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PERFORMANCE EVALUATION OF OFDM USING MIMO-STTC FOR AWGN, RAYLEIGH, COMBINED RAYLEIGH WITH AWGN AND RICIAN CHANNEL FOR WIMAX AND BLUETOOTH APPLICATION

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Key words:
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

This paper discusses the OFDM in wireless communication. It includes Bit Error Rate and Symbol Error Rate verses ratio of bit energy to noise power spectral density (E_b/N_o) for different communication channels like AWGN channel, Rayleigh multipath Channel, combined Rayleigh multipath with AWGN channel and Rician Channel. The BER is 10^{-5}, $10^{-4.5}$, 10^{-4} and 10^{-3} respectively for above communication channels at 30dB of SNR. This simulation is designed on MATLAB 9 version with 64-point FFT. The coding which is done in this paper is STTC for MIMO. It can be used for OFDM Bluetooth 802.16-2004 and mobile WIMAX 802.16e-2005.

INTRODUCATION

Multiple-Input Multiple-Output (MIMO) technology is a technical breakthrough in the field of wireless communications. Multiple antennas at transmitter and receiver side refer to MIMO and such arrangement can be used to increase data rates or to improve link quality due to spatial diversity. MIMO system uses spatial multiplexing by spatially separated antennas to combat with multipath fading. This method offers higher capacity to wireless systems and the capacity increases linearly with the number of antennas. The main idea of MIMO is to improve quality (BER) and/or data rate (bits/sec) by using multiple TX/RX antennas. The core scheme of MIMO is space-time coding (STC). The two main functions of STC: spatial diversity and spatial multiplexing. The maximum performance needs tradeoffs between diversity and multiplexing.

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There are various categories of MIMO techniques. One of the technique aims to improve the power efficiency by maximizing spatial diversity. Such techniques include delay diversity, STBC and STTC. The second one uses a layered approach to increase capacity. In broadband wireless communications, an efficient implementation of space-time coding (STC) improves the performance and diversity gains of the system. The data experiences much impairment during transmission, especially due to the channel noise. The block diagram of M X N MIMO system is represented in figure which consists of M antennas at transmitter side and N antennas at receiver side. In this paper, the effects of using different antenna configuration on the performance of MIMO systems using OSTBC4 over AWGN and Rician channels with Zero Forcing receivers are considered. The impact of antenna selection on the performance of multiple input-multiple output (MIMO) systems over nonlinear communication channels. The author presented improvement in SNR penalty due to nonlinearity of fading channels for the reduced complexity system (Mitalee Agarwal and Yudhishthir

Bhisht, 2011). Orthogonal Frequency Division Multiplexing (OFDM) is one of the most promising technologies for high data rate wireless communications (Mitalee Agarwal and Yudhishthir Bhisht, 2011), 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, MIMO-OFDM is considered a key technology in emerging high-data rate systems such as 4G, IEEE 802.16, and IEEE 802.11n (Michael Speth *et al*., 1999).

where the subcarriers

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

are orthogonal base functions and u(t) is a rectangular shaping function. The frequency separation of the subcarriers, 1/T, ensures that the subcarriers are orthogonal and phase continuity is maintained from one symbol to the next, but is twice the minimum required for the orthogonality with coherent detection. The modulation can be implemented in the discrete domain by using either aninverse discrete Fourier transform (IDFT) or the more computationally efficient inverse fast Fourier transform (IFFT).

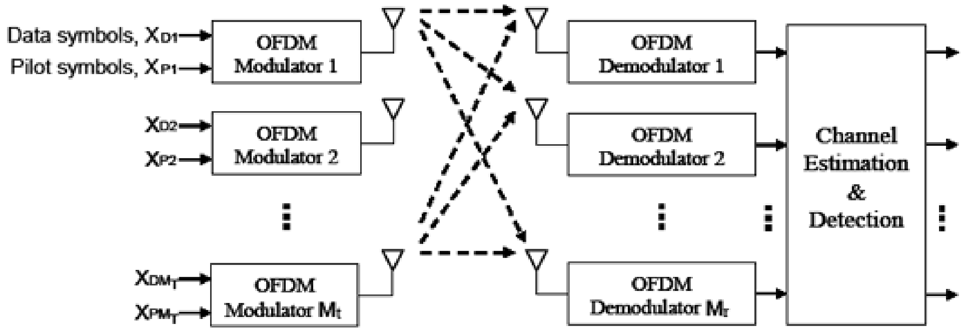

Figure 1. MIMO-OFDM system

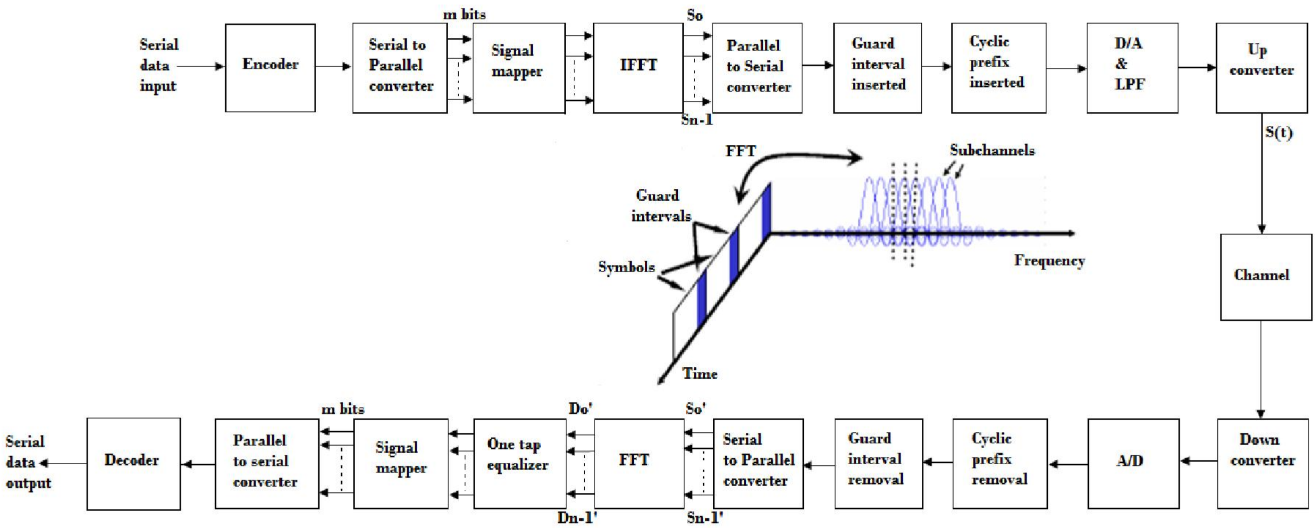

Figure 2. Block diagram of OFDM system

Figure 2 is the basic block diagram of OFDM system using zero padding and cyclic prefix. In this paper OFDM is analyzed for AWGN and Rayleigh fading Channel using trellis 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-

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

The OFDM-modulated signal has a power spectral density-

$$S_w = \frac{A^2}{T}\sigma_x^{\ 2}\sum_{n=0}^{N-1}\left|\sin c[fT - (n - \frac{N-1}{2})]\right|^2 \quad \text{eqn. 3}$$

where $\sigma_x^{\ 2}$ is the variance of the signal constellation. The number of sub-carriers and the occupied bandwidth are proportional to the transmission data rate. For broadband wireless communication applications, the transmitted signals suffers from the fading in both time and frequency domains. OFDM technique is an attractive solution that has advantages of multi-path immunity, bandwidth efficiency as well as good resistance to narrow-band interferences and impulse noise (Ludong Wang and Brian Jezek, 2008).

STTC Encoder

The encoder structure for a 4-PSK scheme with two transmits antennas and memory order v of its STTC coding section is shown in figure below. The binary information bits are spatially de- multiplexed into two sub streams, X_t^1 and X_t^2 and are fed into the upper and lower branches of the STTC encoder with X_t^1 being the most significant bit. The memory orders of the upper and lower branches are v_1 and v_2, respectively, where $v=v_1+v_2$ and

$$v_i = \left[\frac{v+i-1}{2}\right], \text{ i=1,2} \qquad \text{eqn. 4}$$

where [x] denotes the largest integer smaller than x. The two streams of input bits are delayed and multiplied by coefficient pairs (a_p^1, a_p^2) and (b_p^1, b_p^2) respectively, where a_p^1, b_p^1 $\in$ {1, 2, 3, 4}, i=1, 2, p = 0, 1,…..,v_1 , q = 0, 1,……,v_2. The encoder outputs are computed as-

$$C_t^k = \sum_{p=0}^{v_1} X_{t-p}^1 a_p^k + \sum_{q=0}^{v_2} X_{t-q}^2 a_q^k \bmod 4, \text{ k = 1,2} \qquad \text{eqn. 5}$$

and are fed into two OFDM modulating channels (Touhidul Islam *et al*., 2011).

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 and Rayleigh channels using trellis code structure.

AWGN Channels

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 (Navjot Kaur and Lavish Kansal, 2013)-

$$r(t) = x(t) + n(t) \qquad \text{eqn. 6}$$

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 (Navjot Kaur and Lavish Kansal, 2013)-

$$N(f) = \frac{N_0}{2}, -\infty < f < \infty \qquad \text{eqn. 7}$$

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 (Suchita Varade and Kishore Kulat, 2012),

$$Y[n] = V(\theta)s[n] + G[n] \qquad \text{eqn. 8}$$

Where, V (θ) is the array manifold vector and G (n) is AWGN with zero mean and two-sided power spectral density given by No/2. This is simply a plane-wave model.

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. Mathematically, the multipath Rayleigh fading wireless channels modeled by the channel impulse response (CIR) (Suchita Varade and Kishore Kulat, 2012)-

$$h(t) = \sum_{l=0}^{Lp-1} \alpha_l \partial(t - \tau_l) \qquad \text{eqn. 9}$$

Where *Lp* is the number of channel paths, *αl* and *τl* 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 (Suchita Varade and Kishore Kulat, 2012).

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.

$$p(r) = \frac{r}{\sigma^2} e^{-\frac{(r^2+A^2)}{2\sigma^2}} I_o\left(\frac{Ar}{\sigma^2}\right) \text{ for } (A \geq 0, r \geq 0) \qquad \text{eqn. 10}$$

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.

RESULTS

The OFDM system is developed, analyzed, and simulated in Matlab version 2009. The performance results for such channel in two types ie. AWGN channel and Rayleigh channel. The results are shown below-

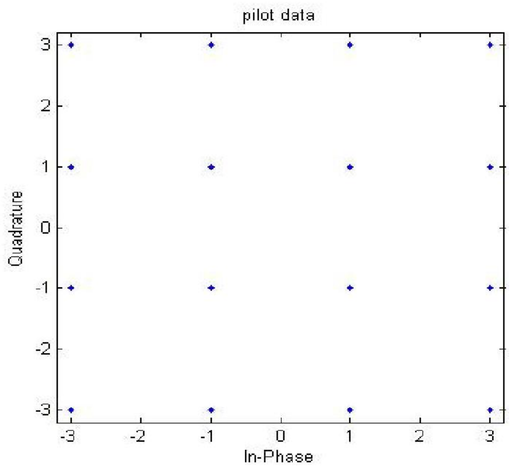

Figure 3. Transmitted 16-QAM constellation diagram

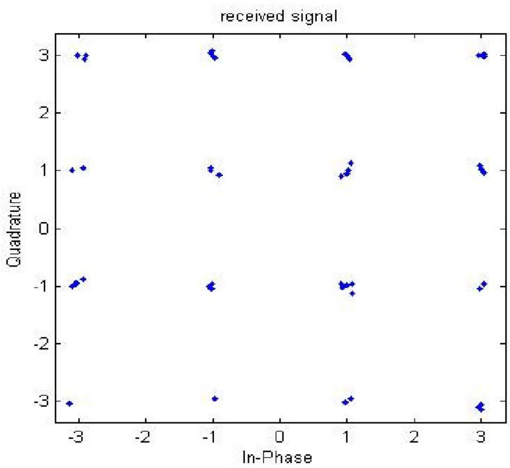

Figure 4. Received 16-QAM constellation diagram

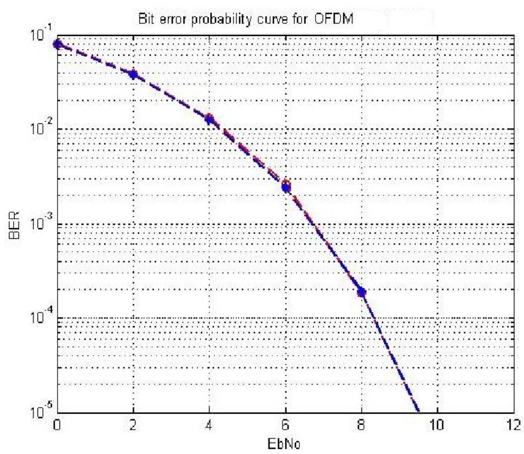

Figure 5. BER of AWGN channel

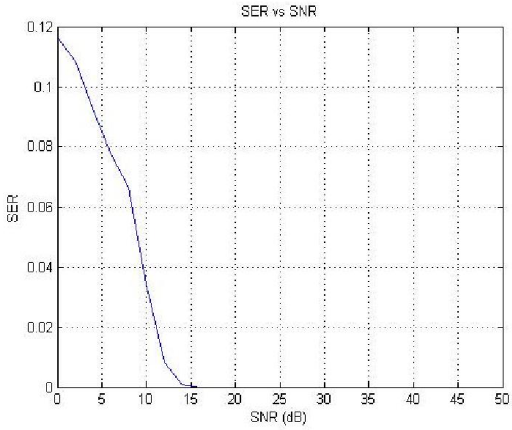

Figure 6. SER of AWGN channel

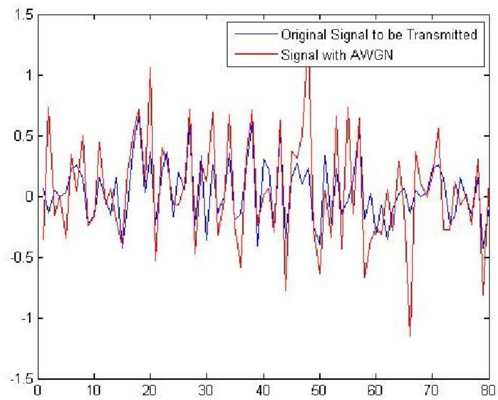

Figure 7. Noise added transmitted signal

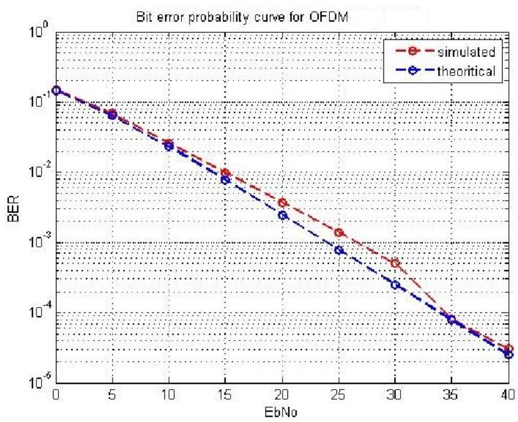

Figure 8. BER of Rayleigh channel

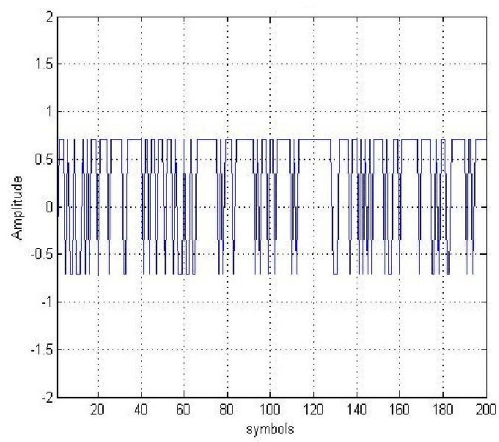

Figure 9. Amplitude spectrum of Rayleigh multipath channel with AWGN

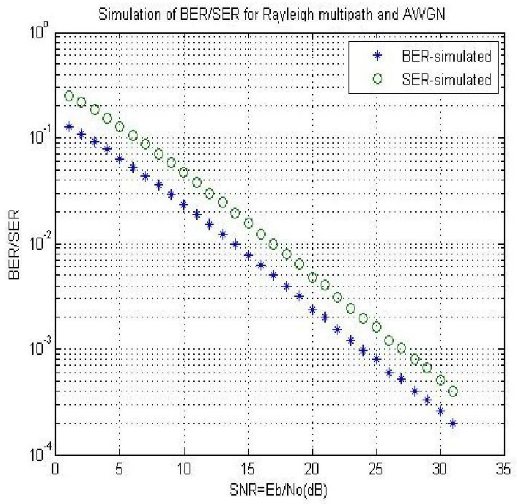

Figure 10. BER and SER of Rayleigh multipath channel with AWGN channel

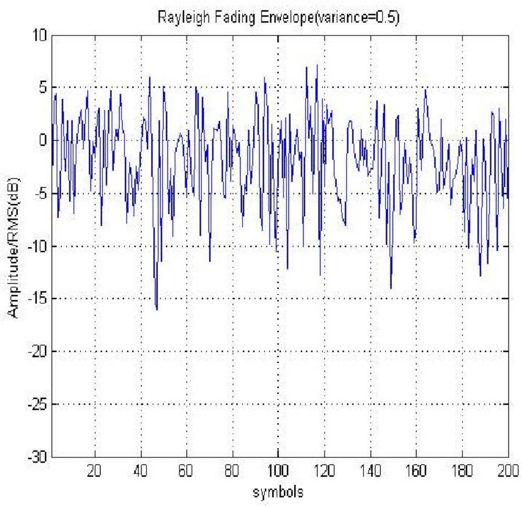

Figure 11. Rayleigh multipath channel with AWGN fading envelope

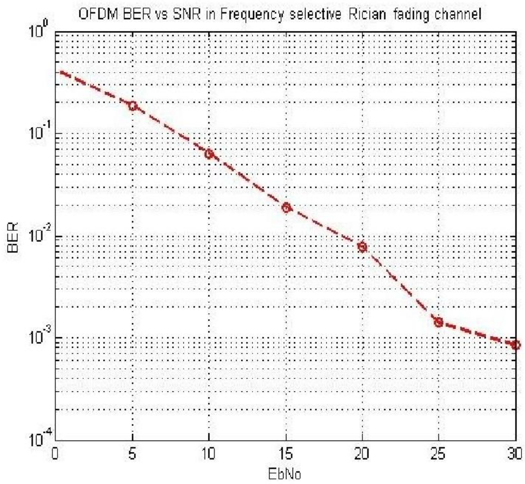

Figure 12. BER of Rician channel

Conclusion

The presence of multipath in wireless STTC MIMO-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 Eb/No required for transferring data means that more energy is required for each bit transfer. Based on convolution coding the cost/complexity may increase.

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