Satellite communication station for Ka and Q-bands

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Abstract. The article reveals the features of the organization of satellite communication systems in the remote and northern territories of Russia. The importance of providing broadband access to multimedia resources and the Internet is shown. The problems of development of an earth station of satellite communication Ka and Q-bands, providing broadband communication, are considered. Its architecture and operating principles are presented. To ensure the possibility of operation of the station in two frequency ranges, replaceable irradiation systems with a microwave path are used. The features of their manufacture are disclosed in detail. The results of experimental studies of irradiating systems with a microwave path are presented. The gain of the irradiating system with a microwave path of the Q-band in the composition with a parabolic mirror with a diameter of 1.2 m was 51.8 dB at the transmission frequencies, and 45 dB at the receiving frequencies. The gain of the irradiating system with the Ka-band microwave path was 47.8 dB at the transmission frequencies and 43.8 dB at the receiving frequencies. Thus, the use of the proposed earth station of satellite communication Ka and Q-bands will allow organizing satellite broadband communication in remote and northern territories of Russia.

1. Introduction
The most important human need in modern society is the ability to freely access multimedia resources and the Internet. These are social networks, distance learning, government services and many other opportunities provided by the Internet, without which modern life is already unthinkable. The active development of digital technologies with access to the Internet has a significant impact on the space surrounding a person: everyday life, education, industrial production, mobile applications, medicine, trade, services, everyday life, recreation. The volume of circulating information in networks is growing exponentially, which requires more and more resources to organize full-fledged broadband access.

A large number of Russian citizens living in remote, inaccessible and northern territories are deprived of access to most information services. They are interested in providing short text messaging, personal voice and broadband Internet access services. However, the solution of these problems is impossible without the organization of reliable high-speed communication networks. The optimal solution for the provision of telecommunications services in the Arctic is the development of a telecommunications network based on satellite communication systems. Satellite communications are an essential part of the information and telecommunications space of the Russian Federation. It should ensure the availability of information resources throughout the territory of the Russian Federation, including remote, hard-to-reach and northern territories with an undeveloped ground communication infrastructure. This determines the high social significance of the creation of such a system, which can also be used to organize the work of state institutions and social infrastructure facilities in hard-to-reach areas.
Currently, the Russian Federation does not have its own fully deployed satellite system, which ensures uninterrupted service throughout the country and provides broadband Internet access, short message service, and personal voice communications. The need for the development of the Arctic is currently one of the directions of the national development of Russia, which is determined by official documents adopted by the Government of the Russian Federation [1]. The development of the Arctic region is gaining particular relevance in the light of the competition of the leading world powers in this region, as well as the development of the Northern Sea Route and cross-polar air routes.

Providing broadband communications in the hard-to-reach, northern and Arctic territories of the Russian Federation is possible using satellite earth stations for operation through the Express, Blagovest satellite constellations, advanced systems in Ka/Q (20/44 GHz) and Q-bands (33/50 GHz) [2-5]. The attractiveness of using these frequency ranges in a satellite communication system is due to high bandwidth, fewer problems in ensuring the coordination of networks, an increase in data exchange rates, a qualitative improvement in spectral characteristics, a large value of the allocated frequency band and the possibility of its reuse.

2. Composition and operation of a satellite earth station Ka and Q-bands

The satellite communication station of Ka and Q-bands is intended for organizing backbone communication through geostationary and highly elliptical space communication satellites (figure 1). It provides the provision of high-speed digital communication channels, data transmission, exchange of multimedia information, including open and encrypted VoIP, video communication. The main areas of application are the organization of communication in hard-to-reach regions and in the elimination of emergencies, the planned organization of high-speed communication channels, coverage of major cultural and sports events.

The main components of any satellite earth station are an antenna system, a transmitting and receiving device, a satellite modem (figure 2). The implementation of the basic technical characteristics of a satellite communication station depends on these components. These are the equivalent isotropically radiated power, quality factor, dynamic range of the receiving device, noise temperature of the receiving system, data transfer rate.

**Figure 1.** External view of the satellite communication station.  
**Figure 2.** Structure of a satellite earth station.
The information flow from the terminal data transmission equipment is sent to the modem UHP-220-SC, which converts the received data into the DVB-S / DVB-S2 standard [6]. The DVB-S2 standard (ETSI EN 302 307) is the main standard for the implementation of high-speed satellite communication channels. This is due to the following features [7]:

- application of modulations with high spectral efficiency - up to 5 bit / Hz (32 APSK);
- the use of the mode of adaptive change of the type of modulation and the rate of error-correcting coding, which allows maintaining the quality of communication when the conditions of signal propagation change;
- use of an efficient system of encapsulation of user traffic in frames of the physical layer, which reduces the proportion of service traffic and reduces the cost of information transmission.

For the implementation of TCP / IP protocol in the DVB-S2 standard used methods of broadband access to multimedia resources and the Internet in remote, northern and Arctic areas of the Russian Federation [8–10]. They provide:

- formation, reception and processing of the TCP / IP protocol using signal-code structures of the DVB-S2 standard in a wide band;
- implementation and adjustment of TCP / IP data for a DVB-S2 standard frame as a payload for various speed modes of signal-code structures with noise-immune BCH and LDPC codes and QPSK, 8PSK, 16APSK, 32APSK modulations;
- receiving TCP / IP data from demodulated and decoded DVB-S2 frame;
- application of time multiplexing TDM for physical frames of DVB-S2 in VCM and ACM modes.

The converted L-band data is fed to the BUC upconverter, which downconverts the input signal to 27510-27804 MHz for Ka / Ka-band and 43924-44524 MHz for Ka / Q-band and amplifies it. A BUP-4346 amplifier-converter developed by Radian LLC was used as a Q-band power amplifier. A GaN-IBUC / Ka-band / 2 package developed by Terrasat Communication Inc. was used to amplify signals in the Ka-band.

The signal from the BUC output is switched to the transmitting part of the antenna system with a microwave path. It not only transmits a signal to a space communications satellite, but also receives it at 17710-18004 MHz for the Ka/Ka-band and 43924-44524 MHz for the Ka/Q-band. The received signal is amplified and converted into an L-band signal in a receiving device (LNB) of the MSHPR-19/K type manufactured by FSUE RNIIRS.

Then the signal goes to the modem, which demodulates the input signal with data and supplies the converted signal to the terminal equipment. In the support-rotary device, two electric drives are used to ensure the movement of the antenna reflector in elevation and azimuth.

3. Irradiation system and microwave path
The irradiator can be conditionally divided into two parts - the emitting part and the microwave path. In the microwave path, waves of the required polarizations are formed, matching, frequency and polarization selection are carried out. The choice of the method for the implementation of these parts is carried out on the basis of the chosen scheme of the construction of the feed.

The radiation pattern of the irradiator and the shape of the counter-reflector should be selected so as to ensure the maximum aperture efficiency of the main reflector. The reflector antenna used in the projected satellite earth station has a diameter d = 1200 mm and a focal length f = 420 mm (f / d = 0.35) and is short-focus. To obtain the maximum aperture efficiency of such an antenna, an irradiation system (irradiator + counter-reflector) with an axisymmetric radiation pattern with a width of about 120° at – 10 dB is required.
The geometry of the hyperbolic counter-reflector in the Cassegrain antenna is set by the distance between its two foci and the eccentricity. One of the focuses of the counter-reflector must coincide with the focus of the main mirror, the other focus must coincide with the phase center of the irradiator. The distance between the focuses of the counter-reflector must be large enough for the counter-reflector to be in the far zone of the feed. The counter-reflector diameter is usually about 10% of the main mirror diameter, which is a compromise between a sufficiently large electrical size and minimizing aperture shading. The width of the irradiator diagram of the irradiator is selected based on the condition of irradiation of the edge of the counter-reflector at a level of −15… −20 dB from the irradiation of the center of the countereflector.

Based on the above conditions, it was calculated that the feed should have an axisymmetric amplitude radiation pattern with a width of about 80 ° at a level of −15 dB in both frequency ranges. The requirements for the phase diagrams of the feed are reduced to the fact that it has a phase center close to a point and the positions of the phase centers in both frequency ranges coincide.

The dual-band irradiation system and microwave path elements include:

- dual-band irradiator;
- filter of the receiving path (filter of the RX range);
- transmission path filter (TX range filter).

For a dual-band Ka/Q-band irradiator, a coaxial configuration with a corrugated horn and slot-based polarizers was chosen. A combined scheme with a corrugated horn and a polarizer based on transverse ribs is used for a dual-band Ka/Ka-band irradiator. The designs also provided for the possibility of attaching a counter-reflector, a unit for attaching the feeds to the main reflector and sealing flange connections.

Figure 3 shows the design of a Ka/Q-band irradiator with a microwave path. The material of dielectric centering sleeves, dielectric antenna and dielectric washer of the matching unit is fluoroplastic. The main material of the irradiator is D16 aluminum with a silver coating 6 µm thick, a copper sublayer of 6 µm and a nickel of 12 µm. Figure 4 shows the design of an irradiation system with a Ka/Ka-band microwave path. The irradiator material is D16 aluminum with a silver coating 6 µm thick, with a copper sublayer of 6 µm and nickel of 12 µm. Dielectric parts are not used in the irradiator.
The Ka/Q dual-band irradiation system has the following characteristics:

- at signal transmission frequencies (43.924–44.524 GHz) – left circular polarization;
- at signal receiving frequencies (19.172–19.792 GHz) – right circular polarization;
- standing wave ratio at transmitting frequencies – 1.26, at receiving frequencies – 1.2;
- the cross-polarization isolation level was 19 dB;
- the coefficient of ellipticity was 0.8;
- the isolation level of the receiving and transmitting ports exceeded 98 dB in both frequency ranges;
- the gain in the composition with the parabolic mirror was 51.8 dB at the transmission frequencies (figure 5a), and 45 dB at the reception frequencies (figure 5b).

A Ka/Ka dual-band irradiation system has the following characteristics:

- at signal transmission frequencies (27.510–27.804 GHz) – left circular polarization;
- at signal receiving frequencies (17.710–18.004 GHz) – right circular polarization;
- standing wave ratio at transmitting frequencies – 1.09, at receiving frequencies – 1.19;
- the cross-polarization isolation level was 19 dB;
- the coefficient of ellipticity was 0.8;
- the isolation level of the receiving and transmitting ports exceeded 102 dB in both frequency ranges;
- the gain in the composition with the parabolic mirror was 47.8 dB at the transmission frequencies (figure 6a), and 43.8 dB at the reception frequencies (figure 6b).

Figure 5. Directional diagram of the irradiation system Ka/Q-band unit with a parabolic mirror.
Figure 6. Directional diagram of the irradiation system Ka/Ka-band unit with a parabolic mirror.

4. Conclusion
Thus, the article presents the developed satellite earth station. It provides communication via the Express, Blagovest satellite constellations, advanced systems in the Ka / Q (20/44 GHz), Q (33/50 GHz) frequency bands. The use of these frequency ranges provides high bandwidth, simpler network coordination, increased data exchange rate, and a qualitative improvement in spectral characteristics. To ensure the possibility of working in two frequency ranges in the considered satellite communication station, replaceable dual-band irradiation systems with a microwave path are used. Their experimental studies have shown the feasibility of the proposed technical solutions and the achievement of the required technical characteristics. Thus, the use of the developed satellite earth station will make it possible to organize satellite broadband communications in the remote and northern territories of Russia.

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