Use of satellite technology for monitoring buildings and structures

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Abstract. Satellite technologies are successfully used in many areas of the economy, allowing you to solve problems that cannot be solved by other methods. The paper explores the possibility of using satellite technologies for monitoring buildings and structures located in remote areas where satellite technologies are the main type of communication (other types of communication are either impossible or economically inexpedient). It is shown that the most rational solution of the tasks set is the use of VSAT (Very Small Aperture Terminal) satellite technology. This technology allows you to deploy a satellite terminal in a short time, to establish communication and transfer data on the state of construction objects to a computer center located at a very large distance from the specified objects. A scheme for monitoring buildings is presented, including a geostationary artificial earth satellite, satellite terminals deployed at remote construction sites, the NOC (Communications control center, Network operations center) and the monitoring Center for all construction sites. The satellite is connected to subscriber terminals using a direct and reverse channel. Data from the NOC is transmitted to the monitoring Center via the Internet through a secure VPN connection. It is noted that the use of certain technical improvements in satellite technology directly depends on economic factors. It is indicated that the monitoring Center of all construction objects receives information on the state not only from remote, but also “ordinary” buildings and structures. It is noted that for efficient information processing it is necessary to use cloud computing, modern intellectual technologies, for large-scale tasks it is most promising to use Big Data technology.

1. Introduction

When considering satellite communications, it is customary to distinguish two types of systems - on the basis of geostationary satellites and on the basis of low-flying satellites [1- 4]. The first is associated with the use of satellites located in a geostationary orbit - approximately at an altitude of 35,800 km above sea level. These systems can provide communication over on wide area, which is extremely important for Russia - communication can be provided in remote areas where there are no other types of communication. The second direction of satellite systems is based on low-flying satellites (for simplicity, we will include satellites located on lower relative to geostationary orbits here). The second direction of satellite systems is based on low-flying satellites (includes satellites located in lower relative to geostationary orbits).

For the task at hand - monitoring of buildings and structures located in remote areas, of interest is the direction associated with the use of geostationary satellites. This technology assumes that the satellite is located in a geostationary orbit and rotates with an angular velocity equal to the angular
velocity of the Earth. A feature of the geostationary orbit is that the receiver in the service area constantly “sees” the satellite at the same point. The “visibility” zone of such a satellite is almost half of the land area. The main advantage of the technology is that it is possible to establish communication and connect to the Internet within a few hours at remote sites - where the use of other types of communication is impossible or impractical. There are several technologies of geostationary satellite communications, of which the most popular - VSAT (Very Small Aperture Terminal). This technology is characterized by a small antenna size - the standard size is 1.2 m. At the exhibition "Communication 2019", held from April 24 to April 26 in Moscow, VSAT equipment with an antenna size of 0.5 m or less was demonstrated, which allows its use, for example, on vehicles.

VSAT technology can be successfully used in the construction industry to monitor the technical condition of construction projects located in remote areas. In these areas, there is usually a problem of communication with the "big land", so obtaining information about the technical condition of the object faces great difficulties.

2. Materials and Methods
The specific implementation of satellite technology depends on a number of reasons: the number of remote objects, the type and amount of data transmitted, economic factors, etc. The paper considers a balanced variant in terms of technical characteristics and cost, points out ways of improving the technical characteristics. The scheme of monitoring the state of remote construction objects using VSAT satellite technology is shown in Figure 1.

![Figure 1. Scheme of monitoring the state of construction objects using VSAT satellite technology.](image)

The system monitors the technical condition of a number of construction projects, including remote objects and “ordinary” objects. Satellite technology VSAT is advisable to use, first of all, for remote objects. At such facilities should be a satellite terminal, consisting of an antenna and receiving and transmitting equipment. In addition, there is a computer center at the remote site, including servers and other equipment. This center performs a number of functions: it manages the collection of data entering the computer network, processes data (it is advisable to process part of the data directly at the facility, the rest is done at the monitoring center of all objects). In addition, a computer center located at the facility performs functions related to information security.
Consider the composition of the processed data. The main part of the information comes from the sensors on the technical condition of the construction object. This strain gauge voltage sensors in the structural elements of the building, tilt control sensors, displacement sensors, pressure sensors, etc.

The second group includes information from video cameras and IP cameras. Observations of buildings during operation are necessary, in particular, for the timely detection of deformations of buildings. Information from camcorders can be viewed in real time and in recording.

The group of data “other sources” may include a variety of information from security systems, energy control systems, etc.

The system for collecting data on the state of a remote object has a rather complex infrastructure. This infrastructure in Figure 1 is not shown for two reasons: first, the drawing will lose visibility, and secondly, the infrastructure depends on the specific object. We present general considerations on this issue. Information from sensors, video cameras and other sources should be reduced to a form suitable for transmission over a computer network and further processing. This requires analog-to-digital converters ADC, UART transceivers, PWM pulse-width modulators and other equipment. For these purposes, Micro Controller Unit, MCU can be effectively used. Modern MCU have sufficiently powerful computing resources and a diverse set of tools for working with peripheral devices. In addition to the devices mentioned above, they include digital to analog DAC converters, comparators, FC, SPI, CAN, USB, IEEE 1394 ports. (Note that as a Micro Controller Unit, you can use domestic developments, in particular, 32-bit MCU of the Milandr (which was exhibited at the above-mentioned exhibition in 2018).

It should be emphasized that the development of a system for collecting data on the state of a remote object should be approached from a system-wide point of view - take into account the entire signal transmission and processing path.

Satellite subscriber terminals have the necessary set of tools to ensure information security. The main tool is a network filter - its functionality is enough to exclude most attacks via satellite communication channels.

The signal from the subscriber VSAT terminal located at a remote object is sent to the satellite, where it is amplified and redirected to the network operator’s network control center NOC of the satellite operator, which is connected to global networks by high-speed communication channels.

Information from the NOC via the Internet goes to the Monitoring Center of all construction objects, which can be located thousands of kilometers away from both the NOC and the monitoring objects. Communication between the NOC and the Monitoring Center is carried out via the Internet. To protect the information used channel VPN. Information security is based on the use of cryptographic protocols. Using cryptography (along with other methods) allows you to: protect data transmitted over the network from an unauthorized user, make sure that the information is sent to the person designated by the sender, ensure the integrity of the data, etc.

We note two important points concerning the organization of communication between the NOC and the terminals of remote objects. Firstly, when monitoring several remote objects, it is advisable to use the star topology. Secondly, this connection should be duplex (two-way).

The satellite channel in the direction from the NOC to the user terminal is called a direct satellite channel. This channel is the same for the entire network of operator’s terminals. It is used to transfer operator control commands, as well as user data. All transmitted data undergo a complex system of transformations and encryption. The broadband channel, respectively, has a high transmission rate (about 110 Mbit/s).

Satellite channels in the direction from the terminals to the NOC are called reverse satellite channels. They have a significantly lower transmission rate, the main communication protocol is TDMA (Time-Division Multiple Access) [5,6], in which several subscribers are located in the same frequency interval, different subscribers use different time slots for transmission. This protocol is widely used in satellite communication systems and cable networks, is dominant in mobile networks (in particular, is used in GSM). In modern applications, modified versions of the transmission on the reverse channel are used. Often used reception - changing the frequency of the reverse channels on
which the terminals transmit from one user session to another. This allows, on the one hand, to eliminate overloads and balance transmission traffic, and on the other, it significantly complicates the interception of transmitted data.

Another solution, aimed at eliminating the following problem: the VSAT Star topology, has a significant drawback - it does not allow direct communication between subscriber stations. Of course, you can transfer data from one subscriber station to another via the Internet, but the path of this data will go through the central station, which means they need to go through the satellite twice. As a result, the signal delay and traffic costs increase significantly. The solution is a combination of Star topology and Mesh topology.

Simplified Mesh topology for remote objects is shown in Figure 2.

![Figure 2. Simplified Mesh topology for remote objects.](image)

Without going into details of the Mesh technology, let us indicate its main features:
- characteristic connection of this network “every with each”;
- a key feature of the Mesh network is the presence of intelligence - each network point automatically receives information about all other access points in the network and “finds out” its role. This behavior eliminates the need for permanent centralized management;
- a large number of connections provides a wide choice of traffic route within the network - therefore, the interruption of one connection (including the satellite channel of one of the remote objects) will not disrupt the functioning of the network as a whole.

There are other possible solutions aimed at improving the technical characteristics of the satellite system. They are considered in the special literature.

For professionals in the construction industry, it is important to know that any technical innovation in telecommunications has an economic side. Therefore, decisions must be made collectively by builders, economists, and communications specialists. For example, the VSAT satellite system shown in Figure 1 is economically preferable when there are three, four or more distant objects. Then with the help of new telecommunication technologies it is possible to provide the necessary information transfer traffic at lower unit costs per channel. This statement holds true for Mesh technology.

Another example: let it be necessary to improve the noise immunity of a satellite transmission channel. From the theory of noise-resistant coding, it is known that such an increase is due to the need to add a certain number of check bits to useful information. Then, to get the previous transfer rate of useful data, additional measures should be taken - for example, to expand the channel bandwidth, which, in turn, is associated with economic costs.

When economic calculations should take into account all factors: the cost of equipment, installation, payment of traffic, the ability to transfer equipment to other object, etc.

We note another advantage of satellite communications - the possibility of video conferencing. Indeed, when monitoring the state of objects, there is a need for a meeting. A modern means of holding such a meeting is video conference. Then you can transfer images, voices, texts, documents,
charts, pictures, diagrams and other information. The possibility of video conferencing with the availability of appropriate means of communication has long been known. In our study, the new is that experts can participate in video conferencing and exchange data with objects located thousands of kilometers from each other, in areas where there was no connection before installing VSAT terminals.

Let’s return to the scheme shown in figure 1. The monitoring center of construction objects processes data coming not only from remote construction objects, but also from “ordinary” objects that can transmit data over the Internet, VPNs can be used to protect information (not shown in Figure 1). In addition, information can come through cable lines, in particular, a fiber-optic communication channel with high bandwidth and excellent noise immunity.

Information supplied to the monitoring center is a huge collection of heterogeneous data. To process this information, you may need the whole arsenal of modern digital technologies: data storage, cloud computing, intelligent computing and others. The use of Big Data technology [7-14] seems particularly attractive, since it has accumulated a number of recent advances in the field of digital information processing. It should be noted that the feasibility of using a particular data processing technology depends on the scale of the problems to be solved. In particular, Big Data technology should be used for computer monitoring of a large complex of construction objects.

3. Conclusions

The paper explores the possibility of using satellite technology for monitoring buildings and structures. It is indicated that these technologies are promising for monitoring buildings located in remote areas - where the use of other types of communication is not economically feasible. It is shown that of all satellite technologies for solving the task the best is VSAT (Very Small Aperture Terminal) technology based on the use of geostationary satellites.

It is noted that the specific implementation of the VSAT technology depends on a number of reasons: the number of remote objects, the type and amount of data transmitted, economic factors, etc. A satellite option has been proposed that allows monitoring of buildings located in remote areas, with a reasonable combination of “technical characteristics - cost”. In the proposed version, buildings and structures are monitored, including remote and “ordinary” objects. It is indicated that it is advisable to use VSAT satellite technology primarily for remote sites. At such facilities there should be a subscriber satellite terminal consisting of an antenna and receiving - transmitting equipment. In addition, there is a computer center at the remote site, which performs a number of functions: data collection management, data processing (it is advisable to process some of the data directly at the object). The signal from the subscriber VSAT-terminal is sent to the satellite, where it is amplified and redirected to the network control center (NOC) of the satellite operator, which is connected to global networks by high-speed communication channels.

Another advantage of satellite communications is indicated - the possibility of a videoconference in which specialists can participate and transmit data between monitoring objects located thousands of kilometers from each other, in areas where there was no connection before.

To cover the monitoring of a wider range of objects, the Monitoring Center receives information not only from remote, but also “ordinary” buildings and structures. It is noted that for efficient information processing it is necessary to use cloud computing, modern intellectual technologies, for large-scale tasks it is most promising to use Big Data technology.

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