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Chapter 5
Signals with an Additive Fractal Structure for Information Transmission

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ABSTRACT

This chapter is devoted to a new class of wideband signals with an additive fractal structure. Properties and characteristics of the new type of signals are studied. It is shown that such signals possess a high level of an irregularity and unpredictability at simple technical implementation. It is shown that an incommensurability of frequencies of fundamental high-stable oscillations leads to the high level of an irregularity of such signals. For an estimation of a level of signal complexity, authors offer to use the fractal dimensionality of their temporal implementations calculated by means of creation of the structural function. Methods of modification of the signal spectrum with the additive fractal structure are offered, permitting to increase the efficiency of the frequency resource application. For reduction of the high low-frequency signal power the authors suggest using signals with the additive fractal structure, centered in a moving average window. Methods of masking of the voice messages by means of signals of a new type are offered. The results of a computer experiment of secretive sound transmission are described.

INTRODUCTION

In the present time there are some important problems of information transfer through radio channels – the electromagnetic compatibility, an increase of data capacity of carrier oscillations, the security and stealthiness of communication. One of the methods of solution of the mentioned problems is based on the reduction of the power spectral density of the message under transmission, at the expense of the extension of its frequency band. Thus in classical methods of the spectrum

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extension (Ipatov, 2007), the sophisticated modulation of clean waves (CW) is used that leads to serious complication of transmitters and receivers.

Without application of technology of the spectrum extension the specified problems can be solved using non-sinusoidal waves, but the wideband carrier signals. Nowadays there is a tendency to use signals on the basis of a dynamic chaos (Pecora & Carroll, 1990, pp.821-824; Cuomo & Oppenheim, 1993, pp.65-68; Kuznetsov, 2000) as carrier oscillations. However, application of chaotic signals in communication systems (Dedieu, Kennedy, & Hasler, 1993, pp.634-642; Kapranov & Morozov, 1998, pp.66-71; Murali & Leung & Yu, 2003, pp.432-441; Yang, 2004, pp.81-130) has revealed two large lacks. Firstly, the complex nonlinear mechanisms of dynamic chaos formation are rather sensitive to inevitable, even insignificant, mismatches of parameters on the reception and transmission ends that lead to the impossibility of correlative processing of chaotic signals in the receiver. Secondly, it is impossible to change the structure of the chaotic carrier spectrum for adaptation to a spectrum of the message or to interference in the communication channel – the chaos characteristics are completely predetermined by a structure of the forming dynamic system and a choice of its parameters. Signals with the fractal structure are an alternative of chaotic oscillations. Fractal signals are as irregular as chaotic signals, but can give benefits on reproducibility and flexibility of characteristic change.

The subject of this chapter is a research and performance evaluation of wideband signal application with an additive fractal structure for the stealthiness transmission of analog voice messages. At first, we select the type of fractal functions for the simplest generation of signals with fractal structure on their basis, and the properties of these functions are researched. Further, from mathematical record of fractal functions, we turn to their engineering interpretation for radio signal generation. Shortcomings of fractal radio signals come to light. For the elimination of these lacks we enter signals with the modified fractal structure. In the last paragraph methods of information transmission by means of new fractal signals are offered, and the computer experiment of secured voice message transmission is carried out.

MAIN CHARACTERISTICS OF FRACTAL FUNCTIONS WITH AN ADDITIVE STRUCTURE

Signals with a fractal structure can be divided into some types according to methods of their formation in the transmitter: signals with additive (Wornell, 1996, Falconer, 1997) and multiplicative (Bolotov & Tkach, 2006, pp.91-98) structure, signals on the basis of iterative fractal functions (Kravchenko, Perez-Meana, & Ponomaryov, 2009) (functions of Cantor, Bolzano, Bezikovich, etc.), solution of nonlinear dynamic systems in the reverse time (Tomashevsky & Kapranov, 2006). The main lack of almost all fractal signals is the impossibility of their generation in the form of self-oscillations in devices with the simple structure. However, fractal functions with an additive structure and signals on their basis, which are a sum of stable sinusoidal oscillations with incommensurable frequencies, can be obtained without the expensive equipment. Except fractal properties and simple generation methods, signals with an additive fractal structure demonstrate a high level of reproducibility. These properties can be used for secured telecommunications, therefore, the research of such signals is urgent and this chapter is devoted only to them.

On determination (for example Wornell (1996)), any fractal function should satisfy the following scaling equation:

$$f\left(x\right)=\frac{1}{\mu}f\left(\lambda x\right) \qquad (1)$$

Usually (Falconer, 1997, Bolotov & Tkach, 2006, pp.91-98, Kravchenko & Perez-Meana &

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