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THE STUDY OF ALGORITHMS REDUCING THE LEVEL OF OUT-OF-BAND RADIATION AND INTER CARRIER INTERFERENCE OF THE OFDM SIGNAL

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Abstract

Orthogonal frequency division multiplexing (OFDM) has been one of the basic techniques. It has been widely used in many high-speed wireless applications. The orthogonal properties of the multiple subcarriers make it possible to obtain high spectral efficiency and an excellent ability to cope with fading, arising from the multipath propagation in the environment [1, 2]. However, OFDM systems have some drawbacks, the main of which is the interference between subcarriers (ICI). Since orthogonal properties are easily destroyed due to an error of the frequency shift caused by inaccuracies in the local oscillator and the overlapping spectra of the individual of subcarriers, the major focus of the OFDM-signal research is to combat this deficiency. This article provides a method of dealing with it is the interference between subcarriers.

Key words: algorithm reducing, OFDM, interference between subcarriers (ICI), out-of-band radiation.

Introduction

In classical data transmission and processing systems, seeking to achieve increasingly high transmission speeds in the frequency domain parallel data transfer is applied by dividing the total signal frequency band Nc non-overlapping frequency subchannels (frequency division multiplexing, FDM). Each subchannel or subcarrier modulated by a separate symbol, and then all the sub-channels are frequency-multiplexed.

In this case the spectral overlap is reduced by inserting between adjacent subchannels by a sufficient length of the guard interval. Herewith, the intercarrier interference (ICI) decreases, the probability of bit error is reduced, and hence capacity of the wireless system is increased.

For more efficient use of the frequency spectrum resource of the individual subchannels may overlap, that does not lead to a distortion of information, if the spectra of of subcarriers are orthogonal to each other. However, due to the fact that the receiver and/or transmitter can move relative to each other, the result of the Doppler effect leads to disruption occurs and orthogonality interchannel interference. Influence of neighboring subcarriers depends on the level of the side lobes of each. As a result, this leads to errors in the division of subchannels at a receiver.

Such interference bit signals deliver a lot of inconvenience, in addition, the influence of the Doppler effect is not the only factor influencing the shift of subcarriers frequencies. For example, the communication system based on OFDM is vulnerable to carrier frequency offset and phase noise.

If the local oscillators in the transmitter and receiver are not aligned on the frequency, spectrum of the wrong "sampled" at the peaks of sinc-function, and frequency counts are left or right of them [1 – 6]. In this case the subcarrier bands overlap, which leads to interference between the bit.

Similarly, the OFDM signal is vulnerable to frequency conversion products due to non-linear amplifiers, DC offset component (the DC) complex envelope by using fast Fourier transform (FFT), etc. Furthermore, distortion deliver many problems in restoring the transmitted information at the receiver side caused by multipath during propagation of the electromagnetic field between the base and mobile stations.

This article gives an analysis of the OFDM-signal model suppression out of band emission level for the entire family of subcarriers in a single operation (each subcarrier). Interference is reduced by the convolution of the complex envelope of the transmitted signal after IFFT to use two δ-functions with a mutual delay of half the length of the transmitted packet, which is equivalent to multiplication by a cosine function of the spectrum, which correspond to the midpoints of the zeros frequency intervals between subcarriers OFDM.

Mathematical description

One of the most important conditions of correct recognition of the receiver on subcarriers information is to maintain orthogonality. To do this, the following conditions must be met:

1. The receiver and the transmitter must be synchronized as accurately as possible in time and frequency (as time mismatch leads to phase distortion OFDM spectrum, and for its frequency shift in the frequency direction).
2. The analog transmitter and receiver components have to be of very high quality (to ensure the required accuracy and stability performance
3. The channel should not include multipath

Unfortunately, multipath distortion almost inevitably exists in radiocommunication systems, resulting in damage to the received signal. To eliminate this kind of interference in OFDM technology employed guard intervals whose duration is necessary to select the more, the larger the maximum propagation delay in the echo channel. All of these effects occurring in the communication channel require eliminating or at least reducing the interference described species: between channels (i.e., interference between subcarriers (ICI)), and between adjacent transmission blocks (i.e., inter-symbol interference (ISI))

If we consider the mobile radio, the effects described above are typical, that influencing the subcarriers, the relative movement between the transmitter and the receiver generates the Doppler frequency shifts, in addition, carry can never be accurately synchronized. These random errors in the OFDM system distort the orthogonality between subcarriers and thus appears ICI.

Special methods have been developed to reduce this sensitivity to frequency offset. In [5] presented a rather simple and effective method, called ICI cancellation scheme of independent account, and then extended in [6], [7], [8], which uses a polynomial encoding in the frequency domain to mitigate the effect of the frequency shift.

The method is based on the fact that copies of the same data for r symbol modulated subcarriers neighboring with optimal weights.

This method can significantly reduce ICI in conjunction with reduced transmission rate by a factor r and a small increase in complexity.

The authors in [9] show the ability of any code FEC eliminate errors caused by ICI. Previous attempts to reduce ICI and include methods based on correlation are presented encoding, for example, in [10-18].

To reduce the level of the first side lobe of the spectral function sinc($\Omega T_0/2$) bit signal with rectangular envelope, where T0 sampling time, it is proposed to delay the output after IFFT (complex envelope) at the sampling interval $T_{symbol} = NT_0$ and add a non-delayed (Fig. 1).

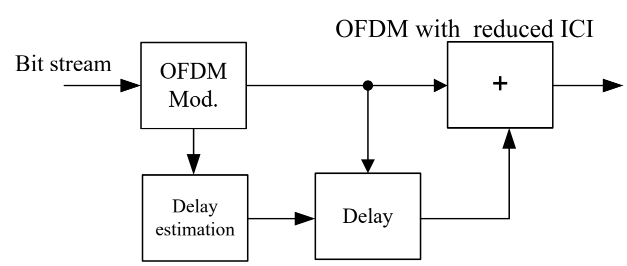

Fig. 1. Block scheme of the algorithm.

This operation corresponds to the convolution of the signal with two δ-functions with an interval therebetween equal T_{symbol}:

$$\int_{-\infty}^{\infty}\left[\delta(t)+\delta(t+\tau_0)\right]\cdot e^{-j\omega t}dt\,.$$

When this is done in the spectral domain spectral sample multiplication function by the function $\left|\cos\left(\Omega T_{выб} / 2\right)\right|$.

Module spectrum $S_i(f)$ obtained by the above operation is given by

$$S_i\left(f\right) = G\left(f\right)\left|\cos\pi f \tau_i\right|,$$

where G (f) - initial modulus spectrum OFDM signal.

The function $S_i(f)$ takes zero values at frequencies $f_{i,k}$ are equal

$$f_{ik} = \left(2k-1\right)/\left(2\tau_i\right) = \left(2k-1\right)f_{i1},\ k=1,2,...;\ i=1,2,...,z.$$

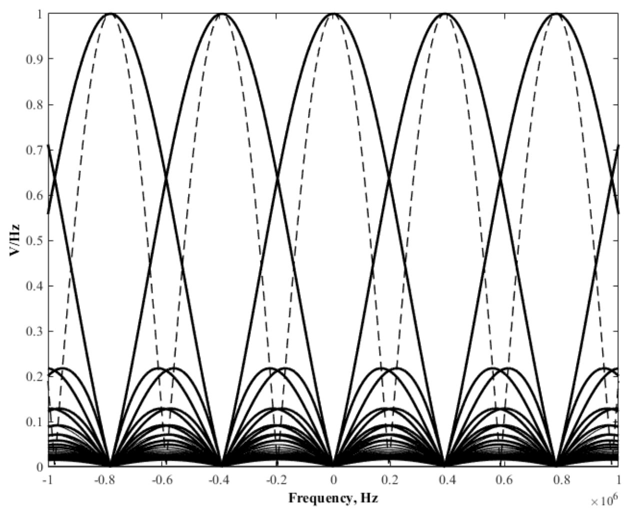

Fig. 2. The spectrum of the OFDM signal and the delta function with a delay τ_0.

The result of multiplying the OFDM spectrum of the module by the function $\left|\cos\left(\Omega T_{выб} / 2\right)\right|$ shown in Fig. 1, which shows a decrease in the sidelobe level of the spectrum function $\left|\cos\left(\Omega T_{выб} / 2\right)\right|$ by entering zero, with a maximum of the same function with the same frequency subcarrier and not distort it.

The proposed algorithm can reduce the effect of ICI in a multipath propagation of the signals when the signals came in different ways, have a Doppler frequency shift

Analysis of the algorithms software implementation and its results in MATLAB

The channel has been selected for the simulation of the algorithm, in which the signal paths through the various receiving frequency shift as a result of reflections from moving objects. Comparison of the data transmission efficiency was performed for three cases (see. Table 1).

Table 1. Parameters of OFDM signals used in the simulation.

Algorithm	Parameters			
	Modulation type	Number of subcarriers	Duration of cyclic prefix	Guard subcarriers
1	QAM	128	1/8	31
2	QAM	256	1/8	31
3	QAM	128	1/8	31

In the first case was a dependence of the probability of bit error is obtained from the signal / noise ratio of the signal without the use of any kind was ICI reduction algorithms.

The second case is considering a way to reduce the influence of interchannel interference by puncturing subcarriers. It is zeroing even OFDM signal components. Despite the fact that this embodiment can reduce ICI, it leads to an increase in the duration of the symbol, and this reduces the bit rate.

Finally, the third option is the algorithm, which also increases the duration of the signal as described above, however, unlike the previous process result generated zeros which fall within the sidelobe peaks of each subcarrier, which results in reducing sidelobe level.

The results of using the above transfer method are shown in fig. 3.

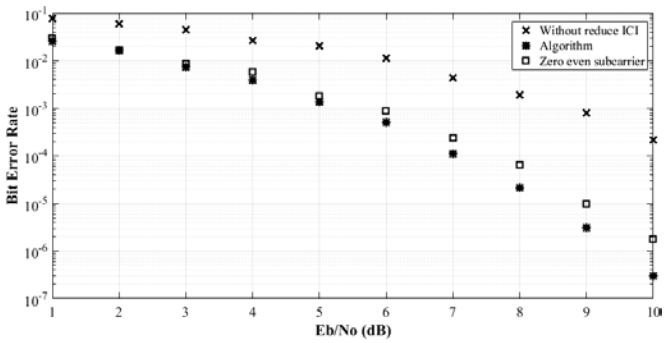

Fig. 3. Comparison of the data transmission efficiency using various algorithms.

As can be seen from the figure, the second and third algorithms provide substantial improvement (for example, for SNR=9 dB, the result BER=10^{-6} for the second and BER=$5*10^{-6}$ for our algorithms) as compared to the algorithm without any means to suppress ICI. At first glance, the difference is small, however, if you take into account the fact that the algorithm does not contain any serious computations, and does not load the processor, then the win becomes obvious. There are methods of the window signal processing, which greatly enhance the suppression of ICI, for example, improved sinc power pulse (ISP), but they are quite complex in computing terms and significantly distort the signal [19].

Conclusion

Although this algorithm does not significantly reduce the sidelobe subcarrier OFDM signal in comparison with other algorithms that use windowed. But it does not require significant computational cost of the transmitter and receiver equipment, since it is based on only a shift operation.

In addition to the definition given in article algorithms for reducing out of band radiation of signals used by the window processing the time signal (for example, the window type is the raised cosine) and the use of protective subcarriers.

The purpose of the window treatment is the implementation of a smooth transition between the end of the previous and the beginning of the current symbol.

In this case, a smooth transition is performed by the overlap in time of the cyclic prefix of the current symbol by a cyclic suffix of the previous symbol by their sum [19].

And with the help of the adaptive algorithm as in [20] other ways can be removed by receiving a signal from the path having the largest power, thereby eliminating the interference which arises the problem of correct reception of a sent message.

The use of set of methods of struggle with out-of-band radiation makes it possible to reduce the probability of bit error at the same time increases the throughput of the system as a whole.

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Fedosov Valentin was born in Rostov, Russian, in 1940. He received a Doctor of Technical Science degree in 1989 (bath in Electrical Engineering) from the Leningrad Institute Aircraft Electronics, Leningrad, Russia. He was promoted to a professor position in 1990. His research interests are include spatial-time signal processing, synthesis of signals with desired spectral properties, processing signals with Array Antenna Systems, selection of slow-moved targets in Synthesis of Array Antenna Systems, signal processing in Monopulse Radars, signal processing in Ultrasonic Systems, digital signal processing and development of compact measurement devices.

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