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Analyzing µ-law Commanding and SQRT Techniques in OFDM systems

S.Chanti [1]& B.Suneetha [2]

sare.chanti511@gmail.com [1], suneetha@diet.edu.in [2]

[1, 2] Department of Electronics and Communications Engineering

Dadi institute of Engineering and Technology, Anakapalli, Visakhapatnam (A.P.)

Abstract:

An Orthogonal FDM (OFDM) method remains a multi carrier modulation as well as multiplexing scheme. OFDM system performance based on mu- law companding and square rooting companding techniques are analysed with CCDF characteristics and BER Performances. As the simulation results show that the SQRT OFDM System is very effective system to reduce the PAPR and is used to improve the BER performance rate than OFDM system with mu-law companding transform. Simulation results also prove that by modulating a signal at fixed subcarriers for different modulation technique, the error in the transmitted signal increases rapidly but in case of fixed modulation techniques, we are analyzing mu law and SQRT companding OFDM signal on M ary QAM modulation technique the BER in the transmitted data is constant and varies by a small fraction so the number of bits of modulation techniques should be kept constant sacrificing the higher data rate.

1. INTRODUCTION

An Orthogonal Frequency Division Multiplexing (OFDM) scheme remains a multicarrier modulation as well as multiplexing scheme which employs a similar processing method letting the synchronized broadcast of data arranged several thoroughly spread out, orthogonal sub-carriers. The distortion is the greatest enemy of all types of communication systems which is caused by the multipath fading channel. Multi path fading occurs in both domain i-e time domain as well as frequency domain. The multi path fading is greatly reduced an Orthogonal Frequency Division Multiplexing (OFDM). An OFDM is very extraordinary speeds data rates, these data rates are spilted into number of subcarriers. The OFDM has lot of advantages, spectral efficiency is very high, to reduce the impulse noise over the channel, robustness against co-channel interference and inter symbol interference. The loss of efficiency is caused by cyclic prefix or guard interval. The wavelet transforms are used to develop the effectiveness of OFDM scheme.

The FFT based conventional OFDM system are used to multiplexing the signals together and also decode the data symbol by the receiver respectively. The cyclic prefix is added before the transmitting signal, to evade the inter-symbol interference (ISI) in addition to inter-carrier interference (ICI). The cyclic prefix is nothing but periodic extension that is to increase the delay spread. But, the CP is reduced the spectral suppression of the channels. Ripple transforms are used to as the alternative platforms for replacing the FFT based OFDM system. Discrete wavelet transform is mainly used in the OFDM system. It has Low Pass Filter (LPF) plus High Pass Filter (HPF) functional as a Quadrature Mirror Filters technique it also satisfying perfect renovation as well as ortho normal bases properties. This is also called as sub-band coding subsequently these signals is distributed into sub-signals of low also high frequencies correspondingly. In wireless communication systems proposal the wave-lets require valuable applicability, by way of channel characterization, interference modification, modulation then multiplexing, numerous access communication, Ultra Wide-band(UWB) communication, cognitive radio in addition interacting [7].

The Discrete Wavelet Transform (DWT) is castoff in a multiplicity of signal processing solicitations, such by means of video compression, Internet communications compression, plus object recognition also numerical study [8].The resolution of that paper is to execute simulation results and compare on the wavelet based MIMOOFDM with Fourier based MIMO-OFDM. To improve the channel capacity of wireless communication system by the execution of Multiple-Input and Multiple-Output of the OFDM scheme. In order to improve signal quality and also increase the throughput and the spectral utilization of the bandwidth. . MIMO systems remain furnished with several numbers of antennas at both transmitters in addition receiver side to develop communication performance [8]. MIMO proposals a substantial progress in data throughput devoid of supplementary bandwidth requirement [8]. MIMO communication system is very attractive technique in wireless communication system. Space time block coding technique (STBC) is used to develop the diversity performance of the MIMO-OFDM system. Space time block coding can accomplish transmit diversity also power gain deprived of give up the bandwidth [13][14]. That paper is shared into three for most sections: section II will give details of conventional FFT based MIMO-OFDM, section III will give to in detail for DWT based MIMO-OFDM, and section IV will converse the bit error rate (BER) section of mutually transformed platforms

2. SYSTEM MODEL

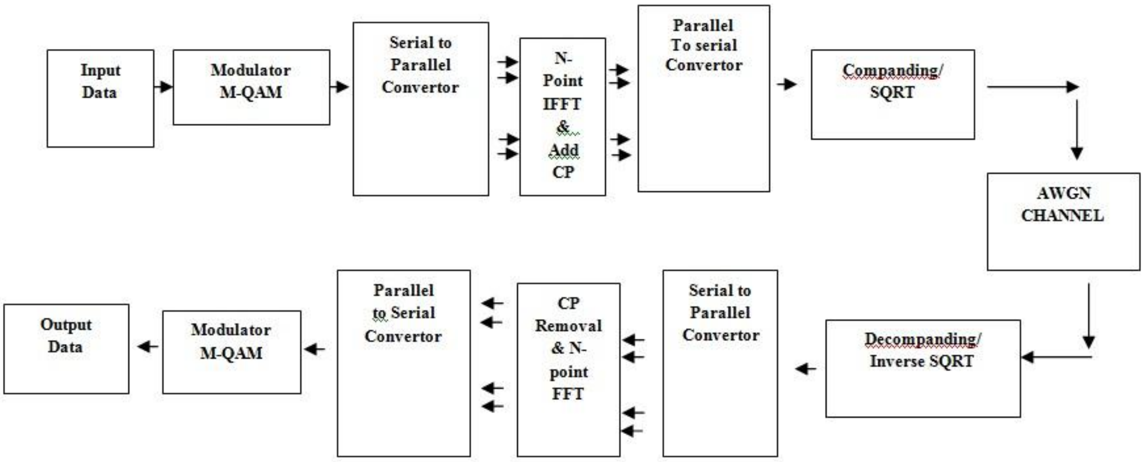

Fig 1. Block Diagram of the Project and its Discretion

2.1 Working Procedure

In OFDM, a block of N information symbols is transmitted in parallel on N subcarriers, An OFDM modulator can be implementation as an IFFT on a block of N information symbols followed by cyclic prefix (CP). The block diagram of OFDM system as shown in fig.1.

The receiver performs the inverse of the transmitter. First, the OFDM data are divided from a serial to parallel convertor. The Fast Fourier Transform (FFT) converts the time domain samples back into a frequency domain representation. The magnitudes of the frequency components correspond to the original data. Finally, the parallel to serial convertor block converts this parallel data into a serial stream to recover the original input data.

2.2 Additive white Gaussian noise (AWGN)

Additive white Gaussian noise (AWGN) is a basic noise model used in Information theory to mimic the effect of many random processes that occur in nature. The modifiers denote specific characteristics:

- 'Additive' because it is added to any noise that might be intrinsic to the information system.

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- 'White' refers to idea that it has uniform power across the frequency band for the information system. It is an analogy to the color white which has uniform emissions at all frequencies in the visible spectrum.
- 'Gaussian' because it has a normal distribution in the time domain with an average time domain value of zero.

Wideband noise comes from many natural sources, such as the thermal vibrations of atoms in conductors (referred to as thermal noise or Johnson-Nyquist noise), shot noise, black body radiation from the earth and other warm objects, and from celestial sources such as the Sun. The central limit theorem of probability theory indicates that the summation of many random processes will tend to have distribution called Gaussian or Normal.

AWGN is often used as a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density (expressed as watts per hertz of bandwidth) and a Gaussian distribution of amplitude. The model does not account for fading, frequency selectivity, interference, no nlinearity or dispersion. However, it produces simple and tractable mathematical models which are useful for gaining insight into the underlying behavior of a system before these other phenomena are considered.

The AWGN channel is a good model for many satellite and deep space communication links. It is not a good model for most terrestrial links because of multipath, terrain blocking, interference, etc. However, for terrestrial path modeling, AWGN is commonly used to simulate background noise of the channel under study, in addition to multipath, terrain blocking, interference, ground clutter and self interference that modern radio systems encounter in terrestrial operation.

Companding:

In these above block diagrams which have two companding techniques that is mu-law and SQRT technique, the companding its design to transmitting the frequency domain to time domain module, in this project work mostly used the mu-law & SQRT companding because this two techniques very useful to reduce the PAPR and BER.

Decompounding:

The decompounding is reverse process of the companding; this is reconstructing the original signal from the AWGN channel.

3. PAPR REDUCTION TECHNIQUEICS

The PAPR reduction methods have been proposed such as clipping, pre-coding, SLM, PTS, Tone Reservation (TR) and Tone Injection (TI). But Algorithmic based Companding (i.e., mu-law) and square rooting Companding (SQRT) has been suggested as simple and effective PAPR technique for OFDM.

3.1 mu-Law Companding

The µ-law algorithm (sometimes written "mu-law") is a companding algorithm, primarily used in 8-bit PCM digital telecommunication systems. Companding algorithms reduce the dynamic range of an audio signal. In analog systems, this can increase the signal-to-noise ratio (SNR) achieved during transmission; in the digital domain, it can reduce the quantization error (hence increasing signal to quantization noise ratio). These SNR increases can be traded instead for reduced bandwidth for equivalent SNR.

3.1.1 Algorithm

There are two forms of this algorithm—an analog version, and a quantized digital version.

3.1.2 Continuous:

For a given input x, the equation for µ-law encoding is[1]

$$F(x) = \mathrm{sgn}(x)\frac{\ln(1+\mu|x|)}{\ln(1+\mu)} \quad -1 \le x \le 1 \qquad \text{………………..} (1)$$

Where, $\mu = 255$ (8 bits) in the North American and Japanese standards. It is

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important to note that the range of this function is −1 to 1.

μ-law expansion is then given by the inverse equation:

$$F^{-1}(y) = \mathrm{sgn}(y)(1/\mu)((1+\mu)^{|y|} - 1) \quad -1 \leq y \leq 1$$ ……

……. (2)

The equations are culled from Cisco's Waveform Coding Techniques.

3.1.3 Usage justification:

This encoding is used because speech has a wide dynamic range. In the analog world, when mixed with a relatively constant background noise source, the finer detail is lost. Given that the precision of the detail is compromised anyway, and assuming that the signal is to be perceived as audio by a human, one can take advantage of the fact that the perceived acoustic intensity level or loudness is logarithmic by compressing the signal using a logarithmic-response operational amplifier (Weber-Fechner law). In telecommunications circuits, most of the noise is injected on the lines, thus after the compressor, the intended signal is perceived as significantly louder than the static, compared to an un-compressed source. This became a common solution, and thus, prior to common digital usage, the μ-law specification was developed to define an inter-compatible standard.

In digital systems this pre-existing algorithm had the effect of significantly reducing the number of bits needed to encode recognizable human voice. Using μ-law, a sample could be effectively encoded in as few as 8 bits, a sample size that conveniently matched the symbol size of most standard computers.

μ-law encoding effectively reduced the dynamic range of the signal, thereby increasing the coding efficiency while biasing the signal in a way that results in a signal-to-distortion ratio that is greater than that obtained by linear encoding for a given number of bits. This is an early form of perceptual audio encoding.

3.2 Square Rooting Compounding Technique (SQRT)

In numerical analysis, a branch of mathematics, there are several square root algorithms or methods of computing the principal square root of a nonnegative real number. For the square roots of a negative or complex number,

The SQRT –OFDM signals X_{SQRT} is processed by

$$X_{SQRT}=\sqrt{|x(n)|}\exp(j\phi n),\ 0 \leq n \leq N-1$$ …

………… (3)

Where,

X (n) is the n^th OFDM Output signal.

X_{SQRT} is the n^th SQRT- OFDM output signal.

ϕ_n is the phase of X (n)

In SQRT process, the real and imaginary part of X_n is denoted by $Re\{X_{SQRT}\}$ & $Im\{X_{SQRT}\}$, are independent & identically distributed Gaussian random variable with zero mean & a common variance. According to central limit theorem, so the amplitude (or) modulus of OFDM signal X_n is given by large number of input samples, the imaginary and real parts of IFFT outputs will follow Gaussian distributions.

$$|X_{SQRT}|=\sqrt{Re^2\{X_n\}+Im^2\{X_n\}}$$

… (4)

The power of OFDM signal can be expressed as,

$$|X_{SQRT}|^2= 1/N \sum_{m=0}^{N-1}\sum_{k=0}^{N-1} x(m)\,x(k)\exp\left(\frac{j(2\Pi(m-k))n}{N}\right)$$

……. (5)

Where,

$|X_{SQRT}|$ denotes the power value of SQRT-OFDM output symbol.

The relationship between the above two equations are random variables is reciprocal ,hence we could easily convert between the two by applying square operation of their samples (or) square rooting for opposite conversion. In SQRT-OFDM system, the phase of the OFDM output signals are kept unchanged while only the amplitudes of the OFDM signals are considered and changed. The impact of this SQRT operation on the average power is higher than that on the peak power value, which is always, leads to reduction in the PAPR value.

3.3 Clipping and Filtering

The clipping and filtering technique for PAPR reduction is one of the simplest techniques is being mostly used for getting reduce values of PAPR. The functioning clipping and filtering technique is clear from its name itself i.e. it clips the part of the signals which are not allowed to enter the specified region. The operation of clipping and filtering technique can be understood by using the HPA (High Power Amplifier) with saturation region below the signal space with automatically cause the signal to be clipped. For Amplitude clipping, that is

$$C(x) = \begin{cases} x, & x \leq A \\ A, & x > A \end{cases}$$

Generally, clipping is performed at the transmitter, however, the receiver need to estimate the clipping that has occurred and to compensate the receiver OFDM symbol accordingly. Typically, at most one clipping occurs per OFDM system, and thus the receiver has to estimate two parameters: location and size of the clip. However, it is difficult to get this information. Therefore, clipping method introduces both band distortion and out of band radiation into OFDM signals, which degrades the system performance de including BER and spectral efficiency. Filtering can reduce out of band radiation after clipping although it cannot reduce in-band distortion. However, clipping may cause some peak rergrowth so that the signal after clipping and filtering will exceed the clipping level at some points. To reduce peak regret, a repeated clipping and filtering operation can be used to obtain a desirable PAPR at a cost of computational complexity increase, As improved clipping methods, peak windowing scheme attempt to minimize the out of band radiation by using narrowband windows such as Gaussian window to attenuate peak signals.

3.4 Pre-coding

Pre-coding is a generalization of beam forming to support multi-stream (or multi-layer) transmission in multi-antenna wireless communications. In conventional single-stream beam forming, the same signal is emitted from each of the transmit antennas with appropriate weighting (phase and gain) such that the signal power is maximized at the receiver output. When the receiver has multiple antennas, single-stream beam forming cannot simultaneously maximize the signal level at all of the receive antennas. In order to maximize the throughput in multiple receive antenna systems, multi-stream transmission is generally required.

In point-to-point systems, pre-coding means that multiple data streams are emitted from the transmit antennas with independent and appropriate weightings such that the link throughput is maximized at the receiver output. In multi-user MIMO, the data streams are intended for different users (known as SDMA) and some measure of the total throughput (e.g., the sum performance or max-min fairness) is maximized. In point-to-point systems, some of the benefits of pre-coding can be realized without requiring channel state information at the transmitter, while such information is essential to handle the inter-user interference in multi-user systems. Pre-coding in the downlink of cellular networks, known as network MIMO or coordinated multipoint (CoMP), is a generalized form of multi-user MIMO that can be analyzed by the same mathematical techniques.

3.5 Selective Level Mapping

The paper that fabricated the "selective mapping technique" first was panned down by bamul, Fischer and Huber in 1996. SLM is one of the favorable reduction technique as it does not introduces distortion and yields effective PAPR reduction in OFDM system. In this technique the input data blocks are multiplied by each of the phase sequences to generate alternative input symbols sequence. Each of the alternative I/P data sequence is processed further under IFFT operation and then the signal with lowest PAPR is selected for transmission.SLM is a technique which is used to lessen the PAPR effect which is observed in OFDM systems.

4. SIMULATION RESULTS

To show the PAPR reduction capacity, BER performance of the mu-law and SQRT system is considered using 1024 subcarriers and different modulation techniques, such as QPSK and M array QAM(for example, M=64,128,356 M is modulation order), simulated by randomly generated date. Using QPSK, M array QAM modulation discreet signal is converted form, IFFT is chosen and divided into 1024 subcarriers for multiplexing. For the error rate Additive White Gaussian Noise (AWGN) is added with SNR 12db.

CCDF curves of 64 arrays QAM is shown fig.2. It can be notice that the PAPR obtained by the SQRT -OFDM system at CCDF 10^{-2} is reduced to about 5db reduction is PAPR obtained from the original OFDM system. Fig.3 shows BER v/s SNR for SQRT OFDM signal with 16, 64 and 128 Array QAM. Compared with mu law Companding, the SQRT Companding scheme has little spectral regrowth, which can increase the immunity of M-QAM OFDM signals from out of band noise.

PAPR is also measured for different number of N (up to 1024 subcarriers) using randomly generated date bits with 64 array QAM OFDM , the result of BER v/s SNR for Different mu factors is shows in fig.4. it is observed that as the number of subcarriers increased ,PAPR value increased. If more data were transmitted, the PAPR is increased. Therefore, the PAPR is depending upon the number of data considered in OFDM system. The performance of BER is degraded with the value of μ is increased. By keeping a fixed number of subcarriers (N=1024) and increasing the mu law companding factor (μ=6, 8, 10 are taken for example) from fig.4 it can be seen that the BER increases rapidly by increasing μ factor. I.e. BER at μ factor =10 is higher than the BER at μ factor=8.

The error relation curve which shows that the BER increases rapidly by increasing SNR. It is clear that the BER is smaller using 16 array QAM modulation techniques rather than 64 and 128 array QAM, by increasing the number bits. It can be seen that by keeping a fined M array QAM modulation ($M=2^6$ I.e. 6 bit are take for example) and increasing subcarrier the BER is not increasing rapidly. The error at each subcarrier changes in small fractions while keeping the number of its constant.

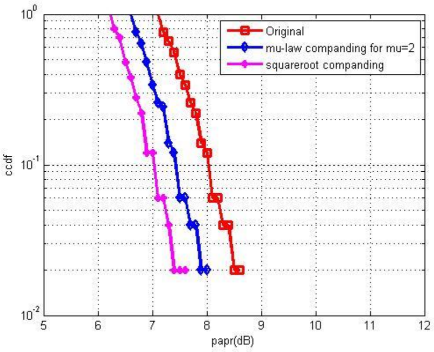

Figure 2. classified Original, mu-law and square root companding signals

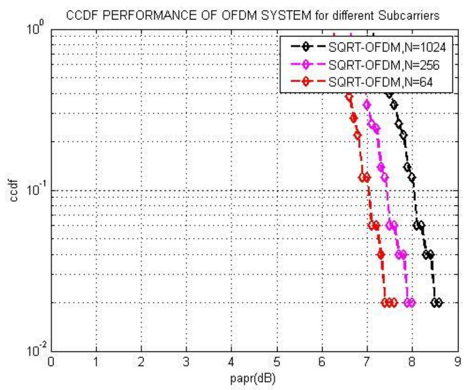

Figure 3. CCDF performance of OFDM system for different subcarriers in SQRT companding

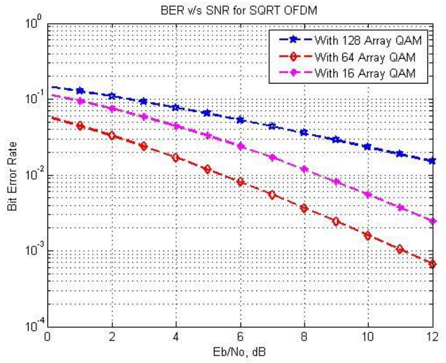

Figure 4. BER v/s SNR for SQRT OFDM signal with 16, 64 and 128 Array QAM

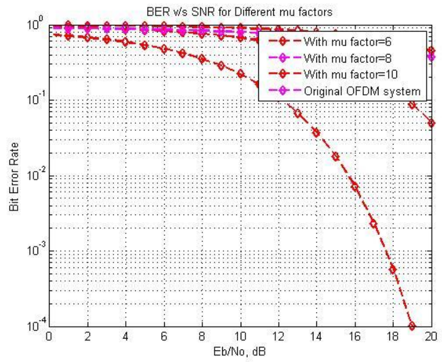

Figure 5. BER v/s SNR for Different mu factors

5. CONCLUSION

In this paper, OFDM system performance based on mu-law companding and square rooting companding techniques are analyses with CCDF characteristics and BER performances. As the simulation results show that the SQRT OFDM system with mu-law companding transform. Simulation results also prove that by modulation a signal at a fixed subcarriers for different modulation technique, the error in the transmitted data increases rapidly whereas in case of fixed modulation techniques, increasing the number of subcarriers the PAPR increases at the transmitter whereas the BER in the transmitted data is constant and varies by a small fraction. Therefore the number of bits in modulation technique should be kept constant sacrificing the higher data rate.

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