SPATIAL INTERFERENCE REJECTION!

Abdugafur Hotamov
Associate Professor of the Samarkand branch of TUIT named after Muhammad al-Khwarizmi
abdugafur_hotamov@mail.ru
Eshnazarov Nodir Tirkashevich
Director of the Samarkand branch of Uzbektelecom JSC
Nurmurodov Jasurbek Khairulloyevich
Assistant of the Samarkand branch of TUIT named after Muhammad al-Khwarizmi
jasurbeknurmurodov1@gmail.com
Uzbekistan

Annatation: Every year, the radio-electronic situation in industrialized regions becomes more complicated. The current allocation procedures for the limited RF resource do not guarantee the operator an uninterrupted operation. It is likely that effective anti-jamming systems for satellite communications will be required in the near future. The most promising, from the point of view of the authors of this article, the solution to this problem is the use of spatial interference rejection systems based on adaptive antenna arrays, which, based on spatial differences in the characteristics of the useful signal and interference, automatically adapt the radio links to the interference environment.

Introduction.

One of the main problems in the development and operation of telecommunication systems is the protection of communication channels from interference of natural and artificial origin. Methods of protection against radio interference were developed in the middle of the twentieth century, carefully systematized and described in domestic and foreign specialized literature, for example, in well-known works [1, 2].

The use of various methods of noise protection is determined by the technical capabilities of their implementation. They are most widely used and developed in special and military communications systems, but more and more often, operators of civilian communications systems are also forced to resort to protection from radio interference. The electronic situation is becoming more complicated, but at the same time, radio electronics is also rapidly developing. This makes it possible to implement technically complex, but very effective anti-jamming systems. We believe that in the coming years, such systems will be in demand by satellite operators

Noise protection methods

In the most general form, based on the principles of implementation, one can single out organizational, energy, signal and spatial methods of protection against radio interference.

The organizational method in its simplest form assumes such an arrangement of radio signal sources and such a choice of frequencies at which the electronic means of the designed systems will not create mutual interference.

It is obvious that at present this method of frequency-territorial separation in the conditions of megacities and industrialized regions, saturated with radio-electronic means, is not becoming very effective. However, it has been approved and is being used in a form that requires the implementation of mandatory procedures for mutual coordination and registration of radio frequency bands of various networks defined by international and national regulations.

During the implementation of these coordination procedures, operators must agree on mutually acceptable signal-to-interference ratios and thereby achieve the required level of electromagnetic compatibility. For this purpose, the polarization decoupling method is widely used. If necessary, the method of frequency segmentation is used, which limits the frequency resource used, but operators are forced to do this in order to achieve coordination agreements on mutually acceptable terms.

20–30 years ago, it seemed that strict implementation of regulatory procedures and compliance with agreements would ensure, with a high degree of probability, the functioning of communication systems without mutual unacceptable interference. However, at present, well-known Russian specialists in radio frequency support [3] believe that a crisis is coming in satellite communications, connected precisely with the very system of distribution of the radio frequency resource.

Many satellite operators recognize that modern satellite communications networks, which have passed all the stages of coordination and registration, nevertheless experience an increasing level of unacceptable interference. This means that the organizational method of protection against interference, based on the current regulatory procedures, has largely exhausted itself and cannot be recognized as sufficiently effective. Despite this, this method of frequency allocation, based on international and national regulations, is the main tool for radio frequency regulation and containment of "radio frequency anarchy".

The energy method of dealing with interference provides for an increase in the transmitter power to a level that is guaranteed to exceed possible interference. It is widely used in special and military satellite communication systems, but its use is in conflict with the need to ensure electromagnetic compatibility, regulatory restrictions, and, moreover, is energy-consuming.

Thanks to the rapid development of digital technology in the last 20 years, it has become possible to put into practice signal interference protection methods based on digital signal processing and allowing to reduce the impact of interference at a level of 20 ... 30 dB. This is, first of all, the use of pseudo-random, multi-frequency and broadband noise-like signals, as well as methods of noise-immune signal coding. They are widely used in modern satellite communication systems and demonstrate satisfactory performance.

The main disadvantage of these methods is the need to expand (in some cases very significant) the radio frequency spectrum to provide protection from radio interference. Given the natural limitation of the radio frequency resource, this is a significant drawback that reduces the effectiveness of such methods, especially in high-speed systems. It is known that the use of signal methods leads to a decrease in the noise protection coefficient in proportion to the increase in the speed of information flow.

Despite these shortcomings, signal methods remain very effective, are constantly being improved, and it should be expected that they will be in demand in the future, especially in combination with some methods of spatial noise protection.

The latter have been developed and used for more than a dozen years. The simplest of them are the shielding of radio-electronic equipment in the direction of interference and the use of radio-absorbing coatings in certain areas of the antenna mirror to reduce the effect of receiving interference from the side lobes of the antenna system.

These types of methods have taken their place, but are not widely used due to the fact that they are not always able to provide the necessary level of protection against radio interference. For example, shielding does not provide reliable noise protection in the event of random interference from an indefinite direction, and at the same time, it involves the creation of rather bulky structures. Radio-absorbing coatings have limitations on the level of interference reduction, which is far from always sufficient.

The method of electronic interference compensation, or spatial interference rejection (the most difficult in terms of technical implementation), is based on reproducing a copy of the interfering signal to be suppressed. Note that the noise protection coefficient of this method, in contrast to the signal method, practically does not depend on the information transfer rate. Its effectiveness depends on the accuracy of reproduction of a copy of the interference signal and, according to some estimates [2], it can reach the level of interference suppression up to 40 dB.

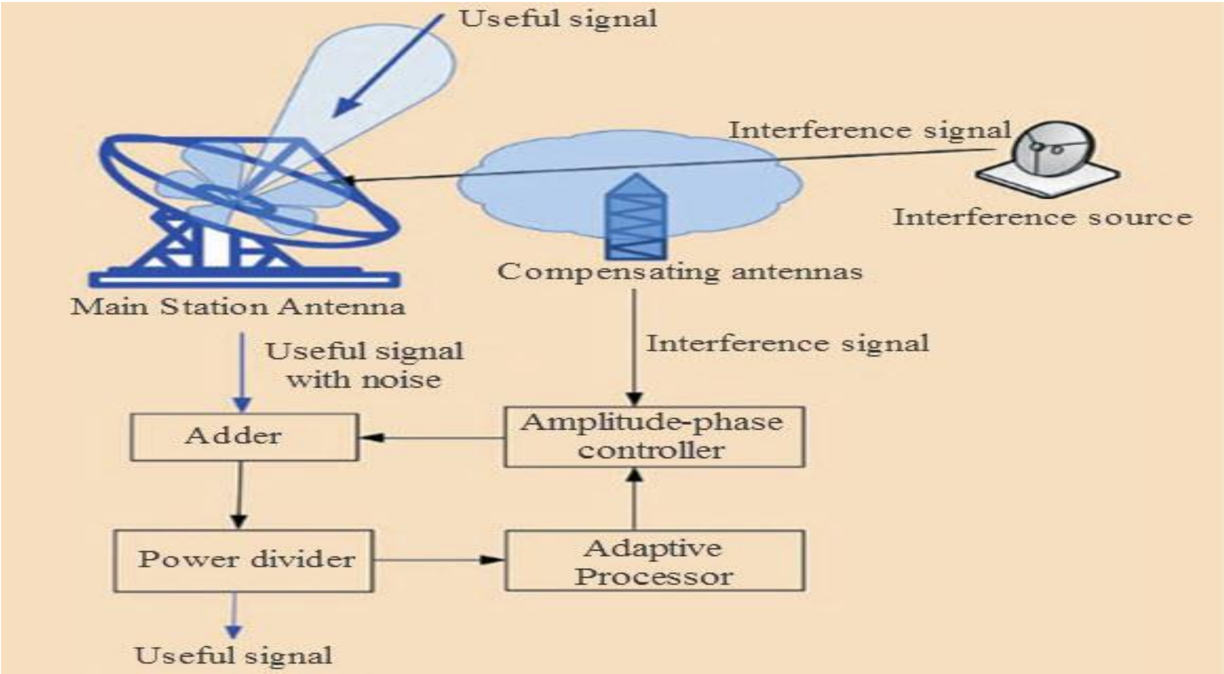
Such a result is quite possible to obtain in the laboratory. In practice, in a spatial interference rejection system operating under real conditions of interference from 2–3 directions, a level of 20–25 dB has already been reached today. Improvement of the electronic component base, as well as the use of a fundamentally new mathematical apparatus and functional software based on it, will significantly improve the results obtained.

Spatial Noise Rejection

At present, a spatial interference rejection scheme (SIRS) is being created based on the spatial or space-time formation of minima in the antenna radiation pattern in the direction of the interfering signals with the processing of input signals at operating or intermediate frequencies.

As is known, modeling the impact of interference from various sources on satellite earth stations demonstrates that the impact of interference on the main lobe of the radiation pattern is unlikely. The most likely and dangerous effect of the interference signal on the side lobes. Thus, when using spatial rejection, the interference signal is received by the side lobes of the antenna pattern of the protected station and the main lobe of one of the compensation antennas of the SIRS

The scheme of SIRS is presented in fig. 1. The interference signal received by the compensation antenna is amplified and fed to one of the inputs of the amplitude-phase controller, where the amplitude and phase of the complex voltage of the interfering signal change in accordance with the selected adaptation algorithm.

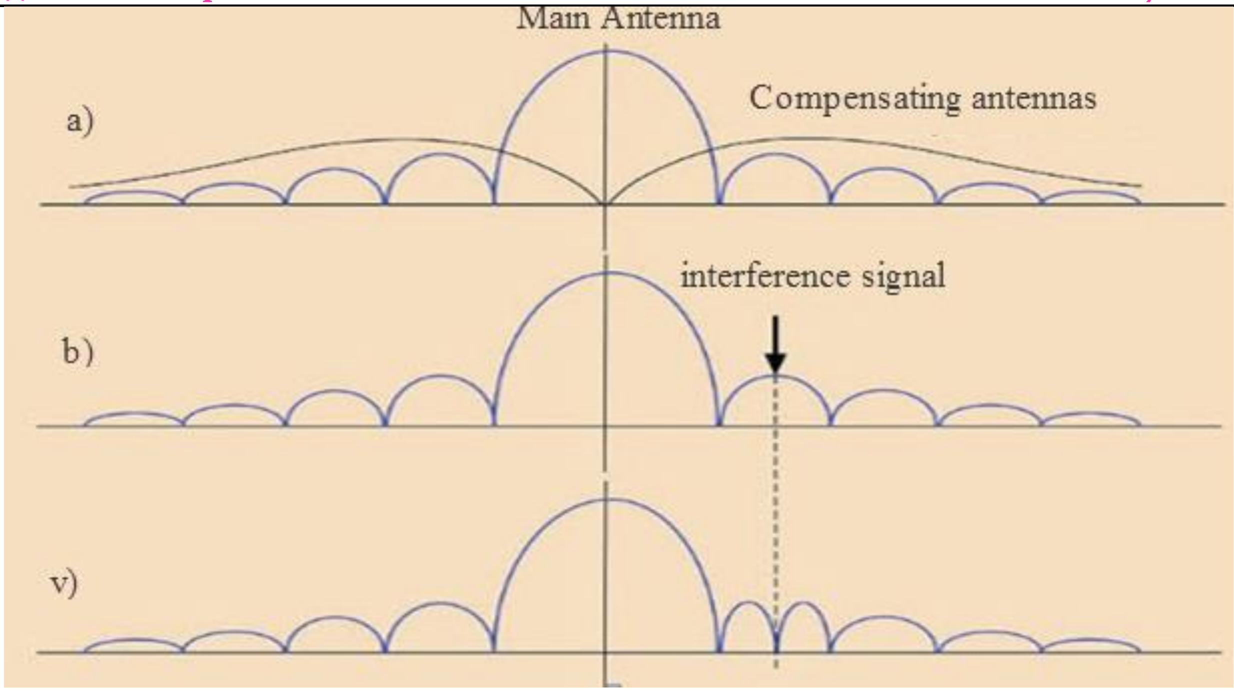


Rice. 1. Scheme of spatial interference rejection

The noise copy obtained in this way is fed to the compensation input of the in-phase power adder, the other input of which receives an additive mixture of the useful signal and noise. From the output of the power adder, the signal is transmitted to the equipment of the protected station and through the adaptive processor to the second input of the amplitude-phase controller, where the next change in the amplitude and phase of the interfering signal occurs.

As a result of iterative processes, an interference voltage appears at the compensation input of the in-phase adder, equal in amplitude and opposite in phase to the interference voltage supplied to the main input of the adder from the receiving channel of the protected station. As a result, at the output of the power adder there is a useful signal and an insignificant, at the noise level, residual interference signal.

In this case, the total noise protection coefficient increases by 20 ... 25 dB in the centimeter and up to 25 ... 30 dB in the decimeter wave range in a relative frequency band of up to 50%. On fig. 2 shows the change in the antenna pattern of a satellite earth station antenna as a result of interference rejection and the formation of a " zero " of the pattern in the direction of the interference.



Rice. 2. Formation of the "zero" of the radiation pattern of the main antenna in the direction of interference:

a) mutual position of the radiation patterns of the main and compensation antennas; b) radiation pattern before adaptation; c) radiation pattern after adaptation.

The design of the SIRS must be carried out taking into account the physical and technical principles of implementation. The main requirements for SPRP are as follows:

• the number of compensation channels (antennas) should not be less than the number of simultaneously acting interference;

• radiation patterns of the main and additional compensation antennas must have a spatial decoupling of at least 20 dB;

• The quality of the compensation receiving channel must be no lower than the quality of the main channel in the direction of interference.

In the spatiotemporal sense, interference signals can be divided into narrowband and broadband. This separation implies fundamentally different algorithms and signal processing technology.

It is known that in the case of a short radio pulse with a duration $\tau = 1/\Delta f$, where Δf is the frequency band occupied by this pulse, the decrease in the gain of the antenna array occurs due to the fact that for different spectral components the shaping beam is shifted by a different angle, therefore the radiation pattern of the antenna array for the pulsed signal is wider than the radiation pattern for the center frequency. If we introduce the concept of "T - opening filling time", defined as the time during which the wave front propagating at an angle Q passes through the entire opening L:

$$T = \frac{L}{c} \sin \Theta$$

where c is the speed of propagation of electromagnetic energy, then with a decrease in the gain of the antenna array by no more than 1 dB, the duration of the radio pulse should be equal to the aperture filling time, then

$$\frac{1}{\Delta f} = \frac{L}{c} \sin \Theta$$

In the " SIRS - earth station" complex, the aperture size LO is defined as the maximum distance between the phase centers of the main and additional antennas. If inequality holds, the interference signal is narrowband.

$$\frac{Lo}{c}\sin\Theta \ll \frac{1}{\Delta f}$$

For a narrowband signal, spatial and temporal processing are separated - the antenna performs only the spatial processing function, and the temporal processing is carried out in the receiver.

If the above inequality is not satisfied, the signal is broadband in the space-time sense, therefore, factorization of such a signal is impossible, and the antenna functions cannot be reduced to only spatial processing. In this case, it is necessary to carry out joint space-time processing of the signal.

Spatio-temporal processing of a signal in SIRS is associated with the need to change the weighting coefficients in accordance with the envelope of the useful signal. There is a need to use transversal filters. But the implementation of a broadband amplitude-phase controller based on transversal filters presents certain technological problems, so it is desirable to create such an antenna device for SPRS that will provide signal factorization and, accordingly, factorization of weight coefficients. The functions of the antenna in this case are reduced only to spatial processing.

To implement this inequality when exposed to narrow-band interference at a constant solid angle, it is advisable to reduce the distance L0 between the phase centers of the main and additional antennas by selecting the same phase shifts of the signals in the main and compensation channels using segments of non-dispersive transmission lines, for example, segments of a phase-stable cable.

In the case of broadband or spatially changing narrow-band interference, it is necessary to use transversal filters based, for example, on an adjustable multi-tap delay line [5]. A relatively narrow-band amplitude-phase controller with quadrature splitting of signals is installed in each tap of the delay line. The efficiency of SIRS when using transversal filters with three and five taps, as shown in [6], is almost the same, and for a relative signal frequency band of up to 40%, transversal filters with three taps are sufficient.

Conclusion

The spatial interference compensation system is implemented in practice on the American military satellite DSCS-3 (Defense Satellite Communications System) [5]. The satellite antenna system is divided into 2 subsystems: receiving and transmitting. The receiving antenna subsystem consists of 2 global ground coverage horn antennas, a 61-beam MLA, providing full amplitude and phase control in each beam. This allows you to form the contour diagram and the "zero" of the antenna pattern in the direction of the interference source.

Literature

1. Baranov V. I. Stechkin B. S. Extremal combinatorial problems and their
2. applications, M.: Nauka, 2000, p. 198.
3. Bertsekas D. Gallagher R. Data transmission networks. M.: Mir, 2000, p. 295.
4. Black Yu. Computer networks: protocols, standards, interfaces, M.: Mir, 2001, p. 320.
5. Bolshova G. "Satellite communications in Russia: Pamir", Iridium, Globalstar ..." "Networks" - 2000 - No. 9. - With. 20-28.
6. Efimushkin V. A. Technical aspects of satellite communication systems "Network" - 2000 - No. 7. - With. 19-24.
7. Nevdyaev L. M. Modern technologies of satellite communication // "Bulletin of Communications" - 2000 - No. 12. - p. 30-39.