BER and PAPR mitigation using Cyclic Prefix optimization by Flower pollination algorithm for MIMO OFDM network

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Abstract

One main drawback of the multiple-input-multiple-output orthogonal frequency-division multiplexing (MIMO-OFDM) system is that the signals transmitted on each antenna may experience high Peak-to-Average-Power Ratio (PAPR) and Bit Error Rate (BER). This current research presents a new hybrid PAPR reduction technique that combines and optimizes two methods, namely BAT algorithm and Modified Flower Pollination Algorithm. The results for the hybrid PAPR reduction technique show that this scheme significantly reduces the PAPR and BER. In addition, it is a flexible technique in which the net gain can be optimized based on the requirements of scheme parameters. This research persists as advisable knowledge source for future upcoming researches on MIMO OFDM.

Keywords: **MIMO-OFDM, BER, PAPR, Flower pollination algorithm.**

1. Introduction:

OFDM is a communication scheme extensively employed in various communication systems, inclusive of commercial applications such as in wireless networks (Wi-Fi 802.11) and cellular systems (LTE). In these systems is also formed by a combination of OFDM system with MIMO. However, to model accordingly the MIMO system, is important to understand the concept of SISO channel and SISO OFDM [1]. Insufficient Cyclic Prefix in OFDM transmission leads to interference in the form of Inter Symbolic Interference and Inter Carrier Interference, which affects the data detection process and, if ignored, can lead to a severe performance degradation. MIMO-OFDM systems also increases receiver design. To alleviate this problem, a number of data detection methods for insufficient CP systems have been proposed. Insufficient CP MIMO-OFDM transmission can be standardized by a time domain (TD) finite impulse response filter, which can reduce the MIMO channel response (to be within the CP) [2]. One of the important implementation drawbacks of OFDM is its inherent high peak-to-average power ratio (PAPR). This problem has been mostly studied, and multiple schemes have been proposed to mitigate the PAPR in the OFDM signal. High PAPR is also an issue in MIMO-OFDM systems, and usually, works that propose to reduce the peaks in such systems proceed by either the OFDM techniques or by taking advantage of MIMO architecture to propose new techniques [3]. In terms of channel estimation, various schemes suppose a pilot signal that consists of some defined pilot OFDM symbols with all sub-carriers dedicated for pilots. The pilot OFDM symbols are equally designed so that a pilot OFDM symbol, or half of it, is free from interference, permitting initial channel estimation. a channel estimation procedure is projected for a non-symmetric pilot OFDM symbol. Although these approaches can produce precise channel approximation, their pragmatism is limited [4]. In order to growth the spectral efficiency even more and to increase the link reliability, this paper presents multiple input multiple output (MIMO) system with F-OFDM. The fading agonized by a wireless signal while propagating through the channel instigated by disparaging interference among multiple copies of the signal (multipath effect) can attenuate the signal. MIMO systems provides diversity, which enables the receiver to distract several multiple copies of the same signal that are ideally independent. There are numerous types of diversities used in MIMO system including time diversity and frequency diversity. However, this paper practices another common form known as spatial diversity that comprises increasing the number of transmit and receive antennas [5].

1. **Literature Survey**:

Wang *et al.* [6], explored spatial- and frequency wideband effects, called dual-wideband effects, in massive MIMO systems from array signal processing point of view. Taking mmWave-band communications as an illustration, researchers defined the transmission process to report the dual-wideband effects. By manipulating the channel sparsity in the angle domain and the delay domain, researchers established the efficient uplink and downlink channel assessment policies that require much less amount of exercise overhead and cause no pilot contamination.

Cao *et al.* [7], had anticipated a cyclic prefix (CP) based MIMO-OFDM range reconstruction scheme and its equivalent MIMO-OFDM waveform design for co-located MIMO radar systems. Projected MIMO-OFDM waveform design achieves the maximum signal-to-noise ratio (SNR) gain after the range reconstruction and its peak-to-average power ratio (PAPR) in the discrete time domain was also optimal, i.e., 0dB, when Zadoff-Chu sequences were used in the discrete frequency domain as the weighting coefficients for the subcarriers. Researchers also explored the concert when there were transmit and receive digital beamforming (DBF) pointing errors.

Arakawa and Ochiai [8], beneath the framework of BICM-OFDM where capacity forthcoming channel codes were employed, Scholars first endeavored to alleviate the deprivation caused by the excessive channel delay spread by appropriately altering the decoder metric that takes into account the resulting signal-to-interference-plus-noise ratio (SINR). Furthermore, based on the trade-off between the attainable SINR and spectral efficiency, researchers attempted to optimize the CP length such that the output is maximized.

Giri and Patnaik [9], had simulated the bit error rate (BER) with respect to diverse parameters like average SNR, link distance at several climate conditions. The simulation results were confirmed in MATLAB environment with the mathematical analysis. The simulation results exhibited that higher order single input multiple output (SIMO) system achieves better BER presentation and hybrid PPM-BPSK-SIM has significant improved performance than the common modulation schemes like PPM, BPSK-SIM.

Bellanger *et al.* [10], had proposed an method, based on the so-called lapped transform, associations a simple yet efficient seamless reconstruction real filter bank with QAM modulation. Real processing of the real and imaginary components of the QAM data samples presented a symmetry of the used carriers and the spectrum of the multicarrier signal can be either continuous or fragmented. Implementing the receiver with an extended FFT allows for frequency domain channel equalization and the performance achieved was adequate to avoid the need for a cyclic prefix. The scheme was suitable for asynchronous access and the filter provides a high level of spectral protection, as essential by users in cognitive radio situations.

3. Research methodology: The chief disadvantage in the MU MIMO-OFDM scheme is the Peak to average power ratio. PAPR binds its effect with ISI and CCI and lastly affects over BER. Several examinations have been carried out to condense the PAPR, but the improvement can be further improved. In this technique we have projected an algorithmic approach to attain optimized length of cyclic prefix (CP) to mitigate ISI and CCI in MIMO-OFDM, the affect would be pragmatic on the BER and PAPR. Carrier sense channel estimation is proposed to improve the performance of the proposed technique. Here, Flower pollination algorithm have been employed for the cp length selection and comparison has been made with the conventional technique. The proposed flow diagram has been depicted in the figure 1 below. The proposed technique has been implemented and performance has been evaluated on the working platform of MATLAB.

3.1 System Model: System model of the proposed technique has been depicted in the figure 1. Initially signal has been generated including parameters as, number of bits per symbol, size of signal constellations, number of samples per symbols, number of transmitting and receiving antennas, number of sub-carriers, number of blocks in each channel, modulation order, sampling time and other parameters.

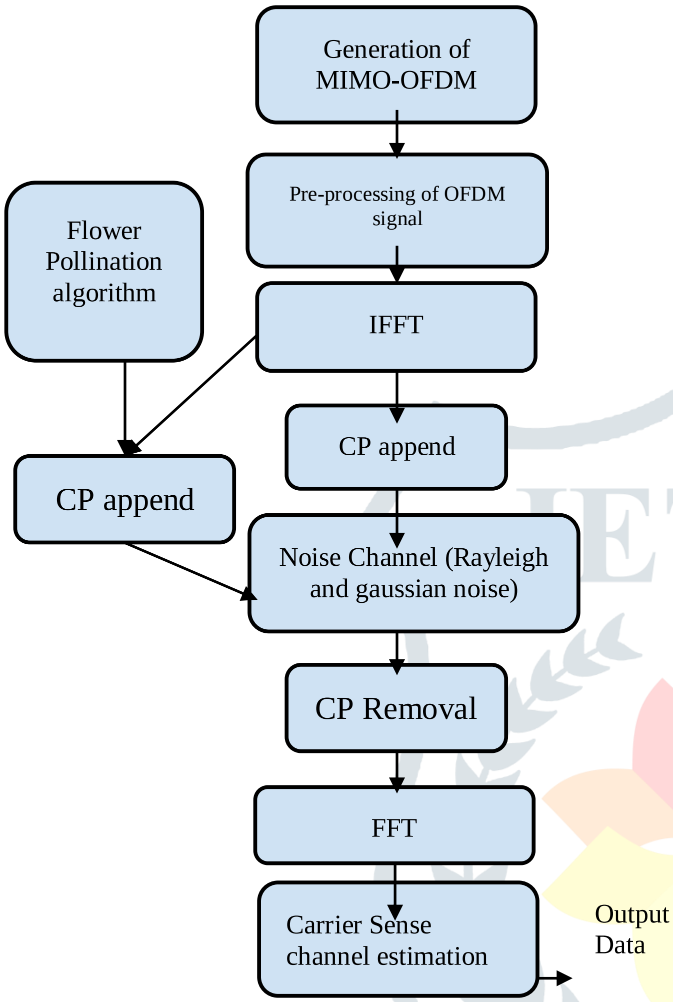

Figure 1: Flow diagram of the proposed technique

The basic random signal has been produced as shown in figure 2. In the proposed technique number of subcarriers are 128, number of blocks in each channel is 1, modulation order is 8, sampling time is 10^7, transmitting antennas are 2 and receiving antennas are 3 and SNR is in the range of 0-30 dB. Afterwards M-array QAM modulated OFDM signal is generated.

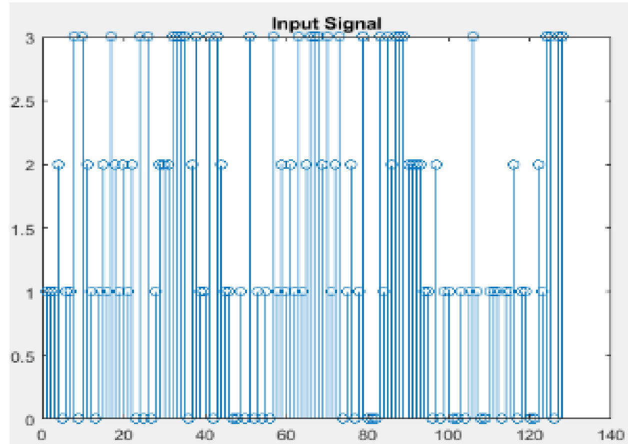

Figure 2. Basic random signal

The discrete implementation of multicarrier modulation -Orthogonal frequency division multiplexing (OFDM) disregards the inter symbol interference (ISI) using the cyclic prefix. The specific subcarriers are orthogonal to each other so that the overlying of the subcarriers does not cause any interference with the adjacent subcarrier. The input bits are modulated by using QAM modulator wherein, the bits are converted to symbols. The symbols are passed through the serial to parallel converter which correspond to the QAM symbols transmitted over each subcarrier. The output of serial to parallel converter is the discrete frequency components. These frequency components are converted to the time domain samples by using the IFFT on these N symbols. The IFFT yields the OFDM symbol consisting of the sequence x[n] of length N. The cyclic prefix is added to the OFDM symbol so that ISI between the data blocks can be disregarded, we have implemented the method in two verticals, in one process conventional way of CP length has been added where as in the second vertical process cyclic prefix length is determined by Flower pollination algorithm. Then the comparative study has been made for the throughputs in term of BER and PAPR. For the subcarriers of N=128, a cyclic prefix of length 16 is added. The received signal is passed through the channel.

3.1 Flow pollination algorithm: Flower pollination is a fascinating process in the normal world. Its evolutionary physiognomies can be used to design new optimization algorithms. We propose a new procedure, namely, flower pollination algorithm, inspired by the pollination process of flowers. From the biological evolution point of view, the objective of the flower pollination is the existence of the fittest and the optimal reproduction of plants in terms of numbers as well as fittest. This is in fact an optimization process of plant species. All the above factors and developments of flower pollination interact so as to achieve optimal reproduction of the flowering plants. Therefore, this can motivate to design new optimization algorithm. In the scope of our work the objective function is depicted as: The CP length should match the channel delay spread if no signal to noise ratio (SNR) degradation is accepted. The spectral efficiency (SE), measured in bps/Hz, of an OFDM link for one spatial layer is expressed in expression below.

$$SE = \frac{T_{OFDM}}{x + T_{OFDM}} \min\left\{ SE_{\max}, \log_2\left(1 + \frac{\beta}{\alpha}\right)\right\} \quad (1)$$

Where, $x = T_{cp}$, T_{cp} and T_{OFDM} are the cyclic prefix length and OFDM symbol length (inverse of subcarrier spacing), respectively, $SE_{\max}$ is the maximum achievable spectral efficiency (limited by largest modulation and coding rate), β is SNR and α is SNR degradation due to non-ideal modulation and coding.

Figure 2: Pseudo code of Flower Pollination Algorithm (FPA)

Objective min *or* max $f(\mathbf{x})$, $\mathbf{x} = (x_1, x_2, ..., x_d)$
Initialize a population of n flowers/pollen gametes with random solutions
Find the best solution $\mathbf{g}_*$ *in the initial population*
Define a switch probability $p \in [0, 1]$
while *(t <MaxGeneration)*
    for $i = 1 : n$ *(all n flowers in the population)*
      if *rand* $< p$,
        Draw a (d-dimensional) step vector L which obeys a Lévy distribution
        Global pollination via $\mathbf{x}_i^{t+1} = \mathbf{x}_i^t + L(\mathbf{g}_* - \mathbf{x}_i^t)$
      else
        Draw ϵ *from a uniform distribution in [0,1]*
        Randomly choose j and k among all the solutions
        Do local pollination via $\mathbf{x}_i^{t+1} = \mathbf{x}_i^t + \epsilon(\mathbf{x}_j^t - \mathbf{x}_k^t)$
      end if
      Evaluate new solutions
      If new solutions are better, update them in the population
    end for
      Find the current best solution $\mathbf{g}_*$
end while

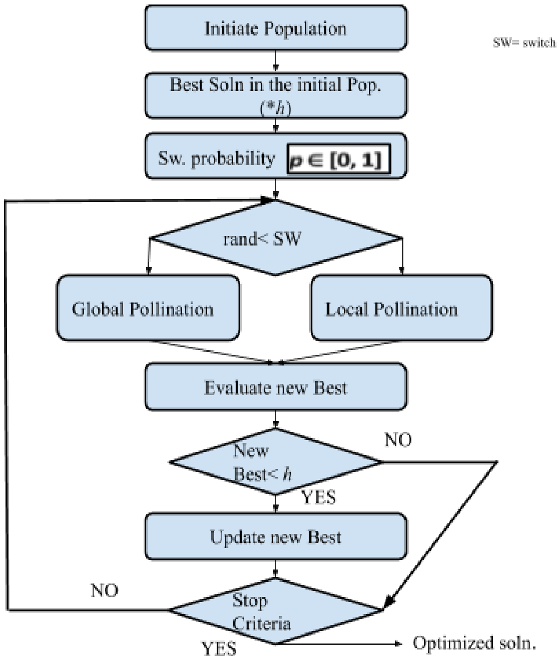

Figure 3: Flow diagram of FPA

3.2 Channel Model: The area of submission of the system is fixed wireless access. In such a situation, we are fronting a multipath slowly time-varying fading channel. Since the channel is slowly time-varying and the training sequences are short, we can model it by a time invariant channel for the training sequence period. With this in mind, we examine four different channels: an AWGN channel, a one-tap Rayleigh fading channel, a 3-tap time-invariant fading channel with a root mean square (rms) delay spread of 2 samples and a 3-tap time-invariant fading channel with a rms delay spread of 10 samples. All paths are Rayleigh fading, except the first path of channel, which is Ricean. At the receiver the cyclic prefix is detached. The time samples are serial-parallel converted and passed through FFT. The FFT output is passed through a QAM demodulator to recover the data. The OFDM decomposes the wideband channel into a number of narrowband sub channels with different QAM symbols sent over each sub channel.

3.3 Cyclic prefix: Cyclic prefix successfully range the length of the symbol, while maintains the orthogonality of the waveform. With this cyclic extended symbol, the samples required for execution the FFT (to decode the symbol), can be taken wherever over the length of the symbol. This offers multi-path immunity as well as symbol time synchronization tolerance. Summary of guard symbol through the guard period specifically. if guard symbol is elected to be a prefix extension to each block will reduce complexity at receiver as this convert the linear convolution of the signal and channel to a circular convolution and thereby triggering the FFT of the circularly convolved signal and channel to merely be the product of their respective FFT's. The comparative length of the cyclic prefix depends on the proportion of the channel delay spread to the OFDM symbol duration. The motives to use a cyclic prefix for the guard interval are to maintain the receiver carrier synchronization and abolition of silent period of guard bands, Also the circular convolution can be applied among the OFDM signal and the channel reply to model the transmission system. Cyclic prefix acts as a safeguard region where delayed information from the previous symbols can get stored. The receiver has to eliminate samples from the cyclic prefix which got corrupted by the previous symbol when choosing the samples for an OFDM symbol. Further, we erudite that a sinusoidal added with a delayed version of the same sinusoidal does not affect the frequency of the sinusoidal (it only affects the amplitude and phase). Specified so, for demodulating the received symbol, the receiver can elect trials from a region which is not affected by the previous symbol. When the pertinent samples of an OFDM symbol is taken the orthogonality facet in OFDM is not affected by the multipath channel i.e. even though the individual subcarriers experience phase and amplitude change, as the frequency is not affected, there is no interference between the subcarriers. The backside of adding cyclic prefix is the loss in data rate as we are conveying redundant information. To minimalize this loss, it is required to minimize cyclic prefix duration. Typically, cyclic prefix period is resolute by the predictable duration of the multipath channel in the functioning environment. The symbols which had been formerly added to the signal, has to be removed in CP removal process.

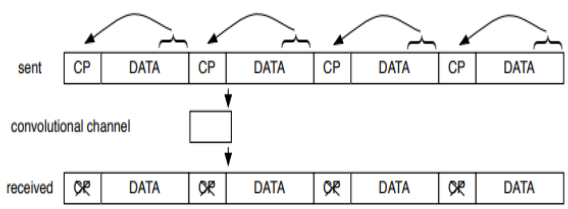

Figure 4: Cyclic prefix removal

In Compressed Sensing channel estimation, MIMO channels are appraised by initiating all sources simultaneously. The receivers measure the cumulative response, which consists of random convolutions between multiple pairs of source signals and channel responses. Their motive is to reduce the channel estimation time. minimization is employed to recover the channel response.

4.Results and discussion:

Peak to Average Power Ratio: PAPR is ratio of maximum instantaneous power (sample) to the average power of OFDM symbol. High PAPR results in distortion and orthogonality loss between OFDM subcarriers. The PAPR performance of MIMO-OFDM system in terms of CCDF is presented in Figures 5. The optimum value of PAPR varies in a very small range with different modulation schemes and therefore it can be considered almost independent of different modulation schemes. the comparison of PAPR of the optimized and unoptimized CP is clearly discriminated. The difference achieved in optimized PAPR graph proves the efficiency of the proposed research work.

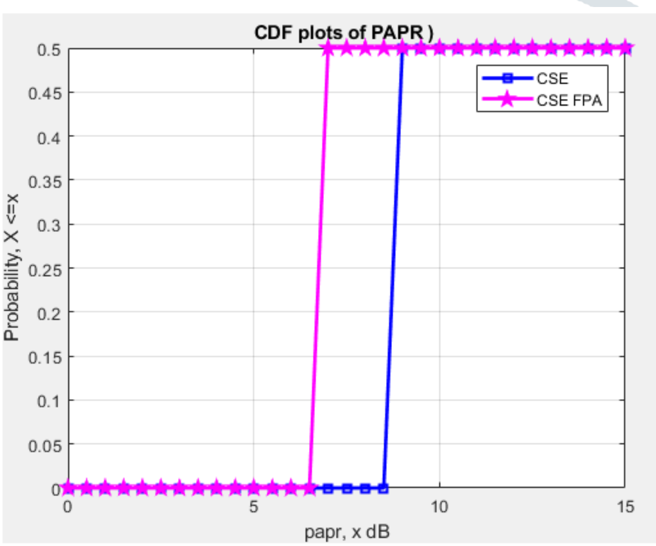

Figure 5: PAPR Performance

Bit Error Rate: In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that has been transformed due to bit synchronization errors, noise, interference and distortion. The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is often represented as a function of the normalized carrier-to-noise ratio measured denoted Eb/N0 that is energy permit to noise power spectral density ratio, or Es/N0 that is energy per modulation symbol to noise spectral density.

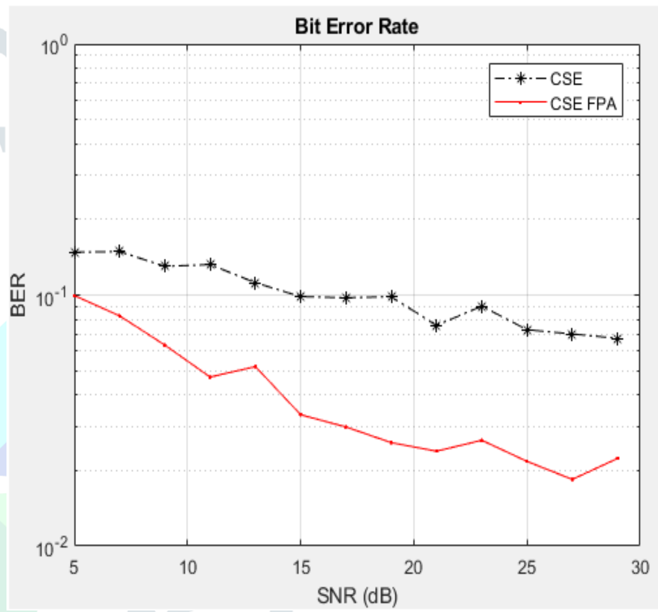

Figure 6: SNR performance

The above Figure 6 describes the reduction in BER by introducing combined optimization technique. Finally, the improvement in PAPR and minimized BER proves the combined optimization concept positively in this research.

Conclusion: CP appending results in the mitigation of the ISI and CCI but also results in the bandwidth wastage. In this project minimum CP length has been considered at which better throughput can be achieved, for the same MFA has been proposed to optimize CP length to achieve Minimum BER and PAPR. the results produced by MFA are considerably better than existing techniques. As an existing technique unoptimized Cp and BAT optimized CP length has been employed.

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