

## ANALYSIS OF SOME FACTORS AFFECTING SIGNAL PROPAGATION IN SATELLITE COMMUNICATION SYSTEMS

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**Abstract.** This article is devoted to the consideration of some factors that lead to signal loss in satellite communication systems. Methods are given for reducing the Faraday effect, which occurs during the propagation of a linearly polarized wave under the influence of the Earth's magnetic field.

**Keywords:** satellite communication systems, Faraday effect, ionosphere, antenna.

**Аннотация.** Данная статья посвящена рассмотрению некоторых факторов, приводящих к возникновению потерь сигнала в системах спутниковой связи. Приведены способы уменьшения эффекта Фарадея возникающего при распространении линейно поляризованной волны под действием магнитного поля Земли.

**Ключевые слова:** системы спутниковой связи, эффект Фарадея, ионосфера, антенна.

**Annotasiya.** Ushbu maqola sun'iy yo'ldosh aloqa tizimlarida signal yo'qotilishiga olib keladigan ba'zi omillarni ko'rib chiqishga bag'ishlangan. Yernig magnit maydoni ta'sirida chiziqli qutiblangan to'liq tarqalganda paydo bo'ladigan Faraday ta'sirini kamaytirish usullari keltirilgan.

**Kalit so'zlar:** sun'iy yo'ldosh aloqa tizimlari, Faraday effekti, ionosfera, antenna.

**Introduction.** Satellite communication is based on the latest achievements in the field of rocket technology, space technology, informatics, digital communication technology. Satellite link - a communication line between earth stations using one earth satellite in each direction, including the "Earth – satellite" and "satellite – Earth" sections. Ground stations are connected to switching nodes of communication networks, to sources and consumers of television programs, sound broadcasting using terrestrial connecting lines [1].

Advanced organizations and enterprises are characterized by a considerable amount of different information, mostly electronic and telecommunications, passing through them daily. In this regard, it is very important to have a high-quality output to the switching nodes, providing access to all necessary communication directions. Consequently, the issue of receiving and transmitting

devices and antennas that are included in satellite communications is relevant at the present time.

The development of satellite communication systems is moving along the path of increasing the throughput of communication lines while maintaining the reliability of information transmission. The same features of satellite communication systems determine to some extent its information security. At the same time, as before, the significant remoteness of the earth station from the spacecraft in geostationary orbit requires the adoption of special measures to ensure reliable radio reception. This task is largely determined by the choice of antenna types and other important parameters to meet the requirements of electromagnetic accessibility.

The electromagnetic accessibility of radio emission sources is understood as the possibility of their detection, technical recognition, reception of transmitted information with the required reliability and reliability. Moreover, the reliability of reception is understood as the ratio of the number of correctly received words (phrases) in telephony and characters in telegraphy and digital communications to the number of transmitted ones. On radio links, the reliability assessment is carried out over time intervals during which the conditions for the propagation of radio waves must remain practically unchanged.

**The main part.** A feature of satellite communication lines is the presence of large signal losses due to the attenuation of its energy on routes of great physical length. In addition to the main spatial attenuation, the signal on satellite communication lines is affected by a large number of other factors, such as absorption in the atmosphere, rotation of the polarization plane caused by the Faraday effect, refraction, and depolarization. The influence of the atmosphere in the frequency ranges allocated for satellite systems manifests itself in the form:

- attenuation (absorption) of radio waves in the troposphere and ionosphere;
- curvature of the trajectory of the radio beam as a result of refraction;
- changes in the shape and rotation of the plane of polarization of radio waves;
- the appearance of interference due to thermal radiation of the atmosphere and absorption noise.

The quality of satellite communication is strongly influenced by effects in the troposphere and ionosphere. The absorption of a signal by the atmosphere depends on its frequency. The absorption maxima are at 22.3 GHz and 60 GHz. In addition to absorption, during the propagation of radio waves in the atmosphere, there is a fading effect, the cause of which is the difference in the refractive indices of different layers of the atmosphere.

The problem of signal propagation delay in one way or another affects all satellite communication systems. Systems using a satellite transponder in geostationary orbit have the highest latency. Propagation delay is most undesirable in real-time applications such as telephone lines. In this case, if the signal propagation time over the satellite communication channel is 250 ms, the time difference between subscribers' replicas cannot be less than 500 ms. Atmospheric

gaseous signal absorption mainly occurs in clear skies. The amount of absorption depends on the absolute humidity or water vapor density. At frequencies below 7.5 GHz, this value is relatively small.

Precipitation also affects signal propagation. Precipitation not only directly attenuates the signal, but also leads to an increase in the noise temperature of the receiving system. The influence of signal propagation conditions becomes significant at frequencies above 8 GHz. Rain, snow, fog or cloud cover will attenuate and scatter the microwave signal. The amount of attenuation depends more on the size of the water droplets than on the intensity of precipitation.

To reduce the influence of the atmosphere on signal transmission, it is proposed to locate all satellites in low Earth orbit [2].

The Faraday effect is due to the fact that when a linearly polarized wave propagates along the meridian under the influence of the Earth's magnetic field, this wave splits into two components that propagate in the ionosphere with different phase velocities. In this regard, a phase shift appears between the components, which leads to a rotation of the polarization plane of the resulting wave [3].

Radio waves passing through the Earth's ionosphere are also affected by the Faraday effect. The ionosphere consists of a plasma containing free electrons that contribute to the Faraday rotation according to the above equation, whereas positive ions are relatively massive and do not have much influence. Thus, in combination with the Earth's magnetic field, the polarization of radio waves rotates. Since the electron density in the ionosphere varies greatly on a daily basis, as well as during the sunspot cycle, the magnitude of the effect varies. However, the effect is always proportional to the square of the wavelength, so even at a UHF TV frequency of 500 MHz ( $\lambda = 60$  cm), more than a complete rotation of the polarization axis can occur. The consequence of this is that, although most radio transmission antennas are vertically or horizontally polarized, the polarization of a medium - or short-wave signal after reflection by the ionosphere is quite unpredictable. However, the Faraday effect due to free electrons decreases rapidly at higher frequencies (shorter wavelengths), so that at the microwave frequencies used by satellite communications, the transmitted polarization is preserved between the satellite and the earth.

Under some simplifying assumptions, the angle of rotation of the polarization plane is defined as [3]

$$\psi \approx \frac{2,32 \cdot 10^{19}}{f^2 \sqrt{1 - 0,91 \cos \alpha}}$$

The results of calculations show that the Faraday effect leads to a noticeable change in the slope of the electric field strength vector, which determines polarization, at frequencies below 5 GHz; at frequencies above 10 GHz, this phenomenon can be ignored.

The effect of the Faraday effect is reflected in the fact that when communicating on linear polarization, signal losses occur between collinear

antennas, defined by the expression:  $Lf_{\phi} = 20lg(\cos\psi)$ . With this in mind, only circular polarization is used in satellite systems at frequencies below 10 GHz; in higher frequency bands, phase effects are small and do not prevent the use of linear polarization.

Phase effects in the atmosphere, or rather their frequency dependence, lead to phase dispersion of the frequency components of transmitted signals and reception distortions. Like the Faraday effect, the degree of influence of these effects is inversely proportional to the square of the frequency. Total phase shift of the signal:  $\psi_0 = \frac{2\pi f}{c} \int n dl$ , where  $n$  is the refractive index of the atmosphere,  $c$  is the speed of light;  $\tau = \frac{d\psi_0}{df}$  is the group delay time of the signal.

**Conclusion.** To eliminate distortion, the difference in the group delay time  $\Delta\tau$  for the extreme frequencies of the broadband signal with the band  $\Delta f$  must satisfy the ratio  $\Delta\tau\Delta f \ll 1$ . Then, for  $\Delta\tau\Delta f = 0.1$ , the bandwidth corresponds to the ratio  $\Delta f \leq \sqrt{3 \times 10^{-11} f^3}$ . It follows from the calculations that the largest signal band transmitted through the atmosphere without phase distortion is approximately 25 MHz in the 1 GHz band and increases to 270 MHz in the 4 ÷ 6 GHz. These bandwidth limitations are taken into account when designing broadband TV and TLF lines in the frequency bands below 4 GHz [3].

#### List of references

1. Спутниковые системы связи: Учебное пособие для вузов / Под ред. А. М. Сомова. – М.: Горячая линия–Телеком, 2012. – 244 с.
2. Условия распространения сигнала в спутниковых системах связи. Ю.В.Сиротинина. XIII Международная научно-практическая конференция «Современные техника и технологии». [https://www.lib.tpu.ru/fulltext/v/Conferences/2012/C2/V1/v1\\_125.pdf](https://www.lib.tpu.ru/fulltext/v/Conferences/2012/C2/V1/v1_125.pdf)
3. Распространение радиоволн и антенны спутниковых систем связи Учебное пособие для вузов / Под ред. А. М. Сомова. – М.: Горячая линия–Телеком, 2015. – 456 с.