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Performance Analysis for OFDM System Using Fourier Transform and Zero-forcing Channel Estimation on Different Modulation

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Abstract: In OFDM multiple carriers are used and it provides higher level of spectral efficiency as compared to Frequency Division Multiplexing (FDM). In OFDM because of loss of orthogonality between the subcarriers there is inter carrier interference (ICI) and inter symbol interference (ISI) and to overcome this problem use of cyclic prefixing (CP) is required, which uses 20% of available bandwidth. Comparison between the conventional FFT based OFDM systems of conventional modulation methods over AWGN. in-depth analysis of the zero forcing (ZF) and minimum mean squared error (MMSE) equalizers applied to wireless multi-input multi-output (MIMO) systems with no fewer receive than transmit antennas. In spite of much prior work on this subject, we reveal several new and surprising analytical results in terms of output signal-to-noise ratio (SNR), by comparing the Bit Error Rate (BER) and the average detection time consuming. Simulation based on the platform of MATLAB.

Keywords: ICI, ISI , ZF, MMSE, MIMO.

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing, also known as OFDM, is becoming a dominant communications tool for technologies such as ADSL, WLAN, HDTV, and G4. OFDM is being heralded as the technology of the future for implementation in such devices as cellular telephones, offering possible greater security and performance over today's traditional methods The OFDM strategy is based off a binary coding system called QPSK, which is a 2-bit per symbol format. The purpose of this system is to help detect errors and increase security by encrypting the data. We will use the following digital encoding system as an example of OFDM strategy.

Efficient use of radio spectrum includes placing modulated carriers as close as possible without causing Inter-Carrier Interference (ICI). Optimally, the bandwidth of each carrier would be adjacent to its neighbors, so there would be no wasted spectrum. In practice, a guard band must be placed between each carrier bandwidth to provide a space where a filter can attenuate an adjacent carrier's signal. These guard bands are wasted bandwidth. In order to transmit high data rates, short symbol periods must be used. The symbol period is the inverse of the baseband data rate (T = 1/R), so as R increases, T must decrease. In a multi-path environment, a shorter symbol period leads to a greater chance for Inter-Symbol Interference (ISI). This occurs when a delayed version of symbol 'n' arrives during the processing period of symbol 'n+1'.Orthogonal Frequency Division Multiplexing (OFDM) addresses both of these problems. OFDM provides a technique allowing the bandwidths of modulated carriers to overlap without interference (no ICI). It also provides a high date rate with a long symbol duration, thus helping to eliminate ISI. OFDM may therefore be considered as a candidate modulation technique in a broadband, multi-path environment.

II. OFDM SYSTEM ANALYSIS

The general full design of the OFDM system starts at an analog to digital converter (ADC) that converts analog data to digital if the system is for example a cellular telephone. If the source of data is a digital component, such as a computer, this step is skipped. Next, the digital data sorted, every two bits into its equivalent QPSK format as shown above in Figure 1. The data is sorted so it is encoded depending on which quadrant of the complex plane it lies in. For example, a bit pairing of [10] would correspond to -0.707+ j*0.707, [01] would correspond to 0.707-j*0.707 and so on. This data is then grouped into 16 distinct, separate channels; the purpose of this will later be shown when noise figures are examined. Next the Inverse Fast Fourier Transform is computed and the data is shifted out serially to an antenna, cable or other transmitting device.

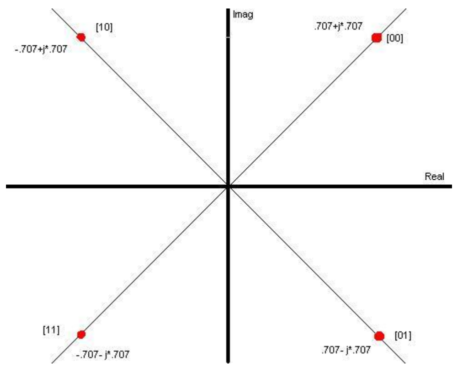

Fig. 1 QPSK Encoding

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During the data's transmission, often noise is mixed in with the signal. So at the receiver, the original data plus noise is entered into a Fast Fourier Transform after a serial to parallel conversion has taken place. The data resulting from the FFT would be complex in nature, and an effort will be made to reconstruct the original binary sequence of numbers for each channel.

The best case scenario would be absolutely zero noise, so after the FFT, the complex data would be exactly as it was before the transmission. Thus if -0.707+j*0.707 was transmitted, -0.707+j*0.707 would be received. What happens however, when noise interferes with the transmitted signal? For example, if 0.707+j*0.707 was indeed transmitted, but at the receiver end we received 0.452+j*0.789, an algorithm needs to be built in order to rectify this data back to 0.707+j*0.707.

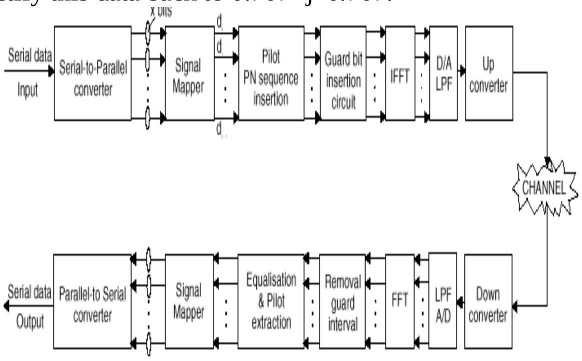

Fig. 2 OFDM block diagram.

This is done by simply mapping all points a complex quadrant to one point, the original points in figure 1. So the algorithm needs to be able to check what complex quadrant a received complex number is located in, and translate it back into its original point. For our example written above, 0.707+j*0.707 [00] would be transmitted, 0.452+j*0.789 (Quadrant 1 - noisy) would be received by the receiver, and then the algorithm would convert this value into 0.707+j*0.707 (Quadrant 1's representative value). Then the program would convert this complex number back into its digital equivalent, [00]. A clearer way to explain the last paragraph is this: whatever quadrant the complex point lies in, it will be interpreted as the digital bit pairing for that quadrant.

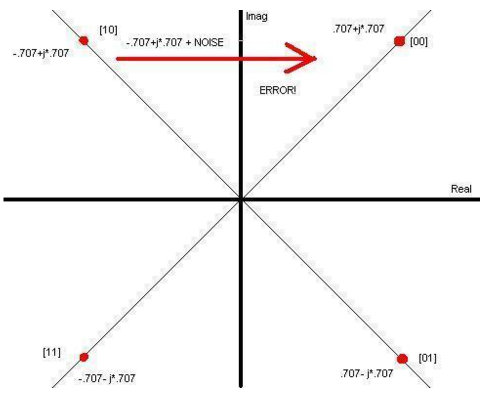

Fig. 3 Noise Generating Decoding Errors

So no matter what its value is, 500+j*500 is the same binary digit as 0.00001+j*0.00001, because they are both in quadrant 1, which is [00]. Depending on how much noise was encountered over the transmission, the data could have shifted far enough so that it its complex point isn't in its original quadrant! For example, noise could have caused a digital [10] point to move to any of the three other points, say [00]. A numerical example of Figure 3 is say -0.707+j*0.707 [10] was transmitted, then the receiver decodes it as 0.3+j*0.394 [00], an error has just occurred! The noise shifted the complex value of the binary bits enough that the point ventured into the next quadrant resulting in an error! Thus an error would be encountered. It is obvious the number of errors increases as more noise is encountered. Thus it would only be natural for us to determine the maximum amount of noise that our system can sustain before the SNR drops below acceptable standards.

III. DFT CHANNEL ESTIMATION

DFT can be used simultaneously as an accurate interpolation method in the frequency domain when the orthogonality between training sequences is based on the transmission of scattered pilots. In received signal constellation before and after channel compensation for the OFDM system with 16-QAM, illustrating the effect of channel estimation and compensation Here; illustrates the channel estimates obtained by using LS- linear, LS-spine and MMSE channel estimation methods with and without DFT technique and reveals that the DFT-based channel estimation method improves the performance of channel estimation.

ZERO-FORCING OFDM CHANNEL ESTIMATION

Linear equalization in communication systems which applies the inverse of the frequency response of the channel. The Zero-Forcing Equalizer applies the inverse of the channel frequency response to the received signal, to restore the signal after the channel It has many useful applications. For example, it is studied heavily for IEEE 802.11n (MIMO) where knowing the channel allows recovery of the two or more streams which will be received on top of each other on each antenna. The name Zero Forcing corresponds to bringing down the intersymbol interference (ISI) to zero in a noise free case. This will be useful when ISI is significant compared to noise. If the channel response (or channel transfer function) for a particular channel is H(s) then the input signal is multiplied by the reciprocal of it. This is intended to remove the effect of channel from the received signal, in particular the intersymbol interference (ISI).

The zero-forcing equalizer removes all ISI, and is ideal when the channel is noiseless. However, when the channel is noisy, the zero-forcing equalizer will amplify the noise greatly at frequencies f where the channel response $H(j2\pi f)$ has a small magnitude (i.e. near zeroes of the channel) in the attempt to invert the channel completely. A

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more balanced linear equalizer in this case is the minimum mean-square error equalizer, which does not usually eliminate ISI completely but instead minimizes the total power of the noise and ISI components in the output.

IV. MODULATION

In modulation, a message signal, which contains the information, is used to control the parameters of a carrier signal, so as to impress the information onto the carrier. analogue – denoted by m(t) digital – denoted by d(t) – i.e. sequences of 1's and 0's The message signal could also be a multilevel signal, rather than binary; this is not considered further at this stage.

TABLE I
MODULATION AND SYMBOL RATE RELATIONSHIP

MODULATION	Bits/Symbol	Symbol Rate
BPSK	2	1/2(0.5)
QPSK	4	1/4(0.25)
QAM-8	8	1/8(0.125)
QAM-16	16	1/16(0.0625)
QAM-64	64	1/64(0.015625)
QAM-256	256	1/256(0.00390625)

V. RESULT ANALYSIS

5.1 BER PERFORMANCE EVALUATION:-

By using MATLAB performance characteristic of DFT based OFDM and wavelet based OFDM are obtained for different modulations that are used for the LTE, as shown in figures. Modulations that could be used for LTE are QPSK, 16 QAM and 64 QAM (Uplink and downlink). QPSK does not carry data at very high speed. When signal to noise ratio is of good quality then only higher modulation techniques can be used. Lower forms of modulation (QPSK) does not require high signal to noise ratio. For the purpose of simulation, signal to noise ratio (SNR) of different values are introduced through AWGN channel.

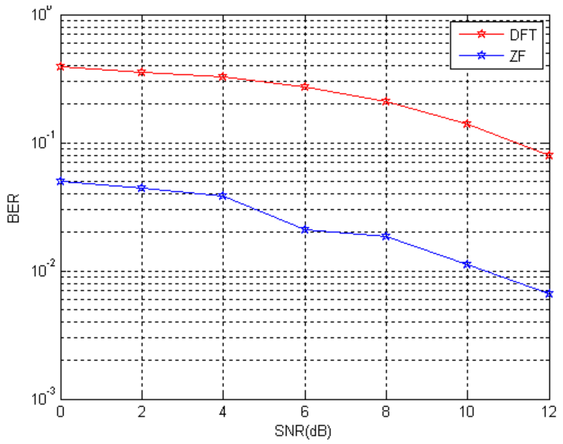

Fig. 4 16QAM Modulation

Data of 9600 bits is sent in the form of 100 symbols, so one symbol is of 96 bits. Averaging for a particular value of SNR for all the symbols is done and BER is obtained and same process is repeated for all the values of SNR and final BERs are obtained.

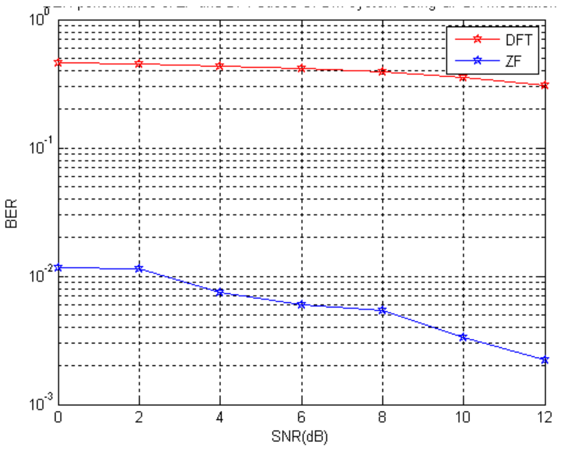

Fig. 5 64QAM Modulation

Firstly the performance of DFT based OFDM and wavelet based OFDM are obtained for different modulation techniques. Different wavelet types biorthogonal, daubechies2 and haar is used in wavelet based OFDM for 16-QAM, 64-QAM, 256QAM.

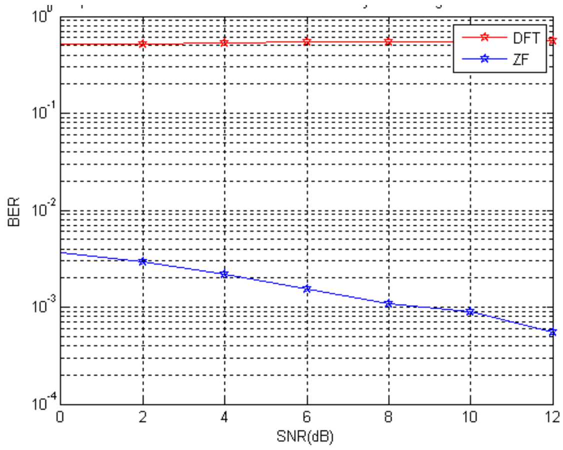

Fig. 6 256QAM Modulation

Quadrature Amplitude Modulation, QAM is a signal in which two carriers shifted in phase by 90 degrees are modulated and the resultant output consists of both amplitude and phase variations. In view of the fact that both amplitude and phase variations are present it may also be considered as a mixture of amplitude and phase modulation [1].

5.2 16/64//256-QAM MODULATION:-

The 16-QAM signal alphabet is the set $\Delta 16 = \{\pm1\pm j, \pm3\pm j, \pm1\pm3j, \pm3\pm3j\}$ without loss of generality, we assume the transmitted symbol to be in the first quadrant; $X0 \in \{1+j, 3+j, 1+3j, 3+3j\}$ Just as with the QPSK case, the correct decision probability can be written as a product of the error function.

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TABLE II
BER-ZF RESULTS

	0	2	4	6	8	10	12
BER-ZF16QAM	0.05151	0.03916	0.02828	0.02717	0.01831	0.01494	0.00861
BER-ZF64QAM	0.01287	0.00925	0.00671	0.006	0.00441	0.00205	0.00199
BER-ZF256QAM	0.0034	0.00242	0.00198	0.00157	0.00071	0.00053	0.00046

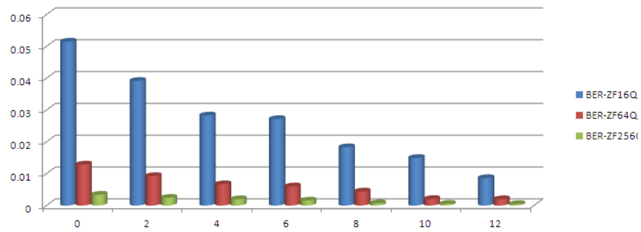

Fig. 7 bars BER-ZF

To send data, the transmitter varies the amplitude and phase of a carrier signal. In QAM64 there are 64 possible combinations of amplitude and phase for each period of time, or symbol, of the carrier [13]. With QAM256 there are 256 possible combinations in the same period - thus increasing the data capacity fourfold but making it more difficult for the receiver to discriminate between each signal.

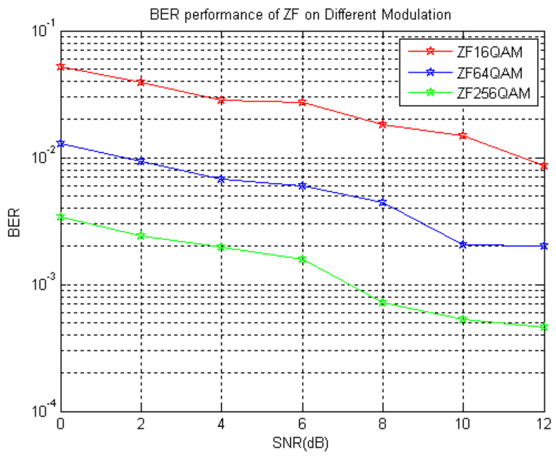

Fig. 8 Different Modulation BER-ZF

VI. CONCLUSION

In this paper we analyzed the performance of wavelet based OFDM system and compared it with the performance of DFT based OFDM system. From the performance curve we have observed that the BER curves obtained from wavelet based OFDM are better than that of DFT based OFDM. We used three modulation techniques for implementation that are 16 QAM ; 64 QAM and 256 QAM which are used in LTE. In Zero forcing based OFDM different types of filters can be used with the help of different wavelets available. We have used different modulation performances at different intervals of SNR.

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BIOGRAPHIES

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