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Performance Elevation Criteria for OFDM Under AWGN Fading Channel using IEEE 802.11a

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Abstract:

The next generation wireless communications systems need to be of a higher standard in order to provide the customers with the multitude of high quality services they demand. In recent years, Orthogonal Frequency Division Multiplexing (OFDM) has been successfully used in terrestrial digital video broadcasting and showed it is a strong candidate for the modulation technique of future wireless systems. This project is concerned with how well OFDM performs when transmitted over an Additive White Gaussian Noise (AWGN) channel only. In order to investigate this, a simulation model was created and implemented using MATLAB. The OFDM signal was transmitted over the AWGN channel for various signal-to-noise ratio (SNR) values. To evaluate the performance, for each SNR level, the received signal was demodulated and the received data was compared to the original information. The result of the simulation is shown in a plot of the symbol error rate versus SNR, which provides information about the system's performance. The plot shows that OFDM performance is good over this type of channel.

Keywords:

BER, OFDM Additive white Gaussian noise (AWGN), BPSK ,QAM.

I. INTRODUCTION:

The requirement for future communication systems to support mobile users to broadband services calls for robustness against fast frequency-selective multipath fadings. A perfect solution to this impairment is to adopt the orthogonal frequency division multiplexing (OFDM) as the multiplexing strategy. Orthogonal frequency division multiplexing (OFDM) is an important wideband transmission technique for wireless communication systems. Compared with the other competing wideband transmission technology i.e. multicarrier code division multiple access an OFDM system can reduce or eliminate inter symbol interference (ISI) and is particularly suitable for transmission over fading channel requiring only a relatively simple equalizer at the receiver for a good performance. OFDM has been a very popular technique for more efficient data communications. OFDM has recently been applied widely in wireless communication systems due to its high data rate transmission capability with high bandwidth efficiency, Fading distribution has been employed as another useful and important model for characterizing the fading channel, specially AWGN fading. Another advantage of this channel is best fit for modeling urban multipath channels, could be better or more severe than Rayleigh fading channel.

The purpuse of using OFDM is to avoid problems caused by multipath reflections by sending the message bits slowly enough so that any delayed copies (reflections) are late by only a small fraction of a bit time. To maintain high bit rate, multiple carriers are used to send many low speed messages. These massages are combined and transmitted. At receiver, they are combined to make up one high speed message. In this way, the distortion caused by reflections can be avoided. In this work the performance evaluation of Orthogonal Frequency-Division Multiplexing –Fast Fourier Transform (OFDM-FFT) in AWGN wireless channel models. The rest of the paper is organized as follows. Section 2 presents OFDM system architecture, Section 3 Radio Channels, Section 4 presents IEEE 802.11 specifications .The Simulation results are presented in Section 5, Section 6 concludes the paper.

II. OFDM SYSTEM ARCHITECTURE:

The OFDM message is generated in the complex baseband. Each symbol is modulated onto the corresponding subcarrier using variants of phase shift keying (PSK) or different forms of quadrature amplitude modulation (QAM). The data symbols are converted from serial to parallel before data transmission.

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The frequency spacing between adjacent subcarriers is 2π/N, where N is the number of subcarriers. This can be achieved by using the inverse discrete Fourier transform (IDFT), easily implemented as the inverse fast Fourier transform (IFFT) operation. As a result, the OFDM symbol generated for an N-subcarrier system translates into N samples, with the sample being. At the receiver, the OFDM message goes through the exact opposite operation in the discrete Fourier transform (DFT) to take the corrupted symbols from a time domain form into the frequency domain. In practice, the baseband OFDM receiver performs the fast Fourier transform (FFT) of the receive message to recover the information that was originally sent. Figure 2.1 shows the basic OFDM system architecture explaining how the modulation is being done and how then it is being transmitted. This figure also explain how the same signal is received and demodulated using the efficient N-point FFT. The most widely used modulation schemes used in OFDM as per IEEE 802.11a standard are BPSK, 16-QAMand 64-QAM.

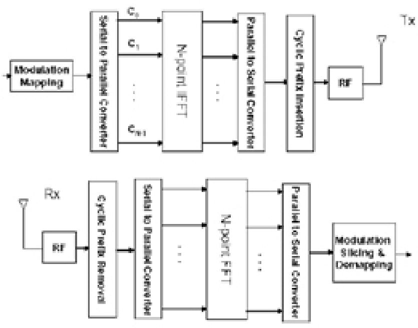

Figure 2.1 Basic OFDM system architecture

The theoretical expressions of symbol error rate (SER) for various uncoded OFDM schemes are as follows. For BPSK system,(BER and SER),

$$P_{s(orb),bpsk} = \frac{1}{2} erfc\left(\sqrt{\frac{E_s}{N_o}}\right) \quad \ldots(1)$$

For 16-QAM,

$$P_{s,16-QAM} = \frac{3}{8} erfc\left(\sqrt{\frac{4E_b}{10N_o}}\right) \quad \ldots(2)$$

For 64-QAM,

$$P_{s,64-QAM} = \frac{7}{24} erfc\left(\sqrt{\frac{18Eb}{126N_o}}\right) \quad \ldots(3)$$

In OFDM transmission, out of the available bandwidth from -10 MHz to +10 MHz, only subcarriers from -8.125 MHz to +8.125 MHz are used. This means that the signal energy is spread over a bandwidth of 16.25 MHz, whereas noise is spread over bandwidth of 20 MHz (-10 MHz to +10 MHz), i.e.

$$(20MHz) \times E_s = (16.25MHz) \times E_b \quad \ldots(4)$$

Simplifying Equation 13, we get Es / Eb > nDSC / nFFT . In an OFDM system, the transmission of cyclic prefix does not carry any extra information. The signal energy is spread over time Td T cp whereas the bit energy is spread over the time Td. i.e.

$$\frac{E_s}{E_b} = \frac{T_d}{(T_d + T_{cp})} \quad \ldots(5)$$

III. RADIO CHANNEL:

An electromagnetic media between the transmitter and the receiver is a radio channel. The most common channel model is the Gaussian channel, which is generally called the additive white Gaussian noise (AWGN) channel. The AWGN channel is simple and usually it is taken as the starting point to develop the basic system for performance evaluation. Under certain conditions, the channel cannot be classified as the AWGN channel but a multipath fading channel. In an ideal radio channel, the received signal would consist of only a single direct path signal, which would be a perfect reconstruction of the transmitted signal. However in a real channel, the signal is modified during transmission in the channel. The received signal consists of a combination of attenuated, reflected, refracted, and diffracted replicas of the transmitted signal, and the delays associated with different signal paths in a multipath fading channel change in an unpredictable manner and can only be characterized statistically. On top of all this, the channel adds noise to the signal and can cause a shift in the carrier frequency if the transmitter or receiver is moving (Doppler Effect). Understanding of these effects on the signal is important because the performance of a radio system is dependent on the radio channel characteristics .

IV. IEEE 802.11 SPECIFICATIONS:

The IEEE 802.11a standard specifies an OFDM physical (PHY) layer that splits an information signal across 52 separate subcarriers. Four subcarriers are pilot subcarriers and the remaining 48 ubcarriers provide separate wireless pathways for sending the information in a parallel fashion. The resulting subcarrier frequency spacing is 0.3125 MHz (for a 20 MHz bandwidth with 64 possible frequency slots). Table 4.1 represents the basic parameters for OFDM systems.

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Parameter	Value
FFT size (*nFFT*)	64
Number of subcarriers (*nDSC*)	52
FFT sampling frequency	20 *MHz*
Subcarrier spacing	312.5 *KHz*
Subcarrier index	{-26 to -1, +1 to +26}
Data symbol duration, T_d	3.2 μs
Cyclic prefix duration, T_{cp}	0.8 μs
Total symbol duration, T_s	4 μs
Modulation schemes	BPSK, 64-QAM 16 QAM.

TABLE - 4.1 OFDM TIME BASE PARAMETERS IN IEEE 802.11A

V. SIMULATION RESULTS:

The OFDM system is developed, analyzed, and simulated in Matlab version 10. The performance results for such system in three types of modulation are obtained using the OFDM parameters listed below

1)No. of bits per symbol : 52
2)No.of symbols : 10^4
3)FFT size : 64
4)No of data sub carriers: 52

Based on Modulation scheme

$$BER_{BPSK} < BER_{16\text{-}QAM} < BER_{64QAM} \qquad \ldots(6)$$

As discussed earlier, we compare the BER performance of OFDM under AWGN channel conditions. Various schemes used for simulation are BPSK, 16-QAM and 64-QAM.

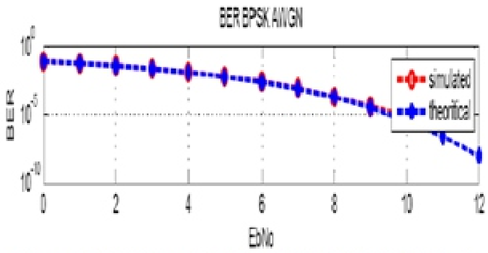

Figure 5.1 BER vs SNR for OFDM-BPSK System

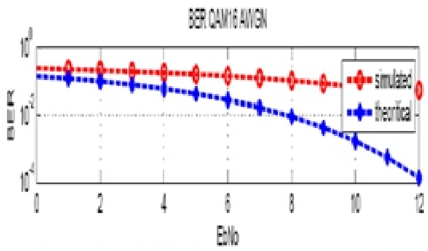

Figure 5.2 BER vs SNR for OFDM-16 QAM System

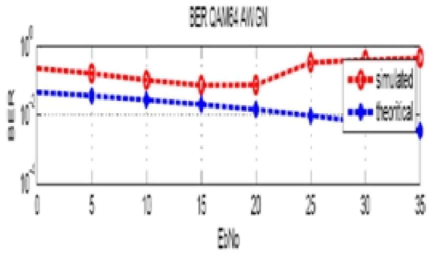

Figure 5.3 BER vs SNR for OFDM-64 QAM System

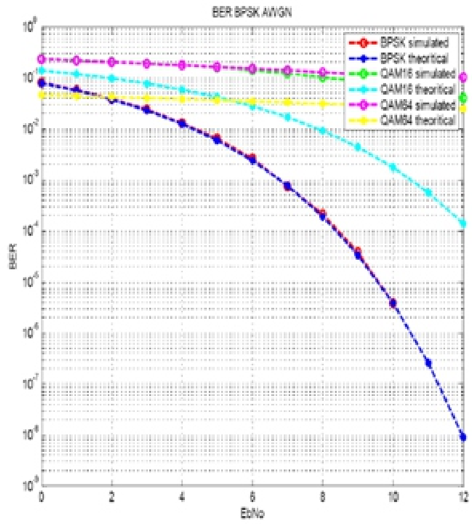

Figure 5.4 BER Comparison of OFDM system under AWGN channel

VI. CONCLUSION:

The simulation done in MATLAB worked well. The Additive White Gaussian Noise (AWGN) corrupted the transmitted signal and this resulted in a different received 4QAM constellation than the original constellation. For small SNR values the calculated error rate was quite large and ISI was produced due the relative high power of noise. As SNR was increased the error rate was decreasing, as expected. In fact, for a SNR value greater than 8 dB, the error was zero. This is a quite different than expected and it is due to the fact that the program is simulating only 68 OFDM symbols (i.e. one frame), sent on by one. If the number of transmitted OFDM symbols is increased, than a more accurate error rate can be obtained, but this necessitates a high processing power PC and time. Letting this aside, the system's performance was good since the simulated error rate for small SNR values was a little bit above the theoretical probability curve. The difference between the two curves is less than 0.5 dB. As the SNR is increased we observe that the simulated symbol error rate intersects and then drops below the theoretical error curve.

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There are more aspects of OFDM that need to be researched since this simulation was only a basic one. As an example, there are a lot of improvements that can be brought to the program. Such as the addition of guard interval, coding the original information, simulation over a multipath channel etc.

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