Features of the construction of the noise compensation circuit of a small-sized active phased antenna array

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Abstract. In an article the influence of active and passive interferences on the operation of X-band radar are considered. A new way to compensate for this interference is proposed. To implement this method, a new interference compensation unit based on horn antennas is developed. The experimental investigation results of unit work, as a separate device, and as part of the radar station are presented.

1. Introduction

In the modern world there is a rapid increase in the workload of the frequency ranges of radar stations (RLS) [1-8]. Constantly happening the commissioning of new stations, an increase in the number of active sites that require the exchange of information. These factors lead to an increase in the number of radiated and reflected signals, as well as interference of various kinds [3, 6, 9-14]. The frequency band from 8 to 12 GHz (X band) [12-18] turned out to be particularly congested. Therefore, the modernization of the operated ones and the development of new devices for protecting radar stations from interference are actual tasks.

Sea-based and air-based radars particularly susceptible to various kinds of interference [2, 6, 15-19]. This is due to the difficult conditions of their operation. These conditions place increased demands on the development of devices for compensate interference in the radar.

There is a great influence on the operation of their equipment of a large number of passive and active interference, as well as noise. This should be taken into account when developing interference cancellation devices for these stations, in contrast to high-power ground-based radars [1, 3, 4, 9-11, 15-18]. Active interference is generated by special receiving-transmitting or transmitting radio devices - stations or transmitters of radio interference, passive - by various artificial reflectors of radio waves [15, 16]. Passive interference also includes reflections of radio waves from local objects and natural formations. To compensate for their development, CPC (cross-period compensators) have been developed and successfully used, since these interferences are not periodic. Active interference in some cases are periodic. They can cause serious disruptions in the information processing system.

The most difficult is the protection against active interference, which is transmitted at radar frequency or near the that [3, 15, 16]. The jammer is trying to tune into this frequency. As a result of such an impact, a noise background is created on the radar indicators, in which the useful signal disappears, and false targets appear. This greatly complicates the detection and tracking of targets [6, 7, 9, 11, 12, 15, 16]. Interference affects the automatic detection and tracking of objects in azimuth and elevation, speed and range. This can cause: overloading of automatic data processing devices, disruption of automatic tracking of objects, to introduce large errors in the determination of the location and parameters of movement of objects.

The radar stations with active phased antenna arrays (APAA) operating in the review mode can create continuous active noise interference (ANI), either intentionally or accidentally. Since these
interferences are the most universal, very high requirements are placed on radar protection devices against active interference.

Under the influence of this interference on the radar in the processing devices is the "suppression" of the useful signal. This makes it difficult for the operator to detect the target, and in automated systems the work of the computing facilities [1, 3, 9, 17-20].

The proposed method in our work using a compensation antenna allows protecting the radar signal processing device from active and other interference. It should be noted that the direction of this interference often does not coincide with the direction of movement of the target [1-4, 9, 11, 15, 18, 20, 21].

2. Method of noise compensation and the design of an active phased antenna array with a compensation unit.

When implementing this method should be implemented compensation of interference adopted by the side lobes of the antenna pattern (AP). Compensation of the signal reflected from the target, received by the main lobe, is not performed. Our preliminary studies have shown that it is most appropriate to use a design of four horn antennas with a total area of responsibility in the azimuthal plane of 160° as a compensation antenna. The block diagram of the developed module with APAA for compensation of active interference is shown in figure 1.

![Figure 1. Block diagram APAA with module developed for compensation interferences: 1 - APAA, 2 - ANI, 3 - superheterodyne receiver with frequency conversion, 4 and 5 - analog-to-digital converter, 6 - interference compensation device with digital signal processing.](image-url)

The signals received from the main and additional channels must be transferred to a lower frequency range in order to conveniently carry out subsequent transformations. For this purpose, superheterodyne radios are used in radars [11, 15]. The operation of these radios is based on the principle of converting the received signal into a fixed signal of an intermediate frequency with its
subsequent amplification. The main advantage of the superheterodyne receiver is the absence of the need for tuning to different frequencies. The local generators have high demands on the stability of the frequency, amplitude and spectral purity of harmonic oscillations. All this allows you to go to the processing of received signals at a frequency of 120 MHz instead of working at frequencies of the X-band.

After frequency conversion, the signal is transformed into digital form using an ADC, which facilitates its processing in a block - the auto-compensator of interference. The result of this block is displayed on the indicator of a circular radar view.

With such a construction of the compensation antenna, its broadband interference always “illuminates”. All four horns. Reflected from the target signal when scanning the pattern of the main antenna arrives only on one of the horns (or two horns). On other horn antennas it is not. The main lobe of the pattern is very narrow. This allows you to compensate for interference by subtracting, without subtracting the useful signal in the channels from the main antenna.

2. The results of experimental investigations and discussion

Experimental verification of the proposed method was carried out using the developed wideband X-band interference compensation module with a total responsibility zone of 160° in the azimuth plane. In figure 2 shows, as an example, the radiation patterns of various horn antennas.

![Radiation patterns](image)

**Figure 2.** The intersection of the radiation patterns of the horn antennas of the compensation module: (a) - antennas 1 and 2; (b) - antennas 2 and 3.

The results obtained confirmed that it is most appropriate to use several horn antennas with overlapping radiation patterns as a compensation antenna. Their radiation patterns are quite predictable and have a relatively small mutual influence with appropriate placement on each other.

The work of the proposed method and its practical implementation was tested for air-based AFAR. In figure 3 shows, as an example, images of targets and interference on a radar monitor.
Figure 3. Images of labels from targets on the radar monitor: (a) - without using the developed block for compensating interference, (b) - with using the block developed by us as part of APAA.

Analysis of the obtained results shows that a substantial part of active and passive interference is compensated. The position of the target on the radar indicator is clear. This allows identifying it, as well as determining the parameters of its movement.

4. Conclusion
The obtained results showed that the module we developed on the basis of the proposed new method makes it possible to compensate for interference in an APAA without a significant change in the received power of the reflected signal from the target along the main lobe of the radiation pattern.

We identified that with an increase in the number of horn antennas to 8 or 12 with a responsibility zone of 20 or 10 degrees, interference compensation improves (in proportion to the increase in the number of horn antennas). If a high-frequency narrow-band interference acts on the main antenna of APAA, the use of a compensation antenna with a large number of horns (more than 8) is one of the necessary conditions for a reliable radar.

The main limitation of using the types of compensation antennas we developed in APAA for airborne is the presence of the necessary place in them for their installation. For the successful implementation of the method developed by us to compensate for active interference in an APAA with a large number of horn antennas, it is necessary to develop their new small-sized structures, taking into account the features of using the method developed by us.

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