ERROR RATE ANALYSIS OF OFDM AND M-QAM FOR DIGITAL AUDIO SIGNAL PROCESSING IN WIRELESS CHANNEL

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Abstract- Orthogonal frequency-division multiplexing (OFDM) is a frequency division multiplexing (FDM) scheme used as a digital multi-carrier modulation method. A large number of closely-spaced orthogonal sub-carriers are used to carry data. The data is divided into several parallel data streams or channels, one for each sub-carrier. Each sub-carrier is modulated with a conventional modulation scheme such as Quadrature Amplitude Modulation (QAM) at a low symbol rate, maintaining total data rates similar to conventional single-carrier (SC) modulation schemes in the same bandwidth. This Proposed work analyses and compares OFDM and M- QAM constellation mapping. The Mat lab / Simulink simulation results show that OFDM signals are having low bit error rate (Low BER) than QAM signals.

Keywords- SC, QAM, BER.DFT, IDFT.

I. INTRODUCTION

The future mobile communication systems require extremely large data rates and therefore large system bandwidth. The conventional single carrier modulation (SC) schemes resulting in very low symbol durations. Due to multi path propagation effects, very strong Inters Symbol interference (ISI) results. For high data rate applications, the symbol duration must be large. OFDM can effectively deal with ISI effects, which occur in multi-path propagation situations and broad band radio channels. The OFDM based new air interface and next generation mobile communications are very promising even in frequency-selective and time-invariant radio channels. Even OFDM has been accepted for several wireless LAN standards, as well as mobile multimedia applications. The Multi-carrier Applications of OFDM are also promising. The Current trends in wireless system design focus on the use of multiple-input multiple-output (MIMO) links to provide capacity gains and OFDM is to facilitate the utilization of these gains on frequency-selective channels with closed-loop techniques to offer a bit error rate (BER) improvement.

In multiuser OFDM, frequency offset, may be caused by mismatch of oscillators, and/or the Doppler Effect due to users' mobility, leads to inter-carrier interference (ICI) and multiuser interference (MUI), and results in an increase in the system BER. An interference-cancellation scheme for carrier-frequency offsets correction in OFDM systems is a novel method. Fundamental concepts of OFDM for signal processing techniques are discussed and proposed from . Two-stage precoder/equalizer to suppress ICI and MUI in downlink multiuser OFDM with multiple transmit antennas.

II. THE PROPOSED SYSTEM STRUCTURE

The general idea of the OFDM transmission technique is to split the total available bandwidth B into many narrowband sub-channels at equidistant frequencies. The sub-channel spectra overlap each other but the subcarrier signals are still orthogonal. The single high-rate data stream is subdivided into many low-rate data streams for the sub-channels. Each sub-channel is modulated individually and will be transmitted simultaneously in a superimposed and parallel form. OFDM transmits data as a set of parallel low bandwidth (100 Hz – 50 kHz) carriers. The frequency spacing between the carriers is made to be the reciprocal of the useful symbol period. The resulting carriers are orthogonal to each other provided correct time windowing at the receiver is used. The carriers are independent of each other even though their spectra overlap.

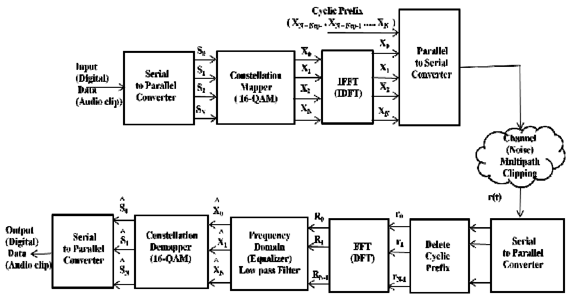

Fig. 1 Proposed System Structure for OFDM Signal processing.

The proposed block diagram for OFDM signal processing is shown in Fig.1. The incoming serial data is first converted form serial to parallel and grouped into X bits each to form a complex number. The number X determines the signal constellation of the corresponding subcarrier, such as M-QAM

(M=16). The individual I and Q input signals of QAM are translated into separate carriers (Resulting in complex Numbers). The complex numbers are modulated in the baseband by the inverse Fourier Transform (IFFT) (Inverse Discrete Fourier Transform (IDFT) in this case) and converted back to serial data for transmission. Receiver performs the inverse process of the transmitter. One-tap equalizer (Low pass filter) is used to correct channel distortion. The tap-coefficients of the filter are calculated based on the channel information. Most OFDM systems use a fixed modulation scheme over all carriers for simplicity. However each carrier in a multiuser OFDM system can potentially have a different modulation scheme depending on the channel conditions. Any coherent or differential, phase or amplitude modulation scheme can be used such as BPSK, QPSK, 8PSK, 16QAM, 64QAM…etc. Each modulation scheme provides a tradeoff between spectral efficiency and the BER.

The IFFT (IDFT) converts the frequency domain data set into samples of the corresponding time domain representation of this data. Specifically, the IFFT is useful for OFDM because it generates samples of a waveform with orthogonal frequency components. Then, the parallel to serial block creates the OFDM signal by sequentially outputting the time domain samples.

The channel simulation will allow examination of the effects of noise, multipath, and clipping. By adding random data to the transmitted signal, simple noise can be simulated. Finally, clipping simulates the problem of amplifier saturation. This addresses a practical implementation problem in OFDM where the Peak to Average Power Ratio (PAPR) is high.

III. MATHEMATICAL ANALYSIS OF OFDM

An OFDM transmit signal therefore consists of N adjacent and orthogonal subcarriers spaced by the frequency distance Δf on the frequency axis. All subcarrier signals are mutually orthogonal within the symbol duration of length T_S. The total symbol duration is given by

$$T = T_S + T_G \quad (1)$$

Where T_G is Guard interval which is larger than the maximum multi-path delay τ_{max}. The guard interval is added by taking ratio of guard band duration (see table I) and useful OFDM symbol period. OFDM transmits a large number of narrowband carriers, closely spaced in the frequency domain. In order to avoid a large number of modulators and filters at the transmitter and complementary filters and demodulators at the receiver, it is desirable to be able to use modern digital signal processing techniques, such as fast Fourier transform (FFT). Mathematically, each sub carrier can be described as a complex wave as:

$$S_c(t) = A_c(t)e^{j[w_c(t) + \emptyset_c(t)]} \quad (2)$$

The real signal is the real part of S_c (t). $w_c(t)$ is frequency term. Both A_c (t) and $\emptyset_c(t)$, are the amplitude and phase of the carrier, can vary on a symbol by symbol basis. The values of the parameters are constant over the symbol duration period t. If the signal is sampled using a sampling frequency of 1/T, then the resulting signal S_s is represented by:

$$S_s(kT) = \frac{1}{N}\sum_{n=0}^{N-1} A_n e^{j[(\omega_0+n\Delta\omega)kT+\phi_n]} \quad (3)$$

For continuous signal : $\omega_n = \omega_0 + n\Delta\omega$

If we consider the waveforms of each component of the signal over one symbol period, then the variables A_c (t) and $\emptyset_c(t)$ take on fixed values, which depend on the frequency of that particular carrier, and so can be rewritten as :

$A_c(t) = A_n$ and $\emptyset_c(t) = \emptyset_n$ in equation (3)

For analyzing signal to N samples. It is convenient to sample over the period of one data symbol. Thus using a relationship $\tau = NT$. Simplifying equation (3) by taking $\omega_0 = 0$ without losing any generality, the sampled signal becomes:

$$S_s(kT) = \frac{1}{N}\sum_{n=0}^{N-1} A_n e^{j\phi_n} e^{j(n\Delta\omega)kT} \quad (4)$$

Equation (4) is compared with the general form of Inverse Fourier Transform (IFT) as

$$g(kT) = \frac{1}{N}\sum_{n=0}^{N-1} G\left(\frac{n}{NT}\right) e^{j2\pi nk/N} \quad (5)$$

Where G is the periodic version of a signal. If equation (4) and (5) are equivalent and $A_n e^{j\phi_n}$ is just a representation of a signal in a sampled frequency domain, S(kT) is the time domain representation. If equation (4) and (5) are said to be equivalent, then

$$\Delta f = \frac{\Delta\omega}{2f} = \frac{1}{NT} = \frac{1}{\tau} \quad (6)$$

Equation (6) is the condition for orthogonality.

At the transmitter, the signal is defined in the frequency domain. It is a sampled digital signal, and it is defined such that the discrete Fourier spectrum exists only at discrete frequencies. Each OFDM carrier corresponds to one element of this discrete Fourier spectrum. The amplitudes and phases of the carriers depend on the data to be transmitted. The data transitions are synchronized at the carriers, and can be processed together, symbol by symbol. The N-point Inverse Discrete Fourier Transform (IDFT) is given by

$$X_p[k] = \frac{1}{N}\sum_{n=0}^{N-1} x_p[n]e^{-j(2\pi/N)}kn \qquad (7)$$

Similarly the N-point Discrete Fourier Transform (DFT) is

$$X_p[k] = \sum_{n=0}^{N-1} x_p[n]e^{-j(2\pi/N)}kn \qquad (8)$$

For the proposed analysis, Consider a data sequence (d_0, d_1, d_2, d_{N-1}), where each d_n is a complex number of the form $d_n = a_n + j b_n$ (Assuming a_n , $b_n = \pm 1, \pm 3$ for 16-QAM). A natural consequence of this method is that it allows us to generate carriers that are orthogonal. The members of an orthogonal set are linearly independent. The data set D_m is represented by the relation:

$$D_m = \sum_{n=0}^{N-1} d_n e^{-j\left(\frac{2\pi nm}{N}\right)} = \sum_{n==0}^{N-1} d_n\, e^{-j2\pi f_n t_m} \qquad (9)$$

$$\& \; k = 0,1,2 \ldots\ldots\ldots\ldots N-1$$

Where $f_n = {}^{n}/_{N\Delta T}$, $t_k = k\Delta t$ and Δt is an arbitrarily chosen symbol duration of the serial data sequence d_n. The real part of the vector D has components, and is given by

$$Y_m = \text{Re}\{D_m\} = \sum_{n=0}^{N-1}[a_n\cos(2\pi f_n t_m) + b_n\sin(2\pi f_n t_m)] \qquad (10)$$

If these components are applied to a low-pass filter at time intervals D_t, then a fundamental periodic signal is obtained that closely approximates the frequency division multiplexed signal.

$$y(t) = \sum_{n=0}^{N-1}[a_n\cos(2\pi f_n t_m) + b_n\sin(2\pi f_n t_m)] \qquad (11)$$

$$\text{and } 0 \le t \le N\Delta t$$

OFDM can be easily generated using an Inverse Fast Fourier Transform (IFFT) and received using a Fast Fourier Transform (FFT). High data rate systems are achieved by using a large number of carriers (i.e. 2000-8000). OFDM allows for a high spectral efficiency as the carrier power, and modulation scheme can be individually controlled for each carrier.

IV. SIMULATION PARAMETERS FOR ANALYSING 16-QAM & OFDM

This proposed work mainly focused on analyzing and comparing 16-bit audio signal transmission of OFDM and the same with 16-QAM modulation with BER. In systems, that uses a fixed modulation schemes for OFDM techniques, the carrier modulation must be designed to provide an acceptable BER under the worst channel conditions. This results in most of the systems using BPSK or QPSK [9]. These give a poor spectral efficiency (1-2 bits/s/Hz) and provide an excess link margin most of the time. Using adaptive modulation, the spectral efficiency can be increased from 1 bits/s/Hz (BPSK) up to 4-6 bits/s/Hz (16QAM or 64QAM), significantly increasing the spectral efficiency of the overall system [10]. The main numerical values considered for the proposed analysis are mentioned in TABLE-I. The spectral efficiency can be maximized by choosing the highest modulation scheme like 16-QAM that will give an acceptable BER. In a multipath radio channel, frequency selective fading can result in large variation in the received power of each carrier. For a channel with no direct signal path this variation can be as much as 30 dB in the received power resulting in a similar variation in the signal to Noise Ratio (SNR).

V. RESULTS AND DISCUSSIONS

The proposed analysis does extensive simulations in Mat lab & Simulink in order to evaluate the performance of 16-QAM and OFDM (using QAM) transmission and Reception for a audio clip of size = 21.00KB and duration Length = 00:00:02 minutes. Fig.2 shows the IFFT (Transmitted QAM) and FFT (Received QAM) analysis. The magnitude variation shows a large dip at the central carrier frequency (obtained only from 16-QAM). The figure also shows the distribution of audio signal with less number of sub carriers.

TABLE I Main Numerical values for Mat lab simulation

Method	Parameters
OFDM Simulation Setup	FFT_ size = 128 Number of Carriers = $\frac{\text{FFT\_size}}{4}$ = 32 Number of carriers used for each data chunk = 32 For having 64 data points, the size of each OFDM block size = 8 length of cyclic prefix = 8 points for the FFT/IFFT Allowed guard intervals = 1/8. carrier frequency = $f_c = q \times \frac{1}{T}$ = Obtained during simulation Where q = carrier period to elementary period ratio & T= Each baseband signal elementary period. $BER_{OFDM} = 100 \times \frac{\text{Binary Error Bits from OFDM}}{\text{Data Length}}$
QAM Simulation Setup	QAM period = Defines the number of periods per QAM. QAM Symbols =10 (sample points between 0 and 2π) FFT Size = 128 Number of Carriers = 32 $BER_{QAM} = 100 \times \frac{\text{Binary Error Bits from QAM}}{\text{Data Length}}$
Channel Simulation Set up	Clip level = 0.0 - 1.0 (0-100%) - Maintaining Constant PAPR Noise level = 0.0 - 1.0 (0-100%) $\text{Noise}_{\text{Random}}$ = (rand (1,length(received)) -0.5) × 2 × Noise level **Multipath Channel Simulation** $d_1 = 6$ (delay in units) $a_1 = 0.32$ (attenuation factor for multipath signal(original signal) $d_2 = 10$ (delay for second multipath signal) $a_2 = 0.28$ (attenuation factor for second multipath signal)

Fig.3 shows the clusters of input QAM symbols (parallel streams) and serial data as a transmitted data, as well as Received QAM data and each cluster of recovered QAM symbols. TABLE II shows the number of Error bits and percentage BER. Fig.4 shows the IFFT (Transmitted OFDM) and FFT (Received OFDM) analysis. The magnitude variation shows substantial dip at the central carrier frequency as well as obtaining similar dips at various other sub-carrier frequencies. The figure also shows the distribution of audio signal with huge number of sub carriers. This property naturally reduces ISI, improves BER and spectral efficiency.

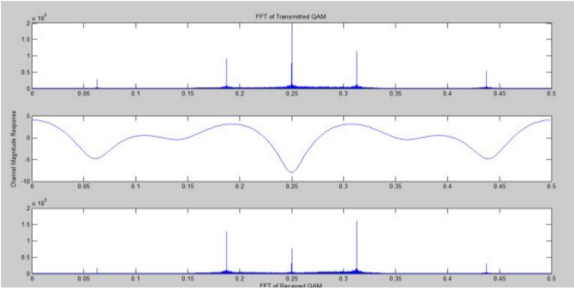

Fig. 2. Transmitted and Received 16- QAM sub-carriers analysis with magnitude variations.

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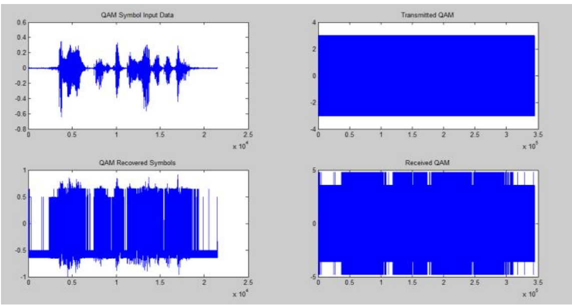

Fig. 3 Transmitted and Received QAM analysis with amplitude variations.

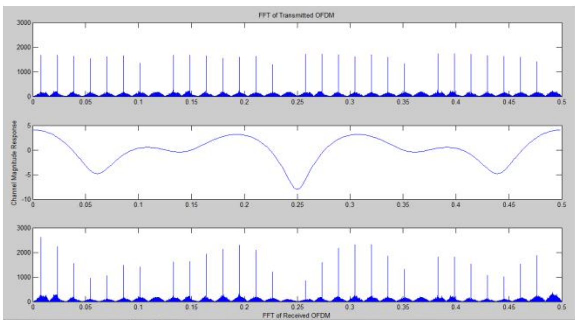

Fig.4. Transmitted and Received OFDM analysis with magnitude variations.

Fig.5 shows the clusters of input OFDM symbols (parallel streams) and serial data as a transmitted data, as well as Received OFDM data and each cluster of recovered OFDM symbols. The transmitted data and Received data is having almost similar shape. TABLE II shows the number of Error bits and percentage BER.

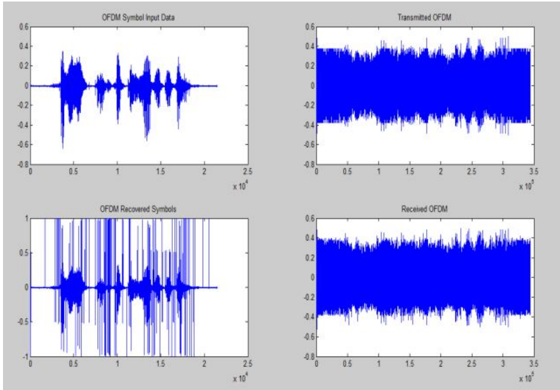

Fig. 5 Transmitted and Received OFDM analysis with amplitude variations.

TABLE II BER Performance between 16-QAM and OFDM

Method	Number of Bits Received	Number of Error Bits	BER %
16-QAM	172216	53475	31.1 %
OFDM	172216	286	0.166%

CONCLUSIONS

The important advantage of the OFDM transmission technique that ISI can be avoided completely or can be reduced at least considerably by a proper choice of OFDM system parameters. The orthogonality of all subcarrier signals is completely preserved in the receiver. Despite of the multi path channel environment may behave in linear time invariant (LTI) manner, only the signal amplitude and phase will be changed. The OFDM transmission techniques also needs less computational complexity in the equalization process inside each receiver.

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REFERENCES

[1] Richard Van Nee, Ramjee Prasad, “OFDM for Wireless Multimedia Communications”, Artech House Publishers, 2000.

[2] Ahmad R. S. Bahai, Burton R. Saltzberg, “Multi-Carrier Digital Communications –Theory and Applications of OFDM”, Kluwer Academic/Plenum Publishers.

[3] R.T. Derry berry, S.D.Gray, D.M.Ionescu, G.Mandyam and B.Raghotham , “ Transmit diversity in 3G CDMA Systems”, IEEE Commun., Mag., vol. 40, no.4, pp. 68-75, April 2002.

[4] Z. Cao, U. Tureli, and Y.D. Yao, “Deterministic multiuser carrier frequency offset estimation for interleaved OFDMA

uplink," IEEE Trans. Commun., vol. 52, no. 9, pp. 1585–1594, Sept. 2004.

[5] D. Huang and K. B. Letaief, "An interference-cancellation scheme for carrier-frequency offsets correction in OFDMA systems," IEEE Trans. Commun. vol. 53, no. 7, pp. 1155–1165, July 2005.

[6] Dr. Hermann Rohling, "OFDM Concepts for Future Communication systems ", ISBN 978-3-642-17495, DOI-10.1007/978-3-642-17496-4, Springer Heidelberg, Dordrecht, London, New-York, June 2010.

[7] Mark. Elo, "Orthogonal Frequency Division Multiplexing", Marketing Director of RF products, Keithley Instruments (White Paper)

[8] Yu Fu, Witold A Krzymien and Chintha Tellambura, "A Technique For Multiuser and Inter carrier Interference Reduction in Multiple Antenna Multiuser OFDM Downlink ", IEEE transactions on wireless Communications, pp, 3493-3497, vol.6, no.10, October 2007.

[9] Mohammed Safiqul Islam, Gouri Rani B and Atiq Mahmood, "Performance analysis of different modulation schemes using OFDM techniques in Rayleigh fading channel", International Journal of Fundamental Physical Sciences (IJFPS), Vol.1, pp. 22-27, March 2011.

[10] Dr. Mary Ann Ingram, "OFDM simulation using Mat lab", Smart Antenna Research Laboratory, Guillermo Acosta, August, 2000

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