USING THE PSEVOCHAOTIC POLARIZATION SIGNAL TO IMPROVE THE ELECTROMAGNETIC COMPATIBILITY OF THE COMMUNICATION

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Abstract

This article discusses the possibility of using pseudo-chaotic polarization signals to improve the electromagnetic compatibility of the communication channel. The estimates of interference suppression in the communication channel are given. It is shown that the use of pseudo-chaotic polarization signals provides additional opportunities for improving the noise immunity of modern communication channels.

Introduction

Further development of communication systems requires the search for effective methods of ensuring electromagnetic compatibility. In conditions when the temporal and frequency differences of the signals used in the actual communication channels are insignificant, other additional differences have to be found. For example, polarization differences may provide an additional gain in terms of electromagnetic compatibility. However, such a gain will be significant for polarized signals [1]. In the presence of partially polarized signals and interference, this gain will be significantly reduced. And when considering signals and unpolarized interference, it is very difficult to talk about suppression. Under such conditions, the influence of partially polarized and unpolarized interference is proposed to use in the communication channels orthogonal signals on orthogonal polarizations. Thus, it turns out that the information component of the transmitted signal after the selection in the orthogonal filters of the multichannel receiver at the receiving position will have a strong correlation of the orthogonal components of the signal itself, and is much weaker for interference. These differences provide additional opportunities for the selection of signals against the background of noise of various degrees of polarization [2]. In this regard, the urgent task is to improve the electromagnetic compatibility of communication channels based on the use of signals of pseudo-chaotic polarization. It is advisable to first consider the characteristics and parameters of pseudo-chaotic polarization signals, methods of generating and processing them, and then assess the effectiveness of using such signals under the influence of interference.

I Polarization characteristics and parameters of orthogonal radiated signals on orthogonal polarizations

To describe the polarization properties of electromagnetic waves, parameters such as ellipticity angle and orientation angle can be used, which in general is true for describing the characteristics of monochromatic electromagnetic oscillations of constant polarization.

According to polarization signs, signals can be polarized and unpolarized. In practice, they often speak of partially polarized signals and interference with the corresponding polarization index. The determination of the polarization characteristics of electromagnetic waves is possible by calculating the instantaneous polarization parameters.

The polarization of an electromagnetic wave is its space-time characteristic and is determined by the type of trajectory described by the end of the electric field vector in the picture plane. The shape described by the end of the vector is called the polarization diagram or the polarization ellipse. To quantitatively characterize the polarization of a wave, the geometric parameters of the PD are used: an ellipticity coefficient or an ellipticity angle with a sign; and also the orientation angle of the major semi axis of the polarization ellipse. Polarization diagrams can be elliptical, circular, linear or complex.

Consider the case of radiation of two mutually orthogonal linear frequency signals on orthogonal linear polarizations - horizontal and vertical.

$$E_x(t)=U_o(t)cos\left\{2\pi\left[\left(f_0-\frac{\Delta f}{2}\right)\cdot t+\frac{\Delta f\cdot t^2}{2\tau_u}\right]\right\}, \quad (1)$$

$$E_y(t)=U_o(t)cos\left\{2\pi\left[\left(f_0+\frac{\Delta f}{2}\right)\cdot t-\frac{\Delta f\cdot t^2}{2\tau_u}+\varphi_0\right]\right\}, \quad (2)$$

where Δf - is the frequency deviation; τ_u - pulse duration; f_0 - carrier frequency; φ_0 - initial phase.

In fig. 1 shows the laws of change in the frequency of signals, in Fig. 2 shows their amplitude-frequency spectrum, and Fig. 3 shows the transmitting and receiving module to ensure the emission of orthogonal signals on orthogonal linear polarizations when transmitting and processing received signals of orthogonal signals on orthogonal polarizations when receiving.

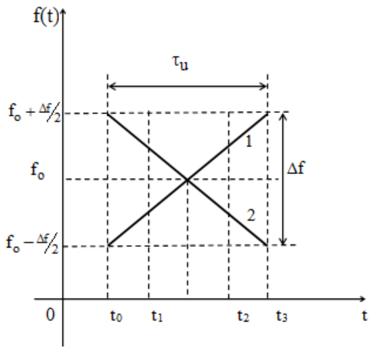


Figure 1. Frequency charts: 1 - $E_x(t)$; 2 - $E_y(t)$.

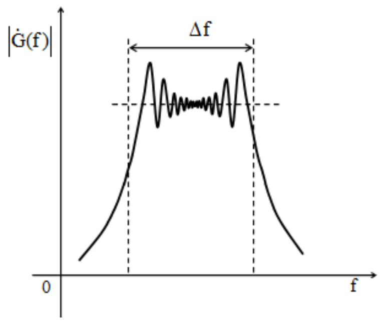


Fig. 2. Amplitude-frequency spectrum of signals

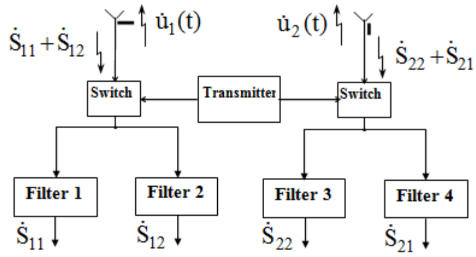


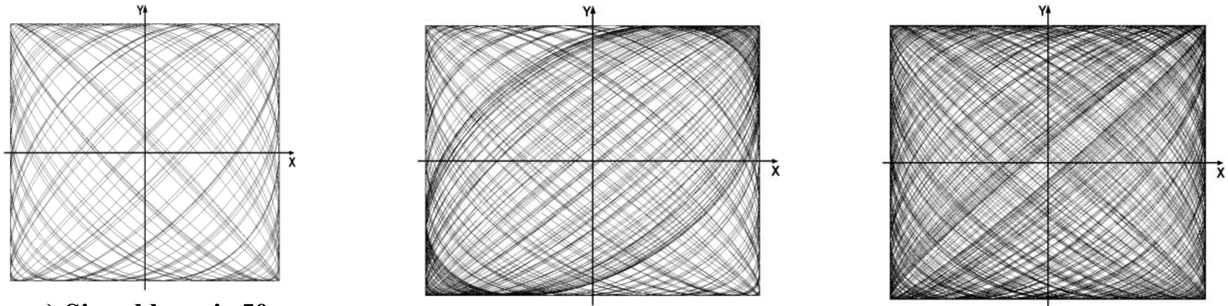
Fig. 3. Transceiver module

The instantaneous values of the parameters of the polarization diagrams of the signals, such as the orientation angle of the polarization ellipse and the ellipticity coefficient, can be determined as follows:

$$\beta(t)=\frac{1}{2}arctg\frac{2E_x(t)E_y(t)cosF(t)}{E_x^2(t)-E_y^2(t)}, \quad (3)$$

$$r(t)=\sqrt{\frac{E_x^2(t)sin^2\beta(t)-E_x(t)E_y(t)sin2\beta(t)cos\Phi(t)+E_y^2(t)cos^2\beta(t)}{E_x^2(t)cos^2\beta(t)+E_x(t)E_y(t)sin2\beta(t)cos\Phi(t)+E_y^2(t)sin^2\beta(t)}}, \quad (4)$$

where $F(t)$ - is the function of changing the difference between the total phases of the indicated signals; $E_x(t),E_y(t)$ - functions to change the corresponding instantaneous amplitudes.



а) Signal base is 50 **б) Signal base is 100** **в) Signal base is 200**

Fig. 4. Polarization diagrams of orthogonal signals of various pulse durations.

The polarization diagrams of signals of different bases are presented in Fig. 4. Note that such polarization diagrams can be attributed to the signals of pseudo-chaotic polarization in their polarization structure.

Thus, the simultaneous emission of two mutually orthogonal in polarization and temporal structure of signals leads to the observation in free space of a qualitatively new signal - a signal with pseudo-chaotic polarization. On the other hand, such a signal is a signal with high-frequency polarization modulation.

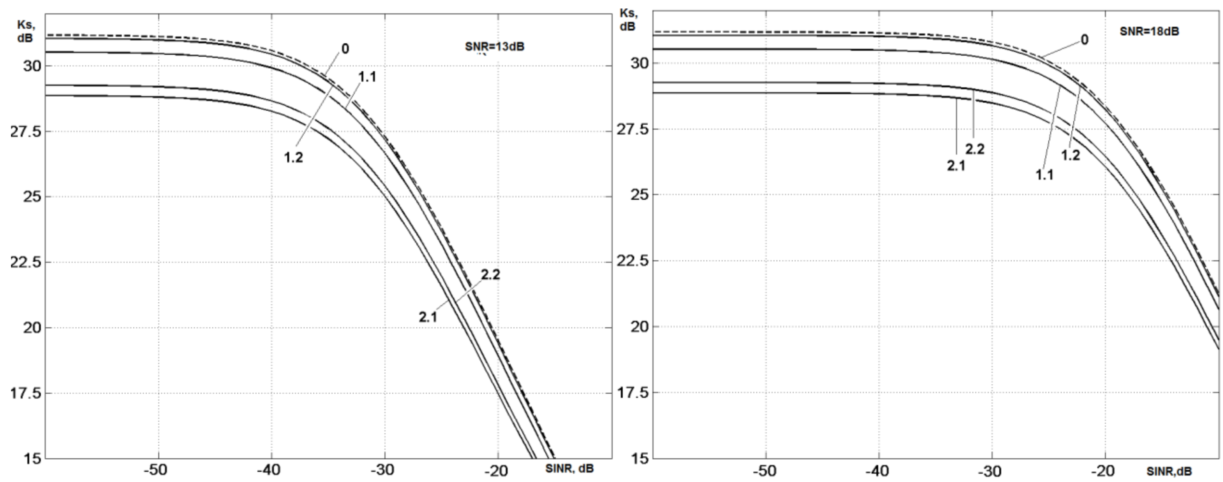
II Modelling Results

To assess the effectiveness of using pseudo-chaotic polarization signals in a communication channel under the influence of active or interference, the interference suppression factor under various conditions, channel capacity and error probability are considered.

The interference rejection ratio depends on the ratio of signal power, noise and interference at the input and output of the processing circuits [3].

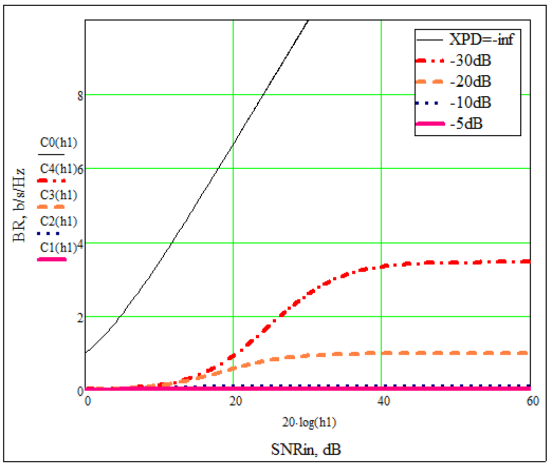
$$K_n = \frac{q_{out}}{q_{in}} = \frac{Sp(\dot{M}_1 \cdot \dot{M}_o^{-1})}{Sp(\dot{M}s)/Sp(\dot{M}_o)}, \quad (5)$$

where $\dot{M}_1$ - the matrix corresponds to the covariance matrix of the mixture of signal, interference and noise; $\dot{M}s$ - the matrix also corresponds to the covariance matrix of the signal, and the matrix $\dot{M}o$ - corresponds to the covariance matrix of the noise

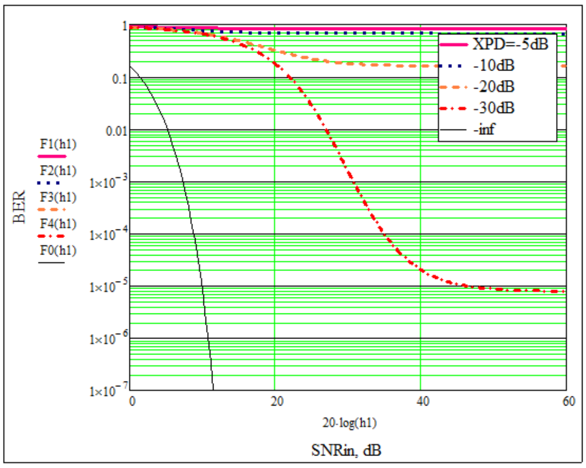


а) - 13дБ б) - 18дБ

Fig. 5. The interference cancellation coefficients for different ratios of the signal power to the noise power (0 is the potential value; 1.1 the chirp 1 signal; 1.2 the chirp 2 signal; 2.1 the chirp signal with base 100; 2.2 the chirp signal with base 200)



a) - Bandwidth

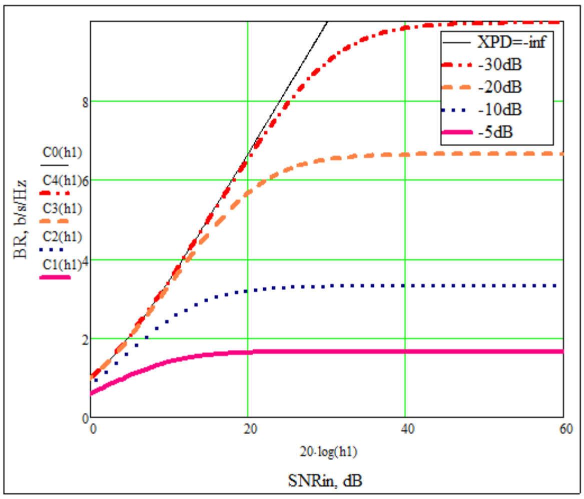


б) - Error probability

Fig. 6. The performance of the communication channel under the influence of interference

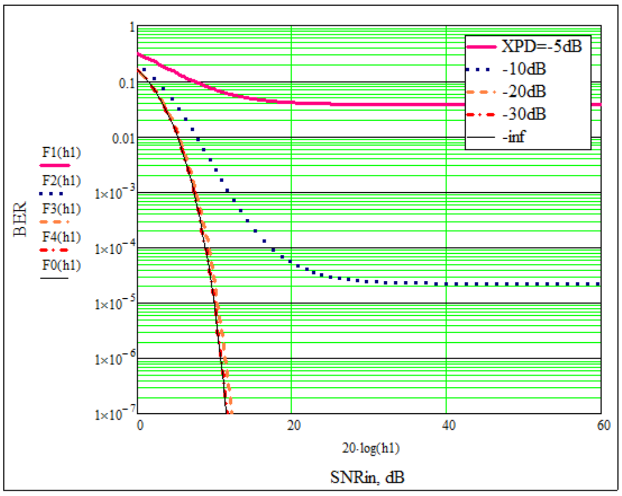
So, using the chirp 2 and chirp 1 signals for, the suppression ratio will be 30.9 dB and 28.7 dB, respectively. The potential value of the suppression ratio for given values corresponds to 31 dB. An increase in the base of chirp signals leads to a slight increase in the suppression ratio.

A comparative assessment of the efficiency of using the pseudo-chaotic polarization signal in the communication channel is presented in Fig. 6 and Fig. 7 under the influence of interference partially polarized with a polarization index of 0.05 and with different decoupling values on the polarization of the antennas (parameter XPD [4]).



a) - Bandwidth

Fig. 7. The performance of the communication channel when applying the signal of pseudo-chaotic polarization under the influence of interference and its suppression by 20 dB



б) - Error probability

Fig. 8. The performance of the communication channel when applying the signal of pseudo-chaotic polarization under the influence of interference and its suppression by 20 dB

We note a significant improvement in throughput and the probability of communication channel errors when using the proposed signals and processing them.

Conclusion

The results of the study indicate the high efficiency of using pseudo-chaotic polarization signals to improve the electromagnetic compatibility of the communication channel.

References

1. Martynchuk A.A., Loshakov V.A., Oliver L.M/. Development of a trans-horizon communication system based on dual polarization MIMO architecture // "Проблемы электромагнитной совместимости перспективных беспроводных сетей связи (ЕМС-2015). – Харьков: ХНУРЭ, 2015.
2. Popovskii V., Loshakov V., Filipenko O., Martynchuk O., Drif A./ Results of development tropospheric communications system / 2015 Second International Scientific Practical Conference "Problems of Infocommunications. Science and Technology". –Kharkiv, ANPRE, 2015.
3. Martynchuk A.A., Nazmutdinov A.A., Skorohod A.N., Assamoi Regis Arnaud. Mathematical model of the signal in the Wi-Fi channel with orthogonal polarization MIMO antennas // Проблемы инфокоммуникаций. Наука и технологии (PIC S&T-2013): Сборник научных трудов первой международной научно-практической конфе-ренции, Харьков 9-11 октября 2013 г. / М-во образования и науки Украины, Харьковский национальный уни-верситет радиоэлектроники. – Харьков: ХНУРЭ, 2013. – 288 с. – С. 201-205.
4. Martynchuk A.A., Nazmutdinov A.A., Skorohod A.N. Influence cross-polarization decoupling on Wi-Fi MIMO system capacity // 5-й Международный радиоэлектронный форум "Прикладная радиоэлектроника. Сос-тояние и перспективы развития" МРФ-2014. Сборник научных трудов: материалы форума в 4-х томах. Том II. Международная научно-практическая конференция "Проблемы инфокоммуникаций. Наука и технологии" (PIC S&T-2014). - Харьков: АНПРЭ, ХНУРЭ, 2014. – С. 260-265.