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TELECOMMUNICATIONS
DEPARTMENT OF TELECOMMUNICATION AND RADIO ENGINEERING
SYSTEMS**

ADMIT TO DEFENCE
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“ ” _____ 2022

**DIPLOMA WORK
(EXPLANATORY NOTE)**

**BACHELOR'S DEGREE GRADUATE
BY SPECIALITY "TELECOMMUNICATIONS AND RADIO ENGINEERING"**

Topic: « A model of telecommunication system using VSAT satellite technology » _____

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Faculty of aeronavigations, electronics and telecommunications

Department of telecommunication and radio engineering systems

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TASK
for execution of bachelor diploma work

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ABSTRACT

Graduate work on the topic «Information and communication system for Online banking». It contains 61 p., 3 tables., 20 figures., 17 references.

KEYWORDS: VSAT, MODEL OF TELECOMMUNICATION SYSTEM, SATELLITE.

The object of study is the VSAT system.

The subject of research is the technology and concept.

The purpose of the thesis is to analysis of the concept, model, and principle of the VSAT technology.

Research of methods – characteristics, history of the Very Small Aperture Terminal.

CONTENTS

LIST OF ABBREVIATIONS	7
Introduction	8
CHAPTER 1	9
RESEARCH ON TELECOMMUNICATION TECHNOLOGIES FOR MODERN TELECOMMUNICATION SYSTEMS	9
1.1. Introduction	9
1.2. Telecommunication technologies for modern telecommunication systems	12
1.3. The concept and definition of the VSAT	17
CONCLUSION TO CHAPTER 1	21
CHAPTER 2.....	22
THE CONCEPT, MAIN UNITS AND PARAMETERS OF THE VSAT.....	22
2.1. The composition of the system	22
2.2. Topologies of networks with VSATs.....	28
2.2. The main parameters of VSAT antennas	31
2.3. Initialization of the operation of a VSAT	35
2.4. VSAT units.....	38
2.5. VSAT Installation procedure	41
2.6. VSAT Pricing.....	43
Fig.2.11 Prices of VSAT systems	43
Antenna Subsystem.....	44
Biggest Issue – Professional Installation Cost	45
CONCLUSION TO CHAPTER 2	46
CHAPTER 3.....	47
Specific model calculations.....	47
3.1 Calculation of signal attenuation during signal propagation	48
3.2 Calculation of additional attenuation of signal energy on the lines up and down	51
3.3 Energy characteristics of the radio link.....	54
3.4 Calculation of the required diameter of receiving terrestrial antennas stations.....	56

CONCLUSION TO CHAPTER 3	59
CONCLUSION	60

LIST OF ABBREVIATIONS

VSAT – Very Small Aperture Terminal

ES – Earth Station

Sat – Satellite

Rc – Receiver

Tr – Transmitter

Add – Additional

N – Noise

A – Absorbtion

R – Precipitation

G_{tr} – transmitter gain

Introduction

Actuality of theme. Modern society cannot be imagined without mobile communications or the Internet. Telecommunications have firmly and deeply penetrated into our lives and strengthened their positions. No area of life today can do without communication. Despite this, the problem of security and reliability of communication channels is still acute. One of the systems to solve this problem is VSAT.

The purpose and objectives of the study. Analysis and study the principles and peculiarities of the VSAT systems. Advantages and disadvantages of it, technical characteristics.

The object of study is the VSAT system.

The subject of research is the technology and concept.

Research of methods. This paper presented an elementary satellite Internet based on the VSAT technology.

The practical significance of the results obtained. Materials of the diploma work are recommended for use in research and practical activities on the planning of the satellite internet system based on VSAT technology.

Approbation of the obtained results. The main provisions of the work were reported and discussed at the diploma defense of the student of the National Aviation University, Kyiv 2022.

CHAPTER 1

RESEARCH ON TELECOMMUNICATION TECHNOLOGIES FOR MODERN TELECOMMUNICATION SYSTEMS



Fig.1.1 The VSAT system

1.1. Introduction

Telecommunication system is a set of interconnected technical means, united by common purposeful rules of interaction and ensuring the exchange of information at a distance [1,2].

Telecommunication systems are quite complex and expensive, therefore, models of such systems are used for their study or preliminary calculation. A model is a representation of an object, system or concept (idea) in some form different from the form of their real

existence. The benefits of modeling can only be achieved if the following fairly obvious conditions are met:

- the model adequately reflects the properties of the original that are essential from the point of view of the purpose of the study;
- the model allows to eliminate the problems inherent in carrying out measurements on real objects.

When experimenting with a model of a complex system, one can obtain more information about the internal interacting factors of the system than when manipulating with a real system due to the variability of structural elements, the ease of changing model parameters, etc.

Modeling principles

The principle of information sufficiency. In the complete absence of information about the object under study, it is impossible to build its model. If the information is complete, then the simulation is meaningless. There must be some critical level of a priori information about the object (the level of information sufficiency), upon reaching which its adequate model can be built.

The principle of feasibility.

The model must ensure the achievement of the set goal with a probability different from zero and in a finite time. Usually, a certain threshold value and an acceptable time limit t_0 for reaching the goal are set. The model is feasible if

The principle of multiple models.

The created model should reflect, first of all, those properties of the modeled system or process that affect the selected performance indicator. Accordingly, with the help of a specific model, only some aspects of reality can be studied. For a more complete study of

it, a number of models are needed that allow a more versatile and with varying degrees of detail to reflect the object or process under consideration.

The principle of aggregation.

A complex system can usually be represented as consisting of subsystems (aggregates), for the mathematical description of which standard mathematical schemes are used. In addition, this principle allows the model to be flexibly rebuilt depending on the objectives of the study.

The principle of parametrization.

In some cases, the simulated system may have relatively isolated subsystems that are characterized by a certain parameter (including a vector one). Such subsystems can be seen in the model by the corresponding numbers, and not describe the process of their functioning. If necessary, the dependence of these quantities on the situation can be given in the form of a table, graph or analytical expression (formula). This allows you to reduce the volume and duration of the simulation. However, it must be remembered that parameterization reduces the adequacy of the model.

Main properties of models:

- purposefulness - the model always displays some system, i.e. has a purpose;
- finiteness - the model reflects the original only in a finite number of its relations and, in addition, the modeling resources are finite;
- simplicity - the model displays only the essential aspects of the object and, in addition, should be easy to study or reproduce;
- approximation - reality is displayed by the model roughly or approximately;
- adequacy - the model must successfully describe the system being modeled;
- visibility, visibility of its main properties and relations;

- availability and manufacturability for research or reproduction;
- information content - the model should contain sufficient information about the system (within the framework of the hypotheses adopted when building the model) and should make it possible to obtain new information;
- preservation of the information contained in the original (with the accuracy of the hypotheses considered in the construction of the model);
- completeness - the model must take into account all the main connections and relationships necessary to ensure the purpose of modeling;
- stability - the model must describe and ensure the stable behavior of the system, even if it is initially unstable;
- integrity - the model implements some system (i.e. the whole);
- closedness - the model takes into account and displays a closed system of necessary basic hypotheses, connections and relationships;
- adaptability - the model can be adapted to various input parameters, environmental influences;
- controllability (simulation) - the model must have at least one parameter, by changing which you can simulate the behavior of the simulated system in various conditions;
- evolvability - the possibility of developing models (of the previous level)

1.2. Telecommunication technologies for modern telecommunication systems

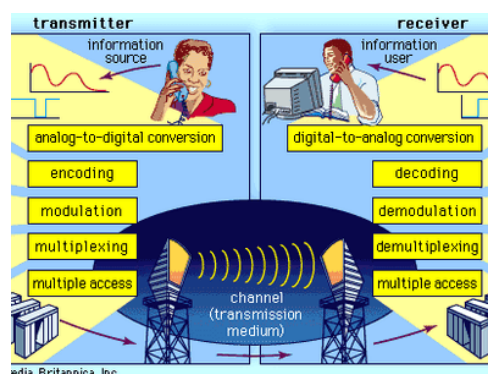


Fig. 1.2. Transmitter and receiver functions

Telecommunication technologies used on the Internet are now undergoing a stage of rapid development and growth. New networks of various types are being created, including:

- local networks of companies or institutions, communication between computers in them is carried out both in a wired and wireless way, the number of users of these networks is limited. Local networks can be corporate, in some countries urban local networks are also being created;
- Wide Area Networks (WANs) are a collection of a large number of computer nodes located in different countries of the world and interconnected by optical fiber communication channels. Local networks are connected to these networks representing the services of providers.

Hardware and software of telecommunication technologies

The performance of the Internet is based on the use of network nodes and communication channels. Hosts include both individual computers and hosts that provide IP addresses and domain names.

Communication channels are generally divided into 4 types:

- analog telephone networks;
- wires through which electricity is transmitted;
- fiber optic communication channels;
- wireless communication channels, modem or satellite.

Telecommunication channels mainly include the third and fourth types.

Among the communications used to organize communications, one can separately note programs that ensure the operation of telecommunications equipment such as:

- IP PBX;
- routers;
- computers.

Some 15-20 years ago, people used modems to access the Internet, and then a speed of 56 Kbps seemed unrealistic. Today, technology has run so far ahead that you will not

surprise anyone with speeds of 1 Gb / s. Part of the reason for this is the ubiquity of fiber optic cable. Today we will look at the advantages and disadvantages of fiber optic cable.

Optical fiber

Optical fiber (aka fiber optic cable) consists of optical dielectric waveguides through which the signal passes. This material is somewhat akin to glass: it is made from quartz in the same way. To transmit a signal over long distances, you have to use special fiber optic modems to convert an electrical signal into an optical one, and vice versa.

The benefits of fiber optics include:

- High data transfer rate (up to 10 Gbps);
- High reliability (electromagnetic interference is not terrible, high protection against environmental influences);
- The signal can be transmitted over vast distances;
- High security (good protection is provided from receiving information by third parties, since it is almost impossible to crash into the cable);
- The cable is compact and light weight;
- Good degree of protection against fire and chemical attack;

The absence of metal in the composition of the cable, which makes it meaningless to steal it.

Fiber optic cable also has several disadvantages:

- The material is somewhat brittle, bends should be avoided during installation to avoid breakage;
- Non-repairable: in the event of a break, it is usually necessary to change the entire section of the laid cable;
- Over time, clouding of the fiber is possible;
- Signal conversion requires special equipment.

The main competitor of optical fiber is now twisted pair. Yes, twisted pair is usually cheaper, and somewhere its implementation can be really reasonable and economically

justified. But if you need a scalable network that is virtually unaffected by environmental influences and can last for decades, then fiber optic cable is the better choice.

Twisted pair

Twisted pair - a type of communication cable, is one or more pairs of insulated conductors twisted together (with a small number of turns per unit length), covered with a plastic sheath.

Benefits of Twisted Pair Cable:

- Well thought out design. By enhancing the interaction between each pair of conductors, users are guaranteed a high level of data transfer efficiency as a result.
- Versatility and wide distribution. Twisted-pair cables can connect almost any device. Since the market is full of varieties of cables, each user can choose what he needs.
- Ease of installation. The main quality of the cable is flexibility. It can be easily placed in places that are inaccessible to sight or physical impact. At the same time, the cable is perfectly suited for the transmission of various signals, both in office local networks and in global city networks.
- Relatively low cost of the product.

Disadvantages of Twisted Pair Cable:

- In some cases, a strong effect of electromagnetic waves is possible (the strength depends on the type of protection).
- Signal attenuation due to minor cable damage.
- Probability of information leakage (rather low).
- At high current frequency, the usable area of the conductor is reduced because the current is displaced from the center of the conductor. Such phenomena lead to signal attenuation.

How does the satellite communication system work?

The principles of satellite communications are very simple - ensuring the uninterrupted exchange of information between subscribers who are located anywhere in the world.

The signal is transmitted as follows - first, a radio wave arrives from the earth to the satellite, where it is amplified, cleared of interference and transmitted to subscribers.

For successful work, specific equipment is required:

- centers on the ground. Special complexes that are equipped with the necessary equipment for receiving, transmitting and switching signals. In order for the subscriber to be in touch anywhere in the world, there are mobile complexes - autonomous objects based on various vehicles that are equipped with amplifying transceiver equipment;

- repeater satellite. It is the key object of the whole system. In fact, this is an antenna that is in low Earth orbit. The first satellites were passive - they worked solely as repeaters, simply transmitting a signal from a ground station to the end user. Modern satellites are active - they not only broadcast the signal, but also encrypt it, amplify it, clear it of distortion, and only then transmit it back to earth;

- terminals (receiving and transmitting equipment). The simplest example is a satellite phone, which is always in touch, regardless of the location of the subscriber.

Satellite communication channels serve not only for telephony, they form television broadcasting and access to the Internet on their basis.

Features and key benefits of satellite communications

Cellular and satellite communications are very similar in their principle of operation - in both cases, the signal is transmitted from the source through intermediate objects (repeaters, amplifiers) to the end user.

Only the features of satellite communications are in the coverage area - if "cells" can provide information transmission to no more than 10% of the planet's terrestrial territories, then the satellite coverage area is located almost everywhere (in the air, in the ocean, at the poles).

The key advantages of satellite communication are as follows:

- the ability to exchange information anywhere in the world;
- ideal solution for areas with lack of appropriate infrastructure, management and coordination of aircraft and ships, as well as land transport
- wide capacity of satellite communication allows to transfer large amounts of information (data packets) to almost any distance;
- high level of signal quality and stable reception;
- secure communication due to encrypted communication channels.

Modern digital satellite communication is a high-quality transmission of information over long distances, regardless of the availability and capabilities of terrestrial communication infrastructure.

The disadvantages of satellite Internet can be considered:

- the need for a permit for radio transmitting equipment;
- high cost and bulkiness of the equipment;
- delay on the communication channel (a satellite signal needs about 250ms to get from the transmitting antenna to the satellite, and the same amount back);
- the ping period on a two-way channel can be 500-800ms;
- incompatibility of equipment from different manufacturers.

1.3. The concept and definition of the VSAT

A satellite communication station is a complex of equipment for transmitting information over long distances, located in places without a terrestrial network infrastructure.

The exchange of information between satellite stations occurs through an artificial earth satellite (AES) operating as a signal repeater: AES - a communications satellite - receives a signal from one station and, having amplified, transmits to another.

More satellite stations are used for backbone leased communication channels using SCPC (Single Channel Per Carrier) technology or are used as central earth communication stations (CZSS) in satellite communication networks to control subscriber VSAT stations. This type of stations is characterized by significant capital (equipment and construction) and

periodic (satellite resource lease) costs, as well as high requirements for the qualifications of engineers. Small satellite earth stations (MZSSS) or VSAT (Very Small Aperture Terminal) are used as user terminals under the control of ZZSSS. Compared to large stations, VSAT is simple and inexpensive to operate, small in size, weight and cost. This makes the use of VSAT convenient, inexpensive and justified in 90% of cases of using satellite communications.

Work principles

A VSAT-based satellite communication network includes three main elements: a central earth station (if necessary), a repeater satellite, and subscriber VSAT terminals.

The central earth station in the satellite communication network performs the functions of the central node and provides control over the operation of the entire network, redistribution of its resources, troubleshooting, billing of network services and interfacing with terrestrial communication lines. Typically, the DSC is installed in the network node, which accounts for the most traffic. This can be, for example, the main office or computer center of a company in corporate networks, or a large city in a regional network.

The subscriber VSAT terminal usually includes an antenna-feeder device, an outdoor external radio frequency unit and an indoor unit (modem). The outdoor unit is a small transceiver or receiver. The indoor unit provides pairing of the satellite channel with the user's terminal equipment (computer, LAN server, telephone, PBX fax, etc.).

Relay satellites of the VSAT network are built on the basis of geostationary communication satellites. This makes it possible to simplify the design of user terminals as much as possible and to equip them with simple fixed antennas without a satellite tracking system. The satellite receives the signal from the earth station, amplifies it, and sends it back to Earth. The most important characteristics of the satellite are the power of the onboard transmitters and the number of radio frequency channels (trunks or transponders) on it. Transmitters with an output power of about 40 W are required to ensure operation through small-sized subscriber stations of the VSAT type. Modern VSATs operate, as a rule, in the 11/14 GHz Ku-band (one frequency value for reception, the other for transmission); there

are also systems using the 4/6 GHz C-band, and the 18/30 GHz Ka-band is also being explored.

Transceiver equipment and antenna-feeder device are usually built on the basis of standard equipment available on the market. The cost is determined by the size of the antenna and the power of the transmitter, which significantly depend on the technical characteristics of the relay satellite used. To ensure communication reliability, equipment usually has 100% redundancy.

Channel-forming equipment provides the formation of satellite radio channels and their docking with terrestrial communication lines. Each of the suppliers of satellite communication systems uses its own original solutions for this part of the DSC, which often excludes the possibility of using equipment and subscriber stations of other companies to build a network. Typically, this subsystem is built on a modular basis, which makes it easy to add new blocks to increase its throughput as traffic grows and the number of subscriber stations in the network grows.

A modern VSAT provides information to the owner of the VSAT at a speed of up to 4 Mbps (in multicast mode up to 30 Mbps) and transmission of information up to 1-2 Mbps.

Modern VSATs have one or more Ethernet ports and built-in router functionality. Some models can be upgraded with 1-4 phone ports.

Advantages of the VSAT:

- Compactness. The equipment of the station has small dimensions and weight, is easily transported, quickly and conveniently mounted. The station's VSAT antenna can be mounted on a flat or pitched roof, on a vertical wall, or directly on the ground. If necessary, it can be quickly dismantled and quickly transported to another location. If such a need arises often, it is possible to organize a mobile small earth station, a satellite communication station on a car. Such a "mobile" VSAT station will make it possible to quickly organize telephone communications for the Ministry of Emergency Situations, broadcast TV reports from the scene, share Internet access at a tourist rally, etc.

- Ease of obtaining permits. The documents necessary for legal work are obtained simply and are inexpensive. As a rule, operators take care of all the hassle of obtaining permits for the user.
- Versatility. The IP/Ethernet interface allows you to use a satellite communication channel for a variety of business tasks: the Internet, corporate networks, voice, video, serial data, etc.
- Autonomy. An earth station does not need any "terrestrial" communication channels to operate, only power is needed. Moreover, the power consumption is so small that the station can operate for up to several hours from the batteries of a desktop "uninterruptible device".

And disadvantages of the VSAT:

- High connection price and traffic transmission price compared to the cost of renting a copper pair at a city exchange.
- Protocols and ports. All modern VSATs operate over IP protocol and have an Ethernet port at the output (usually one, rarely two), no V.35, G.703, RS-232, E1 or Frame Relay. In defense of VSAT, let's say that 99% of customers are fine with this, and the rest can install a transit router that can repacket traffic from one protocol to another.
- Satellite delay. Be that as it may, the speed of light we have is "only" 300 thousand km / s, while the satellite hangs at an altitude of 36 thousand km, and even above the equator, round-trip at least 600 ms for ping, and that's only for a dedicated channel, and for typical VSATs, 800–1000 ms is realistic.

The study showed that VSAT technology is effective for building satellite Internet networks. Thus, the title of the diploma work is relevant. The purpose of the work is the design of additional line of Internet network using VSAT technology based on the river port of Ukrainian city of Izmail.

CONCLUSION TO CHAPTER 1

This chapter discusses what a telecommunications system is, the criteria for creating models of such systems, the main advantages and disadvantages of satellite communication systems. The task was set to prove the feasibility of creating a backup line of satellite Internet using VSAT technology on the basis of the river port of the city of Izmail.

CHAPTER 2

THE CONCEPT, MAIN UNITS AND PARAMETERS OF THE VSAT

2.1. The composition of the system

A satellite communications station is a set of equipment for the transmission of information over long distances, located in locations without the infrastructure of the terrestrial network.

The exchange of information between satellite stations takes place via an artificial Earth satellite (AES), which acts as a signal repeater: AES - a communication satellite - receives the signal from a single station and, amplified, transmit to another.

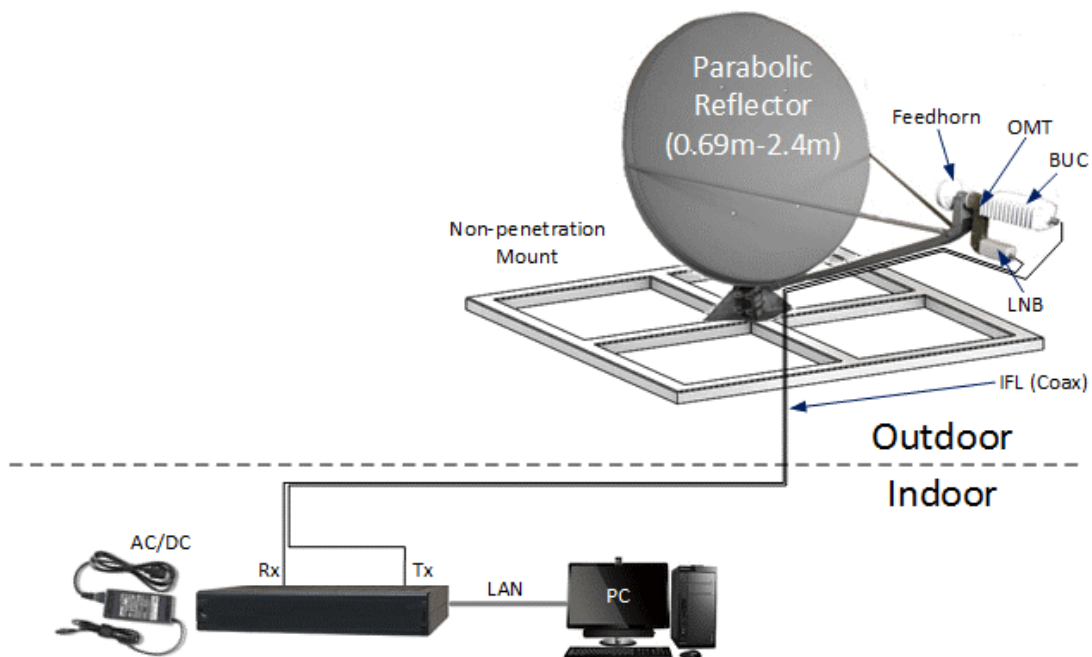


Fig. 2.1. Main components of VSAT system

More satellite stations are used for leased backbone communication channels using SCPC (Single Channel Per Carrier) technology or are used as central terrestrial

communication stations (CZSS) in satellite communication networks to control stations. of VSAT subscribers. This type of station is characterized by significant capital costs (equipment and construction) and periodic (rental of satellite resources), as well as high qualification requirements for engineers. Small Satellite Earth (MZSSS) or VSAT (Very Small Aperture Terminal) stations are used as ZZSSS-operated user terminals. Compared to large stations, VSAT is simple and inexpensive to operate, small in size, weight and cost. This makes the use of VSAT convenient, inexpensive and justified in 90% of cases of satellite communication [3]. VSAT consists of two main parts - an external antenna rack, which includes an antenna and a transceiver unit (ODU, outdoor unit - outdoor unit), and a satellite modem (IDU, indoor unit - outdoor unit). inside).

The transceiver device (ODU) is mounted on the illuminator in the focus of the antenna and transmits and receives modulated satellite signals via satellite. The ODU includes a semiconductor amplifier (SSPB, BUC), usually low power, up to 2-3 watts, though it may be more, and a low-noise amplifier-converter (LNB). LNB and BUC are connected to the power supply via a polarization selector, receiving and transmitting a signal in orthogonal polarization to each other (vertical and horizontal for linear, left and right for circular - depending on which is used by the satellite). OMT can be supplied with ODU or supplied with antenna. The outdoor unit and the modem are connected by coaxial cables with F or N type connectors. The length of the cable route from the antenna location to the modem is generally up to 20- 30 m, with special types of cables - up to 100 m.[3]

An indoor unit (IDU) is a small desktop unit (satellite modem) that converts information transmitted between analog communications over satellite and local devices such as telephones, computer networks, computers, televisions, and more. In addition to basic conversion programs, IDUs may also contain additional features such as security, network acceleration, and other features.

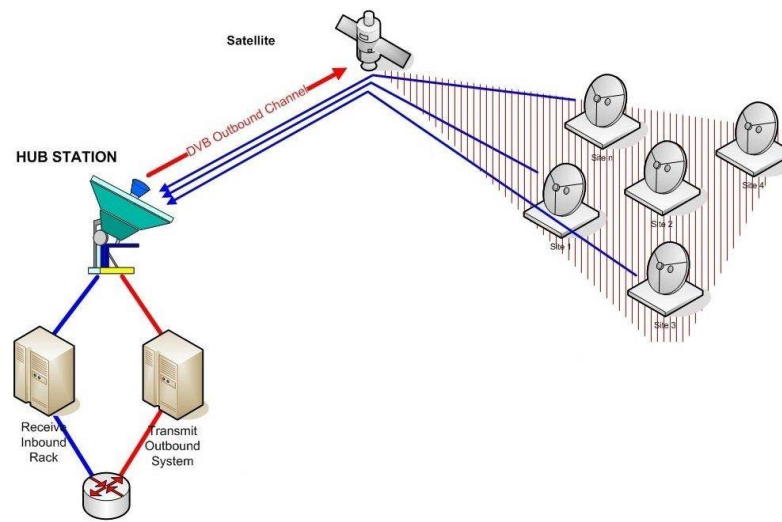


Fig. 2.2. VSAT network

Principles of work

A VSAT-based satellite network includes three main elements: a central ground station (if required), a satellite repeater, and a subscriber's VSAT terminal.

The central earth station in the satellite communication network performs the functions of the central node and provides control over the operation of the entire network, redistribution of its resources, troubleshooting, billing for network services and interaction with terrestrial communication lines. Typically, the DSC is installed on the network node that has the most traffic. This could be, for example, the company's head office or computer center in corporate networks or a large city in a regional network.

The subscriber's VSAT terminal typically includes an antenna power supply, an external external RF unit, and an indoor unit (modem). The outdoor unit is a small receiver or receiver. The indoor unit compares the satellite channel with the user's terminal equipment (computer, LAN server, telephone, PBX, etc.).

VSAT repeater satellites are built on the basis of geostationary communication satellites. This makes it possible to simplify the design of subscriber terminals and equip them with simple stationary antennas without satellite tracking system. The satellite receives a signal from the earth station, amplifies it and sends it back to Earth. The most important characteristics of the satellite are the power of onboard transmitters and the number of radio

frequency channels (trunks or transponders) on it. Transmitters with an output power of about 40 watts are required to operate through miniature VSAT subscriber stations. Modern VSATs operate, as a rule, in the Ku 11/14 GHz band (one frequency value for reception, another for transmission); there are also systems that use the C 4/6 GHz band, and the Ka 18/30 GHz band is being investigated.

Transceiver and antenna-feeder equipment are usually based on standard equipment available on the market. The cost is determined by the size of the antenna and the power of the transmitter, which significantly depend on the technical characteristics of the satellite relay used. To ensure reliable communication, the equipment usually has 100% redundancy.

Channel-forming equipment provides the formation of satellite radio channels and their connection with terrestrial communication lines. Each satellite system provider uses its own original solutions for this part of the DAC, which often precludes the use of other companies' equipment and subscriber stations to build the network. Typically, this subsystem is built on a modular basis, which allows you to easily add new blocks to increase its flow as traffic increases and the number of subscriber stations in the network.

Modern VSAT provides information to the owner of VSAT at speeds up to 4 Mbps (in multicast mode up to 30 Mbps) and data transfer up to 1-2 Mbps.

Modern VSATs have one or more Ethernet ports and integrated router features. Some models can be upgraded with 1-4 phone ports.

Features of VSAT systems:

From a technological point of view, the VSAT system has the following characteristics:

1. Has the ability to digitally process and transmit multiple signals, including voice, data, and television conferencing. When transmitting voice, data, and television conferencing, data compression technology has become widespread.

2. Flexible multi-access mode. The transmission line from the primary station to the remote small station is called the output or output, and the transmission line from the small station to the primary station is called the input or input. The flow of output information is

intermittent, and the flow of input information is intermittent, both trading volumes are asymmetric. Therefore, the VSAT system adopts different multicast continuation modes in both directions of transmission, respectively, to implement asymmetric bidirectional transmission, which is the main difference between VSAT and other satellite communication system.

3. The network management system is becoming more sophisticated. Because small station information is packet information, VSAT must configure a highly intelligent network management system to monitor, control, and manage performance, channel allocation, and statistics. business, which is one of the differences between VSAT and other satellites. communication system.

4. Wide topological structure of the network. The topological structure of the VSAT network has three types: star-shaped, mesh, and composite. The star structure, which is mainly used in data transmission, should have a primary station. The mesh structure, which is mainly used in voice communication, does not have a primary station. For a large website, a comprehensive structure with more sophisticated network and channel management is available, providing an integrated transmission of multiple sets of information. The choice of the topological structure of the network is mainly based on business demands.

5. The VSAT device is gradually miniaturized and integrated, and the price of the device continues to decrease, which makes the VSAT system the features of easy installation, cheap price and easy maintenance, and so on. The initial investment is quite large, but the cost of maintenance is cheaper.

6. Compared with other communication methods, the VAST system has such a feature that the cost of communication channel is not related to distance, so it is used especially in remote areas.

7. It is easier to expand the VSAT system. VSAT utilization and transmission capacity can be expanded as the number of small stations increases and uplink and downlink carrier bandwidth is adjusted to demand. The ability to expand the system largely depends on the choice of equipment model; therefore, it must have some predictability for the prospects of system development in system design.

The VSAT satellite communication system has very obvious features, which mainly include the following aspects:

1. The ground station antenna (remote) has a small diameter, which is usually 2 meters below. Now it mainly takes a diameter of 1.2 ~ 1.8 m. Climbers sometimes use a personal world air station with a diameter of 0.3 m.

2. The transmission power is low, which is usually from 1 to 3 watts.

3. Light weight. It's always tens of kilograms, and some - a few kilograms. And they are easy to wear.

4. The price is low, economical and practical. This system has a low cost and its cost-effectiveness exceeds the cost of the equipment.

5. The construction cycle is short. It's easier than traditional local communications. The cable and optical cable do not need to be disconnected. Unlike microwave communication, it does not need to stop the relay station every 50 km. In the VSAT satellite communication system, it is easier to install only the necessary equipment at both ends of the communication and to assemble the equipment.

6. The cost of communication does not correspond to the cost of communication. As for the general communication system, the greater the distance, the higher the cost. But VSAT satellite is not a distance. The greater the distance, the more adaptive the VSAT connection.

7. VSAT satellite communication is independent of terrain and climate, as it does not require ground-based equipment and is rarely disturbed by land.

8. The biggest advantages of VSAT satellite technology are its flexibility in network combination, easy maintenance and ease of expansion, as it does not have complex terrestrial equipment.

Application of VSAT satellite technology

VSAT can easily create a flexible and cost-effective network system of different scales, different speeds and different applications. The VSAT network can contain from 200 to 500 small stations, which have a wide range of applications, including broadcast type,

point-to-point type, two-way interactive type and data collection type. It can be used not only in developed countries, but also in less technologically advanced and underdeveloped countries, especially in remote areas of difficult terrain, less populated and inconvenient lines. It can be configured directly on a person, so it is important for the military. Typically, VSAT technology can be used in the following aspects.

1. Can be used to promote satellite television and satellite television broadcasting, as well as the transmission of television broadcasting and business television signals. This method of application plays a vital role in both material and spiritual civilization for remote areas of our country.

2. It can be applied to the financial and securities system to monitor and dynamically manage the market situation, which significantly shortens the cash conversion cycle.

3. Can be used to conserve water to manage hydrological changes in order to prevent and reduce natural disasters. The VSAT system can transmit information received from the meteorological satellite, marine satellite, resource satellite and ground detection station in a timely manner.

4. Can be applied to the transport system. Foreign developed countries use it in the operation and shipment of railways, which greatly facilitates transport loads.

5. Can be applied to the military. During the Gulf War in 1999, the international military used VSAT for a large amount of mobile communications and equipped it for each soldier.

6. Can be used for emergency and remote communications. VSAT is the most convenient backup communication system in the event of a natural disaster or emergency.

2.2. Topologies of networks with VSATs

There are several topologies of networks with VSATs as discussed below. The difference in network topology may affect the control and monitoring function of VSATs.

3.1 Star type topology In this topology, there is a “hub” earth station where the user traffic from a group of VSATs is concentrated and which assumes control of the VSATs. However, more than one hub earth station may be utilized in the network for redundancy purposes (i.e.

primary and backup hub earth station). When communicating between VSATs, the “double hop” path must be employed (order $2N$ latency). In many cases, the frequency spectrum is shared between VSATs based on a demand driven protocol. The transmission speed of outbound (i.e. hub to VSAT) and inbound (i.e. VSAT to hub) traffic is often asymmetric for such networks in order to avert bottlenecking of data traffic at the hub. It should also be noted that VSATs with different characteristics (i.e. antenna diameter, transmission power and so forth) may operate in the same network.

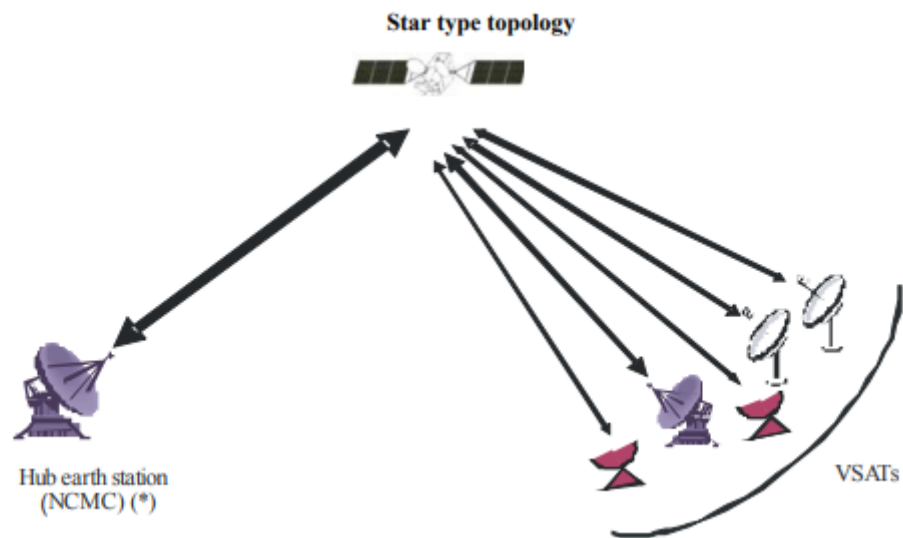


Fig. 2.3. Star type topology

Mesh type topology

In this topology, a group of VSATs can communicate with each other without involving a hub earth station (i.e. “single hop” connection) as depicted in Fig. 2.4 (order N latency). There is a network control and monitoring centre (NCMC) earth station (or more than one NCMC earth station in redundancy) for management and control of the group of VSATs.

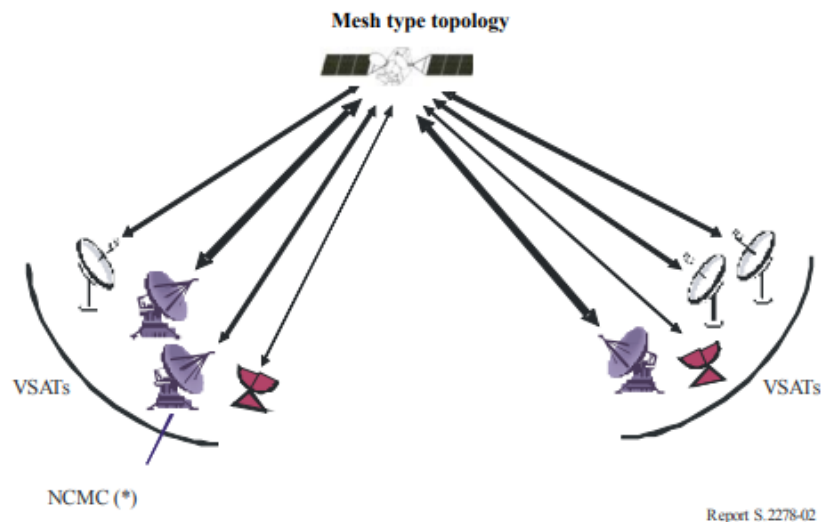


Fig. 2.4. Mesh type topology

Yet the user traffic need not be concentrated to the NCMC earth station. In many cases, the frequency spectrum is shared between VSATs on demand basis. The transmission speeds may vary from station to station independent of type. It should also be noted that VSATs with different characteristics (i.e. antenna diameter, transmission power and so forth) may operate in the same network [3].

Hybrid topology

A network with a hybrid topology uses characteristics of both star and mesh topologies. For example, depending on the number of stations in the network, it may be more efficient to have the edges of the network use a star topology while connecting the “centres” of the stars by means of a mesh network. NOTE – Any combination of topology and multiple access may be used in VSAT networks.

Point-to-point topology

In this topology, only two earth stations on a point-to-point connection are associated as depicted in Fig. 2.5. Either one end or both ends of the connections are VSATs. Basically,

the frequency spectrum is not shared but dedicated to the connection and VSATs operate in stand-alone mode without control by other earth stations. However, one earth station plays a role of “master” earth station that controls the other earth station (“slave”) in some cases.

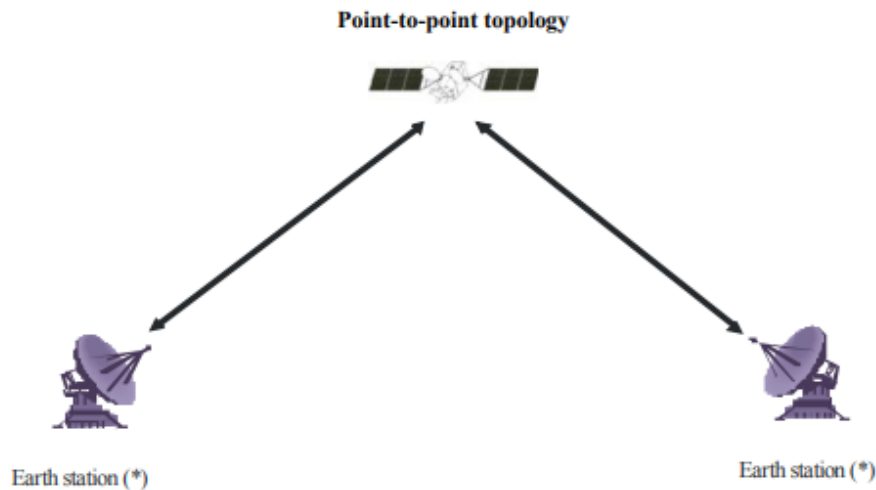


Fig. 2.5. Point-to-point topology

2.2. The main parameters of VSAT antennas

The main parameters of 1m VSAT Antenna are in the table 2.1[4].

Table 2.1

Parameters of 1.0m VSAT antenna		
Antenna	1.0m VSAT antenna	
	Ku-RECEIVE	Ku-TRANSMIT
Frequency (GHz)	10.95-12.7	13.75-14.5
Typical Gain(dBi)	40.01	41.32
VSWR	1.25:1	
Beamwidth: -3dB	1.64°	1.39°
Antenna Noise Temperature(°K)	2Port Feed	
10°Elevation	45	

20°Elevation	39	
40°Elevation	35v	
Power Handling Capability		1KW/Port
Feed interface	WR-75	
Feed Insertion Loss	0.25dB	0.2dB
Tx-Rx	≥85dB	
Cross Polarization Isolation (on axis)	≥35dB	
Sidelobes	CCIR.580-4	
Mechanical		
Antenna Optics	Ring-focus antenna	
Azimuth Travel	360°	
Elevation Trave	0° to 90°	
Surface Accuracy 0.5mm(R.M.S)	0.5mm(R.M.S)	
Environmental		
Wind Loading	72kmph operational (Maintain Precision)	
	97kmph operational (Decrease Precision)	
	200kmph Survival (Fixed Heavenward)	
Ambient Temperature	-45°to 60°	
Relative humidity	0% to 100%	
Seismic(Survival)	0.3G horizontal 0.15G vertical	

The main parameters of 1.2m VSAT Antenna are in the table 2.2.

Table 2.2

Parameters of 1.2m VSAT antenna		
Antenna	1.2m VSAT Antenna	
	Ku-RECEIVE	Ku-TRANSMIT
Frequency(GHz)	10.95-12.75	13.75-14.5

Typical Gain(dBi)	42.16	43.45
VSWR	1.25:1	
Beamwidth: -3dB	1.281°	1.104°
Antenna Noise Temperature(°K)	2Port Feed	
10°Elevation	44	
20°Elevation	38	
40°Elevation	34	
Power Handing Capability	1KW/Port	
Feed interface	WR-75	
Feed Insertion Loss	0.25dB	0.20dB
Tx-Rx	>85dB	
Cross Polarization Isolation(on axis)	≥ 35dB	
Sidelobes	CCIR.580-4	
Mechanical		
Antenna Optics	Ring-focus antenna	
Azimuth Travel	360°	
Elevation Travel	0°to 90°	
Surface Accuracy	0.5mm(R.M.S)	
Environmental		
Wind Loading	72kmph operational (Maintain Precision)	
	97kmph operational (Decrease Precision)	
	200kmph Survival (Fixed Heavenward)	
Ambient Temperature	-45°to 60°	
Relative humidity	0% to 100%	
Seismic(Survival)	0.3G's horizontal 0.15G's vertical	

The main parameters of 1.8m VSAT Antenna are in the table 2.3.

Table 2.3

Parameters of 1.8m VSAT antenna		
Antenna	1.8m VSAT Antenna	
	Ku-RECEIVE	Ku-TRANSMIT
Frequency(GHz)	10.95-12.75	13.75-14.5
Typical Gain(dBi)	44.98	46.29
VSWR	1.25:1	
Beamwidth:-3dB	0.926°	0.796°
-15dB	1.852°	1.59°
Antenna Noise Temperature(°K)	2Port Feed	
10°Elevation	43	
20°Elevation	39	
40°Elevation	35	
Power Handling Capability		1KW/Port
Feed interface	WR-75	
Feed Insertion Loss	0.2dB	
Tx-Rx	≥85dB	
Cross Polarization Isolation(on axis)	≥35dB	
Sidelobe	CCIR.580-4	
Mechanical		
Antenna Optics	Ring-focus antenna	
Azimuth Travel	360°	
Elevation Travel	0°to 90°	
Surface Accuracy	0.5mm(R.M.S)	
Environmental		
Wind Loading	72kmph operational (Maintain Precision)	
	97kmph operational (Decrease Precision)	
	200kmph Survival (Fixed Heavenward)	

Ambient Temperature	-45° to 60°
------------------------	-------------

2.3. Initialization of the operation of a VSAT

When a VSAT is powered on, its operational status is assessed by both the NCMC as well as the command processor on the terminal. The VSAT transmission is enabled when the following conditions are met[2]:

- 1) the VSAT determines that it is correctly receiving and interpreting a specified command signal generated by the NCMC;
- 2) the VSAT confirms that no faults have been detected that could result in harmful interference;
- 3) the initial transmission parameters such as frequency, power, modulation, timing and coding schemes and so forth are in compliance with expected performance. Conditions 1) and 3) are not applicable in a point-to-point topology when a VSAT operates in a stand-alone mode.

In determining the initial transmission parameters of a VSAT, the NCMC may take into account some of the following profiles:

- geographical location of the VSAT (to establish transmission timing, propagation loss and if the terminal is authorized for operation at that location);
- satellite gain in the direction of the VSAT (to determine transmission power towards and from the VSAT);
- local rain statistics
- service subscription profiles of the VSAT (e.g. maximum transmission speed of outbound/inbound direction);
- the current number of terminals already authorized or currently in operation (to prevent overloading of satellite resources).

Control and monitoring functions during the operation of a VSAT

During its operation, the VSAT is continuously assessed by the NCMC and its own command processor for correct operation, and it is usually possible for the NCMC or an equivalent facility to monitor the health of a VSAT and to determine if a VSAT has failed.

The VSAT should cease its transmission when one of the following events occurs:

- 1) the VSAT loses the control carrier from the NCMC;1
- 2) the VSAT detects a fault that could result in harmful interference being produced;
- 3) a command is received from the NCMC that directs the VSAT to change the transmit frequency;
- 4) the angle between the orbital location of the target satellite and the axis of the main lobe of the VSAT antenna exceeds allowed limits;
- 5) the VSAT has been relocated to a geographic area where it does not have administrative permission to operate.

The VSAT may resume transmission once the issue that caused the shutdown as listed above has been cleared. However, a VSAT network with “point-to-point topology” and stand-alone VSAT operation may continue transmission after its local malfunction is cleared without receiving the carrier from the other VSAT because otherwise the network will never restore after rain fades if both sides stop transmission.

In addition, the VSAT should accept the commands for “enable transmission disable transmission” from the NCMC or an equivalent facility (e.g. in a case of emergency).

Dynamic power control function during the operation of a VSAT

In order to achieve the efficient use of transmission power of satellites and VSATs, dynamic power control mechanisms may be employed. Figure 5 shows an example of dynamic power control of a VSAT (in star topology). In this example, it is assumed that the uplink power of the hub earth station has already been properly adjusted in advance.

The VSAT periodically measures the signal quality (e.g. C/N) of the outbound carrier and reports it to the NCMC. The NCMC determines the transmit power requirement of the VSAT based on the quality report from the VSAT and its own measurement on the signal quality of the inbound carrier and command it to the VSAT accordingly.

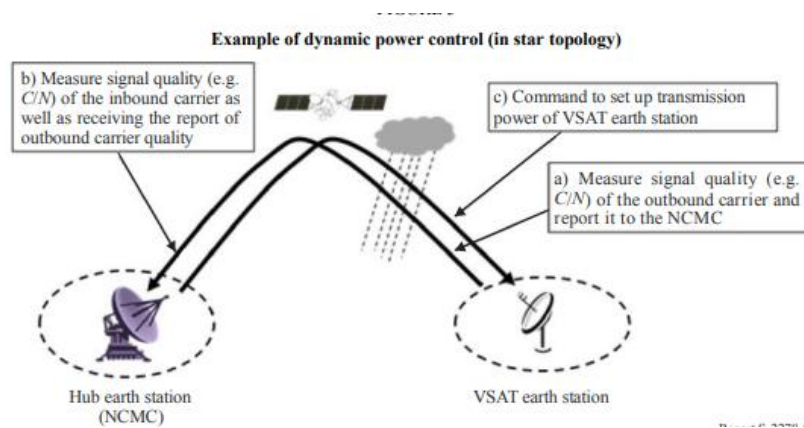


Fig. 2.6 Example of dynamic power control

The VSAT will then carefully adjust its transmit power in order to avoid excess power emission.

Adaptive coding and modulation function

In order to improve the link availability and spectral efficiency, the ACM function may be effective in a VSAT system. With ACM, a VSAT system can change its modulation and coding (MODCOD) rates adaptively depending on the channel condition. In clear sky conditions, a spectrally efficient MODCOD (e.g. 16APSK 4/5 FEC) is used, and in rain fading conditions, a more power-efficient MODCOD (e.g. QPSK ½ FEC) is used. In order to implement adaptive rain fade compensation according to the channel conditions, it is required to predict the channel condition. For this purpose, an ACM control algorithm may also be combined with a dynamic power control algorithm. The detailed ACM control algorithm is provided in Recommendation ITU-R S.1061. Figure 6 shows an example of ACM of a VSAT (in star topology). In this example, the VSAT periodically measures the SNR of the outbound carrier and reports it to the NCMC. Also the NCMC measures the SNR of the inbound carrier and predicts the channel condition based on Recommendation ITU-R S.1061. The NCMC determines the modulation schemes of the outbound and inbound carriers and finally changes its own MODCOD adaptively. Then, the NCMC commands the VSAT to change the MODCOD. When implementing the ACM function, it

should be taken into account that the MODCOD needs to be carefully adjusted in order to prevent packet loss caused by unwanted oscillation in choice of the MODCOD.

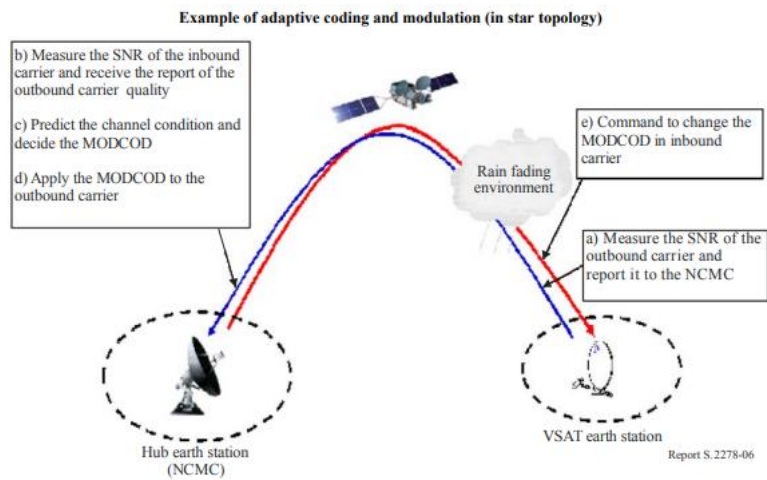


Fig. 2.7 Example of adaptive coding and modulation

2.4. VSAT units

The main units of the VSAT are shown in Fig. 2.8.

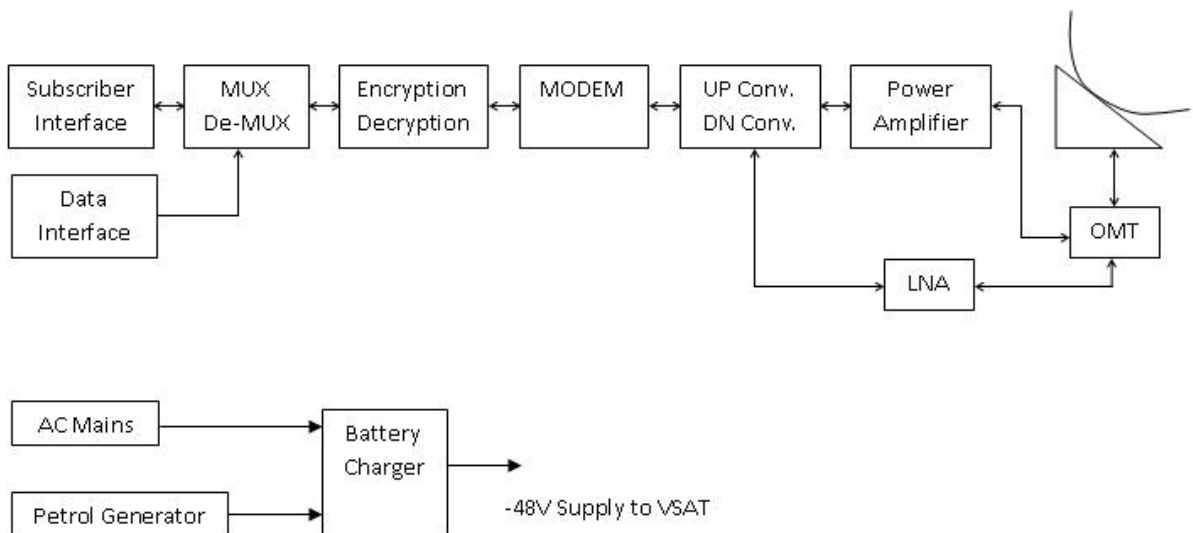


Fig. 2.8 Main VSAT units

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 dish and will go to the medium consecutively. It also collects the received power from dish and will enter into the LNA. Feed horn is made of array of microwave passive components. The outdoor unit is connected through coaxial cable to the indoor unit, which is situated inside the room/building. Length of the cable is usually about 300 foot (approx. 90 meter).

VSAT Indoor Unit

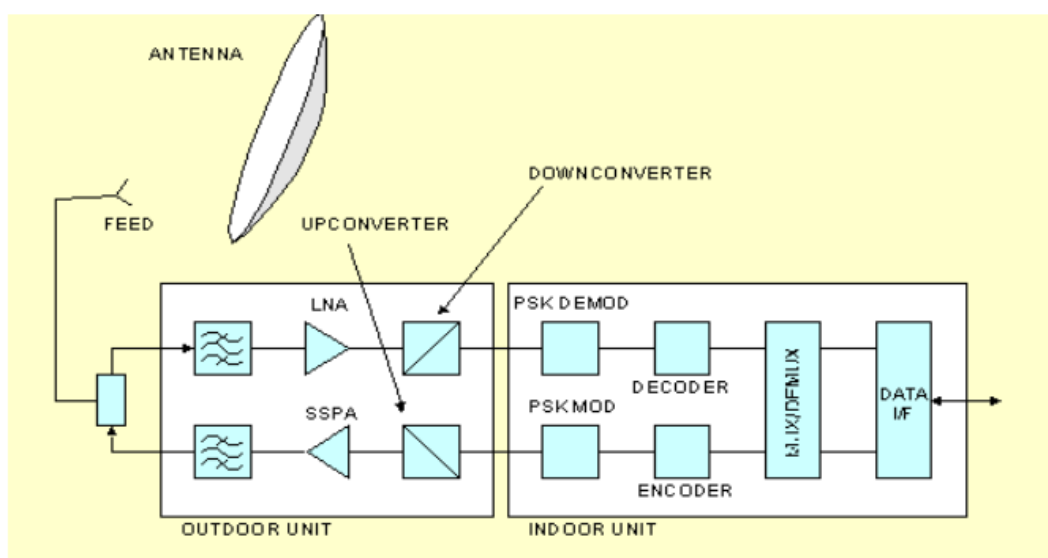


Fig. 2.9 Indoor unit

- 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. This is done based on modulation scheme set. Usually QPSK scheme is used in satellite communication. Forward Error Correction is also employed in modem which enhances the BER for the same transmitter power usually used in non-FEC systems.

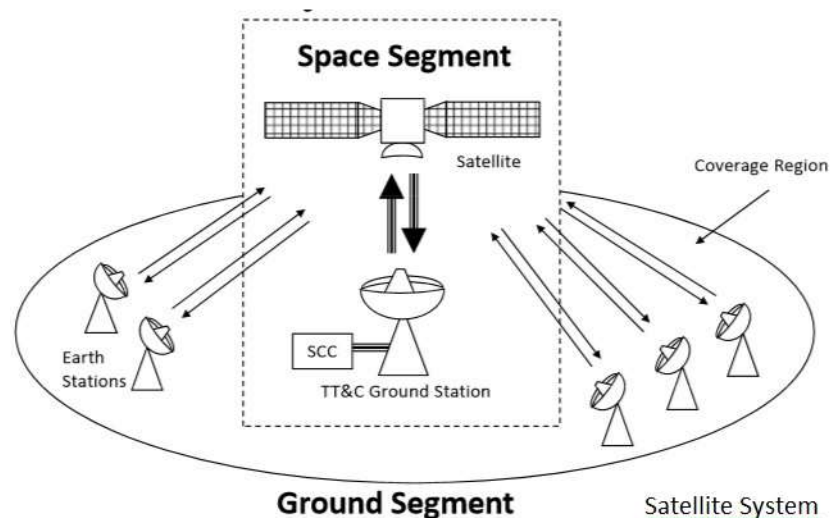


Fig. 2.10 Satellite system

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 VSAT frequency assignments as per FDMA, frequency settings in various modems and RF transceivers are set appropriately.

2.5. VSAT Installation procedure

Let us understand step by step procedure for VSAT installation.
 Step 1- Open all the sub systems from the received boxes. Sub systems include Antenna and accessories, Feed Horn, OMT, BUC, LNB, Satellite Modem, MUX, EDU.

Step 2- Mount Antenna along with support, Do not tight all the screws.
 Step 3- Check satellite latitude and longitude with which VSAT has to be tuned. Calculate Azimuth and Elevation required for antenna alignment using calculators available in putting latitude and longitude of the place where VSAT need to be installed.

If calculators are not available, one can calculate required azimuth and elevation angles for pointing an antenna towards Geo satellite using latitude of site, longitude of site and equatorial longitude of the satellite as mentioned below.

First calculate angle Beta and path length L.

$$\text{Beta} = \cos^{-1}(\cos[DI] \cdot \cos[la])$$

Where, "DI" is the difference between the longitude of the Earth Station and the Satellite.
 "la" is the earth station latitude

$$L = (18.2 - 5.4 \cos[\text{Beta}]) \times 10^4 \text{ Km}$$

$$\text{ElevationAngle} = \cos^{-1}[4.22 \times (10^4/L)] [\sin(\text{Beta})]$$

$$\text{Azimuth} = [180\text{degree} + \tan^{-1}(\tan(DI)/\sin(la))]$$

Step 4- Adjust Antenna Azimuth using compass and also elevation using tools available

If tools are not available roughly place antenna and first complete all other steps as mentioned below then connect the spectrum analyzer at IF OUT of LNB and check for good signal, tighten the antenna in that position.

Step 5- Run the IF cables from LNB and BUC to indoor unit (satellite modem). Connect LNB cable to IF IN of modem and BUC to IF OUT of modem.

Step 6- Do necessary connections between MUX and Satellite modem for the Data (or voice or voice plus Data) to be transmitted using satellite link.

Step 7- Connect MUX with EPABX for voice connection and with PC for data connection depending on the system designed for.

Step 7- Do setting for appropriate VSAT frequency and power in RF equipments (RF Transceiver unit) and modem.

Following settings need to be done in IF Modem for VSAT 1 and VSAT 2 to be communicated via satellite. Need to take care of Bandwidth so that one spectrum does not overlap the other.

The example of the VSAT frequency settings

Following are the typical VSAT frequency settings at modems and RF transceivers units applied for VSAT installation. This establishes VSAT to VSAT communication via satellite.

Mod:	71.1MHz	Demod:	71.1MHz	(VSAT1)
Demod:	71.2MHz	Mod:	71.2MHz	(VSAT2)
UC:	6176.1MHz	UC:	6176.2MHz	(VSAT1)
DC:	3951.1MHz	DC:	3951.2MHz	(VSAT2)

Typical VSAT system specification

1. Access is TDM-QPSK-FDMA
2. Information rate 128kbps
3. Hub station antenna 11 meter or 7.5 meter
4. VSAT antenna 2.4 meter, 5 watt PA, 65s deg K LNA
5. Rate 1/2 Convolution FEC, Viterbi soft decision decoder and outer Reed Solomon encoder-decoder
6. Support for 5-7 voice channels, Data channel for Network Management
7. Frequency of operation -C band

2.6. VSAT Pricing

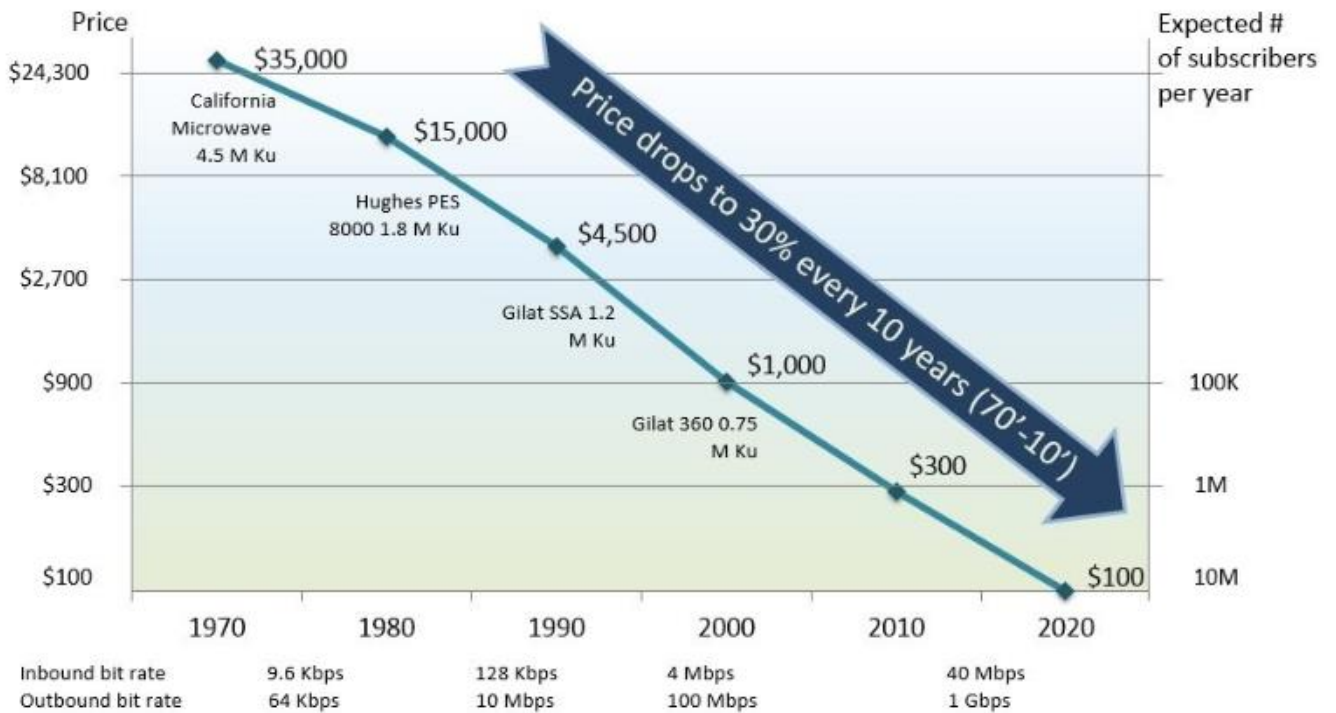


Fig.2.11 Prices of VSAT systems

If you look at the price point of VSATs over the years (Fig.2.11), one can see that the price dropped to roughly 30% every 10 years. Starting from the early 70s where the price was \$35K per VSAT (California Microwave and the Alascom program), down to \$300 in 2010. Several announcements of products and their announced price are presented on this

chart. Many times, people ask if the price could go any lower, but it always did. The key question for this post is “where do we go from here”.

Antenna Subsystem

Antenna – cost in the DTH market is in the range of \$10. The Key factor in price are ODU weight and environmental requirements (wind speed etc...). An antenna structure can be priced at \$22 without Feed-horn can be used as a baseline for 2-way. LNB – In general per VSAT application, LNB is around \$2.5 for Ku and \$7.5 for Ka. RF – A New Ku/Ka Direct Conversion Modulator/Demodulator Chips (>\$10 each), the demodulator chip conceptual block diagram is shown in Fig.2.12.

Direct RF sampling and Full Band Capture (FBC) – New ADCs and DACs at 64 Gsample/sec with SiGe based front end at the cost of ~\$5 are also becoming available, and with a low cost SiGe front end for the LNAs and HPAs cost point of the RF is reduced to below \$30.

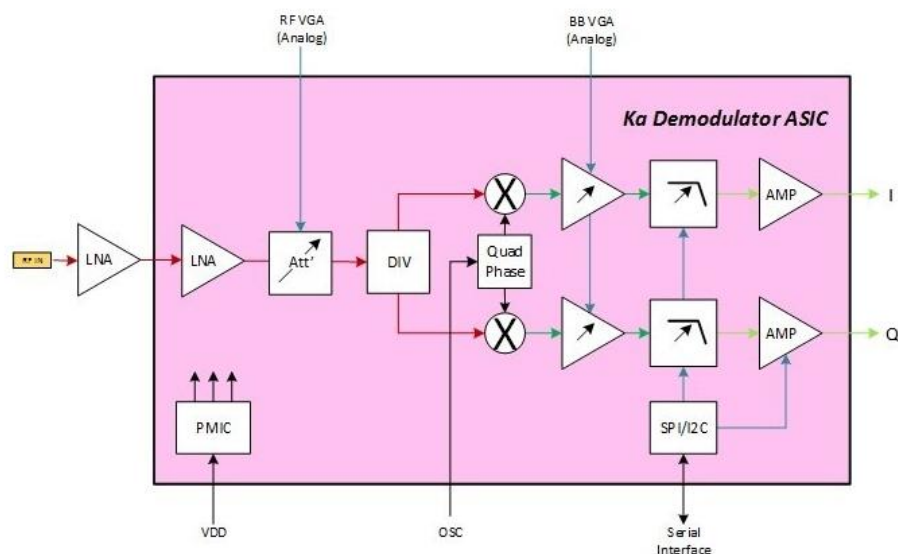


Fig.2.12 Demodulator chip conceptual block diagram

Biggest Issue – Professional Installation Cost

One of the highest cost factors is the terminal installation and commissioning[5]. The “dream” install price was always \$199. Actual installation costs (when the installer leaves the site) could get to \$500. The whole process can take 30 min for experienced installer up to 4 hours for a non-experienced installer.

VSAT prices were constantly reduced over the years, and nowadays the potential to get to \$100 VSAT price is getting closer. The availability of antennas based on DTH at price point below \$30 in quantities, seems to be close. LNBS and BUCs for low power, 1W operation are getting integrated into SiGe-based ICs that cost a few dollars each. Either an LNA, PA and direct conversion ICs or direct RF sampling at frequencies such as Ku band, are approaching the \$30 range as well. The key is a very low cost, highly integrated baseband modem SoC which the next version (and definitely the one after it) will enable very low-cost IDU or baseband part.

VSAT pricing also includes the IFL cables, the mount, and the power supply but those are much time counted as part of the installation, which is the next main target to go after.

As it becomes clear, the VSAT system has a number of advantages such as low price, versatility, energy efficiency, reliability and relative simplicity of the system as a whole. based on these considerations, it was decided to organize a system of backup Internet and telephony bands specifically on VSAT technology.

CONCLUSION TO CHAPTER 2

In this section, we examined the composition of the VSAT system, what components the outer and outer parts of the system consist of, the principle of operation, the types of topology and the main parameters of the antennas. They also learned about operation initialization, function control and monitoring, dynamic power management, and adaptive coding and modulation function.

CHAPTER 3

Specific model calculations

In this chapter all calculations for our VSAT system will be done. The task is about to design additional Internet system using VSAT satellite technology for Izmail river trading port. Here the satellite image of the port:



Fig. 3.1 The territory of the port

As we can see port is divided into several parts that are at some distance from each other. The main part is this building:



Fig 3.2 The main building

So, as it the main building, we will design the spare Internet system for it.

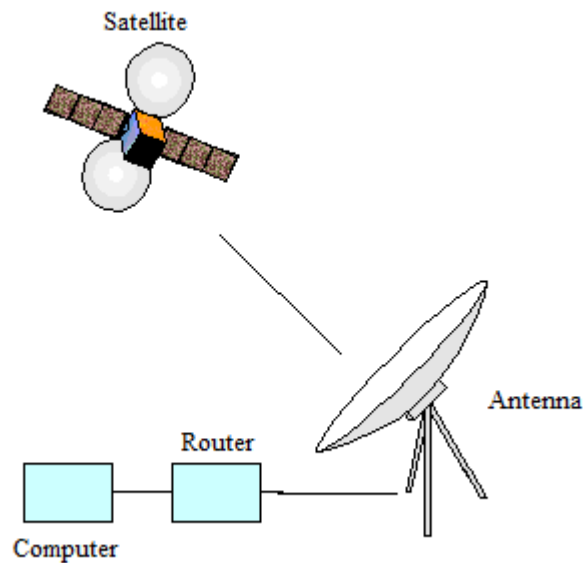


Fig 3.1 Scheme of the system

3.1 Calculation of signal attenuation during signal propagation

The main reason for the attenuation of the radio signal is the attenuation in the free space caused by the spherical divergence of the wave front. This value can be found from the formula:

$$L_0 = 20 \lg \left(\frac{4\pi d}{\lambda} \right),$$

where L_0 is the energy attenuation in free space, dB;

d is the distance between the satellite and the ES, m;

$\lambda = c/f$ is the wavelength of the transmitted signal, m;

$c=3*10^8$

is the speed of light, m/s;

f is the signal frequency, Hz.

Calculate the distances from earth stations to onboard satellite repeater according to the formula:

$$d = 42644 \sqrt{1 - 0,2954 \cdot \cos \psi}$$

where $\cos \psi = \cos \xi \cos \Delta\beta$;

ξ is the latitude of the ground station, degrees;

$\Delta\beta = |\beta_{ks} - \beta_{ss}|$ is the difference between the longitudes of the space and earth stations(ES), deg.;

d is the distance from the earth station to the satellite, km.

Substituting the initial data into the formula for determining the distance, we will get the distances between the satellite and earth stations:

1) Distance between ES1 to the satellite:

$$d = 42644 \sqrt{1 - 0,2954 \cdot \cos \xi \cos \Delta\beta} = 42644 \sqrt{1 - 0,2954 \cdot 0,728 \cdot 0,982} = 39280 \text{ km}$$

2) Distance between ES2 to the satellite:

$$d = 42644 \sqrt{1 - 0,2954 \cdot \cos \xi \cos \Delta\beta} = 42644 \sqrt{1 - 0,2954 \cdot 0,743 \cdot 0,966} = 37850 \text{ km}$$

The attenuation of signal energy in free space strongly depends on frequencies. When working with satellite Intelcat 17, according to the frequency plan, we select operating frequencies of the sixth trunk: AP reception frequency 11158.33 MHz; frequency 14208.33 MHz transmissions.

Calculate the operating wavelengths for the earth station in Ku-band:

$$\lambda_{\text{tm}} = \frac{c}{f_{\uparrow}} = \frac{3 \cdot 10^8}{14208,33 \cdot 10^9} = 0,021 \text{ m}$$

$$\lambda_{\text{rev}} = \frac{c}{f_{\downarrow}} = \frac{3 \cdot 10^8}{11158,33 \cdot 10^9} = 0,027 \text{ m}$$

Ka-band:

$$\lambda_{\text{tm}} = \frac{c}{f_{\uparrow}} = \frac{3 \cdot 10^8}{30 \cdot 10^9} = 0,01$$

$$\lambda_{\text{rev}} = \frac{c}{f_{\downarrow}} = \frac{3 \cdot 10^8}{20 \cdot 10^9} = 0,015$$

For EAs, the attenuation of signal energy in free space is:

1) ES1-satellite:

$$L_{0 \text{ tm}} \uparrow = 20 \lg \left(\frac{43,1439280 \cdot 10^3}{0,021} \right) = 207,423 \text{ Db}$$

and on the propagation path of satellite -ES1:

$$L_{0 \text{ rec}} \downarrow = 20 \lg \left(\frac{43,1439280 \cdot 10^3}{0,027} \right) = 205,24 \text{ Db}$$

2) ES2-satellite:

$$L_{0 \text{ tm}} \uparrow = 20 \lg \left(\frac{43,1437850 \cdot 10^3}{0,021} \right) = 207,101 \text{ Db}$$

and on the propagation path of satellite -ES2:

$$L_{0 \text{ ПРМ}} \downarrow = 20 \lg \left(\frac{43,1437850 \cdot 10^3}{0,027} \right) = 204,918 \text{ Db}$$

In addition to attenuation in free space, the signal in the lines satellite communication is influenced by a large number of other factors such as atmospheric absorption, refraction, the effect of rainfall and etc. On the other hand, to the receiver of the satellite and the earth station in addition to their own fluctuation noise, various kinds of interference in the form of radiation from space, the sun and planets. In these conditions correct and accurate consideration of the influence of all factors makes it possible to carry out optimal system design, ensure its reliable operation in the most difficult conditions and at the same time eliminate unnecessary energy reserves leading to an unjustified increase complexity of earth station equipment.

Calculation of additional signal attenuation in the atmosphere and additional attenuation caused by rain, fog and clouds due to refraction and inaccuracies in pointing the antenna to the satellite is made once for the line up and downlinks, since geostationary satellites are used, and within Ukraine, these parameters will change slightly. Most signal loss in the troposphere is random because depends not only on the path length in this medium

and the elevation angle, but also on signal absorption in sediments. The higher the communication frequency, the greater the loss in precipitation at a given intensity, which, in turn, is random. In the troposphere, the main losses are caused by O₂ oxygen, water H₂O vapor and precipitation in the form of fog, rain and snow.

Attenuation in hydrometeors depends on the intensity of the rain, the size zones of their fallout and distribution of intensity over the zone. Absorption in fog, as a rule, is an order of magnitude less than during rain, and when estimates may not be taken into account. Wet snow in the form large flakes falling on the antenna can cause absorption by 4-6 dB greater than during rain, but the probability of this phenomenon is low.

3.2 Calculation of additional attenuation of signal energy on the lines up and down

Additional losses are associated with the following phenomena:

- absorption of signal energy in the gaseous atmosphere;
- losses due to refraction and inaccuracies in pointing antennas;
- phase effects in the atmosphere;
- losses due to inconsistency of antenna polarizations;

Depolarization of radio waves in the atmosphere. Thus, the above can be stated as:

$$L_{\text{add}} = L_{\text{a}} + L_{\text{r}} + L_{\text{n}},$$

where L_{add} – additional attenuation (losses) of the signal, dB;

L_{a} is the absorption of signal energy in the atmosphere, dB;

L_{r} is the loss in precipitation (rain, sleet), dB;

L_{n} are losses due to refraction and antenna pointing inaccuracy, dB.

Calculation of signal loss in normal atmosphere

In the frequency bands allocated for satellite systems, the influence atmosphere manifests itself in the form of attenuation (absorption) of radio waves in troposphere and ionosphere, curvature of the radio beam trajectory as a result of refractions, shape changes

and rotation of the plane of polarization of radio waves and the appearance of interference due to thermal radiation of the atmosphere and absorption noise.

Consider the first factor - the absorption of radio waves in the atmosphere, which is quantified by the coefficient L_a . For $f > 500$ MHz absorption is determined by the troposphere, or rather by the gases of the troposphere - oxygen and water vapor, rain and other hydrometeors :

$$L_a = L'_{O_2} l_1 + L'_{H_2O} l_2,$$

where L'_{O_2} is the per unit absorption coefficient in oxygen, dB/km;

L'_{H_2O} - coefficients of linear absorption in water vapor, dB/km;

l_1 is the equivalent length of the signal path in oxygen, km;

l_2 is the equivalent length of the signal path in water vapor, km.

The equivalent signal path length in a standard atmosphere depends on and from the equivalent thickness of the atmosphere for oxygen and water vapor (h_{O_2} and h_{H_2O}), as well as the elevation angle of the earth station antenna γ and the height of the earth stations above sea level h_3 .

$$l_1 = \frac{h_{O_2} - h_3}{\sin \gamma}, \quad l_2 = \frac{h_{H_2O} - h_3}{\sin \gamma}$$

where γ is the elevation angle of the antenna EA, deg;

h_3 - height ES above sea level 681 m;

$h_{O_2} \approx$ equivalent oxygen layer thickness in standard atmosphere 5.3 km;

$h_{H_2O} \approx$ equivalent water vapor layer thickness in standard atmosphere 2.1 km.

Transforming the formulas, we get expression:

$$L_a = \frac{L'_{O_2}(h_{O_2} - h_3) + L'_{H_2O}(h_{H_2O} - h_3)}{\sin \gamma}$$

It is obvious that the absorption coefficients per unit length in oxygen and in water vapor from Figure 3.2, for a frequency of 14 GHz are:

$L'_{O_2} = 0.007$ dB/km, $L'_{H_2O} = 0.015$ dB/km,

and for 11 GHz they are:

$$L'_{O_2} = 0.007 \text{ dB/km}, L'_{H_2O} = 0.006 \text{ dB/km}.$$

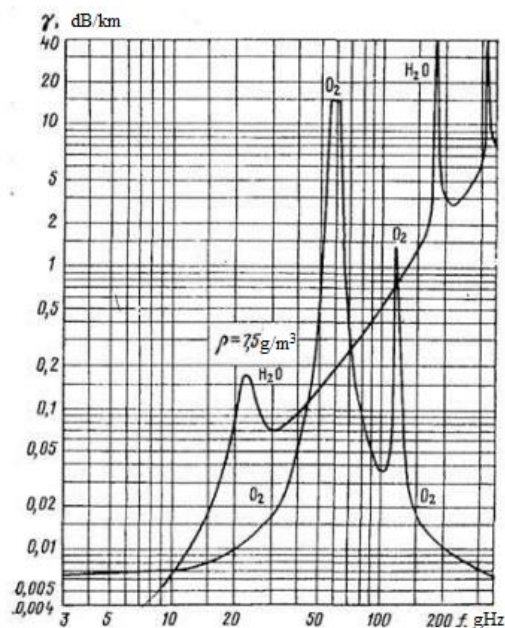


Fig 3.2 The dependence of the molecular absorption coefficient for oxygen O₂ and water vapor H₂O

Coefficients of linear absorption in oxygen and in water vapor from Figure 3.2, for a frequency of 30 GHz are:

$$L'_{O_2} = 0.015 \text{ dB/km}, L'_{H_2O} = 0.07 \text{ dB/km},$$

and for 11 GHz they are:

$$L'_{O_2} = 0.01 \text{ dB/km}, L'_{H_2O} = 0.06 \text{ dB/km}.$$

Finally, according to the available data, we find the weakening signal in the atmosphere, since the value of the elevation angle differs only by 0.001 share, let's make one calculation:

Ku-band:

a) uplink for ES1 and ES2:

$$L_a = \frac{0,007(5,3 - 0,681) + 0,015(2,1 - 0,681)}{\sin 0,59} = 0,096 \text{ dB}$$

b) downlink for ES1 and ES2:

$$L_a = \frac{0,007(5,3 - 0,681) + 0,006(2,1 - 0,681)}{\sin 0,59} = 0,073 \text{ dB}$$

Ka-band:

a) uplink for ES1 and ES2:

$$L_a = \frac{0,015(5,3 - 0,681) + 0,07(2,1 - 0,681)}{\sin 0,59} = 0,303 \text{ dB}$$

b) downlink for ES1 and ES2:

$$L_a = \frac{0,01 \cdot (5,3 - 0,681) + 0,06 \cdot (2,1 - 0,681)}{\sin 0,59} = 0,236 \text{ dB}$$

3.3 Energy characteristics of the radio link

The satellite radio link consists of a section ES-satellite uplink, satellite-ES downlink.

For these sections, the following relations are valid:

for the ES1-satellite section:

$$P_{\text{trES}} = \frac{16 \cdot \pi^2 \cdot d_{\uparrow}^2 \cdot L_{\uparrow \text{add}} P_{\text{n}\Sigma \text{SS}}}{\lambda_{\uparrow}^2 \cdot G_{\text{trSS}} \cdot G_{\text{rcvES}} \cdot \eta_{1 \text{ES}} \cdot \eta_{1 \text{SS}}} \cdot a \cdot \left(\frac{P_s}{P_n} \right)_{\Sigma} \quad (3.1)$$

For the site

$$P_{\text{trSS}} = \frac{16 \cdot \pi^2 \cdot d_{\downarrow}^2 \cdot L_{\downarrow \text{add}} P_{\text{n}\Sigma \text{ES}}}{\lambda_{\downarrow}^2 \cdot G_{\text{trSS}} \cdot G_{\text{rcvES}} \cdot \eta_{1 \text{SS}} \cdot \eta_{1 \text{ES}}} \cdot b \cdot \left(\frac{P_s}{P_n} \right)_{\Sigma}$$

where, P_{trSS} is the signal power at the transmitter output, dB;

G_{tr} – transmitter gain, dB;

η_1 – losses in the antenna-waveguide path, dB;

a - is the safety factor for the uplink;

b - is the safety factor for the downlink.

When calculating the energy of a radio link, it is necessary to consider attention, not only the main losses L_0 , but also additional losses L_{add} , which are also present on the ES-satellite track.

Airborne repeater (AR) receiving system noise power is determined by the formula:

$$P_{nSS} = k \cdot T_{\Sigma SS} \cdot \Delta f_{nSS, W}$$

The description of satellite indicates the quality factor of the station for reception Q , which calculated as follows:

$$Q = 10 \lg \frac{G_{rcSSR}}{T_{\Sigma SS}} = 16,7, \text{ dB/K}$$

Using this ratio we get:

$$\frac{G_{rcSSR}}{T_{\Sigma SS}} = 10^{\frac{16,7}{10}} = 46,774 \quad (3.2)$$

The signal-to-noise ratio for satellite communication lines is selected from range from 11 to 16 dB. Since the designed line is intended for data transmission, a minimum value of 11 dB can be used.

$$\left(\frac{P_S}{P_n}\right)_{\Sigma} = 10^{\frac{11}{10}} = 10^{1,1} = 12,59.$$

We will install antennas with a diameter of 2.4 m at the central earth stations.

The antenna gain is determined by the formula:

1) For Ku-band:

$$G = \frac{q \cdot 10 \cdot D_A^2}{\lambda^2} = \frac{0,8 \cdot 10 \cdot 2,4^2}{0,021^2} = 103603,52 \text{ dB}$$

2) For Ka-band:

$$G = \frac{q \cdot 10 \cdot D_A^2}{\lambda^2} = \frac{0,8 \cdot 10 \cdot 2,4^2}{0,015^2} = 204800 \text{ dB}$$

Substituting into equation (3.1) the noise power of the receiving system onboard repeater and relation (3.2) we get:

$$P_{\text{trES}} = \frac{16 \cdot \pi^2 \cdot d_{\uparrow}^2 \cdot L_{\uparrow\text{add}} \cdot k \cdot \Delta f_{\text{nSS}}}{\lambda_{\uparrow}^2 \cdot G_{\text{trES}} \cdot \eta_{\text{trES}} \cdot \eta_{\text{trSS}}} \cdot 10^{\frac{q}{10}} \cdot a \cdot \left(\frac{P_c}{P_{\text{tr}} \Sigma} \right), \text{ W}$$

Calculate the power of ES transmitters when working with satellite Intelsat 17 in program Mathcad14:

For Ku-band:

$$P_{\text{trES}} = \frac{16 \cdot \pi^2 \cdot d_{\uparrow}^2 \cdot L_{\uparrow\text{add}} \cdot k \cdot \Delta f_{\text{nSS}}}{\lambda_{\uparrow}^2 \cdot \frac{q \cdot 10 \cdot D_A^2}{\lambda^2} \cdot \eta_{\text{trES}} \cdot \eta_{\text{trSS}}} \cdot 10^{\frac{q}{10}} \cdot a \cdot \left(\frac{P_S}{P_n} \right) = 24,362 \text{ W}$$

For Ka-band:

$$P_{\text{trES}} = \frac{16 \cdot \pi^2 \cdot d_{\uparrow}^2 \cdot L_{\uparrow\text{add}} \cdot k \cdot \Delta f_{\text{nSS}}}{\lambda_{\uparrow}^2 \cdot \frac{q \cdot 10 \cdot D_A^2}{\lambda^2} \cdot \eta_{\text{trES}} \cdot \eta_{\text{trSS}}} \cdot 10^{\frac{q}{10}} \cdot b \cdot \left(\frac{P_S}{P_n} \right) = 24,362 \text{ W}$$

The results of the calculations make it possible to choose AP transmitters with a power of 25 watts for Ku-band, and 63 watts for Ka-band, which will provide the specified signal-to-noise ratio and a small energy margin.

3.4 Calculation of the required diameter of receiving terrestrial antennas stations

The transmitter power SS is known, so from the equation for transmitter power SS we express the antenna gain receiving earth station providing the required signal ratio noise on the satellite line.

$$G_{\text{rcES}} = \frac{L_{0\downarrow} L_{\downarrow\text{add}} \cdot P_{\text{n}\Sigma\text{ES}} \cdot b}{G_{\text{tr sat}} \cdot P_{\text{trSS}} \cdot \eta_{\text{rep.MC3}} \cdot \eta_{\text{rep.3C}}} \cdot \left(\frac{P_s}{P_n} \right)_{\Sigma}$$

The technical data of the onboard repeater indicates Effectively isotropically radiated power (EIRP), which is determined by according to the following formula:

$$\text{EIRP}_{\text{SS}} = G_{\text{trSS}} \cdot P_{\text{trSS}} \cdot \eta_{\text{trSS}}, \text{ W}$$

Substituting this expression into the formula for calculating the coefficient antenna gain, we get the following simplified equation:

$$G_{rcES} = \frac{L_{0\downarrow} L_{\downarrow add} \cdot P_{n\Sigma ES} \cdot b}{EIRP_{SS} \cdot \eta_{trSS}} \cdot \left(\frac{P_s}{P_n} \right)_{\Sigma}$$

According to the data on airborne repeaters, EIRP will be equal to:

$$EIRP_1 = 10^{\frac{47}{10}} = 50118,72 \text{ w}$$

$$EIRP_2 = 10^{\frac{49}{10}} = 79432,82 \text{ w}$$

Substituting the known values, we obtain for ES1:

$$G_{rcES} = \frac{L_{0\downarrow} L_{\downarrow add} \cdot P_{n\Sigma ES} \cdot b}{EIRP_{SS} \cdot \eta_{trSS}} \cdot \left(\frac{P_s}{P_n} \right)_{\Sigma} =$$

$$= \frac{3,33 \cdot 10^{20} \cdot 3,015 \cdot 2,306 \cdot 10^{-13} \cdot 1,26 \cdot 12,59}{79432,82 \cdot 0,9} = 51370$$

According to all parameters and calculations find the diameter of the antenna:

$$D_A = \sqrt{G_{rcES} \cdot \lambda_{\downarrow}^2 / 8} = \sqrt{51370 \cdot 0,0267^2 / 8} = 2,14 \text{ m}$$

Analyzing the results of calculations for receiving terrestrial stations, you can select antennas with a diameter of more than 2.2m. Since the calculation for the uplink was carried out for antennas with a diameter of 2.4 m, and the antenna will be used for both reception and transmission, stop on a diameter of 2.4 m. Antennas of the selected diameter will provide headroom of the received signal and the possibility of increasing the throughput channels. Let's choose SVEC antennas. Figure 3.2 Appearance antenna and its technical characteristics [6].



Fig. 3.3 Appearance antenna and its technical characteristics

Such antennas will be installed in the main building. Also, routers need in this system. UHP-200 has approach characteristics [7].

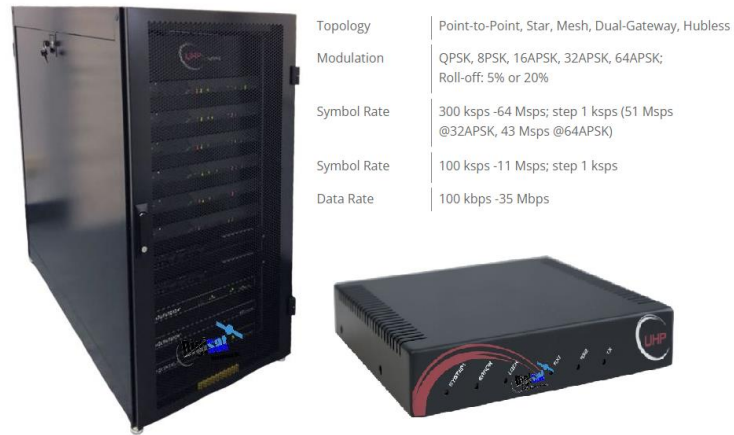


Fig 3.4 Appearance of the router

CONCLUSION TO CHAPTER 3

An energy calculation was carried out at the frequencies of the existing Ku band. We made an energy calculation of the communication line at the frequencies of the Ka range, made a comparative analysis of the energy of the lines. We carried out a review of equipment for building a data transmission system, considering technical requirements.

Since the enterprise is a strategic facility and currently the largest operating port in Ukraine now, building a secure and reliable backup Internet line using the VSAT system is useful.

CONCLUSION

In the course of the thesis the issue of designing a satellite communication line based on VSAT technology for the Izmail River Trade Port was considered.

An energy calculation was carried out at the frequencies of the existing Ku band. Energy calculation of the communication line at the frequencies of the Ka-band were made, also a comparative analysis of the energy of the lines. Carried out a review of equipment for building a data transmission system, considering technical requirements. Special attention is paid to the types of topologies, advantages and disadvantages of this type of satellite communication. VSAT systems are great for large customers who need secure communications and have plenty of room for equipment. For single users, this type of connection is beneficial mainly in extreme conditions.

To demonstrate characteristics of the VSAT technology the model of telecommunication system were developed and theoretically considered.

In most cases, I would recommend the VSAT system for the using, especially in the hard-to-reach areas, for the factories or mines, in forests or deserts. Or whatever else where people need secure and reliable channel of the internet or telephone communication.

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