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Performance Analysis of MB-Pulsed-OFDM for Different Channel Models

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Abstract

For wireless communication system multipath fading is a common problem specially in urban areas where a large number of buildings reflects the radio signals which results in interference amongst the reflected signals which causes the multipath fading effect since its selective by nature some spectrum at some specific location cancels out hence the receive signal losses some part of their information this abruptly increases the BER of communication system in slight movement of receiver, this paper specially analyzes the BER performance under Rayleigh fading channel conditions of MB-PULSED-OFDM in presence of AWGN (Additive White Gaussian Noise) for different number of subcarrier, different number of users, and different path gains system analysis is performed by simulating the MB-PULSED-OFDM using MATLAB program, and finally the paper also presents a comparison between simulated results.

Keywords: PULSED-OFDM, AWGN (Additive White Gaussian Noise), Rayleigh fading.

1. Introduction

Multipath fading is not a new problem for wireless communication but recent growth in mobile communication system; attracts the designer to seriously think about the problem because it is difficult to avoid such problem under moving conditions. Because the device is continuously moving we can’t impose the restrictions on it and it could travel to many points which fall under selective fading.

In wireless communication multipath fading could occur by reflection of radio signals from different objects, (causes of multipath include atmospheric ducting, ionospheric reflection and refraction, and reflection from water bodies and terrestrial objects such as mountains and buildings) which cause the reception of signals at different phase angles on receiver. The effects of multipath include constructive and destructive interference, and phase shifting of the signal. This causes Rayleigh fading. The standard statistical model of this gives a distribution known as the Rayleigh distribution. Rayleigh fading with strong line of sight content is said to have a Rician distribution, or to be Rician fading. In digital radio communications (such as GSM) multipath can cause errors and affect the quality of communications. The errors are due to inter-symbol interference (ISI). Equalizers are often used to correct the ISI. Alternatively, techniques such as orthogonal frequency division modulation (OFDM) and rake receivers may be used.

2. Pulsed-OFDM

A multi-band OFDM system [5]-[6]-[9] divides the available bandwidth into smaller non-overlapping sub-bands such that the bandwidth of a single subband is still greater than 500MHz (FCC requirement for a UWB system). The system is denoted as an ‘UWB-OFDM’ system because OFDM operates over a very wide bandwidth, much larger than the bandwidth of conventional OFDM systems. OFDM symbols are transmitted using one of the sub-bands in a particular time-slot. The sub-band selection at each time-slot is determined by a Time-Frequency Code (TFC). The TFC is used not only to provide frequency diversity in the system but also to distinguish between multiple users. The proposed UWB system utilizes five sub band groups formed with 3 frequency bands (called a band group) and TFC to interleave and spread coded data over 3 frequency bands. Four such band groups with 3 bands each and one band group with 2 bands are defined within the UWB spectrum mask (Figure 2). There are also 4 3-band TFCs and 2 2-band TFCs, which, when combined with the appropriate band groups provide the capability to define eighteen separate logical channels or independent piconets. Devices operating in band group #1 (the three lowest frequency bands) are selected for the mandatory mode (mode #1) to limit RF phase noise degradations under low-cost implementations.

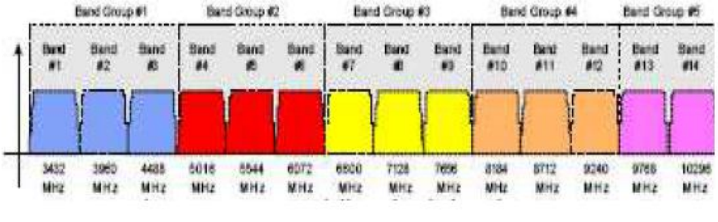

Figure 2: UWB Spectrum Division into Band Groups and sub-bands.

Figure 2 gives an example of a TFC, where the available bandwidth of 1.584GHz (3.168-4.752 GHz) is divided into 3 sub-bands of 528MHz each.

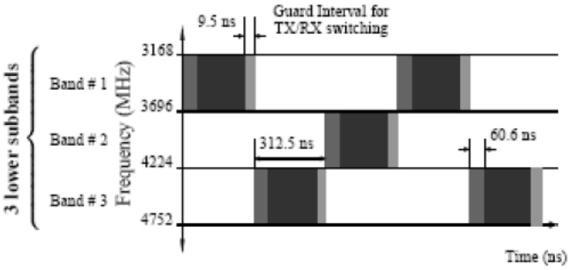

Figure 3: Example of Time-Frequency Code in MB-OFDM system.

There are many advantages associated with using the 'MB-OFDM' approach. This includes the ability to efficiently capture multipath energy, simplified transceiver architecture, enhanced frequency diversity, increased interference mitigation capability and spectral flexibility to avoid low quality sub-bands and to cope with local regulations. The TX and RX architecture of an MB-OFDM system is very similar to that of a conventional wireless OFDM system. The main difference is that MB-OFDM system uses a time-frequency kernel which provides TX with a different carrier frequency at each time-slot, corresponding to one of the center frequencies of different sub-bands.

2.1. Multiband Pulsed-OFDM System

Multiband pulsed-OFDM uses orthogonal 'pulsed' subcarriers, instead of continuous subcarriers [8]. Pulsed OFDM signal is generated by up-sampling the digital OFDM symbol after IFFT block. Up-sampling is done by inserting $1 - K$ zeros between samples of the signal. K can be termed as the 'redundancy-factor' of the pulsed OFDM system. The up-sampled signal is fed into a D/A converter and sent over the channel.

As reported in [7], up-sampling a signal in time domain by factor K results in its K time repetition in frequency-domain. Hence, pulsed-OFDM provides K diversity branches which can be combined together using any diversity combining technique (MRC, EGC, etc.), to enhance system performance in dense multipath UWB channels. Clearly, this approach has the potential of simulating large OFDM systems (i.e. with a large number of subcarriers) while actually using short FFT's, the ratio being the redundancy factor. The corresponding constraint is that the various groups of subcarriers that are commuted are now interleaved.

3. The Rayleigh Fading

Rayleigh fadingis a statistical model for the effect of a propagation environment on a radio signal, such as that used by wireless devices. Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium (also called a communications channel) will vary randomly, or fade, according to a Rayleigh distribution — the radial component of the sum of two uncorrelated Gaussian random variables. Rayleigh fading is viewed as a reasonable model for tropospheric and ionospheric signal propagation as well as the effect of heavily built-up urban environments on radio signals. Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver.

Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. The central limit theorem holds that, if there is sufficiently much scatter, the channel impulse response will be well-modelled as a Gaussian process irrespective of the distribution of the individual components. If there is no dominant component to the scatter, then such a process will have zero mean and phase evenly distributed between 0 and 2π radians. The envelope of the channel response will therefore be Rayleigh distributed.

Calling this random variable R, it will have a probability density function:

$$p_R(r) = \frac{2r}{\Omega} e^{-r^2/\Omega}, r \geq 0$$

were $\Omega = E(R^2)$.

Often, the gain and phase elements of a channel's distortion are conveniently represented as a complex number. In this case, Rayleigh fading is exhibited by the assumption that the real and imaginary parts of the response are modeled by independent and identically distributed zero-mean Gaussian processes so that the amplitude of the response is the sum of two such processes [9].

4. Performance Simulation

Computer simulations are done to simulate SNR vs. BER performance of PULSED-OFDM for different fading channels and noise conditions, different number of subcarriers and to analyze the effect of number of users in BER. To make the results more useful, the results are generated for varying number of users and for different number of subcarriers. Throughout the simulation, the information symbol is BPSK modulated at the transmitters and detected by using the maximum likelihood method in the demodulation at the receiver. A cyclic prefix is added to protect the symbol. Walsh codes are chosen as the spreading codes of the system. The simulation codes are written for MATLAB, and simulated on Pentium class processor.

5. Simulated Results

All results are calculated for 10^3 bits of transmission, the length of spreading code is same as number of sub-carriers and results are collected for each SNR step changing from 0 to 20 dB with a step size of 1 dB. For the Rayleigh channel four paths are considered, the delay for each path is taken as multiple of $\lambda/2$ and the gain of each path are selected during simulation also mentioned on the figure description.

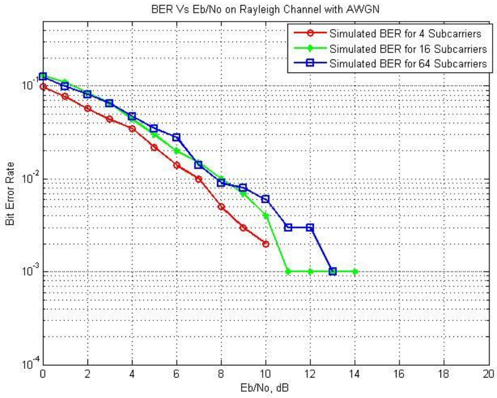

Figure 5.1: SNR/BER for single user 4, 16 and 64 sub-carriers, path gains are p1 = 0.7, p2 = 0.1, p3 = 0.1, p3 = 0.1.

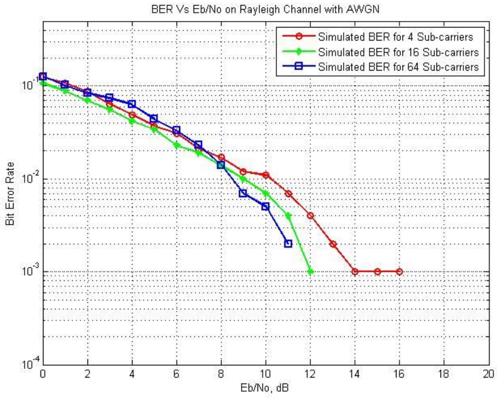

Figure 5.2: SNR/BER for single user 4, 16 and 64 sub-carriers, path gains are p1 = 0.7, p2 = 0.3, p3 = 0.0, p3 = 0.0.

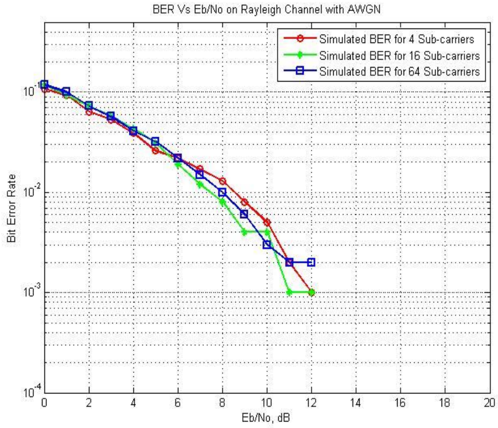

Figure 5.3: SNR/BER for 2,8 & 32 users for corresponding 4,16 & 64 sub-carriers, path gains are p1 = 0.7, p2 = 0.1, p3 = 0.1, p3 = 0.1.

Conclusion

Simulation results shows that the increase in sub-carriers decreases the effects of multipath fading, as the comparison in figure 5.1 results significant reduction on BER curve with higher sub-carriers (from 4 to 64), the effect of larger number of reflecting path can also be analyzed by comparing the graphs in figure 5.2 the final conclusion in figure 5.3 shows the case of multiuser (50 percent of capacity) which shows almost same BER performance irrespective number of sub carriers.

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