Elimination of Interference in Through-Wall Radars

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Abstract. The fight against terrorist threats is highly relevant in the modern world. When developing devices for countering terrorism, their reliability and stability are very important. One such device is a device for detecting people behind optically opaque obstacles, which can detect the movement of people behind a wall and determine their number. However, the influence of interference effects that occur when summing up the reflected signals arriving by different propagation paths and, accordingly, having different phase shifts, leads to the fact that the observed image of the target can flicker and even disappear from the device screen for a considerable time, which is unacceptable in combat conditions. This article discusses various ways to eliminate interference, and on the basis of theoretical calculations, the most effective and cost-effective ways to eliminate the influence of interference effects in devices for detecting people behind optically opaque barriers are proposed. The obtained theoretical conclusions are confirmed experimentally.

1. Introduction
One of the areas of the fight against terrorism is the development of methods and means for detecting mine-explosive devices and other illegal means in caches and caches, as well as people hidden behind optically opaque barriers (walls, underground, in woodlands).

When choosing means to control terrorism, such capabilities of the devices as efficiency and ability to detect remotely are important. These capabilities are characteristics of devices using radio-wave methods. [1, 2]. Usage of ultra-wide-band signals represented by nanosecond radio pulses, development of microprocessor technology and new methods and algorithms for signal processing enabled creating new types of radars, such as subsurface sensing radars - GPR and radars for detecting people behind optically opaque barriers.

2. Methods used to eliminate interference effects of radio communication and radar
Due to the random nature of interference phenomena in conditions of multipath propagation, it is impossible to eliminate or compensate for them. However, methods have been developed that significantly reduce their negative manifestation. These methods include [3, 4]:

- applying redundant encoding to detect and correct a certain number of erroneous characters;
- use of convolutional, block and turbo coding;
- adaptive delay equalization using an equalizer;
- application of methods of posting;

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• using of directional and multi-antenna systems;
• optimal modulation methods.

In practice, combinations of encoding methods are often used. The methods described above are mainly used for transmitting information, but they can also be used for radiosounding.

Redundant encoding is used in almost all modern transmission systems. To increase the reliability of transmission, additional (redundant) bits are introduced into the loop of transmitted data (traffic plus control bits), which allows detecting a certain number of erroneous bits at the receiving end. In general, the speed of information traffic transmission due to the use of these additional characters is slightly reduced.

A powerful tool for improving the reliability of information delivery over an unreliable channel is the use of channel encoding with the use of ultra-precise, turbo and block encoding and interleaving. Their application is particularly effective in multi-beam multi-channel transmission mode. The essence of these methods is that the blocks of information from users, arranged in the initial queue, are mixed together according to the law determined by the chosen encoding method, and only then are fed to the modulator. In this case, users who have problems with short-term failures due to interference will not lose the entire data block, but only a small part of it. For the next time in the incoming data stream, the "place and time" of the data intended for a particular user will be different, and the interference for this case may not be so disastrous. It is particularly effective to apply simultaneous frequency changes to all participants of this communication session, as is done in the GSM cellular system.

Adaptive alignment is a way to eliminate intersymbol interference. Using sophisticated digital processing algorithms, the delay time of multiple copies of reflected signals is equalized in order to increase the power of received characters. This method of increasing the reliability of data transmission requires significant computing power.

The separation methods are based on the fact that fading in different channels is independent. If the transmitted information is distributed over several channels, only part of the information will be affected. You can post either by time (temporary posting) or by frequency (frequency posting). When time is distributed, for example, by moving (alternating) through time channels, information for each user is transmitted at different times. With frequency diversity, the user's signal is distributed either over a wide frequency range, or is transmitted on multiple carriers.

The use of directional and multi-antenna systems can be attributed to the methods of spatial separation. You can use several antennas directed at different angles. By processing signals from different directions in the receiver, they are summed up. For multi-antenna reception, the location of the antennas is related to the wavelength of the transmitted signal. Depending on the direction of arrival of the electromagnetic wave (for example, reflected signals), the time of their arrival at each antenna will be different. The delay difference is determined by the diversity of the antennas, so the signals can be divided and summed. Using directional antennas or a system of multiple antennas, you can create a directional pattern so that you receive the strongest signal from the desired direction and weaken unwanted signals from other directions.

It is also possible to reduce the negative impact of interference, noise and interference in specific transmission systems by using the optimal modulation method for this type of communication. Different modulation methods provide not only different transmission rates, but also have different bandwidth or bandwidth per 1 transmitted bit. Therefore, the influence of external noise and interference will have a different negative impact on different types of modulation and different technologies of their application.

The first three methods considered require significant computing power to encode and decode the signal, but this is difficult in a portable device. Using a complex type of modulation (for example, LFM) also complicates the device's circuitry and increases its power consumption. Using narrow-directional antennas is a more acceptable solution, but it requires increasing the size and, consequently, the weight of the device. Therefore, we will only consider using spaced channels. We will take into account that both spatial separation and carrier frequency separation of the signal are possible.
3. The results of calculation

The dependence of the received signal amplitude $A$ on the distance $r$ to the reflecting object and the height of the device $h$ above the floor level can be represented by the formula

$$A(f, r, h) = A_0 \left( e^{ikr} + R \cdot e^{ik\sqrt{r^2 + 4h^2}} \right),$$

where $k = \frac{2\pi f}{c}$ – wave number, $f$ - signal carrier frequency, $A_0$ – amplitude coefficient, which takes into account the effective reflectivity of the target and the coefficient of spherical divergence of radio waves when the signal is propagated from the transmitter to the target and back.

Calculations for three frequencies of the radiated signal (3.0, 3.1 and 3.16 GHz) when the transceiver system is located at a height of 1.5 m are shown in Fig. 1. This figure shows that the interference “fading” of the signal occurs in different ranges, so this method is suitable for combating interference.

![Figure 1](image_url)

**Figure 1.** Dependence of the received signal amplitude on the range $r$ for different frequencies of the radiated signal $f=3.0, 3.1, 3.16$ GHz.

Now let’s consider the possibility of using several transmitting antennas that are located at different heights. Calculations for three positions of transmitting antennas (1.4, 1.5, 1.55 m) relative to the receiving antenna system located at a height of 1.5 m are shown in Fig.2. The carrier frequency of the signal is selected to be 3 GHz. The figure shows that interference “fading” of the signal also occurs at different ranges, which means that at the input of the receiving antenna system, when summing signals from different transmitting systems, the ripples will be smoothed out. It should be taken into account that the use of multiple transmitting antennas is easier to implement than the formation of multiple carrier frequencies of the signal.
4. CONCLUSIONS

Thus, you can eliminate the impact of interference by installing two or more transmitting antennas. This statement has been verified and confirmed by numerous experiments in field conditions. The work was performed within the framework of the state task of the Kotelnikov’s FIRE RAS.

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