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RESULTS FROM STUDY OF SIGNAL DISTORTION IN RADAR SENSING OF EXPLOSIVE DEVICES IN SOIL COLUMN

(presented DSc, Prof. Krivtsovoj V.I.)

It is shown that the solution to the problem of detecting explosive devices placed in the soil column, it is advisable to use methods for radar sensing of complex signals. The necessity of minimizing noise in the spectrum of the emitted signal with the allowable values is proved. The investigation of the nature and level of in-band distortion of the radiated signals to determine the area and value of the minimum intensity distortion is carried out.

Keywords: radar sensing, explosive devices, in-band signal distortion.

Formulation of the problem. The implementation of the state policy in the sphere of civil defence, prevention and liquidation of technogenic, natural and military emergencies, both in peacetime and in special period, is one of the main tasks of the SSES.

One of the reasons of military emergencies is unauthorized actuation of explosive devices (ED). The problem of detection and neutralization of munitions and weapons left after the Second World War, modern munitions deliberately installed has a global, state character.

Analysis of recent research and publications. The solution to these problems by traditional methods is ineffective. Search Systems – detectors and sensors are currently used for the detection of explosive items, do not provide the necessary probability of correct detection. [1, 2]

In these conditions, for the detection and recognition of the considered objects, it is possible to apply radar sensing with complex signals, synthesized on the basis of the digital analog method [2, 3]. However, high level of noise in the spectrum of the reflected signal due to a number of natural factors [3], reduces the probability of detection and, therefore, limits the use of radars. One way to reduce the noise level in the spectrum of the reflected signal is to minimize the distortion level in the spectrum of the radiated oscillations to acceptable values [3].

Statement of the problem and its solution. For synthesis of signals with allowable level of distortion, devices of narrow-band tracking filter are used [3]. However, the capability of tracking filters to reduce the level of distortion of the synthesized signals are not unlimited and are 15-30 dB when passband of less than tens-hundreds kHz [3]. In this connection, it is necessary to explore the nature and in-band distortion level of the radiated signal. The purpose of research is to identify areas and the value of the minimum intensity of distortion. It is necessary to enhance the probability of detection of explosive devices using radar sensing.

In a software synthesizer of the computing type in discrete moments of time $t_i=i/f_т$ codes instantaneous values of the phase of the generated signal – $K_φ(i)$ – are determined. A transformation phase code $K_φ(i)$ in codes instantaneous values of voltage $K_u(i)$ is carried out in accordance with the functions of sine or cosine by using trigonometric converter.

As a result of the operation of synthesizer signals are generated codes of the instantaneous values of voltage $K_u(i)$ and as a result of the digital to analog conversion - quantized voltage U(t). Real and imaginary parts of spectral components of the synthesized signal is calculated by means of Fourier analysis algorithm - a Fast Fourier Transform (FFT)

$$\mathrm{Re}(G(m)) = \sum_{i=0}^{N}\left(U(i)\cos\frac{2pmi}{N} + U^{*}(i)\sin\frac{2pmi}{N}\right);$$
$$\mathrm{Im}(G(m)) = \sum_{i=0}^{N}\left(-U(i)\sin\frac{2pmi}{N} + U^{*}(i)\cos\frac{2pmi}{N}\right), \quad (1)$$

where m = 0,1,... – counts of FFT

For determination of spectral density power of phase noises of complex signals - $G_φ(m)$ - we use the expression

$$G_{ц}(m) = \left|ДG_{ц}(m)\right|^{2} = \left|G_{ци}(m) - G_{цр}(m)\right|^{2}, \quad (2)$$

where $G_{ци}(m)$ – values of coefficients of a phase-frequency spectrum of an ideal signal; $G_{цр}(m)$ – values of coefficients of a phase-frequency spectrum of an real signal.

To get Gφ(m) use the recording of the spectral density through its modulus and argument

$$G_{И}(m)=|G_{И}(m)|\cdot\exp(-j\cdot G_{ци}(m)); \; G_{P}(m)=|G_{P}(m)|\cdot\exp(-j\cdot G_{цр}(m)). \quad (3)$$

As a result of the multiplication of a spectrum $G_{И}(m)$ of ideal oscillation and a complex-conjugate spectrum $G_{P}^{*}(m)$ of the real signal we receive

$$G(m)= |G_{И}(m)|\cdot\exp(-j\cdot G_{ци}(m))\cdot|G_{P}(m)|\cdot\exp(j\cdot G_{цр}(m))=$$

$$=|G_И(m)\cdot G_P(m)|\cdot \exp(-j\cdot(G_{ци}(m)-G_{цр}(m)))=|G(m)|\cdot \exp(-j\cdot ДG_ц(m)). \quad (4)$$

From the expression (4) find the spectral allocation of phase noise of the output signal

$$ДG_ц(m)=G_{ци}(m)-G_{цр}(m)=\operatorname{arctg}\left(\frac{\operatorname{Im}(G(m))}{\operatorname{Re}(G(m))}\right). \quad (5)$$

Using expression (2) we receive values of spectral density power of phase noises $G_\varphi(m)$. The spectral density of power of frequency noise $G_f(m)$ is characterized as an average square of deviations of frequency of a signal from her nominal value under the influence of noise at an analysis frequency F_m in a band of frequencies Δf. The spectral density power of the frequency noise is found from the expression (6)

$$G_f(m)= G_\varphi(m)\cdot F_m^2. \quad (6)$$

An analysis frequency Fm is calculated from the expression Fm=(i·n/fт), where n- quantity of counts of FFT. Then the expression (6) takes the form

$$G_f(m)= G_\varphi(m)\cdot(i\cdot n/ f_т)^2. \quad (7)$$

As a result of the simulation found, that the spectral allocation of distortion of complex signals, synthesized by the shapers of search systems, has an uneven character. Research of in-band distortion level of the considered signals allowed to define area of the minimum intensity of distortions, which is located at the distance of 200 kHz from main frequency. At a distance of more than 200 kHz from the main frequency distortion level is increased by 15-20 dB, what does use of a tracking filter of a search system less effective.

Conclusions. In the construction of devices for the formation of complex signals for search system, which solve problems with detection of explosive objects, it is necessary to consider width of area with the minimum intensity of distortions in the choice of passband active tracking filter. It will allow the most effectively to use possibilities of devices of narrow-band tracking filtering to reduce the distortion level of the synthesized signals and, as a consequence, to increase probability of detection, identification and accuracy of determination of explosive devices coordinates.

LITERATURE

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Результати дослідження спотворень сигналів при радіолокаційному зондуванні вибухових пристроїв в товщі ґрунту

Показано, що при вирішенні задачі виявлення вибухових пристроїв, які розташовані в товщі ґрунту, доцільно використання методів радіолокаційного зондування із застосуванням складних сигналів. Обґрунтовано необхідність мінімізації рівня шумів в спектрі сигналу, що випромінюється, до допустимих значень. Проведено дослідження характеру і рівня внутрішньосмугових спотворень сигналів, що випромінюються, з метою визначення області і величини мінімальної інтенсивності спотворень.

Ключові слова: радіолокаційне зондування, вибухові пристрої.

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Результаты исследования искажений сигналов при радиолокационном зондировании взрывных устройств в толще грунта

Показано, что при решении задачи обнаружения взрывных устройств, расположенных в толще грунта, целесообразно использование методов радиолокационного зондирования с применением сложных сигналов. Обоснована необходимость минимизации уровня шумов в спектре излучаемого сигнала до допустимых значений. Проведены исследования характера и уровня внутриполосных искажений излучаемых сигналов с целью определения области и величины их минимальной интенсивности.

Ключевые слова: радиолокационное зондирование, взрывные устройства, внутриполосные искажения сигналов.