WIDEBAND WIRELESS COMMUNICATION WITH SPECTRAL PROCESSING OF NOISE CONTINUOUS WAVEFORM

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ABSTRACT

Wireless communication system with double spectral processing of wideband noise continuous waveforms is considered. The method of code spectral modulation is proposed on the basis of the interference of perfect incoherent noise waveforms. The spectral compression of coded wideband waveforms is performed by means of double spectral processing. Correlation measurements with successive selection of transmitting data are discussed.

INTRODUCTION

Nowadays considerable attention is paid to development of wireless wideband telecommunications with high information capacity of channels. Wideband communications are characterized by high immunity against electromagnetic interference (EMI), low probability of interception (LPI), and the best electromagnetic compatibility (EMC) performance [1-3].

The new approach in this paper is based on direct use of wideband noise continuous waveforms for the data transmitting over 3.1-3.6 GHz communication channel. We propose to generate noise-like carrier and modulate its spectrum by information binary symbols directly in microwave band [4-5]. This communication scheme has a simple construction without up and down frequency conversion [6]. Wireless wideband noise communication system is designed to work at short distance [4,6]. The direct use of noise-like continuous waveform with low spectral density of transmitted power allows better performance of communication channel [6-8].

In this paper we present some recent results of experimental investigation of the wideband wireless communication with double spectral processing. The spectral compression of received noise waveforms is demonstrated in real time with data rate. Several main characteristics of the proposed communication are discussed.

CODE SPECTRAL MODULATION

Code spectral modulation is used as a method for inputting digital information onto wideband noise carrier [4]. This noise-like waveform is generated by the microwave chaotic system, which is constructed on the basis of nonlinear transistor oscillators coupled by microstrip lines [6]. Microwave chaotic generator provides noise continuous waveform with the total power $2\langle n^2(t)\rangle$ and with the uniform power spectrum in the 3.1-3.6 GHz frequency range.

Generated noise wideband waveform with the frequency bandwidth Δf=500 MHz is split into two in-phase components with equal level. One of these components $n(t)$ serves as the reference waveform. The other part of noise waveform $n(t)$ is fed to the microstrip electron switch on the input of the spectral modulator. Electron switch is guided by binary inform symbols of the time length t_s. The transmission of binary inform symbols is performed with the rate $U=1/t_s$. Electron switch passes the formed noise waveform $n(t)$ on the first channel of the spectral modulator when "1" inform symbol is sent, or on the second channel when "0" inform symbol is sent. The first and second channels of transmitter spectral modulator involve wideband delay lines with different delay-time 56 ns and 27 ns consequently. We suppose that transmit coefficients $H_{1,0}=h_{1,0}exp(i\theta_{1,0})$ and delay times $T_{1,0}$ of the both channel delay lines are independent of a frequency f in the frequency bandwidth Δf of noise continuous waveform $n(t)$.

We will discuss the signal processing of one of the channels since other channel operation is essentially identical. When "1" binary symbol is sent, switched noise waveform is delayed in the first delay line at the time T_1 = 56 ns more largely, then the noise coherence time $\tau_c = 1/\Delta f$ = 2 ns. After that the first delayed waveform $H_1 n(t-T_1)$ is linear summed with the reference waveform $n(t)$:

$$z_1(t) = n(t) + H_1 n(t - T_1) \qquad (1)$$

The interference of perfect incoherent noise waveforms occurs when the delay time T_1 between the first delayed waveform $z_1(t)$ and the reference $n(t)$ substantially exceeds the coherence time $\tau_c = 1/\Delta f$ = 2 ns for these noise waveforms:

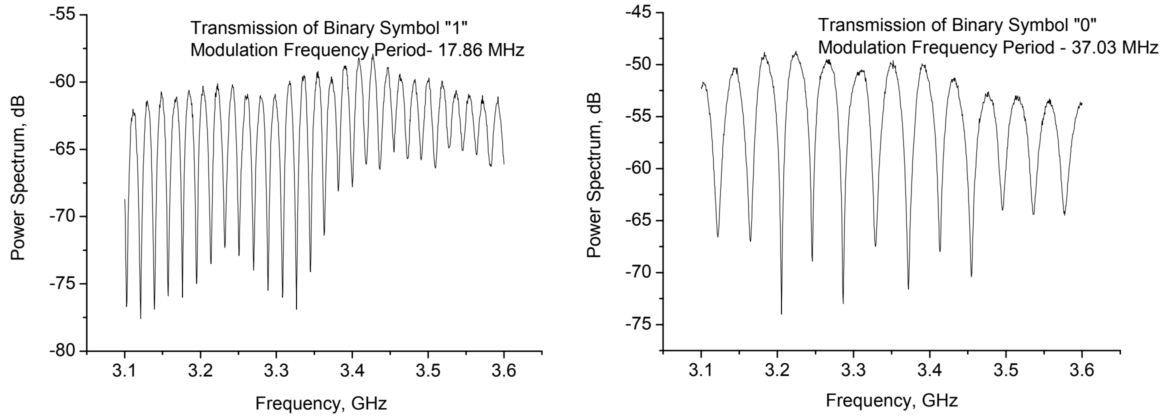
$$T_1 >> \tau_c \qquad \text{or} \qquad T_1 \Delta f >> 1 \qquad (2)$$

The power spectrum of the first interference waveform $z_1(t)$ is estimated over the symbol duration t_s in the form:

$$S_z(f) = S_n(f)[1 + h_1^2 + 2h_1 \cos(2\pi f T_1 + \theta_1)] \qquad (3)$$

where $S_n(f)$ is the power spectrum of the reference waveform $n(t)$.

The power spectrum density (3) has the periodic modulation as a result of the interference of perfect incoherent reference and delayed waveform. In Fig.1a, the experimental power spectrum $S_z(f)$ of the first interference waveform is presented. The frequency period $F_1=1/T_1$ =17.86 MHz of the spectral modulation is inversely proportional to the first channel delay time T_1 = 56 ns.



(a) (b)

Fig.1. Periodic modulation of interference power spectrum at binary symbol transmission of (a) "1"and (b) "0".

The noise continuous waveform is switched to the second channel when "0" inform symbol of the same duration t_s is sent. In that case the switched waveform is delayed in the second delay line at the different interval time T_0 = 27 ns more largely, then the noise coherence time $\tau_c = 1/\Delta f = 2$ ns

$$T_0 >> \tau_c \qquad \text{or} \qquad T_0 \Delta f >> 1 \qquad (4)$$

The power spectrum of the second interference waveform

$$z_0(t) = n(t) + H_0 n(t - T_0) \qquad (5)$$

is identical estimated over the symbol duration t_s in the form:

$$S_z(f) = S_n(f)[1 + h_0^2 + 2h_0 \cos(2\pi f T_0 + \theta_0)] \qquad (6)$$

The interference spectrum (6) has the periodic modulation with the another frequency period $F_0=1/T_0$ =37.03 MHz that depends on the second delay time T_0. In Fig.1(b), experimental power spectrum $S_z(f)$ of the second interference waveform is presented when "0" inform symbol is sent. The power spectrums shown in Figs.1(a) and (b) are experimental measured by means of spectrum analyzer with 500 KHz frequency resolution bandwidth.

The transmitted noise waveforms both $z_1(t)$ and $z_0(t)$ have the same 3.1-3.6 GHz frequency band and the same coherence time $\tau_c = 1/\Delta f = 2$ ns. The large frequency bandwidth Δf =500 MHz of used noise continuous waveforms is the necessary condition (2), (6) for the realization of the offered communication [4,7-8]. For the case of wideband waveforms, the condition (2) and (6) can be written as

$$\Delta f >> F_1; F_0 \qquad (7)$$

In consequence of the interference of perfect incoherent reference and delayed waveforms we observe many interference periods in power spectrums shown in Figs. 1(a) and (b). The spectrum modulation depth is not uniform as a function of frequency argument f. This performance is the result of dispersion distortion of wideband waveforms in the transmitter channels.

The interference noise waveforms $z_1(t)$ and $z_0(t)$ with code spectral modulation (3) and (6) are radiated by a transmit antenna to a communication link. The transmitter radiates coded noise waveforms with the frequency bandwidth Δf = 500 MHz and the total power of (–14) dBm. The lower level of (–101.3) dBm/Hz of radiated power spectrum density is established according to standard regulations in 3.1-10.6 GHz unlicensed frequency band [2]. Wideband wireless communication is characterized by the excellent EMC and LPI performances due to a low spectral density of transmitted power and noise-like continuous radiated waveforms [4,7-8].

SPECTRAL COMPRESSION OF RECEIVED WIDEBAND WAVEFORMS

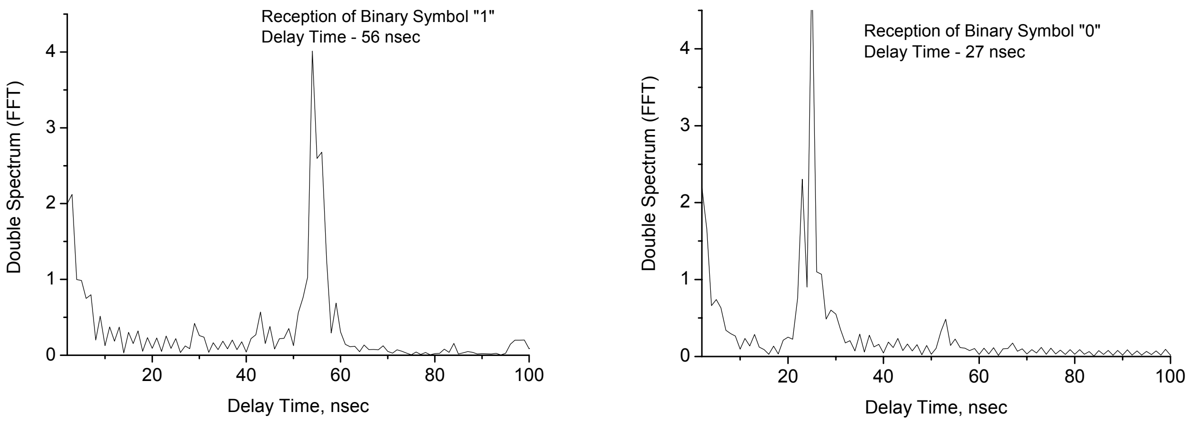
Traditional real time correlator accomplishes the optimal processing of received noise waveform [9]. Double spectral processing (Spectral Interferometry) is another method of correlation measurement [4-5]. In the receiver the spectral compression of noise waveforms $z_1(t)$, $z_0(t)$ is performed over the symbol duration t_s according to suggested procedure. The power spectrum of received noise waveforms $z_1(t)$, $z_0(t)$ is estimated by means of spectrum analyzer during the symbol time length t_s. The power spectrum evaluations (3) and (6) are random functions those dispersions are inversely proportional to the averaging time interval t_s . The dispersion of spectrum evaluations (3), (6) grows when date rate $U = 1/t_s$ is increased [4,9].

The measurement of frequency intervals F_1; F_0 of periodic modulation spectrums (3) and (6) one can make in this way. Auto-correlation functions of both received noise waveforms $z_1(t)$; $z_0(t)$ are obtained in result of Fourier transform of noise power spectral density (3) or (6) consequently:

$$R_z(\tau) = 4\pi k^2 \int_0^\infty S_z(f)\cos(2\pi f\tau)df = 2k^2\left[R_n(\tau) + R_n(\tau - T_{1,0}) + R_n(\tau + T_{1,0})\right] \qquad (8)$$

where k is signal transmit coefficient of communication link, and $R_n(\tau)$ is correlation function of noise continuous waveform $n(t)$. The relation (8) is derived in the case $h_0=h_1=1$.

Auto-correlation functions (8) shown in Figs.2(a) and (b) content the information correlation peaks at T_1 or T_0 time shifts when "1" or "0" inform symbols are consequently received.



(a) (b)

Fig.2. Double Spectrums are experimentally measured at binary symbol reception of (a) "1"and (b) "0".

The peak detector analyzes digital spectral responses shown in Figs.2(a) and (b). The peak search function is used to position the marker at the peak of the digital spectral response. The peak detector can find the information correlation peaks at time shifts T_1 or T_0 when "1" or "0" inform symbols are consequently received. In this way transmit data are unequivocal reconstructed in result of double spectral processing of received noise waveforms.

The frequency compression of received wideband noise waveforms $z_1(t)$, $z_0(t)$ is performed with a data rate by means of double spectral processing. The compression value $G = (\Delta f\ \tau)$ of received noise continuous waveform is defined as the product of the frequency bandwidth Δf and the duration τ of binary information symbol. The compression value G=5000 is achieved if binary symbols are transmitted with the rate 100 Kbits/s. Wireless digital communication system with such high spectral compression value of wideband noise waveforms has a high immunity against electromagnetic interference [4].

Wideband noise-like continuous waveform *n(t)* generated by microwave chaotic coupled oscillators can be approximately described as Gaussian stationary random signal with the limited frequency bandwidth Δf. According to Shannon information capacity equation

$$C = \Delta f \log\left[1 + \frac{W}{N_0 \Delta f}\right] \tag{9}$$

where C is information capacity of communication channel (bit/sec), Δf is channel bandwidth (Hz), W is received waveforms power (watts), and N_0 is noise power spectral density (watts/Hz), the proposed communication allows practically transmitting the digital information in real time with very high rate [3].

CONCLUSIONS

The results obtained in this paper suggest that the wideband wireless communication system with double spectral processing of noise continuous waveforms is useful for digital information transmitting with high data rate. Code spectral modulation in the transmitter and double spectral processing of 3.1-3.6 GHz noise waveforms in the receiver can be successfully realized using fast digital technology. Low spectral density of the transmitted noise power, high immunity against electromagnetic interference (EMI), and excellent EMC and LPI performance characterize the proposed wideband wireless communication with double spectral processing of noise continuous waveforms.

ACKNOWLEDGMENTS

This work has been supported in part by the Russian Foundation for Basic Research, grants No. 04-02-16536, and 04-07-08013.

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