diagrams of the planned network.** These diagrams should show all the VSAT terminals, how they are interconnected, and whether or not the links are one-way or two-way. It is most probable that changes will be made as the planning and preparation of the network progresses. It is important to keep the network diagrams up-to-date.

Definition of the traffic requirements should indicate the values used for network availability, BER, and blocking probability. Traffic analyses should also indicate the overall network size, and geographic location of each node.

## 5.2 Data Networks

Often client networks require mesh interconnections for their data transmissions. Although the physical configuration of a data network may be a star topology, logically a full mesh topology exists using double-hop. Data from VSAT-to-VSAT can be transported via a connectivity through the hub; however, delay sensitive applications should use single hop links preferably.

A significant portion of the up-front capital cost in a VSAT network is for the hub. Therefore for a cost-effective network, it is important to have a sufficiently large pool of remote users. This reduces the per- VSAT cost of the hub. A single client may not have enough remote users to justify the investment. To cope with such situations, two concepts have been developed: shared-hubs and distributed-hub VSAT networks.

### 5.2.1 Shared Hub Networks

In a shared-hub network, the VSATs are divided into subnetworks, and each subnetwork is assigned to a particular CUG. Typically a different CUG is created for each client. Each CUG can (but not necessarily) request their own:

1) outbound and inbound carriers;
2) sub-Network Control Center, deriving information from the hub Network Monitoring and Control Center (NMCC);
3) specific FEP equipment to process the out- in-route traffic data flow;
4) high-speed data line to connect the FEP (at the hub location) to the host computer at the user’s premises

Generally, the biggest challenge lies in linking the host computer, at the client’s premises, to the FEP at the hub site. There are two possible solutions. One solution provides high-speed terrestrial data lines connecting the hub with the client’s host computers. Alternatively, the network service provider may provide a separate satellite link to connect the hub with the client’s host computer.

Figure 5-1 shows a block diagram of a shared hub configuration.

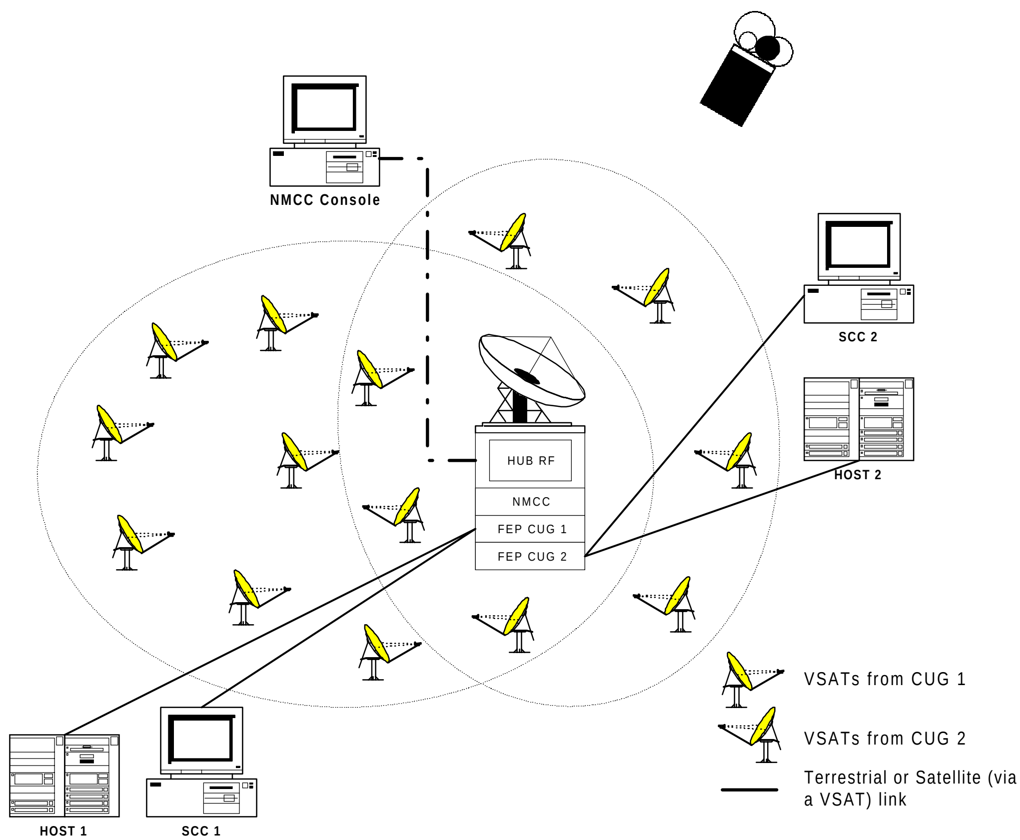


**Figure 5-1. Shared Hub Configuration.**

### 5.2.2 Distributed hub Networks

An alternative solution to the hub - host link problem is a distributed hub operation. Under this concept, each subnetwork has its own hub station, which allows the location of a mini-hub near the host computer at the client's premises. Overall network control is implemented in a common location at the system level, but each client has its own traffic hub dedicated to its CUG. An additional link between the subnetwork hub and the network management center will be required to manage the entire network and to route, if it exists, inter-CUG traffic.

The distributed hub is considered an intermediate solution between a shared hub and completely independent network. A block diagram of a distributed hub configuration is found in Figure 5-2.

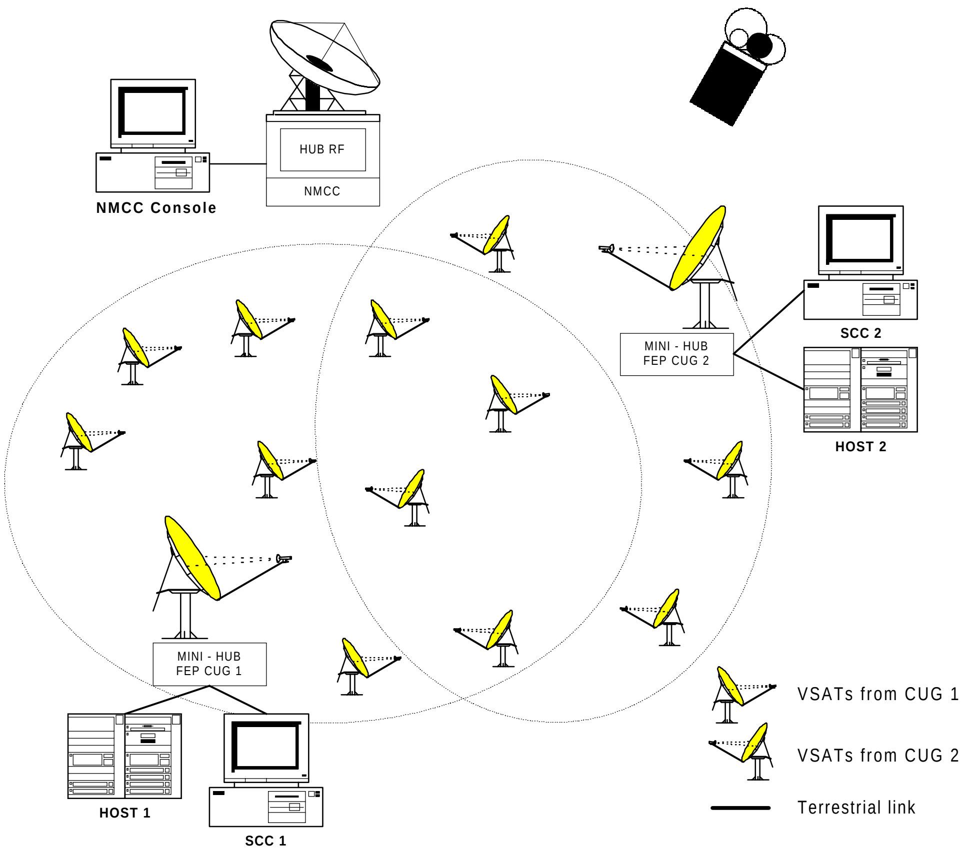


**Figure 5-2. Block Diagram Illustrating the Distributed Hub Concept.**

### *5.2.3 Shared Hub or Distributed Hub?*

Several factors will affect the decision to choose a shared hub or a distributed hub VSAT network. Some key issues to consider follow.

**Distributed hub:**

1) **Antenna:** The mini-hubs will require a larger antenna than the VSATs to economically operate via satellite.
2) **Equipment:** Each mini-hub will contain its own RF, IF, BB, and power equipment. In addition, because some redundancy must be provided to improve the availability, implementation costs increase.
3) **Staff:** Due to the importance of the mini-hub for the sub-network, it may be necessary to staff each mini-hub.

**Shared hub:**

1) **Antenna:** A larger single antenna may be installed to reduce space segment recurring costs.
2) **Equipment:** Because there is only one hub, equipment redundancy can be provided cost effectively. The overall network cost will be driven by the VSAT hardware.
3) **Staff:** Large gateways already have, in most cases, around the clock shifts.

## *5.3 Network Management and Control Center (NMCC)*

Another important aspect to consider when defining a VSAT network and its specifications is the NMCC. The NMCC selection can determine the success or failure of a system. The required NMCC functions can be grouped into administrative functions, and operational functions.

### *5.3.1 Administrative Functions*

The administrative functions are:

A. Configuration management: This allows the operator to:

- add/Delete VSAT terminals, network interfaces or satellite channels;
- create capacity pools for subnetworks;
- enable and disable network components;
- upgrade network hardware or software; and
- incrementally add functions and capabilities to the network.

B. Account management: This tracks for the cost of network operation and allocates costs to users. Parameters such as packet count, call duration, connection time, and others are relevant here.

C. Inventory management: This maintains and controls the inventory of equipment in the network, including options, redundancy, etc.

D. Security management: This prevents unauthorized access to network resources. It must provide the ability to disable components that may compromise network integrity.

### *5.3.2 Operational Functions*

Operational functions can be categorized into:

A. Data collection, archiving, and report generation. This data collection enables planners to analyze long-term needs such as growth projections and reconfigurations.

B. Operator interface that allows easy access to various functions of the NMCC. The friendlier the interface, the more efficient the operation.

C. Monitoring and control to provide real-time status monitoring. Special emphasis should be placed on alarm and event monitoring, logging and filtering events by VSAT.

## 5.4 Voice Networks

Requirements for voice networks should be listed in a table similar to Table 5-1.

**Table 5-1. Required Number of Channels.**

| DAMA NETWORK | PHASE 1 | PHASE 2 |
|---|---|---|
| Number of VSATs | 100 | 100 |
| VSATs with 4 channels | 70 | 35 |
| VSATs with 2 channels | 30 | 15 |
| Total VSATs with 4 channels | 70 | 105 |
| Total VSATs with 2 channels | 30 | 45 |
| Total number of VSAT DAMA channels | 340 | 510 |
| Offered traffic per VSAT DAMA channel | 0.3 Erlang | 0.3 Erlang |
| Total network traffic | 102 Erlangs | 153 Erlangs |
| Call loss probability | 5 percent | 5 percent |
| Number of satellite channels | 120 | 175 |

The number of satellite channels calculated in Table 5-1 depends upon factors such as the call loss probability and offered traffic per DAMA channel. A call loss probability of 5 percent is commonly found in VSAT networks. The offered traffic per DAMA channel can vary as follows:

DAMA channel unit serving a single telephone: 0.015 to 0.025 erlangs per channel

DAMA channel unit serving a trunk line: 0.15 to 0.3 Erlang per line (See Figure 5-3.)

The number of channels is the basis for calculating the space segment, antenna sizes and the rated power of the VSAT power amplifier. However, several other key issues must be considered:

**Voice compression.** Compression rates at 4.8 kbit/s to 16 kbit/s per channel offer high quality and provide bandwidth savings.

**Voice activation.** DAMA can employ VOX. VOX turns the carrier off during pauses of a conversation. VOX reduces the required capacity by conserving satellite power.

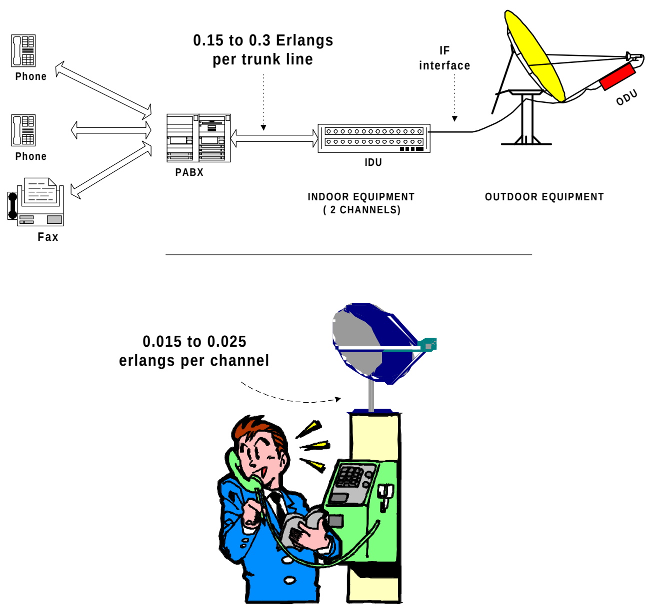


**Figure 5-3. Erlangs per DAMA Channel Under Different Applications.**

### *5.4.1 ITU and Voice Compression*

Voice compression reduces the bandwidth requirements and the cost of the satellite resources. In the past, compression was not considered useful because of the reduction in voice quality caused by the inherent distortion introduced by the compression process. Today, advances in technology have improved the compression algorithms such that large compression ratios with low delay and low distortion can be achieved. One example of modern compression algorithms is the Algebraic Code Excited Linear Prediction (ACELP) algorithm. In 1995, the ITU-T adopted the ACELP algorithm as a standard, and is described in Recommendation G.729. A brief description of the G.729 capabilities follows.

A. ***Voice Quality:*** Tests have shown that the ACELP algorithm operating at 8 Kbit/s per voice channel results in a Quantization Distortion Unit (QDU) measurement of 2 and a Mean Opinion Score (MOS)[16] of 4. These values fit well within the

[16] *A Quantization Distortion Unit (QDU) is equal to the distortion introduced in a voice channel after passing through a Mu-law or A-law PCM encoder. If the channel passes two PCM encoders in cascade, (analog/pcm/analog/pcm/analog), the total distortion will be 2 QDUS.*

telecommunication companies' definition of the 'Toll Quality' limit of 4 QDUs and a minimum MOS of 3.6. It is also comparable with the 1 QDU and MOS 4 for PCM, and 3 QDUs and MOS 3.8 for ADPCM.

B. ***Voice band data and facsimile:*** Voice compression devices handle facsimile calls by detecting the presence of a facsimile signal. They demodulate the signal back to its original digital form and pass it transparently across the VSAT network. The remote end restores the original facsimile format and delivers the original facsimile signal to the remote fax machine. This process allows the facsimile modems to run at higher speeds. A side benefit of processing modem signals this way is bandwidth efficiency. The compression algorithm will allocate only 9.6 Kbit/s in the VSAT network to handle a channel with a 9.6 kbit/s facsimile call instead of using a 64 Kbit/s PCM.

There are several other proprietary compression algorithms that are ITU standards and provide acceptable voice quality at rates around 9.6 kbit/s.

## *5.5 VSAT IBS Networks*

The INTELSAT Business Service (IBS) has been extended to VSAT Earth stations. The service called VSAT IBS provides a specific solution to enable business communications using small Earth station antennas. VSAT IBS services are charged on a carrier basis, and the operational parameters are defined by INTELSAT. This pre-engineered service allows the digital links to carry applications such as:

- real-time banking transactions;
- digital videoconferencing;
- data and voice communications networks to link a manufacturing plant to the corporate headquarters; and
- transparent links for IISPs.

VSAT antennas can have a diameter as small as 1.8m at C-band, and 1.2m at Ku-band. Before VSAT IBS, the smallest Earth station size that could use IBS was 4.5m at C-band, and 3.7m at Ku-band. This extension enables network providers to use low-cost VSAT terminals to establish communication links in a rapid and cost-effective manner.

Tables 5-2 and 5-3 summarize the VSAT IBS antenna characteristics[17].

**Table 5-2. Summary of Characteristics for the VSAT IBS C-Band Antennas.**

| C-BAND ANTENNA STANDARD | F1 | H4 | H3 | H2 |
|---|---|---|---|---|
| G/T (4 GHz), dB/K | 22.7 | 22.1 | 18.3 | 15.1 |
| Typical Antenna Diameter, m | 3.5 - 5.0 | 3.5 - 3.8 | 2.4 | 1.8 |
| Voltage Axial Ratio - Circular polarization (isolation value dB) | 1.09 (27.3 dB xpol isolation) | 1.09 (27.3 dB xpol isolation) | 1.3 (17.7 dB xpol isolation) | 1.3 (17.7 dB xpol isolation) |

**Table 5-3. Summary of Characteristics for the VSAT IBS Ku-Band Antennas.**

| KU-BAND ANTENNAS | E1 | K3 | K2 |
|---|---|---|---|
| G/T (11 GHz), dB/K | 25.0 | 23.3 | 19.8 |
| Typical Antenna Diameter, m | 2.4 - 3.5 | 1.8 | 1.2 |
| Voltage Axial Ratio - Linear polarization (Isolation value dB) | 31.6 (30.0 dB xpol isolation) | 20.0 (26.0 dB xpol isolation) | 20.0 (26.0 dB xpol isolation) |

The VSAT IBS service offers flexible carrier sizes ranging from 64 Kbit/s up to 8.448 Mbit/s, and allows communications between a gateway[18] station and a VSAT or between two VSATs.

VSAT IBS operates in C-band or Ku-band of any INTELSAT satellite. The service, subject to availability of capacity, is available in zone, hemi, or spot beams.

*[17] Though the diameters of the antennas are completely compatible with VSATs, the VSAT IBS terminals are fully specified by INTELSAT. Complete specifications are contained in IESS-207 for C-Band antennas, and IESS-208 for Ku-Band antennas. IESS-309 contains specifications for the modem*

*[18] The term gateway describes an antenna larger than 6.1 m for C-Band and 4.5 m for Ku-Band.*

### *5.5.1 Description of Technical Characteristics*

The VSAT IBS technical characteristics have been designed to be cost-effective by optimizing the satellite resources used. The technical characteristics are summarized in Table 5-4.

**Table 5-4. Summary of Technical Characteristics for the VSAT IBS Carriers.**

| CHARACTERISTICS | VSAT IBS |
|---|---|
| Satellites | VI, VII, VIIA, and VIII |
| Beams | All beams except global |
| VSAT Earth Station Standards | E-1 , F-1, H and K<br>(Note that a larger gateway may be required at the other end of the link.) |
| Information Rate | 64 kbit/s to 8.448 Mbit/s |
| Forward Error Correction (FEC) | Rate 1/2 convolutional encoding and Viterbi decoding with Reed Solomon (219,201) outer coding |
| Modulation | QPSK or BPSK |
| Quality | Threshold BER: $\leq 10^{-10}$ for more than 99.6 percent of the year.<br>Clear Sky BER <<:$10^{-10}$ |

VSAT IBS service provides the very high transmission quality that is required for modern data communications protocols, such as, frame relay and Asynchronous Transfer Mode (ATM). This is achieved by the use of Reed-Solomon concatenated coding used in conjunction with rate 1/2 convolutional encoding.

The normal modulation scheme will be QPSK, but if a link exceeds the off-axis emission requirements, BPSK is used.

### *5.5.2 Typical VSAT Configuration*

A typical VSAT IBS terminal consists of a small antenna and communications equipment. As depicted in Figure 5-4, a typical installation consists of an ODU, the IFL, and an IDU. (Refer to Figure 5-4.) The ODU integrates the Solid State Power Amplifiers (SSPA) in the range of 5 watts in C-band, and 2 watts in Ku-band. The indoor unit consists of a modem and interfacing equipment required to carry the user services. The VSAT IBS modem requirements are included in IESS-309 (Rev 6), and a number of suppliers are capable of providing equipment that meets these requirements.

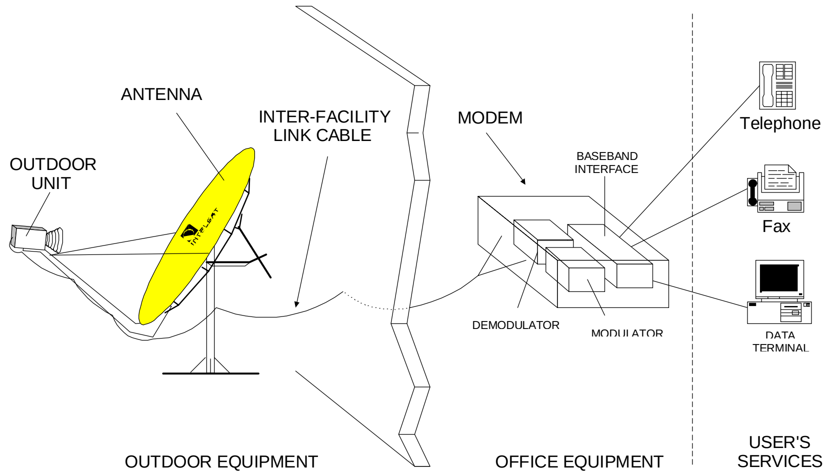


**Figure 5-4. Block Diagram Of Typical VSAT/IBS Terminal**

### *5.5.3 Type Approved Antennas*

Under the INTELSAT Antenna Type Approval Program, INTELSAT works with antenna manufacturers to ensure compliance with INTELSAT antenna specifications. These antennas, type approved by INTELSAT, can generally be used in the system without further antenna verification testing.

Users of the INTELSAT system are encouraged to use type-approved antennas. The use of a type-approved antenna will generally result in lower cost, faster implementation, and guaranteed performance. An INTELSAT type-approval means that a manufacturer's equipment meets INTELSAT's operating performance requirements, and that each unit of a particular model closely replicates the performance of every other unit of this model. The use of type-approved equipment significantly reduces or totally eliminates the need for verification testing on each individual antenna unit.

With the introduction of VSAT IBS, INTELSAT is expanding its type-approval process to include the category of “VSAT IBS terminal”. With this category, suppliers can offer complete, RF-to- baseband, INTELSAT type-approved VSAT solutions.

Nonetheless, there are four levels of type approval:

**Antenna Model:** Consists of the antenna reflector, the sub-reflector, and the feed system.

**Antenna System:** Consists of an Antenna Model and a low noise amplifier.

**Earth Station Model**: Consists of an Antenna System and its associated power amplifier.

**VSAT IBS Terminal:** Consists of an Earth Station Model, up/down converters, IFL cables (if supplied), and a VSAT IBS compliant modem.

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# CHAPTER 6

## *CALCULATION OF SATELLITE BANDWIDTH*

***BUDGETING BANDWIDTH***

Determining the satellite bandwidth required for a VSAT network is one of the most important pieces of information that a planner will prepare. Satellite bandwidth is a recurring expense for network operations, therefore, the smaller the satellite bandwidth, the lower the recurring costs. To evaluate the satellite bandwidth cost, the network planner has to have a good estimate of the required bandwidth. This bandwidth estimate is obtained by preparing a link budget. A link budget calculates the required satellite bandwidth for a given network. INTELSAT users prepare link budgets by using the *Lease and Sales Transmission Plan Program* (LST). Devised for INTELSAT's satellites, the LST is provided free of charge to any user wishing to operate on the INTELSAT system[19].

LST is available to help INTELSAT's users implement their leases. It determines the required transponder leased resources, generates a transmission plan, and determines the optimum high power amplifier (HPA) and Earth station sizes. LST is a Windows-based program that incorporates databases of key satellite technical parameters. The parameters include the Leased Transponder Definitions of IESS 410 for all INTELSAT satellites.

The LST program is offered in a compressed form, and is available as a self-extracting file. The documentation and user manuals are in Microsoft Word for Windows Version 6.0™. It is also a self-extracting file that can be downloaded from the Internet.

[19] *The reader can download the most current version of LST by visiting INTELSAT's web site at "www.intelsat.int"*

## 6.1 The LST Program

Before running the LST for Windows program, it is necessary to decompress the file. To do so:

- Go to Windows "Program Manager".
- Select "File|Run".
- Select the file 'LSTPGM4x.EXE'.
- Follow the instructions on the self-extracting window.

Once installed, create a shortcut to open the 'LST.EXE' program file'[20].

LST4x consists of a set of separate files, one for each satellite series. The satellite series and the file names are listed in Table 6-1.

**Table 6-1. Satellite Series.**

| SATELLITE SERIES: | LST4X FILE NAME: |
|---|---|
| INTELSAT V (500 series) | V.BWB |
| INTELSAT VI (601 to 605) | VI.BWB |
| INTELSAT VII (701 to 705 & 709) | VII.BWB |
| INTELSAT VII-A (706 & 707) | VIIA.BWB |
| INTELSAT VIII (801 to 804) | VIII.BWB |
| INTELSAT VIII-A (805) | VIIIA.BWB |
| INTELSAT APR-1 | APR1.BWB |

LST will let you enter all the data needed in a link budget using dialog boxes, edit boxes, and data entry screens. The program assumes that the user *knows* certain parameters, which are explained later in this chapter. This handbook provides charts, tables, and graphics whenever necessary.

*[20] This handbook does not intend to replace the LST user's manual. INTELSAT encourages the reader to read the LST user's manual provided under the compressed file LSTDOC4x.EXE.*

## *6.2 Performing a Link Budget with LST*

The following section describes how to perform a link budget using the LST4x [21]. To get started, open the program by clicking on the **LST4x** icon as shown in Figure 6-1. (Refer to Table 6-1 for file identification.)


**Figure 6-1. Program Icon for LST4x.**

Once the program is running, it will display a window menu. (See Figure 6-2.) At this point, you must select the satellite series that you are likely to use. For example, if you want to use an INTELSAT VII satellite select ***vii.bwb***. [22] (Refer to Table 6-1 for file identification.)

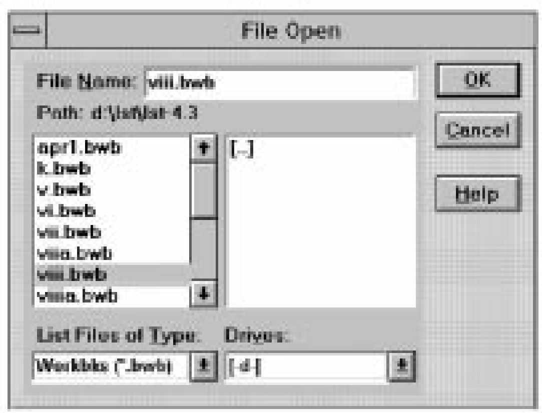



**Figure 6-2. Satellite Selection Window.**

After choosing the satellite, click **OK**. On the new window, click on the ***Enter Data*** menu, and a drop down menu will appear. Select ***New Data*** (See Figure 6-3.)

[21] *It is recommended to follow this description by running the LST4x program in a PC.*

[22] *INTELSAT V series are not likely to be used for VSATs because most of them are operating in inclined orbit. Because VSATs do not have tracking, the inclined orbit will impede proper operations. In most cases, you will likely use an INTELSAT VII or later series of satellite.*

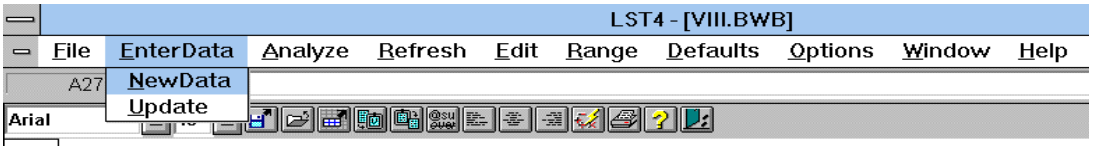



**Figure 6-3. Startup Menu for the LST Program.**

### *6.2.1 Preliminary Information*

After choosing ***New Data***, you will be asked to perform several selections. The sequence is indicated in Figure 6-4. The rationale for the initial selections follows the sequence of Figure 6-4.

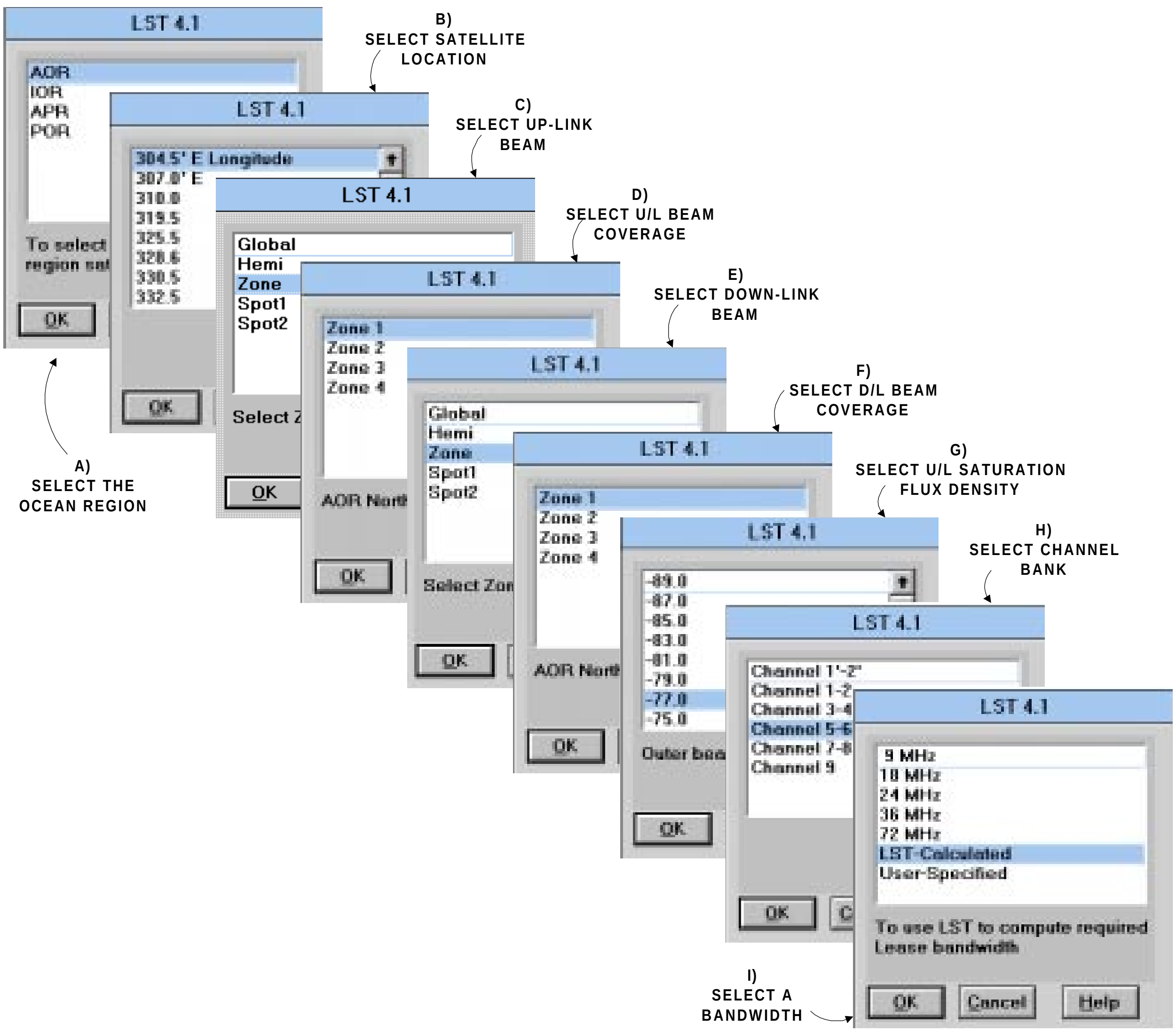



**Figure 6-4. Dialog Boxes for the Selection of Satellite and Satellite Bandwidth.**

**A.** Select the ocean region. (Refer to Figures 6-4a and 6-5.) INTELSAT satellites operate in four different regions including the Atlantic Ocean Region (AOR), Indian Ocean Region (IOR), Pacific Ocean Region (POR), and Asia Pacific Region (APR). These regions provide the highest connectivity available in the world.

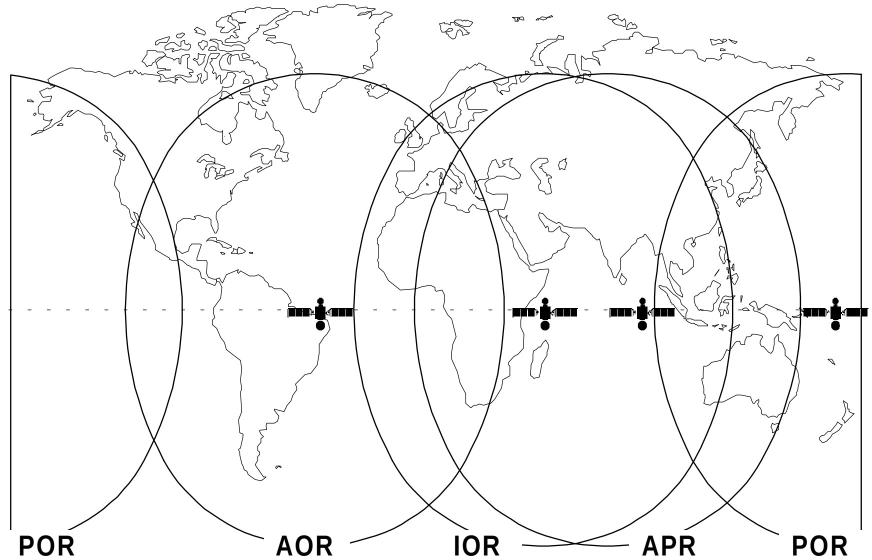



**Figure 6-5. INTELSAT Four Service Regions.**

Select the satellite region that covers your service area. If more than one region covers your country, then select the region that can provide you with the highest elevation angle.

**B.** **Select the satellite location** (Refer to Figure 6-4b.) The satellite series and orbital locations for the four regions for the period from June 1998 to December 2000 are listed in Table 6-2. These locations are updated from time to time. Check INTELSAT's web page for the most up-to-date satellite location list.

**Table 6-2. Regional Orbital Locations.**

| AOR | IOR | POR | APR |
|---|---|---|---|
| IS 805 @ 304.5 $^o$ E. | IS ___ @ 33.0 $^o$ E. [23] | IS 802 @ 174.0 $^o$ E. | IS _____ @ 72.0 $^o$ E. [24] |
| IS 706 @ 307.0 $^o$ E. | IS 604 @ 60.0 $^o$ E. | IS 702 @ 177.0 $^o$ E. | IS APR1 @ 83.0 $^o$ E. [25] |
| IS 709 @ 310.0 $^o$ E. | IS 602 @ 62.0 $^o$ E. | IS 701 @ 180.0 $^o$ E. | IS ____ @ 157.0 $^o$ E. [26] |
| IS 601 @ 325.5 $^o$ E. | IS 804 @ 64.0 $^o$ E. | | |
| IS 801 @ 328.5 $^o$ E. | IS 704 @ 66.0 $^o$ E. | | |
| IS 511 @ 330.5 $^o$ E. | | | |
| IS 605 @ 332.5 $^o$ E. | | | |
| IS 603 @ 335.5 $^o$ E. | | | |
| IS 705 @ 342.0 $^o$ E. | | | |
| IS 707 @ 359.0 $^o$ E. | | | |

**C.** **Select the type of uplink beam** (Refer to Figure 6-4c.) An INTELSAT satellite can have five different types of beam coverage, i.e., global, hemispherical, zone, C-band spot, and Ku-band spot. The type of beams available in a satellite depends on the satellite series. Choose the beam coverage that best matches your connectivity requirements.

**D.** **Select the uplink beam coverage** (Refer to Figure 6-4d.) The different series of satellites have different numbers of beams. The uplink coverage selected will depend on the service area for the VSAT network. Make this selection based on the beam that provides the best coverage for your location. [27]

**E.** **Select the type of downlink beam and downlink beam coverage.** (Refer to Figure 6-4e and 6-4f.) Usually, VSAT networks operate domestically or regionally.

[23] *Satellite to be defined in the future.*
[24] *Satellite to be defined in the future*
[25] *IS 805 and APR1 operate in linear polarization for C-band.*
[26] *Satellite to be defined in the future.*
[27] *To know which beams cover a particular area of interest, you can check the coverage maps provided by INTELSAT in the Internet web page at* ***http://www.intelsat.int/cmc/connect/globlmap.htm****, or check the INTELSAT Satellite Guide Handbook.*

F. **Select the uplink saturation flux density value.** (Refer to Figure 6-4g.) Specific values must be requested from your INTELSAT representative.

G. **Select the satellite channel bank.** (Refer to Figure 6-4h.) Channel bank is another way of naming a transponder. Because a satellite has several beams and each beam several transponders, INTELSAT created a convention to number them according to their coverage. At this point it is only important to know that:

**For C-band:**

- Channel banks with one digit represent a 36 MHz transponder.
- Channel banks with two digits represent a 72 MHz transponder.

**For Ku-band:**

- Channel banks with two sequential numbers represent a 72 MHz transponder.
- Channel banks with two nonsequential numbers, but skipping only one number, represent a 112 MHz transponder.
- Channel banks with two nonsequential numbers, but skipping four numbers, represent a 241 MHz transponder.

For the purpose of this handbook, we will use 72 MHz transponders.[28]

H. **Select a bandwidth.** (Refer to Figure 6-4i.) If you know the bandwidth you want to lease from INTELSAT, select the value from the available options. If you want to enter a different value, select **User-Specified**. If you do not know the bandwidth and would like LST to calculate it for you, then select **LST-Calculated**.

[28] *Detailed information on capacity, beam coverage, saturation flux density is available by contacting your INTELSAT sales and marketing representative.*

### *6.2.2 Earth Station Specific Information*

Once you have entered all the initial selections, LST will open a window in which you will enter the Earth station parameters. (See Figure 6-6.)

Enter the Earth station's name for each type of link. For example, if link 1 describes the hub to VSATs link, name the transmit station as the **hub,** and the receive station as **VSAT**. There is no need to create a link for every VSAT. The same link number will reference all the VSATs using carriers with equal characteristics or receiving the same carrier. If a group of VSATs operates with different carrier rates or parameters, use different links with different numbers.

Enter the parameters for the worst-case link for a group of similar VSATs. The worst case will be the link to a VSAT with the lowest pattern advantage or the lowest antenna G/T. The idea is that if you set a performance for the worst-case, the rest of the VSATs will exceed that performance.

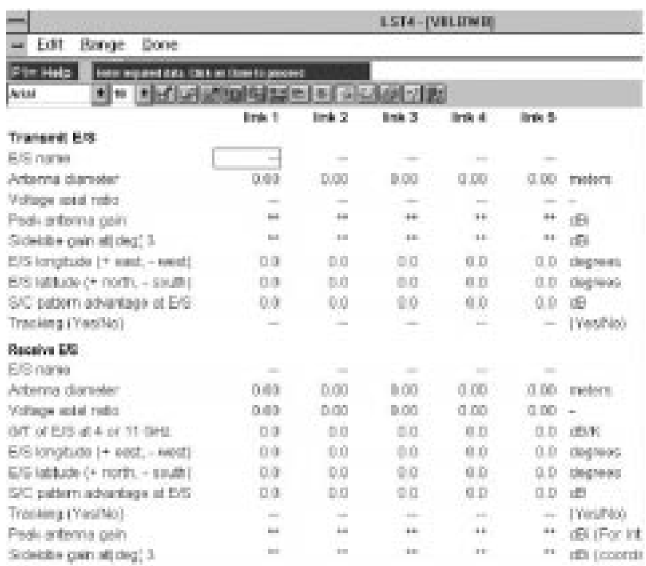



**Figure 6-6. Information Specific to Earth Stations.** [29]

**Voltage axial ratio**: Enter the voltage axial ratio value for transmit and receive antennas following the guidelines of Table 6-3.

**S/C pattern advantages at E/S**: Enter the pattern advantage value for each link. Calculate the value for the transmit and receive sites. Each beam has a particular footprint and the border of the footprint, known as beam edge, is the place to which all satellite parameters are referred (G/T, e.i.r.p., and saturation flux density). Pattern advantage equals the difference in dB between location parameters and beam edge parameters. Because most antennas will be within a particular coverage area, the pattern advantage will most likely be a positive value. Detailed footprints are available in the IESS documents. To obtain detailed footprints, see the IESS documents or ask your INTELSAT sales representative.[30]

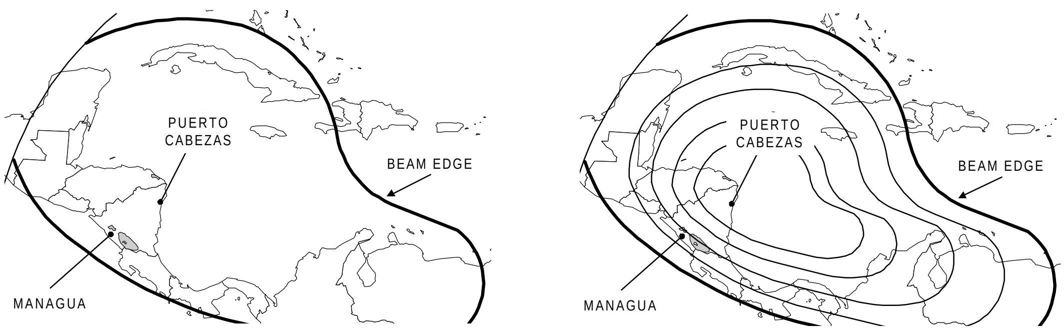



**Figure 6-7. Example of Pattern Advantage Estimation.** [31]

[29] *Values in cells showing double asterisks (* *) will be calculated by the LST4x program. So, do not over write them.*
[30] *Customers with access to the INTELSAT Business Network (IBN) can prepare their own coverage maps by visiting the ACP/2 Browser located at 'http://pc6m41a/acp2/MainPage.Asp'.*
[31] *Notice that the drawing in figure 6.7 is only an example and such footprint does not exist in real life.*

**Table 6-3. Voltage Axial Ratio Values for Different Antenna Sizes (Based On IESS 207 and 208).**

| FREQUENCY BAND | POLARIZATION TYPE | ANTENNA STANDARD | FREQUENCY REUSE | AXIAL RATIO (R) | ISOLATION (DB) |
|---|---|---|---|---|---|
| C - Band | Circular | A & B | Yes | 1.06 | 30.7 |
| | | F1; F2; F3; & D2 | Yes | 1.09 | 27.3 |
| | | D1 | Yes | 1.3 | 17.7 |
| | | Receive Only | No | 1.4 | 15.5 |
| | | Other < 4.5 Mt. | Yes | 1.3 | 17.7 |
| | Linear | A; B; D2 & F3 | Yes | 31.6 | 30 |
| Ku - Band | Linear | D1; F1 & F2 | Yes | 22.4 | 27 |
| | | C & E | Yes | 31.6 | 30 |

**G/T of Earth station**: Enter the G/T value using Figure 6-8 to estimate the value for each antenna diameter. If you have manufacturer's information, use those values. Refer to Table 6-4 for clear sky G/T for typical VSAT receivers and antennas.

After entering all the data for the Earth station, click on ***Done*** and proceed to enter the information on the carrier parameters.

**Table 6-4. Clear-Sky G/T [dB/K],for Typical (VSAT) Receivers and Antennas.**

| ANTENNA DIAMETER | TYPICAL G/T [DB/K] |
|---|---|
| **Ku-band** | |
| 4.5 m | 31.0 |
| 2.4 m | 25.6 |
| 1.8 m | 23.1 |
| 1.2 m | 19.5 |
| **C-band** | |
| 7.0 m | 27.54 |
| 5.5 m | 25.45 |
| 3.5 m | 21.5 |
| 2.4 m | 18.6 |
| 1.8 m | 15.1 |

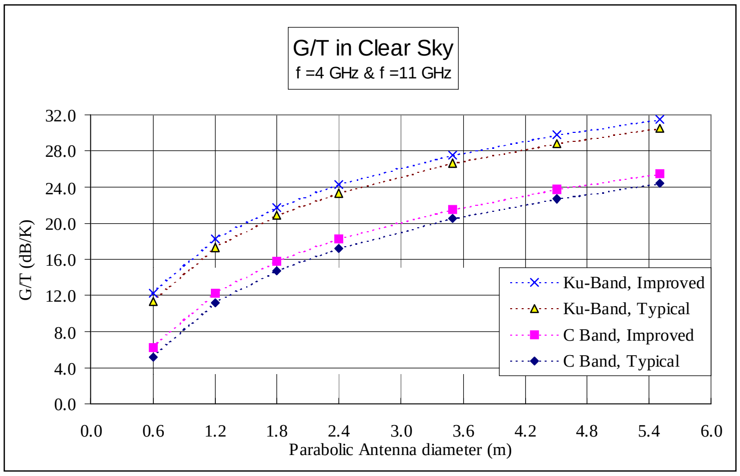



**Figure 6-8. Antenna's G/T.**

### *6.2.3 Carrier Parameters*

The next dialog boxes automatically allow you to select the carrier parameters. The process follows the sequence detailed in Figure 6-9.

**A. Select a link.** (See Figure 6-9a.) Select link 1 for the link describing the hub-to-VSAT link, and link 2 for the VSAT-to-hub link.

**B. Select a carrier type.** (See Figure 6-9b.) LST calculates the resources needed for any type of carrier. In most cases, you will use **Digital** carriers for calculating the resources needed in digital networks.

C. **Select a carrier rate.** (See Figure 6-9c.) Different link types have different rates. Choose the rates here. If the rate you plan to use is not listed in the menu, choose **More** and enter the new data rate.

D. **Enter the carrier overhead value.** (See Figure 6-9d.) Usually carriers for the VSAT network do not use overhead. Enter "0".

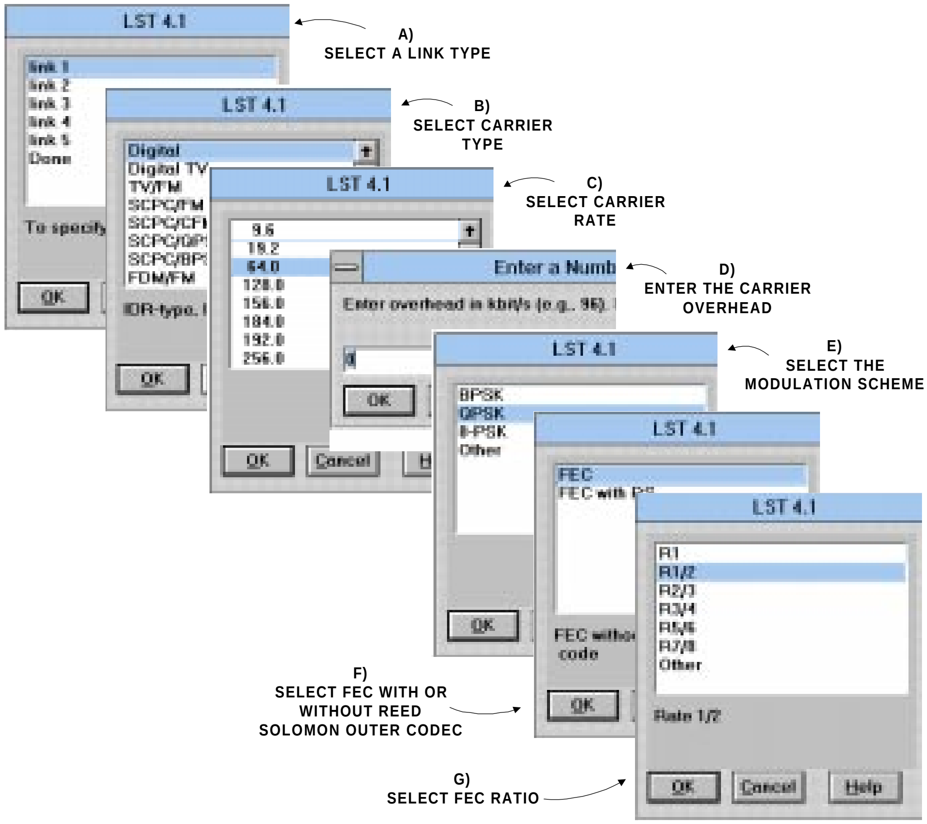



**Figure 6-9. Carrier Parameters Dialog Boxes.**

**E. Select the modulation scheme.** (See Figure 6-9e.) The three most common schemes are listed. You can start by using QPSK for all links.

**F. Select the type of Forward Error Correction (FEC) coding.** (See Figure 6-9f.). Select the type of FEC ratio you will use for the links. Use "FEC" for VSATs. "FEC with RS" is used in Digital TV or on Internet broadcasting links using the DVB parameters.

**G. Select the FEC ratio.** (See Figure 6-9g.) Select the FEC ratio you will use for the links. Typically use **R1/2 for** the link hub-VSAT, and **R3/4** for the VSAT-hub link

When the carrier parameters have been entered, the following editing box will appear. (See Figure 6-10.) Enter the values requested for each link.

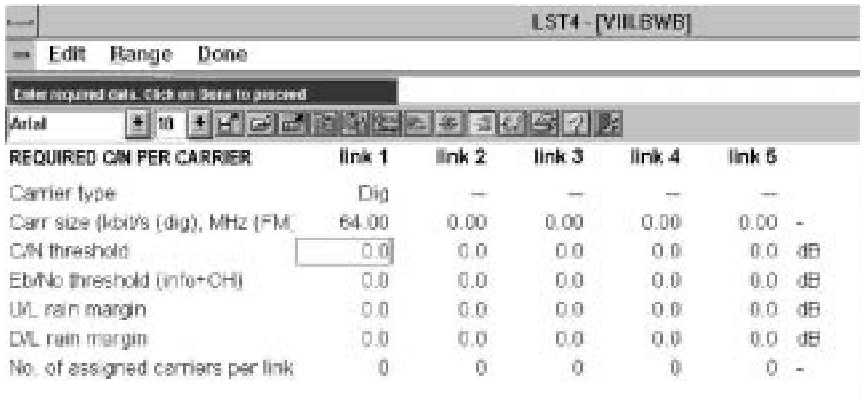



**Figure 6-10. Edit Box for the Link Performance.**

**C/N Threshold or Eb/No threshold (Info+OH)** (See Figure 6-10.) It is not necessary to provide both C/N and Eb/No values. When provided with Eb/No, LST will calculate C/N, and vice versa. The Eb/No is preferred and its value depends on the modulation scheme and the BER performance. The value entered for Eb/No is the threshold value and represents the maximum BER allowed in the link before declaring it unavailable.

Typical BER threshold values are $10^{-3}$ for digital voice links, and $10^{-4}$ for data links.

The Eb/No value for these thresholds is estimated from the chart in Figure 6-11.

For example, if we need a threshold of $10^{-4}$, BPSK and FEC 1/2, the Eb/No will be 5.1 dB.

To calculate the Eb/No for a carrier using an RS outer code, use Figures 6-12 and 6-11 as follows.

A. Select the BER value you want from the values at the BER-out (Y-axis) of Figure 6-12. Select the curve that corresponds to the outer code that you want to use. Calculate the BER-in value (X-axis).
B. Calculate the anti-log of the BER-in value, and use Figure 6-11 to calculate the Eb/No.

Example:

To achieve a BER threshold of 1x $10^{-11}$, and use FEC Rate ½ RS (204,188,8) as inner and outer codes. The result will be:

Log BER out = -11 (From Figure 6-12);

Log BER in = -3.1 (From Figure 6-12);

BER in = $[10^{-3.1}] = 7x10^{-4}$;

Determine from Figure 6-11 that, if BER = $7x10^{-4}$,

then: Eb/No = 4.5 dB.

A link using FEC ½ and RS (204, 188, 8) will need an Eb/No of 4.5 dB to achieve a BER = $1x\ 10^{-11}$.

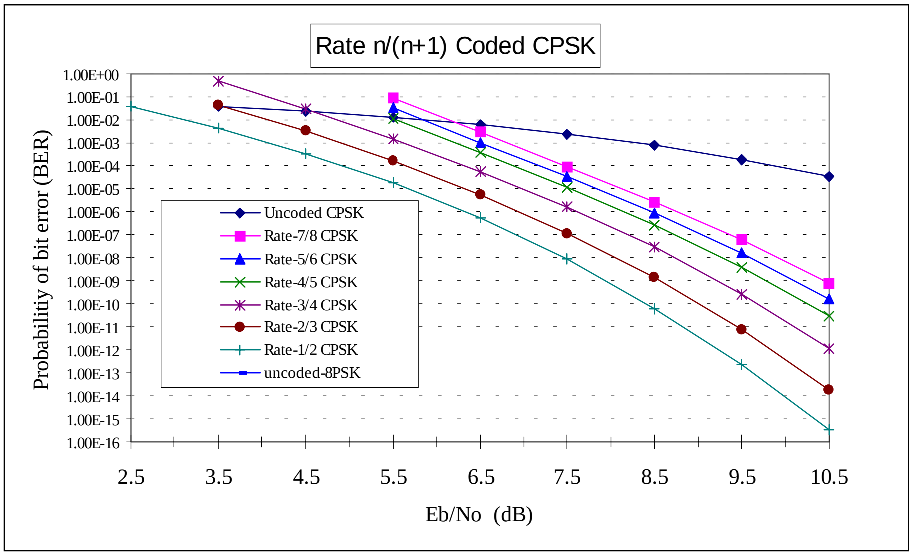



**Figure 6-11. Eb/No versus BER for BPSK/QPSK and Different FEC Ratios (Viterbi Decoding).**

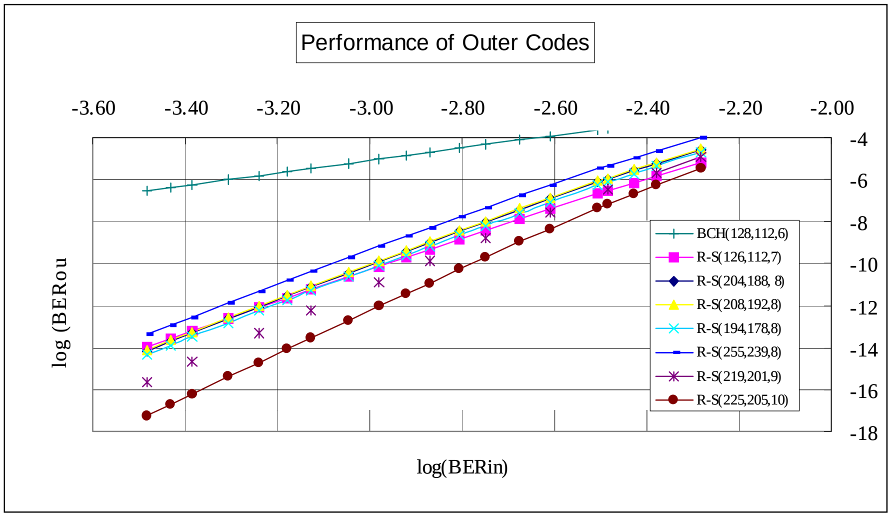



**Figure 6-12. BER IN/BER OUT for Outer Codes.**

**Uplink and downlink margins** (See Figure 6-10.) The values of the uplink and downlink margins depend on the availability target that is being planned. Notice that Eb/No defines the threshold for the link quality. The margins define the link availability. Moreover, the addition of the margins to the threshold allows the link to operate with higher quality during clear sky conditions. For example, a link with a threshold Eb/No of 5.1 dB (BER= $5x10^{-10}$ with FEC ½) using 2 dB up and 2 dB down for margins, will operate with an Eb/No higher than 9 dB during clear sky conditions (BER < $10^{-11}$). The same link will operate with an Eb/No of 7 dB if the rain attenuates either the up or downlink by 2 dB

**How are the margins defined?** Margins are very important, especially in Ku-band, because they counter the effect of rain attenuation and allow the link to be available for longer periods of time. Adding margins allows the network to achieve the availability target set forth during the planning process.

To understand margins, rain attenuation must be understood first. Rain absorbs RF energy. The amount of absorbed energy is directly related to the drop size and intensity of the rain, as well as the operating frequency, elevation angle, size of the clouds, and the geographical region. The heavier the rain, the higher the attenuation. Using meteorological data, attenuation is calculated statistically for a region.

The meteorological data consist of statistical information collected over several years. It includes the rain pattern in millimeters per day as a percentage of the time. This statistical information can be used to calculate the rain attenuation pattern results, and presented in an attenuation chart, called the Attenuation Exceedance Curve. The *attenuation exceedance curve* represents the maximum attenuation calculated for a given percentage of any year. For example, Figure 6-13 shows the maximum attenuation for an uplink between Rio de Janeiro and a satellite located at 304.5 degrees E for Ku-band and C-band. Figure 6-13 shows that 99.9 percent of the time, the attenuation will not exceed 7.1 dB for Ku-band or 0.6 dB for C-band. The remaining 0.1 percent of the time the attenuation will be higher than these values. To counter this attenuation, the margins will need be at least 7 dB for Ku-band and 0.6 dB for C-band, to achieve 99.9 percent availability.

Several methods have been developed to calculate rain attenuation. All the methods make use of the database of meteorological data collected by the ITU. The ITU-R proposes one under Recommendation 618 in which the Earth is divided into *climatic zones*. These climatic zones describe the rain intensity in the globe from the arctic to the tropics, and are labeled zones A through Q.

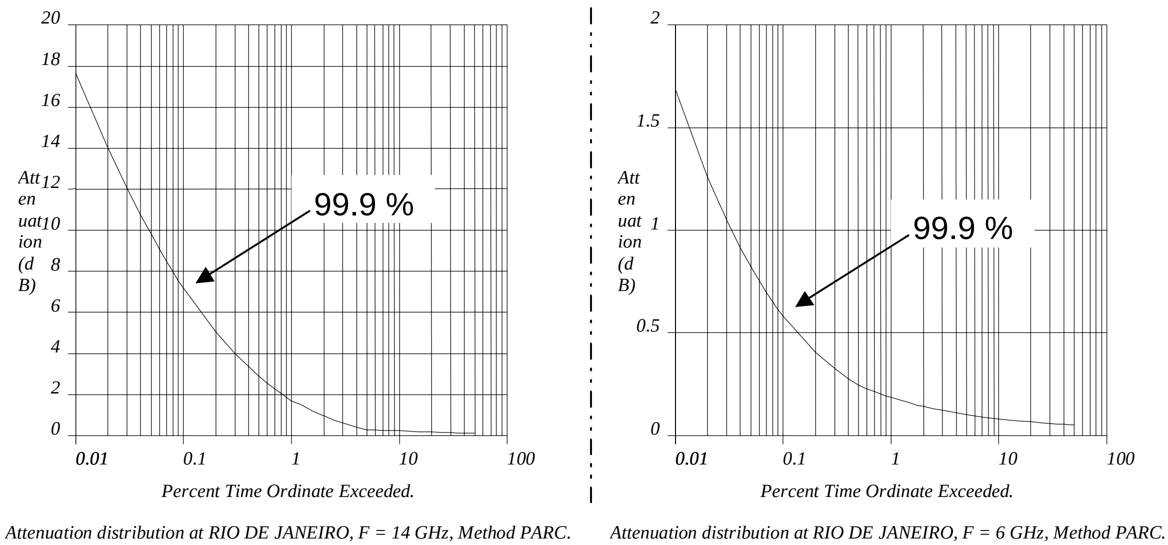



**Figure 6-13. C-Band and Ku-Band Attenuation Exceedance Curves for an Uplink.**

To calculate the rain attenuation, the reader can use the curves provided in Appendix B. Appendix B contains the exceedance curves for all climatic zones. The curves were calculated assuming an antenna with an elevation angle of 20 degrees in and located at 500 meters above the sea level.

**Number of carriers** (Refer to Figure 6-10.) Returning now to the LST software, it is necessary to enter the number of identical carriers for each link type. For example, assume that a TDM/TDMA network is transmitting 2 outbound carriers to all VSATs, and receiving 10 inbound carriers from the VSATs. The numbers to enter will be “2” under the hub-VSAT link 1, and “10” under the VSAT-hub link 2. Click on ***Done*** to proceed.

### *6.2.4 Link Budget Analysis Option*

The next window to open will ask you about the type of link analysis that you want to perform. The two options are shown in Figure 6-14.

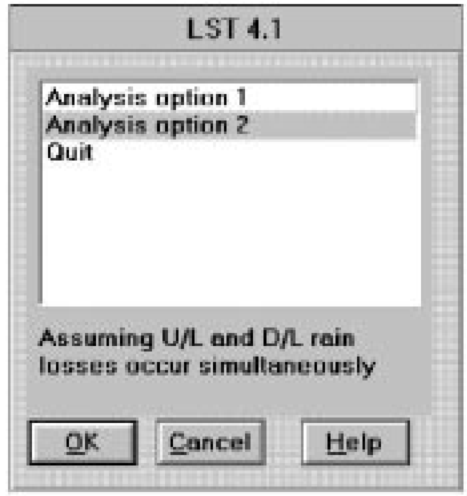



**Figure 6-14. Analysis Type Window.**

Select Analysis option 1:

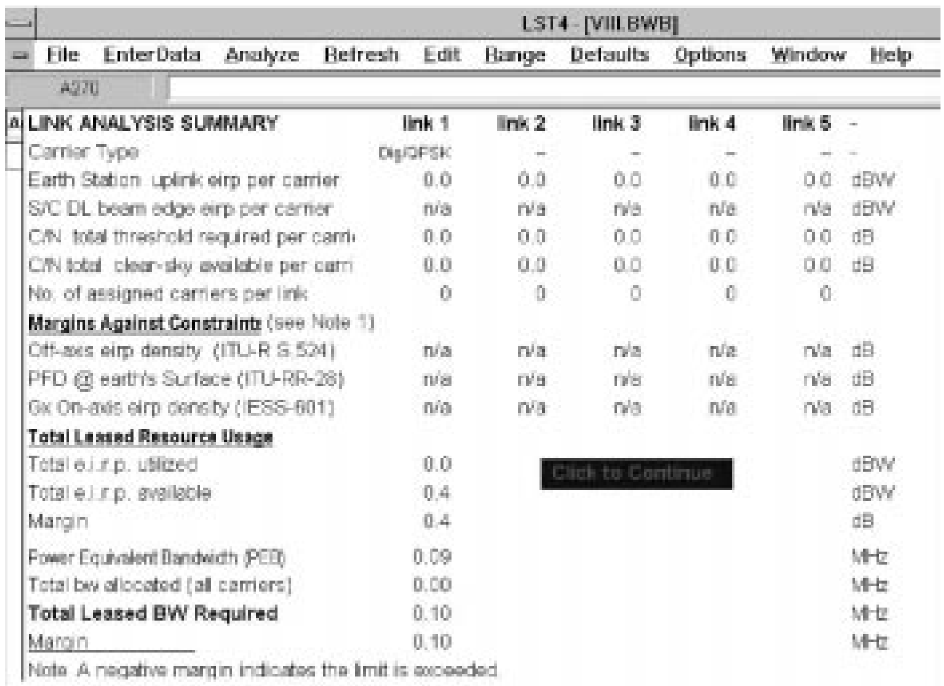
- If the VSATs are distributed in a wide geographical area.
- If the VSAT uses mesh topology because it uses larger antennas.

Select Analysis option 2:

- If most of the VSATs are located within 50 km of the hub.

### *6.2.5 Interpreting the Results*

A summary table with the results of the LST calculations is shown in Figure 6-15. An interpretation of the information in the summary table follows.



LST4 - [VIII.BWB]

File EnterData Analyze Refresh Edit Range Defaults Options Window Help

A270

| LINK ANALYSIS SUMMARY | link 1 | link 2 | link 3 | link 4 | link 5 | - |
|---|---|---|---|---|---|---|
| Carrier Type | Dig/QPSK | – | – | – | – | - |
| Earth Station uplink eirp per carrier | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | dBW |
| S/C DL beam edge eirp per carrier | n/a | n/a | n/a | n/a | n/a | dBW |
| C/N total threshold required per carri | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | dB |
| C/N total clear-sky available per carri | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | dB |
| No. of assigned carriers per link | 0 | 0 | 0 | 0 | 0 | |
| **Margins Against Constraints** (see Note 1) | | | | | | |
| Off-axis eirp density (ITU-R S.524) | n/a | n/a | n/a | n/a | n/a | dB |
| PFD @ earth's Surface (ITU-RR-28) | n/a | n/a | n/a | n/a | n/a | dB |
| Gx On-axis eirp density (IESS-601) | n/a | n/a | n/a | n/a | n/a | dB |
| **Total Leased Resource Usage** | | | | | | |
| Total e.i.r.p. utilized | 0.0 | | Click to Continue | | | dBW |
| Total e.i.r.p. available | 0.4 | | | | | dBW |
| Margin | 0.4 | | | | | dB |
| Power Equivalent Bandwidth (PEB) | 0.09 | | | | | MHz |
| Total bw allocated (all carriers) | 0.00 | | | | | MHz |
| **Total Leased BW Required** | 0.10 | | | | | MHz |
| Margin | 0.10 | | | | | MHz |

Note: A negative margin indicates the limit is exceeded.

**Figure 6-15. Summary Table with the Results from LST.**

**Carrier Performance** By subtracting the C/N total threshold from C/N total clear sky, the planner can see the margin for the carriers.

**Margins Against Constraints** This section summarizes the performance against the ITU and IESS constraints. A negative value means the e.i.r.p. is too large or the antenna is too small.

**Total Lease Resource Usage:**

**Total e.i.r.p. Utilized** This value shows the total satellite e.i.r.p. used for all the carriers in a network.

**Total e.i.r.p. Available** Indicates the total e.i.r.p. available from the transponder and for the leased bandwidth required.

**Margin** The difference between used and available e.i.r.p. A positive value indicates that the network performance can be improved (increasing the Eb/No requirement) to the point where the margin is near zero. Alternately, additional traffic can be supported in the lease resource.

**Power Equivalent Bandwidth (PEB)** A link can be limited by power or bandwidth. If the link is limited by power, it means that the carriers require more power from the satellite than what is available for the carrier's allocated bandwidth. I

If the link is limited by bandwidth, the PEB represents the actual carrier allocated bandwidth. It may happen that the e.i.r.p. margin is a positive value. The bandwidth margin will be zero.

**Total Leased BW Required** This represents the total bandwidth needed for lease from INTELSAT to set up your network.

Because of power constraints in a hub-to-VSAT link, the link budgets for VSAT networks are almost always power limited. In most applications the VSAT service provider tries to reduce the satellite bandwidth to reduce the recurring operational costs.

### 6.2.6 How to Reduce the Required Leased Bandwidth

***What actions can be taken to reduce the satellite bandwidth?***

There are several steps to take to reduce the satellite-leased bandwidth, all of which can be tested by reiterating the calculations in the LST4x spreadsheet.

**Factors Affecting the Required Satellite Bandwidth in Any Network** The factors that affect the bandwidth in any network are: antenna sizes, carrier parameters, BER threshold, offered traffic, call loss probability, efficiency of the multiple access protocol, and satellite link availability.

**Antenna Sizes** The single most influential parameter in the LST calculation is the antenna size. Antenna size is directly related to antenna G/T. Antenna G/T is the determining factor to meet an Eb/No performance. It defines the e.i.r.p. necessary from the satellite and thus determines the bandwidth. The satellite bandwidth can be reduced by increasing the VSAT antenna size and, thereby, its G/T. Increasing the hub antenna diameter (and G/T) also reduces the required bandwidth. Increasing the hub G/T generally has less impact than increasing the VSAT antenna size[32].

**Carrier Parameters** Change the modulation scheme from QPSK to BPSK, and use a higher FEC rate like FEC 1/2. If the application can tolerate additional delay, include the Reed Solomon (RS) outer code, or choose sequential decoding rather than Viterbi decoding for FEC. However, RS cannot be used for bursty traffic. The use of RS with IBS carriers with rates below 384 kbit/s is not recommended because of the delay introduced to the data.

**BER Threshold** The BER threshold defines the service availability and must be appropriately selected, taking into consideration the application and it's the sensitivity to errors. In voice systems, for example, a threshold BER of $10^{-3}$ is considered adequate, while for data users a typical value is $10^{-4}$. Moreover, BER translates into Eb/No, and Eb/No changes with modulation scheme and FEC. The user must be careful to use the right Eb/No value for the type of modulation and FEC used.

*[32] Notice that some manufacturers offer antennas with improved G/T, try using improved G/T at the VSAT and the hub before increasing the antenna size.*
*[33] This footnote has been changed to footnote 34.*

**Offered Traffic** This parameter affects the number of satellite channels required for a given network. Its value depends on a number of factors including the traffic pattern during the peak busy hour (PBH) and the tariff structure for the service. Reducing the offered traffic reduces the number of carriers and, therefore, the required bandwidth. However, in many cases, where operators introduce new services, the tendency is to underestimate the traffic demand. Consequently, care should be exercised in traffic dimensioning because underestimating the traffic will lead to congestion.[34]

**Efficiency of the Multiple-Access Protocol** For data networks, rather than reducing the offered traffic, the VSAT service provider can select a multiple-access protocol with higher efficiency. For example Aloha offers an efficiency of 18 percent while DA-TDMA offers an efficiency of >80 percent. Greater efficiency requires fewer carriers.

**For Voice Networks**, the VSAT service provider can alter the voice compression rate and the voice activation factor.

**Voice Compression** minimizes bandwidth requirements. DAMA systems use voice compression without compromising the voice quality. Compression rates at 4.8 kbit/s to 16 kbit/s per channel are available and offer bandwidth savings.

**Voice Activation.** DAMA can employ Voice Activation (VOX), which turns the carrier off during the pauses of a conversation. VOX reduces the required bandwidth and, in pools of 100 channels or more, VOX provides a net reduction of satellite power utilization of up to 2.2 dB. In the LST program, to change value of VOX, change the value of cells E73 through I73. Notice that 100 percent means that the carrier is always “ON”. Typical voice activity factors range from 50 percent to 75 percent.

[34] *This phenomenon is recognized by the ITU-T in the annex to the Recommendation E.506.*

**Call Loss Probability** This factor applies to voice networks and defines the number of call attempts that will be dropped during the PBH. If the call loss probability is high, the number of channels will be lower than if the probability is low

**Satellite Link Availability** An easy way to reduce the satellite bandwidth is by reducing the rain margin. Though it reduces the satellite bandwidth, it also reduces the network availability. Table 6-5 contains a calculation of the number of hours in outage in a year as a function of the availability. If the RF equipment includes Dynamic Uplink Power Control (DPC), it is possible to reduce the rain margins, while maintaining the availability. DPC increases the e.i.r.p. when the Eb/No falls and, therefore, improves availability. However, implementing DPC increased the overall equipment cost.

**Activity Factor** For the inbound carriers in a TDM/TDMA network, the efficiency of the access protocol can be used as an activity factor in cells E73 through I73.

**Table 6-5. Hours in Outage per Availability Percentage.**

| AVAILABILITY | 99.96% | 99.90% | 99.36% | 99.00% |
|---|---|---|---|---|
| Number of hours in outage per year | 3.5 | 8.8 | 56.1 | 87.6 |

It is important to realize that all these factors interrelate. For example, link availability can influence the call loss probability and will add to the blockage. The VSAT service provider must carefully consider the selection of these parameters.

Some users of LST may want to consider changing the **Defaults** to reduce the bandwidth. The **Defaults** option allows users to change values like the intermodulation, adjacent satellite interference (ASI), terrestrial interference, and transponder backoff, among others. Although the option is available, INTELSAT does not recommend changing these values. The preset values presume the worst case scenario and will ensure that the link performance meets the requirements under the most stringent conditions.

To perform the discussed changes, go to the menu and select **Enter Data,** and select **Update,** and follow the screen menus. (Refer to Figure 6-3.)

### *6.2.7 Saving or Retrieving a File*

There are two options for saving the LST output.

1) ***.BWB File**. A *.BWB is a complete workbook including macros, databases, dialog boxes, etc.
   - Select **File/Save As** to provide a new name to the file.
2) ***.BDT File**. This method is more efficient and only saves the users input data. *.BDT files are much smaller than the *.BWB files. To save your spreadsheet as *.BDT files:
   - Select **File/Put Version**; enter the file name and save.

**To recover a *.BDT file** you must have opened the *.BWB file.

- Proceed to **File/Get Version**. Select desired *.BDT file name.

## *6.3 Capacity Cookbook*

For customers who wish to obtain a rough estimate of the space segment needed in a network, the following cookbook will prove a useful starting point. INTELSAT strongly recommends that network operators do a complete LST analysis for their network. The tables in the cookbook include all the satellite series and were prepared with the assumptions listed in Table 6-6.

**Table 6-6. Capacity Cookbook Assumptions.**

| | C-BAND LINKS | KU-BAND LINKS |
|---|---|---|
| Pattern advantage: | 2 dB Up / 2 dB Down | 2 dB Up / 2 dB Down |
| Rain margin: | 0.5 dB Up / 0.2 dB Down | 3 dB Up / 2 dB Down |
| BER threshold | $10^{-7}$ | $10^{-7}$ |
| Eb/No (FEC 1/2) | 6.2 dB | 6.2 dB |
| Eb/No (FEC 3/4) | 7.7 dB | 7.7 dB |
| Transponder SFD | INTELSAT VI = Low<br>INTELSAT VII & VIII = -79 $dBW/m^2$ | INTELSAT VI = Low<br>INTELSAT VII & VIII = -83 $dBW/m^2$ |
| Antennas diameter | G/T (INTELSAT STD[35]) | G/T (INTELSAT STD) |
| 1.2 meter | - - - - | 20.1 dB/K (K-2) |
| 1.8 meter | 15.1 dB/K (H-2) | 24.1 dB/K (K-3) |
| 2.4 meter | 18.6 dB/K (H-3) | 26.1 dB/K (E-1) |
| 3.8 meter | 22.8 dB/K (H-4) | 29.0 dB/K (E-2) |
| 4.5 meter | 24.0 dB/K (F-1) | 31.3 dB/K (E-2) |
| 6.1 meter | 27.0 dB/K (F-2) | 34.3 dB/K (E-3) |
| 7.2 meter | 29.0 dB/K (F-3) | 35.5 dB/K (E-3) |
| 8.1 meter | 30.7 dB/K (F-3) | 36.5 dB/K (E-3) |

*[35] Each antenna falls under the indicated INTELSAT antenna standard. These values of G/T do not indicate the G/T requirements for the standard qualification. The G/T requirements are indicated in IESS 207 Rev. 2, table 1, for C-band, and in IESS 208 Rev. 3, page 1, for Ku-band.*

To calculate a bandwidth using the cookbook follow the procedures below:

- Select a beam.
- Choose the PEB for the carriers in link 1 from the rates and the antenna diameters ($PEB_1$). If the rate is not available, calculate it by scaling the 9.6, 64, or 512 kbit/s rates[36].
- Indicate the number of carriers for that link ($N_1$).
- Choose the PEB for the carrier in link 2 from the rates and the hub antenna diameter ($PEB_2$).
- Indicate the number of carriers for that link ($N_2$).
- Calculate the total PEB as follows:
-

$$PEB_T = PEB_1 \times N_1 + PEB_2 \times N_2$$

- Round the total PEB value to the nearest 100 KHz value.
- Calculate the total occupied bandwidth in the same manner, but rather than using the carrier PEB, use the allocated bandwidth value. Round the value to the nearest 100 KHz.
- For BPSK carriers use the indicated PEB, but double the allocated BW.
-

$$BW_T = BW_1 \times N_1 + BW_2 \times N_2$$

- The larger value of $PEB_T$ or $BW_T$ will be the leased bandwidth.

**Example:**

Estimate the leased bandwidth for a VSAT network using Ku-band in an INTELSAT VII. The network will have 2 x 128 kbit/s outbound carriers and 12 x 64 kbit/s inbound carriers. The antenna sizes will be 1.2 m for the VSAT and 6.1 m for the hub.

[36] *For example, a rate of 384 Kbits/s is 64x6. Therefore the value for 64 can be scaled to 384 by multiplying them by 6.*

Assuming that Spot beam 3 provides the coverage, (refer to Table 6-19), the results are as follows.

PEB for 2 x 128 kbit/s FEC 1/2 and 1.2 m VSAT = (0.38 MHz) x 2 = 0.76 MHz.

PEB for 12 x 64 kbit/s FEC 3/4 and 6.1 m hub = (0.06 MHz) x 12 = 0.72 MHz.

$PEB_T$= 0.76 MHz + 0.772 MHz = 1.48 MHz ~ 1.5 MHz.

Allocated bandwidth for 2 x 128 kbit/s = (0.18 MHz) x 2 = 0.36 MHz.

Allocated bandwidth for 12 x 64 kbit/s = (0.059 MHz) x 12 = 0.70 MHz.

$BW_T$ + 0.36 MHz + 0.70 MHz = 1.06 MHz ~ 1.1 MHz.

$PEB_T$ = 1.5 MHz > $BW_T$ = 1.1 MHz.

The leased bandwidth can be estimated to be around 1.5 MHz.

**INTELSAT VI Satellite Series:**

Power Equivalent Bandwidth and Allocated Bandwidth for QPSK Carriers on INTELSAT VI Satellites.

**Table 6-7. ZONE and HEMI Beams (FEC 1/2).**
**INTELSAT VI**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.8 m | 0.23 | 0.38 | 1.52 | 12.17 |
| 2.4 m | 0.1 | 0.17 | 0.69 | 5.49 |
| 3.8 m | 0.04 | 0.07 | 0.27 | 2.15 |
| 4.5 m | 0.03 | 0.05 | 0.21 | 1.65 |
| 6.1 m | 0.02 | 0.03 | 0.11 | 0.88 |
| 7.2 m | 0.01 | 0.02 | 0.07 | 0.6 |
| 8.1 m | 0.01 | 0.01 | 0.05 | 0.43 |
| Allocated BW | 0.0134 | 0.0224 | 0.0896 | 0.7168 |

**Table 6-8. ZONE and HEMI Beams (FEC 3/4).**
**INTELSAT VI**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.8 m | 0.39 | 0.64 | 2.57 | 20.56 |
| 2.4 m | 0.17 | 0.29 | 1.16 | 9.27 |
| 3.8 m | 0.07 | 0.11 | 0.45 | 3.63 |
| 4.5 m | 0.05 | 0.09 | 0.35 | 2.79 |
| 6.1 m | 0.03 | 0.05 | 0.18 | 1.48 |
| 7.2 m | 0.02 | 0.03 | 0.13 | 1.01 |
| 8.1 m | 0.01 | 0.02 | 0.09 | 0.72 |
| Allocated BW | 0.009 | 0.0149 | 0.0597 | 0.4779 |

**Table 6-9. EAST SPOT Beam (FEC 1/2).**
**INTELSAT VI**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.2 m | 0.04 | 0.06 | 0.25 | 1.98 |
| 1.8 m | 0.02 | 0.03 | 0.11 | 0.85 |
| 2.4 m | 0.01 | 0.02 | 0.07 | 0.58 |
| 3.8 m | 0.01 | 0.01 | 0.04 | 0.35 |
| 4.5 m | 0.01 | 0.01 | 0.03 | 0.25 |
| 6.1 m | 0.01 | 0.01 | 0.02 | 0.18 |
| 7.2 m | 0.01 | 0.01 | 0.02 | 0.16 |
| 8.1 m | 0.01 | 0.01 | 0.02 | 0.15 |
| Allocated BW | 0.0134 | 0.0224 | 0.0896 | 0.7168 |

**Table 6-10. EAST SPOT Beam (FEC 3/4).**
**INTELSAT VI**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.2 m | 0.05 | 0.09 | 0.35 | 2.83 |
| 1.8 m | 0.02 | 0.04 | 0.15 | 1.22 |
| 2.4 m | 0.02 | 0.03 | 0.1 | 0.83 |
| 3.8 m | 0.01 | 0.02 | 0.06 | 0.51 |
| 4.5 m | 0.01 | 0.01 | 0.04 | 0.36 |
| 6.1 m | 0.01 | 0.01 | 0.03 | 0.25 |
| 7.2 m | 0.01 | 0.01 | 0.03 | 0.23 |
| 8.1 m | 0.01 | 0.01 | 0.03 | 0.21 |
| Allocated BW | 0.009 | 0.0149 | 0.0597 | 0.4779 |

**Table 6-11. WEST SPOT Beam (FEC 1/2).**
**INTELSAT VI**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.2 m | 0.04 | 0.06 | 0.25 | 1.98 |
| 1.8 m | 0.02 | 0.03 | 0.11 | 0.85 |
| 2.4 m | 0.01 | 0.02 | 0.07 | 0.58 |
| 3.8 m | 0.01 | 0.01 | 0.04 | 0.35 |
| 4.5 m | 0.01 | 0.01 | 0.03 | 0.25 |
| 6.1 m | 0.01 | 0.01 | 0.02 | 0.18 |
| 7.2 m | 0.01 | 0.01 | 0.02 | 0.16 |
| 8.1 m | 0.01 | 0.01 | 0.02 | 0.15 |
| Allocated BW | 0.0134 | 0.0224 | 0.0896 | 0.7168 |

**Table 6-12. WEST SPOT Beam (FEC 3/4).**
**INTELSAT VI**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.2 m | 0.05 | 0.09 | 0.35 | 2.83 |
| 1.8 m | 0.02 | 0.04 | 0.15 | 1.22 |
| 2.4 m | 0.02 | 0.03 | 0.1 | 0.83 |
| 3.8 m | 0.01 | 0.02 | 0.06 | 0.51 |
| 4.5 m | 0.01 | 0.01 | 0.04 | 0.36 |
| 6.1 m | 0.01 | 0.01 | 0.03 | 0.25 |
| 7.2 m | 0.01 | 0.01 | 0.03 | 0.23 |
| 8.1 m | 0.01 | 0.01 | 0.03 | 0.21 |
| Allocated BW | 0.009 | 0.0149 | 0.0597 | 0.4779 |

## INTELSAT VII Satellite Series:

Power Equivalent Bandwidth and Allocated Bandwidth for QPSK Carriers on INTELSAT VII Satellites.

**Table 6-13. ZONE and HEMI Beams (FEC 1/2).**
**INTELSAT VII**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.8 m | 0.11 | 0.18 | 0.73 | 5.86 |
| 2.4 m | 0.05 | 0.09 | 0.35 | 2.81 |
| 3.8 m | 0.02 | 0.04 | 0.15 | 1.2 |
| 4.5 m | 0.02 | 0.03 | 0.12 | 0.97 |
| 6.1 m | 0.01 | 0.02 | 0.07 | 0.56 |
| 7.2 m | 0.01 | 0.01 | 0.06 | 0.44 |
| 8.1 m | 0.01 | 0.01 | 0.05 | 0.37 |
| Allocated BW | 0.0134 | 0.0224 | 0.0896 | 0.7168 |

**Table 6-14. ZONE and HEMI Beams (FEC 3/4).**
**INTELSAT VII**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.8 m | 0.17 | 0.29 | 1.16 | 9.26 |
| 2.4 m | 0.08 | 0.14 | 0.54 | 4.35 |
| 3.8 m | 0.04 | 0.06 | 0.24 | 1.89 |
| 4.5 m | 0.03 | 0.05 | 0.19 | 1.53 |
| 6.1 m | 0.01 | 0.03 | 0.11 | 0.88 |
| 7.2 m | 0.01 | 0.02 | 0.09 | 0.69 |
| 8.1 m | 0.01 | 0.02 | 0.07 | 0.58 |
| Allocated BW | 0.009 | 0.0149 | 0.0597 | 0.4779 |

**Table 6-15. SPOT 1 Beam (FEC 1/2).**
**INTELSAT VII**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.2 m | 0.03 | 0.05 | 0.21 | 1.7 |
| 1.8 m | 0.02 | 0.03 | 0.11 | 0.86 |
| 2.4 m | 0.01 | 0.02 | 0.08 | 0.65 |
| 3.8 m | 0.01 | 0.02 | 0.06 | 0.45 |
| 4.5 m | 0.01 | 0.02 | 0.05 | 0.38 |
| 6.1 m | 0.01 | 0.01 | 0.04 | 0.33 |
| 7.2 m | 0.01 | 0.01 | 0.04 | 0.32 |
| 8.1 m | 0.01 | 0.01 | 0.04 | 0.31 |
| Allocated BW | 0.0134 | 0.0224 | 0.0896 | 0.7168 |

**Table 6-16. SPOT 1 Beam (FEC 3/4).**
**INTELSAT VII**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.2 m | 0.05 | 0.08 | 0.31 | 2.47 |
| 1.8 m | 0.02 | 0.04 | 0.16 | 1.25 |
| 2.4 m | 0.02 | 0.03 | 0.12 | 0.95 |
| 3.8 m | 0.01 | 0.02 | 0.08 | 0.66 |
| 4.5 m | 0.01 | 0.02 | 0.07 | 0.55 |
| 6.1 m | 0.01 | 0.02 | 0.06 | 0.52 |
| 7.2 m | 0.01 | 0.02 | 0.06 | 0.5 |
| 8.1 m | 0.01 | 0.02 | 0.06 | 0.49 |
| Allocated BW | 0.009 | 0.0149 | 0.0597 | 0.4779 |

**Table 6-17. SPOT 2 Beam (FEC 1/2).**
**INTELSAT VII**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.2 m | 0.04 | 0.06 | 0.26 | 2.04 |
| 1.8 m | 0.02 | 0.03 | 0.13 | 1.01 |
| 2.4 m | 0.01 | 0.02 | 0.09 | 0.76 |
| 3.8 m | 0.01 | 0.02 | 0.06 | 0.52 |
| 4.5 m | 0.01 | 0.01 | 0.05 | 0.43 |
| 6.1 m | 0.01 | 0.01 | 0.05 | 0.39 |
| 7.2 m | 0.01 | 0.01 | 0.05 | 0.38 |
| 8.1 m | 0.01 | 0.01 | 0.05 | 0.37 |
| Allocated BW | 0.0134 | 0.0224 | 0.0896 | 0.7168 |

**Table 6-18. SPOT 2 Beam (FEC 3/4).**
**INTELSAT VII**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.2 m | 0.06 | 0.09 | 0.37 | 2.97 |
| 1.8 m | 0.03 | 0.05 | 0.18 | 1.47 |
| 2.4 m | 0.02 | 0.03 | 0.14 | 1.1 |
| 3.8 m | 0.01 | 0.02 | 0.09 | 0.75 |
| 4.5 m | 0.01 | 0.02 | 0.08 | 0.62 |
| 6.1 m | 0.01 | 0.02 | 0.07 | 0.57 |
| 7.2 m | 0.01 | 0.02 | 0.07 | 0.55 |
| 8.1 m | 0.01 | 0.02 | 0.07 | 0.53 |
| Allocated BW | 0.009 | 0.0149 | 0.0597 | 0.4779 |

**Table 6-19. SPOT 3 Beam (FEC 1/2).**
**INTELSAT VII**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.2 m | 0.03 | 0.05 | 0.19 | 1.53 |
| 1.8 m | 0.01 | 0.02 | 0.1 | 0.79 |
| 2.4 m | 0.01 | 0.02 | 0.08 | 0.62 |
| 3.8 m | 0.01 | 0.01 | 0.05 | 0.44 |
| 4.5 m | 0.01 | 0.01 | 0.05 | 0.38 |
| 6.1 m | 0.01 | 0.01 | 0.04 | 0.36 |
| 7.2 m | 0.01 | 0.01 | 0.04 | 0.35 |
| 8.1 m | 0.01 | 0.01 | 0.04 | 0.34 |
| Allocated BW | 0.0134 | 0.0224 | 0.0896 | 0.7168 |

**Table 6-20. SPOT 3 Beam (FEC 3/4).**
**INTELSAT VII**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.2 m | 0.04 | 0.07 | 0.28 | 2.22 |
| 1.8 m | 0.02 | 0.04 | 0.14 | 1.15 |
| 2.4 m | 0.02 | 0.03 | 0.11 | 0.9 |
| 3.8 m | 0.01 | 0.02 | 0.08 | 0.64 |
| 4.5 m | 0.01 | 0.02 | 0.07 | 0.55 |
| 6.1 m | 0.01 | 0.02 | 0.06 | 0.52 |
| 7.2 m | 0.01 | 0.02 | 0.06 | 0.5 |
| 8.1 m | 0.01 | 0.02 | 0.06 | 0.49 |
| Allocated BW | 0.009 | 0.0149 | 0.0597 | 0.4779 |

**Table 6-21. C-SPOT Beam (FEC 1/2).**
**INTELSAT VII**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.8 m | 0.03 | 0.05 | 0.21 | 1.65 |
| 2.4 m | 0.02 | 0.03 | 0.11 | 0.85 |
| 3.8 m | 0.01 | 0.01 | 0.06 | 0.45 |
| 4.5 m | 0.01 | 0.01 | 0.05 | 0.39 |
| 6.1 m | 0.01 | 0.01 | 0.03 | 0.28 |
| 7.2 m | 0.01 | 0.01 | 0.03 | 0.26 |
| 8.1 m | 0.01 | 0.01 | 0.03 | 0.24 |
| Allocated BW | 0.0134 | 0.0224 | 0.0896 | 0.7168 |

**Table 6-22. C-SPOT Beam (FEC 3/4).**
**INTELSAT VII**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.8 m | 0.05 | 0.08 | 0.32 | 2.54 |
| 2.4 m | 0.02 | 0.04 | 0.16 | 1.31 |
| 3.8 m | 0.01 | 0.02 | 0.09 | 0.69 |
| 4.5 m | 0.01 | 0.02 | 0.08 | 0.6 |
| 6.1 m | 0.01 | 0.01 | 0.05 | 0.42 |
| 7.2 m | 0.01 | 0.01 | 0.05 | 0.41 |
| 8.1 m | 0.01 | 0.01 | 0.05 | 0.37 |
| Allocated BW | 0.009 | 0.0149 | 0.0597 | 0.4779 |

## INTELSAT VIII Satellite Series:

Power Equivalent Bandwidth and Allocated Bandwidth for QPSK Carriers on INTELSAT VIII Satellites.

**Table 6-23. ZONE and HEMI Beams (FEC 1/2).**

**INTELSAT VIII**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.8 m | 0.09 | 0.15 | 0.59 | 4.72 |
| 2.4 m | 0.04 | 0.07 | 0.28 | 2.28 |
| 3.8 m | 0.02 | 0.03 | 0.13 | 1.06 |
| 4.5 m | 0.02 | 0.03 | 0.11 | 0.88 |
| 6.1 m | 0.01 | 0.02 | 0.07 | 0.55 |
| 7.2 m | 0.01 | 0.01 | 0.06 | 0.46 |
| 8.1 m | 0.01 | 0.01 | 0.05 | 0.4 |
| Allocated BW | 0.0134 | 0.0224 | 0.0896 | 0.7168 |

**Table 6-24. ZONE and HEMI Beams (FEC 3/4).**

**INTELSAT VIII**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.8 m | 0.14 | 0.23 | 0.91 | 7.26 |
| 2.4 m | 0.07 | 0.11 | 0.44 | 3.51 |
| 3.8 m | 0.03 | 0.05 | 0.2 | 1.63 |
| 4.5 m | 0.03 | 0.04 | 0.17 | 1.35 |
| 6.1 m | 0.02 | 0.03 | 0.11 | 0.84 |
| 7.2 m | 0.01 | 0.02 | 0.09 | 0.7 |
| 8.1 m | 0.01 | 0.02 | 0.08 | 0.61 |
| Allocated BW | 0.009 | 0.0149 | 0.0597 | 0.4779 |

**Table 6-25. SPOT 1 Beam (FEC 1/2).**

**INTELSAT VIII**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.2 m | 0.04 | 0.07 | 0.28 | 2.27 |
| 1.8 m | 0.02 | 0.03 | 0.14 | 1.11 |
| 2.4 m | 0.02 | 0.03 | 0.1 | 0.83 |
| 3.8 m | 0.01 | 0.02 | 0.07 | 0.56 |
| 4.5 m | 0.01 | 0.01 | 0.06 | 0.46 |
| 6.1 m | 0.01 | 0.01 | 0.05 | 0.39 |
| 7.2 m | 0.01 | 0.01 | 0.05 | 0.37 |
| 8.1 m | 0.01 | 0.01 | 0.05 | 0.36 |
| Allocated BW | 0.0134 | 0.0224 | 0.0896 | 0.7168 |

**Table 6-26. SPOT 1 Beam (FEC 3/4).**
**INTELSAT VIII**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.2 m | 0.06 | 0.1 | 0.41 | 3.26 |
| 1.8 m | 0.03 | 0.05 | 0.2 | 1.6 |
| 2.4 m | 0.02 | 0.04 | 0.15 | 1.19 |
| 3.8 m | 0.01 | 0.03 | 0.1 | 0.8 |
| 4.5 m | 0.01 | 0.02 | 0.08 | 0.66 |
| 6.1 m | 0.01 | 0.02 | 0.08 | 0.6 |
| 7.2 m | 0.01 | 0.02 | 0.07 | 0.58 |
| 8.1 m | 0.01 | 0.02 | 0.07 | 0.56 |
| Allocated BW | 0.009 | 0.0149 | 0.0597 | 0.4779 |

**Table 6-27. SPOT 2 Beam (FEC 1/2).**
**INTELSAT VIII**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.2 m | 0.04 | 0.07 | 0.28 | 2.27 |
| 1.8 m | 0.02 | 0.03 | 0.14 | 1.11 |
| 2.4 m | 0.02 | 0.03 | 0.1 | 0.83 |
| 3.8 m | 0.01 | 0.02 | 0.07 | 0.56 |
| 4.5 m | 0.01 | 0.01 | 0.06 | 0.46 |
| 6.1 m | 0.01 | 0.01 | 0.05 | 0.39 |
| 7.2 m | 0.01 | 0.01 | 0.05 | 0.37 |
| 8.1 m | 0.01 | 0.01 | 0.05 | 0.36 |
| Allocated BW | 0.0134 | 0.0224 | 0.0896 | 0.7168 |

**Table 6-28. SPOT 2 Beam (FEC 3/4).**
**INTELSAT VIII**

| CARRIER | 9.6 KBIT/S | 16 KBIT/S | 64 KBIT/S | 512 KBIT/S |
|---|---|---|---|---|
| 1.2 m | 0.06 | 0.1 | 0.41 | 3.26 |
| 1.8 m | 0.03 | 0.05 | 0.2 | 1.6 |
| 2.4 m | 0.02 | 0.04 | 0.15 | 1.19 |
| 3.8 m | 0.02 | 0.03 | 0.1 | 0.8 |
| 4.5 m | 0.01 | 0.02 | 0.08 | 0.66 |
| 6.1 m | 0.01 | 0.02 | 0.08 | 0.6 |
| 7.2 m | 0.01 | 0.02 | 0.07 | 0.58 |
| 8.1 m | 0.01 | 0.02 | 0.07 | 0.56 |
| Allocated BW | 0.009 | 0.0149 | 0.0597 | 0.4779 |

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# CHAPTER 7

# *THE ITU RECOMMENDATIONS AND INTERNATIONAL REGULATIONS*

Efforts to standardize the VSAT market at the level of applications and protocols have, by enlarge, been unsuccessful. Each VSAT vendor offers a proprietary product that operates as a closed network. However, there are several regulations that apply to the radio portion of VSATs and these are reviewed in this chapter.

## *7.1 ITU Recommendations*

The ITU, specifically Study Group 4 Task Group TG 4/2, has produced documents and recommendations on VSAT topics that are intended to serve as guidelines for countries planning to prepare licensing procedures. This Section presents an overview of the major issues.

### *7.1.1 General Recommendations (Rec. ITU-R S.725)*

ITU-R Recommendation S.725 includes a general description of VSATs. Generally, VSAT networks are closed, have dedicated applications, and have one, or a set, of compatible applications. VSATs are usually located at the end-user premises. Any given region or country tends to have many VSAT installations. Some VSAT E/S facilities are shared. Antenna diameters are typically no more than 2.4 m, but some larger dishes are justifiable. It is usually assumed that digital modulation is used, that FEC coding is applied, and always beneficial, and that the information bit rate has a range from 4.8 Kbit/s to less than 2 Mbit/s. Low-power RF transmitters are used, consistent with economy and safety.

Recommendation S.725 notes that new recommendations are being considered by Study Group 4 Task Group TG 4/3. The new recommendations consider the connection of VSAT to public switched networks (PSTN, PSPDN, ISDN), and will likely include interfaces, protocols, and compatibility issues. Several drafts of the new recommendations have been prepared for future approval.

### *7.1.2 Recommendation on Spurious Emissions (Rec. ITU-R S.726-1)*

Recommendation S.726-1 describes the requirements to protect the terrestrial and satellite radio services from interference, and deals with limits on spurious emissions. The limits set forth in Recommendation 726-1 are summarized in Figure 7.1.

Notice that the off-axis spurious emissions limits are given for any 100 KHz band at off-axis angles > 7 degrees. The on-axis spurious limit is 4 dBW in any 4 KHz band.

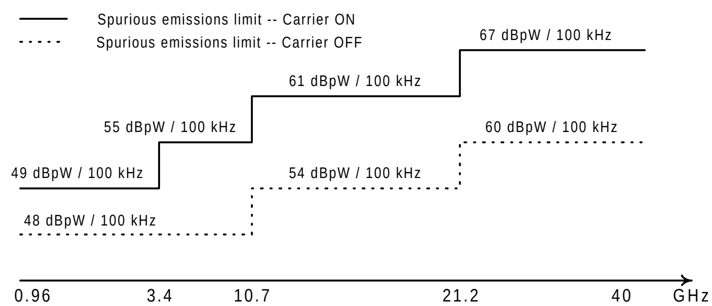


**Figure 7-1. Limits for Off-Axis Spurious Emissions.**

### *7.1.3 Recommendation on Cross-Polarization Isolation (Rec. ITU-R S.727)*

To enable frequency reuse by use of dual polarization, cross-polarization isolation is an important factor to consider for VSATs. The ratio of the on-axis co-polar gain to the cross-polar gain of the antenna in the transmit frequency band should not be less than 25 dB. This ratio must be maintained within the 0.3 dB contour of the main beam. For angles away from the 0.3 dB contour, the ratio must be better than 20 dB. These requirements are covered in Rec. ITU-R S.727.

### *7.1.4 Recommendations on Off-Axis e.i.r.p. (Rec. ITU-R S.728)*

Recommendation S.728 tightens the off-axis e.i.r.p. value of Rec. ITU-R S.524. The reason for the tightening is to further protect services in adjacent satellites. Only Ku-band systems are covered in S.728.

VSAT Earth stations operating in the fixed-satellite services in the 14 GHz frequency band should be designed in such a manner that at any angle $\varphi$ off the main lobe axis of an Earth station antenna, the e.i.r.p. density in any direction within 3 degrees of the geostationary satellite orbit should not exceed the following values:

| ANGLE OFF-AXIS | MAXIMUM E.I.R.P. DENSITY PER 40 KHz |
|---|---|
| $2.5^o \leq \varphi \leq 7^o$ | 33-25 log $\varphi$ (dBW/40 KHz) |
| $7^o < \varphi \leq 9.2^o$ | 12 (dBW/40 KHz) |
| $9.2^o < \varphi \leq 48^o$ | 36-25 log $\varphi$ (dBW/40 KHz) |
| $> 48^o$ | -6 (dBW/40 KHz) |

In addition, the cross-polarized component in any direction $\perp$ degrees from the antenna main lobe axis should not exceed the following limits:

| ANGLE OFF-AXIS | MAXIMUM E.I.R.P. DENSITY PER 40 KHz |
|---|---|
| $2.5^o \leq \varphi \leq 7^o$ | 23-25 log $\varphi$ (dBW/40 KHz) |
| $7^o < \varphi \leq 9.2^\circ$ | 2 (dBW/40 KHz) |

For networks operating in regions with satellite separation of 2 degrees, the off-axis e.i.r.p. must be reduced by 8 dB. To achieve this reduction in off-axis e.i.r.p., the manufacturers are working intensely on developing new VSAT antennas that achieve better radiation patterns.

### *7.1.5 Recommendations on Control and Monitoring Functions (Rec. ITU-R S.729)*

This recommendation suggests the use of a network control center that inhibits the VSAT transmission during initial start up, after a “parameter change” command, or when a fault condition or malfunction is detected. Moreover, the network control center must monitor the performance of the VSAT during normal operations and must detect the status of the VSAT.

## *7.2 European Standards*

ETSI, the European Standards body has issued seven standards on VSATs, in three broad categories.

**1)** General specifications of VSATs

***ETS 300 157****: "Receive-only Very Small Aperture Terminals (VSATs) used for data distribution operating in the 11/12 GHz frequency bands";

***ETS 300 159****: "Transmit/receive Very Small Aperture Terminals (VSATs) used for data communications operating in the Fixed-Satellite Service (FSS) 11/12/14 GHz frequency bands".

***ETS 300 333***: "Receive-only Very Small Aperture Terminals (VSATs) used for data distribution operating in the 4 GHz frequency band";

***ETS 300 332***: "Transmit/receive Very Small Aperture Terminals (VSATs) used for data communications operating in the Fixed Satellite Services (FSS) 6 GHz and 4 GHz frequency bands".

**2)** Control and monitoring of VSATs

***ETS 300 160****: "Control and monitoring at a Very Small Aperture Terminal (VSAT)";

***ETS 300 161****: "Centralized control and monitoring for VSAT networks".

**3)** Interconnection of VSATs to terrestrial networks

***ETS 300 194***: "The interconnection of VSAT systems to Packet Switched Public Data Networks (PSPDNs)".

Those recommendations marked with an asterisk (*) were approved as of 1995.

## *7.3 INTELSAT Standards*

The INTELSAT Earth Station Standards (IESS) documents define the requirements of Earth stations and services operating in the INTELSAT system.

### *7.3.1 Type-Approved VSATs*

INTELSAT has granted type approval to specific C- and Ku-band Earth stations[37]. The use of type-approved antennas for VSAT networks is strongly encouraged. The use of such stations avoids the time and cost of antenna verification testing on every antenna in the network. The requirements and test procedures to certify an antenna as 'Type Approved' are described in the SSOG-220.

### *7.3.2 INTELSAT Business Services for VSATs (VSAT IBS)*

INTELSAT has released Revision 6 to IESS-309 that extends the popular INTELSAT Business Service (IBS) to VSAT Earth station Standards H and K. (See IESS 207 and 208.)

[37] *A list of this equipment is available on the INTELSAT Internet site, under "Technical Information/Earth Stations".*

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# CHAPTER 8

## *CASE STUDIES OF VSAT APPLICATIONS AND SERVICES*

The following case studies illustrate how well the INTELSAT system works for VSAT network applications. These case studies also demonstrate some of the technical tradeoffs necessary when translating user requirements into a network design. Each case study presents the user requirements, the service provider's concerns, design trade-offs, and the results.

### *8.1 Case Study 1. VSAT Financial Network*

This case study is for the establishment of a VSAT network for a financial organization in the Pacific Rim.

**User Requirements**

The client wants to interconnect 125 widely separated branch offices with the organization's headquarters. Rooftop antennas are needed for each branch office. The minimum services requested are: financial account inquiries, batch file transfer, electronic mail, and remote printing. The service requirements are detailed in Table 8-1. Traffic will be divided equally between each of the branch offices.

**Table 8-1. Summary of User's Requirements.**

| SERVICE TYPE | AVERAGE # OF TRANSACTIONS PER DAY | TRANSACTIONS PER MINUTE IN BUSY HOUR | INBOUND (CHARACTERS) | OUTBOUND (CHARACTERS) | RESPONSE TIME (SECONDS) |
|---|---|---|---|---|---|
| Financial traffic | 880 | 125 | 500 | 500 | 3 |
| File transfer | 1 | 5 | 250,000 | 500 | 120 |
| E-mail | 500 | 15 | 500 | 500 | 60 |
| Remote printing | 500 | 15 | 500 | 500 | 120 |

### Design Considerations

The design will begin by considering the star topology and how Ku-band will comply with the stipulation of rooftop antennas. The initial antenna sizes will be 1.2 and 4.5 meters for, respectively, the VSATs and the hub. To minimize the bandwidth requirement, the availability will be 99.6 percent and a BER performance of $10^{-8}$.

Now, we need to convert the information in Table 8-1 into bits per seconds and carriers.

Table 8-2 shows the result of converting the transaction during the PBH into bits per second.

**Table 8-2. Calculated Information Rate during the PBH.**

| SERVICE TYPE | INBOUND RATE (BIT/S) | OUTBOUND RATE (BIT/S) | NETWORK PEAK RATE (BIT/S) |
|---|---|---|---|
| Financial traffic | 8,333 | 8,333 | 16,667 |
| File transfer | 166,666 | 8,333 | 167,000 |
| E-mail | 1,000 | 1,000 | 2,000 |
| Remote printing | 1,000 | 1,000 | 2,000 |
| TOTAL traffic (bit/s) | 176,999 | 18,666 | 187,667 |

To calculate the number of carriers, we needed to make some traffic calculations. The following assumptions will be used for the calculations.

- For the inbound carrier, the efficiency of the satellite access protocol will be 25 percent for interactive information and 75 percent for non-interactive file transfers and remote printing. This efficiency assumes the use of DA-TDMA.
- The protocol efficiency for the outbound carrier will be 85 percent.
- The carrier rate is 64 Kbit/s for the inbound and outbound carriers.

The number of carriers is calculated as 5 x 64 Kbit/s for the inbound link and 1 x 64 Kbit/s for the outbound link. These carriers are calculated following the guidelines given in Chapter 4. Notice that, even though the file transfer protocol (FTP) provides a better efficiency, the file transfer still drives the network size by consuming 87 percent of the inbound capacity.

**Satellite Link and Equipment Dimensioning**

The link is set up in the Spot 3, Ku-band capacity on INTELSAT 701 satellite located at 180.0 degrees East.

The LST gives the following results.

| | |
|---|---|
| Satellite bandwidth to lease: | 0.70 MHz |
| Carriers' allocated bandwidth: | 0.63 MHz |
| Minimum SSPA for 4.5 m antenna: | 40 Watts[38] |
| Minimum SSPA for 1.2 m antenna: | 1 Watt |
| Antenna transmit gain: | 54.6 dBi for 4.5m<br>43.1 dBi for 1.2 m |
| Earth station pattern advantage: | 2 dB in the Uplink<br>2 dB in the Downlink |
| Antenna G/T: | 31.5 dB/K for 4.5 m<br>20.1 dB/K for 1.2 m |
| Uplink margin: | 4 dB |
| Downlink margin: | 2 dB |
| Eb/No for BER = 1 x $10^{-7}$ | 6.5 dB |
| Carrier modulation scheme: | BPSK Outbound<br>QPSK Inbound |
| Number of carriers: | 1 Outbound<br>5 Inbound |
| Carrier allocated bandwidth: | 0.18 MHz for the BPSK<br>0.9 MHz for the QPSK |

[38] *A 20-watt SSPA at the hub will allow future expansion. The actual power needed for the VSAT link at its initial stage is about 1 watt.*

### Tradeoff Possibilities

Several parameters affect equipment size, network performance, and satellite bandwidth. Those parameters must be selected after a trade-off. A brief discussion follows.

**What if the file transfer is done during non-peak hours?**

As expressed before, the network size in the inbound traffic direction is driven by the file transfer traffic. By limiting the file transfer to non-peak hours and assigning only one file transfer to the PBH, the number of carriers can be reduced to 3 x 64 Kbit/s inbound carriers. The leased bandwidth can be reduced to 0.6 MHz.

**What if the client is willing to reduce the BER threshold to $1 \times 10^{-5}$ but needs an availability of 99.9 percent?**

The Eb/No to get a BER equal to $1 \times 10^{-5}$ is 5.1 dB. The availability is expressed in rain margins; by increasing the availability to 99.9 percent the rain margins must increase to 7 dB in the uplink, and 4 dB in the downlink. The change results in an increase in the leased bandwidth[39] to 1 MHz. Notice that the clear sky BER will be better than $1 \times 10^{-11}$.

**What if the hub antenna is 3.7 meters instead of 4.5 meters?**

If the antenna size changes to 3.7 meters, assuming an availability of 99.6 percent, a BER threshold of $1 \times 10^{-7}$, and 5 inbound carriers, the leased bandwidth will increase to 0.8 MHz. The increment in bandwidth is due to the reduction in G/T at the hub. We are reducing from 31.5 dB/K (for the 4.5-meter antenna) to 29.0 dB/K (for the 3.7-meter antenna).

**What if there are no facilities to interconnect the VSAT hub to the client's host computer?**

If the terrestrial facilities to interconnect the network hub to the client's host are unavailable, the VSAT service provider can implement the link using another VSAT at the client's host premises. This link can be sized according to the client's traffic and will operate in a permanent mode. Assuming that the network hub to the client's premises uses a 64 Kbit/s duplex link, the increment in leased bandwidth will be 0.3 MHz.

[39] *This bandwidth still assumes that there are only three inbound carriers.*

Notice that we assumed the conditions established in the previous paragraph. (Refer to Figure 8-1.)

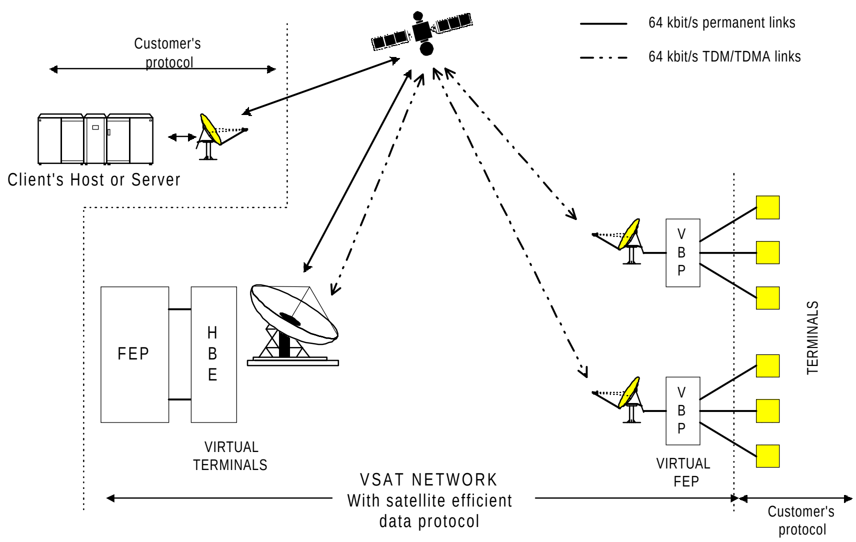


**Figure 8-1. Block Diagram of a VSAT Network Using a Satellite Link for the Hub-to-Host Link.**

## *8.2 Case Study 2. VSATs for Rural Communications*

This case examines the implementation of a rural communications network. The case will examine its implementation using C-band and will discuss several tradeoffs to improve the network performance.

**User Requirements**

A VSAT network is needed to provide economic telephony services in a country in Central Asia. The network will provide 2 to 4 channels per site, and will grow from 75 nodes to 500 nodes over a 2-year period. The network must allow connection from the VSATs to two major cities (A and B) using single hop. Remote to remote connectivity will be allowed using double hop. The double hop channels will be switched at the station in city A. City A will handle 60 percent of the traffic from the VSATs and the remaining 40 percent will terminate at city B. In addition, 10 channels are required for intercity traffic between cities A and B. The central station at City A will provide the network management and control facilities.

**Network Design Considerations**

The network must employ digital voice at 9.6 Kbit/s to save satellite bandwidth and provide good quality. For this traffic SCPC/DAMA would be used. The links will use a C-band transponder in the Zone beam of the INTELSAT APR-1 satellite located at 83.0 degrees E.

The design will consider VSAT dishes of 1.8m for the remote sites, and 4.5m antennas for the two large cities. Figure 8-2 presents a block diagram of this network. The user’s telephone can be connected either directly to the Earth station facility or through a PBX.

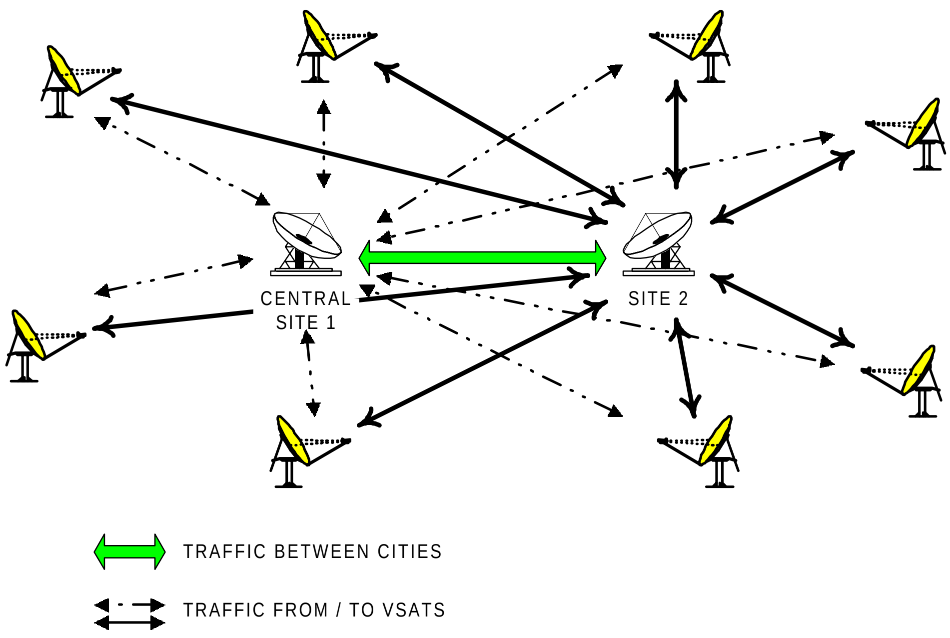


**Figure 8-2. SCPC/DAMA Network Topology.**

To reduce the space segment requirement, voice activation will be used with an activity factor of 50 percent. The threshold BER is selected at $10^{-4}$ because this is a voice-only network intended to provide an economical service. The links between large antennas will have an availability of 99.8 percent while the links to the VSATs will operate at 99.5 percent.

**Table 8-3. Link Types and Networks for Telephony Service.**

| LINK TYPE | VSAT - HUB | HUB - HUB | HUB - VSAT |
|---|---|---|---|
| Transmit station | 1.8 m | 4.5 m | 4.5 m |
| Receive station | 4.5 m | 4.5 m | 1.8 m |
| Modulation | QPSK | QPSK | QPSK |
| FEC coding | 1/2 | 3/4 | 1/2 |

**Table 8-4. Network Dimensioning.**

| | INITIAL INSTALLATION | YEAR 1 | YEAR 2 |
|---|---|---|---|
| Number of VSAT terminals | 75 | 300 | 500 |
| Number of 2-channel terminals | 35 | 150 | 200 |
| Number of 4-channel terminals | 40 | 150 | 300 |
| Total number of remote channels | 230 | 900 | 1600 |
| Erlangs per channel[40] | 0.1 | 0.15 | 0.2 |
| Erlangs per network | 23 | 135 | 320 |
| Number of satellite channels [41] | 30 | 139 | 322 |
| Number of channels to the main station (60 percent) | 28 | 93 | 203 |
| Number of channels for the site 2 (40 percent) | 22 | 66 | 136 |

## Satellite Link and Equipment Dimensioning

The link is set up in the C-band capacity on the INTELSAT APR-1 satellite located at 83.0 degrees East. The LST calculation gives the following results. (See Table 8-5.)

*40 The planned increment in the erlangs per channel is due to the fact that the channel occupancy will grow with the introduction of the VSAT network to new areas.*

*41 Calculated assuming a probability of loss of 5 percent.*

**Table 8-5. LST Result for Case Study 2.**

| | INITIAL INSTALLATION | YEAR 1 | YEAR 2 |
|---|---|---|---|
| Satellite bandwidth to lease: | 1.6 MHz | 6.0 MHz | 13.5 MHz |
| Carriers' allocated bandwidth: | 1.6 MHz | 6.0 MHz | 13.5 MHz |
| Minimum SSPA for 4.5 m antenna: | 150 watts, to accommodate traffic of Year 2 | | |
| Minimum SSPA for 1.8 m antennas with 2 channels: | 1 watt | | |
| Minimum SSPA for 1.8 m antennas with 4 channels: | 2 watts | | |
| Antenna transmit gain: | 47.8 dBi for 4.5 m antenna<br>39.9 dBi for 1.8 m antenna | | |
| Earth station pattern advantage: | 2 dB Up and 2 dB down | | |
| Antenna G/T: | 24.1 dB/K for the 4.5 m<br>15.1 dB/K for the 1.8 m | | |
| Uplink margin: | 1 dB | | |
| Downlink margin: | 0.5 dB | | |
| Eb/No for BER = $1 \times 10^{-4}$ | 6.0 dB | | |
| Carrier modulation scheme: | QPSK | | |
| FEC rate | 1/2 Viterbi decoding | | |

## Tradeoff Possibilities

### Reduction of Satellite Bandwidth

The LST results indicate that the downlink power margin is 3 dB. This positive margin indicates that the network is bandwidth-limited, and that the bandwidth can only be reduced if the number of required satellite channels is reduced. To reduce the bandwidth, the VSAT service provider could consider reducing the erlangs per line. The reduction will cut the number of carriers and the bandwidth as a result. However, customers may not accept the resulting blockage increase.

**What if the size of the antenna in Cities A & B is 3.7 meters?**

The size of the antennas can be reduced to 3.7 meters without increasing the satellite bandwidth. This takes advantage of the fact that the network has power margin in the downlink. However, the reduction on hub G/T will require that the 2-channel VSATs use a 2-watt SSPA and that the 4-channel VSAT use a 5-watt SSPA. The power requirement at the 3.8 antennas will increase to 250 watts.

**What if other values for VOX are used?**

VOX can be used to further reduce the satellite bandwidth on power-limited networks. However, because this network is bandwidth-limited, changing the VOX values will not reduce the satellite resource.

Finally, because the link is bandwidth-limited, the VSAT service provider must avoid the use of BPSK because it is not bandwidth-efficient. BPSK would be needed only if the on-axis emission constrains are exceeded.

The outcome of this case study shows that the INTELSAT APR-1 satellite is well suited to handle VSAT services, and to allow the customers to use the smallest dishes possible.

## *8.3 Case Study 3. Internet Services via INTELSAT*

This case study shows the feasibility of implementing asymmetric Internet links via satellite.

**User Requirement**

The user requirement is to extend Internet access to 12 sites in Eastern Europe. Each site will have access to the European backbone via asymmetric links. The link from Europe to Eastern Europe will be a 512 Kbit/s carrier and the return link from the 12 sites will be 64 Kbit/s.

**Network Design Considerations**

Of particular significance is the asymmetry of the link, the size of the central antenna, and the rate of the outbound carrier. The fact that the carriers are permanent and that only 12 remote antennas are needed make this case a candidate for VSAT IBS. To compare both services, the network resources will be calculated using LST and the VSAT IBS parameters. The BER threshold is $10^{-8}$.

The links will use QPSK and FEC 1/2 with Viterbi decoding for the LST calculation. For the VSAT IBS parameters, the links will use BPSK in the outbound and FEC 1/2 with sequential decoding.

The network will be set up using the Ku-band Spot 1 beam of INTELSAT 705 located at 342 degrees E.

The network is depicted in Figure 8-3.

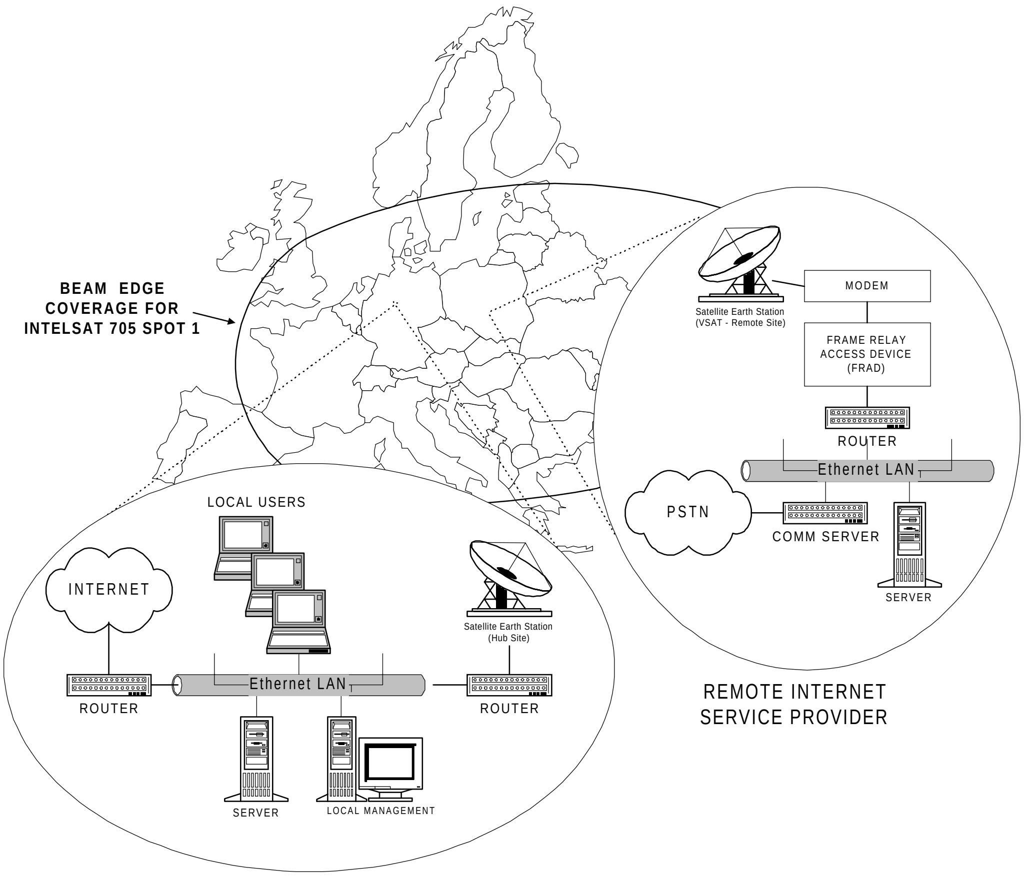


**Figure 8-3. Coverage Map and Block Diagram of the Internet Network.**

The link must have an availability of 99.96 percent. The services will be multiplexed in the outbound carrier, and the asymmetry makes the service highly cost effective in comparison with terrestrial alternatives.

### Satellite Link and Equipment Dimensioning

The link is set up using the Ku-band capacity of the Spot-1 beam on INTELSAT 705 located at 342 degrees E. The LST gives the following results.

| | |
|---|---|
| Satellite bandwidth to lease: | 3.5 MHz |
| Carriers' allocated bandwidth: | 1.79 MHz |
| Minimum SSPA for 2.4 m antenna: | 40 Watts[42] |
| Minimum SSPA for 1.8 m antenna: | 2 Watts |
| Antenna transmit gain: | 49.2 dBi for 2.4 m<br>46.7 dBi for 1.8 m |
| Earth station pattern advantage: | 2 dB in the Uplink<br>2 dB in the Downlink |
| Antenna G/T: | 26.1 dB/K for 2.4 m<br>24.1 dB/K for 1.8 m |
| Uplink margin (availability 99.96 percent): | 3.5 dB |
| Downlink margin (availability 99.96 percent): | 2 dB |
| Eb/No for BER = $1 \times 10^{-8}$ | 7.2 dB |
| Carrier modulation scheme: | QPSK outbound and inbound |
| Carrier rate: | 512 Kbit/s outbound<br>64 Kbit/s inbound |
| FEC | Rate ½, Viterbi O/BRate ½, sequential I/B |
| Number of carriers: | 1 Inbound<br>12 Outbound |

**Tradeoff Possibilities**

**What if Viterbi decoding is changed to sequential decoding?**

The use of FEC 1/2 with sequential decoding improves the link performance by 1.2 dB in comparison with the FEC 1/2 and Viterbi decoding. So by choosing sequential decoding the VSAT service provider can reduce the space segment to 2.5 MHz while keeping the BER performance.

*[42] A 40-watt SSPA will allow future expansion. The maximum carrier rate with a 40 watts SSPA will be 2048 kbit/s. The actual power needed for the 512 kbit/s link is about 8 watts.*

**What if the VSAT IBS carriers are used?**

The VSAT service provider can choose to use the VSAT IBS parameters for the VSAT network and will get the following benefits.

A. The network performance is guaranteed by INTELSAT in $1 \times 10^{-8}$. The clear sky BER will surpass $1 \times 10^{-10}$.
B. The carriers will use either FEC ½, Viterbi decoding, concatenated with Reed Solomon or FEC ½, sequential decoding, and no R-S outer coding.
C. The charges will be carrier-based.
D. The space segment cost will be reduced by 16 percent compared to the lease cost.
E. The service provider need not engineer the link.

The equipment size remains within the previously calculated values.

**Comments to the Implementation of an Internet Network**

INTELSAT is actively involved in the development of advance products for the Internet. INTELSAT has participated in the development of several enhancements to the TCP/IP suite of protocols. The enhancements are the multicasting protocol, the quick start algorithm, and the asymmetrical links. These enhancements improve the performance of the Internet.

These initiatives are undertaken to help the industry and service providers cope with the enormous increase in Internet traffic by ensuring that the Internet operates smoothly over satellite.

Finally, the adoption of the extension of IBS to VSATs was the last stitch needed to provide customers with off-the-shelf and standardized solutions that allow swift implementation of services.

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# *Appendix A.*

## *List of Acronyms and Abbreviations*

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# *Appendix A. List of Acronyms and Abbreviations*

These acronyms and abbreviations are typically used in the telecommunication industry[43].

| COMPANY AND ENTITY NAMES AND USAGE | |
|---|---|
| ETSI | European Telecommunications Standards Institute |
| FCC | Federal Communications Commission (USA) |
| INTELSAT | INternational TELecommunications SATellite organization |
| ITU | International Telecommunications Union |
| ITU-R | International Telecommunications Union – Radio committee |
| ITU-TS | International Telecommunications Union – Telecommunications Sector |
| WRC | World Radio Communication conference (ITU) |
| **TECHNICAL TERMS** | |
| 2B + D | Basic rate ISDN channel (2x64 + 16 Kb/s) |
| 8-PSK | Octal Phase Shift Keying |
| 16-PSK | 16-ary Phase Shift Keying |
| ADCCP | Advanced Data Communications Control Protocol |
| ADPCM | Adaptive Differential Pulse-Code Modulation |
| AFC | Automatic Frequency Control |
| AGC | Automatic Gain Control |
| AM | Amplitude Modulation |
| ARQ | Automatic ReQuest for retransmission |
| ATPC | Automatic Transmit Power Control |
| AWGN | Additive White Gaussian Noise |
| AzEl | Elevation over Azimuth |
| BBP | BaseBand Processor (payload) |
| BCH | Bose, Chaudhuri, Hocquenghem (coding) |
| BCM | Block-Coded Modulation |
| BER | Bit Error Ratio |
| BERT | Bit Error Ratio Tester |
| B-ISDN | Broadband ISDN |
| BISYNC | BInary SYNchronous Communication |
| BLER | Block Error Radio |

[43] *Taken with permission, from A Guide to Some Acronyms & Abbreviations, published by W.L. Pritchard & Co., Inc., available from http:/www.WLPCO.com.*

| | |
|---|---|
| BPSK | Binary Phase-Shift Keying |
| CAS | Channel Associated Signaling |
| C-band | 4,000 MHz - 8,000 MHz |
| CCS | Common Channel Signaling |
| CDM | Code Division Multiplexing |
| CDMA | Code-Division Multiple Access |
| CELP | Code Excited Linear Prediction |
| C/I | Carrier-to-Intermodulation ratio |
| C/N | Carrier-to-Noise power ratio |
| $C/N_o$ | Carrier power to Noise density ratio |
| CNR | Carrier-to-Noise Ratio |
| CODEC | COder/DECoder |
| CPE | Customer Premises Equipment |
| CRC | Cyclic Redundancy Check |
| CSC | Common Signalling Channel |
| C/T | Carrier power to system Temperature ratio |
| CW | Continuous Wave |
| D/C | Down Converter |
| DA | Demand Assignment |
| DA-FDMA | Demand Assignment-Frequency Division Multiple Access |
| DA-TDMA | Demand Assignment-Time Division Multiple Access |
| DAMA | Demand Assignment Multiple Access |
| dB | deciBel |
| DCPSK | Differential enCoding Coherent PSK |
| DOS | Disk Operating System |
| DPSK | Differential encoding Phase-Shift-Keying with non-coherent detection |
| DS | Direct Sequence |
| DS-0 | Data Stream (voice channel at 64 Kb/s) |
| DS-1 | Data Stream (24 DS-0 multiplexed) |
| DS-3 | Data Stream - 3 (45 Mb/s) |
| DS-CDMA | Direct Sequence-Code Division Multiple Access |
| DSI | Digital Speech Interpolation |
| DTE | Data Terminal Equipment |
| E1 | European equivalent of DS-1; 30 DS-0 multiplexed (2048 Kbit/s) |
| E3 | 16 E1s |
| $E_b/N_o$ | Energy per bit to Noise density ratio |
| e.i.r.p. | effective isotropic radiated power (also EIRP) |
| FDM | Frequency-Division Multiplexing |

| | |
|---|---|
| FDMA | Frequency-Division Multiple Access |
| FEC | Forward Error Correction |
| FFSK | Fast Frequency Shift Keying |
| FR | Frame Relay |
| FRAD | Frame Relay Access Device |
| FSK | Frequency-Shift Keying |
| FSS | Fixed Satellite Service |
| FTP | File Transfer Protocol |
| GEO | Geostationary Earth Orbit |
| GHz | GigaHertz |
| GIF | Graphics Interface Format |
| GII | Global Information Infrastructure |
| G/T | Gain to system Temperature ratio |
| HDLC | High-level Data Link Control |
| HDSL | High Speed Digital Subscriber Loop |
| HPA | High-Power Amplifier |
| HPF | HighPass Filter |
| HTML | Hyper Text Markup Language |
| HTTP | Hyper Text Transfer Protocol |
| IAPP | Inter Access Point Protocol |
| IBS | INTELSAT Business Service |
| IDR | Intermediate Data Rate (INTELSAT) |
| IF | Intermediate Frequency |
| IM | InterModulation product |
| IOT | In-Orbit Tests |
| IP | Internet Protocol; Internal Protocol |
| IPX | Internet Packet eXchange |
| IRR | Internal Rate of Return |
| ISDN | Integrated Services Digital Network |
| ISI | Inter-Symbol Interference |
| ISP | Internet Service Provider |
| K-band | 18 GHz - 27 GHz |
| Ka-band | 27 GHz - 40 GHz |
| kb/s | kilobits per second |
| Ku-band | 12 GHz - 18 GHz |
| kV | kiloVolts |
| LAN | Local Area Network |
| LEO | Low Earth Orbit |

| | |
|---|---|
| LHCP | Left-Hand Circular Polarization |
| LIN-SSPA | LINearized Solid State Power Amplifier |
| LIN-TWTA | LINearized Traveling Wave Tube Amplifier |
| LNA | Low Noise Amplifier |
| LNB | Low Noise Block |
| LNC | Low Noise Converter |
| LO | Local Oscillator |
| Mb/s | Megabits per second |
| MCPC | Multiple Channel Per Carrier |
| MHz | MegaHertz |
| MODEM | MOdulator/DEModulator |
| MPEG-2 | Motion Picture Experts Group, standard #2 |
| MSK | Minimum Shift Keying |
| MTBF | Mean Time Between Failures |
| MTTF | Mean Time To Failure |
| NAK | Negative AcKnowledgment |
| NCC | Network Control Center |
| NPR | Noise Power Ratio |
| NPV | Net Present Value |
| OOK | On/Off Keying (modulation) |
| OQPSK | Offset Quaternary Phase-Shift Keying |
| OSI | Open Systems Interconnection |
| PA | Power Amplifier |
| PAM | Pulse Amplitude Modulation |
| PBX | Private Branch Exchange |
| PC | Personal Computer |
| PCM | Pulse Code Modulation |
| POP | Point Of Presence (Internet) |
| PSK | Phase-Shift Keying |
| PSN | Public Switched Network |
| PSPDN | Packet Switched Public Data Network |
| PSTN | Public Switched Telephone Network |
| QAM | Quadrature Amplitude Modulation |
| QOS | Quality Of Service |
| QPSK | Quaternary Phase-Shift Keying |
| RELP | Residually Excited Linear Predictive coder |
| RF | Radio Frequency |
| RHCP | Right-Hand Circular Polarization |

| | |
|---|---|
| RMS | Root Mean Square |
| RO | Receive Only |
| RX | Receiver; Receive |
| SCPC | Single Channel Per Carrier |
| SCPC-DAMA | Single Channel Per Carrier - Demand Assignment Multiple Access |
| SDLC | Synchronous Data Link Control |
| SDMA | Spatial-Division Multiple Access (frequency reuse) |
| SNR | Signal-to-Noise Ratio |
| SSPA | Solid-State Power Amplifier |
| T1 | digital Transmission link at 1.544 Mb/s |
| T3 | 28 T1 lines |
| TAG | Technical Advisory Group (ITU-R) |
| TCM | Trellis-Coded Modulation |
| TCP/IP | Transmission Control Protocol / Internet Protocol |
| TDM | Time-Division Multiplex |
| TDMA | Time-Division Multiple Access |
| T/R, Tx/Rx | Transmit / Receive |
| TV | TeleVision |
| TVRO | TeleVision Receive Only |
| TWT | Traveling Wave Tube |
| TWTA | Traveling Wave Tube Amplifier |
| TX | Transmit; Transmitter |
| U/C | UpConverter |
| UPS | Uninterruptible Power Supply |
| VF | Voice-Frequency signal |
| VFRAD | Voice Frame Relay Access Device |
| VSAT | Very Small Aperture Terminal |
| VSWR | Voltage Standing-Wave Ratio |
| WAN | Wide Area Network |
| WWW | World Wide Web |
| XPC | X.75 Protocol Converter |
| XPOL | cross-POlarization Level |

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# *Appendix B.*

## *Exceedance Curves for Different Climatic Zones of the World*

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# *Appendix B. Exceedance Curves for Different Climatic Zones of the World*

To assist the VSAT service providers in determining the required rain margins, INTELSAT has prepared this compendium of attenuation exceedance curves for the different climatic zones of the world.

The curves were prepared using the INTELSAT Propagation Analysis for Rain and Clear-air program (PARC), and assuming 20-degrees elevation angle, at 500 m. above the sea level. *These curves are intended to provide a rough estimate for the rain margins in C- and Ku-band. INTELSAT strongly recommends that network providers undertake a more thorough analysis for their particular network.*

Use the curves as follows.

A. Select the appropriate ITU climatic zone for your location from the attached maps.
B. Select the appropriate curve for the climatic zone and frequency band.
C. Select the appropriate rain margin based on the availability target.

For example, The Republic of El Salvador is located in Central America. (See Figure B-1.) El Salvador is located in climatic zone P. The exceedance curves for climatic zone P are provided in Figure B-13. Finally, if Ku-band is chosen, the rain margin values can be calculated from the upper curves.

It is important to note the difference in the uplink and downlink curves, and in the values for the different frequency bands.

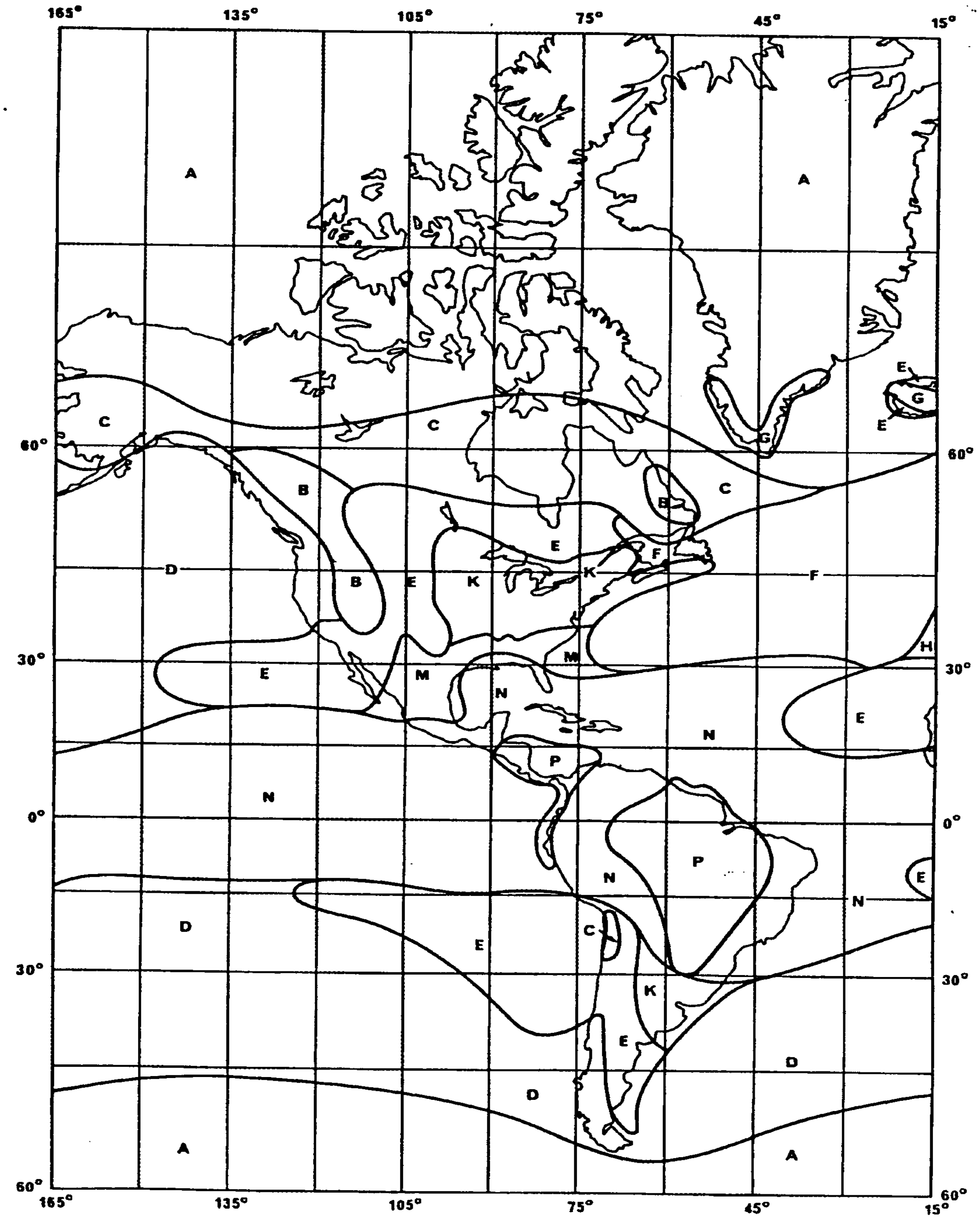



**Figure B-1. ITU[44] Climatic Zones - Americas.**

[44] *Printed with permission.*

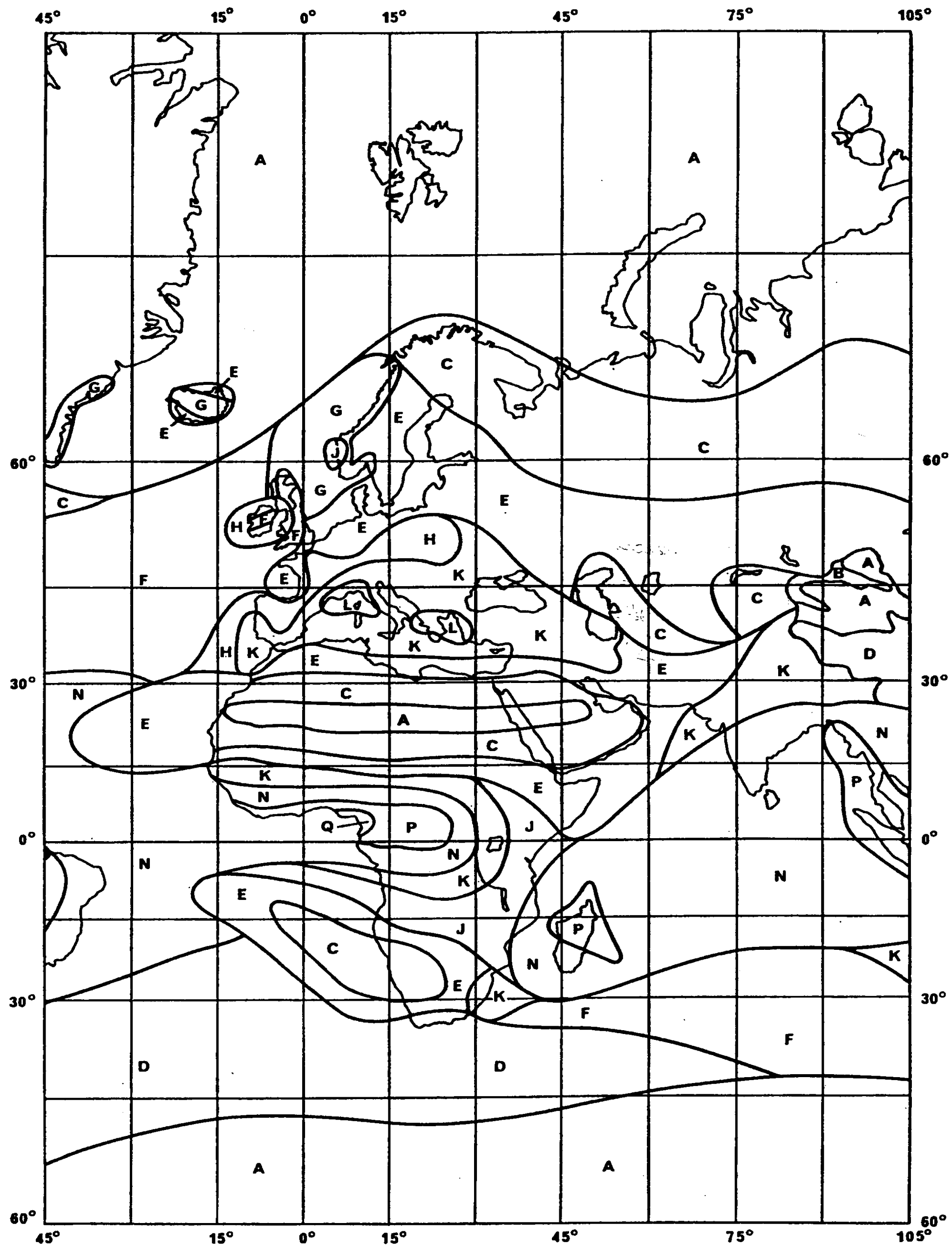



Figure B-2. ITU[45] Climatic Zones - Europe and Africa.

[45] *Printed with permission.*

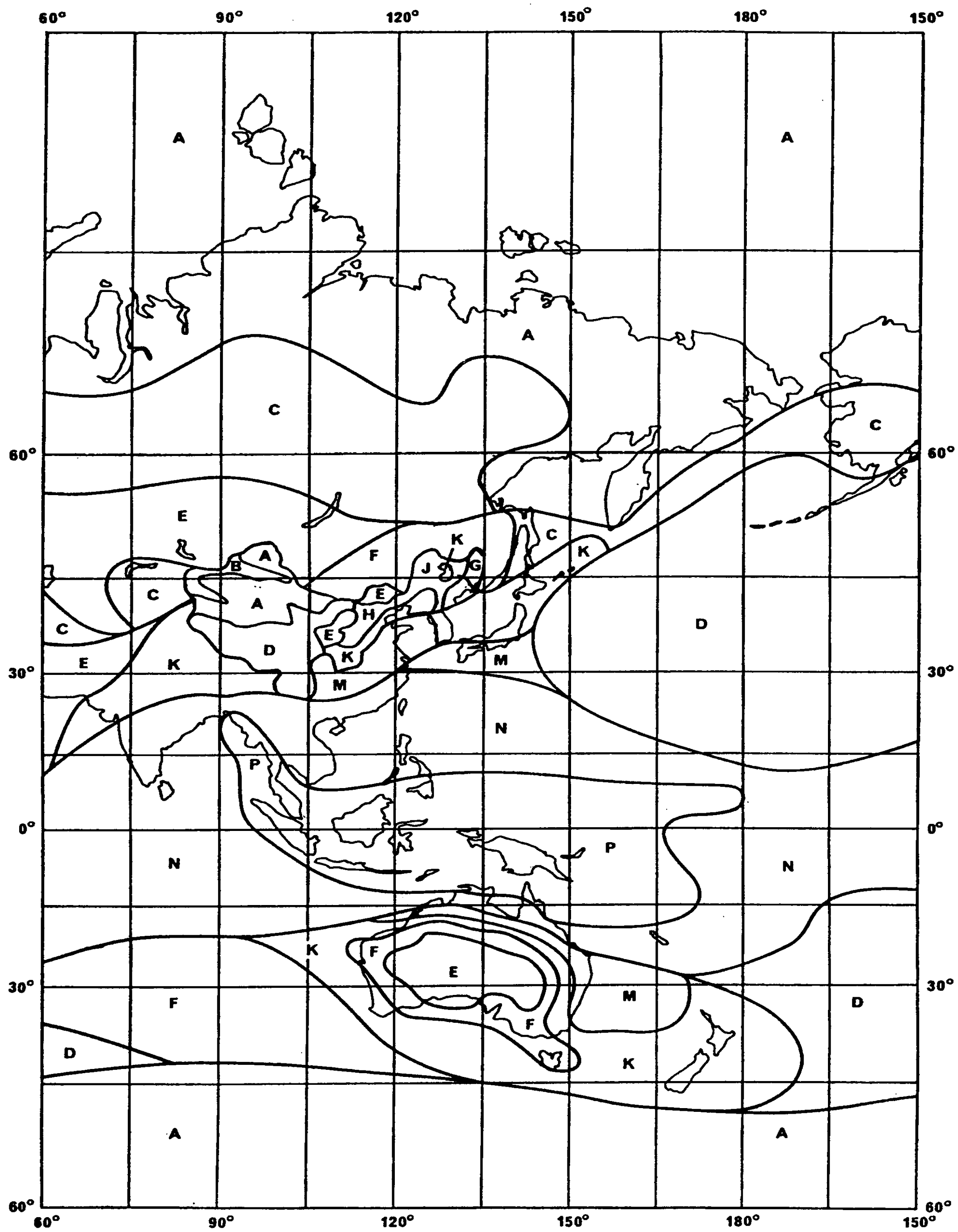
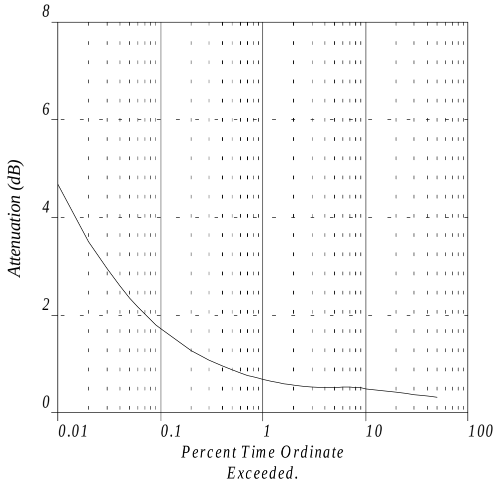
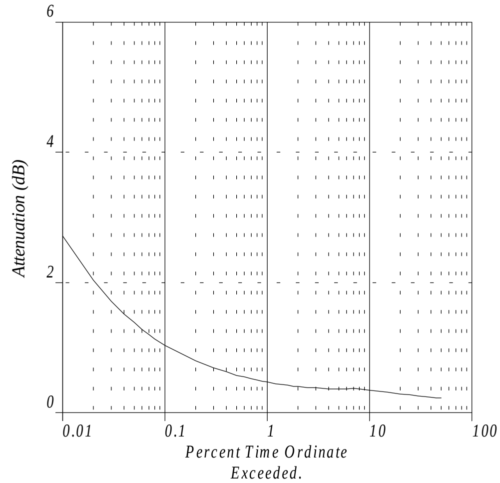



**Figure B-3. ITU[46] Climatic Zones - Asia, Australia, and Oceania.**

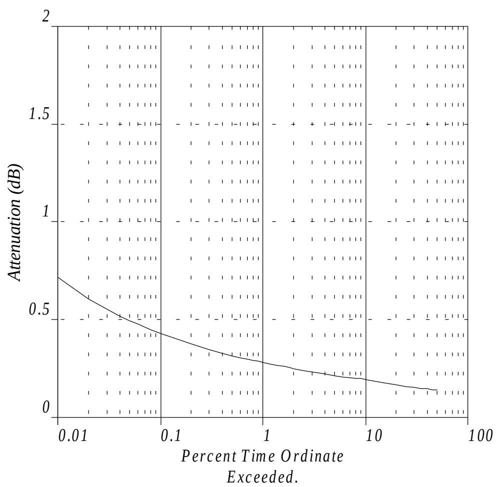
[46] *Printed with permission.*



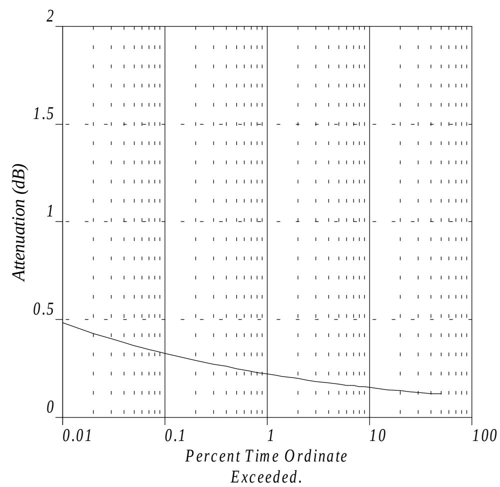

*Attenuation distribution at (Climatic Zones A, B & C), F = 14 GHz, Method PARC.*




*Attenuation distribution at (Climatic Zone A, B & C), F = 11 GHz, Method PARC.*

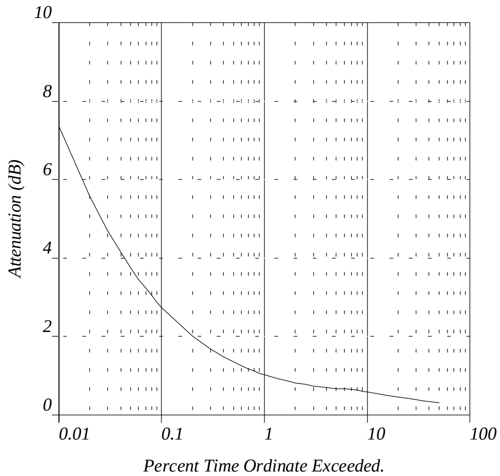



*Attenuation distribution at (Climatic Zone A, B & C), F = 6 GHz, Method PARC.*

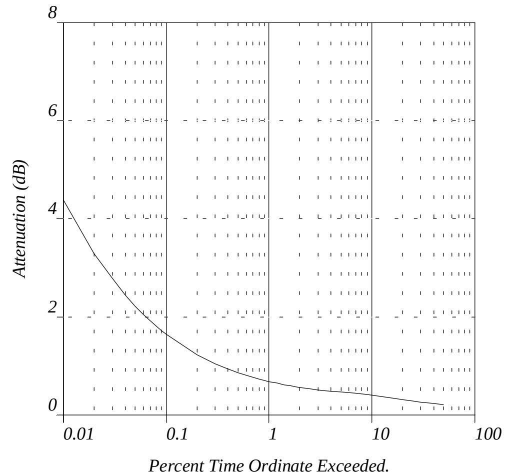



*Attenuation distribution at (Climatic Zone A, B & C), F = 4 GHz, Method PARC.*

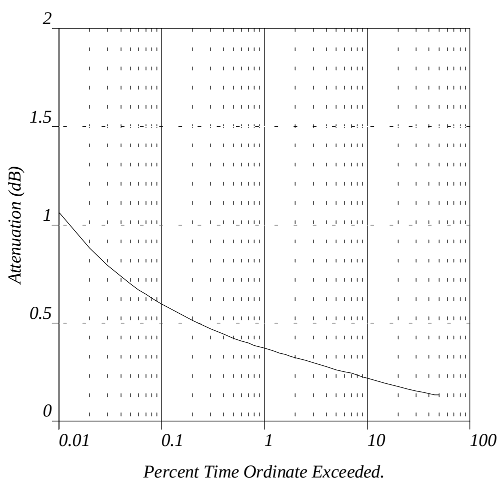
**Figure B-4.   Exceedance Curves for Climatic Zones A, B, and C.**



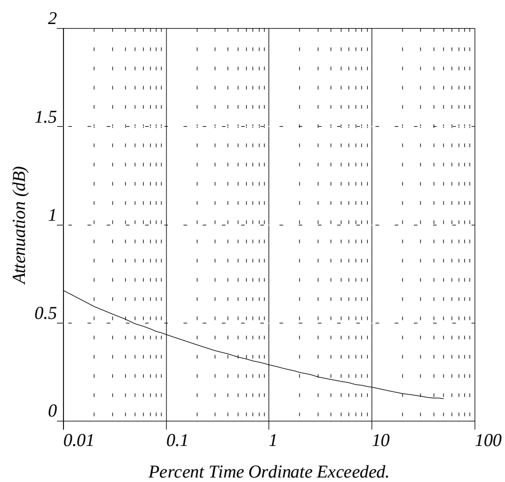

*Attenuation distribution at (Climatic Zone D), F = 14 GHz, Method PARC.*




*Attenuation distribution at (Climatic Zone D), F = 11 GHz, Method PARC.*

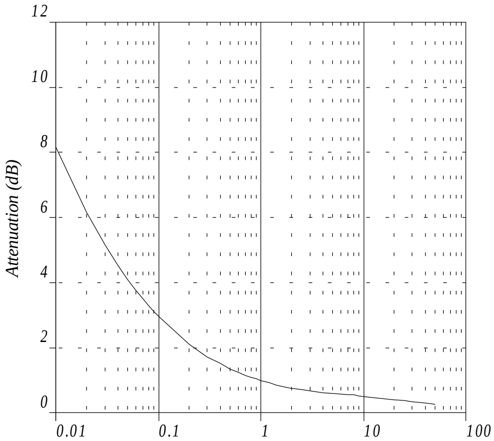



*Attenuation distribution at (Climatic Zone D), F = 6 GHz, Method PARC.*

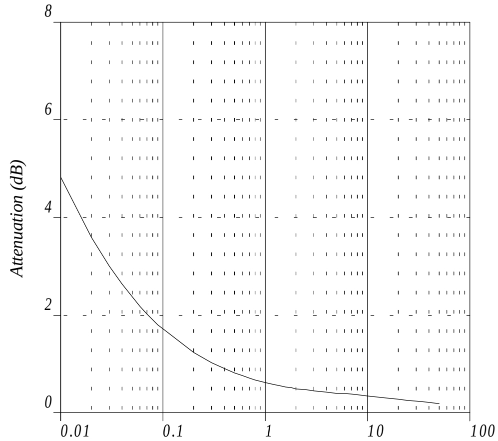



*Attenuation distribution at (Climatic Zone D), F = 4 GHz, Method PARC.*

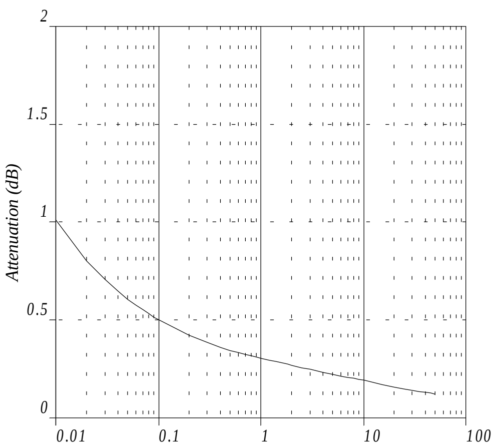
**Figure B-5. Exceedance Curves for Climatic Zone D.**



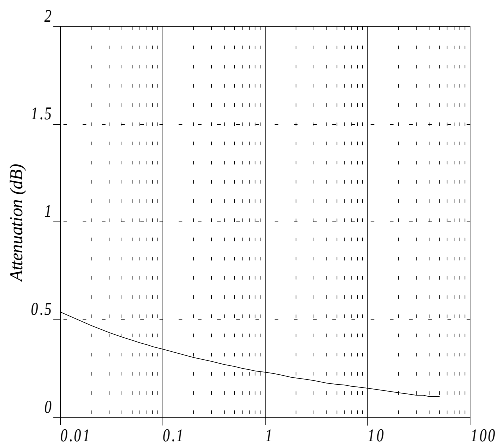

*Percent Time Ordinate Exceeded.*
*Attenuation distribution at (Climatic Zone E, F & G), F = 14 GHz, Method PARC.*




*Percent Time Ordinate Exceeded.*
*Attenuation distribution at (Climatic Zone E, F & G), F = 11 GHz, Method PARC.*

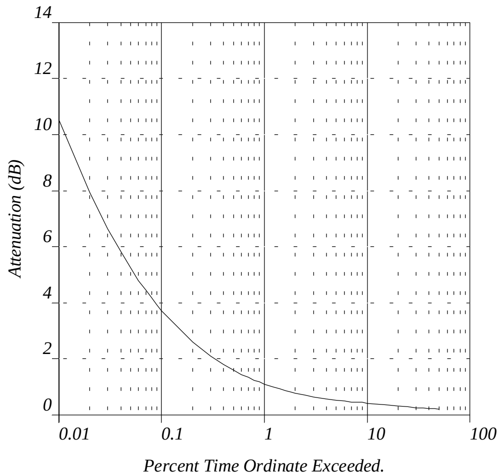



*Percent Time Ordinate Exceeded.*
*Attenuation distribution at (Climatic Zone E, F & G), F = 6 GHz, Method PARC.*

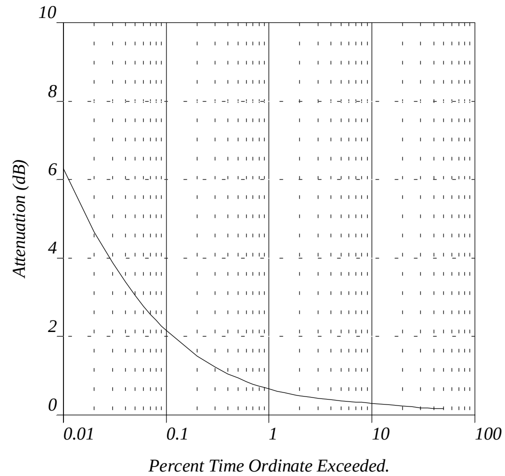



*Percent Time Ordinate Exceeded.*
*Attenuation distribution at (Climatic Zone E, F & G), F = 4 GHz, Method PARC.*

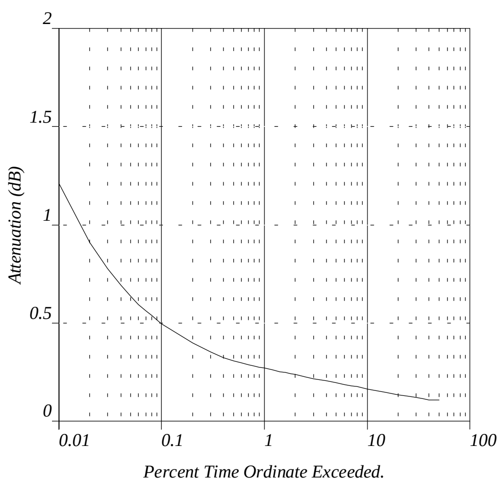
**Figure B-6.   Exceedance Curves for Climatic Zones E, F, and  G.**



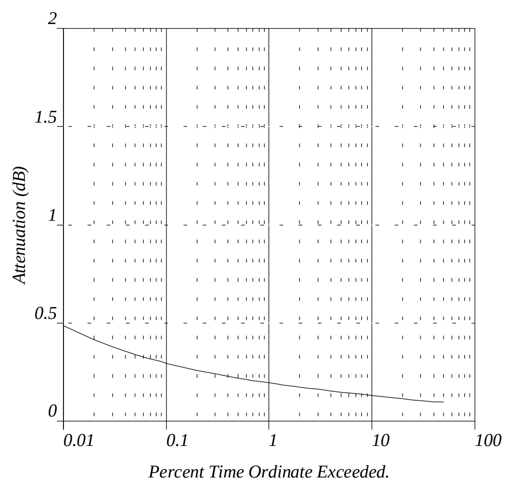

*Attenuation distribution at (Climatic Zone H), F = 14 GHz, Method PARC.*




*Attenuation distribution at (Climatic Zone H), F = 11 GHz, Method PARC.*

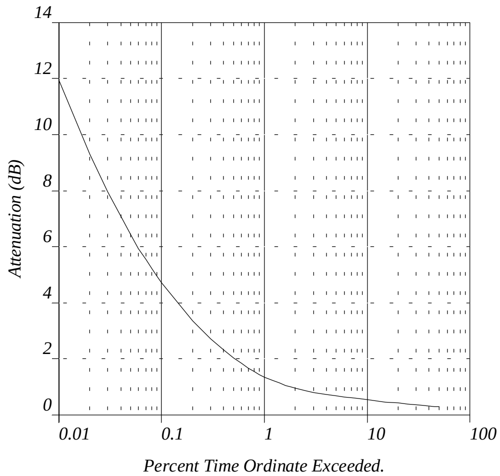



*Attenuation distribution at (Climatic Zone H), F = 6 GHz, Method PARC.*

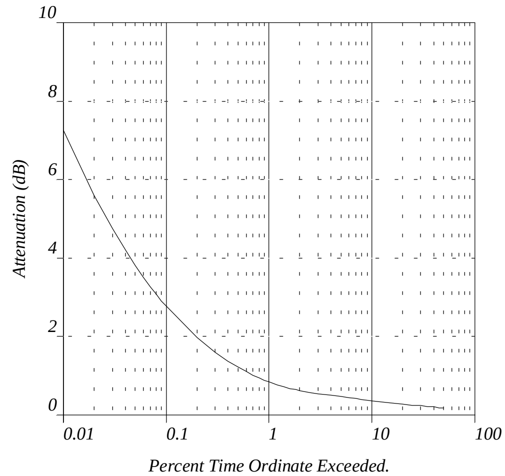



*Attenuation distribution at (Climatic Zone H), F = 4 GHz, Method PARC.*

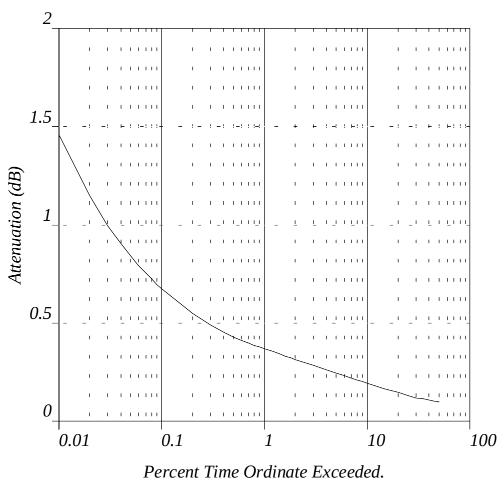
**Figure B-7.   Exceedance Curves for Climatic Zone H.**



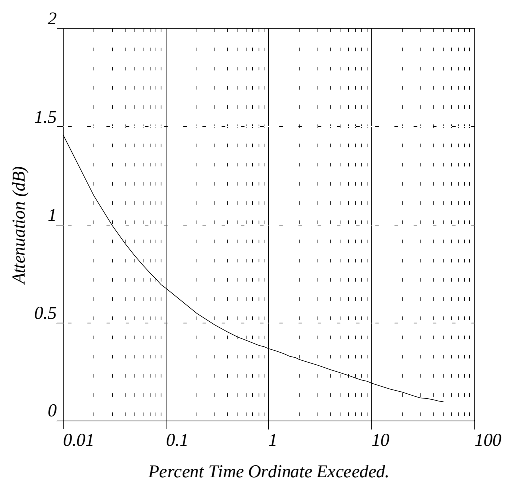

*Attenuation distribution at (Climatic Zone J), F = 14 GHz, Method PARC.*




*Attenuation distribution at (Climatic Zone J), F = 11 GHz, Method PARC.*

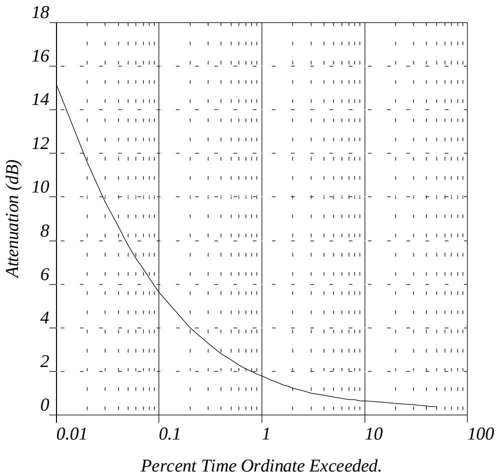



*Attenuation distribution at (Climatic Zone J), F = 6 GHz, Method PARC.*

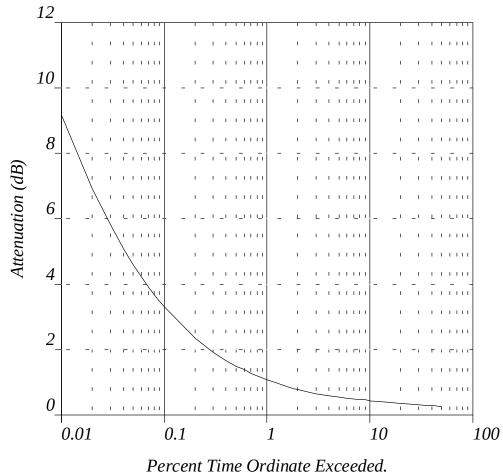



*Attenuation distribution at (Climatic Zone J), F = 6 GHz, Method PARC.*

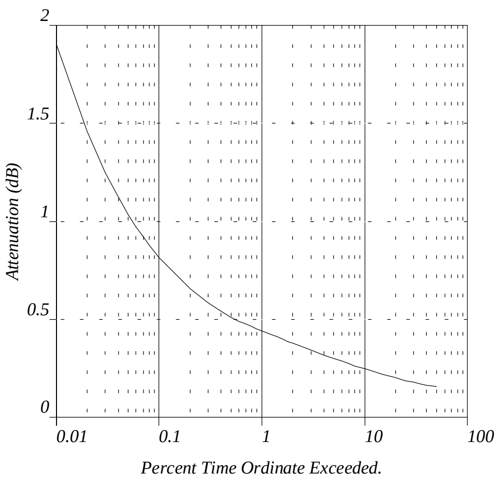
**Figure B-8. Exceedance Curves for Climatic Zone J.**



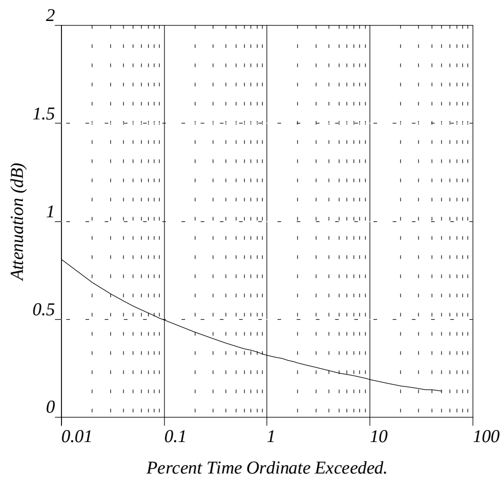

*Attenuation distribution at (Climatic Zone K), F = 14 GHz, Method PARC.*




*Attenuation distribution at (Climatic Zone K), F = 11 GHz, Method PARC.*

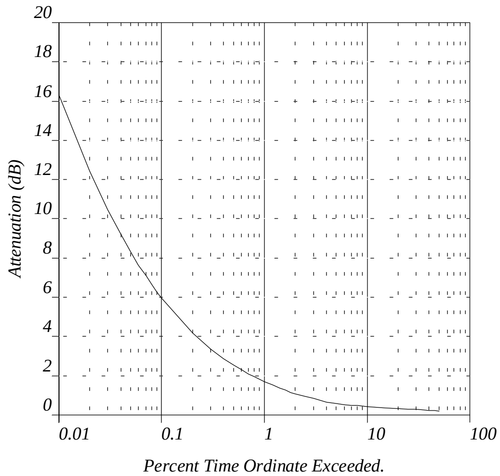



*Attenuation distribution at (Climatic Zone K), F = 6 GHz, Method PARC.*

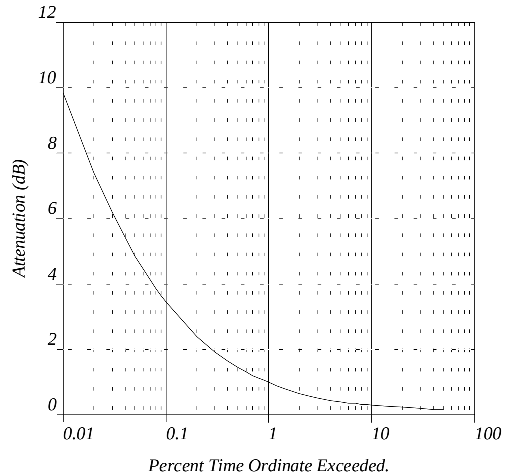



*Attenuation distribution at (Climatic Zone K), F = 4 GHz, Method PARC.*

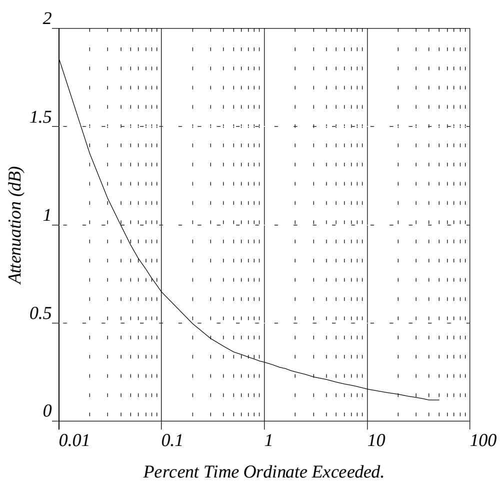
**Figure B-9. Exceedance Curves for Climatic Zone K.**



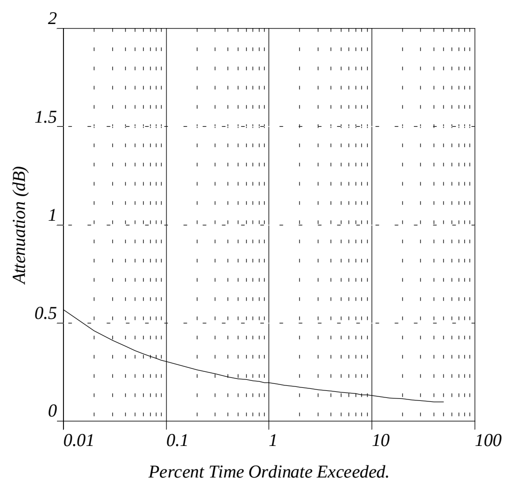

*Attenuation distribution at (Climatic Zone L), F = 14 GHz, Method PARC.*




*Attenuation distribution at (Climatic Zone L), F = 11 GHz, Method PARC.*

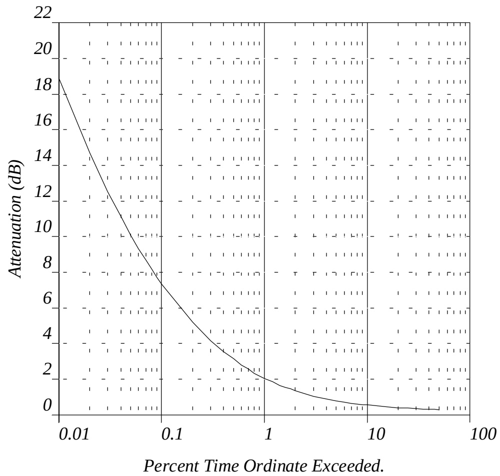



*Attenuation distribution at (Climatic Zone L), F = 6 GHz, Method PARC.*

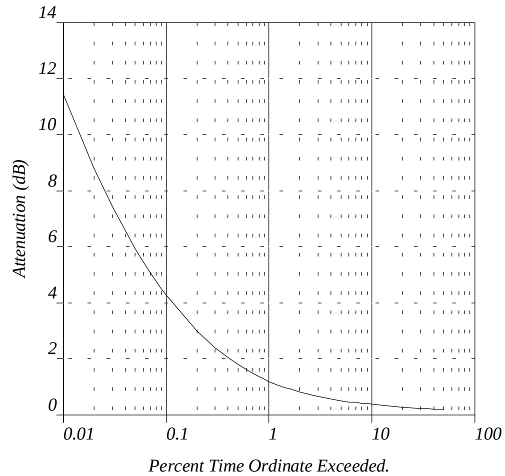



*Attenuation distribution at (Climatic Zone L), F = 4 GHz, Method PARC.*

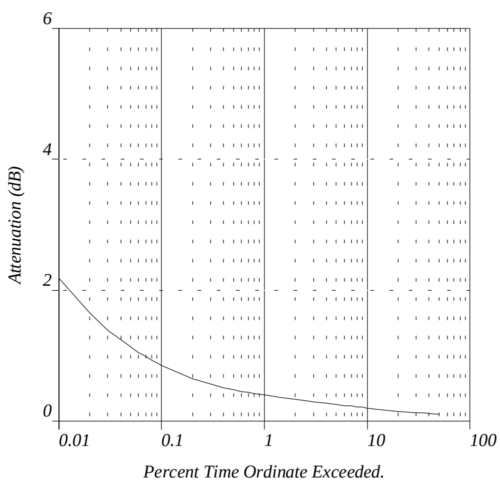
**Figure B-10. Exceedance Curves for Climatic Zone L.**



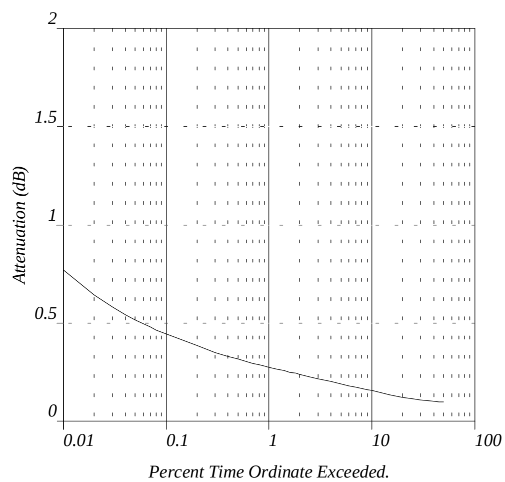

*Attenuation distribution at (Climate Zone M), F = 14 GHz, Method PARC.*




*Attenuation distribution at (Climate Zone M), F = 11 GHz, Method PARC.*

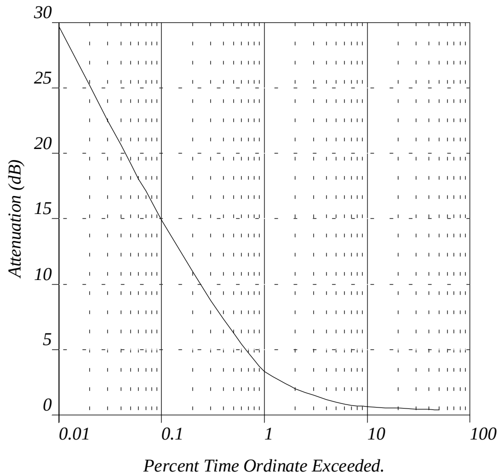



*Attenuation distribution at (Climate Zone M), F = 6 GHz, Method PARC.*

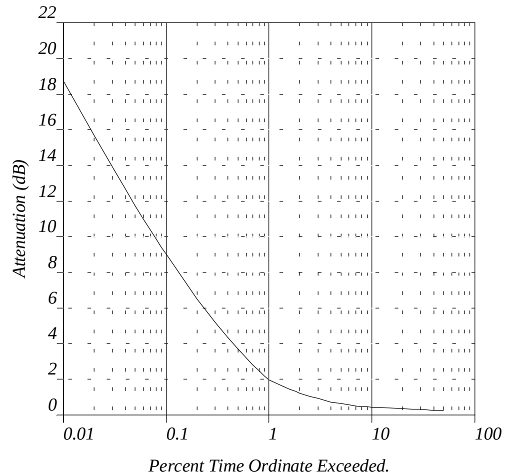



*Attenuation distribution at (Climate Zone M), F = 4 GHz, Method PARC.*

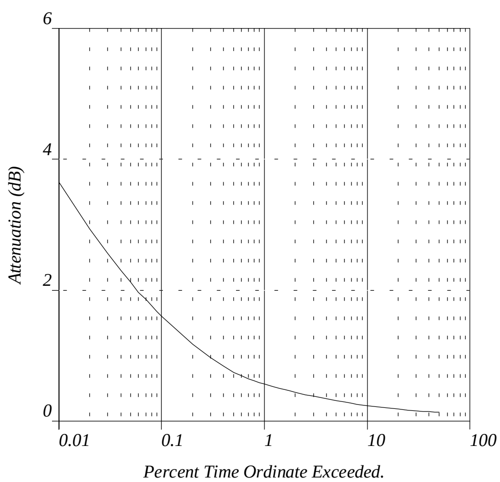
**Figure B-11. Exceedance Curves for Climatic Zone M.**



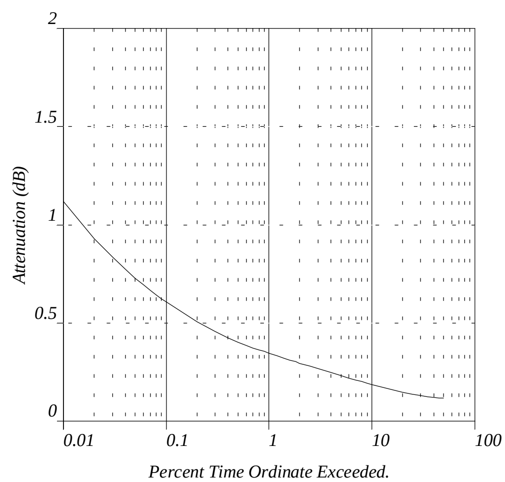

*Attenuation distribution at (Climate Zone N), F = 14 GHz, Method PARC.*




*Attenuation distribution at (Climate Zone N), F = 11 GHz, Method PARC.*

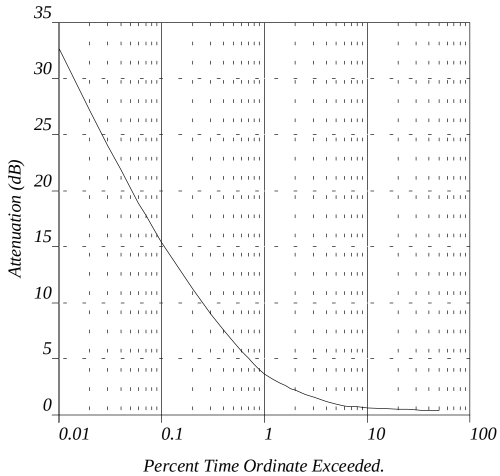



*Attenuation distribution at (Climate Zone N), F = 6 GHz, Method PARC.*

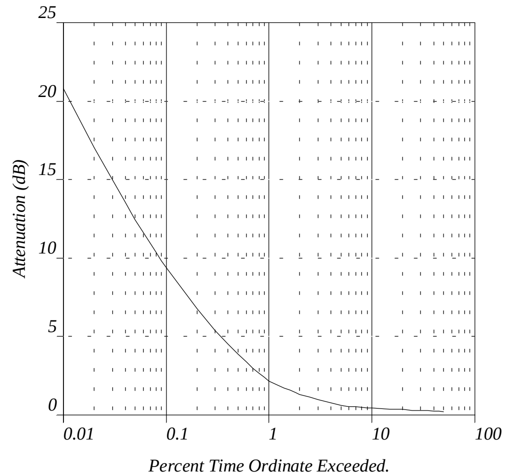



*Attenuation distribution at (Climate Zone N), F = 4 GHz, Method PARC.*

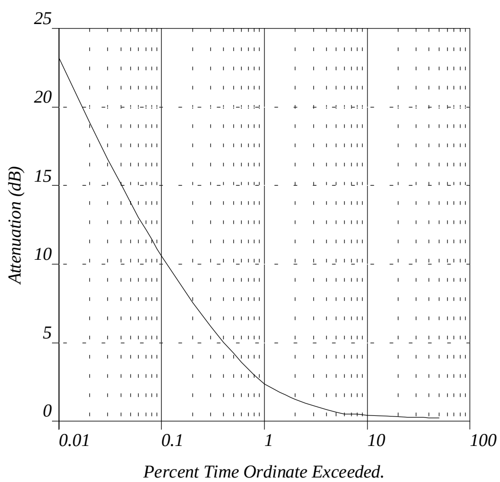
**Figure B-12. Exceedance Curves for Climatic Zone N.**



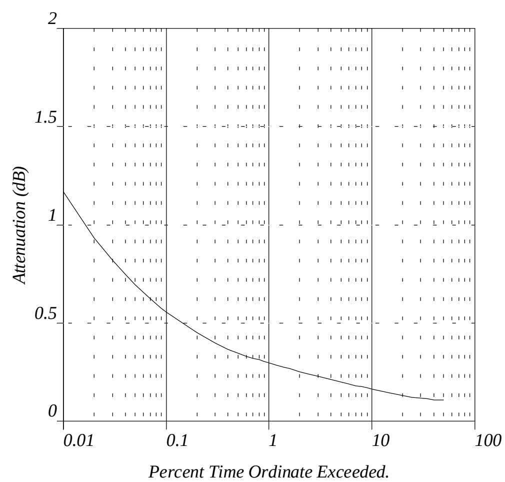

*Attenuation distribution at (Cliamte Zone P), F = 14 GHz, Method PARC.*




*Attenuation distribution at (Cliamte Zone P), F = 11 GHz, Method PARC.*

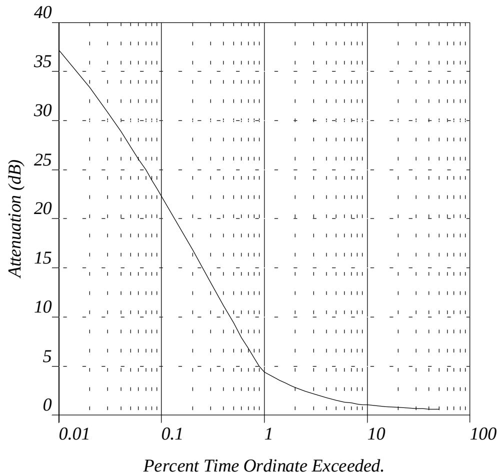



*Attenuation distribution at (Cliamte Zone P), F = 11 GHz, Method PARC.*

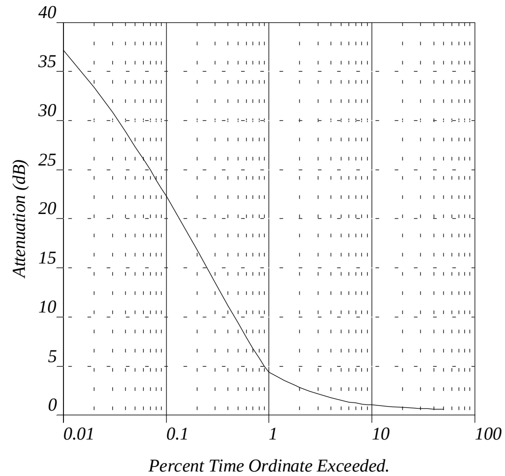



*Attenuation distribution at (Cliamte Zone P), F = 4 GHz, Method PARC.*

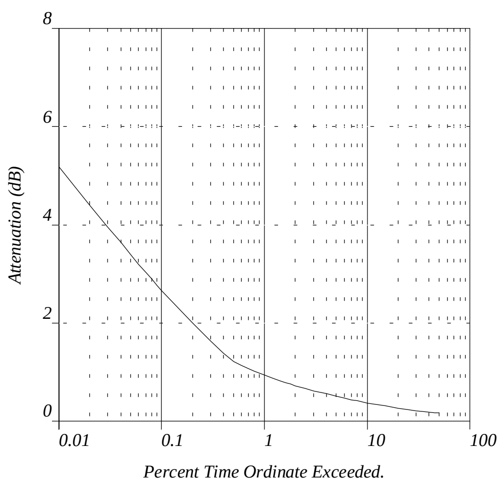
**Figure B-13.   Exceedance Curves for Climatic Zone P.**



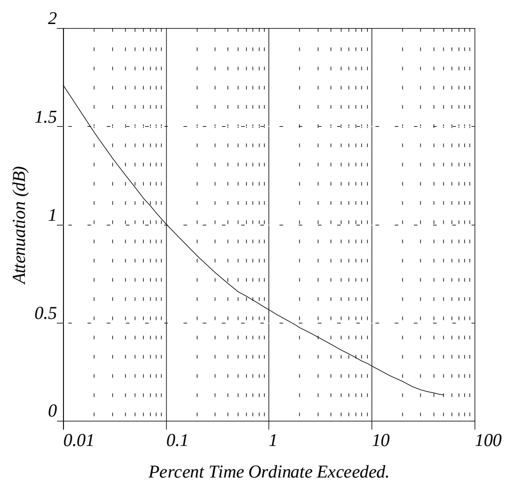

*Attenuation distribution at (Climatic Zone Q), F = 14 GHz, Method PARC.*




*Attenuation distribution at (Climatic Zone Q), F = 14 GHz, Method PARC.*




*Attenuation distribution at (Climatic Zone Q), F = 6 GHz, Method PARC.*




*Attenuation distribution at (Climatic Zone Q), F = 4 GHz, Method PARC.*

**Figure B-14. Exceedance Curves for Climatic Zone Q.**

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# *Appendix C.*

## *Model VSAT Request for Proposal*

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# *Appendix C. Model VSAT Request for Proposal*

## *C.1 Introduction*

The annex summarizes the major aspects in developing an RFP for the implementation of a VSAT network. The RFP should include a Statement of Work (SOW), the specifications of the network, and the implementation schedule. This appendix gives an overview of the issues that need to be considered in preparing these documents.

## *C.1.2 Preparing the RFP*

The following summary includes a list of issues to consider when preparing the RFP.

### *C.1.2.1 The Statement of Work (SOW)*

The SOW is a narrative description of the work to be accomplished by the contractor. It must include the objectives of the project and a brief description of the work. A list of details to consider when preparing the SOW follows:

- Before preparing the SOW, gather as much user information as possible. It will help in determining the user's requirements. The user's data must be uniformly organized and formatted.
- Remember that the SOW will identify design criteria, drawings and other related studies prepared for the VSAT network. Use language that is as accurate as possible and avoid contradictions.
- Include a checklist of the mandatory and optional items.

- Prepare the SOW as early as possible in the planning stage to provide sufficient time to include all the requirements. Make certain that every piece expected from the contractor is accurately described, and that the responsibility for each task is clearly defined.
- Ensure that the SOW is clearly written. The writer must realize that this document will be read and interpreted by people of various backgrounds. It is important to avoid ambiguity, to not overlook details, and to not be repetitive. Be specific. Avoid using ambiguous terms such as “as necessary” or “as needed”.
- Write each sentence in an active voice.

### *C.1.2.2 The Specifications to the RFP*

Specifications are standards for pricing out a proposal. It is better to concentrate on required end-results, rather than on methods or work process descriptions. Specifications should stress quality, and be concise. Avoid unnecessary design and schematics, or information that is difficult to update. Do not over-specify because this can inadvertently reduce the number of vendors who will submit proposals.

### *C.1.2.3 Implementation Schedule*

The implementation schedule must contain the project start date, project end date, and other major milestones.

## *C.2 Itemized List of SOW Topics*

The following check list highlights the necessary information provided in a SOW.

1) **Site listing:** List all the sites where the VSAT terminals will be installed. Include the hub location and geographical coordinates for each site. Describe the satellite to access. (See Table C-1).
2) **Description of services to be carried on the network:** Describe all the services and applications to be carried on the network. Provide as much traffic information as possible and include the most recent forecast to analyze the network potential growth. (Refer to Tables C-2 and C-3).
3) **Network requirements description:** The network description must include the requirements set forth for satellite links. Provide specific values of BER, availability, preferred INTELSAT satellite, preferred frequency band, and preliminary network topology.
4) **Contractual requisites:** Describe at a high level all the contractual requisites. Include what you expect in terms of: quotation format, review meetings, progress reports, test reports, in-plant testing, and documentation.
5) **Compliance:** Describe how you expect the contractor to demonstrate compliance of the submitted proposal with the specifications and SOW. The compliance should be indicated in a table for all systems and sub-system of the RFP. Any non-compliance must be indicated by the contractor along with proper explanation. (See Table C-4).
6) **Documents:** Describe required language, format, and delivery dates of contractual documents. Indicate which documents are to be delivered, and when. A typical list of documents include, network manuals, network operations manuals, equipment manuals, cabling manuals, test reports, test procedures, and equipment layout.
7) **Warranties:** Describe the type of warranties you require. Indicate the period and state the response time you expect to fix a failed system or equipment.
8) **Tasks to be performed by the purchaser:** Describe in detail what tasks the purchaser will perform and when the tasks will be completed. For example, the purchaser may provide a building or antenna foundation. These schedules must be indicated.
9) **Options:** Describe the possible options you might consider purchasing or allow the contractor to make suggestions. Request that the contractor provide costs for the options separately.
10) **Training:** Describe the scope and requirements for training. Include the number of trainees, expected duration, training location, language and required training material. Onsite training will allow the largest number of staff to be trained.
11) **Software packages:** Describe any special capabilities that may require software.

13) **Technical support:** Detail the technical support expected and the response time required of the contractor to guarantee you and your customers. Indicate a preference for 24-hour or online support. Some companies contract on-site technical support during a period of time, e.g., a year, to assist the local staff to operate more confidently.

14) **Link budgets:** Indicate whether you want the contractor to perform link budgets for you, and have the contractor specify the expected outcome in terms of antennas, satellite bandwidth, performance, and carrier rates.

**Table C-1. Summary Table Containing the Site Locations.**

| SATELLITE TO USE: INTELSAT ____ LOCATED AT ____ DEG. EAST. | | | |
|---|---|---|---|
| **Number** | **Name of the site** | **Location:** | **Applications** |
| | | Longitude | Latitude |
| 1 | HUB Station | | |
| 2 | VSAT 1 | | |
| 3 | VSAT 2 | | |
| 4 | VSAT 3 | | |
| 5 | VSAT 4 | | |
| 6 | VSAT 5 | | |
| .. | | | |
| .. | | | |
| N-1 | VSAT N-1 | | |
| N | VSAT N | | |

**Table C-2. Traffic Information for Voice Networks -- Number of Minute-Traffic per Destination[47].**

| NODE | 1 | 2 | 3 | 4 | 5 | 6 | TOTAL |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 161943 | 150139 | 1295144 | 95713 | 395774 | |
| 2 | 161943 | 0 | 719180 | 40701 | 1891282 | 197720 | |
| 3 | 150139 | 719180 | 0 | 84565 | 831489 | 241145 | |
| 4 | 1295144 | 40701 | 84565 | 0 | 247042 | 111363 | |
| 5 | 95713 | 1891282 | 831489 | 247042 | 0 | 174757 | |
| 6 | 395774 | 197720 | 241145 | 111363 | 174757 | 0 | |
| Total | 2098714 | 3010828 | 2026521 | 1778819 | 3240288 | 1120765 | 13,275,934 |

**Table C-3. Traffic Information for Voice Networks -- Number of Channels per Destination.**

| YEAR | 1 | 2 | 3 |
|---|---|---|---|
| Number of sites with 2 channels | 60 | 100 | 150 |
| Number of sites with 4 channels | 25 | 50 | 70 |
| Number of sites with 8 channels | | 20 | 30 |
| Total sites | 85 | 170 | 250 |
| Total number of channels | 220 | 560 | 820 |

*47 Minute-traffic is available from records of phone bills, switching centers, and other devices. The total number of channels in the right-most column will be used to calculate the total network requirements in terms of leased bandwidth, antenna sizes, and number of channels. Convert this information to number of channels using the guidelines in Chapter 4.*

**Table C-4. Traffic Information for Data Networks -- Number of Packets per Destination.**

| CLIENT | APPLICATION | T | $C_I$ | $C_O$ | $N_U$ | $N_{VSAT}$ | $T_M$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|
| A-; Bank | Account management and ATM transactions | 18000 | 100 | 400 | 5 | 75 | 4 | 2 |
| Insurance Co. | LAN to LAN interconnection [48] | 5800 | 60 | 300 | 25 | 15 | 3 | 2 |
| Manufacturing ABC, Inc. | Inventory control | 300 | 500 | 500 | 1 | 25 | 1 | 5 |
| Toys Retailers | Inventory control, Point-of-Sales (POS) operations | 15000 | 50 | 200 | 8 | 75 | 8 | 2 - 5 |
| Credits Unlimited | ATMs and Credit Card verification points | 50 | 40 | 100 | 10 | 50 | 0.5 | 2 - 5 |
| INTERNET Services Ltd. | Internet, Intranet for multiusers, corporations and universities. | n/a | 60 | 600 | 15 | 25 | N/A | 2 |

Where:

T: = Number of transactions per day

$C_I$: = Input characters per transaction in bytes

$C_O$ = Output characters per transaction in bytes

$N_u$: = Number of data terminals or end users per VSAT node

$N_{vsat}$: = Number of VSATs with providing the same application

$T_m$: = Transactions per minute in the PBH

$R_T$: = Response time (in seconds)

[48] *The LAN-to-LAN interconnection can handle several protocols and services like TCP/IP for Internet, voice over IP, desktop videoconferencing.*

**Table C-5. Example Format to Indicate Compliance with Technical Specifications. (To be completed by contractor).**

| **BIDDER'S NAME:** | | | |
|---|---|---|---|
| **Item:** | **Description:** | **Indicate Compliance:** | **Comments on page:** |
| CHAPTER 1 | GENERAL SPECIFICATIONS | YES | |
| 1.0 | General | YES | |
| 2.0 | Design requirements | YES | |
| 3.0 | Safety of Personnel | YES | |
| 4.0 | Protection of Equipment | YES | |
| 5.0 | Special Tools | YES | |
| 6.0 | Configuration of Electronic Equipment | YES | |
| 7.0 | Finishing | NO | |
| 8.0 | Components | | |
| 9.0 | Intersite Cabling | | |
| 10.0 | Environmental Requirements | | |
| 11.0 | Documentation | | |
| 12.0 | Spare Parts List | | |
| 13.0 | Software Packages | | |
| 14.0 | Training | | |
| 15.0 | Acceptance Test Plan | | |
| 16.0 | Warranty and Guaranty | | |
| 17.0 | Management Proposal | | |

A similar format MUST be followed for all chapters of the specifications.

***Note to the user:*** *While you are required to understand the basics of calculating the network size, the ultimate responsibility for delivering a network that is properly sized resides on the bidder or manufacturer. Therefore, make your estimates for the network size but do not try to calculate the network for the bidder. Rather, provide as much information on the applications as you can collect.*

## *C.3 General Specifications, Standards, and Requirements*

This chapter defines the general design requirements and applicable standards for the electrical, electronic, and mechanical equipment to be provided by the Bidders for the VSAT network in [_____][49].

### *C.3.2 Design Requirements*

**Design Life:**

A design life of [ (15) ] years is established as an overall network objective.

**Reliability:**

The overall design objectives and the operation and maintenance philosophy must ensure a minimum equipment availability of [99.99 percent], excluding the scheduled downtime.

**Equipment Type:**

All electronic equipment must be solid-state.

**Human Factors:**

Safety devices must be implemented so that false operation of any control does not entail damage to personnel or equipment.

[49] *Brackets indicate information or values that must be determined by the user.*

### C.3.3 Safety of Personnel

The following provisions must be met for the safety of personnel:

A. Safety shields must be provided over all moving parts in which personnel could become entangled or caught. This provision includes ladders and stairways.
B. All cabinets, racks, and chassis of all motors and generators, all external metal parts, meter cases, control shafts, and adjusting devices must be grounded.
C. Cautioning notes and appropriate labels must be provided where voltages are in excess of 300V peak A.C. or 300V D.C.
D. Earth devices (rods, etc.) must be installed to hang equipment racks or cabinets in areas in which voltages in excess of 240V exist.
E. Power cables must be segregated from cables carrying communications and control signals.
F. Cabinets and RF connections and all RF enclosures must be designed to protect personnel from radiation hazards.

### C.3.4 Protection of Equipment

Suitable protection devices must be provided in such a way that failure of any component or unit does not entail failure of other components or units.

### C.3.5 Earthing

Provide a complete grounding system for lightning protection, safety of personnel, and suppression of radio frequency interference. The value of Earth resistance must be [10 Ohms] for lightning protection and less than [1 Ohm] for system grounding. There must be isolation between the lightning and power grounding systems.

### *C.3.6 Radio Frequency Interference (RFI)*

**Internal:**

Any device used that produces RFI must be equipped with interference suppressing filters.

**External:**

The bidders must ensure that the selected locations will not be affected by RFI. If a location is affected by RFI, the bidders must provide alternate suggestions for consideration.

### *C.3.7 Special Tools*

The bidder must provide any special jigs, tools, fixtures and test equipment required for installation, assembly, disassembly, test, adjustment, or repair of any equipment or subsystem during regular installations or during maintenance.

### *C.3.8 Configuration of Electronic Equipment*

**Cabinets and Racks:**

The bidders must provide [standard 19-inch] racks.

**Chassis and Drawers:**

All drawers and chassis must permit frontal access to the components, wiring, connectors, and test points of any unit.

**Plug-in Units and Modules:**

The use of plug-in replaceable units or modules is preferred.

**Monitoring Facilities:**

All electronic equipment must have integral and/or remote monitoring facilities. Sufficient test points must monitor all circuit parameters.

**Spare space:**

All cabinets, racks, consoles, trenches, cable trays, etc. must have at least [25 percent] spare capacity for future use.

### *C.3.9 Finishing*

- The antenna reflective surface must be finished with a highly diffusive flat paint of the highest quality available.
- Outdoor equipment and surfaces must be properly protected from sand and dust storms and the corrosive effect of the atmospheric salt. Additionally, all outdoor equipment and surfaces must be painted or galvanized to avoid corrosion.
- All metal surfaces internal to the equipment and not normally visible must be suitably protected from corrosion.

### *C.3.10 Intersite Cabling*

- Intersite cabling must allow maximum flexibility to cope with further expansion and possible changes in the location of equipment.
- Cables and distribution frames must provide a minimum of [25 percent spare capacity for future needs].
- When conventional telephone-type terminal blocks are used, the wire connections must be wire-wrapped.
- All cables located in underground cable trenches must be installed in cable trays. The cable trays and their accessories must be protected against corrosion.

### *C.3.11 Pressurization of R.F. Transmission Lines*

- Wave-guides and air-dielectric coaxial cables must be pressurized with dry air to avoid any dust or entrance of moisture.
- At the very minimum, a compressor/dehydrator system must be provided with low pressure and humidity alarms.

### *C.3.12 Environmental Requirements*

The equipment provided must withstand the following conditions without degradation or service interruptions.

| | |
|---|---|
| Indoor Equipment[50] | Temperature: [ +0º C to +50º C ]<br>Relative humidity: [ up to 90 percent ] |
| Outdoor Equipment | Temperature: [ -40º C to +60º C ]<br>Relative humidity: [ up to 90 percent ] |

### *C.3.13 Documentation*

The bidder's printed material must follow these recommendations.

**General:**

The documentation must be offset printed, written in plain [ English ], and contain all pertinent descriptions of all equipment in the network.

**Copies:**

The bidders must provide at least [4] copies of all the documentation.

**Document List:**

The delivered documents must consist of:

- network manuals;
- installation manuals;
- system manuals;
- equipment manuals;
- equipment part list;
- wiring schematic diagrams;
- maintenance plans and procedures; and
- test reports, including in-plant, onsite, and acceptance tests.

[50] *Indicate the maximum and minimum temperatures for the location.*

## *C.3.14 Training*

**Introduction:**

The bidders must provide a training program consisting of theoretical and practical hands-on instructions to accomplish the following:

- To enable personnel to properly operate the system, and to perform system and network monitoring, measurements, testing, and in-service adjustments that are necessary for the system to maintain proper operating condition.
- To enable the personnel to maintain the system in its nominal operational status through a program of preventive and corrective maintenance.
- To enable the personnel to properly install new terminals and to accomplish system reconfigurations and growth.

The training must be in [ _______ ] (language).

Printed training materials must be in [ English].

The training must consist of:

- System Training
- Operations and Maintenance Training
- Practical Training

The scope of the training is discussed below:

**System Training at [LOCATION]:**

- **[ XX ]** weeks duration at [ **LOCATION** ] for [ **YY** ] participants.

The system training program must address the following objectives.

- Subsystem and equipment configuration
- Subsystem and equipment operation
- Subsystem interconnection and interfacing
- Commissioning and integration with existing network
- Procedures for installation

- Failure diagnosis and modules repair

**Operation and Maintenance Training at [ LOCATION: ]**

- **[ XX ]** weeks duration at **[ LOCATION ]** for **[ YY ]** participants.

The system operation and maintenance training program must address the following basic requirements.

- Configuration
- Subsystem operation and maintenance
- Installation procedures
- Failure diagnosis and corrective maintenance
- Emergency procedures
- All operational procedures

**Practical training at [ LOCATION: ]**

The bidder's installation and commissioning crew must provide On-the-Job Training (OJT) to customer technical personnel during the installation and commissioning phases.

### *C.3.15 Acceptance Test Plan*

A series of formal acceptance tests must be organized to verify the correct functioning of the equipment. The test must demonstrate that actual performance meets specifications with a sufficient margin of error. Test procedures must be proposed by the bidders, but analyzed by the **[ CUSTOMER.]**[51]

An individual sent by the [CUSTOMER] and/or their representatives will witness all tests. All necessary test equipment must be provided by the Bidder, who must be able to demonstrate its correct calibration. Moreover, the **[ CUSTOMER ]** has the right to verify the equipment and to call for repetition of one or more tests if the results are inconclusive.

> **Note:** The acceptance tests must demonstrate that the subsystems, equipment, and units have not suffered from its transport and final integration on-site, and that they comply with the SOW and planned applications.

[51] *Replace [customer] with company name.*

Final acceptance, end-to-end commissioning and line-up tests must also be conducted with the support and the participation of the **[CUSTOMER'S ]** staff. Final acceptance tests must include live applications demonstrations via the VSAT network.

### *C.3.16 Warranty and Guaranty*

The bidders must provide warranty for the replacement of faulty equipment for a minimum period of [ (18) months]. The bidder must guarantee that major faults will not occur for a minimum period of [12 months] after successful completion of the provisional acceptance. Any replacement, within the stated timeframe must be done free of charge.

### *C.3.17 Management Proposal*

The bidder must submit a management proposal. The proposal must contain a detailed description of the methodology to be used to manage the implementation of the VSAT network. This proposal must identify the bidder's schedules and organization to implement the project, and must contain adequate text with supporting graphics (charts, diagrams, etc.) to clearly demonstrate the bidder's complete understanding of the requirements, and the capability to fulfill them in a logical manner within the contractual schedule.

The project management plan consisting of:

- work breakdown structure;
- major milestone schedule;
- project implementation schedule;
- critical path schedule;
- project organization chart; and
- manpower loading schedule.

## *C.4 Technical Specification for the Hub RF Electronics and Antenna Subsystem*

These technical specifications address the requirements of the hub station. The hub will be the gateway for the VSAT network and will include the function of traffic hub and network management and control. The bidder must install the hub at [_____________ ] as indicated in the SOW.

### *C.4.1 General Specifications*

**ANTENNA DIAMETER:**

[ ≥ **INDICATE SIZE** ] in meters, as required to achieve the G/T.

**ANTENNA BASIC FUNCTIONS:**

The antenna must have continuous tracking, and
[ C (or Ku) ]-band transmit and receive capabilities, and must conform to any applicable INTELSAT IESS and ITU-R standards.

**FIGURE OF MERIT (G/T):**

≥ **G/T** [52] + 20 $\log_{10}$ F/11 ... dB/K for Ku-band.

≥ **G/T** + 20 $\log_{10}$ F/4…dB/K for C-band.

[52] *Select G/T using the following values:*

| *C-Band std.* | *d [m]* | *G/T (dB/K)* |
|---|---|---|
| *H-2* | *1.8* | *15.1* |
| *H-3* | *2.4* | *18.3* |
| *H-4* | *3.5* | *22.1* |
| *F-1* | *4.5* | *22.7* |
| *F-2* | *7.2* | *27.0* |
| *F-3* | *9.0* | *29.0* |

| *Ku-Band std.* | *d [m]* | *G/T (dB/K)* |
|---|---|---|
| *K-2* | *1.2* | *19.8* |
| *K-3* | *1.8* | *23.3* |
| *E-1* | *2.4* | *25.0* |
| *E-2* | *3.5* | *29.0* |
| *E-3* | *5.5* | *34.0* |

The antenna must meet or exceed the G/T under any elevation angle above 10 degrees.

**OPERATING FREQUENCY BAND:**

Transmit: C (or Ku) -band

Receive: C (or Ku) -band

### *C.4.2 Antenna and Tracking Subsystem*

The hub antenna must have a tracking system consisting of the following blocks.

1) Antenna Drives and Servo
2) Antenna Control Subsystem
3) Antenna RF Subsystem

The antenna and tracking subsystem must be capable of operation from an Antenna Control panel. The panel must include alarms, remote controls, meters, and monitoring indicators.

#### *C.4.2.1 Antenna Structure*

The antenna must meet the following requirements:

**Angular travel:**

Azimuth: ± 180 degrees from the north, in segments of 80 to 120 degrees.

Elevation: +5 to +85 degrees

**Antenna Foundation:**

[If the CUSTOMER will build the foundation, the bidder must provide specifications for the structure.]

### *C.4.3 Antenna Drive and Servo*

An automatic tracking system must follow these specifications.

**Slew Velocity:**

[≥ 0.08 degree] per second with drive to STOW capability under 130 Km/h winds.

**Tracking Pointing Rates:**

[≥0.01 degree ] per second with acceleration in each axis and simultaneous axis operation.

**Tracking Pointing Accuracy:**

Better than [0.025 degree]

**Antenna Position Readout:**

With a resolution of 0.01 degree for elevation and azimuth.

**Antenna Safety Features:**

The Bidders must provide appropriate safety features such as brakes, stowing devices, buffers, or mechanical stops, interlocks, RF, and AC power disconnect switches, grounding, disable switches, and battery powered emergency lights, lighting (automatically controlled aircraft warning lights), and other devices needed to ensure safety of personnel and proper operations.

### *C.4.4 Antenna Control Subsystem*

The Antenna Control Unit (ACU) must provide an integrated capability for controlling the antenna in all operational and maintenance modes.

**Operational Modes:**

- Autotracking
- Manual Tracking
- Program Tracking with provision for entering the 11-Ephemeris parameters from INTELSAT

**Controls and Indicators:**

The following minimum controls and displays must be available at the ACU.

- Antenna angle digital displays for both axes
- Relative beacon signal strength
- Pre- and final-limit indicators for both axes
- Low elevation cutoff indicator
- Manual positioning controls for both axes
- Limit control override
- Operational mode control and display

**Beacon frequencies:**

The network will operate in INTELSAT [ ________ ] Satellite.

Refer to IESS documents for the pertinent INTELSAT satellite.

### *C.4.5 Antenna RF Performance*

**Side Lobes: Polarization:**

[Circular (or Linear) ] as dictated by the satellite to be used.

**Polarization Isolation:**

$\geq$ 30 dB within the 1 dB contour of the antenna pattern in any plane and any frequency of the operating band.

**Axial Ratio:**

[$\geq$ 1.09 for C-band antennas]

[ ($\geq$ 31.6 for Ku-band antennas) ]

Transmit & Receive:

$G = 29 - 25 \log \theta$ dBi, $1° \leq \theta \leq 20°$

$G = -3.5$ dBi, $20° < \theta \leq 26.3°$

$G = 32 - 25 \log \theta$ dBi, $26.3° < \theta \leq 48°$

$G = -10$ dBi, $\theta > 48°$

Where: G is the gain of the sidelobe envelope relative to an isotropic antenna in the direction of the geostationary orbit in dBi.

**Feed pressurization:**

Provide pressurization with a dew point at -40° C, and provide low pressure alarms.

**TX/RX Isolation:**

85 dB minimum

### *C.4.6 Environmental Conditions*

The antenna must be capable of supporting the environmental conditions stated in Table C-6.

**Table C-6. Environmental Conditions.**

| | OPERATION WITHIN SPECIFICATIONS | HOLD IN ANY POSITION | DRIVE TO STOW | SURVIVAL WITHOUT DAMAGE* |
|---|---|---|---|---|
| Wind | 50 km/h**<br>Gusting 72 km/h (3ΣÍ)***<br>72 km/h | 120 km/h | 130 km/h | 200 km/h (no ice)<br>100 km/h (4 cm radial ice) |
| Rain | 16 cm/hour | | | |
| Snow | 1 cm water equivalent per hour | | | |
| Seismic | | The station must be able to survive earthquakes of Intensity IX (Mercalli modified with a 50 km/h wind). | | |
| Solar Radiation | | 350 BTU per square feet | | |
| **HUMIDITY** | | 0 to 100 % | | |
| **TEMPERATURE** | | -10° C to +50° C | | |

**(Survival stresses must not exceed those allowed by the applicable documents; i.e., AISC, ACI, ASCE, etc.).*
*** Wind velocities are the fastest kilometer values.*
****Gusts are 3 sigma values. The 1 sigma value is the standard deviation for a normal distribution of wind gusts about the fastest kilometer wind and 3 sigma represents the peak gust.*

### *C.4.7 Receive Subsystem*

The receive subsystem (if required), must contain line amplifiers (LNA), and cables, etc. The receive chain must perform as follows.

**Type of Amplifiers:**

Uncooled FET

**Configuration:**

[ 1:1 (but 2:1 preferred) ]

**Bandwidth:**

[ C-band (or Ku-band) ]

**Gain:**

60 dB

**LNA Noise Temperature:**

To meet the proposed G/T

**Resistance to Overload:**

Designed to withstand prolonged overload to input level up to 0 dBm

**Control Panel:**

Must provide power supply, status, and switching condition indicators

### *C.4.8 Transmit Subsystem*

The transmit subsystem must consist of High Power Amplifiers (HPAs), and waveguide runs. The HPA must provide the following performance:

**Frequency bandwidth:**

[ C-band (or Ku-band) ]

**Configuration:**

[ 1:1 ]

**Gain Control:**

Continuous over a 20 dB range

**e.i.r.p.:**

[Consistent with stated transmission performance]

**e.i.r.p. Stability:**

±0.5 dB/24 hours

**Group Delay in any 40 MHz band:**

Linear: ±0.25 ns/MHz

Parabolic: ±0.05 ns/$MHz^2$

Ripple: 5 ns p-p max

**Harmonic Outputs:**

60 dB below carrier with maximum output power

**Meters and controls:**

RF output power

RF input power

RF reflected power

Prime power on

Transmit or RF Inhibited

Standby

**Alarms:**

Low RF power

Equipment failure

Summary fault

**Cooling:**

Air-cooled

**Switches:**

Electronically and manually controlled with isolation better than 60 dB

**Control panel:**

Must indicate the switches' status and amplifiers' alarms

## C.5 Specifications of the Ground Communications Equipment (gce)

This section sets forth the technical specifications applicable to the equipment to be supplied and installed by the Bidders as GCE at the hub location.

### C.5.1 Transmit Subsystem

The transmit subsystem comprises the equipment between the output of the modems, and the input of the SSPAs. It includes the following parts.

- RF combiner
- Up converter subsystem
- IF combiners
- IF and RF patch panels

#### C.5.1.1 RF Combiner

The input of the SSPAs must be equipped with a RF combiner to add the signals from several up-converters.

**Number of inputs:** [4].

**In case of a two-polarization operation:** Provide a combiner for each polarization.

### *C.5.1.2 Up Converters*

**IF frequency:** [70 or 140 MHz].

**IF bandwidth:** [40 MHz minimum].

**RF frequency range:** [C-band (or Ku-band)].

**Frequency stability:** $\geq \pm 2 \times 10^{-8}$ per month and $\pm 5 \times 10^{-8}$ per day over temperature ranges from 0 C to 45 C

**Output level:** Adjustable over a range of +10 dB to -20 dB around the SSPA saturation drive level

**Phase noise:** Consistent with INTELSAT document IESS 308.

**Amplitude response:** ± 0.5 dB at ±36 MHz.

**IF/RF group delay:** ± 2ns at ± 24 MHz and ± 4ns at ± 36 MHz

**Frequency synthesizer step size:** 1 MHz

**Gain stability:** better than ± 0.5 dB per day over temperature ranges of 25 C ± 10 C.

### *C.5.1.3 IF Combiners Network*

The Bidders must supply an IF combiner network that combines the outputs of modulators within a contiguous IF band for the interconnection with the frequency up-converters. The IF combiner must have a minimum of 50 percent of free input ports. The combiner network must be rack-mounted on a front panel plate above the up-converters.

### *C.5.2 Receive Subsystem*

The receive subsystem comprises the equipment between the output of the LNAs, and the input of the modems. Receive subsystem includes the following parts:

- RF dividers
- Down converters
- IF dividers

#### *C.5.2.1 RF Dividers*

The Bidders must supply a RF divider network that divides the entire receive frequency band into an appropriate number of ports with equal level and performance.

The proposed dividers must be [ 1:4 ] for each polarization with 50 percent of unused ports.

#### *C.5.2.2 Down-Converter Performance*

**Frequency band:** [ C-band (or Ku-band) ].

**IF center frequency:** [ 70 or 140 MHz ].

**IF bandwidth:** 40 MHz minimum.

**Phase noise:** Compliant to IESS-308 Rev. 7.

**Frequency Stability:** $\pm 2 \times 10^{-8}$ per month and $\pm 5 \times 10^{-8}$ per day.

**Output:** -15 to +10 dBm.

#### *C.5.2.3 IF Dividers Network*

The Bidders must supply an IF divider network that provides the inputs to the demodulators for the interconnection with the frequency down converters. The IF dividers must have a minimum of eight (8) output ports. The divider network must be rack-mounted on a front panel plate above the down-converters. Type BNC Connectors must be used with coaxial cables as patching cords.

The Bidder must provide detailed schematics about this proposal.

### C.5.3 Terrestrial Interface

**VOICE NETWORK—DAMA TERMINAL**

***The following information is provided for a voice network.***

At the hub, the DAMA terminal must consist of the DAMA channel equipment, the DAMA network controller, and the operator's interface. At the VSAT, the DAMA terminal will consist of the DAMA channel equipment. The requirements for each unit follow.

### C.5.3.1 DAMA Channel Equipment at the Hub

The bidder must supply DAMA channel equipment that uses FDMA/SCPC access and has the following characteristics.

**IF interface:** Consistent with the frequency converter IF.

**Output IF power:** Variable in steps of 1 dB, with individual TX ON/OFF control for each channel.

**Input IF level:** Variable from -50 to -30 dBm.

**Modularity:** The equipment must be modular to allow future expansion. The bidder has to explain how the equipment will expand.

**Built-in IF combiner/divider:** The chassis must include a 1:4 combiner/divider.

**Power supply:** either 48 VDC or 120/240 VAC 60 Hz.

### *C.5.3.2 DAMA Voice Channel Unit (VCU)*

Each VCU must comprise the modem, filtering, voice compression, and baseband interface with the following characteristics.

**Operating Frequency Range:** 70 ± 18 MHz or 140 ± 36 MHz for TX and Rx

**Modulation:** BPSK/QPSK

**FEC:** Convolutional encoding - Vitervi decoding, rate 3/4 and ½

**Data Scrambler/Descrambler:** V.35

**Voice Compression:** 4.8 to 16 Kbit/s

**Compression Algorithm:** VSELP, CELP, RELP, or IMBE.

**Voice Activation (VOX):** Yes. With VOX ON - VOX OFF selection

**Facsimile Handling:** Group 3 facsimile demodulation - remodulation.

**Echo Cancellation:** Built-in with 16-m sec of tail delay.

**Signaling:** The VCU must handle R1 and R2 signaling as well as DTMF signaling via a 2-wire interface.

**Telephone Side Interface:**

4-wire E&M types I to V.

2-wire loop start and connector RJ- 45.

It is preferred to have an E-1 interface to the PST rather than 4-wire interfaces at the hub.

**Audio Bandwidth:** 300 ~ 3400 Hz.

**Telephone Side Interface Impedance:** 600 Ohm.

Optional features: The bidder is invited to provide these optional features to the proposed equipment. They are not mandatory features but the [**CUSTOMER** ]will consider them for future expansion of the network.

**Data capabilities:**

The VCU must provide capabilities to transmit synchronous and asynchronous data on-demand.

**Data interface:**

RS-422/449, V.35, RS-232C or G.703.

**Data rate:**

[4.8 to 192 Kbit/s].

### *C.5.3.3 DAMA Network Controller*

The DAMA network controller's primarily purpose is to support the DAMA incoming and outgoing control channels (CCs). The controller must have the following characteristics:

**Mode of operation for the control channels:**

Outgoing CC: permanent TDM stream

Incoming CC: Aloha or S-aloha

**Control channel rate:**

[TBD by bidder]

**Call set up time:** < 3 seconds

**Call tear down time:** < 3 seconds

**Link power control:**

The network controller must provide real-time link quality monitoring to dynamically adjust the system uplink power to overcome the rain attenuation. [ (Applicable for Ku-band networks) ]

**Redundancy:** See 3.4.5.

**Network controller functions:**

- Control the operation of all VSATs.
- Control the configuration of the DAMA VSAT terminals.
- Maintain the network operation.
- Control the call set up and tear down, call routing, call statistics, and to perform test calls.
- Assign satellite frequencies and manage the resources.
- Monitor the VSAT status.
- Select frequency for CC and VCUs.
- Reset system and components.
- Control the in-service, out-of-service, and maintenance state of the VSAT terminals.
- Monitor detailed traffic status and statistics.
- Modify parameters associated with configuration.
- Add/Delete network terminals or components.

**PC requirements:** TBD by bidder

**Operating system:** TBD by bidder.

### *C.5.3.4 Operator interface*

The operator interface will provide the operator with the network information, and allow for the configuration, monitoring, and control of the network.

**Purpose:** Provide the operator with an interface to configure, monitor, and control the DAMA network.

**Display:** Color oriented graphical display with a series of windows showing the different functions of the system.

**Menu presentation:** Drop down menus or buttons for mouse selection.

**Language:** [ English. Quote prices for a Spanish or French text display ].

**Functions:**

At a minimum, the interface must show the following.

- Customer records including profiles of all VSAT services
- Satellite traffic statistics
- Site record including geographical locations, configuration, and status
- Module port definition at each terminal
- Operator records including profiles and access privileges
- Alarms records

**Remote access:** The operator's interface must provide the capability of remotely controlling the network. To this aim, the bidder must provide a laptop computer with a modem and the required software.

### *C.5.3.5 Redundancy Requirements*

The Bidder must provide the MTBF figures of all major GCE system components and the detailed computations to evaluate the overall availability performance of this subsystem.

The bidders must demonstrate that the redundancy scheme of the proposed GCE system must meet the availability objectives set forth in the SOW. The bidders must fully describe the power supply arrangement and demonstrate the reliability figure of these modules.

The Bidder must state any particular operational constraints caused by the proposed redundancy scheme.

### *C.5.3.6 DAMA Terminal at the VSAT Terminals*

The specifications are the same as in C.4.2 above.

## *C.6 Power Subsystem*

The power supply will be provided by [**CUSTOMER**]. The bidder will be responsible for:

1) distributing the power in the hub equipment;
2) connecting the power to the VSAT terminals; and
3) indicating the load requirements to [CUSTOMER].

## *C.7 Station Control and Supervisory Facilities*

This section outlines the requirements for station control and supervision of the Earth station subsystem.

### *C.7.1 Purpose*

The bidder must provide an operation and control console. The purpose of the operation console is to gather, within the same operational room, the control and monitoring information of all the subsystems comprising the Earth station. A single person should accomplish all operation and control of the network.

### *C.7.2 General Description*

The Bidders must provide an integrated functional Station Control Facility (SCF). The bidder will optionally decide whether this facility is an integral part of the DAMA network controller.

### C.7.2.1 Station Status and Alarms

The bidder must provide the ability to indicate station status, i.e., units in operation, and readiness of standby equipment. Indicators and alarms must cover all essential operations of the Earth station, including at least the following.

- Antenna and tracking subsystem indicators and alarms
- Equipment status (online, standby, maintenance, failure, and jack-out) for all signal paths in the transmit or receive chain, with alarms upon any path failure, including DAMA equipment
- Operation status of nonredundant equipment (i.e., satisfactory operation, ready to operate, failed)

### C.7.2.2 Switching and Controls

The switching and control capability must include at least the following functions.

- Ability to manually switch to stand-by equipment, in case of failure of in-service equipment, loss of power or signal, degradation of performance, etc.
- Remote and local switching must be controlled at the local position and indicated at both locations.

### C.7.3 Alarms and Summary Indicators

Equipment for remote control through the operator's console follows:

- antenna and tracking subsystem
- tracking converter/receiver
- High Power Amplifiers (HPAs)
- up-converter subsystem
- Low Noise Amplifier (LNA) power supply and switches
- down converter
- DAMA equipment (alarms only)
- Earth station facilities like air conditioning, pressurizer

### *C.7.4 Computerized Control and Monitoring Subsystem (CCMS)*

The operation console must include a Computerized Control and Monitoring System terminal.

**Note:** The Computerized Control & Monitoring System must incorporate spare capacity to accommodate future expansions of the equipment. The bidders must indicate the spare capacity available.

### *C.7.5 Weather Station*

The operation console must include a weather station terminal that indicates outside temperature, humidity, wind speed, and direction.

It must be possible to set an alarm by the operator for wind speeds exceeding 50 Km/h.

The range of measurements must be from 0 up to 250 Km/h.

## *C.8 VSAT Terminal Specifications*

The VSAT terminal comprises the far-end equipment to provide the telecommunications services, and consists of an antenna, outdoor equipment, and interfacility cables to connect to the VSAT-DAMA terminal. It must adhere to the following specifications.

**Channels per VSAT:** [2 or 4 channels] with capabilities to expand to [4 and 8 channels].

**VSAT antenna size:** [2.4 m or smaller]

**Operating frequency:** [C-band (or Ku-band)]

**Figure of merit (G/T):** TBD by bidder

**Polarization:** To be compatible with INTELSAT satellite

**Transmit side lobes:**

Transmit & Receive:

$G = 29 - 25 \log \theta$ dBi, $1° \leq \theta \leq 20°$

$G = -3.5$ dBi, $20° < \theta \leq 26.3°$

$G = 32 - 25 \log \theta$ dBi, $26.3° < \theta \leq 48°$

$G = -10$ dBi, $\theta > 48°$

Where: G is the gain of the sidelobe envelope relative to an isotropic antenna in the direction of the geostationary orbit in dBi.

**Polarization isolation:** ≥ 26 dB within the 1 dB contour of the antenna pattern in any plane and any frequency of the operating band

**Axial ratio:** ≥ 20

**Polarization ports:** 2 switchable ports

**Tracking:** NO

**Outdoor unit functions:** Power amplifier, LNA, and frequency converters

**Outdoor unit power rating:** [TBD by bidder]

**IF output frequency range:** 70 or 140 MHz

**Supporting structure:** [Any.  Roof top nonpenetrating preferred]

**Environmental conditions:**

| | |
|---|---|
| Wind load: | 55mph |
| Temperature: | -5 $^{o}$ C to +50 $^{o}$ C |
| Rain: | 1/2 inch/hour |
| Atmospheric conditions: | Salt and pollutants as in coastal or industrial areas |
| Solar radiation: | 360 BTUs/hour/foot$^2$ |

### *C.9 Test and Measurement Equipment*

*Use the following list only as a reference. Bidders must list minimum measurement sets required by their own configuration:*

1) [Spectrum Analyzer]
2) Frequency Counter]
3) [IF Noise Generator]
    - [Opt. 2 110 dB Attenuation in 1 dB step]
    - [Opt. 4 Combiner for Input Signal]
    - [Opt. 8 BNC Remote Output Connector]
    - [Opt. 10 1-dB Attenuation in 0.1 dB Steps]
4) [Fixed Attenuation Set ]
5) [Selective Level Meter]
6) [Level Generator]
7) [Power Meter and Sensor]
8) [Frame Analyzer]
    - [Opt. 2048 Kbit/s Generator]
    - [Opt. Bit Error Measurements]
    - [Opt. Printer Paper]
    - [Opt. Transcript Case TPK-3]
9) [Digital Multimeter]
10) [Set of Accessory and Cables]
    - [10 dB, 20 dB Coaxial Couplers]
    - [BNC, N, SMA Transitions]
    - [Waveguide Couplers]
    - [Circulators]
    - [and 50 Ohm dummy Loads]
    - [Waveguide Term]
    - [50 Ohm Connecting Cables with BNC, N, Ends]
    - [75 Ohms Connecting with BNC Ends]
    - [Tool Kits]
    - [Test Translator (14 to 11 GHz) or 6 to 4 GHz]

### *C.10 General Specifications*

In general, the network must comply with all the <u>mandatory and</u>

recommended specifications below. Even if these were not explicitly defined in the paragraphs above.

INTELSAT Earth Station Standards (IESS)

IESS No.207 (or 208) Standard A, B, F & H. Wideband RF Performance Characteristics of C band Earth Stations accessing the INTELSAT space segment. (or Standard C & E. Wideband RF Performance Characteristics of Ku band Earth Stations accessing the INTELSAT space segment).

IESS No 401 Performance Requirements for Intermodulation Products Transmitted from INTELSAT Earth Stations (6 and 14 GHz Frequency Bands).

IESS No 402 Earth Station e.i.r.p. Adjustment Factors to Account for Satellite Antenna Pattern Advantage and Path Loss Differential with Elevation Angle (k1 and k2).

IESS No 412 Earth Station Pointing Data:

IESS No 601 Performance characteristics for Earth Stations accessing the INTELSAT space segment for international and domestic services not covered by other Earth station standards.