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Potential Limits of Frequency Division Multiplexing of N–OFDM Signals Based on Hartley's Basis Functions

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Abstract—The limiting capabilities of the frequency division multiplexing of signals generated by using the N–OFDM method based on the Hartley transform have been studied. The validity of the appropriate Cramer–Rao lower bound for estimates of signal amplitudes was examined by simulation modeling.

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Communication line capacity can be enhanced by using the method of non-orthogonal discrete frequency modulation (N–OFDM) based on frequency division multiplexing of channels by way of transmitting the carriers on non-orthogonal frequencies [1, 2]. Realization of this method by using the classic Fourier transform gives rise to a number of difficulties among which one should note the computational complexity taking into account the complex form of representation of numbers. The application of the Hartley transform (HT) makes it possible to renounce the complex form of data recording and simplify the hardware implementation of the N–OFDM method [3].

The purpose of this study is to determine the potential limits of frequency division multiplexing of signals formed by the N–OFDM method on the basis of the Hartley transform with the probability of the correct demodulation of message equal to 0.9973.

In order to determine the potential limits of frequency division multiplexing of N–OFDM signals, we performed a computational experiment based on using the simulation program developed in the Delphi 7 environment. In essence the experiment consisted of the following steps. A message of fixed length was transformed into a sequence of decimal symbols $A = [a_1 \quad a_2 \quad \dots \quad a_M]^T$ used as amplitudes of signals of different carriers. Next, sampling W of T temporal indications of voltages of the signal mixture to be transmitted at M frequencies [3] was simulated:

$$W = P \cdot A = \begin{bmatrix} \operatorname{cas}\omega_1(s_1 - z_1)\Delta t & \operatorname{cas}\omega_2(s_1 - z_2)\Delta t & \cdots & \operatorname{cas}\omega_M(s_1 - z_M)\Delta t \\ \operatorname{cas}\omega_1(s_2 - z_1)\Delta t & \operatorname{cas}\omega_2(s_1 - z_2)\Delta t & \cdots & \operatorname{cas}\omega_M(s_2 - z_M)\Delta t \\ \vdots & \vdots & \vdots & \vdots \\ \operatorname{cas}\omega_1(s_T - z_1)\Delta t & \operatorname{cas}\omega_2(s_T - z_2)\Delta t & \vdots & \operatorname{cas}\omega_M(s_T - z_M)\Delta t \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ a_M \end{bmatrix}, \qquad (1)$$

where $\operatorname{cas}\omega_M S_{TM} = \cos\omega_M S_{TM} + \sin\omega_M S_{TM}$ is the Hartley function [3]; $\omega_m = 2\pi f_m$; f_m is the frequency of the mth carrier at the output of a digital-to-analog converter (DAC); s_t is the sequence number of the tth temporal reading of the signal sampling; z_m is the shift of the beginning of the sampling formed with respect to zero phase of the mth carrier ($\varphi_m = 2\pi f_m z_m \Delta t$ is the initial phase of the mth carrier); Δt is the clock step of DAC.

In order to ensure the possibility of transmitting N–OFDM signals by DACs having the different capacity (number of bits), the following restriction was introduced

$$|W_{\max}| \le 2^{R-1} - 1, \qquad (2)$$

where R is DAC's number of bits.