Overview of VSAT system

I. Introduction

VSAT (Very Small Aperture Terminal) describes a small terminal that can be used for two-way communications via satellite. VSAT networks offer value-added satellite-based services capable of supporting the Internet, data, video, LAN, voice/fax communications, and can provide powerful private and public network communication solutions. They are becoming increasingly popular, as VSATs are a single, flexible communications platform that can be installed quickly and cost efficiently to provide telecoms solutions for consumers, governments and corporations. The benefits of VSAT technology are being realized in many sectors, both private and public. From banks to administrations, schools, hospitals and rural telecommunications, VSATs are being seized upon to elevate economic, educational, and health standards. VSATs have been in use for more than 20 years and, with already millions installed all over the world, VSATs are a mature and proven technology. VSAT comprises of two modules viz. an outdoor unit and an indoor unit. Outdoor unit mainly houses Antenna, feed horn,RF Transceiver,LNA,Power amplifier. The antenna size is typically 1.8 or 2.4 meter in diameter, although smaller antennas are also in use. The indoor unit functions as mux-demux, modem and interfaces with the end user equipments like PCs, LANs, Telephones or an EPABX. Following diagram describes typical schematic consisting various VSAT subsystems.

[1] VSAT outdoor unit

The Outdoor unit is usually mounted near the antenna systems outside hence the name. It consists of RF frequency converters (Up/Down converter), Power Amplifier, Low Noise Amplifier (LNA), OMT and Antenna system. The Up/Down converters convert frequencies IF to RF frequencies and vice versa. For example, Up converter converts 70MHz to 6175 MHz and Down converter converts 3950MHz to 70MHz for C band application. Power Amplifier will amplify the signal before transmitting to the feed horn of the Antenna system. LNAs are designed to amplify the noise added received signal received from the satellite. It is designed such that it will amplify the signal and not the noise. Noise temperature defines LNA performance. Antenna system houses reflector,feed horn,mount and cables. VSAT antenna usually varies from 1.8 meters to 2.4 or 3.8 meters. Feed horn is mounted at focal point of the antenna. The feed horn guides transmitted power towards the antenna.

[2]VSAt indoor unit

The IDU consists of MUX/DEMUX, EDU (Encryption Decryption Unit), modem (modulator-demodulator). MUX will interface with end user equipments viz. telephone, computers and sometime with EPABX and LAN or router, if it has to carry more information. MUX will multiplex all the channels connected with it using TDM. On receiver side DEMUX is used to de-multiplex the channels and passed on to respective end user equipments. EDU is basically the Encryption-Decryption unit which provides security by modifying the information to be transmitted. On receiver side encryption technique will be conveyed so that the information can be retrieved back again. MODEM is basically performs modulator-demodulator functionality on transmit and receive side respectively. Modulator inserts information on intermediate frequency (IF), usually called carrier.

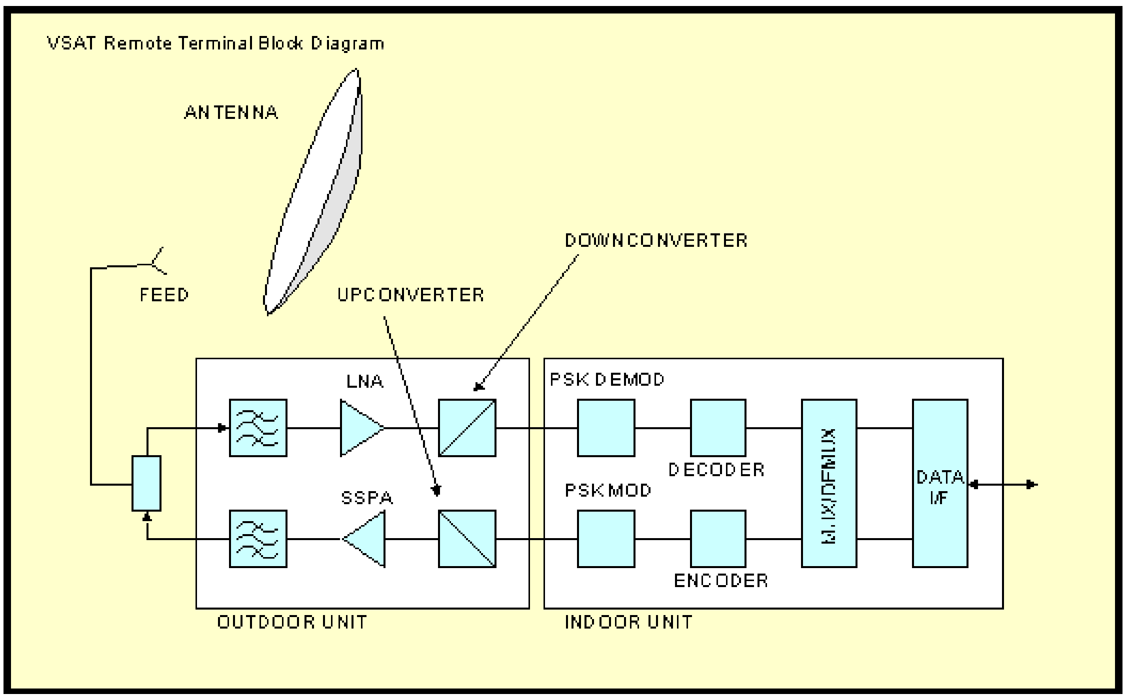


Figure (2): components of outdoor and indoor units.

This is done based on modulation scheme set. Usually QPSK scheme is used in satellite communication and Forward Error Correction is also employed in modem which enhances the BER for the same transmitter power usually used in non-FEC systems. In order to communicate between VSAT 1 and VSAT 2, modulator frequency of VSAT 1 and demodulator frequency of VSAT 2 need to be same and vice versa to complete full duplex communication channel. Based on frequency assignments as per FDMA various modem and RF frequency converters are set.

I. VSAT Features

VSAT networks uses very small dish antennas therefore, in order to employ the 6/4 –GHz frequency band it has to utilize the spread spectrum also called CDMA code division multiple access) technique to reduce the signal power spectral density. This is due to the interference produced for using the same band as terrestrial microwave transmission does. Alternatively the 14/12 GHz frequency band may be utilized (if available) which provide satellite capacity with much more efficiency although as we know, with the rain as old enemy. Star VSAT network at 2-Mbps are now available using Single Channel Per Carrier (SCPC) access which is provided by most of the vendors however, occasionally , TDMA (Time division multiple access) technique is also used. VSAT are connected by radio frequency link via satellite. Those links are radio frequency link with a so-called uplink from the station to the satellite and so-called downlink from station to station, sometime called hop consists of an uplink and downlink.

1. Ability to target small dish audiences from space and meet specialized services requirements.
2. High powered, fully steerable Ku-band spot beams
3. Applications include POS, banking, SCADA, LAN/WAN networking internet /intranet, video conferencing , remote site networking .
4. End users with 90cm to 120 cm dish can downloaded internet data 20 times faster than PSTN.
5. **Uplink**

   A radio frequency link is modulated carrier conveying information. Basically the satellite receives the uplink carriers from the transmitting earth station within the field of view of its receiving antenna
6. **Downlink**

   Within the field of view Transponder amplifies those carriers, translates their frequency to a lower band in order to avoid possible output/input interference, and transmits the amplified carrier to the station located of its transmitting antenna.
7. **Vsat frequency band**

   VSATs operate in the Ku band and C band frequencies. As a rule of thumb C- band (which suffers less from rain attenuation but requires larger antennas) is used in Asia, Africa and Latin America. Ku-band (which can use smaller antennas but suffers from rain fade in monsoon like downpour) is used in Europe and North.

Advantagesof VSAT technology .

- Full availability –all sites on the same network .
- Flexible network topology –easy to add , relocate or deleted sites.
- Transmission cost not distance dependent as with terrestrial network.
- Predictable cost.
- One point of contact for all network issues.
- More cost-effective than leased or dedicated phone lines to remote location .
- Performance is insensitive to terrain or distance.
- Cost effective emergency backup for critical data flow.

VSATs Network Architecture

VSATs are connected by radio frequency(RF) links via a satellite, with a so-called uplink from the station to the satellite and a so-called downlink from the satellite to a station,The overall link from station to station, sometimes called hop, consist of an uplink and a downlink. A radio frequency link is a modulated carrier conveying information.From any telecommunication services there are three basic implementation services:

1. One-way
2. Split-two-way
3. Two-way implementation.

Futherdivision of two-way implementation are star and mesh network architectures.

1.One-Way implementation:

One-way implementation mode of satellite is used in the BSS(broadcast satellite service).This digital technology allows the user and provider much flexibility in the operation of broadcasting.

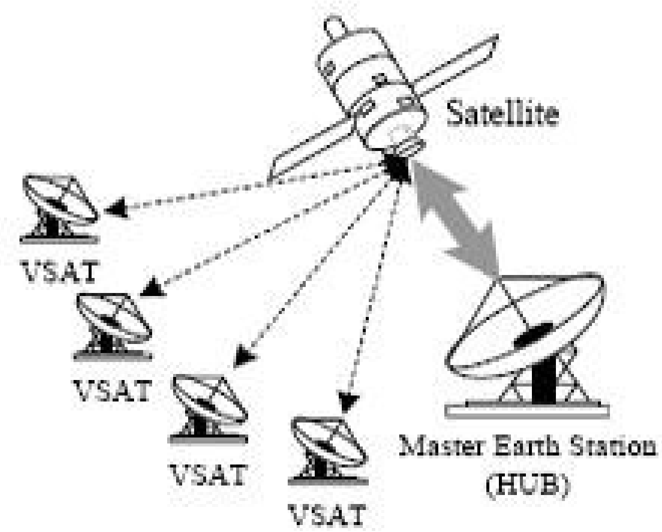


Fig.One-way implementation.

By using different software in the user terminal, different subscriber can access different parts of the downlink according to programs offered by supplier. This channel selection from is called narrowcasting.

2.Split-two-way:

This implementation is used when there is no normal return channel as,e.g. The KU-BSS system that carry internet traffic.From the user end terminal uplink capability is not complemented by high capacity downlink stream relatively.If the BSS downlink is used as the download channel from an ISP(Internet service provider), the only option left for users return link is via another telecommunications channel, such as telephone line.

The internet protocol is therefore split between terrestrial telephone channel and satellite downlink channel.VSAT terminal does not require a transmit capability due to this approach, which significantly reduce its complexity and cast.The disadvantage of this approach is that the terrestrial telephone connection must usually be through a modem, with a bit rate generally less than or 56kbps.

3. Two-Way implementation:

A return link is designed in this implementation method so that two-way communication can be set up over the same satellite, from the user to hub and from the hub back to the user.The architecture selected is the key to the economics of two-way connection; it can be either star or mesh.

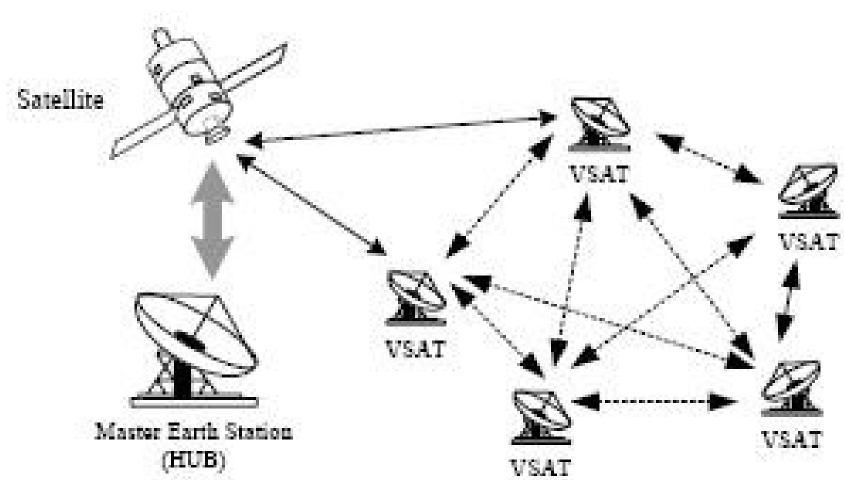
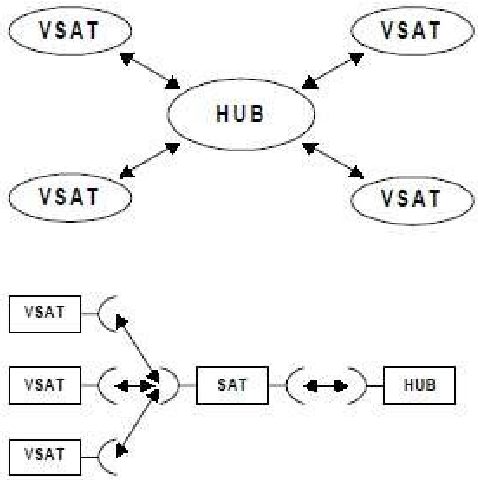
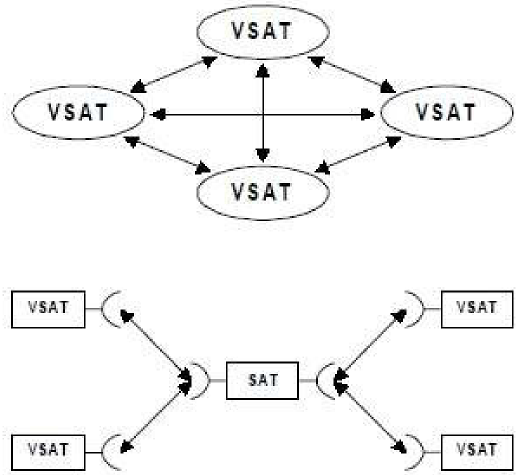


Fig.Two-way implementation.

Basically, the satellite receivers the uplinked carriers from the transmitting earth sations within the field of view of its receiving antenna, amplifier those carriers, translates their frequency to a lower band in order to avoid possible output/input interference and transmits the amplified carriers to the station located within the field of view of its transmitting antennaVSAT network architecture is the way Hub station and/or VSATs are interfaced with satellite to provide the services.



VSAT STAR NETWORK



VSAT MESH NETWORK

Star Topology:

In star topology, there are three entities hub station,VSATs and satellite.All the communication between VSATs happen through Hub station; hence,here if VSAT1 and VSAT2 need to communicate then link is VSAT1-satellite-Hub-Satellite-VSAT2.Hence,two-hop communicate between anytwo VSATs in the network. The star-shape network comprise N VSATs and a hub. The most popular of these is star topology. Here we have a big, central earth-station known as the hub.

Generally, the hub antenna is in the range of 6-11 meter in diameter. This hub station controls,monitors and communication with a large number of dispersed VSATs.Since all VSATs communicate with the central hub station only, this network is more suitable for centralized data applications.Large organization, like banks, with centralized data processing requirements is a case in point.Every VSAT can transmit up to K carriers, corresponding to connections between terminals attached to the VSAT and the corresponding application at the host computer connected to the hub station.

Mesh Topology:

In Mesh topology,VSATs can communicate with one another directly and no Hub station is needed. But, each VSAT need to be complex owing to more functionality required similar to the hub station. Also antenna specification need to be different than star type of topology.The meshed network comprises N VSATs. Every VSAT should be able to establish a link to any other one across the satellite.

In a mesh topology, a group of VSATs communicate directly with any other VSAT in the network going through a central hub. A hub station in a mesh network performs only the monitoring and control functions. These network are more suitable for telephony application. These have also been adopted to deploy point to point high speed links.

Access control protocols

The international standard organisation (essentially of standard committee of the United Nations) has specified the open system interconnection(ISO/OSI) that mandates a seven layer model for a data communication system,as shown in given fig.(a)

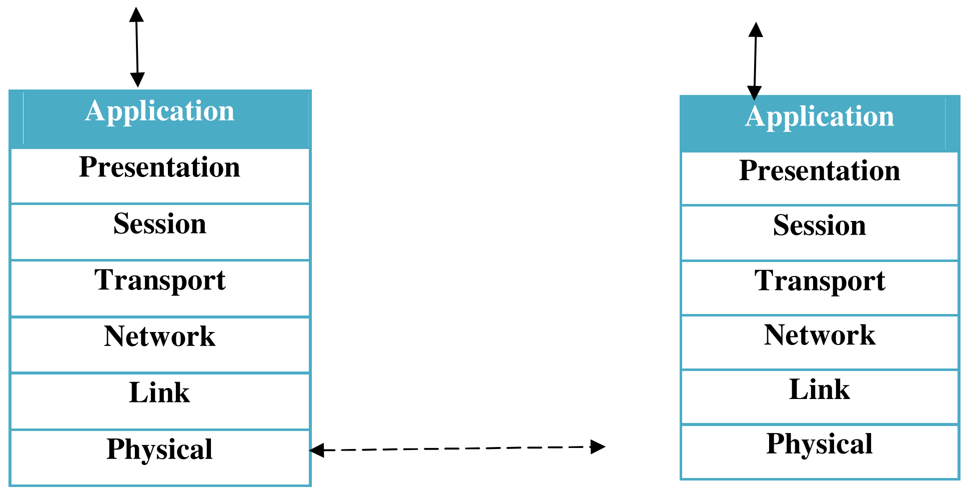


Fig.(a) The ISO-OSI seven layer "stack" for interconnecting data terminals.In this example user one and user two are conducting a two way communication station with each other is user interact with their local device (e.g.., a computer keyboard/visual display unit)at the application layer of the ISO-OSI stack.Their transaction is then routed via the various layers, with suitable conversion, etc., until the content is ready to be transmitted via the physical layer.

A satellite communications link occupies primarily the physical layer, which is where bits are carried between the terminal. A VSAT network mast have terminal controllers and of the link and these occupy the network and link layers, the two layers above the physical layer.
the network control centre typically controls the system and responsible for the remaining layers. Unfortunately few communications system conform in and easily identifiable way to the seven layers of the ISO-OSI model.(For example, the IP protocol stack of five layers simply puts the

first three layers of the ISO/OSI stack into one layer.)It is, however, very useful as a conceptual model which identifies functions that must be performed somewhere in every data communication network. Most data communication networks use some form of packet transmission, in which blocks of data tagged with an address, error control parity bits, and other useful information before transmission. The receiving end of a link checks arriving packets for errors, and then sends an acknowledge signal (NAK) that tells the transmit end to resend a particular packet because the packet had an error. Some systems do not send acknowledgements, only NAK signals to request a retransmission of a packet with an error, since this speeds up data transmission. This is the error control method used in the Internet protocol TCP/IP. Generically, such systems are known as automatic repeat request (ARQ) systems.

The ISO-OSI step was initially developed for terrestrial communication systems. For this reason the protocols that implement the functions of each layer were designed for use in terrestrial circuits with low delay and low bit error rate (BER), that is, very high performance levels. These are key points when trying to use such protocols over satellite, particularly those in geostationary earth orbit (GEO).Many of the early protocols had a connection time-out of a few milliseconds. If no reply was received from the recipient in this interval, transmissions ceased. Similarly,anerrored signals received from the source or an intervening node would trigger an automatic error recovery sequence. For example, the X.25 and X.75 packet system use an ARQ approach, which,on detecting an error in a packet, immediately requests a retransmission and halts further transmissions until the corrected packet is received. Frame relay and ATM (asynchronous transfer mode) systems flag the error but continue the flow of information (continues transmission ARQ). In both cases, the errored transmission must be corrected and suitable buffers at the reciever end (or intermediate node) used to restore the packets in their original order. The more errors that effective data throughput rate of the link becomes. The potential for delay and (propagation induced) errors are therefore critical design elements in digital VSAT connections.

Delay Consideration

A typical slant range to a GEO satellite is 39,000km. The one-way delay over such a GEO link (earth station to satellite to earth station) is 2* (range/velocity)= 260ms. The one-way delay in a typical 4000km transcontinental link via fiber-optic cable is little over 13ms. Neither example including processing delay (eg., source coding and/or compression channel coding, baseband processing in the switching element, frame length) which can add several tens of milliseconds or even over a hundred milliseconds.

The timeout element of a protocol is often referred to as the window of the connection. As long as the window is "open," communication can continue without interruption.
Fig.(b) Illustrates of a continuous transmission ARQ system that has a 60ms

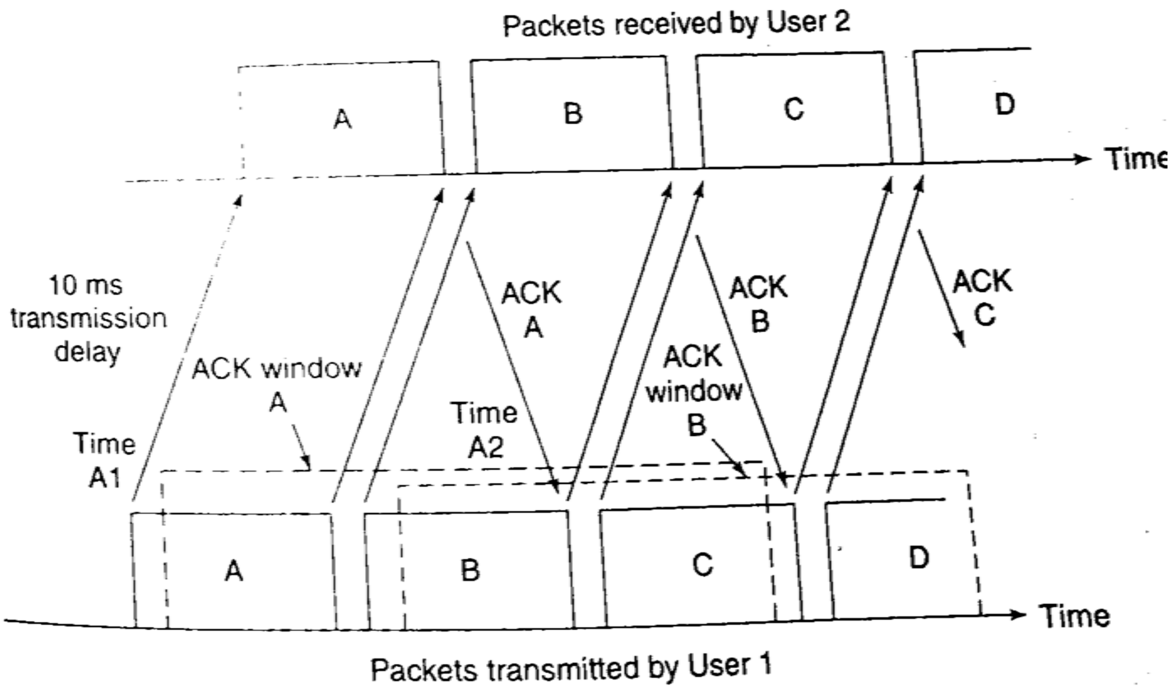


Fig.(b) Illustration of a communication link with a 10ms one way delay and 60ms window. In this example a packet or frame is sent at instant A1 from user 1 to user 2. User 2 receives the transmission without error and sends an acknowledgement back, which is received at instant A2, 20ms after the initial transmission from user 1. Thos is well within the time window of 60ms. The time window rolls forward after each successful acknowledgement. Thus the transmission from user 1 at instant B1 is received by user 2, and the acknowledgement received by user 2 at instant B2, within the new rolling time window of 60ms. Each packet or frame successfully received in this example.

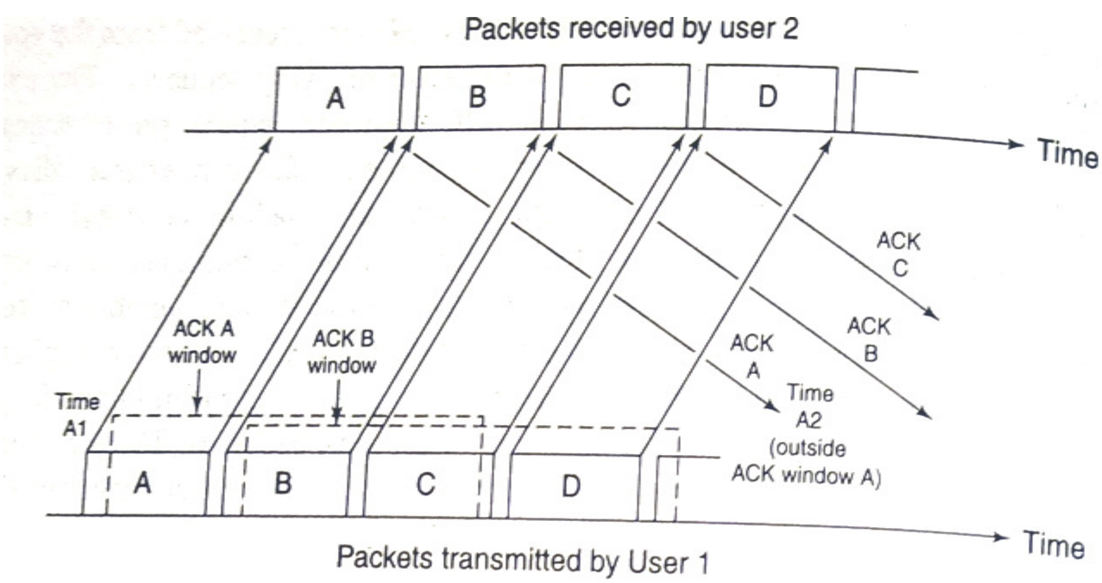


Fig.(c) Illustration of communication link with a 260ms one way delay and a 60ms window. In this example a packet or frame is sent at a instant A1 from user 1 to user 2. User 2 receives the transmission without error and sends an acknowledgment back, which is received at instant A2, 260ms after the initial transmission from user 1. Unfortunately instant A2 is well after the rolling window timeout of 60ms. Transmission from user 1 are automatically shut down by the protocol when the timeout of 60ms is exceeded. Ignoring processing delay in the example, user 1 is only transmitting for 60ms in every 260ms, thus drastically lowering the throughput. Again no propagation errors are assumed to occur.

window with a 10ms one way delay and fig. Illustrates a link with a 60ms window and 260ms one way delay.

Clearly, satellite systems have to operate satisfactorily, and seemlessly (i.e., the user has no idea whether the link os terrestrial or via a satellite), with existing terrestrial networks or their utility is severely compromised. This is particularly true for GEO systems and there are two ways to make terrestrial protocol work with a satellite link. First, the protocols can be changed so that the timeout window is well in excess of 260ms, the satellite elements of the packet network can be configured to exists as separate subnetwork within the global packet network. In practice, both solution are adopted. Fig.(d) Illustrate the concept.

The VSAT and hun "protocol" equipment act as a processing buffers to separate the satellite (VSAT) network from the terrestrial network. This is sometimes known as spoofing because the terrestrial part of the system uses the conventional protocol and osunware of the VSAT network's existence. The electronic processing and emulation permits traffic to flow seamlessly between two very different networks, without operator intervention. In essence this is the interface through which the VSAT user is connected to the VSAT network via physical layer (see fig.(e)). Once the users traffic has moved from the terrestrial network through the interface and inside the VSAT network, the packet header is recognised, with the appropriate routing and address of the traffic attached, so that the information can pass successfully over the satellite network to the correct recipient. Network management of the VSAT system, which is include congestion control, is also carried out in this element of the VSAT network, termed as network kernel. In addition, all of the necessary protocol conversions are carried out so that the packet or frame can successfully pass over the satellite connection with a long delay.

A typical data link layer protocol (layer 2 in the ISO-OSI stack) that is used in a low delay, terrestrial link employs modulo 8 operation. That is, protocol will transmit

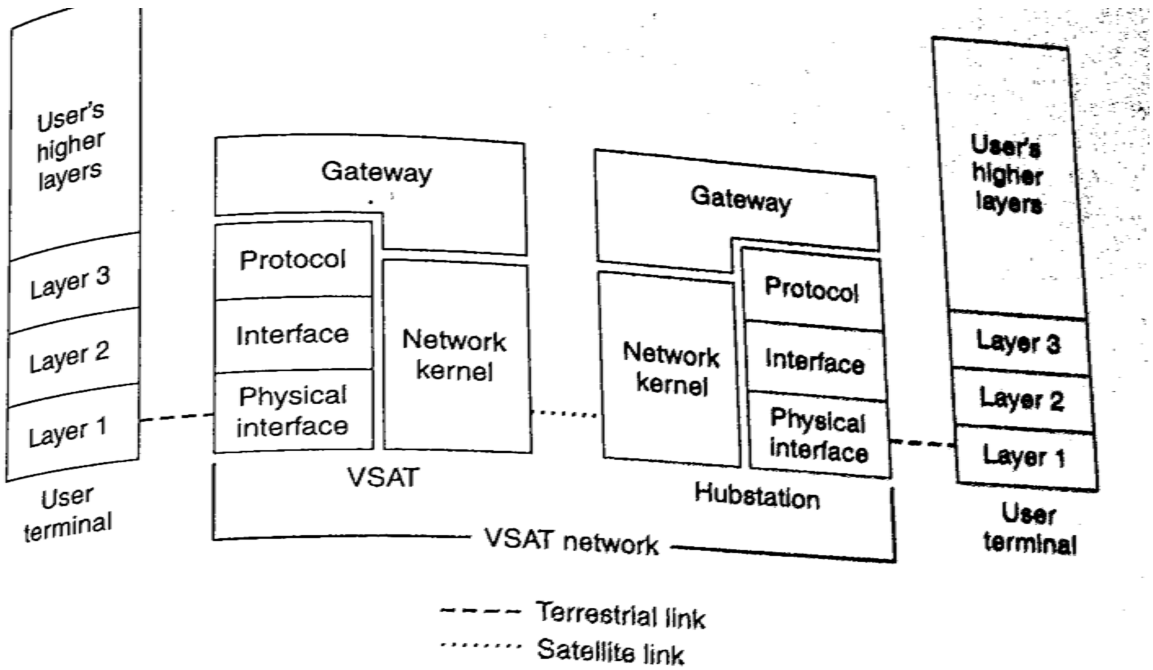


Fig.(d) Protocol architecture of star VSAT network. VSAT networks are normally maintained as independent, private networks, with the packetization handle at the user interface units of the VSAT terminals. The satellite access protocol (with a large timeout window) is handled in the VSAT/ hub network kernal, which also handled packet addressing, congestion control, packet routing and switching, and network management function. Protocol conversion, and if necessary, emulation is handled by the gateway equipment.

only7 acknowledged frames before it stops transmission, this leads to low throughput demonstrated in fig., particularly for GEO satellite links. The high level data link control(HDLC) protocol used in layer 2 for satellite system therefore usually employs modulo 128 operation. That is 127 frame may be sent without receiving any acknowledgements before the protocol shuts down the transmissions. Moving from modulo 8 to modulo 128 operation significantly increases the "window"size permitted for the link layer control. The concept called protocol emulation, is demonstrated in fig.(e).

Another critical function performed in the VSAT interface/kernel sections is to responds to polling activity from the terrestrial packet network. It is normal for packets network to poll user to see if there are packets to be sent. The interface/kernel elements in VSAT network responds to polling signals of the terrestrial network immediately, thus avoiding the long delay that occur if the polling signal had to be passed over the satellite link. Negative acknowledgement are made topolling signal until a request to send data is received over the satellite link. Given that the correct protocols had been inserted in ISO-OSI layer 2 within the VSAT system, and the management function have been carried out (i.e., polling, switching, routing, addressing and flow control) so that the link can operate successfully at a protocol level, there still remains, the major part of the system design question to answer; how is the physical connection to be established over the satellite? To answer this question we must move from protocol design/emulation to transmission engineering. First, we will cover some of the basic techniques involve in developing a transmission design.

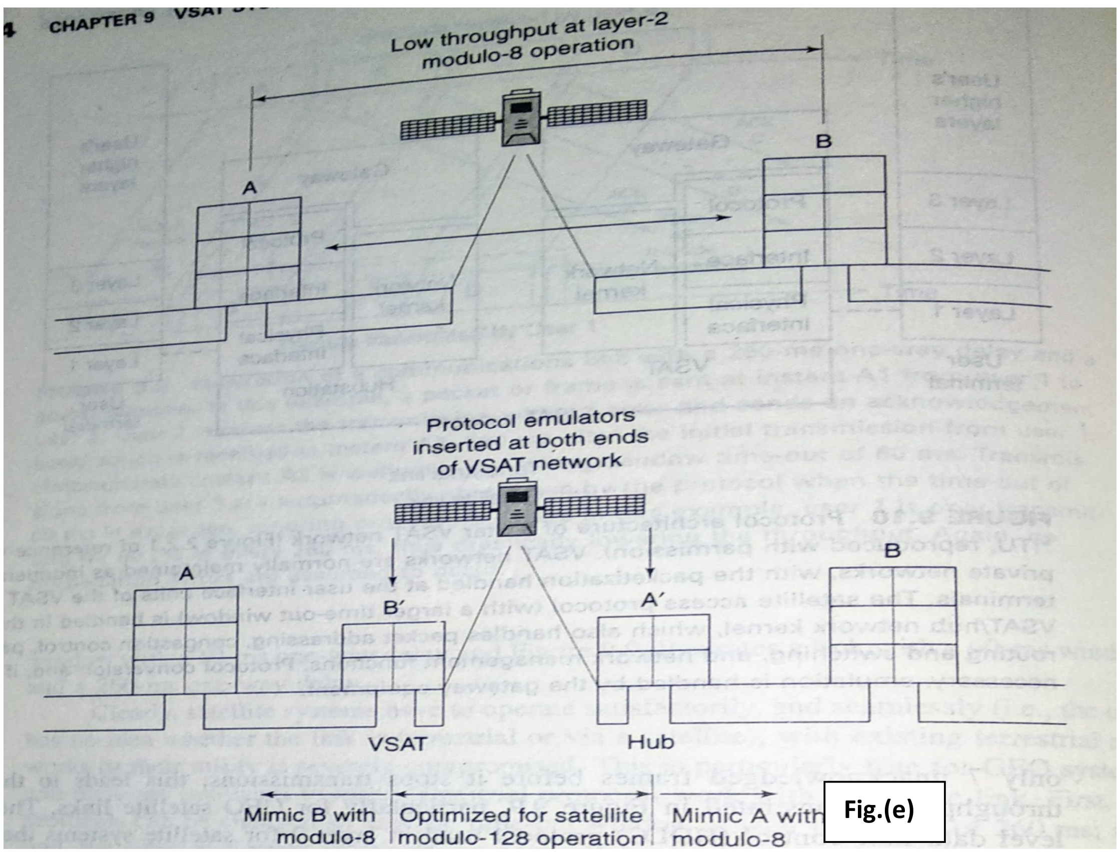


Fig.(e) Schematic protocol emulation to permit a VSAT network to operate seamlessly with a terrestrial network. In the modulo 8 operation shown in the top part of the fig, the VSAT network simply passes on the traffic over the satellite without any change to the protocols in the link layer (layer 2). This is results in extraordinarily low throughput for GEO systems. In the lower part of the fig, the bottom two layers of the ISO-OSI stacks are form inside the VSAT network and modulo 8 operation is changed to modulo

128. The two layers stack also emulates the other side of the VSAT network so that terrestrial network A believes it is linked directly with terrestrial network B. That is, both terrestrial network are mimicked at the VSAT interface/kernel.

MODULATION, CODING AND INTERFERENCE ISSUES

Modulation

Modulation and channel coding are key consideration in determining the efficient and error free transfer of information over a communication channel. They also have an impact on the potential for interference to another system and from another system. A modulation that has large number of bits per symbol will occupy a relatively small bandwidth but it will require relatively high amplifier linearity and a high C/N ratio in the receiver. It is also more susceptible to interference than modulations with fewer bits per symbols. High-index modulations require significantly more margin than low-index modulation. In choosing the most appropriate modulation channel coding foe VSAT systems, ease of implementation is also a major factor since VSATs are very cost-sensitive. Faced with these trade-off decisions, the most common forms of modulation used in VSAT systems are QPSK and, when spectrum efficiency is less important, BPSK. In an ideal QPSK with ideal RRC filters and no channel coding, a value of E_b/No of 10.6 db will provide BER of 10^{-6}, Corresponding to a receiver overall C/N ratio of 13.6 db, ignoring any implementation margin.

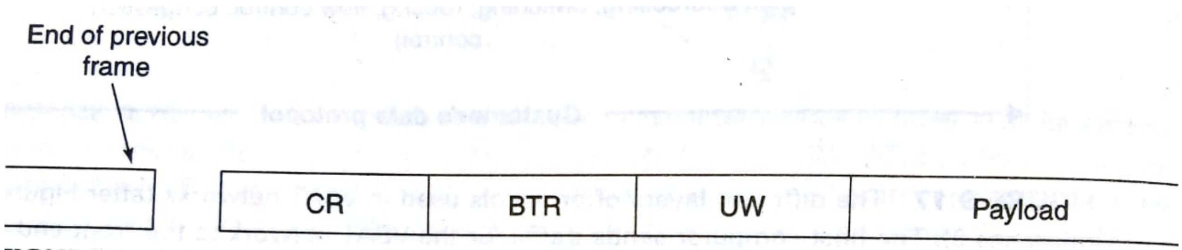
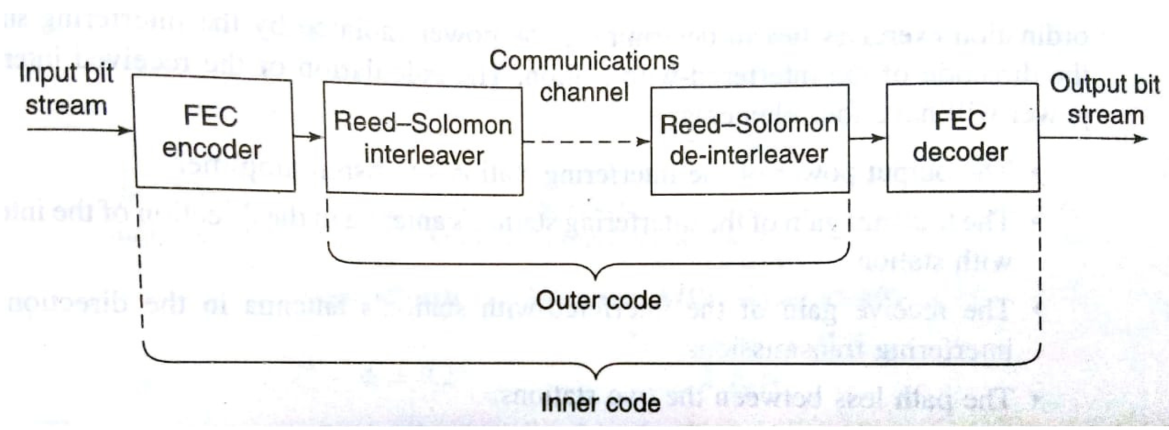


Figure: Generic sequence for the start of a burst from a VSAT inbound signal. When the the burst is received at the hub, the first part if the packet enables the carrier recovery(CR) to occur, followed by the bit timing recovery(BTR). The unique word(UW) identifies the start of the payload in the new frame.

Coding

Channel coding can take the form of a block code or a convolutional code. Convolutional coding is a process where the encoding and decoding process is applied to a group of bits in sequence rather than a bit at a time, as in a block code. The number of a bits in encoding sequence k, is called the constraint length of the convolutional. Since the encoding process is applied to the signal prior to transmission and is used to detect and correct for bit errors, it is called forward error correcting(FEC) code. In like manner, a block FEC code is applied to the channel prior transmission. Convolutional and block codes can be used together on a channel.

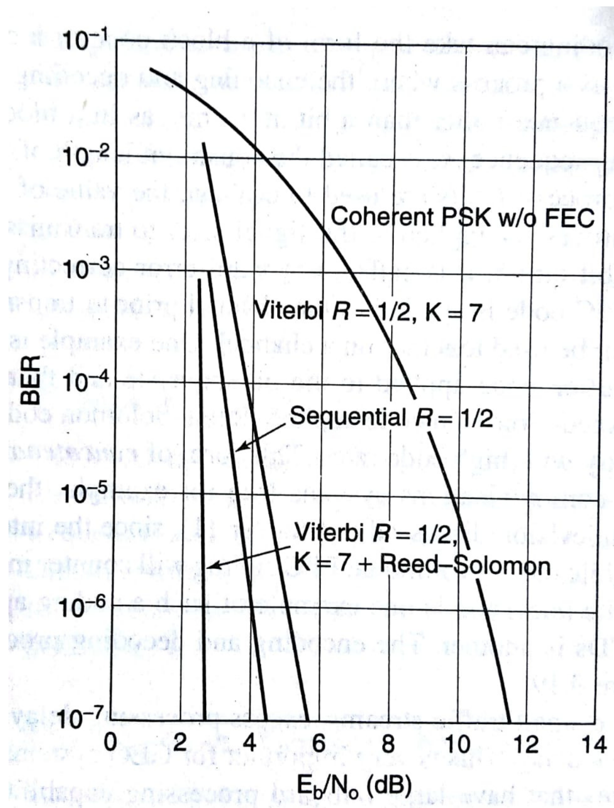
One example is a channel that first has an inner convolution code applied to the bit sequence and then has an outer interleaved code such as a Reed-Solomon code applied. Reed –Solomon code combine good error detection capability with high code rates. This form of concatenated coding is used extensively in many communications systems, since the interleaved coding will counter burst errors while the convolutional FEC coding will counter individual bit errors.



Figure(a): Schematic of a encoding and decoding process when an "inner" and "outer" codes are applied to a communications signal.

The Red-Solomon interleaved block code is applied after the FEC on the encoding side. The reverse occurs on the decoding side. While it may look like the FEC code is outside the Reed-Solomon code, it is the time they are applied that counts. Since the FEC applied first in the encoding process, it is then wrapped by the Reed-Solomon code, which becomes the outer wrapping of the doubly coded signal.

For VSAT systems that have small traffic streams, excess processing delay can add significantly to the end-to-end link delay. This is very important for GEO systems and for LEO/MEO systems with satellites that have large onboard processing capabilities. The processing delay due to first interleaved a signal and then de-interleaving it adds a fixed amount of overhead, as well as requiring buffering at both ends of the transmission link. For this reason, Reed-Solomon outer codes are not normally added to signals that have information rate below about 256 kbits/s, even though the lower E_b/No value for a given BER performance is so significant.



Figure(b): BER vsE_b/No performance of coherent QPSK for various types of codes.

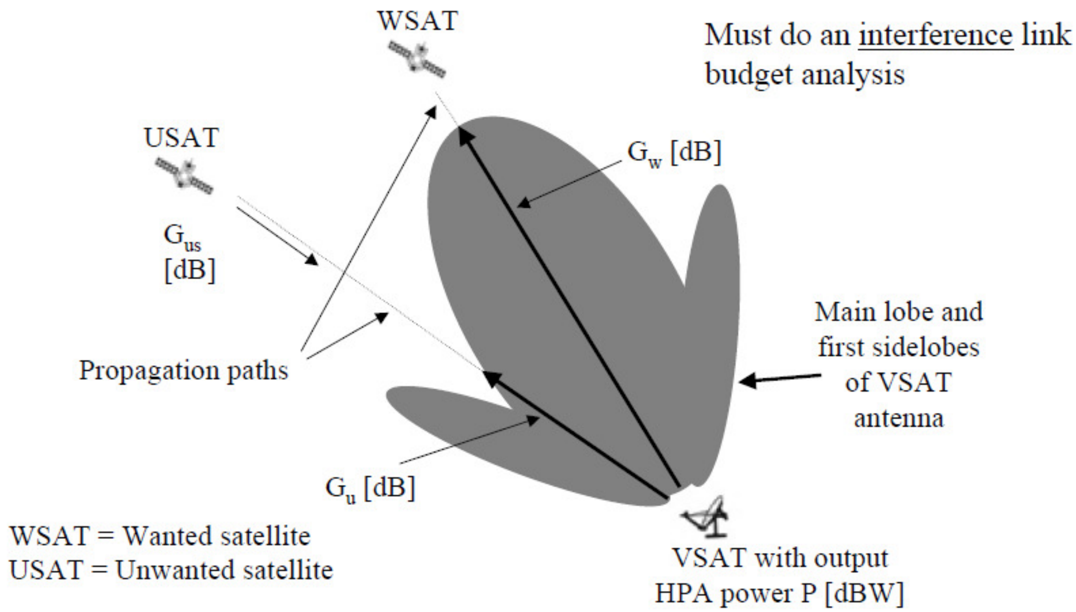
Interference

Interference between systems operating with similar characteristics(i.e. frequency bands, polarization and service) is usually the subject of intense debate, particularly when a new system seeks to operate close to an existing system, in terms of orbital separation or antenna beam direction. The interaction between operators seeking to ensure that no harmful interference is caused by, or to, their respective systems is called coordination.

The calculation of the received interference power will have four elements:

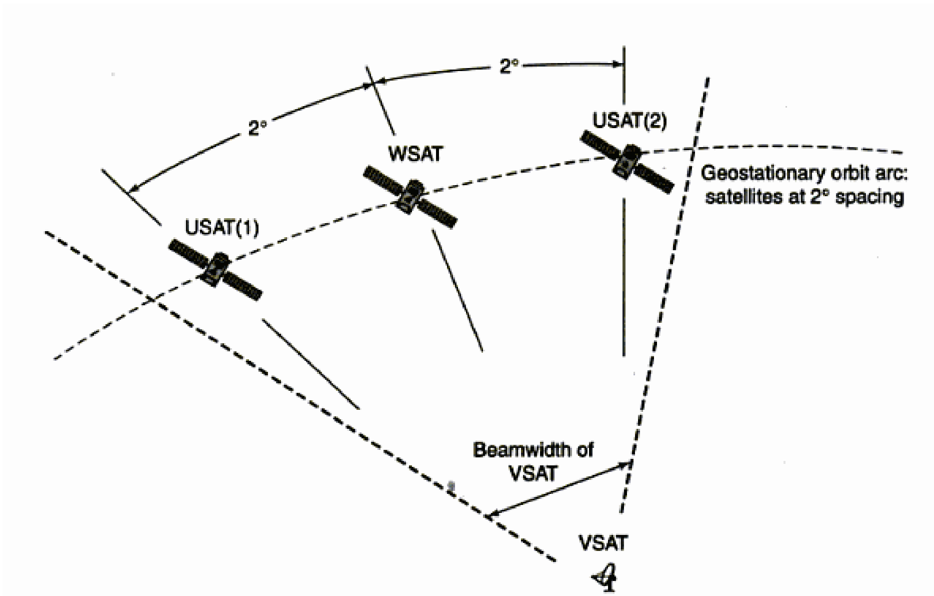
- The output power of the interfering stations transmit amplifier
- The transmit gain of the interfering stations antenna in the direction of the interfering station
- The receive gain of the interfered-with stations antenna in the direction of the interfering transmission
- The path loss between the two stations

The interference geometry is illustrated in the following figure-



Figure(c): Illustration of the interference geometry between a VSAT and a satellite of another system.

The EIRP of the VSAT toward the interfered-with satellite is the interference power from the VSAT into the interfered –with satellite. To develop the interference link budget, the gain of the interfered-with satellite in the direction of the VSAT, G_s(db), would be used, plus any additional effects along the(such as site shielding, if used, expected rain effects for given time percentages, etc.)



Figure(d): Interference Scenario

The off axis limits may need to be reduced by up to 8 db where the satellite spacing is 2^{o} . When there are N VSATs expected to transmit simultaneously on the same frequency, the maximum permitted EIRP values should be decreased by 10 logN. The rapid increase expected in satellite delivery of Internet-like traffic direct to homes and offices has led to a multitude of proposed new constellations of satellite systems, with the result that interference aspects have received a lot of study within the ITU and ETSI.

VSAT Antennas Transmitters and Receivers

Antennas:

The key element in a VSAT system is the earth station antenna used at the VSAT earth stations.The small size and low transmit power of VSAT station are the factors that keep the price of the earth station at a low level that makes a VSAT network an economic alternative to a terrestrial data network using telephone lines and modems. Large antennas are usually implemented using a symmetrical configuration, for ease of construction ,the feed on the boresight axis. The feed can either be in front of antenna or behind the antenna, as in a cassegrain design

The front feed has a paraboloidal reflector with a feed as it focus. the feed is often a scalar horn,a circular waveguide horn with a wide flare angle and corrugations on the internal surface. A scalar horn has a circularly pattern leading to equale beamwidth in all planes, and good aperture efficiency.when only a portion of the paraboloid is used an offset reflector result. An offset fed by a scalar horn is used as the preferred configuration foe most DBS-TV receiving antennas.

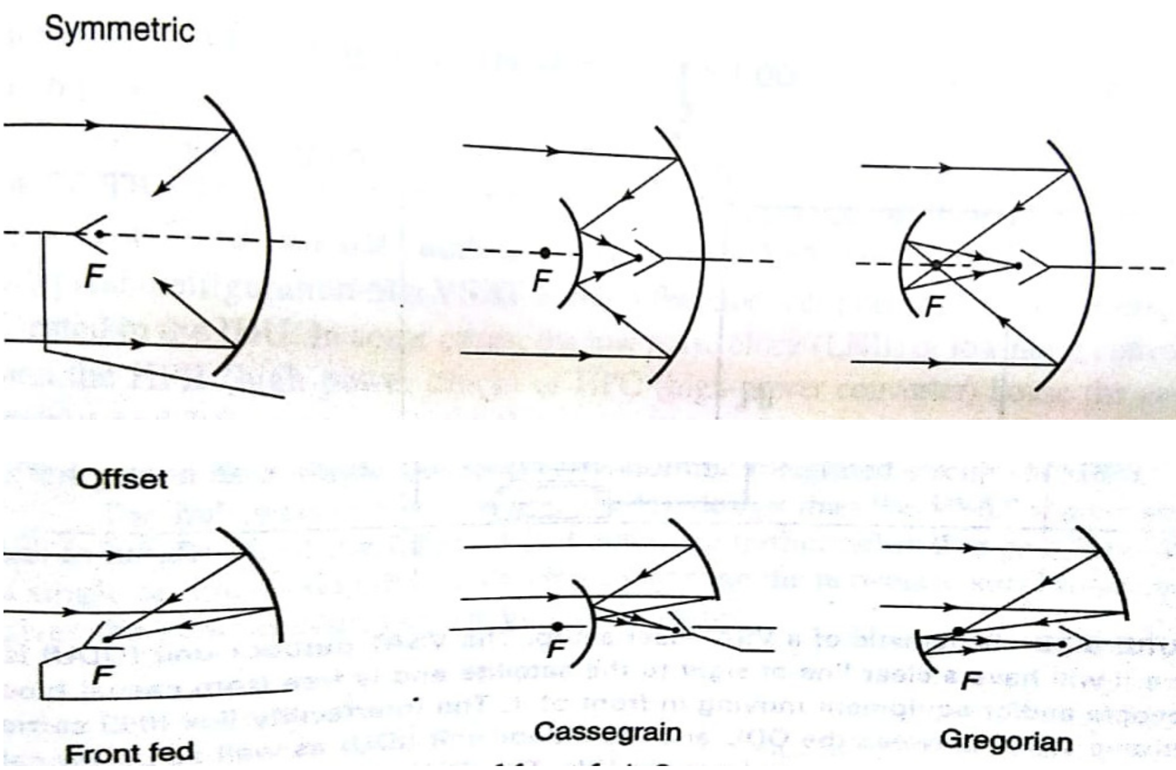


Figure: Configuration of front feed, cassegrain, and Gregorian antennas. The top three configuration are axially symmetric while the bottom three are offset-fed designs that reduce the aperture blockage considerably.

The basic design of the cassegrain antenna has a paraboloidal main reflector and a hyperboloidal sub reflector. one focus of the sub reflectors coincident with the focus of the main reflector the feed is at the other focus of the sub reflector. The surface profile of both reflector can be modified by redistributing energy across the aperture so as to increase the aperture efficiency and reduce blockage caused by the subreflector. This is a called a reflector cassegrain antenna. thecassegrain configuration is widely used for large earth station antenna. It is preferred over the Gregorian configuration because the sub reflector is closer to main reflector and therefore easier to support. However, where there is a severe off axis interference environment an offset fed Gregorian design is the best to use. Gregorian antennas are also occasionally used on DBS-TV satellites with a phased array feed to create complex coverage regions on earth.

Transmitters and Receivers

Historically, large earth stations are assembled element. On the receive side, the antenna and antenna and feed components are connected by waveguide to the front end side, low noise amplifier (LNA).behind the LNA, a mixture/down converter changes the singnal from radio frequency(RF) to an intermediate frequency(IF).after filtering and amplification, the IF signal os demodulated, demultiplexed, and decoded, and the baseband signal forwarded to the user. The transmit side is the mirror image of the receive replaced by a high power amplifier (HPA) transmitter . the design of earth station is typical of a hub station used in a VSAT network. Much of this discrete component design has changed with the Introduction od digital receiver and the need to develop cheap, masss produced VSAT terminals.

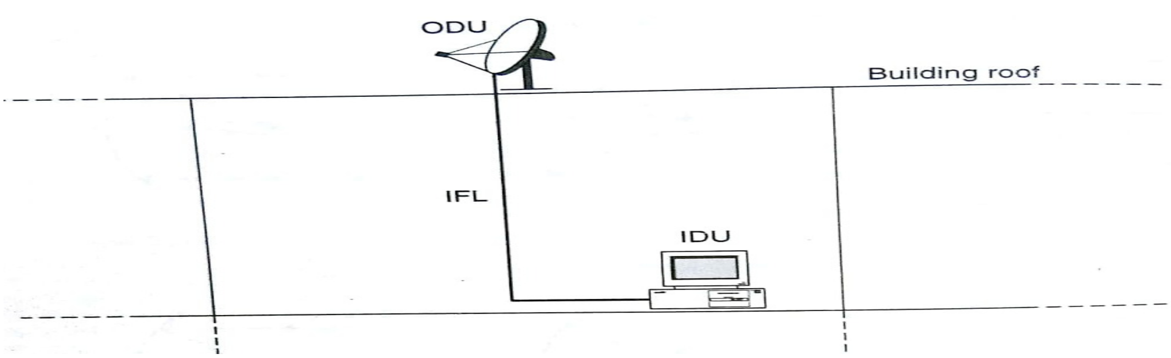
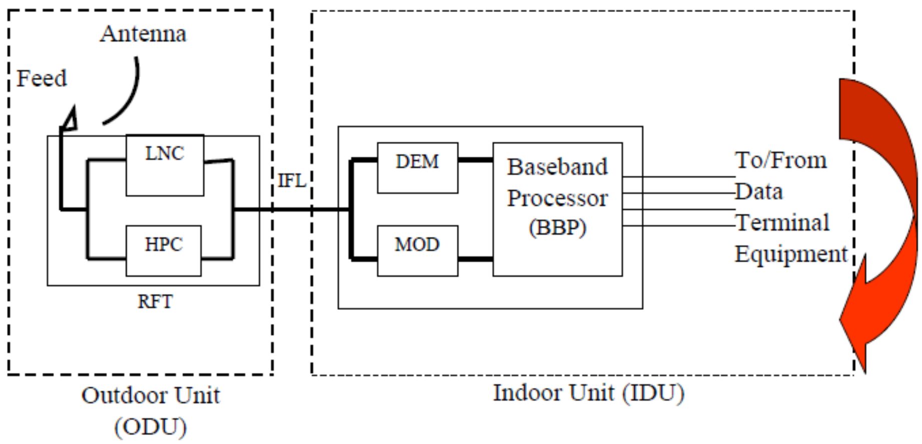


Figure: Schematic of VSAT user setup.the VSAT outdoor unit(ODU) is located where it will have a clear line of sight to the satellite and is freefrom casual blockage by people and/or equipment moving in front of it.theinterfacility link(IFL) carries the electronic signal between the ODU and the indoor unit(IDU) as well as power cables for the ODU and control signals from the IDU. The IDU is normally housed ina desktop computer at the users workstation and consist of baseband processor units and interface equipment (e.g. computer screen and keyword). The IDU will also house the modem and multiplexer/demultiplexer(mux/dmux) units if these are not already housed in the ODU.



LNC = Low Noise Converter (amplification, IF conversion)
HPC = High Power Converter (amplification, RF conversion)
IFL = Interfacility Link
DEM = Demodulator
MOD = Modulator

Figure: schematic of the typical configuration of a VSAT earth station the low noise converter(LNC) takes the received RF signal and after amplification, mixes it down to IF for passing over the interfacility link(IFL) to the IDU. In the IDU, the demodulator extracts the information signal from the carrier and passes it at baseband processor. The data terminal equipment then provides the application layer for the user to interact with the information input. On the transmit operation, the user inputs data via the terminal equipment to the baseband processor and from there to modulator. The modulator places the information on a carrier at IF and this is sent via the interfacility link to the high power convertor(HPC) for upconversion to RF, amplification, and transmission via the antenna to the satellite .

The VSAT earth station can now considered as two basic components an outdoor unit ODU) and an indoor unit(IDU).

The ODU and IDU units are broken down further in fig. fig gives a typical configuration of a VSAT that has the modulator/demodulator equipment located in IDU. In some cases, the low noise block or low noise convertor and the HPB or HPC house the complete RF output and input stages of the transmitter and receiver, the up converts and down coverts and in many cases, the modem. with the mass production of VSATs, the LNBs and LNCs are being developed on application specific integrated circuits(ASICs),very often grow as a single microwave monolithic integrated circuit(MMIC).

The hub station has more complex design than the VSAT station since it not only has to handle all of the inbound and outbound traffic, rather than just thin route traffic of a single or a few users, but it also has to manage the network control functions.

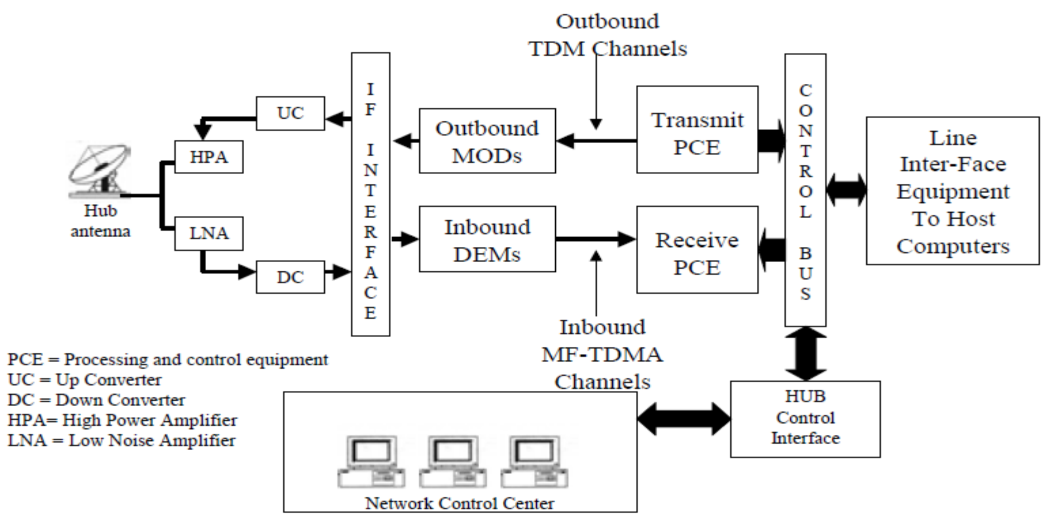


Figure: Schematic of a typical hub master control station . The line interface equipment handles the terrestrial port the host computer. The control bus via the hub control interface allow all of transmit ,receive , and switching functions to be carried out. The transmit processing and control equipment (PCE) prepares the TDM stream for the outbound link to VSATs. This stream passes through the IF to RF. The high power amplifiers the TDM stream and the antenna transmit the signal. On the receive side, the antenna passes the individual inbound MF-TDMA signals to the low noise amplifier (LNA) for amplification prior to down-conversion (DC) , demodulation, and so on to the user.

AS far as possible, all the equipment used is purchased as commercial off-the-self(COTS) to reduce costs. A critical part in the economics of satellite access it the antenna. All satellite system controlled access to the satellite and it is usual to specify the frequency tolerances allowed , the rang of power flux densities acceptable at transmit side. On the receive side, a minimum antenna G/T will be set for given elevation angle.antenna tracking tolerances will also be specified (if needed). To keep costs a given antenna purchased , performance and availability will be guaranteed by the space segment provider for that antenna standard and for power level specified. If a non-standard antenna is used however , the satellite system owner will require on-site testing of the complete earth station system to ensure compliance with the specifications . this would be extremely for a VSAT user.

Link Analysis for VSAT

Satellite Uplink

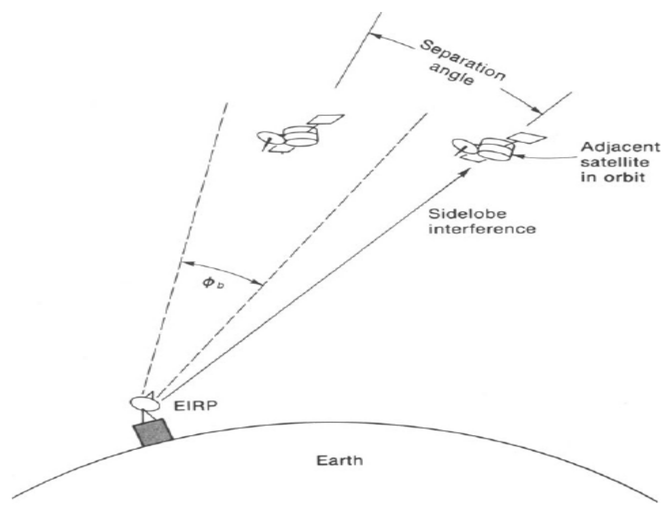


Fig. Satellite Uplink

Figure sketches a simplified earth-station-satellite uplink. Transmit-ter power for earth stations is generally provided by high-powered amplifiers, such as TWTs and klystrons. Since the amplifier and transmit-ting antenna are located on the ground, size and weight are not prime considerations, and fairly high transmitter EIRP levels can be achieved. Earth-based power outputs of 40-60 dBw are readily available at fre-quency bands up through K-band, using cavity-coupled TWTA or kly-strons (Angelakos and Everhart, 1968). These power levels, together with the transmitting antenna gains, determine the available EIRP for uplink communications.

In the design of satellite uplinks, the beam pattern may often be of more concern than the actual uplink EIRP. Whereas the latter determines the power to the desired satellite, the shape of the pattern determines the amount of off-axis (sidelobe) interference power impinging on nearby satellites. The beam pattern therefore establishes an acceptable satellite spacing, and thus the number of satellites that can simultaneously be placed in a given orbit with a specified amount of communication interference. The narrower the earth-station beam, the closer an adjacent satellite can be placed without receiving significant interference. On the other hand, an extremely narrow beam may incur significant pointing losses due to uncertainties in exact satellite location. For example, if a satellite location is known only to within ± 0.20. a minimum earth-station half-power beamwidth of about 0.60 is neces-sary. This sets the transmit antenna gain at about 55 dB.this produces the off-axis gain curve shown in Figure

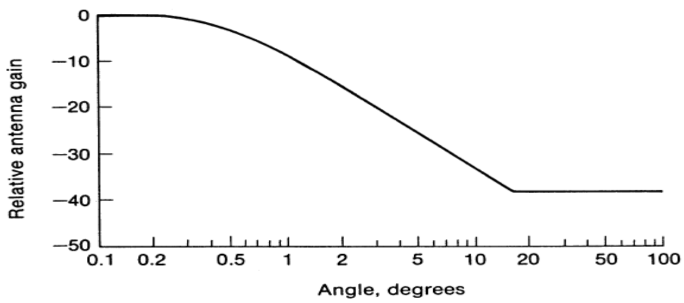


Fig.Uplink earth-station antenna pattern. Angle measured from bore sight.

For a 20 dB reduction in adjacent satellite interference, we see that the nearest satellite must be at least 3° away. That is, when observed from Earth, two satellites in the same orbit must be separated by about 3° in Figure . Thus, the uplink beam width is set by the pointing accuracy of the earth station, whereas satellite orbit separation is determined by the acceptable side lobe interference. If satellite pointing is improved, the uplink beam width can be narrowed, allowing closer satellite spacing in the same orbit. This would increase the total number of satellites placed in a common orbit, such as the synchronous orbit.

With the half-power beam width set, a higher carrier frequency will permit smaller earth stations. Figure shows the relation between earth-station antenna diameter and frequency in producing a given uplink beamwidth and gain, Note that while increase of carrier frequency does not directly aid receiver power, we see that an advantage does accrue in reducing earth-station size and, possibly, in improving satellite trafficking (allowing more satellites in orbit).

With a 0.6° uplink beamwidth (gain ~ 55 dB) earth-station EIRP values of about 80--90 dBw are readily availableshowing the way in which the entries are individually computed and combined. Figure generalizes this budget to show how CNR will vary with earth-station EIRP and satellite receiver

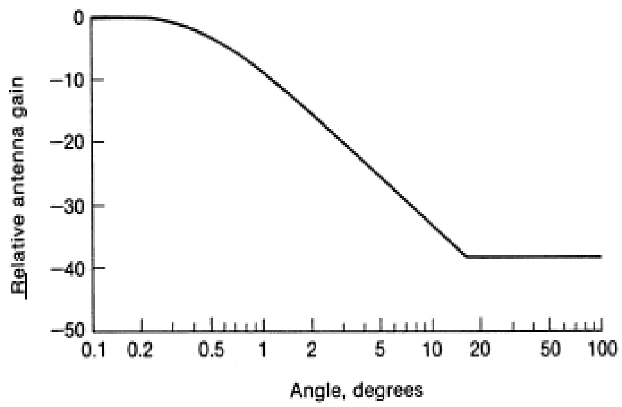


Fig.Earth-station antenna size versus frequency *(CPb*= halfpowerbeamwidth, *g* = gain, *Pa* = 1).

g/T~q. Even with significant range losses (~200 dB) and relatively low*g/To*values, an acceptable uplink communication link can usually beestablished

Satellite Downlink

A satellite downlink is constrained by the fact that the power amplifier and transmitting antenna must be spaceborne. This limitsthe power amplifiers to the efficient, with limited output power capabilities that are dependent on the carrier frequency. The spacecraft antenna, ,while similarly limited in size, must use beam patterns that provide the required coverage area on Earth. Recall that the coverage area for a specified minimal viewing elevation angle depends only on the satellite altitude. Hence, the satellite downlink beam width for a given coverage area is automatically selected as soon as the satellite orbit altitude is selected. This also means the corresponding downlink antenna gain is established by the orbit altitude. By using higher-frequency bands (smaller *A),* this required downlink beamwidth can be achieved with smaller satellite antenna sizes, as stated before. Spacecraft antennas that provide the maximal coverage area are referred to as *global antennas.*

With satellite power level and antenna gain established, the carrier power collected at the earth station depends only on the *g/Tfactor,* just as for the uplink. Figure shows an example of a downlink power

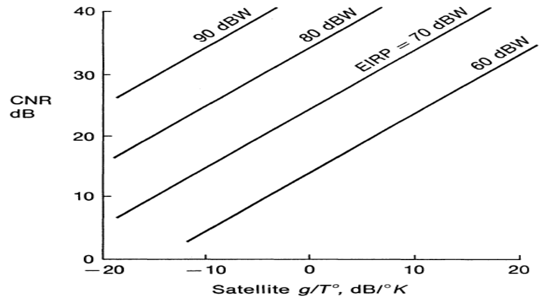
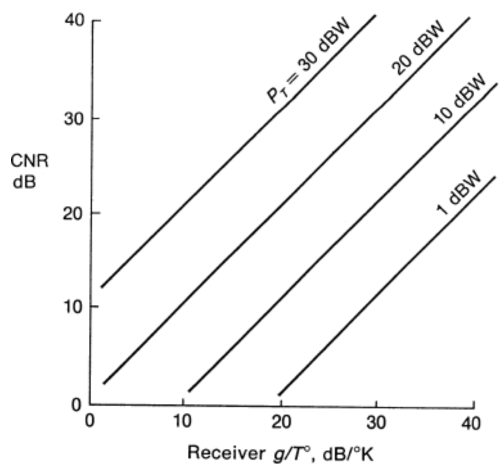


Fig. Uplink CNR versus satellite *giro*C-band link, bandwidth= 10 MHz;

budget for a 10-MHz bandwidth and global satellite antennas, and again generalizes to a CNR plot in terms of satellite power and receiver *g/TOeq*. Itis evident that relatively large earth-station *g/TOeq*is needed toovercome the smaller EIRP of the satellite. This means small earth stations will be severely limited in their ability to receive wide bandwidth carriers.

a.



(b)

Fig. (a) Downlink C-band link budget (b) Downlink CNR versus receiver *g/To*. *PT* = satellite power, global antenna, bandwidth =10 MHz, link parameters are given in Figure

Although use of higher carrier frequencies allows smaller satelliteantennas, care must again be used in accounting for its effect in downlinkanalysis . It will produce higher earth-station*g/T* values, but it will not increase CNR owing to the increased downlinkspace loss. To emphasize this point, let us rewrite the CNR formula in

$$\mathrm{CNR}_d = \frac{P_T A_r L_a}{\phi_b^2 z^2 k T^{\circ}_{\mathrm{eq}} B_{\mathrm{RF}}}$$

With the terms in the denominator fixed by the link, we see that downlink CNR depends only on available satellite power *PT* and on receiver collecting area *Ar* • Note that neither satellite EIRP nor receiver gain directly affects downlink quality. The choice of frequency band is, of

course, important in determining available *PT* and indetermining atmospheric losses. A secondary consideration in frequencyband selection is the possible advantage that may be attained by allowing wider RF bandwidths.

Satellite Crosslinks

Satellite systems often require communications between two satellites via a crosslink. A crosslink can be established between synchronous satellites, low-earth-orbiting satellites, or deep-space satellites. A crosslink between two orbiting satellites is referred to as an *intersatellite link* (ISL). As a communication link, an intersatellite link has the disadvantage that both transmitter and receiver are spaceborne, limiting operation to both low *PT* and low*giro*values. To compensate in long links, it is necessaryto increase EIRP by resorting to narrow transmit beams for higher-power concentration. With satellite antenna size constrained, the narrow beams are usually achieved by resorting to higher carrier frequencies. Hence, satellite crosslinks are typically designed for K-band (20-30 GHz) or EHF (60 GHz) frequencies.

Consider the crosslink model in Figure. Two satellites at altitude *h* are separated by angle*cPs*as shown. The transmitting satellite hastransmission power *PT* available, and we assume both satellites use antennas of diameter *d.*

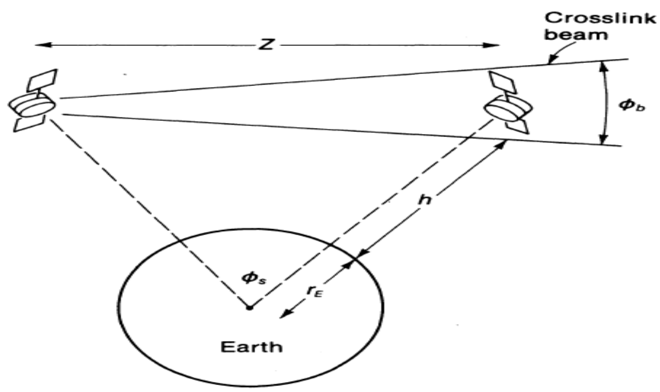


Fig.Satellite crosslink model

The receiving satellite has noise temperature *TOeq.* The propagation distance between the satellites is given by

z = 2(h +rE) sin(<ps/2)

wherer_E is the Earth's radius. The maximum line-of-sight distance occurs when

Z_{max}=2$[(h-r_E)2-r_E2]1/2$

$$z_{\max} = 2[(h + r_E)^2 - r_E^2]^{1/2}$$

$$z_{\max} = 2[(h + r_E)^2 - r_E^2]^{1/2}$$

which, for *h»rE'* is approximately 2 *h.* We assume first that both satellite locations are known exactly by each, and each is perfectly stabilized, so that each satellite uses antenna beamwidths<*Ph* pointed exactly at each other. The CNR delivered to the receiving satellite over the crosslink,with*La*= 1, is then

$$\text{CNR} = \frac{P_T(\pi d^2/4)}{\phi_b^2 z^2 k T^\circ_{eq} B_{RF}}$$

The crosslink transmitting beamwidth<*Ph* is related to the carrier fre-quency. Assuming *Pa*= 1, we substitute <*Ph~A/d,* and above Equation can be simplified to

$$\text{CNR} = 8.7 P_T \left[\frac{f^2 d^4}{z^2 T^\circ_{eq} B_{RF}} \right]$$

where*PT* is in watts,fis in GHz, and *d* and *z* are in meters. We see that CNR increases as the fourth power of the antenna diameters. Hence, the most efficient way to improve a crosslink is to increase antenna size. With the antenna selected, CNR can be increased only by lowering front end temperature, increasing transmitter power, or operating at the higher EHF crosslink frequencies.

The increase in CNR with antenna size and frequency is a direct result of a more concentrated beamwidth. The limitation of extremely narrow crosslink beams, however, is the pointing error that exists due to the relative uncertainty of the location of each satellite with respect to each other and to the satellite attitude error (the inability of a satellite to properly orient itself so as to point exactly in a desired direction). These errors are invariably much larger than those encountered in earth-based links, where ground control of tracking and pointing is feasible. If*r* is the relative location uncertainty distance when observed

from each satellite, and if the attitude error is *cJ>a,* the total uncertainty angle is

$$\emptyset e = (r/z - \emptyset a)^2$$

The transmitted beamwidth must be wide enough to encompass these pointing errors. This shows that a key element in crosslink systems is the ability to point between satellites. It is evident that a trade-off exists between reducing the crosslink beam (more concentrated power) and improving the pointing accuracy.

VSAT (Very Small Aperture Terminal)

Working Principle, Components, Types, and Functions for IAS Exam!

VSAT (Very Small Aperture Terminal) is a satellite-based data transmission technology that is used for communication purposes in business space, backward and remote areas. The topic **'VSAT'** is very important for the UPSC IAS exam and it falls under the **'Science and Technology'** portion of the **General Studies Paper-3** of UPSC IAS Mains examination This article deals in detail about the VSAT technology and today we will learn about the background, components, working, functions all the important aspects of VSAT technology relevant to the UPSC exam.

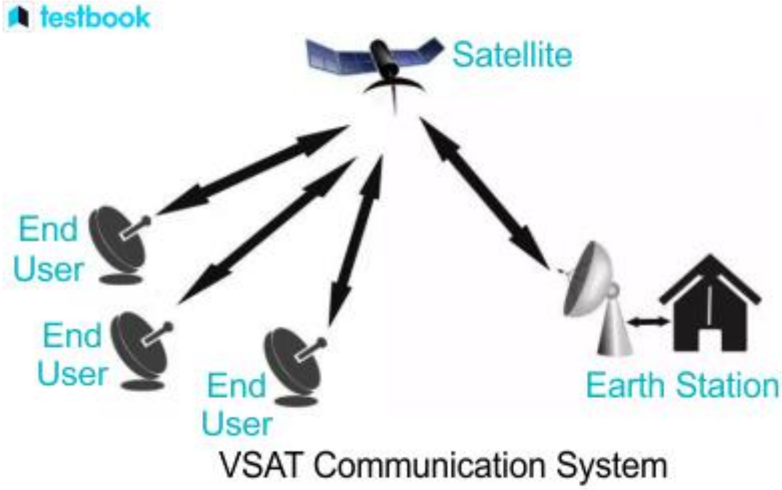
What is VSAT?

VSAT (Very Small Aperture Terminal) is a **two-way**, low-cost, advanced **satellite communication technology** that transfers data from one station to another station on the earth by accessing the satellite in the geostationary and geosynchronous orbits around the earth. VSATs are used to transmit narrowband as well as broadband data and also for maritime communication purposes.

Background on VSAT

The history of VSAT dates back to the early 20th century when Russian theorist Konstantine Tsiolkovsky originated the concept of geostationary orbit. The further development of VSAT continued as follows:

- October 1945 Arthur C Clarke discussed the necessary frequencies, power, and orbital characters needed for communication.
- In the 1960's NASA developed live satellite communication by launching SYNCOM series satellites.
- 1964 SYNCOM-3 satellite transmitted live coverage of the 1964 Japan Olympics in the US and Europe.
- 1965: first commercial satellite INTELSAT-1 (Early Bird) launched into space.
- 1980- first commercial C-band VSAT sets were sold and later Ku-bands were also developed.
- 2005 Ka-band VSATs were deployed for the first time.



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Very Small Aperture Terminal (VSAT)

VSAT is a dual-way ground station that has a small antenna and is used for the purpose of transmitting and receiving data to and from the satellite orbiting the earth. It is used both by home users and also by big and small private companies as VSAT offers a number of advantages over the other available terrestrial alternatives.

Components of VSAT

A VSAT system usually consists of the following two components:

- The **outdoor unit** which consists of- a dish antenna, block up-converter (BUC), low noise block downconverter (LNB), Ortho Mode Transducer (OMT) is placed in direct line of sight to the satellite outdoors.
- **Indoor unit** consists of a satellite modem and IP routers that connect to the device of the end user.

VSAT Working Principle

VSAT works on the principle of satellite communication. There is a Central Office also called the HUB station. The HUB station is connected to all the End Users via satellite. The HUB station controls the communication between all the End Users.

How are the signals sent and received?

For a VSAT user, there is a need for a box that interfaces between the user's system i.e. computer or TV or any other device, and an outside antenna with a transceiver.

- The transceiver receives or sends signals to a transponder placed on the satellite in orbit.
- The satellite then sends and receives these signals from an earth station which is also called the HUB station of the VSAT system.
- All the end users are interconnected with one another through the HUB station via the satellite.
- The end users can communicate with each other only through the HUB station.
- Each and every transmission first go to the HUB station which then transmits it via the satellite to the desired end user.

Check the Article Nanotechnology here!

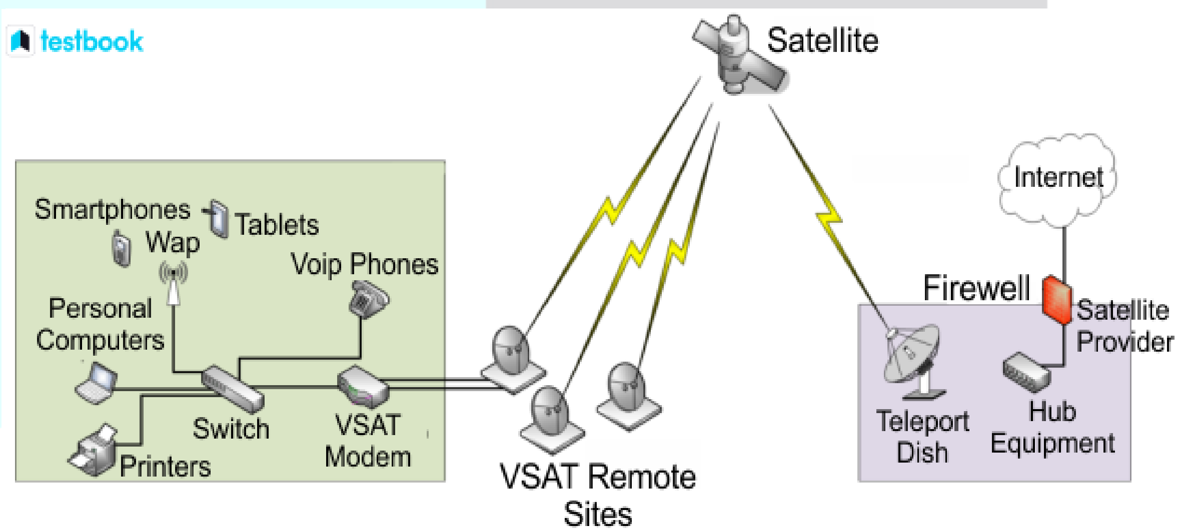
Functions and Important Applications of VSAT

VSAT usually function in the C, Ku, and Ka frequency bands, and the data flow rate is between 4 KBPS to 16 MBPS. Its main function is to establish a private and secure fast communication system to send and receive data including voice and video calls. Important applications of the VSAT technology include:

- Due to the highly versatile nature of VSAT, it allows all types of communications with satellites in geostationary and geosynchronous orbits.
- The small size of VSATs allows them to be used for transportable, on the move, and mobile communication purposes in addition to being used in stationary locations.
- The dish antenna used for Direct to Home satellite television broadcast is the most common example of the VSAT terminals.

Other useful applications of VSAT are

- Efficient resource management by businesses.
- Live coverage by the media.
- Airline and hotel booking.
- Live remote classes.
- Controlling and management such as stock.
- In banking and financial institutions.
- In mobile maritime communication.
- In data management and high-frequency trading.
- Video conferencing.
- Billing system.
- In navigation.
- Medical consultancy services.
- In large retail outlets
- File transferring system and database inquiry system.
- E-mail or computer communications.
- Credit card transactions.
- ISDN services.



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Types of VSAT

VSAT is generally used to refer to- any two-way satellite communication which does not teleport to earth stations. VSAT generally is classified into four types which are discussed below:

Portable VSAT

- Used by military establishments.
- The portable VSAT is also known as Fly Away VSAT units and can be easily mobilized and carried to different places.
- There can be an increase in cost with an increase in portability features such as the size of the antenna and the light weight of the module.
- They can be both Trailer-Mounted type and Fly Away type.

Marine VSAT

- Used for maritime communication purposes at distant seas.
- These are gyroscopically stabilized VSATs so that the movement of boats or ships does not affect the precision of the VSAT antenna.
- Marine VSAT antennas are placed in a special fiberglass radome to prevent the antenna from the windy and harsh environmental conditions at sea,

Vehicle Mounted Mobile VSAT

- Used commonly by emergency management professionals like Media houses.
- These VSATs are so agile that they can be deployed in minutes by the push of a single button on the automatic satellite controller located in the vehicle.
- Their size varies from 0.75 m to 1.2 m which can cater to almost all the commercial requirements.
- Vehicle Mounted Mobile VSAT allows the quick establishment of on-screen voice, video, and data communications.

Fixed VSAT

- Used commonly for local level broadcasting..
- Fixed VSATs are the best and sometimes the only way to bring communication services to remote and underdeveloped areas.
- Fixed VSAT antenna should be installed in a location having a clear view of the southern sky.
- Fixed VSAT can be installed in various ways like- nonpenetrating roof mounts, nonpenetrating ridge mounts, and also on a steel pole buried in concrete.

Check out this Article Internet of Things here!

Advantages and disadvantages of VSAT

This remote two-way communication technology have various advantages over other old-school communication technologies but there are some disadvantages as well.

Advantages

- **Eliminates Large Physical Networks**: In VSAT, satellite signals are not bound to any physical network light Ethernet cables but are directly bound by satellite. Thus, structural issues and infrastructure needs are completely eliminated.

- **Operates Independently:** VSAT provides independent operation to local telecom networks where no backup system is required. Instead, VSAT itself is used as a backup for the wired network to continue the operations in case of failure.
- **Ease of Deployment:** it is the biggest advantage of we said that it can be installed in remote locations independent of any infect structural needs. This is possible as satellite signals can be redirected to different locations via the hub station.

Disadvantages

- **Latency Issue:** Latency issue is a major drawback of VSAT as signal delay is experienced while reaching the ground from the satellite.
- **Fluctuating Signal Quality**: Weather conditions are largely responsible for changes in signal quality transmitting between earth stations and satellites. Sometimes obstructions like buildings or trees in transmission paths can also result in signal distortion.

Conclusion

At present VSAT technology offers consumers quality and comfort and can be a game changer in the communication field in remote areas. It also has a low per unit cost and provides immediate global coverage for hard-to-reach locations and is economical too. But at the same time, the latency issue is a major concern and should be addressed with innovation and technical knowledge in order to make VSAT more reliable and useful and can also play a crucial role in making Digital India Mission a success.

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