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THE METHOD FOR DETECTING NOISE-LIKE SIGNALS BASED ON SPECTRAL SYMMETRY

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Noise-like signals are widely used in various fields due to their noise immunity, stealth, and other properties. This signals detecting in interference and noise conditions is an important technical challenge. This paper proposes a method for detecting PSK NLS based on the symmetry of their spectrum. This method involves sum-and-difference processing of their spectral components. Simulation results show that this method is more effective than the traditional energy detecting.

Noise-like signals (NLS), or signals with a long baseline, are widely used in communication systems, radar, and radio navigation. They are characterized by interference immunity, energy and parametric stealth, and some other useful properties. NLS are used for information security tasks, the military sphere including. They can be received even with a negative SNR (in dB), that is, when the signal is weaker than the noise. This is achieved by processing the signal in an optimal filter. However, detection at such a signal-to-noise ratio is quite a difficult task, because NLS are practically invisible on the screen of an oscilloscope or spectrum analyzer. Minor deviations in the signal's spectral density are masked by the natural spread of the noise's spectral density in different frequency bands. As a result, NLS is hidden against the background of natural noise. This is what makes it energy stealthy.

The traditional method for detecting NLS is energy accumulation. Its physical meaning is that, with prolonged accumulation, the spread of noise components in the spectrum in different frequency bands evens out. Then, against the background of average noise, even slight excesses of this average value become noticeable. Energy accumulation is a universal method for detecting noise-like signals and is applicable to any signals. However, it requires a relatively long time to implement. This may be unacceptable in situations where decisions must be made quickly or when the signal lifetime is short.

Note that the spectrum of PSK NLS is symmetrical with respect to the center frequency f_0, as shown in Fig. 1. Previously, in [1], a detection method based on calculating the mean value of the absolute multiplying results values of the signal's spectral components, taken symmetrically relative to its central frequency, was considered. Here, we also propose using the symmetry property of the PSK NLS spectrum to reduce detection time, too.

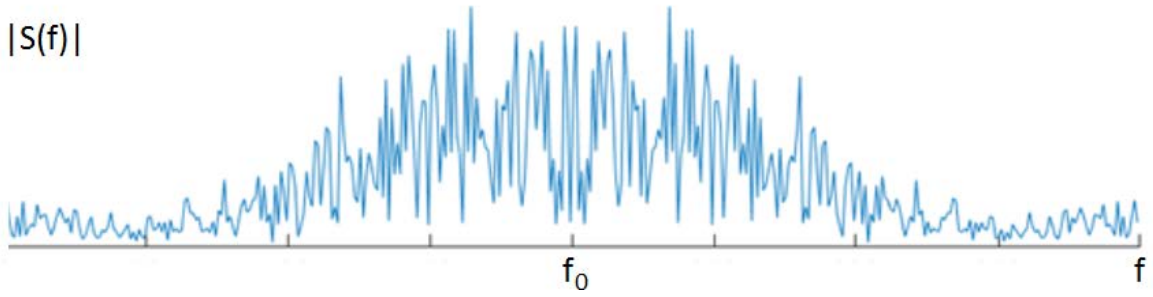

Fig. 1

If we find the difference between two spectral components of a signal taken symmetrically with respect to f_0,

$$|S(f_0 + f_x)| - |S(f_0 - f_x)| \quad (1)$$

then in the absence of noise this difference will be equal to zero.

This is true for all spectral samples within the signal bandwidth $\pm M\Delta f$. Therefore,

$$\sum_{m=0}^{M} |S(f_0 + m\Delta f)| - |S(f_0 - m\Delta f)| = 0 \quad (2)$$

If a different frequency is substituted for f_0 in (2), then equality to zero will not be achieved. Adding noise will certainly "blur" the picture, and equality to zero will also not be achieved. However, one can assume that in this case the function's minimum will be reached:

$$\sum_{m=0}^{M} \begin{bmatrix} |S(f_0 + m\Delta f) + N(f_0 + m\Delta f)| - \\ -|S(f_0 - m\Delta f) + N(f_0 + m\Delta f)| \end{bmatrix} = 0 \quad (3)$$

To test this hypothesis, mathematical modeling was performed. The developed model includes the formation of a PSK NLS with different bases, the addition of noise, the calculation of the spectrum of the signal-noise mixture, and the determination of function (3) relative to frequencies near f_0. The calculation result in the absence of noise is shown in Fig. 2.

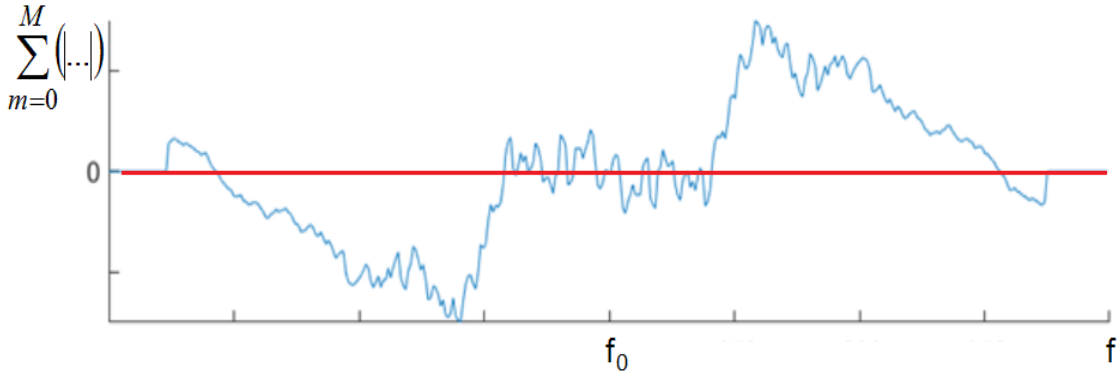

Fig. 2

Calculations performed at different SNR show that at SNR = 1:3 the difference method is 25% faster than the energy accumulation method in detecting a signal, while also finding the exact value of its average frequency (center of symmetry).

Reference

1. Виявлення широкосмугових сигналів за особливостями їх спектра / І. Є. Антіпов, О. М. Нікітін // Радіотехніка : Всеукр. міжвід. наук.-техн. зб. – Харьків, 2024. – Вип. 218. – С. 110–117 – URl: https://openarchive.nure.ua/entities/publication/e5e3454c-c8ba-40d1-8341-a1f7b9074dc0/full