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[ijrset@gmail.com](mailto:ijrset@gmail.com)

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# Survey Paper on PAPR Reduction for Massive MIMO Systems for 5G Application

Kundan Kumar, Dr. Ram Milan Chadhar

M. Tech. Scholar, Department of Electronics and Communication Engineering, Patel College of Science & Technology, Bhopal (M.P.), India<sup>1</sup>

Head of Department, Department of Electronics and Communication Engineering, Patel College of Science & Technology, Bhopal (M.P.), India<sup>2</sup>

**ABSTRACT:** A compact 5G technology can be defined as a system which consist of high signal data transmission, maximizing frequency diversity and can combat noise interference. By theory, it is significantly to improve system's performance in order to obtain better voice quality, tolerance to noise interference, excellent spectral efficiency, higher network capacity, low latency and frequency selective fading in multipath environment, which is robust to the channel impairments. 5G network uses multipath environment or multiple transmissions technique, which known as multiple input multiple output, (MIMO). MIMO operates with multiple antennas technology, which includes the multiple transmitters with receivers' circuits to minimize errors and optimize data speed. Orthogonal frequency division multiplexing (OFDM) is a multicarrier modulation technique for high-speed data transmission in wireless communications. In an OFDM system, a large number of subcarriers are used to transmit the modulated symbols and consequently, the OFDM signals have a high peak-to-average power ratio (PAPR). Massive system is of great interest for researchers and research laboratories all over the world. OFDM is widely used in contemporary communication systems for its good robustness in multipath environment, and its high spectral efficiency.

**KEYWORDS:** Massive Multiple Input Multiple Output (MIMO), Orthogonal frequency division multiplexing (OFDM), Peak Average Peak Ratio (PAPR)

## I. INTRODUCTION

A combination of multiple input multiple output (MIMO) and orthogonal frequency division multiplexing (OFDM) (MIMO-OFDM) is an emerging technology for high speed data multi-carriers transmission in future wireless communication network systems such as digital audio broadcasting (DAB), digital video broadcasting (DVB), medical body area networks (MBANs) applications, the fourth and the fifth generation (4G,5G) of mobile network. In MIMO-OFDM system, the output is the superposition of multiple sub-carriers. Whenever, the phases and frequencies of these carriers match coherently, instantaneous power outputs may increase greatly and become higher than the mean power of the high power amplifier (HPA) resulting in large PAPR [1]. Lot of research work has been done for solving the problem of PAPR that concerns all kind of multicarrier signals. So, many techniques have been proposed such as clipping [2], tone reservation [3], nonlinear transformations [4], coding [5], selecting mapping (SLM) [6] and partial transmit sequence (PTS). Modified approaches of PTS are proposed in that produce better results; however, the computational complexity is still remaining unsolved totally. In this paper an approach is proposed to reduce the PAPR in STBC MIMO-OFDM systems with less computational complexity. So, the mean idea is based on separating the input vector data into real and imaginary parts for computational simplification reasons and then C-A-PTS is applied individually on these parts, moreover, PAPR is conjointly optimized in real part and imaginary part for the first antenna and by symmetry property the optimum weighting coefficient is deduced for the second antenna without any extra optimization which leads to decreasing of the complexity of the computation [7].

Orthogonal frequency division multiplexing (OFDM) is a multicarrier modulation scheme for wireless communications [1]. The OFDM technique is widely used to obtain the high-speed transmission over frequency-selective fading channels [2]. Due to its multicarrier nature, the OFDM signals have usually amplitude variation in the time domain and have a relatively large dynamic range which is referred to as the peak-to-average power ratio (PAPR) [1]. In the case of high PAPR, the OFDM signal will be clipped when it passes through a non-linear high

power amplifier (HPA) and consequently, the performance will be degraded and in-band distortion and out-of-band radiation will occur. Thus, the OFDM transmitters require expensive linear HPA with a wide dynamic range [2]. There are many PAPR reduction approaches for OFDM systems, as clipping, coding, non-linear companding, ton reservation and ton injection, selective mapping (SLM) and partial transmit sequence (PTS) [3]. Among these approaches, the PTS technique is the most efficient and distortion-less scheme for PAPR reduction in OFDM systems. In PTS technique, the input data block is split into several independent sub-blocks, the inverse FFT (IFFT) procedure is applied to each independent sub-block and each corresponding time-domain signal is multiplied by a phase rotation factor. The objective of the PTS scheme is the selection of phase factors in order to minimize the PAPR of the combined signal of all sub-blocks [3]. In the PTS, the exhaustive search complexity of optimal phase factors exponentially increases with the number of sub-blocks and phase rotation factors. To mitigate the search complexity, several different suboptimal PTS methods have been investigated in the previous studies [[4], [5], [6]].

First we introduce the basic concepts of massive MIMO systems and explain how they give the ability to the users to use the same physical layer resources (frequency band and/or time slots), simultaneously. After studying advantages and challenges of massive MIMO systems, we will give a brief review of the candidate waveforms for massive MIMO systems and introduce the two strong candidate waveforms: Orthogonal frequency division multiplexing (OFDM) and single-carrier frequency domain processing (SC-FDP). Next, we will specifically focus on the issue of hardware impairments and channel time variation in massive MIMO systems considering the two main waveform candidates. Since in massive MIMO systems we have large number of antennas at the BS, we have to use low-cost RF chains to have a cost effective system. This results in hardware impairments and degrades the performance of the system. Also, the performance of massive MIMO systems is very dependent on channel knowledge at the BS side. Due to Doppler effects, the channel varies in time (especially for high speed environments) and, therefore, estimating the channel and following its time variations is difficult. Therefore, paying attention to these two issues in massive MIMO is very important.

## II. SYSTEM MODEL

MIMO in combination with OFDM is widely used nowadays due its best performance in terms of capacity of channels, high data rate and good outcome in frequency selective fading channels. In addition to this it also improves reliability of link. This is attained as the OFDM can transform frequency selective MIMO channel to frequency flat MIMO channels [8]. So it is widely used in future broadband wireless system/communications. Cyclic prefix is the copy of last part of OFDM symbol which is appended to the OFDM symbol that is to be transmitted. It is basically 0.25% of the OFDM symbol. We can say that one fourth of the OFDM symbol is taken as CP (cyclic prefix) and appended to each OFDM symbol. IFFT is used at the transmitter and FFT is used at the receiver which substitutes the modulators and demodulators. Doing so eliminates the use of banks of oscillators and coherent demodulators. Moreover the complex data cannot be transmitted as it is; therefore it is first converted to analog form which is accomplished by IFFT. It basically converts the signal from frequency domain to time domain. Prior to IFFT operation symbol mapping is performed which is nothing but the modulation block. Any of the widely used modulation techniques can be applied like BPSK, QPSK, QAM, PSK etc.

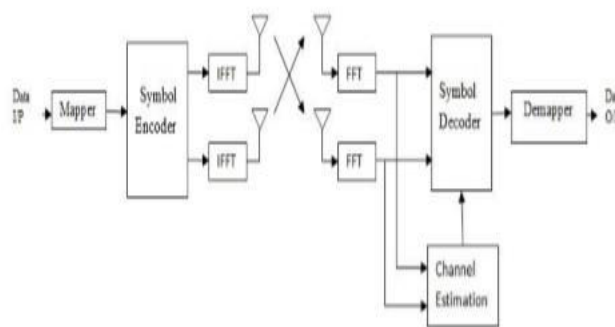


Figure 1: MIMO-OFDM system model



Further there are higher order modulations are also available which provide more capacity at little expense of BER performance degradation. After IFFT block pilot insertion is done and then CP (cyclic prefix) is added. Figure 1 below shows the block diagram constituting MIMO and OFDM. Any antenna configuration for the MIMO can be used according to the system requirement. Higher the configuration more will be the capacity and more will be the computational complexity of the transceiver design. It is seen that in the case of estimating channel the computational complexity is increased. Mapper defines the modulation to be used. Symbol encoder takes the shape of the STBC (Space Time Block Code) if spatial diversity is to be used and it takes the shape of the de-multiplexer/multiplexer if spatial multiplexing is to be used.

The received signal at  $j^{\text{th}}$  antenna can be expressed as

$$R_j[n,k] = \sum H_{ij}[n,k] X_i[n,k] + W[n,k] \quad (1)$$

Where  $H$  is the channel matrix,  $X$  is the input signal and  $W$  is noise with zero mean and variance. Also  $b_i[n,k]$  represents the data block  $i^{\text{th}}$  transmit antenna,  $n^{\text{th}}$  time slot and  $k^{\text{th}}$  sub channel index of OFDM. Here  $i$  and  $j$  denoted the transmitting antennas index and receiving antenna index respectively.

The MIMO-OFDM system model [9] with  $N_R$  receives antennas and  $N_T$  transmits antennas can be given as:

$$\begin{bmatrix} Z_1 \\ Z_2 \\ \vdots \\ Z_N \end{bmatrix} = \begin{bmatrix} H_{1,1} & H_{1,2} & \dots & H_{1,N_T} \\ H_{2,1} & H_{2,2} & \dots & H_{2,N_T} \\ \vdots & \vdots & \ddots & \vdots \\ H_{N_R,1} & H_{N_R,2} & \dots & H_{N_R,N_T} \end{bmatrix} \begin{bmatrix} A_1 \\ A_2 \\ \vdots \\ A_{N_T} \end{bmatrix} + \begin{bmatrix} M_1 \\ M_2 \\ \vdots \\ M_{N_T} \end{bmatrix} \quad (2)$$

Where,  $Z$  represents O/P data vector,  $H$  denotes Channel matrix,  $A$  denotes I/P data vector and  $M$  represents Noise vector. The wireless channel used is AWGN channel. After receiving the signal the CP is removed then the pilots are also removed from main signal received. After this the signal that is in time domain can be again converted to frequency domain by taking FFT of the received signal.

The sequence on each of the OFDM block is then provided to channel estimation block where the received pilots altered by channel are compared with the original sent pilots. Channel estimation block consists of the algorithms that are applied to estimate the channel.

### III. LITERATURE REVIEW

**Zhitong Xing and others [1]**, isolated balanced repeat division multiplexing (f-OFDM) is seen as one of the competitor for future compact correspondence because of its versatile limit arrangement for different circumstances. Regardless, the unique handset structure of f-OFDM makes impedance testing extremely challenging, particularly in the uplink with non-ideal synchronization. This review examines the uplink obstruction of f-OFDM frameworks under non-ideal synchronization; taking into account the transporter recurrence offset (CFO) and timing offset (TO) of numerous client equipment (UE). A few sub-impedances separate the obstruction. After inferring the close structure articulations of each sub-obstruction and its distinction, reproductions are used to validate the inferences. First, the effects of non-ideal variables and framework boundaries like CFO, TO, watch band (GB), and subcarrier dividing (SCS) on the uplink impedance of f-OFDM frameworks are reproduced and examined on the basis of the inferred shut structure articulations. This study is affirmed by automatic encounters, and the speculative derivation of hindrance agrees with the multiplication result. Second, previous f-OFDM frameworks utilized Hanning window channels, which resulted in piece blunder rate (BER) awkwardness between subgroups. Accordingly, the effect of waveform channel on the impedance and BER is similarly analyzed in this assessment. Results show that ideal hindrance and BER displays over Hanning window channels can be gotten by using reasonable channel settings. Plus, a couple of channel design rules are shut. By and large, the assessment and reenactments uncover various normal impedance ascribes of f-OFDM, which will help the future f-OFDM system plans.

**Ebubekir Memisoglu and Associates [2]**, due to its numerous advantages, OFDM will probably continue to be utilized in previous 5G (B5G) correspondence frameworks in addition to being sent in 5G frameworks. However, the high top-to-average power proportion (PAPR) of OFDM systems is a major drawback, particularly when transmitting large amounts of data. A regularization improvement based adaptable cross breed companding and cutting plan (ROFHCC) for reducing PAPR in OFDM frameworks is presented in this paper. The companding capacity has two sections to simplify the plan. It restricts the sign examples with amplitudes greater than a predetermined value to a consistent incentive for both low power pay and peak power loss. For signals with tests under a given sufficiency, they are stretched out by a direct companding limit. For bit error rate (BER) and power unearthy thickness (PSD) execution, we develop a regularization enhancement model to mutually improve the companding contortion as well as the congruity of the companding capacity. The reproduction results show that the proposed companding plan outperforms the referred to companding plans for the same PAPR execution. For example, when the typical sign power is normalized to be 1, we pick both PAPR for ROFHCC plan and two-piecewise companding (TPWC) scheme as 4 dB, then, we can find that at  $BER=10^{-4}$ , the base required  $E_b/N_0$  for ROFHCC plot is around 2.3 dB lower than TPWC contrive.

**S. Rajasekaran et al. [3]**, in the field of current remote correspondences, symmetrical recurrence division multiplexing (OFDM) is one of the most common advancements. However, the framework's high top to average power proportion (PAPR) issue has severely restricted its application range, making it impossible to present. For the purpose of further improving the PAPR execution of OFDM frameworks, incomplete send succession (PTS) was proposed. Nevertheless, its presentation significantly increases the framework's computational complexity. In light of the majority of time-area tests, a low-intricacy PTS plot is proposed and two new measurements for selecting these examples are presented in this paper. Additionally, a gathering strategy has been employed with the proposed conspire to reduce computational complexity. Reenactment results show that the proposed low-complexity PTS plan can outfit an ideal PAPR decline execution with more computational multifaceted design save reserves.

**Z. Zhou et al. [4]**, for the chosen planning (SLM)-based unevenly cut optical symmetrical recurrence division multiplexing (ACO-OFDM) visible light correspondence (VLC) framework, a novel low-intricacy least sufficiency contrast (MAD) decoder is proposed. With the proposed plot, a specific plan of symmetric vectors is expected to restrict the top to-average power extent (PAPR) of sign without the transmission of side information (SI) and recover SI capriciously by the proposed Frantic decoder. Reproduction results demonstrate that the proposed plot actually reduces the PAPR, and the cycle error rate execution of an ACO-OFDM framework equipped with a MAD decoder is very similar to that of a traditional chosen planning (CSLM) conspire equipped with the greatest probability decoder, albeit at a much lower level of complexity.

**W. Hu et al. [5]**, this paper propose a different actual layer design for uplink different access using symmetrical recurrence division multiplexing (OFDM). With fixed decoder inactivity, it focuses on immediate low-inertness remote applications, such as the transmission of control data in machine-to-machine (M2M) and device-to-gadget (D2D) exchanges. For high coding gain and recurrence variety and low top to average power proportion (PAPR) flagging, our proposed framework uses a well-balanced combination of subcarrier bouncing and super-symmetrical convolutional codes. The low PAPR nature enhances the transmission range upgrade and further develops the power effectiveness at a power intensifier (PA).

**Y. Hori et al. [6]**, in addition, ghostly effectiveness can be elevated to a higher level by presenting non-symmetry among clients through the task of arranging subcarriers in a similar manner for various clients. Multiuser discovery (MUD) is used to reduce different access impediments caused by clients switching in an unsymmetrical way. Speculative explanations of vague piece screw up rate for the proposed system with MUD are moreover advanced. Numerical results uncover that our proposed system achieves higher immovable quality and higher absurd viability than the standard balanced repeat division different access (OFDMA)- based structure.

**Ashna Kakkar et al. [7]**, MIMO-OFDM, or multiple input, multiple output orthogonal frequency division multiplexing, is an appealing transmission method for systems with high bit rates. Like OFDM, one principal inconvenience of MIMO-OFDM is the high top to-average power proportion (PAPR) of the transmitter's result signal on various radio wires. The best performance for PAPR reduction is provided by the partial transmit sequences (PTS) method. However, the traditional PTS method has a tremendously high computational complexity. In this paper, a

helpful and substitute PTS (C-A-PTS) plot for STBC MIMO-OFDM framework is proposed which can accomplish almost ideal PAPR execution at significantly less intricacy. The advanced algorithm's effectiveness is demonstrated by the simulation results.

**Ho-Lung Hung et al. [8]**, they concentrated on the effect of nonlinear gadgets on OFDMA signals. As a result, they employ FDMA (Frequency Division Multiple Access) and OFDM modulation simultaneously. The nonlinear interference levels on the received signals and an analytical spectral analysis of the transmitted signals are made possible by their findings. They thought about nonlinear signal processing methods that work with OFDM signals that have been sampled. For the analytical characterization of the transmitted signals, they will make use of the Gaussian nature of OFDMA signals with numerous subcarriers. In, they presented an analytical tool for assessing the effects of nonlinear distortion on OFDMA signal-based systems.

**P. Kothai et al. [9]**, they proposed the novel transceiver schemes for the MIMO interference channel based on the mean square error (MSE) criterion. Their goal is to optimize the system performance under a given feasible degree of freedom. They also proposed tire robust MSE based transceiver schemes that take channel estimation error into account. In specific, two types of MSE were studied. One is the total MSE among all users without considering user fairness, and the other is the maximum per-user MSE when user fairness is concerned. In, the channel model used in the simulations is a quasi-static flat Rayleigh fading channel. They also proposed robust Sum-MSE Minimization and Min-Max algorithm in the presence of channel estimation errors.

**Muhammet Nuri Seyman et al. [10]**, they provided analytical framework for calculating the large-system throughput of a MIMO cellular network with channel estimation errors. The studies assumed that each AP only decodes the users in its service region without AP cooperation. If the average path gain of one link is relatively low, ignoring its contribution is worth consideration while slightly sacrificing system performances but greatly reducing system complexity. In addition to the optimal MMSE detector, this study also utilizes the suboptimal but simple linear MMSE (LMMSE) detector. It finally, they have reported that the weak path hardly contains useful information, and the additional training segment seems to be wasted and decrease the available data transmission period.

#### IV. PTS SCHEMES

##### 1. SISO PTS Scheme

In the SISO-PTS scheme, the original data sequence in the frequency domain is partitioned into  $M$  disjoint, equal length sub blocks  $X_v$  ( $v = 1, 2, \dots, M$ ) as follows.

$$X = \sum_{v=1}^M X_v \quad (3)$$

By multiplying some weighting coefficients to all the subcarriers in every subblock, we can get the new frequency sequence.

$$X' = \sum_{v=1}^M b_v X_v \quad (4)$$

Finally, at each transmitting antenna, there are  $(V-1)$  sub blocks to be optimized, and the candidate sequence with the lowest PAPR is individually selected for transmitting. Assume that there are  $W$  allowed phase weighting factors. To achieve the optimal weighting factors for each transmitting antenna, combinations should be checked in order to obtain the minimum PAPR [10].

Implementation in FDD mode: The performance of massive MIMO systems is very dependent on the channel knowledge at the BS. In the uplink the users send orthogonal pilots and the BS estimates the channel of each user considering the pilots. In the downlink of conventional MIMO systems, the BS sends pilots to the users and the users feedback the channel information to the BS, after estimating it. However, since the number of resources needed for

channel estimation is proportional to the number of antennas at the transmitter, estimating the channel in downlink of massive MIMO systems where we have large number of antennas at the BS is not suitable and it requires many resources. Also in these systems, the number of channels which each user has to estimate is large and, therefore, a large amount of information has to be fed back to the BS. One solution is to use time division duplex (TDD) mode and take advantage of channel reciprocity to estimate the downlink channel in the uplink. However, this mode also has some drawbacks, for example the hardware impairments in the BS and user side may affect channel reciprocity, not to mention possible channel variations between the time it is estimated and the time it is used (i.e., channel aging effects). Also many current systems work with FDD mode, and for massive MIMO to be compatible with these systems we need to be able to implement it in FDD mode. So, implementing massive MIMO in FDD mode with low training and feedback overhead is an issue that needs further studies.

**Pilot contamination:** In TDD mode, each user sends an orthogonal pilot for channel estimation. Since the coherence time of channel is limited, there is a limited number of orthogonal pilots and therefore users in other cells have to reuse these pilots. So, the estimated channel of a specific user will be contaminated with a linear combination of the channel of other users which use the same pilot. Since the beamforming is done considering these estimated channels, an interference between users who use the same pilot will occur.

**Channel model:** Most of the works on massive MIMO systems are done with the assumption of time invariant flat rayleigh fading channels. Since in OFDM systems the channel over each sub-carrier is considered flat, the studies on flat fading channels can be extended to OFDM systems. However, in many practical scenarios, the channel is frequency selective and time variant. The channel coefficients can also have different distributions. So, studying these systems in more realistic environments is an issue which needs further investigations.

## V. CONCLUSION

In this work, we focus on the MIMO-OFDM communication system due to their significant nature of improving the wireless cellular communication. MIMO communication system have several advantages and disadvantages, hence, to overcome the limitations of MIMO, recently, MIMO-OFDM communication systems is developed which improved the communication performance but due to increased demand of good QoS communication, these systems face several challenges. Several approaches have been introduced to improve the performance of MIMO-OFDM. In this work, we review these techniques of MIMO-OFDM and present a comparative study to identify the research gap in this research direction. This review study revealed that the PAPR reduction techniques can be improved further with the help of optimization schemes. Similarly, the error correcting codes are also important factor which affects the QoS of the system.

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