Antenna with the dielectric width 1,575 mm shows good matching qualities on the part of frequency from 6,2 GHz to 20 GHz, but more uniform meaning SWR can be seen on frequency 9,5 – 12,5 GHz.

Antenna with the dielectric width 2 mm shows good matching qualities on the part of frequency from 6 GHz to 13,3 GHz and 17,6 – 20 GHz.

Antenna with the dielectric width 3 mm shows good matching qualities on the part of frequency from 8 GHz to 12,4 GHz and 17,6 – 20 GHz and meaning SWR is changing from 1,3 to 2.

In the antenna with dielectric thickness 1.575 mm, the reflection coefficient decreases from the entrance of -3 dB at 2.5 GHz to -30 dB at 9.5 GHz.

With further increase in the frequency value of S11 rises. The magnitude of the reflection coefficient varies from -31 dB to -10 dB. at a frequency of 9.5 GHz an extreme point (minimum) with the value of *S*11 exists.

In the antenna with the dielectric thickness of 2 mm, the reflectance decreases from the entrance of -2.5 dB at 2.5 GHz and -23 dB at 12 GHz.

With further rise in frequency the value of S11 will increase. The magnitude of the reflection coefficient varies from -23 dB to -15 dB. at 12 GHz. An extreme point (minimum) with the value of S11 exists.

In the antenna with a dielectric thickness of 3 mm, the reflectance decreases from the entrance of -3 dB at 2.5 GHz and 17.5 dB at 8.7 GHz. With further increase in frequency the value of S11 will increase. The magnitude of the reflection coefficient varies from -17.5 dB to -10 dB at a frequency of 8.7 GHz and has the minimum point value S11.

In the course of the simulation it is set that:

– The thickness of the dielectric base elliptical slot antenna affects its band width. When the thickness of the band used tapers, set the optimum thickness of the dielectric in which the antenna has the highest broadband, which is 1,575 mm. The operating frequency band in this case is 6.2 – 20 GHz, i.e. band width is 13,8 GHz.

– The analysis showed that the thickness of the dielectric also affects the directional properties of the antenna. Increasing the thickness of the dielectric leads to the expansion pattern diagram corresponding to the smallest width of the substrate thickness 1,575 mm, when the level 2 equals to 0,707 and 80°. When the substrate thickness of 3 mm is a division of the main lobe and 2 in the direction of the maximum observed failure pattern.

– As a result of the simulation set the thickness of the insulator has an impact on the value of VSWR. By increasing the thickness of the substrate matching properties deteriorate and uneven frequency response SWR increases significantly. Good agreement with the feeder link antenna is observed in the dielectric thickness of 1,575 mm.

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METHOD OF ESTIMATING PROTECTION FROM SPEECH SIGNALS LEAKAGE THROUGH LOW-FREQUENCY TECHNICAL CHANNELS OF INFORMATION LEAKAGE BASED ON THE CORRELATION FUNCTION

IRYNA BURACHONAK, VLADZIMIR ZHELEZNYAK
Polotsk State University, Belarus

There have been studied the parameters of a measuring broadband chirped signal in bands of equal intelligibility and offered the estimation of protection of informatization object from speech information leakage through low-frequency technical channels of leakage by a broadband chirped signal based on the correlation function in the bands of equal intelligibility. Source data for implementation of the method of estimating the parameters of a broadband chirped signal on new principles in terms of influencing factors have been obtained.

The level of protection of informatization object is objectively assessed by release of weak measuring signals from the high level noise in channels of speech information leakage. To assess protection of channels of speech information leakage harmonic signal is widely used as a measuring, substantiated correlation theory of speech intelligibility [1]. State standard RST 34.101.29-2011 establishes the use of harmonic measurement signal when splitting the spectral density of the speech signal by 20 bands of equal intelligibility. The analysis of the literature [1,2] showed, that the use of a harmonic signal solves this problem with a high precision, frequency resolution and high sensitivity. However, for a speech signal with a frequency range from 100 Hz to 10 kHz estimation by only 20 harmonic components does not exclude some methodological errors. Method for estimating channels of speech information leakage by broadband chirp signal processing with time-frequency Wigner transformation [2, 3] excludes methodological errors, inherent harmonic signals and improves the methodological precision, frequency resolution and sensitivity, which requires significant additional processing time.

The **aim** is to develop on a new principle the evaluation method of protection against leakage of speech signals through the low-frequency technical channels of information leakage which is based on the correlation function in terms of high level noise and other influencing factors.

For this we have researched the characteristics and parameters of broadband chirped signal when splitting the spectrum of the speech signal by 20 bands of equal intelligibility and assessed the impact of base size and duration of the signal on sensitivity and accuracy.

The research of broadband chirped signal`s parameters in 20 bands of equal intelligibility. Unlike harmonic signal a broadband chirp signal allows extending the capabilities of protection evaluation of speech and controls the deformation of the spectral density in the bands of equal intelligibility, which the speech signal spectrum is splitting, rather than at isolated points on the real axis.

Using the expression of [4], 20 broadband chirp signals is formed and investigated in the bands of equal intelligibility with various initial values of their base and duration.

According to [5] initially base B of signals is set as a permanent and the residence time T_s of every single broadband chirp signal in the bands of equal intelligibility is determined for values of base B = 200, 500, 5000. It has been established that broadband chirp signal has the smallest variations of frequency deviation $\Delta f_{N=3}$ =140 Hz in the third N_3 band equal intelligibility, and the largest $\Delta f_{N=20}$ =2750 Hz – in the twentieth N_{20} band equal intelligibility. Frequency deviation broadband chirped signal in the twentieth N_{20} band equal intelligibility is almost 20 times more than the frequency deviation of the signal in the third N_3 band equal intelligibility. This difference significantly affects the estimate signal formed for a constant value of base.

If we talk about the total time of 20 broadband chirp signals at the value of the base B =200, it is equal to T_{total} =16,86 s. However, with this value of base it is not possible to do evaluating in the band equal intelligibility in the same conditions, because the duration of broadband chirp signal in the band N_{20} will be T_s =0,07 s, whereas, in the band N_3 the duration of broadband chirp signal will be T_s =1,43 s, that means the difference in energy of signal more than 20 times. In order to assess broadband chirp signals in equal conditions it is necessary to use a constant value of base not less than the B =5000, however, at such value of base, the total time of all 20 wideband signals in all bands equal intelligibility will be T_{total} =421,79 s, that does not allow to achieve a set goal.

According to [5] and on condition, that the value of the signals duration T_s is set as a permanent, the base value of every single broadband chirp signal in the bands of equal intelligibility is defined for values of signal duration T_s =1,2,4,6 s. According to the research it has been found, that for duration T_s =4 s base broadband chirp signal in the third band N_3 (the narrowest) is equal to B =560, whereas, in the band N_{20} (the widest) base is equal to B =11000. Increasing the base signal allows to reduce the level of oscillation of the spectral density chirp signals in the last bands of equal intelligibility and does not change the quality of the assessment. Thus, the total time equal in duration signals all in 20 bands of equal intelligibility is $T_{total} = T_s \cdot 20 = 2 \cdot 20$ =40 s when the duration of the signal T_s =2 s and accordingly, T_{total} =80 s when the duration of the signal T_s =4 s.

The result of research broadband chirp signals in 20 bands of equal intelligibility with constant value of base has determined, that with increasing bandwidth, duration of broadband chirp signals decrease and using broadband chirp signals with constant value of base is not expedient. Proposed to use identical in duration and having different values of base signals. This greatly reduces the total time estimation of channel of information leakage.

Parameter estimation broadband chirp signal based on the correlation functions. Analytical description of signals and their spectra are the most important and comprehensive characteristics on which signal characteristics were obtained: the autocorrelation function (ACF) and the cross-correlation function (CCF).

The autocorrelation function – a time function, which allows to estimate the level of similarity of two signals and has the dimension of energy. ACF is given by [4]:

$$R_{1,2}(\tau) = \int_{-\infty}^{\infty} s_1(t) s_2(t-\tau) dt \ , \tag{1}$$

where $s_1(t)$ и $s_2(t)$ – the input and output signals; τ – time shift between the signals; $R_{1,2}(\tau)$ – ACF of two signals $s_1(t)$ и $s_2(t)$. Function (1) further allows to estimate the level of similarity of two signals, as well as their relative position on the time axis. At the time, when the output signal $s_2(t)$ is the most similar to the input signal $s_1(t)$, the correlation function will have a maximum. The width of this maximum – twice the length of the initial pulse and is symmetrical about the centre. If $s_1(t) = s_2(t)$, the expression (1) for $R_{1,2}(\tau)$ is an expression ACF of signal $s(t) = s_1(t) = s_2(t)$:

$$R(\tau) = \int_{-\infty}^{\infty} s(t) s(t-\tau) dt \ . \tag{2}$$

Figure 1 shows the ACF and its envelope broadband chirp signal with a frequency f_0 =640 Hz (Δf =140 Hz, N_3), base B =280 and duration T_s =2 s. ACF allows to assess the level of compliance (correlation) signal with its time-shifted copy. The main property of the ACF – at time offset τ equal to zero, it defines the energy of signal.

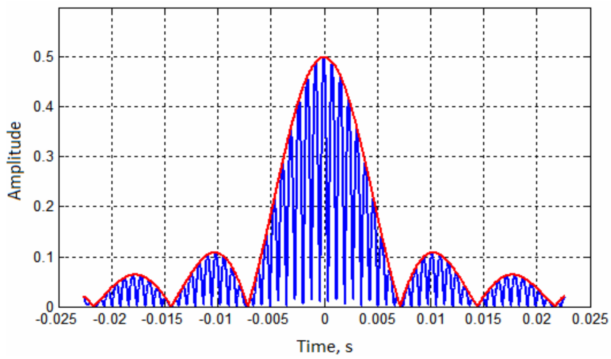

Fig. 1. ACF and its envelope of the signal at the input of channels of speech information leakage

The energy of the signal shows total energy released in the resistor R =1Ohm for a specified time. Unjammable reception is possible on condition when the necessary energy of the desired signal in the optimal receiver is provided, and its magnitude is in its turn, increases with: increasing time signal processing; increasing the amplitude of the signal $s(t)$; expanding the range of the signal.

To estimate the parameters of the broadband chirp signal at the output channel of speech information leakage with high accuracy it is required to consider a random signal delay relative to input of the measuring signal, due to its passage through the propagation medium and equipment delays. Even a small random delay 10-200 ms duration significantly increases the error of the estimate output parameters. The method based on the estimation of parameters of the cross-correlation between broadband chirp signal, passed through the propagation medium with a specified delay, and measuring broadband chirp signal eliminates errors associated with the delay of the signal in channels of speech information leakage. Figure 2, *a*) shows the ACF function of the signal at the output of channels of speech information leakage. Figure 2, *b*) – CCF function between the measuring signal at the input and output signals in channels of speech information leakage. Random delay time is determined by the difference between the maximum cross-correlation function between the signal at the output of channels of speech information leakage and measuring broadband chirp signal, and the maximum of the autocorrelation function of the measuring broadband chirp signal. This time span is the delay of the broadband chirp signal at the output of channels of speech information leakage.

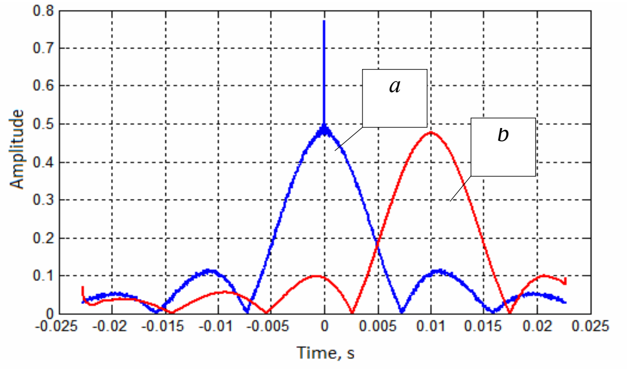

Fig. 2. The joint display ACF and CCF:
a) ACF signal at the output of channels of speech information leakage;
b) CCF between the generated measuring signal and the signal at the output of speech information leakage

Sensitivity defined as the ratio of change of output value signal/noise Q_{out} to the value signal/noise Q_{in} causes it to change the input signal. The dependence of the output value of the signal/noise ratio from change of the input values of the signal/noise ratio can be represented by [6]:

$$Q_{out} = f(Q_{in}), \quad (3)$$

where $Q_{in} = \left(\frac{P_s}{P_n}\right)_{in}$ – ratio of the power of the measurement signal to noise power at the input; P_s, P_n – power of broadband chirp signal and power of noise.

For broadband chirp signal in the bands of equal intelligibility Q_{out} is given by [6]:

$$Q_{out} = 2 \cdot E / N_n, \quad (4)$$

where E – the energy of the signal at the output of channels of speech information leakage; N_n – power spectral density of noise in the band equal intelligibility broadband chirp signal.

By the formula [5] on the basis of correlation functions were obtained results output parameters broadband chirp signal in the bands $N_1, \ldots, N_{20}$ and sampling frequency F_s = 44100 Hz.

The values of the ultimate sensitivity for each k band at a constant base value B = 200,300,500,600 was obtained [5]. It has been established that at B = 200 in bands N_{19} (T_s =0,09 s, Δf =2240 Hz), N_{20} (T_s = 0,07 s, Δf = 2750 Hz), the signal is almost not detected. When the B = 500 in bands N_{19} (T_s =0,22 s), N_{20} (T_s = 0,18 s) signal is detected, however, the system has very low sensitivity. According to the results of the experiments, the optimum value of base in bands N_{19}, N_{20} should be not less than 5,000. If we consider the ultimate sensitivity in other bands of equal intelligibility, then at values of base above 500 the value of maximum sensitivity increases insignificantly, thus further increasing the value of base is impractical, because with increasing value of base, the total time of broadband chirp signals increases rapidly. In Figure 3 shows the dependence of the coefficient of variation [7] of the maximum sensitivity with a constant value of base signals.

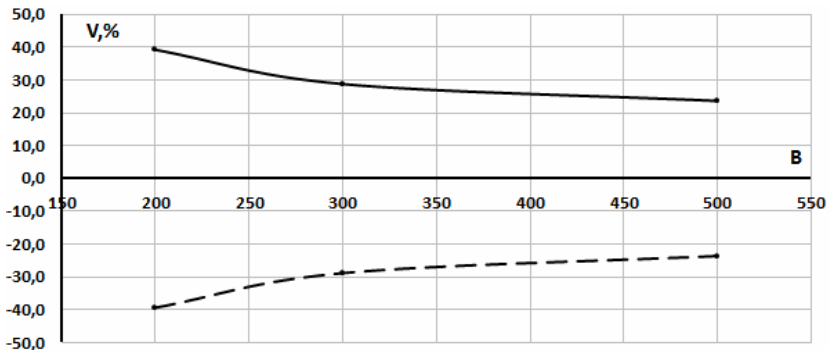

Fig. 3. Coefficient of variation of the maximum sensitivity of measuring instrument output broadband chirp signals in noise at a constant value B

Further values of the limiting sensitivity were obtained for each k band with at a constant value of the signal duration T_s = 1, 2, 4, 6 s [5]. Figure 4 shows the dependence of the coefficient of variation of the maximum sensitivity with a constant value of signals duration. From Figure 4 it follows that under the condition that the duration of the signal has a constant value and the value of the base size is different for each of the k band, the coefficient of variation decreases with the increasing duration of signals.

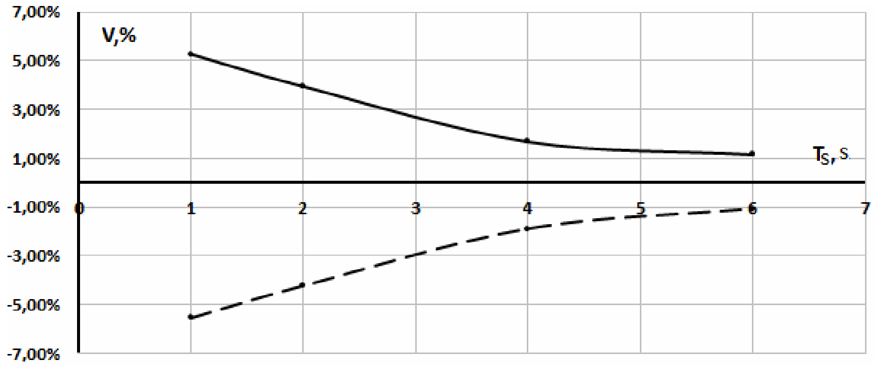

Fig. 4. Coefficient of variation of the maximum sensitivity of measuring instrument output broadband chirp signals in noise at a constant value T_s

To estimate the parameters of broadband chirp signal in conditions of high-level noise, in order to save the total evaluation time of channels of speech information leakage, it is reasonable to use 20 test signals in each band of equal intelligibility duration T_s = 4 s. This time allows keeping as a constant, reached earlier parameters by maximum sensitivity, high accuracy and fine structure of the processed measurement signal.

It has been justified, that the method of assessment of protection against leakage of speech signals through low-frequency technical channels of information leakage based on the correlation functions of broadband chirp signal for values of duration $T_s \geq$ 4 s provides the value of the maximum sensitivity and accuracy in all bands of equal intelligibility, reached earlier by method of assessing by broadband chirp signal with processing time-frequency transformation Wigner and allows to simplify the procedure for automated measurements, reducing the time of security estimation of channels of speech information leakage in 30 times.

Using a 20-broadband chirp signals, identical in duration, but with different values of the base size allows to reduce time assessment in each band of equal intelligibility more than 5 times compared with the processing time of 20 broadband chirp signals with a constant value of base and the variable value of duration time. Considering the fact, that in assessing the protection of channels of speech information leakage, the duration of the formed measuring harmonic signal in each band of equal intelligibility, is regulated T_s = 1, 10, 25 s, then the use of identical in duration (for example, T_s = 4 s) broadband chirp signals with different value of bases, allows to reduce assessment time in each band of equal intelligibility from 6 s to 20 s.

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