BER with different modulation schemes in OFDM System

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***Abstract* - Bit error rate (BER) is common problem in OFDM transmission. This paper investigates the effects of companding technique to improve the bit error rate (BER) of Orthogonal Frequency Division Multiplexing (OFDM). Companding technique with QPSK, DQPSK and BPSK modulation is used to calculate the bit error rate (BER). Show that here companding technique using QPSK modulation gives better performance in BER as compare to DQPSK and BPSK modulation. This companding model is very efficient to gives the better bit error Rate in OFDM System. In this paper, evolution of performance of A-law and µ-law companding technique is compared in terms of bit error rate (BER).Computer simulations, which consider an baseband OFDM system with Additive White Gaussian Noise (AWGN) channel show that the proposed companding scheme as a function of A and µ can offer better Bit-error-Rate (BER).**

***Keywords* - BER, OFDM, A-law and µ-law companding, AWGN, QPSK.**

I. Introduction

OFDM has been widely applied in modern wireless networks due to its advantages: high spectrum efficiency in supporting broadband wireless communications [1], lower implementation complexity compared with single carrier solution [2] and immunity to the interference caused by multipath fading channels [3]. Therefore, OFDM is believed to be a suitable technique for broadband wireless communications and has been used in many wireless standards, such as Digital Audio Broadcasting (DAB)[4], Terrestrial Digital Video Broadcasting (DVB-T)[5], the IEEE 802.11a standard for Wireless Local Area Networks(WLAN)[6] and IEEE 802.16a standard for Wireless Metropolitan Area Networks (WMAN).

OFDM can be implemented efficiently by using fast Fourier transforms (IFFTs and FFTs) at the transmitter and receivers end, respectively. When OFDM signal passes through high power amplifier (HPA), it increases the dynamic range of digital-to-analog converter (DAC) and creates the problems of spectral broadcasting, which results in high cost and reduced efficiency [7]. Because of the spectral broadcasting, in-band distortion and out-band radiation occurs. Performance degradation in system and adjacent channel interference (ACI) [8] that affects system working in neighbor band are the eventual effects of these two problems.

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As a result of the whole problem bit error rate (BER) performance degrades. As recognized, by most publications on companding, many authors have investigated further alternative approaches to conventional companding techniques for improving BER some are as follows in table (1):

TABLE 1. BER PERFORMANCE DEGRADATION

Author	Modulation	Method	BER level at SNR (in dB)
A.N.Jadhav,M. V.Kutwal[4]	QPSK	µ-law and Exponential Companding	10^{-4} at 11 dB
V.N.Sonawane, S.V.Khobragade [6]	QPSK	A-Law companding,µ-law Companding	10^{-3} at 27.3 to 28 dB
Subaha Mahamuda ,T.N. Haque Feroz Ahmed[8]	QPSK	Adaptive, Single, Double Companding	10^{-3} at 26, 27 and 30 dB
B.G.Stewart, A.Vallavaraj[9]	QPSK /64 QAM	µ-law Companding	10^{-4} at 16 dB
P.P.Patil, V.B.Malode	QPSK,DQPSK, BPSK	A-Law companding,µ-law Companding	$10^{-4.5}$ at 16 dB

To overcome this severe problem of OFDM system, many techniques have been proposed so far. In this the use of companding technique shows better performance than the clipping technique, because the inverse companding transform (expanding) can be applied at the receiving end to reduce the distortion of signal. Non-uniform amplification of signals of all amplitude increases the signal strength that helps the signal to attain better BER performance. This paper therefore investigates the influence and effects on BER for companded OFDM transmissions as a function of: the companding coefficient A, µ.Simulation results have shown that our companding scheme could offer better system performance in terms of BER than other author as shown in Table (1).

This paper structured as follows. Section II presents the numerical formulation and Simulink model of BER for OFDM and A-law and µ-law companded OFDM signals. Section III describes briefly the technique of companding to improve BER performance using simulation results. Section IV is a conclusions section and summarizes the main results from the paper.

II. PERFORMANCE OF COMPANDING SYSTEM

In companding, the OFDM signal is compressed at the transmitter and expanded at the receiver. Companding improves the quantization resolution of small amplitude signals at the cost of lowering the quantization resolution of large signals. This also introduces quantization noise,

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however, the peaks is relatively small as the as the peaks occur less frequently. The companding algorithm as described by [9] amplifies the signals of lower amplitude with the peaks remaining unchanged [10].

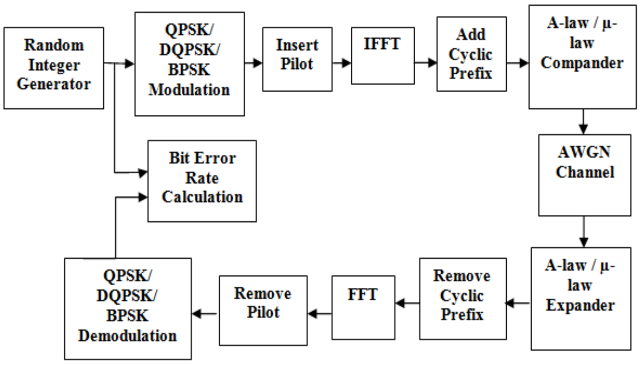

Fig.1 Block diagram of the model used for the BER measurement.

All computations and simulations of BER are undertaken using Matlab. Fig.1 depicts conceptual block diagram of the model used for the measurement of companded and general OFDM signals. As is often the practice, to minimize spectral interference in OFDM signals, as suggested by Li and Cimini [11], oversampling by a factor of 8 is performed by padding zeroes to the baseband modulated signals.

The instantaneous amplitude of a baseband OFDM signal comprising N frequency tones derived from the output of an IFFT can be written as

$$x(t) = \sum_{n=0}^{N-1} X_n expj(\Phi_n + \frac{2\pi nt}{N}) \quad (1)$$

Where $X_n expj\Phi_n$ is the n^{th} complex baseband symbol of amplitude X_n and phase Φ_n and N is the no. of subcarriers in the OFDM system. The instantaneous OFDM envelope power developed across 1Ω impedance is given by

$$P(t) = |x(t)|^2 = \sum_{n=0}^{N-1} X_n^2 + 2\sum_{n=0}^{N-2}\sum_{m=n+1}^{N-1} X_n X_m \cos\psi_{nm} + 2 \quad (2)$$

Where ψ_{nm}- (Φ_n-Φ_m+2π (n-m) t/N). The average OFDM envelope power, defined as the expectation value of the instantaneous OFDM envelope power is given by,

$$P_{avg} = E\{|x(t)|^2\} = E\{\sum_{n=0}^{N-1} X_n^2 + 2\sum_{n=0}^{N-2}\sum_{m=n+1}^{N-1} X_n X_m \cos\psi_{nm}\} \quad (3)$$

Where E {.} is the expectation value. If the symbols on different subcarrier are assumed to be independent, then $E(X_nX_m)=E(X_n).E(X_m)$. For orthogonal signals, the second term in (3) reduced to zero.[9] Therefore, the average power of the OFDM signal is given by

$$P_{avg} = E\{|x(t)|^2\} = E\{\sum_{n=0}^{N-1} X_n^2\} \quad (4)$$

For M-PSK symbols, as magnitude of symbols is unity, the instantaneous envelope power given in (2) reduces to

$$P(t) = N + 2\sum_{n=0}^{N-2}\sum_{m=n+1}^{N-1}\cos\psi_{nm} \quad (5)$$

Similarly, the average power of an M-PSK OFDM signal, using (4) reduces to

$$P_{avg} = \{\sum_{n=0}^{N-1} X_n^2\} = N \quad (6)$$

The OFDM signals are then obtained by taking the IFFT. Additive White Gaussian Noise (AWGN) channel is used as the noise channel. The IFFT modulates a block of input modulation (QPSK) values onto a number of subcarriers. In the receiver, the subcarriers are demodulated by the FFT, which is the reverse operation of the IFFT. These two operations are almost identical. In fact, the IFFT can be made using an FFT by conjugating input and output of the FFT and dividing the output by the FFT size. The length has been taken to be 256. OFDM systems use cyclic prefix insertion to eliminate the effect of Intersymbol Interference (ISI) and require a simple one-tap equalizer at the receiving end. OFDM brings in unparalleled bandwidth savings, leading to higher spectral efficiency. These properties make OFDM system extremely attractive for high speed wireless applications.

In OFDM systems different modulation schemes can be used on individual sub-carriers which are adapted to the transmission conditions on each sub-carrier. To deal with the problem of an OFDM signal cyclic-prefix (CP) insertion is typically used. Cyclic-prefix insertion implies that the last part of the OFDM symbol is copied and inserted at the beginning of the OFDM symbol. Cyclic-prefix insertion is thus increases the length of the OFDM symbol duration from *T*S to *TS* + *T*CP, where *T*CP is the length of the cyclic prefix, a time interval *T*S. Cyclic prefix insertion also avoids inter block interference (IBI).The µ-law and A-law are the two most popular compressing functions used worldwide. The term additive means the noise is superimposed or added to the signal that tends to obscure or mask the signal where it will limit the receiver ability to make correct symbol decisions and limit the rate of information transmission.

A. A-law Companding

For two positive or negative chords near zero volts, A-law companding has equal voltage weighting per step. Companding schemes deal with the data bit format. A-law inverts the least significant bit (LSB) and every other bit, leaving the sign bit unchanged relative to a conventional binary code. A-law companding used as European standard [12]. In A-law companding, for a given input x, the curve is divided into two sections, viz. linear and logarithmic. Compression is performed according to the well known A-law viz.

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$$y = V\frac{\log(1 + A\frac{|x|}{V})}{\log(1 + A)}\, sgn\,(x) \qquad (7)$$

Where V is the peak amplitude of the input and output signals specified for the A-law compander (Constant with a standard value of 87.6) and x is the instantaneous amplitude of the input signal. Decompression is simply the inverse of Eq. (7).

B.µ-law Companding

The step weighting voltage for chord zero is one-half the step weighting voltage for A-law chord zero. This reduces the A-law resolution for small signals near the voltage origin. One more companding scheme is µ-law companding. It is used as a standard scheme in North America and Japan. µ-law maintains positive polarity for the sign bit with all of the magnitude bits inverted. Compression is performed according to the well known µ-law in (8)

$$y = V\frac{\log(1 + \mu\frac{|x|}{V})}{\log(1 + \mu)}\, sgn\,(x) \qquad (8)$$

Where V is the peak amplitude of the input and output signals specified for the µ-law compander (Constant with a standard value of 255) and x is the instantaneous amplitude of the input signal. Decompression is simply the inverse of (8).

III. Simulation Results

To show the BER performance of the A-law and µ-law companding technique, an OFDM system using QPSK, DQPSK and BPSK modulation scheme, based on randomly generated data is considered. The BER performance is evaluated to analyze the system degradation. A BPSK modulation (M = 2) is the most robust of all the PSKs since it takes the highest level of noise or distortion to make the demodulator reach an incorrect decision. It is, however, only able to modulate at 1 bit/symbol so is unsuitable for high data-rate applications.

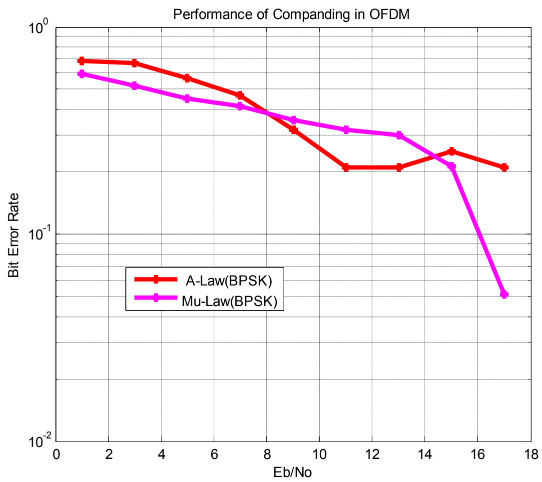

Fig.2 A-Law and µ-law Companding method using BPSK modulation

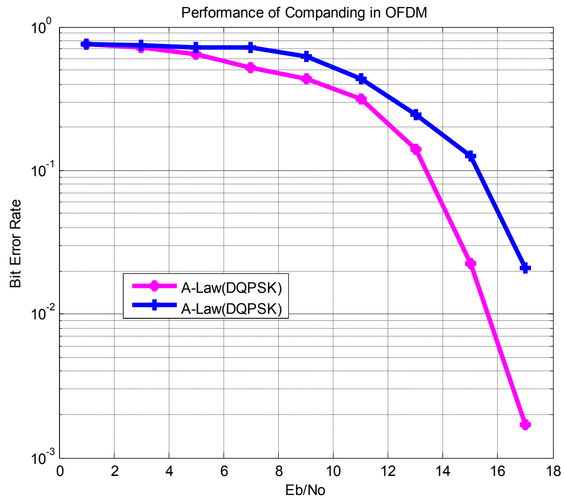

Fig.3 A-Law and µ-law Companding method using DQPSK modulation

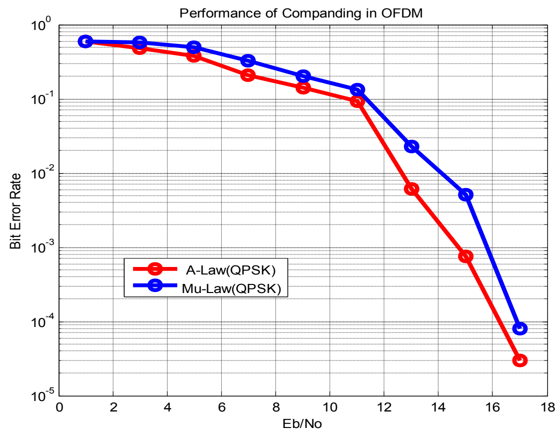

Fig.4. A-Law and µ-law Companding method using QPSK modulation

Fig.2 and Fig.3 reveals the performance of BER of an OFDM signal using BPSK modulation it is found that to achieve BER level of $10^{-1.5}$ for A-law companding and less than 10^{-1} for µ-law companding and using DQPSK modulation for A-law companding it is found that to achieve BER of 10^{-3} and for µ-law companding BER level is less than 10^{-2}. So, after comparison it is proved that In Fig.4 A-Law Companding technique is better than µ-Law Companding using QPSK modulation.

A QPSK is one example of M-ary PSK modulation technique (M = 4) or DQPSK (M=4) where it transmits 2 bits per symbol. The phase carrier takes on one of four equally spaced values, such as 0, π/2, π and 3π/2, where each value of phase corresponds to a unique pair of message bits as shown in Fig.(1).The implementation of QPSK is more general than that of BPSK and also indicates the implementation of higher-order PSK.

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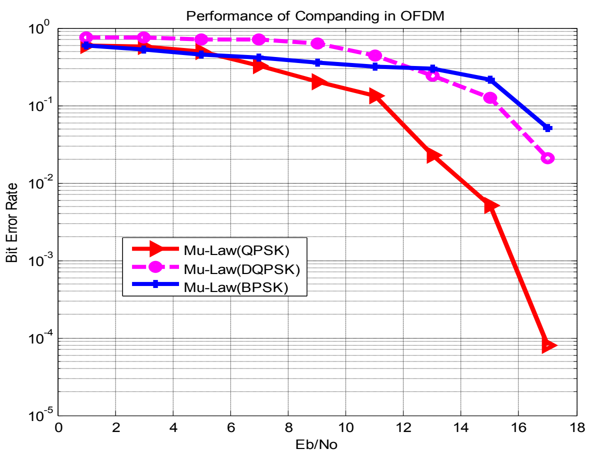

Fig.5 μ-Law Companding method using QPSK, DQPSK and BPSK Modulation

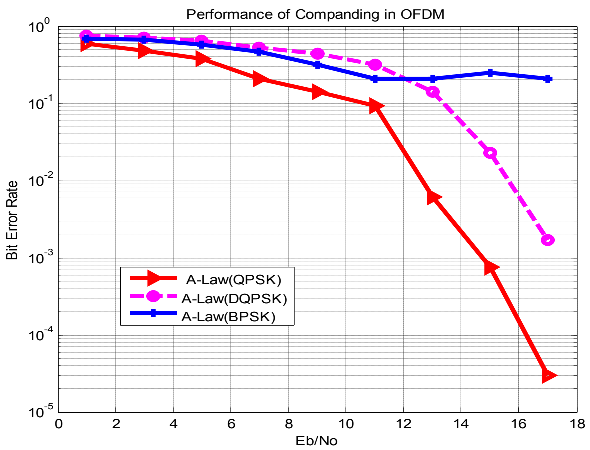

Fig.6 A-Law Companding method using QPSK, DQPSK and BPSK modulation

The *x* axis represents the signal to noise ratio in the OFDM signal and y-axis denotes the bit error rate of the OFDM signal.Fig.5 and Fig.6 reveals the performance of BER of an OFDM signal of A-law companding, μ-law companding with QPSK, DQPSK and BPSK modulation at $10^{-4.5}$, 10^{-3}, 10^{-2} respectively.Fig.7 depicts the BER performance versus Energy-per-bit to Noise power ratio (E_b/N_o) curves using different methods over PSK modulation with AWGN channel. As a benchmark, the curve of the ideal performance bound is also provided. As it is apparent, while using companding, the BER performance is however degraded at the receiver.

All BER curves of the companded signal are located at the right of the ideal bound. As can been observed in Fig.7, to reach a BER level of $10^{-4.5}$, for example, the required E_b/N_o for the proposed scheme with A-law companding is 16 dB, which is about 1 dB to 2.5 dB superior to others. As expected, since the power of transmitted signal has been reallocated more reasonably, the impact of companding distortion on the BER performance can be effectively reduced. In this work by compressing large signal along with partially enhancing small one simultaneously, the power distribution of the comapnded signal can be reallocated more reasonably.

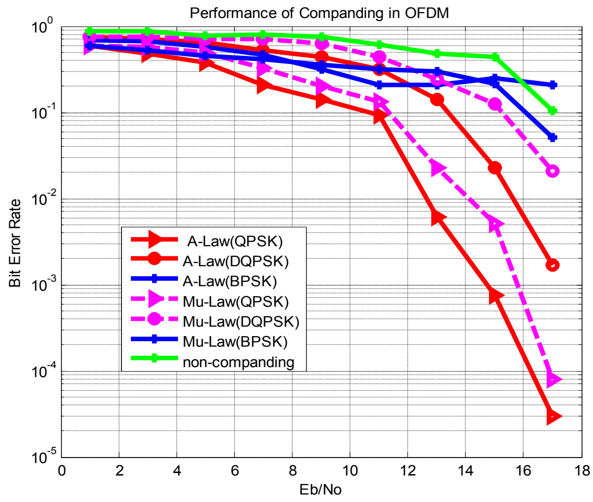

Fig.7 A-law and μ-Law Companding method using QPSK, DQPSK and BPSK modulation

IV. CONCLUSION

The moderate BER performance degradation is critical challenge for companding method in OFDM system. It is proven that with appropriate selection of the companding method, a significant BER performance can be offered to satisfy various design requirements. The OFDM system performance is simulated by using A-law, μ-Law and non-Companding. Companding technique show better performance in comparison with different modulation technique. It observed that the value of SNR increases with decreasing BER using QPSK modulation as compare to other modulation shown in Fig.5 and Fig.6. It is conclude that by choosing the appropriate value of A-law and μ-law, one get the desired BER value. Further, it is found that to achieve BER of $10^{-4.5}$ for A-law companding as shown in Fig.7. So, after comparison it is proved that A-Law Companding technique is better than μ-Law Companding. Also, it is better to use QPSK modulation than DQPSK and BPSK modulation.

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