Optimization of Massive MIMO-OFDM Systems for PAPR Reduction

J. Sivasankari a, B. Sridevi b, I. Mahima a

a Department of ECE, Ultra College of Engineering and Technology, Madurai, Tamil Nadu, India.
b Department of ECE, Velammal Institute of Technology, Tiruvallur, Tamil Nadu, India.

* Corresponding Author: jsivash11@gmail.com DOI: https://doi.org/10.34256/bsr2024

Received: 13-06-2020
Accepted: 30-09-2020

Abstract: Of late there has been an increase in use of wireless communication system. The recent approach used is Massive-MIMO technology. But in the current scenario where spectrum is limited, the demand for high data degrades the quality of services. Therefore, OFDM system was proposed. Though coupling OFDM system with MIMO can further improve the performance of next generation wireless systems, there are certain issues like antenna design, channel estimation, PAPR etc. which requires due consideration. Amongst them, PAPR is the major problem that contributes high in performance degradation. To overcome this issue, Modified Firefly algorithm is used which was inspired the behaviour of fireflies. With the firefly algorithm, PAPR is highly reduced leading to better performance.

Keywords: Massive-MIMO-OFDM, PAPR, Firefly Optimization

1. Introduction

The communication and technology industry are going through turbulent times. Instead of simple voice calls of the past, now want the 3A’s-Anything, Anywhere, Anytime communication. This leads to the evolving of wireless communications. Wireless communication on simply wireless is the process of transferring information or power from one point to two or more points that are not connected physically by means of electrical conductors [1].

With the recent evolution of next generation networks, Massive-MIMO seems to be effective candidate for the prominent hassle-free communication. Massive MIMO deals with a greater number of low power antennas highly forecasting with OFDM concepts.

2. Mimo-OFDM

The MIMO have the numerous receiving antennas transmitting the various signals and OFDM separates the different channels into sub channels for exact and rapid correspondence [2]. Because of this high unearthly proficiency, it is the reason for WLAN organizes versatile broadband correspondence [3]. The transmitter and receivers are utilized for performing beam forming and diversity actions. In the OFDM, numerous channels are isolated into various sub channels that are firmly separated for dependable correspondence [4]. This course of action wipes out most noteworthy issue in the MIMO-OFDM.

The MIMO-OFDM framework, receivers do not accurately decode the transmitted signals, because of the Inter Symbol Interference (ISI) [1]. The high rate information streams separated into low rate streams that are transmitted parallel in sub channels. Each subcarrier signals are isolated by guard bands,
for that message signals are not covered
between them. Utilizing the channels at
beneficiary end, the subcarriers are
demodulated for isolating the frequency bands.
On the off chance that one signal is meddled
with resulting signals that lessens the
unwavering quality of correspondence [3]. Due
to the multipath spread, Inter Symbol
Interference happens. The progressive signals
are combined as a result of the nonlinear
recurrence reaction of a channel. ISI has great
impact on both transmitter and receiver ends
[3, 5]. Bit error rate happens because of Inter
Symbol Interference.

A. Guard Bands:

The ISI is expanded when the signal
span is shorter in the high rate of information
correspondence. Inter Symbol Interference is
anticipated by the guard bands [3]. At the point
when the guard interval is longer than delay
spread, it does not produce overlapping of
signals and do not leads to ISI [5].

MIMO - OFDM decoders work at low
SNR. The major drawback of OFDM is high
PAPR of the transmitted signal [4]. The signal
power gets large peaks, so that the amplifiers
work at saturation region which prompts to
signal distortion. Protect interim in guard
interval is embedded in two ways. Those are
zero padding and cyclic extensions. The cyclic
extension is the cyclic prefix or cyclic suffix. The
subcarrier for every client and each frame is
contrastingly appointed.

a. Cyclic prefix

Delay dispersion additionally prompts
to lost orthogonality between the subcarriers,
and therefore to inter carrier interference (ICI)
[1]. Fortunately, both these negative impacts
can be disposed of by an extraordinary sort of
watch interval, called the cyclic prefix. The
accessible data transmission is devoured by
cyclic prefix at low rate, which diminishes
ghostly limit. This cyclic prefix reduces spectral
efficiency.

b. Issues in MIMO-OFDM:

In current scenario where spectrum is
limited, the demand for such high-speed data
degraded the quality of the services. Hence,
OFDM system was proposed in this literature to
overcome the problem of limited spectrum.
Also integrating OFDM system with MIMO can
further improvise the performance of
upcoming generation wireless systems [1, 3].
More number of antennas are used at both
transmitter and receiver side in MIMO system.
This exploits spatial diversity. So, MIMO OFDM
has been adopted as one of the most important
techniques for upcoming mobile wireless
systems [4].

However, there are few design
issues/challenges while considering MIMO-
OFDM system like, synchronization, Inter-
Symbol- Interference (ISI), Inter- Carrier-
Interference (ICI), Peak-to-Average-Power-
Ratio (PAPR), etc. that requires due
consideration [1].

c. Peak-to-Average Power Ratio (PAPR)

The PAPR of the signal, x(t) is then given
as the proportion of the peak instantaneous energy to the normal power, composed as:

\[ \text{PAPR} = \max \frac{|x(t)|^2}{|E[x(t)]|^2} \quad 0 \leq t \leq T \quad \ldots \quad (1) \]

Here,

\[ E[.] \] is the expectation factor.

\[ x(t) \] Amplitude of the complex pass-band signal.

PAPR is the proportion between the most extreme power and the normal force of the unpredictable pass band signals [1, 3]. In the OFDM framework with N subcarriers, the greatest power happens when the majority of the N subcarrier parts happen to be included with indistinguishable stages. We are regularly keen on finding the likelihood that the signal power is out of the straight scope of the HPA [4]. Towards this end, we first consider the dissemination of yield signs for IFFT in the OFDM framework. While the information signs of N-point IFFT have the autonomous and finite sizes which are consistently appropriated for QPSK and QAM, we can accept that the genuine and nonexistent parts of the time-space complex OFDM signals have asymptotically Gaussian circulations for an adequately substantial number of subcarriers by as far as possible hypothesis [1].

3. Existing Models

A. PAPR Reduction Techniques:

PAPR reduction techniques are broadly classified into the distinctive methodologies [4]:

- Clipping and filtering
- Block coding
- Partial transmit sequence (PTS)
- Tone injection (TI) scheme
- Tone reservation (TR) scheme
- Selective mapping (SLM)
- Cross-Entropy (CE) method

| Reduction Technique | Parameter | Operation required at Transmitter (TX)/Receiver (RX) |
|---------------------|-----------|------------------------------------------------------|
| Clipping and Filtering | Less Distortion: No, Power raise: No, Defeat data rate: No | TX: Clipping RX: None |
| Block Coding | Less Distortion: Yes, Power raise: No, Defeat data rate: Yes | TX: Coding RX: Decoding |
| Partial Transmit Sequence (PTS) | Less Distortion: Yes, Power raise: No, Defeat data rate: Yes | TX:N times IDFTs operation RX: Side information extraction, inverse PTS |
| Tone Reservation(TR) | Less Distortion: Yes, Power raise: Yes, Defeat data rate: Yes | TX: Parallel to serial RX: Serial to parallel |
| Tone Injection (TI) | Less Distortion: Yes, Power raise: Yes, Defeat data rate: No | TX: N times IDFTs operation RX: N TIMES DFTs operation |
| Selective Mapping (SLM) | Less Distortion: Yes, Power raise: No, Defeat data rate: Yes | TX: N times IDFTs operation RX: Side information extraction, inverse SLM |
B. Drawbacks:

Clipping causes in-band signal bending, bringing about BER execution corruption [6-10]. Clipping likewise causes out-of-band radiation, which forces out-of-band impedance signs to neighboring channels. Code blocking process is highly complexes because the entire process is performed using algebraic function [6]. This complexon affect the bandwidth efficiency. The PTS requires several Inverse Fast Fourier Transform (IFFT) operations are performed [8]. Selective mapping strategy is the overhead of side data that requires to be transmitted to the recipient of the framework keeping in mind the end goal to recover information [9, 11, 12].

4. Proposed Technique

A. Firefly Algorithm

The recent modern approach for optimization process in any technology for best solutions, firefly algorithm is engaged. This was formally developed by Dr. Xin She Yang in 2007 at university of Cambridge.

This was inspired by the behavior of fireflies. Any fireflies have unique flashing pattern. Usually female flies respond to the unique flashing pattern of the male flies. When the distance between the flies increases, the light intensity becomes weaker and weaker [13, 14]. This is more like a particle swarm intelligent. Their attractiveness is proportional to brightness and those both decreases as distance increases.

A. Purpose of flashing

The main purposes of flashing are,

- Attract mating partners
- Attract potential prey
- Protective warning mechanism

B. working principle of fireflies

In a standard firefly algorithm, there are two important points to be considered. The formulation of light intensity and the change of attractiveness. Suppose the light intensity \( I \) varies with the distance \( r \) and light absorption parameter \( \gamma \) exponentially and monotonically [15]. That is

\[
I = I_0 e^{-\gamma r^2} \quad \text{------- (2)}
\]

Firefly’s light attractiveness \( \beta \) is

\[
\beta = \beta_0 e^{-\gamma r^2} \quad \text{------- (3)}
\]

The distance between two fireflies \( i \) and \( j \), at position \( d_i \) and \( d_j \) can be calculated as,

\[
r_{ij} = d_i - d_j \quad \text{------- (4)}
\]

\[
d_i = d_i + \beta_0 e^{-\gamma r_{ij}^2} (d_i - d_j) + \alpha (\text{rand} - 1/2) \quad \text{------- (5)}
\]

The flow of proposed work can be represented in the following figure. 3

![Flowchart of Proposed work](image-url)
Symbols on FFT are performed to form frames and basic scatter plot is shown in figure 4.

![Fig 4. Scatter Plot of 16-QAM](image)

Symbols on FFT are performed to form frames. White Gaussian noise added with the transmitted symbols that is shown in fig 5. Signal is formed as symbols in transmitting medium. N times IFFT is performed.

![Fig 5. QAM-16 scatter plot with noised samples](image)

Population of firefly to be optimized using Resen brock objective function.

Fitness Function was calculated using,

\[ P_{SI} = \frac{f_{v_i}}{\sum_{i=1}^{N} f_{v_i}} \]  

Fitness function is calculated for different noise variance. And it is represented as D=1,2,3..., depicted in fig.6

![Fig 6. Fitness function optimization for various noise variance](image)

After the optimization process, the reduction in PAPR with respect to fitness function is depicted in fig.7

![Fig 7. PAPR for QAM-Expansion module](image)

As seen from the results and discussion, PAPR can be reduced with help of optimization using firefly algorithm. Impact of firefly optimization has been retrieved using the fitness function, represented in eqn.6. To test the performance of the proposed algorithm,
computational algorithms were carried. It is important to select $\alpha$ and $\gamma$ appropriately for good PAPR reduction.

5. Results and Discussion

Compared to the existing scheme, firefly algorithm contributes more in PAPR reduction. We compare our algorithm with various existing algorithms in terms of cumulative distributive function. Results and discussion show that firefly optimization algorithm works better for reducing PAPR in Massive-MIMO system.

References

[1] Y. S. Cho, J. Kim, W. Y. Yang, C. G. Kang, (2010) MIMO-OFDM wireless communications with MATLAB, John Wiley & Sons.

[2] J. Prasanth Kumar, R. Sowjanya P. Sameena, P. Madhavi Sankar Gowd, Techniques for Improving BER and SNR in MIMO Antenna for Optimum performance, International Journal for Modern Trends in Science and Technology, 2 (2016) 61-65.

[3] L. Amhaimar, S. Ahyoud, A. El Yaakoubi, A. Kaabal, K. Attari, A. Asselman, (2018) PAPR reduction using fireworks search optimization algorithm in MIMO-OFDM systems, Journal of Electrical and Computer Engineering, 1-12.

[4] J. Li, Y. Tan, A Comprehensive Review of the Fireworks Algorithm, ACM Computing Surveys (CSUR), 52 (2019) 1-28.

[5] M. M. Haque, M. S. Rahman, K. D. Kim, Performance Analysis of MIMO-OFDM for 4G Wireless Systems under Rayleigh Fading Channel, International Journal of Multimedia and Ubiquitous Engineering, 8 (2013) 29-40.

[6] Jaya Misra, Rakesh Mandal, A Review on Various Approaches to Reduce Intersymbol Interference in MIMO – OFDM System, IJIRST –International Journal for Innovative Research in Science & Technology, 1 (2015) 74-78.

[7] A.K. Thakre, S.B. Meshram, Peak-To-Average Power Ratio Reduction in OFDM System Using Block Coding Technique, International Journal of Advanced Research in Computer and Communication Engineering, 2 (2013).

[8] P. D. Gawande, S. A. Ladhake, PAPR Performance of OFDM System by Using Clipping and Filtering Method, International Journal of Advances in Engineering & Technology, 6 (2013) 789-794.

[9] P. Varahram, B. M. Ali, A Low Complexity Partial Transmit Sequence for Peak to Average Power Ratio Reduction in OFDM Systems, Radio Engineering, 20 (2011) 677-682.

[10] B. Poudel, B. Mishra, Performance Analysis of PAPR Reduction in 4× 4 Spatially Multiplexed MIMO-OFDM System using SLM and Optimum-PTS Techniques, Journal of Telecommunications System and Management, 5 (2016) 2167-0919.

[11] W. C. Lee, J. P. Choi, C. K. Huynh, A Modified Tone Injection Scheme for PAPR Reduction Using Genetic Algorithm, ICT Express, 1 (2015) 76–81.
[12] S. S. Anwar, S. L. Koţgire, S. B. Deosarker, D. E. Rani, New Improved Clipping and filtering technique algorithm for peak-to-average power ratio reduction of OFDM signals, *International Journal of Computer Science and Communication*, 3 (2012) 175-179.

[13] Ibrahim Abdullah, Zulfiker Mahmud, Shamim Hossain, Nurul Islam, Comparative Study of PAPR Reduction Techniques in OFDM, *ARPN Journal of Systems and Software*, 1 (2011) 263-269.

[14] H. L. Hung, Application firefly Algorithm for Peak-To-Average Power Ratio Reduction in OFDM Systems, *Telecommunication Systems*, 65 (2017) 1-8.

[15] Aman Dhillon, Sonia Goyal, PAPR Reduction in Multicarrier Modulations Using Firefly Algorithm, *International Journal of Innovative Research in computer and communication engineering*, 1(2013) 1270-1275.

**Acknowledgement:** NIL

**Funding:** NIL

**Conflict of Interest:** NIL

**About the License:** © 2020 The Authors. This work is licensed under a Creative Commons Attribution 4.0 International License which permits unrestricted use, provided the original author and source are credited.