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Evaluation of MC-CDMA Using Non Adaptive Pre Distortion Algorithm

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ABSTRACT

"Multi-Carrier Code Division Multiple Access (MC-CDMA) is one of the suitable choice to achieve high data rate for next generation wireless communication system. MC-CDMA is the combination of CDMA and OFDM schemes, resulting into getting the advantages of both the schemes. MC-CDMA is a better technique to improve the performance over multipath links. In this dissertation, Non-adaptive Pre distortion Algorithm technique will be demonstrated to linearise the gain of a High Power Amplifier. Clipping noise is produced in high power amplifier system due to non linear gain. This clipping noise affects the BER of the system. Hence by above technique the gain will be linearised and BER will improve. The performance of BER is evaluated using a MATLAB simulation and the results are promising. The simulation results shows that in proposed system, as increasing the number of subcarriers and number of users, there should be increase in peak to average power ratio (PAPR)".

1. Introduction

Wireless communications is an emerging field, which has seen enormous growth in the last several years. The spectacular growth of video, voice and data communication over the Internet and the equally rapid pervasion of mobile telephony, justifies great expectations for mobile multimedia. Due to this growth of multimedia communication, the users demanded high date rate communication systems in wireless environment where the spectral resource is scarce. To fulfil the requirements new technologies like Code Division Multiple Access and Orthogonal

Frequency Division Multiplexing (OFDM) are few promising systems for the 4G communication standards [1].

CDMA achieves soft capacity limit by using the same bandwidth all time by assigning different spreading codes to each user. The only limitation is the self interference and multiuser interference [1, 2]. One of the reasons for this impairment is contributed by the channel.

Orthogonal Frequency Division Multiple Access (OFDM) is another technology adopted by the digital broadcasting society to counter the Inter Symbol Interference (ISI) problem. The fusion of OFDM and CDMA has yielded MC-CDMA which applies the spreading sequences in the frequency domain.

Unique codes are used to distinguish different users using same frequency band is the basic idea behind CDMA. This led to an achievement of soft capacity with limitations only imposed by self interference and Multiple User Interference (MUI) [1]. Thus the channel characteristics and spreading code characteristics which are responsible for the above interference should be taken care to increase the capacity. The other advantages are the soft handoff and unity frequency reuse factor.

Conventional analysis of the effects of clipping on a multi-carrier signal treats the distortion caused by clipping as additive Gaussian noise, with variance equal to the energy of the clipped portion of the composite waveform. This approach is reasonable if the clipping level is set sufficiently low to produce several clipping events during an OFDM symbol interval. In most realistic cases, however, particularly when the desired error probability is low, the clipping level is set high enough such that clipping is a rare event, occurring more infrequently than once every symbol interval. Clipping under these conditions then forms a kind of impulsive noise rather than a continual background noise, leading to a very different type of error mechanism.

Besides, the conventional additive noise model offers no spectral characterization of the nature of the distortion, i.e. the interference between adjacent bands that arises as a result of clipping. An alternate approach presented by some author seeks to factor in the effect of this spectral leakage by considering the power spectral density (PSD) of the distortion component (which can be computed, for example, by taking the Fourier transform of its autocorrelation function). However, note that any technique that involves such spectral estimation would imply an inherent statistical averaging. Therefore, once again, such estimation cannot accurately reflect the instantaneous or impulsive nature of the clipping process.

2. MC-CDMA-OFDM SYSTEM

2.1 Block Diagram

MC-CDMA transmitter is similar to OFDM transmitter but there is very small difference between them. In OFDM different symbols are transmitted by subcarriers but in MC-CDMA same symbol is transmitted by different subcarriers. The explanation of the above concept is clearly shown in Fig 2.1.

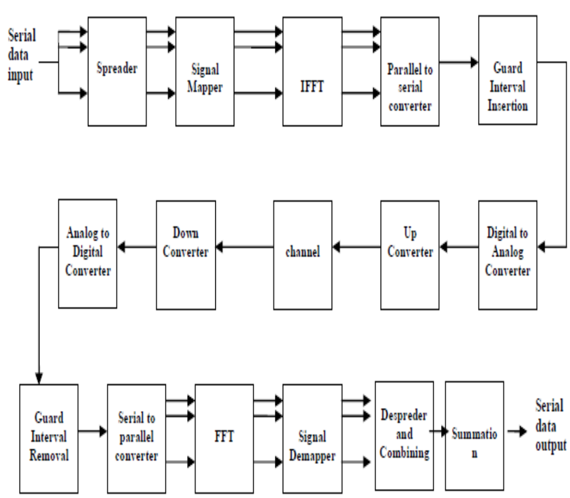

Fig 2.1 CDMA OFDM Block Diagram

2.2 Transmitter Hardware

The OFDM system associated with the CDMA system converts the symbols to time domain samples by Inverse Fast Fourier Transform (IFFT) and assigns a subcarrier for each symbol. Then the subcarriers are multiplexed to form as a serial stream. Before transmission, the serial stream is converted to blocks and each block is separated by a guard frame. The guard frame is usually a zero symbols or known symbols. In OFDM, the guard symbols are cyclic prefix of the block where a part of the symbols belonging to a block is appended which has various advantages.

2.3 CDMA Receiver
The receiver consists of a bank of M_f matched filters followed by MRC. Each of the received modulated sub band carriers is first passed through a band pass chip-modulated filter $H^*(f)$, then coherently demodulated, sampled, dispread and summed, all these operations assume that the receiver is correctly phase and time synchronized at every branch. We denote by $X(f)=H(f)H^*(f)=|H(f)|^2$ the overall frequency response of the chip wave shaping Nyquist filter and assume that X(f) is a root-cosine frequency response given by [3]

With $W=1/T_c=1/(M_fT_c)$ for multicarrier and $W=1/T_c$ for single carrier

3. Clipping Noise
3.1 Effect
The OFDM uses High Power Amplifiers (HPA) which are usually non linear for targeting high efficiency. This amplifier however does not have equal gain throughout the frequency range. This leads to clipping of few symbols and usually called as clipping noise. This makes OFDM to suffer from spectral spreading and In-Band distortion. This clipping noise reduces spectral efficiency and BER performance. One of the solutions is using Golay Sequences for small number of users and Walsh Hadamard sequences for high number of users. The modeling of the clipping effect on the OFDM signal is shown for a distorting system with characteristics denoted as f(x)[27]. Let x(k) be the discrete OFDM signal in time domain which follows the complex Normal distribution with equal variance $P_x/2$.. When this signal is passed through a clipping amplifier, the resultant will be of two components. One component will be the signal itself and the other is the distorted component.

3.2 Description
Orthogonal frequency division multiplexing (OFDM) [6] is an attractive multicarrier modulation for high-speed wireless access in multipath fading environments. Further, OFDM signals exhibit a large peak to mean envelope power ratio which requires a highly linear power amplifier; otherwise, the signal may suffer from significant spectral spreading and in-band distortion. Many alternative solutions have been proposed to reduce the PMEPR of OFDM signals. Clipping the OFDM signal in the digital part of the transmitter seems to be the simplest method [7]. However, digital clipping suffers from three problems: in-band distortion, which reduces the bit error rate (BER) performance [2], out-of-band radiation, which degrades the spectral efficiency and peak re-growth after digital to analog conversion, which results in an increase of PMEPR.

Finally, considering the out-of-band radiation of the clipped signal, we will show through extensive simulations that it is not necessary to preserve all the out-of-band radiation caused by clipping. It will be shown that by increasing the system bandwidth by 1.25 to at most 2 times, we can improve the BER performance while lowering the clipping threshold value. The improvement becomes more significant for higher signal to noise ratio (SNR) values when the major part of BER [3] is due to clipping noise rather than the channel noise. While we were developing this thesis, we found that Henkel has suggested the RS decoding method to reconstruct the clipped samples in multicarrier systems for high values of SNR of 50 dB, and also without removing the out-of-band radiation of the signal. However, we propose the least square, decoding instead of RS decoding to have a more robust method against channel noise. We also investigated the tradeoff between bandwidth expansion and BER improvement. This thesis is organized which introduces the OFDM signals and PMEPR factor to measure the amplitude fluctuation and then describes a typical system of interests.

4. Non Adaptive Pre Distortion Algorithm
Typically, linearity is achieved either by reducing efficiency or by using linearization techniques. For a Class A PA, simply 'backing off' the input can improve linearity, but this reduces power efficiency and increases heat dissipation. When considering the vast numbers of base stations wireless operators need to account for, increased power consumption is not a viable tradeoff. Not all linearization methods are equal. One method, known as feedforward technique, is frequently employed. Feedforward technique generally provides good linearity, but it results in poor PA efficiency. All linearization methods are limited in their maximum correctable range, which is region of power output level near the onset of saturation. In this article, a promising linearization method, known as pre distortion technique is used.

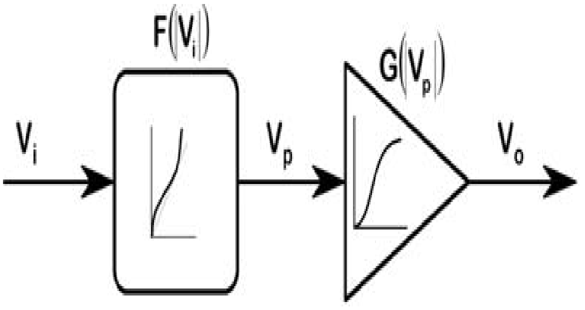

Fig 4.1 Pre distorter followed by a power amplifier

The Predistortion principle is extremely simple and has given its name to the technique. The idea is to preprocess, or predistort, the signal applied to the Power Amplifier, rather than trying to improve the Power Amplifier itself.

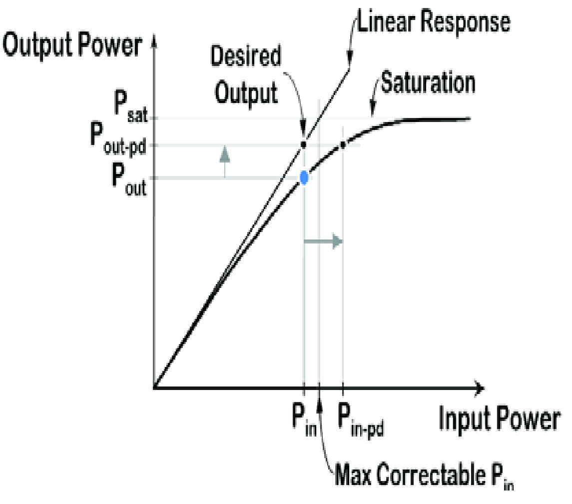

Fig 4.2 Power amplifier input v/s output

The developed pre distorter uses static values for the PA transfer function, defined using the Saleh model. Using the model, following equation (4.1) defines the input to the PA.

$$x(t) = r(t)\cos[\omega_0 t + \varphi(t)] \qquad (4.1)$$

where r(t) and ψ(t) are the normalized amplitude and the phase of the input signal, respectively. Equation (4.2) used to define the magnitude of the PA output A [r(t)] in response to the normalized input magnitude or the AM-AM characteristics [2].

$$A[r(t)] = \frac{\alpha_a r(t)}{1+\beta_a r(t)^2} \qquad (4.2)$$

Equation (4.3) used to define the PA output phase Φ[r(t)] in response to the normalized input magnitude, or the AM-PM characteristics.

$$\varphi[r(t)] = \frac{\alpha_\varphi r(t)^2}{1+\beta_\varphi r(t)^2} \qquad (4.3)$$

In above equation α_a, β_a, α_φ and β_φ are the coefficients which produced the best fit model of the measured amplifier characteristics. The final output of the PA, y(t), was then defined by following equation.

$$y(t) = A[r(t)]\cos\{\omega_0 t + \varphi(t) + \emptyset[r(t)]\} \quad (4.4)$$

Above equations are used to create arrays of values for the PA characteristics. The digital input was randomly generated. The pre distorter found the ideal output for any given input by multiplying the input by a constant which defines the linear gain in the model. Once the ideal output was determined, the AM-AM and AM-PM arrays were used to find the appropriate magnitude and phase of the input to the PA to achieve the desired linear gain and constant phase shift. The magnitude was determined by searching the AM-AM index i for the closest value to the desired linear gain and returning the input value at that index point [2]. To determine the input phase, the AM-PM output value at that same index point was subtracted from the actual input phase, resulting in a zero phase shift through the system. Having determined the input magnitude and phase, the signal was then separated into the in-phase and quadrature signals. By separating the vector of input magnitude and phase into its Cartesian components, first the I signal is determined using above equation.

$$I_{PD}(i) = \frac{P_{in}(i)}{\sqrt{1+\tan(\theta(i))^2}} \qquad (4.4)$$

$I_{PD}(i)$ is the predistorted I signal where $P_{in}(i)$ and $\theta(i)$ are the magnitude and phase of the input signal respectively. The predistorted Q signal can be calculated using following formula.

$$Q_{PD}(i) = \sqrt{P_{in}(i)^2 - I_{PD}(i)^2} \qquad (4.5)$$

The predistorted I and Q signals are then ready to be analyzed. Figure 4.3 displays a block diagram of the described predistortion algorithm.

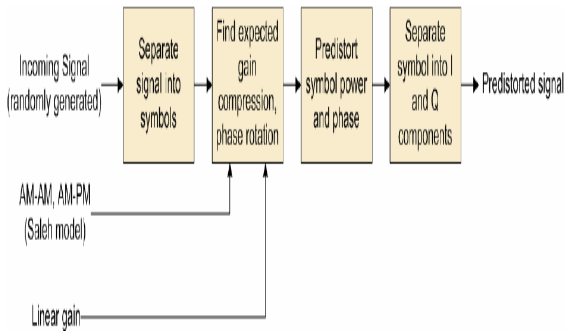

Fig 4.3 Predistortion Algorithm Block Diagram

The above technique will be used to perform the pre distortion and the following block diagram shows its flow.

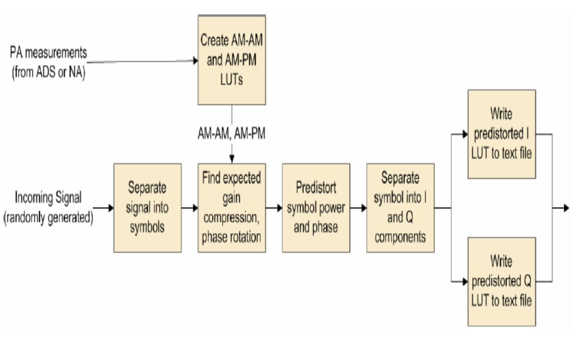

Fig. 4.4 Predistorter System

Pre distorter system allows the user to enter S-parameter measurements from a network analyzer or values exported from an Advanced Design System (ADS) model of the PA, instead of relying on the Saleh model. The algorithm uses the PA measurements to calculate the expected gain compression and phase rotation for each symbol, with *n* possible values for *n*-QAM. Each symbol is then pre distorted by compensating for the expected nonlinearities as described in this section. Each pre distorted symbol is separated into 16-bit I and 16-bit Q components which are stored in arrays.

5. Simulation Results

Bit error rate (BER) of a communication system is defined as the ratio of number of error bits and total number of bits transmitted during a specific period. It is the likelihood that a single error bit will occur within received bits [2].

It is essential to analyze the Bit Error Rate which is an important factor for reliable data communication. The improvement in the linearity of the above high power amplifiers result is better gain ratio than in normal conditions. Due to this the Signal to Noise Ratio (SNR) or the Energy per bit to the Noise Ratio (E_b/N_o) also improves and hence results in better BER.

The clipping noise results due to non linear gain of high power amplifiers and as a result, during the transmission some symbols get clipped. These clipped symbols can be saved by using the above technique.

The following figure shows a plot of BER versus E_b/N_o for all the above amplifiers mentioned above viz. HLZ 42W, HMC 308, HMC 474.

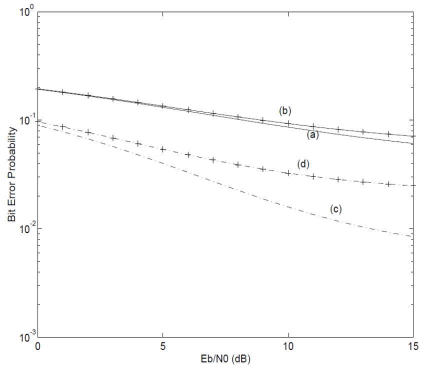

Fig 5.1 Plot of BER versus Eb/No before Predistortion.

The graph shows BER response for HMC 308, ZHL-42, HMC 474 at 3.3 V and HMC 474 at 5 V as (a),(b), (c) and (d) respectively. The above graph is plotted before the predistortion is applied to the system. It can be noted that at (E_b/N_o) of 10 dB the HMC 474 at 3.3 V has a better BER than the other three PAs. Then, the predistortion technique is applied to the system and again a graph of BER versus (E_b/N_o) is being plotted. The result is shown in following plot.

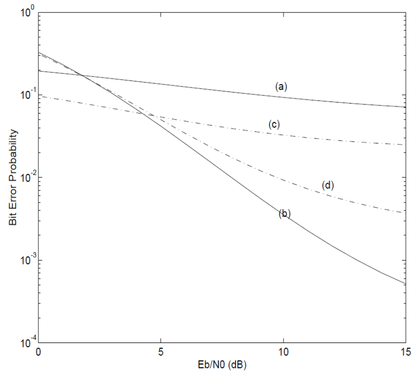

Fig 5.2 Plot of BER versus Eb/No after Predistortion.

It can be observed from the above graph that when predistortion technique is applied the BER of ZHL 42W shows a rapid improvement than the other three PAs. At a (E_b/N_o) of 10 dB BER is nearly 10^{-3} which can create a major change in the performance of the system. Hence, it can be said that using predistortion technique BER of the system improves and helps in reducing clipping noise which is our main concern.

The performance of MC-CDMA system would be affected by clipping noise introduced from the High power amplifier. The clipping noise causes significant spectral leakage (out of band

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interference) and degraded Bit error rate performance. T he operating point of HPA is defined by input backoff(IBO) parameter which corresponds to the ratio of saturated output power(Po) and the average input power(Pav) which is given by:

IBO = 10 log10 (Po/Pav) dB (20)

The normalized minimal signal to noise ratio is given by:

(SNR)o = 10 log10 (Po Tb/ No) dB (21)

which is needed to achieve the required BER. Tb is the equivalent duration of one information bit, No is the two sided spectral noise density and Po is the given reference power of HPA. The SNR can be minimized by optimization of HPA backoff.

6 Conclusion

Here, In this paper We have represented the overview of clipping noise reduction technique for MC-CDMA system. To reduce Clipping noise, the Non adaptive pre distortion algorithm is used to assist bit error rate and non linearity problem in MC-CDMA affected by clipping noise. The simulations are done using ADS system and MATLAB. It has been shown that the Non adaptive pre distortion procedure is a suitable candidate for the BER and non linear problem.

7 Future Scopes

The above technique is an effective technique which if used can prove to be a useful means of transmitting the data with a higher level of reliability. If deployed commercially then the power requirements of the CDMA transmitters can be reduced to lower level. At the receiver side, the power requirements reduce to demodulate the incoming signal and hence design can be reduced in size.Also a further improvement can be made using different PA.

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