Series

Introduction to satellite communications technology

Topic

Design of satellite network - ground segment. Fundamentals.

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1. Glossary

BUC	Block Up Converter
GEO	Geo-stationary orbit
GPS	Global Positioning System
ISO/OSI	Open Systems Interconnection
LEO	Low Earth Orbit
LNB	Low Noise Block down-converter
MEO	Medium Earth Orbit
OMT	Orthomode Transducer
OTP	On-The-Pause
QoS	Quality of Service
RFT	Radio Frequency Transmitter
SCPC	Single Channel Per Carrier
TDMA	Time Division Multiple Access
VLAN	Virtual LAN (Local Area Network)
VRF	Virtual Routing & Forwarding
VSAT	Very Small Aperture Terminal

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2. Introduction

Satellite communications, although often unnoticed among the multitude of other information transmission technologies such as fiber optic connections, Wi-Fi or LTE, play a key role in everyday life of entire communities. It enables fast and reliable communication over long distances, even in places where other ways of radio communication are unavailable or insufficient. In many remote or hard-to-reach regions of the world, where building telecommunications infrastructure is unprofitable or technically impossible, satellite systems are the only ones that offer the possibility of access to the Internet, and therefore: a chance for online education, remote work, access to information and digital services. Systems such as GPS (Global Positioning System) rely on satellites to provide location and navigation services, which are essential in vehicle navigation, aviation, maritime and in everyday life, as maps on smartphones for instance. Satellite transmission enables global broadcast of television and radio content, providing access to TV programs, movies and music. Finally, satellites deployed on various Earth orbits are used to monitor climate change, manage and respond to natural disasters, providing key information needed to act rapidly and to minimize damage, as well as providing telecommunications services such as satellite telephony, which is crucial in the event of terrestrial network failure.

Since satellite communications is frequently used as a reliable form of communication, such systems should be implemented with particular attention to uninterrupted access to services. The response to this key issue are multi-orbital and multiband satellite terminals, as well as terminals that can be quickly reconfigured to operate with other frequency ranges (bands) or orbits. For the above requirements to be met, an important aspect within design of satellite terminals is to keep the independence of individual components. Thus, satellite modems, due to the fact they operate on intermediate frequencies, can be used in terminals designed for operation in any satellite band (including: C, X, Ku, Ka). However, the task of converting the frequency from the satellite band to the intermediate band rests with the radio module, which, using appropriate frequency conversion systems, often built into receivers and transmitters accordant for the satellite band used, allows receiving and transmitting the signal through any modem.

One of the important point of satellite communication is the relatively lower bandwidth of the link compared to other technologies of radio communication. One may therefore raise a question why this form of communication is needed or what is the purpose of satellite terminals? First of all, the satellite communication solutions provided by GISS (using our own products) is more reliable and enables to establish connectivity even in hard weather conditions. As a result, it makes it possible to reach areas with poorly developed terrestrial network infrastructure - areas of the globe with a harsh climate, far from communication centers. Its role is particularly important during crises and natural disasters. Emergency services can establish communication quickly (immediately after reaching the scene of the incident) using small, portable backpack terminals, and then develop an extensive infrastructure based on larger portable VSAT terminals to restore full connectivity and operability of the affected area. One of the most important advantages of satellite communication is its high mobility. For this reason, it is very often used by the military and other services to transmit key information, exchange reconnaissance data and other strategic content determining success of the missions. In solutions where uninterrupted access to services is crucial (e.g. information synchronization between data centers), it serves as a highly reliable backup connection. It should be emphasized that all the above mentioned aspects are considered during the design and production of equipment developed by GISS, as they are crucial for the ergonomics and reliability of the product.

3. Terminal design

Satellite terminals differ in design depending on their purpose and the technologies used, but all of them have key elements enabling data communication. The main functional modules of the terminal are: antenna system, satellite modem, control subsystem (terminal controller), mounting system, power supply module. The detailed construction of the terminal will be presented on the example of the SatPack COBALT backpack satellite terminal manufactured by GISS.

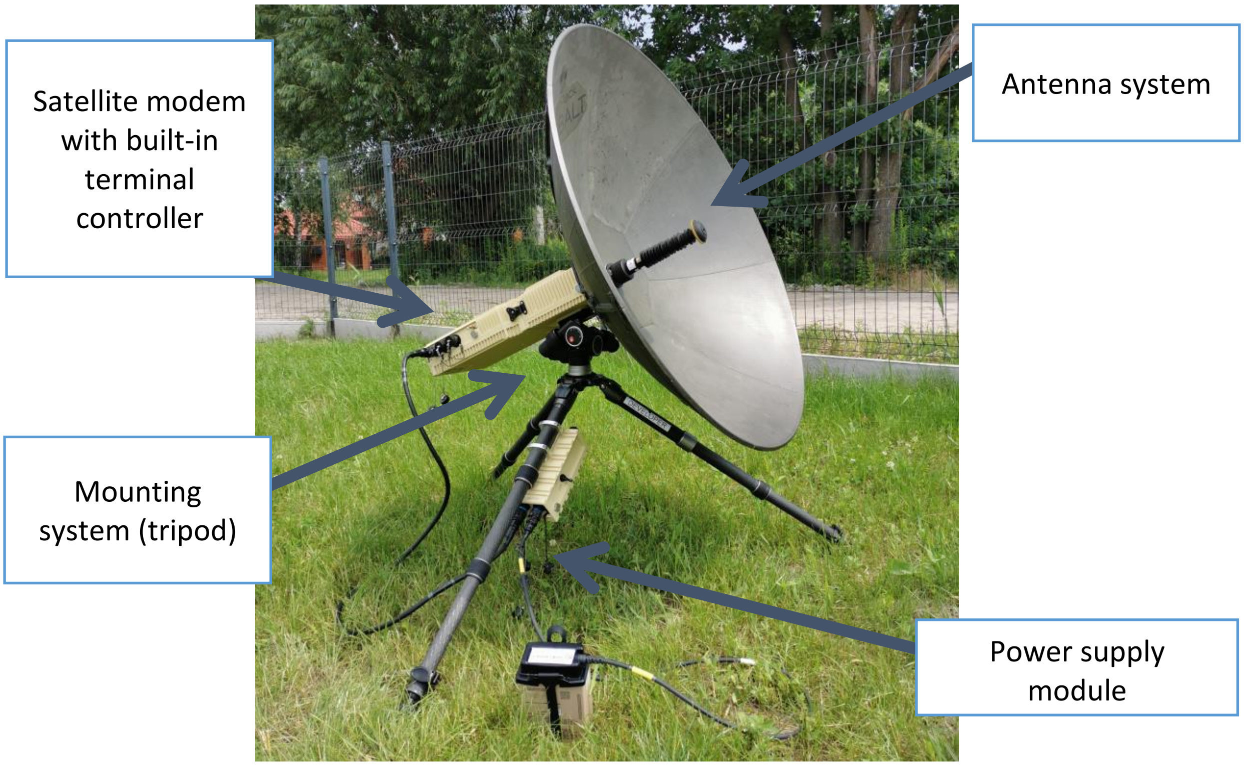

Fig. 1 SatPack COBALT - the flagship representative of the Manpack class, modular backpack terminals

The **antenna system** includes a reflector, radiator, an OMT (orthomode transducer), filters, isolators, a receiver (LNB - Low Noise Block Down Converter), a transmitter (BUC - Block Up Converter or RFT Radio Frequency Transmitter, terms used interchangeably), cable and waveguide connections.

The **reflector** in the antenna plays a key role in shaping and directing electromagnetic radiation. It brings the antenna directional properties, increasing its gain, which in practice means the ability to receive weaker signals and transmit signals with higher power level while maintaining the same parameters of the receiver and transmitter. The special design of the reflector allows to limit the reception of signals coming from unwanted directions, which helps reduce interference and improve signal quality.

The **radiator**, i.e. the source emitting electromagnetic radiation, in case of a parabolic antenna is placed at the focus of the reflector. This ensures the capture of almost all of the energy falling on the reflector and translates into a high energy gain of the antenna.

An **orthomode transducer** is used to separate or combine signals (electromagnetic waves) with two orthogonal polarizations. This allows for more effective use of the satellite band by supporting two independent communication channels on the same frequency (waves oriented orthogonally do not affect each other).

Filters in the antenna system are used to improve quality of the received and transmitted signal, reduce interference and protect against entering of unwanted signals into the radio path. There are many types of filters with various physical and electromagnetic characteristics. Their selection for use in specific system depends on both place of their use (transmitting or receiving path) as well as the expected final parameters of the system. Carefully selected filtering elements prevent mixing of signals from both paths and allow maintaining good parameters of the entire antenna set despite degradation of quality of other elements over time (e.g. transmitters or receivers).

Receiver (LNB - Low Noise Block) and **transmitter** (BUC - Block Up Converter) are two key components of the antenna system. The receiver is installed in the receiving path of the antenna set and is responsible for receiving the signal, converting it from the satellite to intermediate frequency and amplifying the signal. Due to the fact that the signal reaching Earth from the satellite is very weak, low-noise amplifiers are used in receivers to provide better signal quality. The transmitter is part of the transmission path being responsible for converting the intermediate frequency to the appropriate satellite frequency and amplification of the signal. When selecting a transmitter, one of the most important issues is the appropriate choice of its gain, which will ensure the amplification of the transmitted signal to a level sufficient to reach the satellite despite significant losses related to satellite-ground distance, as well as the influence of the atmosphere on signal attenuation. An insulator is used along with the transmitter, whose main role is to protect the transmitter against damage of its output stage caused by the reflection of the radiated high-power electromagnetic wave.

The last element of the antenna system is the **cabling** and **waveguides** that connect the components of the radio path, ensuring the transmission of electromagnetic waves. When selecting these passive elements, the attention should also be paid on their properties such as attenuation, declared standing wave coefficient or rated power.

Another element without which satellite communication cannot be established is a **satellite modem**. These are composite network devices that perform the tasks of network switches, routers and packet filters. They can implement, among others, tasks such as: packet routing, separation of network traffic both in the second layer of the ISO/OSI model (VLAN) and the third layer (VRF), quality of service (QoS) management, ensuring data link security (packet filtering, authorization, authentication, monitoring). They are also equipped with modulators and demodulators that shape the signal, ensuring the ability to encode and decode digital information and thus - sending information from the ground network infrastructure via satellite.

In addition, before establishing communication, each satellite terminal shall be properly configured, adapted to the existing network infrastructure and be capable to find the selected satellite on the horizon, through which communication will be carried out. An **antenna controller** is used to manage individual terminal modules. It provides the ability to set the required radio parameters of the satellite modem, such as receiving and transmitting frequency, modulation, correction mechanism. It allows to control the active elements of the terminal (selecting the appropriate voltage for the receiver, turning on/off the transmitter, setting the carrier frequency) and monitoring the operating parameters of the terminal (readings from sensors, GPS receiver, quality of the received and transmitted signal and many others). Most satellite terminals, including SatPack COBALT, are equipped with software that assists the operator during the process of pointing the antenna to the satellite signal.

However, for the system to work, it has to be based and powered. A **mounting system** (terminal base) is used to position the terminal in space. It must enable precise control of the antenna, which is crucial for accurate pointing to the selected satellite. In case of the terminal described here, the base is a foldable tripod with adjustable leg length and a manual head that allows the terminal to be rotated in azimuth and elevation planes. The polarization, depending on the operating band, is adjusted manually by changing the orientation of the radiator or automatically using a DC motor integrated with the radio module. The element ensuring continuous operation of the terminal is the **power supply system**. Due to the fact that terminal systems often operate in difficult conditions, with intermittent or no access to power infrastructure, the designed power supply modules should be able to power the terminal from number of available energy sources, with capability to act as a buffer to maintain communication in case of power failure. The power supply systems offered by GISS have several inputs dedicated to different voltage sources: alternating (AC, from the mains), constant (DC, for example from a car battery or solar mat) and battery, dedicated to standard BB-2590 military batteries. This allows for automatic changeover between the power sources and thus avoid communication interruptions.

Classification of satellite terminals

Due to the large variety of services using satellite communications, nowadays there is a need to cover many types of satellite terminals that differ in structure, method of access to the satellite link and terminal size. Such various division criteria forced the development of different classifications of equipment. As an example, the SMART family terminals produced by GISS are also FlyAway class mobile terminals with a parabolic offset antenna, dedicated to multi-band & geostationary orbit operation. The main criteria for classifying terminals are described below.

Classification by orbit

Satellite terminals are capable for operation using satellites in various orbits: GEO (geostationary, e.g. SatPack COBALT), MEO and LEO (medium and low, e.g. SatPack AutoMate). Terminals with the least complicated hardware and software architecture are those designed to work with geostationary orbit. This is due to the fact that GEO satellites do not move relative to the Earth (we do not take into account the change in satellite inclination, which is important for antennas with large apertures), which in most cases eliminates the tracking problem. At the same time, the large distance from the Earth introduces significant delays in data transfer. Communication using satellites moving at Lower Earth orbits, such as MEO and LEO, have lower latency and thus ability to transmit larger amounts of data. Nevertheless, lower orbit based communications require to use the terminals capable to track satellites flying on a predetermined trajectory over the horizon.

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Fig. 2 Terminals designed for operation using GEO orbits - SatPack COBALT, SMART, HUB-Master station

Fig. 3 SatPack AutoMate - terminal designed for operation using GEO, MEO and LEO orbits.

Classification by antenna type

Depending on the individual needs of the system, the most frequently used antennas in satellite terminals are flat antennas (with fixed or electrically steered beam) and parabolic antennas: front feed (e.g. SatPack family) or offset feed (e.g. SMART).

Fig. 4 Phoenix - terminal with a flat panel terminal antenna

Fig. 5 SatPack COBALT - terminal with central feed parabolic antenna.

Fig. 6 SMART - terminal with offset dish parabolic antenna

Classification by network design

Single terminals usually operate in larger satellite networks, which are built basing on different topologies and thus use several methods of access to the satellite link. Possible topologies include: point-to-point communication, i.e. direct connection of two terminals, usually offering higher bandwidths; star topology, with a central station that connects all terminals in the network; Full Mesh topology, where each terminal can establish communication with any other; and hybrid networks, using the features of all above mentioned topologies, depending on the application.

Classification by medium access method

The simplest type of medium access method is a single access channel per carrier frequency (SCPC). It is characterized by quite high satellite bandwidth utilization, while being easy to set up and guarantying the expected throughput for each terminal. In more extensive networks, time-division multiple access (TDMA) is used, which saves bandwidth or frequency, enabling the use of more effective numerical codes and consequently increasing throughput.

Classification by solution mobility

Satellite terminals can be divided into stationary and mobile (portable). Stationary solutions include Teleports and single HUB-Master stations, which are part of the entities' telecommunications infrastructure. The challenges of today's world often require the use of highly mobile terminals, such as SatPack COBALT terminals - a Manpack class backpack solution, transportable VSAT terminals, such as SMART solution, or communications vehicles, e.g. the SkyRay solution also developed by our company.

Fig. 7 SatPack COBALT - backpack-type, Manpack-class terminal

Fig. 8 SMART - transportable, FlyAway-class terminal

Fig. 9 SkyRay - vehicle for On-The-Pause communication

4. Summary

It may be noticed, that variety of satellite communication terminals is considerable and the task to choose the solution tailored to end user's needs is non-trivial. For this reason, it is crucial to have reliable engineering support, which will facilitate the process of configuring your own network, including selecting the appropriate system components, thus will help you to avoid many mistakes.

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