Performance Evaluation of OFDM System with Rician, Rayleigh, Rayleigh with Awgn and Awgn Channel for Bluetooth, Fixed and Mobile Wimax Application

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Keywords
OFDM (Orthogonal Frequency Division Multiplexing),
AWGN (Additive White Gaussian Noise),
BER (Bit Error Rate),
SER (Symbol Error Rate),
SNR (Signal to Noise Ratio),
QAM (Quadrature Amplitude Modulation),
ZP (Zero Padding),
CP (Cyclic Prefix),
CS (Cyclic Suffix),
PSD (Power Spectral Density)

Abstract
The emergence of WIMAX has attracted interest from wireless communication researchers. This paper discusses the OFDM for wireless communication. It include Bit Error Rate and Symbol Error Rate versus the ratio of bit energy to noise power spectral density (Eb/No) for different communication channels like AWGN channel, Rayleigh multipath channel, combined Rayleigh multipath with AWGN channel and Rician channel. The simulation is designed on computer MATLAB 9 version with 64-point FFT. It demonstrates that AWGN has better performance than any other channel. The BER of AWGN channel is 10-5 at 8dB SNR for Rayleigh multipath channel is 10-4.5 at 40dB SNR for Rayleigh multipath channel with AWGN is 10-4 at 30dB SNR and for Rician channel is 10-3 at 30dB SNR. The SER of AWGN channel is 0.02 at 12dB and approximately 0 at 14dB whereas SER for Rayleigh multipath channel with AWGN is 0.0009 at 30dB. So, AWGN channel has better SNR than any other channel. It can be used for OFDM Bluetooth 802.11g-2003, fixed WIMAX 802.16-2004 and mobile WIMAX 802.16e-2005

1. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is one of the most promising technologies for high data rate wireless communications [1], due to its robustness, high spectral efficiency, frequency selective fading, and low computational complexity. OFDM can be used in conjunction with a Multiple-Input Multiple-Output (MIMO) transceiver to increase the diversity gain and/or the system capacity by exploiting spatial domain. Because the OFDM system effectively provides numerous parallel narrowband channels which is considered a key technology in emerging high-data rate systems such as IEEE 802.11g-2003, IEEE 802.16-2004 and IEEE 802.16e-2005. [2] Figure 1 is the basic block diagram of OFDM system using zero padding and cyclic prefix. In this paper OFDM is analyzed for different channel using convolutional coding and each sub-carrier being modulated with QAM-16. OFDM is a block transmission technique. A block of data N serial source symbols each with duration Ts are converted into a block of N parallel modulated symbols each with period T = NT_s. The block length N can be determined to address various concerns and constraints. In wireless transmission, for example, N is chosen such that $NT_s >> \sigma_\tau$, where σ_τ is the rms delay spread of the channel. The complex envelope of an OFDM signal can be expressed as-

$$S(t) = A\sum_{k}\sum_{n=0}^{N-1} x_{k,n}\phi_n(t-kT) \quad (1)$$

Where the subcarriers

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$$\phi_n(t) = \exp[\,j2\Pi(n-\frac{N-1}{2})\frac{t}{T}]u_T(t), 0 \le n \le N-1 \quad (2)$$

are orthogonal base functions and u(t) is a rectangular shaping function. The serial input data is in the form of a matrix of uniformly distributed random integer. The data generates an m-by-n binary matrix, each of whose entries independently takes the value 0 with probability 1/2.

The IEEE 802.11g-2003 standard is defined for OFDM Bluetooth. It is an amendment to the IEEE 802.11 specification that extended throughput to up to 54 Mbit/s using the same 2.4 GHz. The IEEE 802.16-2004 is an air interface for fixed broadband wireless access system. The IEEE 802.16e-2005 is a mobile broadband wireless access system. The 802.16 standard essentially standardizes two aspects of the air interface – the physical layer (PHY) and the media access control (MAC) layer.

2. Convolutional Encoder and Viterbi Decoder

The convolutional function which is used in the model formation accepts a polynomial of a convolution encoder and returns the corresponding trellis structure description. It encodes the binary vector message using the poly2trellis convolutional encoder function the vector message contains one or more symbols. The output vector contains one or more symbols.

The viterbi decoder convolutionally decodes binary data using viterbi algorithm. The encoder is assumed to have started at the all-zero state. The decoder traces back from the state with the best metric. The 'trunc' mode incures no delay. This mode is appropriate when we cannot assume the encoder ended at the all-zero state and when we do not want to preserve continuity between successive invocation of the function. The figure 4 describes the trellis encoder used to form the model.

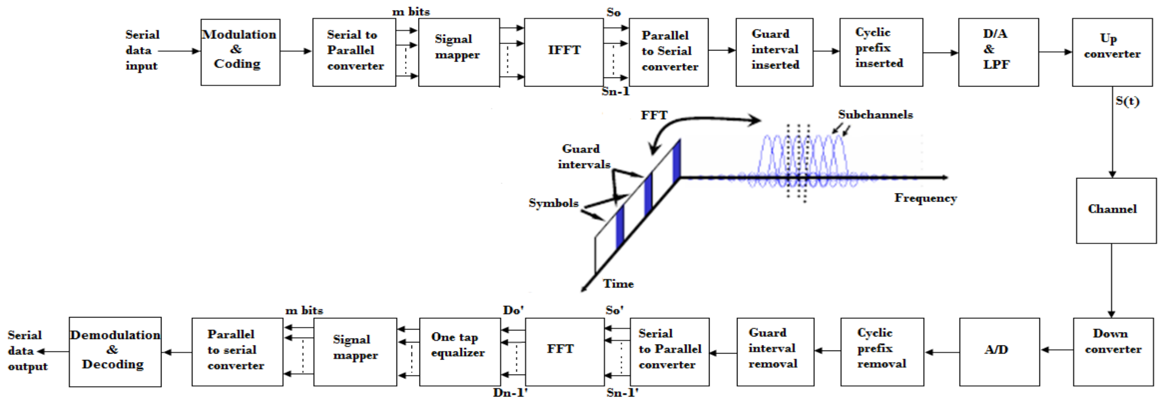

Fig: 1. Block Diagram of OFDM System

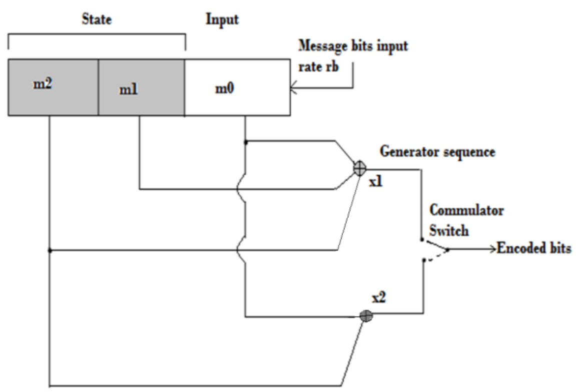

Fig: 2. Trellis Encoder

3. Inter Symbol Interference

To optimize the performance of an OFDM link, time and frequency synchronization between the transmitter and receiver is of absolute importance. This can be achieved by using known pilot tones embedded in the OFDM [1], signal or attach fine frequency timing tracking algorithms within the OFDM signal's cyclic extension (guard Period/ Period). To prevent ISI, the individual blocks are separated by guard periods wherein the blocks are periodically extended. In addition, once the incoming signal is split into the respective transmission sub-carriers, a guard period is added between each symbol. Each symbol consists of useful symbol duration, Ts and a guard period, Δt, in which, part of the time, and a signal of Ts is cyclically repeated. This is shown in Fig. 2.

As long as the multi path propagation delays do not exceed the duration of the period, no inter-symbol interference occurs and no channel equalization is required. For a delay spread that is longer than the effective guard period, the BER (Bit Error Rate) rises rapidly due to the inter-symbol interference. The maximum BER that will occur is when the delay spread is very long (greater than the symbol time) as this will result in strong inter-symbol interference.

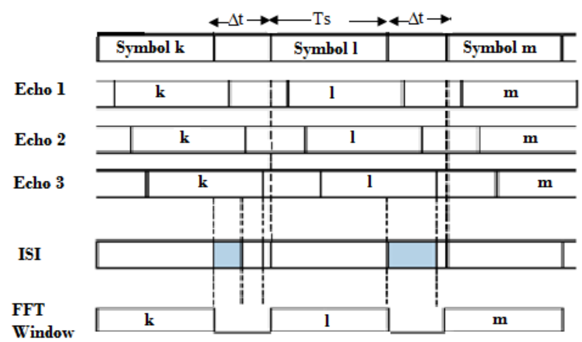

Fig: 3 (a). Combining ISI using a Guard Period [1]

The Guard Period in OFDM System can be inserted in two different ways. One way is the zero padding (ZP) i.e. pads the guard period with zeros. The other way is the cyclic extension of the OFDM symbol (for some continuity) by insertion of CP (cyclic prefix) or CS (cyclic suffix). CP is to extend the OFDM symbol by copying the last samples of the OFDM symbol into its front.

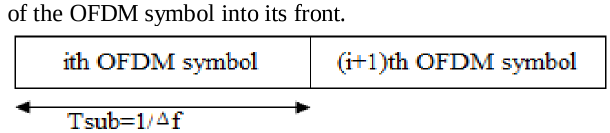

Fig: 3(b). OFDM Symbol without Guard Period [4]

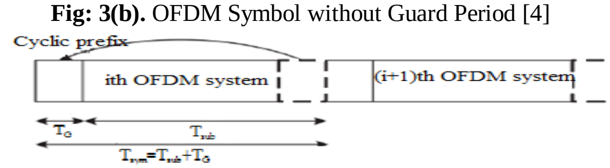

Fig: 3(c). OFDM symbol with CP [4]

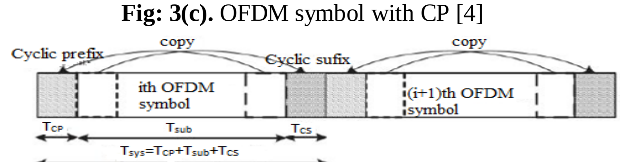

Fig: 3(d). OFDM Symbol with CP and CS [1]

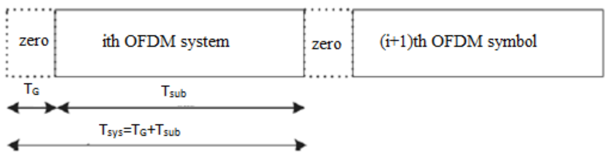

Fig: 3(e). OFDM Symbol with ZP [4]

4. Channels

In wireless communications, channel is a physical transmission medium such as a wire or to a logical connection over a multiplexed medium such as a radio channel. A channel is used to convey an information signal, from transmitter to receiver. Communication channels can be classified as fast and slow fading channels. A channel is fast fading if the impulse response changes approximately at the symbol rate of the communication system, whereas a slow fading channel stays unchanged for several symbols. In this paper, the focus will be on performance analysis of OFDM system over AWGN channel, Rayleigh multipath channel and Rician channel using trellis code structure.

4.1 AWGN Channel

AWGN is a channel model used for analyzing modulation schemes. It adds a white Gaussian noise to the signal passing through it. The channel's amplitude frequency response is flat and phase frequency response is linear for all frequencies so that modulated signals pass through it without any amplitude loss and phase distortion of frequency components. Fading does not exist but the only distortion is introduced by the AWGN. The received signal is simplified to [6]-

$$r(t) = x(t) + n(t) \tag{3}$$

where n(t) is the additive white Gaussian noise. The whiteness of n(t) implies that it is a stationary random process with a flat power spectral density (PSD) for all frequencies. It is a convention to assume its PSD as [6]-

$$N(f) = \frac{N_0}{2}, -\infty < f < \infty \tag{4}$$

For an AWGN (Additive White Gaussian Noise) channel, 'θ' is a constant and is equivalent to the AoA of the LoS propagation path. In this case, we use the so-called narrowband data model to model the received signal at the antenna arrays. The narrowband data model assumes that the envelope of the signal wave front propagating across the antenna array essentially remains constant. This model is valid when the signals or the antennas have a bandwidth that is much smaller than the carrier frequency f_c. Under the above assumptions, the vector from of the baseband complex equivalent received signal can be written as [7],

$$Y[n] = V(\theta)s[n] + G[n] \tag{5}$$

Where, *V* (θ) is the array manifold vector and G (n) is AWGN with zero mean and two-sided power spectral density given by $N_o/2$. This is simply a plane-wave model.

4.2 Rayleigh Fading Channel

In wireless telecommunications, multipath is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths. Causes of multipath include atmospheric ducting, ionosphere reflection and refraction, and reflection from water bodies and terrestrial objects such as mountains and buildings. 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 is a term used when there is no direct component, and all signals reaching the receiver are reflected. The multipath Rayleigh fading wireless channels modeled by the channel impulse response (CIR) [7]-

$$h(t) = \sum_{l=0}^{Lp-1} \alpha_l \partial(t - \tau_l) \tag{6}$$

Where L_p is the number of channel paths, α_l and τ_l are the complex value and delay of path l, respectively. The paths are assumed to be statistically independent, with normalized average power. The channel is time variant due to the motion of the mobile terminal, but we will assume that the CIR is constant during one OFDM symbol. [7]

4.3 Rician Fading Channel

When there is line of sight, direct path is normally the strongest component goes into deeper fade compared to the multipath components. This kind of signal is approximated by Rician distribution. As the dominating component run into more fade the signal characteristic goes from Rician to Rayleigh distribution.

$$p(r) = \frac{r}{\sigma^2} e^{-\frac{(r^2+A^2)}{2\sigma^2}} I_o\left(\frac{Ar}{\sigma^2}\right) \text{ for } (A \geq 0, r \geq 0) \tag{7}$$

Where A denotes the peak amplitude of the dominant signal and I_0[.] is the modified Bessel function of the first kind and zero-order.

5. Result

The OFDM system is developed, analyzed, and simulated in Matlab version 2009. The performance results for such channels ie. AWGN channel, Rayleigh multipath channel, Rayleigh multipath channel with AWGN and Rician channel. The results should be on the basis of BER and SER which are shown below:

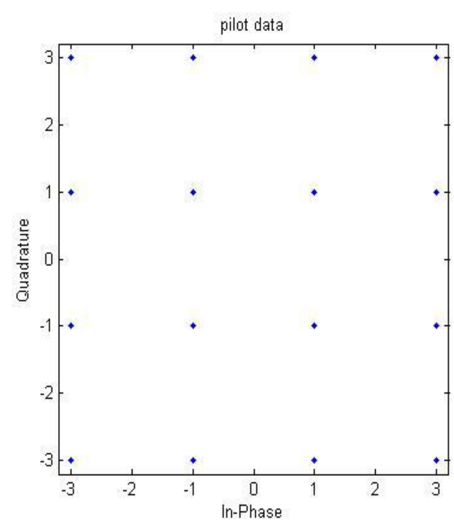

Fig: 4(a). Transmitted 16-QAM Constellation Diagram

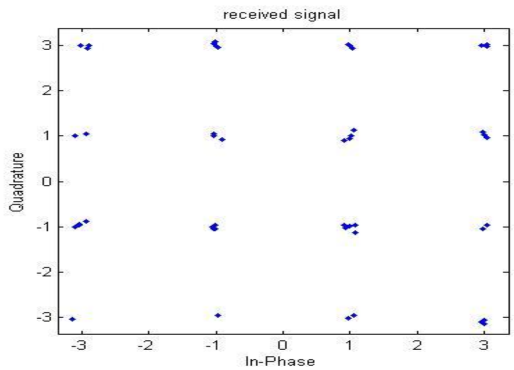

Fig: 4(b). Received 16-QAM Constellation Diagram

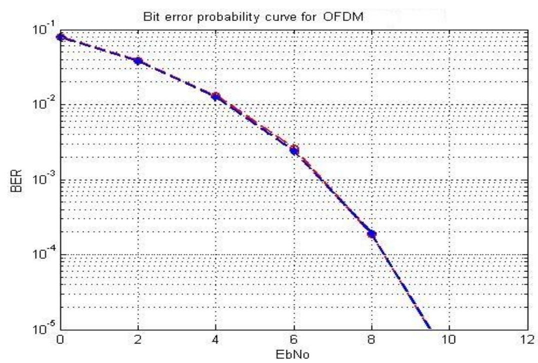

Fig: 4(c). BER of AWGN Channel

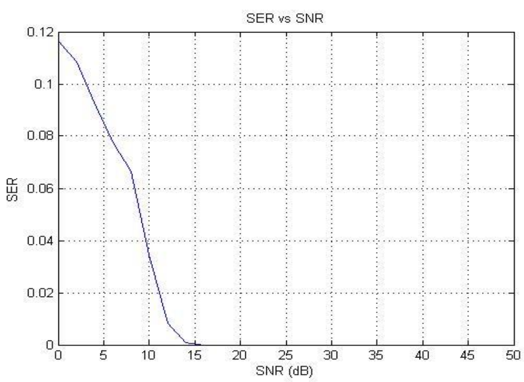

Fig: 4(d). SER of AWGN Channel

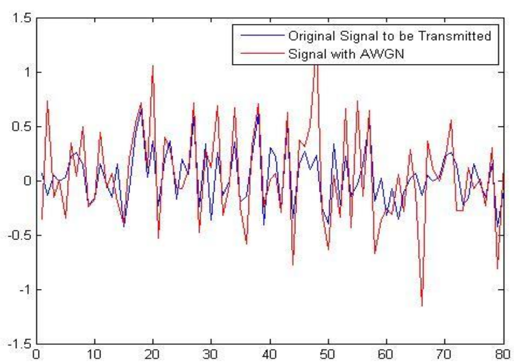

Fig: 4(e). Noise Added Transmitted Signal

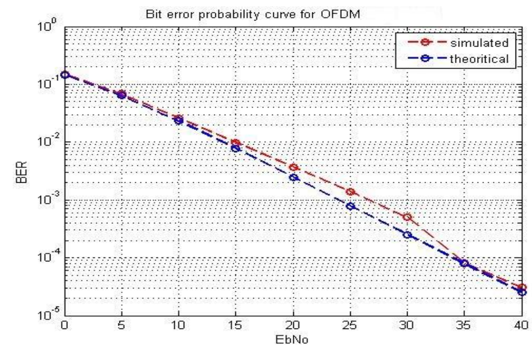

Fig: 4(f). BER of Rayleigh Channel

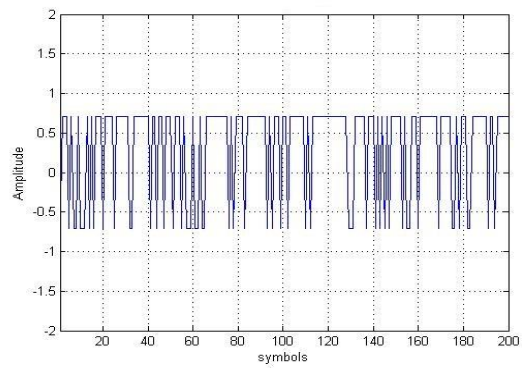

Fig: 4(g). Amplitude Spectrum of Rayleigh Multipath Channel with AWGN

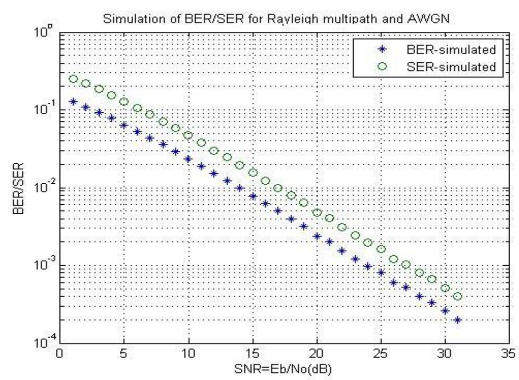

Fig: 4(h). BER and SER of Rayleigh Multipath Channel with AWGN Channel

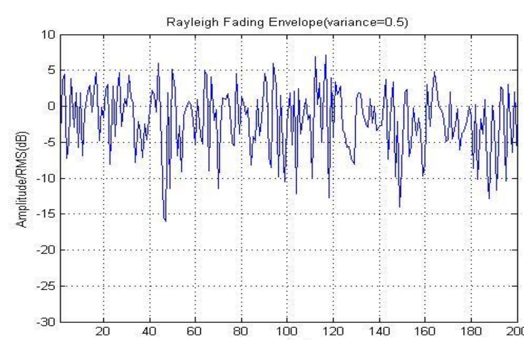

Fig: 4(i). Rayleigh Multipath Channel with AWGN Fading Envelope

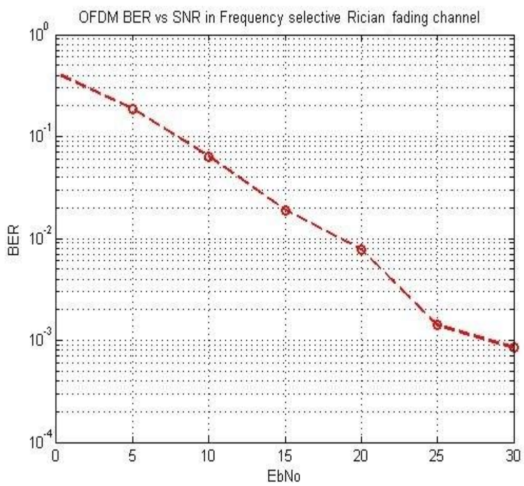

Figure 4(j): BER of Rician Channel

6. Conclusion

The presence of multipath in wireless OFDM transmission does not allow AWGN channel assumption due to fading. In this paper the performance of OFDM in AWGN wireless channel models, Rayleigh channel model, Rayleigh with AWGN model and Rician model are evaluated. The higher E_b/N_o required for transferring data means that more energy is required for each bit transfer. The BER of AWGN channel is 10^{-5} at 8dB SNR for Rayleigh multipath channel is $10^{-4.5}$ at 40dB SNR for Rayleigh multipath channel with AWGN is 10^{-4} at 30dB SNR and for Rician channel is 10^{-3} at 30dB SNR. The SER of AWGN channel is 0.02 at 12dB and approximately 0 at 14dB whereas SER for Rayleigh multipath channel with AWGN is 0.0009 at 30dB. At last, I conclude that BER (AWGN)< BER (Rayleigh channel)< BER(Rayleigh multipath channel with AWGN) < BER (Rician channel) and SER (AWGN)< SER (Rayleigh channel)< SER (Rayleigh multipath channel with AWGN)< SER (Rician channel).

The simulation is based for IEEE standards 802.11g-2003, 802.16-2004 and 802.16e-2005 it can further be modified for other IEEE standards. In the conventional papers, the BER for fixed WIMAX using 16-QAM technique is approximately 10^{-2} and for mobile WIMAX using 16-QAM technique is approximately 10^{-4}. So it is better technique for practical utilization which gives better result. Based on convolution coding the cost/complexity may increase. So in future, better convolution codes such as STTC, etc can be used to decrease cost and complexity of the model. Other channels such as Nakagami channels can used to get better results regarding BER and SER.

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