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PAPR Reduction using PTS, Companding and Cultural Algorithm

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Abstract – **Communication is very important aspects of life. With the advancement in age and its growing demands, there has been rapid growth in the field of communications. Initially the signal was sent in the analog domain but today signals are sent in the digital domain. For better transmission, even single carrier waves are being replaced by multi carriers. Multi carrier systems like OFDM is now a day's being implemented commonly. In the OFDM system, orthogonally placed sub – carriers are used to carry the data from the transmitter end to the receiver end. Presence of guard band in this system deals with the problem of ISI and noise is minimized by larger number of sub carriers. But the large Peak to Average Power Ratio of these signal have some undesirable effects on the system. OFDM signals are very sensitive to nonlinear effects due to the high PAPR, which leads to the power inefficiency in the RF section of the transmitter. This paper proposes a PAPR reduction framework by undertaking various methods; PTS, SLM and a hybrid PTS-Companding-CA (Culture Algorithm). Simulation results show that the proposed hybrid method outperforms other methods of PAPR reduction.**

Keywords –**CA, Companding, MIMO, OFDM, PAPR, PTS.**

I. Introduction

Now a day's huge change has been observed in the lifestyle of people by approaching of wireless communication. Initially Wireless communication was implemented in analog domain for transmission of a signal but today it is working in digital domain [1]. In the communication system to make the wireless communication process more easy by using multiple sub-carrier instead of a single carrier

Recently there is a highly demand for multimedia data services which give us a life in the age of 4th generation wireless communication system. By using of multimedia data service, where the users are in large number with bounded spectrum and this modern digital wireless communication system has a requirement to adopt a technology which is bandwidth efficient and which is robust against multipath channel environment and that technology is known as multi- carrier communication system [2], [3]. It provide high speed data rate at minimum cost for many users as well as with high reliability by using advance digital multicarrier wireless communication system. If we talk about single carrier system it requires the entire communication bandwidth but in multicarrier system the available communication bandwidth is divided in many sub-carriers. In the multicarrier system each sub-carrier has smaller bandwidth as compare to the bandwidth of the single carrier system. These positive features of multicarrier technique encourage us to study Orthogonal Frequency Division Multiplexing (OFDM). OFDM is a platform for all 4G wireless communication systems due to its huge capacity in terms of number of subcarriers, high data rate in excess of 100 Mbps and ubiquitous coverage with high mobility.

II. Orthogonal Frequency Division Multiplexing

As we have seen earlier that due to tremendous growth of digital communication system, there is a highly demand for high-speed data transmission. For a high speed transmission the mobile telecommunications industry face a problem for choosing such kind of technology that be able to provide a platform for different services of which ranging starting from voice communication which required bit rate of a few kbps for wireless multimedia up to 2 Mbps. Different system models have been proposed for this multimedia transmission but they are not much attractive then OFDM system based model gained attention in a different areas of wireless transmission. Although OFDM was developed in the 1960s but it has been recognized as an outstanding method for high-speed cellular data communication where its implementation relies on very high-speed digital signal processing and it has

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become freshly available model with reasonable prices of hardware implementation [3].

The great attention in multi-carrier system is drawn by the necessity of high data rate. The researchers also increase their interest in the OFDM technology for looking that the applied technology should be able to operate smoothly in the environment of mobility, high carrier frequency and high data transmission rate. As OFDM fulfil all the necessities to be a multi- carrier system. So we can say that OFDM is a multi-carrier modulation (MCM) technique in which complex data symbols (i.e., BPSK, QPSK, QAM etc.) are transmitted in parallel after modulating them over orthogonal sub-carrier [3]. In single carrier (SC) system one complex data is transmitted employing one carrier and in parallel transmission complex data is transmitted over sub-carrier. Here the effective data rate of the system is same as of SC system [4]. The parallel transmission enhances the time period of symbol and the comparative amount of separation in time caused by multipath delay decreases.

As we know that OFDM system is based on the concept of FDM, the difference is that in OFDM all the subcarriers are orthogonal to each other and the orthogonality among sub-carriers is preserved by using inverse Fast Fourier Transform (IFFT). As all the OFDM symbols are very near to each other so there is a possibility of inter-symbol-interference i.e. why a guard band is inserted between successive OFDM symbols to avoid ISI. In OFDM symbols guard band can be introduced by three methods- cyclic prefix, cyclic suffix and zero padding. By adding of guard band in OFDM symbols, OFDM convert wideband frequency selective channel into number of parallel narrowband flat fading channel, one channel across each subcarrier [4]. By this way this process removes the ISI. Due to these features like unaffected to multipath fading, high data rate transmission and less complex equalizer is required. Present generation has been exploited OFDM for many high data rate broadband wireless communication systems.

The objective of this paper is to develop a PAPR reduction system using PTS, Companding and Cultural Algorithm along with comparative analysis of bit error rate for above-mentioned schemes.

III. Multipath Channel

In a wireless communication system the transmitted signal faces various obstacles or surfaces of reflection by which the transmitted signals from the same source reach to the destination at different times. Due to this delay in the receiving time there is formation of 'echoes' between the signals and it affects the other incoming signals. The main factors affecting the system are Dielectric constants, permeability, conductivity and thickness [2], [3].

Figure 1: Multipath channel

For this problem Multipath channel propagation is constructed in such a manner that there will be a minimum effect of the echoes in the communication system. Here there is a need to measure minimum echo for avoiding ISI problem [3].

IV. Peak -to-Average Power Ratio

As we know that OFDM has become the most wanted modulation technique in high speed wireless communications. It is highly advantageous over other technologies. But in place of its advantages it has some obstacles also. The main obstacle is high peak-to- average ratio for OFDM system which degrades the system performance at the transmitter end and it causes non-linearity at the receiving end. In this work we discuss about the impact of PAPR in the OFDM system and we will also discuss on the reduction techniques which used to reduce the PAPR of the system but these reduction technique choose by the person according to the requirement of the system. OFDM is become an advanced modulation technique which is suitable for high-speed data transmission with the advantages of handling a multipath propagation problem, bandwidth efficiency and higher order data rate. OFDM has several attractive features which make this technology more advantageous for high speed data transmission over other data transmission techniques [5]. These features includes-

- High Spectral Efficiency
- Robustness to channel fading
- Immunity to impulse interferences
- Flexibility

OFDM system is using because of its benefits there are some obstacles also like:

- OFDM signal shows very high Peak to Average Power Ratio (PAPR)

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- Very sensitive to frequency errors (Tx. & Rx. offset) Intercarrier Interference (ICI) between the subcarriers [4].

Mathematical Definition of PAPR

The PAPR of the OFDM signal can be written as:

$$\text{PAPR}\ \{S(t),\tau\} = \frac{max_{t\epsilon\tau}[s(t)]^2}{E\{[s(t)]^2\}} \quad (1)$$

Where,

$S(t)$ is the original signal

τ is the time interval

$max_{t\epsilon\tau}[s(t)]^2$ is the peak signal power

$E\{[s(t)]^2\}$ is the average signal power

Effects of PAPR

The large variation in signal power affects both the transmitter and receiver design. This is because a very linear power amplifier with a large dynamic range is required at both the transmitter and the receiver. Any amplifier nonlinearity will result in a significant signal distortion.

OFDM must keep its average power below the nonlinear region to accommodate the infrequent signal power peaks. But this result in a lower output power and also affects the efficiency and the range of the signal. Thus a careful design will compensate the distortion and the output power. In order to select an average input level, it must be assured that the average input level is possible of generating sufficient output power with no interference. Higher number of subcarriers used also will increase the value of PAPR. This is because PAPR is defined as

$$\text{PAPR} = 10\log N \quad (2)$$

Where N is the number of subcarriers

Thus PAPR depends on the number of subcarriers and the level of SNR that must be maintained at the receiver.

Presence of large number of independently modulated sub-carriers in an OFDM system the peak value of the system can be very high as compared to the average of the whole system. This ratio of the peak to average power value is termed as Peak-to-Average Power Ratio. Coherent addition of N signals of same phase produces a peak which is N times the average signal.

V. Proposed Method

PAPR Reduction using PTS Scheme

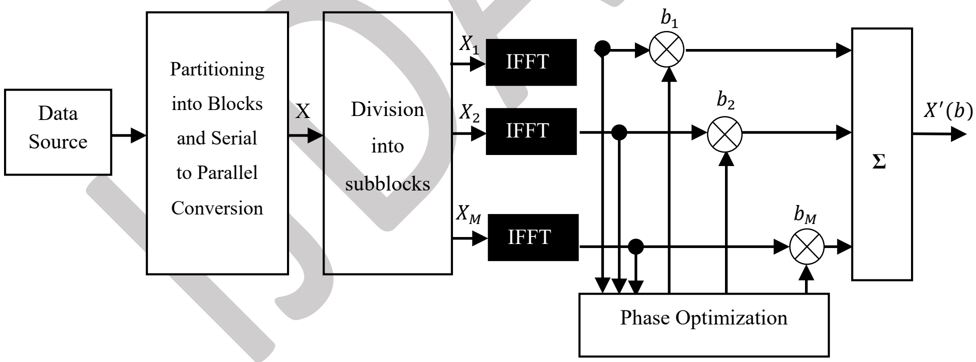

Figure 2: Block diagram of Partial Transmit Sequence method

In the PTS technique, input data block X is partitioned in M disjoint sub-blocks $X_m = [X_{m,0}, X_{m,1}, \ldots . X_{m,N-1}]^T$, $m = 1,2, \ldots \ldots M$, such that $\sum_{m=1}^{M} X_m = X$ and the sub – blocks are combined to minimize the PAPR in the time domain. The L times oversampled time domain signal of X_m, $m = 1,2, \ldots \ldots M$, is obtained by taking the IFFT of length NL on X_m concatenated with $(L-1)N$ zeros. These are called the partial transmit sequences. Complex phase factors, $b_m = e^{j\emptyset m}, m = 1, 2, \ldots \ldots M$ are introduced to combine the PTSs. The set of phase factors is denoted a vector $b = [b_1, b_2, \ldots \ldots . b_M]^T$. The time domain signal after combining is given by

$$x'(b) = \sum_{m=1}^{M} b_m . x_m \quad (1)$$

Where $x'(b) = [x'_0(b), x'_1(b), \ldots \ldots . x'_{NL-1}(b)]^T$.

The objective is to find the set of phase factors that minimizes the PAPR. The optimum signal $x'(b)$ with the lowest PAPR is to be found out.

Both b and x can be shown in matrix form as follows:

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$$b = \begin{bmatrix} b_1, b_1 \ldots\ldots b_1 \\ \vdots \;\; \vdots \ldots\ldots \vdots \\ b_m, b_m \ldots\ldots b_m \end{bmatrix}_{(M\times N)} \quad (2)$$

$$x = \begin{bmatrix} x_{1,0}, x_{1,1} \ldots\ldots x_{1,NL-1} \\ \vdots \;\; \vdots \ldots\ldots \vdots \\ x_{m,0}, x_{m,1} \ldots\ldots x_{m,NL-1} \end{bmatrix}_{(M\times NL)} \quad (3)$$

It should be noted that all the elements of each row of matrix b are of the same values in this method. In order to have exact PAPR calculation, at least 4 times over sampling is necessary. As the over sampling of x, add zeros to the vector, hence the number of phase sequence to multiply to matrix x will remain the same.

The PTS consist of several inverse fast Fourier transform (IFFT) operations and complicated calculations to obtain optimum phase sequence which results in increasing the computational complexity of PTS.

PAPR Reduction using Companding Scheme

The compander consists of compressor and expander. Any invertible function with compression feature can be used for companding.

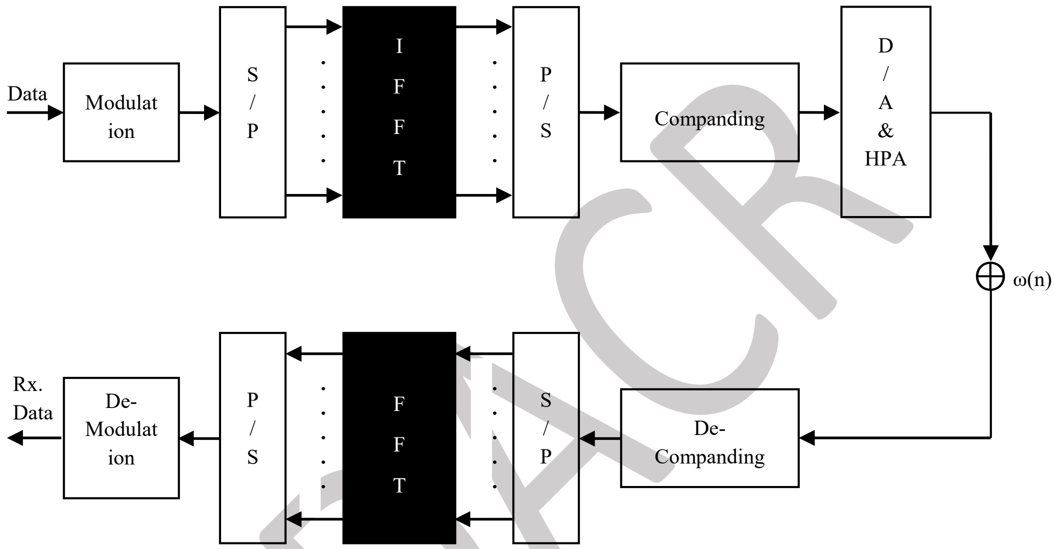

Figure 3: Block diagram of companding transform

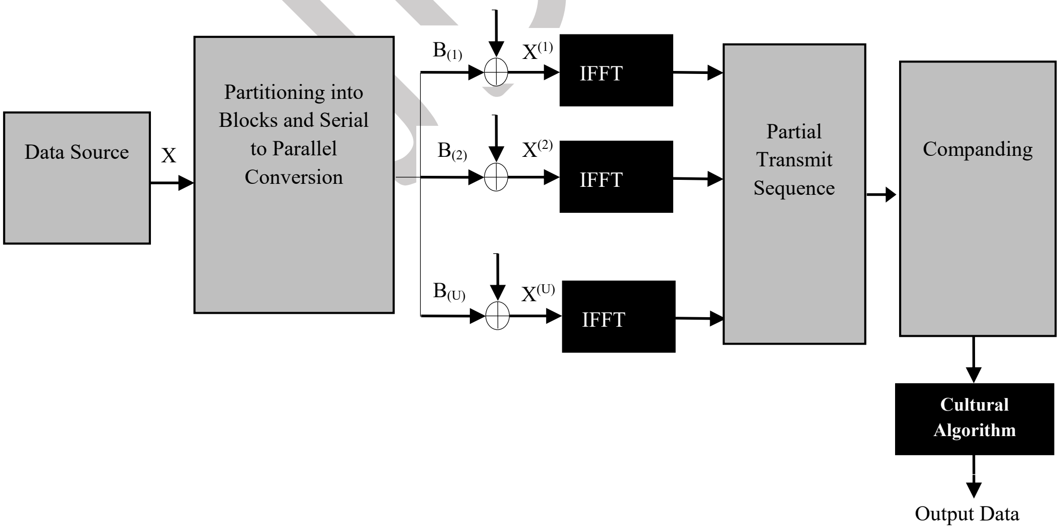

Figure 4: Block diagram of proposed work

Here we apply the transformation. Because the transformation is invertible, the signal can be recovered in the receiver. First a quadrature demodulator generates the estimate of transformed signals with the aid of receiver signal level control and low pass filter. Using the inverse function of

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compression, the nonlinear distortion introduced by the compressor is corrected after reconstruction at the receiver with an expander. Compression improves the quantization resolution of small amplitude signals at the cost of lowering the resolution of large signals. This also introduces quantization noise; however, the effect of the quantization noise due to reduction in resolution of the peaks is relatively small as the peaks occur less frequently. The compression algorithm as described by amplifies the signals of lower amplitude with the peaks remaining unchanged.

In companding the OFDM signal is compressed at the transmitter and expanded at the receiver. Compression is performed according to the well-known μ-Law viz.

$$y = V \frac{\log\left[1+\mu\frac{|x|}{V}\right]}{\log(1+\mu)} \mathrm{sgn}(x) \qquad (4)$$

Where V is the peak amplitude of the signal, and x is the instantaneous amplitude of the input signal. Decompression is simply the inverse of equation (4). Figure 4 shows concatenation of PTS, Companding and Cultural Algorithm techniques.

Here the value of V in equation (4) will be optimized by Cultural Algorithm.

Cultural Algorithm (CA)

Inspired by the process of social and cultural changes, the CA was developed to enhance evolutionary computation. Besides the population component that evolutionary computation approaches have, there is an additional peer component belief space and a supporting communication protocol between these two components, which makes CAs perform better in some special optimal cases than other evolutionary algorithms (EAs). The following figure presents the basic CA framework.

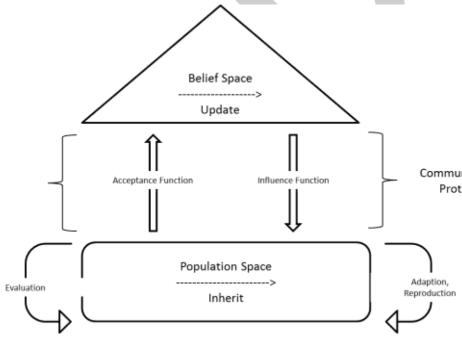

Figure 5: CA framework [10]

As Figure 5 shows, the population space and the belief space can evolve respectively. The population space consists of the autonomous solution agents and the belief space is considered as a global knowledge repository. The evolutionary knowledge that stored in belief space can affect the agents in population space through influence function and the knowledge extracted from population space can be passed to belief space by the acceptance function.

In the process of the CA evolution, the population space is initialized with candidate solution agents at random, meanwhile, the initial knowledge sources in the belief space are built. At first the two spaces evolve independently. Then the selected agents from the population space are used to update the belief space. After the knowledge sources being updated, the belief space will reversely guide the evolution of the population space. These procedures repeat till a termination condition has been reached. The CA pseudo code presented by [10] is given as follows:

t=0;
Initialize Population POP(t);
Initialize Belief Space BLF(t);
Repeat
Evaluate Population POP(t);
Adjust (BLF(t), Accept(POP(t)));
Adjust (BLF (t));
Variation(POP (t) from POP (t-1));
Until termination condition achieved

VI. Simulation And Results

The performance of proposed algorithms has been studied by means of MATLAB simulation.

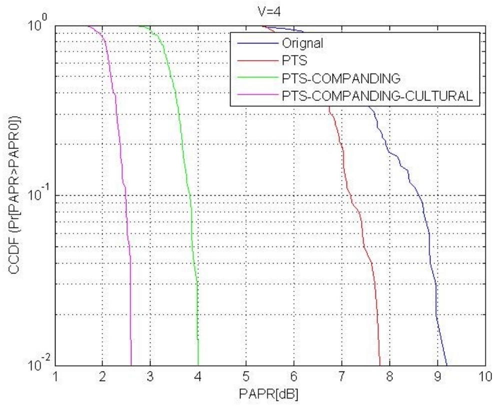

Figure 6: Comparison of different schemes (showing PAPR v/s CCDF)

VII. Conclusion

Orthogonal frequency division multiplexing (OFDM) signals have a generic problem of high peak to average power ratio (PAPR) which is defined as the ratio of the peak power to the average power of the OFDM signal. The drawback of the high PAPR is that the dynamic range of the power amplifiers (PA) & digital-to-analog (D/A) converters required during the transmission and reception of the signal is higher. As a result, the total

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cost of the transceiver increases, with reduced efficiency. After analyzing some specific algorithms, we propose a novel algorithm by combining the Partial transmit sequence (PTS), Companding and Cultural Algorithm techniques which includes an idea of the PAPR constraint, along with the implementation and analysis for PAPR reduction of the OFDM signals. This algorithm is implemented and tested in the OFDM transceiver designed using MATLAB. The simulation result conclude the output obtained by cascaded technique reduces the PAPR drastically rather than PTS technique only.

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