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THE COHERENT DEMODULATION PROCEDURE OF MUTUALLY NON-ORTHOGONAL DIGITAL SIGNALS

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ПРОЦЕДУРА КОГЕРЕНТНОЇ ДЕМОДУЛЯЦІЇ ВЗАЄМНО НЕОРТОГОНАЛЬНИХ ЦИФРОВИХ СИГНАЛІВ

У роботі досліджується процедура когерентної демодуляції взаємно неортогональних цифрових сигналів з гаусівською мінімальною частотною маніпуляцією з метою повторного використання радіочастотного ресурсу.

The efficient use of radio frequency resources plays a crucial role in the world, considering that the social, economic and technical development of the country no less depends on the effectiveness of its use.

According to the Law of Ukraine "On Radio Frequency Resource of Ukraine", the main principles of radio frequency resource management in Ukraine are: protection of radio frequency assignments; efficient use of distributed radio frequency bands; development of scientifically substantiated recommendations for making appropriate decisions to increase the efficiency of use and meet the needs of users of the radio frequency resource of Ukraine [1].

In order to reuse the radio frequency resource, it is proposed in this paper to use the methods of digital signal separation statistical theory to perform a synthesis of the non-orthogonal digital signals with Gaussian Minimum Shift Keying (GMSK) processing procedure.

The coherent demodulation procedure of mutually non-orthogonal digital signals with Gaussian minimum frequency manipulation has a number of advantages [2]:

- if the average power of the first GMSK signal is significantly exceeded over the power of the second GMSK signal and there are no errors in estimating the parameters of a stronger signal, and the potential noise immunity of the procedure is the same as in the absence of the first powerful signal;
- in the absence of the first GMSK signal, this procedure degenerates into a classical coherent demodulation of GMSK signal;
- this procedure can be used in the implementation of frequency resource reuse programs and in the development of promising interference-protected radio communications.

Despite the great variety of modulation types, methods, etc. in practice only a limited number of them can be used. Modern communication systems require special attention to the efficient use of resources such as transmission power and channel bandwidth. According to these criteria, GMSK is well suited for mobile communication and is already implemented in GSM systems and IEEE 802.15 specification (Bluetooth), the used concept has the advantage that the information is transmitted in phase changes, rather than in the phase itself.

The GMSK signal can be easily detected using an orthogonal coherent detector, which is similar to the classic signal with Minimum Shift Keying (MSK).

GMSK modulation is based on MSK, which is a form of Continuous Phase Frequency Shift Keying (CPFSK). One of the problems with standard PSK forms is that the sidebands strongly expand out of the media. And we can use MSK and GMSK to overcome this. MSK as well as GMSK is implemented as a continuous phase circuit. There are no phase breaks, because the frequency changes occur at the points of zero carrier intersection. This is due to the unique quality for MSK and GMSK. Thus, the frequency difference between logic 0 and 1 states is always equal to half of the data rate. This can be expressed in terms of the modulation index equal to 0.5.

At the k-th clock interval, the signal is determined by the following formula:

$$s_i(r_{ik}, t) = A_i \cos\left(\omega_0 t + r_{ik}\Omega_д t + \varphi_{ik} + \varphi_{i0}\right), t \in [t_{k-1}, t_k), \tag{1}$$

where A_i – amplitude of the signal with MSK, ω_0 – carrier frequency, Ω_∂ – frequency deviation, r_{ik} – discrete parameter (informational symbol), φ_{i0} – initial phase.

Thus, we see that the signal with MSK depends not only on the informational symbol on k-th clock interval but also on the previous values of it.

The MSK makes the phase change linear and limited to ± (π / 2) per bit interval T. This allows MSK to provide a significant improvement over the QPSK. Due to the effect of linear phase change, the power spectral density has weak side lobes that help control the interference of the adjacent channel. However, the main lobe becomes wider than in quadrature manipulation. Since we have the task of separating two signals, it will accordingly be necessary to represent both signals in such a way that it would be possible to record the observation of input and the likelihood functionals following it.

There are two main ways in which the GMSK signal can be generated. The most obvious way is to filter the modulating signal using a Gaussian filter, and then transmit it to the frequency modulator, where the modulation index is set to 0.5. This method is very simple, but it has a major drawback, which is that the modulation rate should be equal to 0.5 and in practice this method is not suitable, because certain values affect the signal and it is impossible to accurately set the modulation index.

The second method is more widely used and it consists in the fact of using a quadrature modulator that means the signal phase is quadrature or changed by 90 degrees relative to the initial. The quadrature modulator uses components, which are in-phase and the quadrature. Due to the phase and quadrature elements, this type of modulator is often called the I-Q modulator. Using this type of modulator, the modulation rate can be maintained at exactly 0.5, without the need for additional settings. This makes it relatively easy to use and provide the required level of accuracy without the need for adjustment.

For demodulation, this technique is used in the opposite direction. Since the spectrum of the MSK signal in such scheme will also have side lobes extending beyond the bandwidth, it is necessary to reduce them by passing the modulating signal through the low-pass filter before applying it to the carrier. The requirements for the filter are: it must have a sharp limit, a narrow bandwidth, and its impulse response must not exceed.

The optimal filter known as a Gaussian filter has the Gaussian response to the pulse we need. Actually, by adding such a filter to the circuit, a GMSK signal is obtained.

The possibility of reuse of the radio frequency resource will be provided by building the model, which will be working with given conditions and providing the needed task, namely - ensuring the processing of two mutually non-orthogonal digital signals. To build a workable model, the mutual energies for these two signals will be calculated, one of which, provided, is more powerful than the other.

Its implementation is planned and already developing by using Matlab software package, Simulink application. Initially, for the case of ideal coherent receiving, it is necessary to synthesize a model that will operate on one clock interval, which, although will be losing in noise immunity to a signal from BPSK however still emerging a new quality, that is the ability to separate each of the signals in one radio channel operating simultaneously.

An important factor is to determine the noise immunity of this model, which is also possible in this software package, and the indicators that will be measured to evaluate it: Bit Error Rate (BER) and the signal-to-noise ratio (SNR). A high BER causes increased packet loss, increased latency, and reduced system bandwidth, and is the opposite of SNR [3]. The GMSK modem performance in many works is determined by measuring the SNR to BER.

Conclusion. Thus, this procedure allows using the same frequency band for both digital mutual non-orthogonal signals that is beneficial in the way of reusing the radio frequency resource. It is expected that the difference in power of 6 dB will allow the receiving side to separate two signals without loss of information. This will increase the number of subscribers operating simultaneously within one GSM cell, which will have a positive impact on the performance of the system as a whole.

References

1. Law of Ukraine “On Radio Frequency Resource of Ukraine” of June 1. 2000, № 1770. URL: https://zakon.rada.gov.ua/laws/show/1770-14 (access date 23.03.2021).
2. Lupas L., Verdu S. “Linear Multiuser Detectors for Synchronous Code-Division Multiple-Access Channels” IEEE Trans. Information Theory Vol. IT-35, pp. 123–136, Jan. 1989.
3. Peer-reviewed technical communication: Estimating signal-to noise ratio (SNR) / B. T. Bosworth and others. IEEE Journal of Oceanic Engineering. 2008. Vol. 33, № 4. P. 414–418. DOI: 10.1109/JOE.2008.2001780.