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# An Evaluation of Peak-to-Average Power Ratio (PAPR) and Bit Error Rate (BER) Using Peak Clipping Technique in 5G Communication

Fehma Aftab<sup>1</sup>, Rishi Sharma<sup>2</sup>

M Tech Scholar, Department of Electronics and Communication Engineering, OIST, Bhopal, M P, India<sup>1</sup>

Assistant Professor, Department of Electronics and Communication Engineering, OIST, Bhopal, M P, India<sup>2</sup>

**ABSTRACT:** In our study, we have proposed an improved architecture for Orthogonal Frequency Division Multiplexing (OFDM) by incorporating advanced techniques such as 1024-QAM modulation and 2048-IFFT/FFT. These enhancements effortlessly contribute to a notable reduction in the Bit Error Rate (BER) while simultaneously improving the Signal-to-Noise Ratio (SNR). We observed a satisfactory decrease in BER when compared to previous works. Our results clearly demonstrate that as the SNR increases, the BER decreases, indicating improved performance. Furthermore, we have successfully reduced the Peak-to-Average Power Ratio (PAPR) by utilizing a selective mapping method based on Discrete Fourier Transform (DFT). By introducing the combination of 1024-QAM and 2048-IFFT/FFT techniques, our proposed OFDM architecture exhibits enhanced performance in terms of BER reduction and improved SNR. Additionally, the incorporation of the DFT-based selective mapping method effectively lowers the PAPR.

**KEYWORDS:** Trellis codes, DFT Spreading, AWGN, OFDM, BER, PAPR etc.

## I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a highly efficient multi-carrier modulation technique that enables the sharing of information among multiple carriers. Its robustness to channel fading makes it particularly suitable for wireless communication environments. OFDM is a specialized form of Frequency Division Multiplexing (FDM), where the available bandwidth is divided into non-overlapping frequency sub-bands. Each sub-band is assigned to communicating sources, with a slightly wider bandwidth than what is required by each source. This additional bandwidth, known as a guardband, allows for the use of cost-effective filters. The independent sub-channels can be multiplexed using Frequency Division Multiplexing (FDM) or Code Division Multiplexing (CDM), resulting in multi-carrier or multi-code transmission, respectively. However, FDM has some drawbacks. It requires expensive and complex bandpass filters, which are needed in both the transmitters and receivers. Additionally, practical communication systems often employ nonlinear power amplifiers in the transmitters, which generate out-of-band spectral components that can interfere with other FDM channels. Consequently, more complex linear amplifiers are necessary for FDM systems.

In summary, OFDM offers efficient bandwidth utilization and resilience to channel fading, making it a valuable modulation technique for various wireless communication applications. While FDM presents challenges related to expensive filters and nonlinear amplification, the benefits of OFDM outweigh these limitations. Traditional Orthogonal Frequency Division Multiplexing (OFDM) has long been employed as a solution to mitigate the complexities associated with equalizing broadband channels. In our study, we have introduced a modified constellation shaping algorithm that leverages the pairing of adjacent OFDM carrier frequencies exclusively within the transmitted OFDM frame. As a result, this approach automatically leads to a proportional reduction in Peak-to-Average Power Ratio (PAPR) for the second OFDM frame transmitted. To assess the efficacy of our approach, we conducted extensive computer simulations utilizing two different channel models, each representing varying levels of sophistication. The performance of the new transmission system was then compared against a reference uncoded system. The results, presented in graphical form, clearly demonstrate a significant improvement achieved by our proposed technique. To achieve even higher performance, our scheme can be extended in two directions. Firstly, by incorporating more efficient components such as super-orthogonal space-frequency trellis codes with larger memory. Secondly, by exploring alternative techniques, including a secondary method for reducing the PAPR of the OFDM signals. Through

our research, we provide a compelling solution to address the challenges of equalization in broadband channels, offering enhanced PAPR reduction in OFDM communication

## II. LITERATURE SURVEY

1. Dayou Qian, Neda Cvijetic, Ting Wang work on “Novel Optical OFDM Transceiver Structures”. In their paper titled "Novel Optical OFDM Transceiver Structures," Dayou Qian, Neda Cvijetic, and Ting Wang address the increasing bandwidth demand in optical access/metro networks, where per-channel information rates are pushing towards 10+ Gb/s [1]. However, achieving such capacity enhancements in access/metro applications comes with strict cost and complexity constraints. To tackle this challenge, Optical Orthogonal Frequency Division Multiplexing (OFDM) has emerged as a promising solution for next-generation access/metro systems. OFDM offers high spectral efficiency, linear dispersion tolerance, and efficient implementation based on FFT [2-5]. Previous studies have demonstrated the use of optical OFDM in combination with polarization multiplexing (POLMUX) to achieve a record spectral efficiency of 5.6 bits/s/Hz in 640km transmission [6]. It's important to note that these results rely on coherent detection, which significantly increases receiver complexity due to the narrow line-width local oscillator, optical phase-locked loop, and polarization controller. Therefore, coherent detection is not suitable for cost-sensitive access/metro applications [7].

2. S. Herbst, S. Bayer, H. Wernz and H. Griesser work on “21-GHz Single-Band OFDM Transmitter with QPSK Modulated Subcarriers” [6]. Researchers have proposed the use of multilevel codes to increase the bitrate and spectral density of optical signals for 40G and 100G transmission. This increase in spectral efficiency offers potential cost savings and drives the development of higher data rates on a single wavelength. Orthogonal Frequency Division Multiplexing (OFDM) is considered a promising modulation format for further enhancing the spectral efficiency on optical single-mode fiber. OFDM has achieved spectral efficiencies as high as 7 bit/s/Hz [1]. Different versions of optical OFDM exist based on how subcarriers are modulated and demodulated. The optical approach modulates and demodulates subcarriers individually [2], while the electrical variant efficiently generates and demodulates all modulated carriers in the electrical domain using Fast Fourier Transforms (FFT) with a single modulator and optical frontend for conversion. The electrical approach allows for a greater number of subcarriers, benefiting parallel, low-complexity receiver architectures when combined with appropriate cyclic extension. On the other hand, the optical variant of OFDM requires large-scale optical integration, even for a small number of subcarriers, to achieve cost-effective and reliable products. A crucial aspect of future FFT-based OFDM systems is the generation of fast analog signals from digital data, necessitating high-speed digital-to-analog converters (DA converters) to enable modulation at high bit rates with a single optical modulator. Previous implementations of OFDM signals with a bandwidth beyond 16 GHz have relied on multi-band approaches, which combine independently modulated sub-bands in the frequency domain [3, 4]. A broadband OFDM signal with a bandwidth of up to 21 GHz was generated using an FPGA-based setup and high-speed DA converters (Micram Vega DAC25) operating at a sampling rate of 25 GSamples/s. This setup enabled the transmission of 27 Gb/s on a single polarization using QPSK modulation.

3. R. Schmogrow, M. Winter, B. Nebendahl, D. Hillerkuss, J. Meyer, M. Dreschmann, M. Huebner, J. Becker, C. Koos, W. Freude, and J. Leuthold work on “101.5 Gbit/s Real-Time OFDM Transmitter with 16QAM Modulated Subcarriers”. In this work, Orthogonal frequency division multiplexing (OFDM) has become of most important hobby for long-haul and access networks applications [1,2]. So some distance in most experiments offline processing was once employed for producing and receiving high velocity optical OFDM indicators [3] as real-time processing is a challenge. At absolute best bit-rates all-optical FFT processing may be an alternative [4,5]. For decrease subcarrier spacing optical filter barriers preclude optical processing and electronic processing becomes mandatory. Recently, real-time DSP primarily based coherent OFDM transmitters with quadrature segment shift keying (QPSK) on the subcarrier stage and height information costs of 8.36 Gbit/s [6] and 12.1 Gbit/s [7] have been demonstrated. A coherent real-time OFDM receiver decoding a 3.55 Gbit/s sign has additionally been proven [8]. First real-time OFDM transmission hyperlinks with depth modulation achieved records fees of up to 11.25 Gbit/s [9].

4. Orlando Grigoriadis, H. Srikanth Kamath BER Calculation Using Matlab Simulation For OFDM Transmission”. In an OFDM [4] scheme a massive wide variety of subchannels or sub-carriers are used to transmit digital data. Each sub-channel is orthogonal to each and every other. They are closely spaced and slim band. The separation of the sub-channels is as minimal as feasible to attain excessive spectral efficiency. OFDM is being used because of its capability to deal with with multipath interference at the receiver. These two are the primary effects of multipropagation [3]. Frequency selective fading and Inter Symbolic Interference (ISI) [5]. In OFDM the massive wide variety of slender band sub-carriers presents sufficiently “flat” channels. Therefore the fading can be treated via easy equalizing techniques for each channel. Furthermore the massive quantity of carriers can grant identical statistics prices of a single carrier modulation at a decrease image rate. The image charge of each channel can be dropped to a factor that makes

each image longer than the channel's impulse response. This eliminates ISI. The two most important drawbacks of OFDM are the giant dynamic vary of the alerts being transmitted and the sensitivity to frequency errors.

5 R. Schmogrow, M. Winter, B. Nebendahl, D. Hillerkuss, J. Meyer, M. Dreschmann, M. Huebner, J. Becker, C. Koos, W. Freude, and J. Leuthold conducted research on "101.5 Gbit/s Real-Time OFDM Transmitter with 16QAM Modulated Subcarriers." Orthogonal Frequency Division Multiplexing (OFDM) has gained significant interest in long-haul and access network applications [1,2]. However, in most experiments, offline processing was used for generating and receiving high-speed optical OFDM signals [3], as real-time processing posed a challenge. All-optical FFT processing could be a potential alternative for achieving the highest bit rates [4,5]. For lower subcarrier spacing, optical filter limitations prevent optical processing, and electronic processing becomes necessary. Recently, real-time DSP-based coherent OFDM transmitters using quadrature phase shift keying (QPSK) at the subcarrier level achieved peak data rates of 8.36 Gbit/s [6] and 12.1 Gbit/s [7]. A coherent real-time OFDM receiver, capable of decoding a 3.55 Gbit/s signal, has also been demonstrated [8]. Initial real-time OFDM transmission links with intensity modulation achieved data rates of up to 11.25 Gbit/s [9].

6. Orlandos Grigoriadis, H. Srikanth Kamath conducted BER Calculation Using Matlab Simulation for OFDM Transmission. In an OFDM scheme [4], a large number of subchannels or subcarriers are used to transmit digital data. Each subchannel is orthogonal to each other and is closely spaced and narrowband. The subchannel separation is minimized to achieve high spectral efficiency. OFDM is chosen for its ability to handle multipath interference at the receiver, which are the main effects of multipropagation [3], such as frequency-selective fading and Inter-Symbol Interference (ISI) [5]. The multitude of narrowband subcarriers in OFDM provides sufficiently "flat" channels, enabling simple equalization techniques for each channel to mitigate fading effects. Moreover, the large number of carriers allows for equivalent data rates of single-carrier modulation at a lower symbol rate. The symbol rate of each channel can be reduced to a point where each symbol is longer than the channel's impulse response, effectively eliminating ISI. The two main drawbacks of OFDM are the significant dynamic range of the transmitted signals and its sensitivity to frequency errors.

7 "A Novel Sub-block Linear Combination Scheme for Peak-to-Average Power Ratio Reduction in OFDM Systems" (IEEE-2012) Conference. In the paper titled "A Novel Sub-block Linear Combination Scheme for Peak-to-Average Power Ratio Reduction in OFDM Systems" presented at the IEEE-2012 Conference, the author proposes a new sub-block linear combination (SLC) scheme based on the cyclic projections algorithm to reduce the PAPR (Peak-to-Average Power Ratio) of OFDM signals. Additionally, an extended SLC approach called the R-SLC scheme is introduced to improve the convergence rate of the SLC scheme. The main idea behind these novel techniques is to divide an OFDM block into multiple sub-blocks and iteratively generate a linear combination of these sub-blocks with low PAPR. Unlike the traditional partial transmit sequence (PTS) scheme, the coefficients for the linear combination in the proposed schemes are obtained through iterative calculations using the cyclic projections algorithm, eliminating the need for exhaustive searching and selecting from a pre-set discrete set. As a result, one significant advantage of the proposed schemes is their lower computational complexity compared to the conventional PTS scheme. Theoretical analysis and simulation results demonstrate that the proposed schemes achieve effective PAPR reduction and low bit-error-rate performance while maintaining low computational complexity [5].

### III. PROPOSED METHODOLOGY

A digital-to-analog converter (DAC) is required to convert the discrete value of  $S_n$  (nth sample) to the continuous analog value of  $s(t)$ , while an analog-to-digital converter (ADC) is needed to convert the continuous received signal  $r(t)$  to discrete sample  $r_m$ . In order to implement a practical system, the ability to utilize commercial off-the-shelf converters at both ends of the transmission scheme becomes a crucial consideration. Numerous techniques are available to leverage digital signal processing stages and simplify analog processing, thereby reducing the requirements for both the DAC and the ADC.

Trellis coding offers a way to increase data rate without increasing the transmitted bandwidth, making it well-suited for experimental verification. The gain is achieved through multi-level, multi-phase signaling. The Trellis-coded modulation (TCM) bit error rate (BER) will be measured under defined conditions and compared to the performance of transmitting the same pseudo-random binary sequence (PRBS), with the same bandwidth and operating under similar conditions but without TCM.

The TCM system adds bits to the raw data, which means that for a 2-level transmitted format, the message rate would need to be slower than the raw data rate, considering the same transmitted bandwidth. However, in this case, since the TCM is a 4-level signal, an additional bit is added per message bit.

When independent strings are transmitted in parallel using PSK or QAM, there is a probability that all  $N$  subchannels transmit simultaneously at maximum power, resulting in a large peak-to-average power ratio (PAPR) with



challenging implications for the design of the final transmit amplifier. Various solutions have been proposed in the literature, but most of them require transmitting side information to the receiver, which reduces the data rate. Constellation shaping through shell mapping, however, allows for PAPR reduction without compromising the transmission rate.

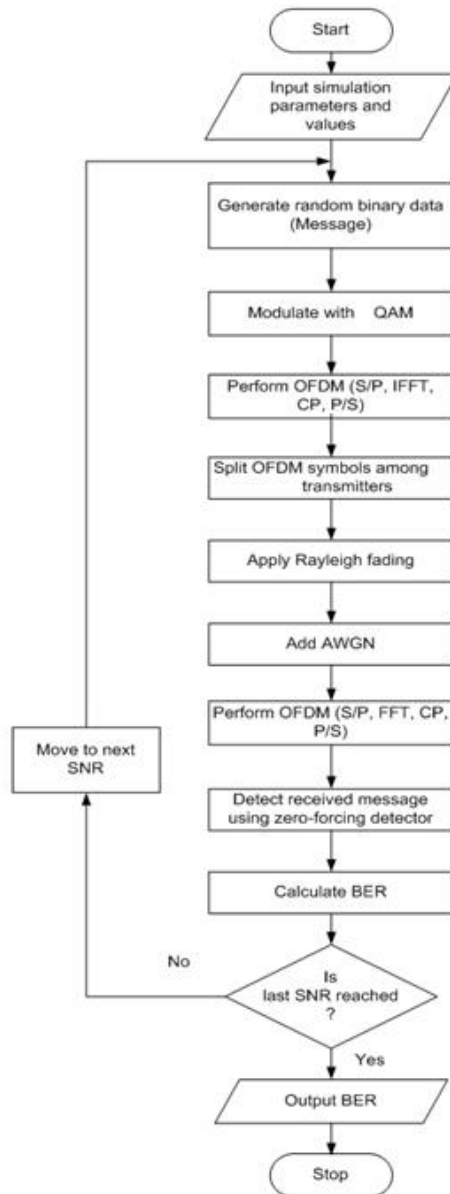


Fig 1 Flow chart

#### IV. PROPOSED ALGORITHM

Algorithm at the transmitter end:

- Generate the Data "D".
- While D != Null:
- Encode the generated data.
- Insert the interleaving Bits into Data.
- Perform QAM Mapping of data.
- Insert the Pilot Carrier.
- Convert the data into the IFFT Domain.

- Append Cyclic Prefix.
- Transmit the generated data through the AWGN channel.

Algorithm at the Receiver end:

- Receive the Data Bits "T".
- While T != Null:
- Remove Cyclic Prefix.
- Convert the data into the FFT Domain.

- Synchronize the Pilot Carrier.
  - Perform QAM Demodulation of the received data.
  - De-interleave Bits from Data.
  - Decode the generated data.
- Calculate the Bit Error Rate for the received Data.

### V. SIMULATION AND RESULTS

In this section, we present our findings on the Peak-to-Average Power Ratio (PAPR) through simulations conducted on an OFDM transmitter with sixteen subcarriers. We examined the performance of the system using two modulation schemes: 512 QAM for the basic system and 1024 QAM for the coded system. Throughout the simulations, we used a sequence of 50 zero-filled OFDM symbols and employed an oversampling factor of eight.

To evaluate the impact of constellation shaping, we analyzed the Complementary Cumulative Density Function (CCDF) of PAPR. This involved estimating the probability that the PAPR exceeds a given threshold, represented by the expression

$$CCDF(PAPR_0) = P_r(PAPR > PAPR_0).$$

Furthermore, we provide comprehensive simulated results in this section, encompassing PAPR and Bit Error Rate (BER) measurements for both 512 QAM and 1024 QAM. These results are visually depicted in figures, allowing for a direct comparison with the findings presented in the original paper..

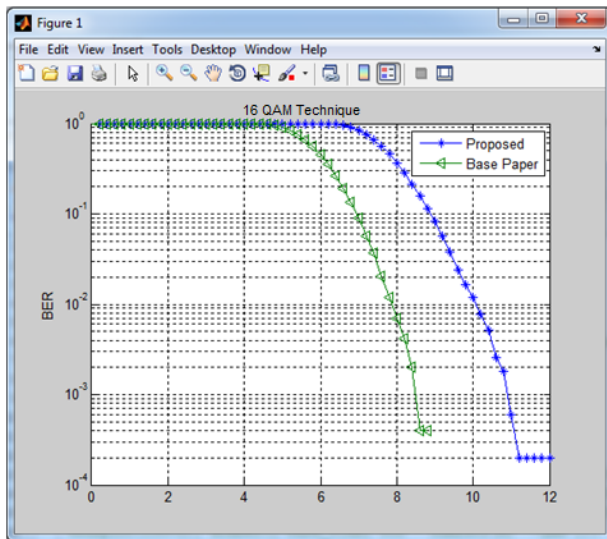


Fig 2 PAPR Graph for 16\*32 (512) QAM OFDM Base Vs Proposed

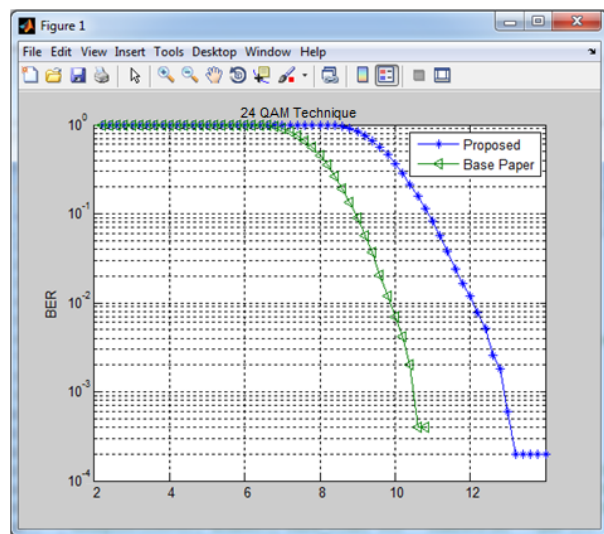


Fig 3 PAPR Graph for 101024 QAM OFDM Base Vs Proposed

The first curve, represented by a solid line, illustrates the PAPR characteristics of an OFDM signal using a standard 16 QAM constellation without any constellation shaping. The second curve, indicated by a dashed line, corresponds to an OFDM signal with constellation shaping as described in the literature. Specifically, it represents a 1024 QAM signal employing constellation shaping with 6 rings for a single transmit antenna.

Moreover, the continuous line on the graph depicts the PAPR behavior of an OFDM signal using constellation shaping. This line corresponds to a modified 1024 QAM constellation shaping with 36 super-rings for two transmit antennas. The results presented in the figure demonstrate that the 1024 QAM signal utilizing constellation shaping with six rings achieves a shaping gain of more than 0.5 dB over the reference 1024 QAM signal without constellation shaping, considering a Complementary Cumulative Density Function (CCDF) of less than  $10^{-3}$ . Table I provides us the values of Bit error rate at various Signal to Noise ratio for the method we used.

Table I Bit Error rate at Various SNR consideration

S.No.	SNR (dB)	Bit Error rate
1	0	0.5968
2	5	0.5961
3	10	0.5093
4	15	0.5911
5	20	0.5958
6	25	0.5035
7	30	0.5987
8	35	0.5961
9	50	0.5973

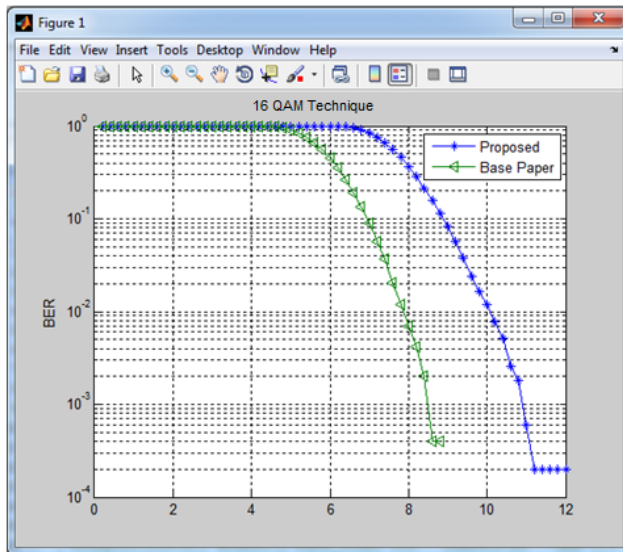


Fig 4 BER Graph for 16 \* 32 (512) QAM OFDM

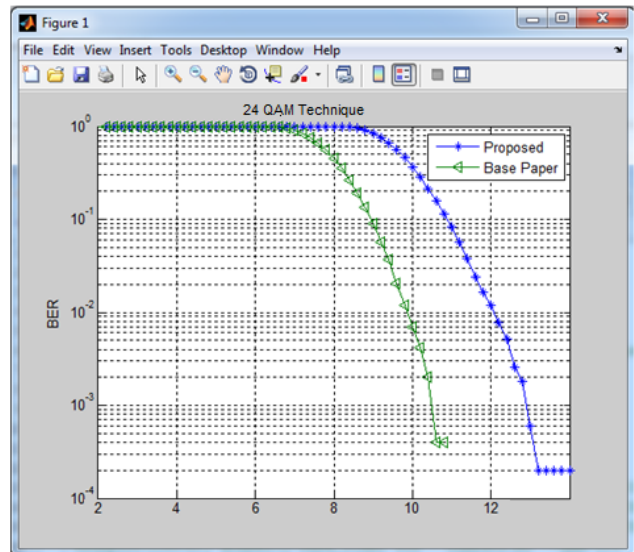


Fig 5 BER Graph for 1024 QAM OFDM Base Vs Proposed

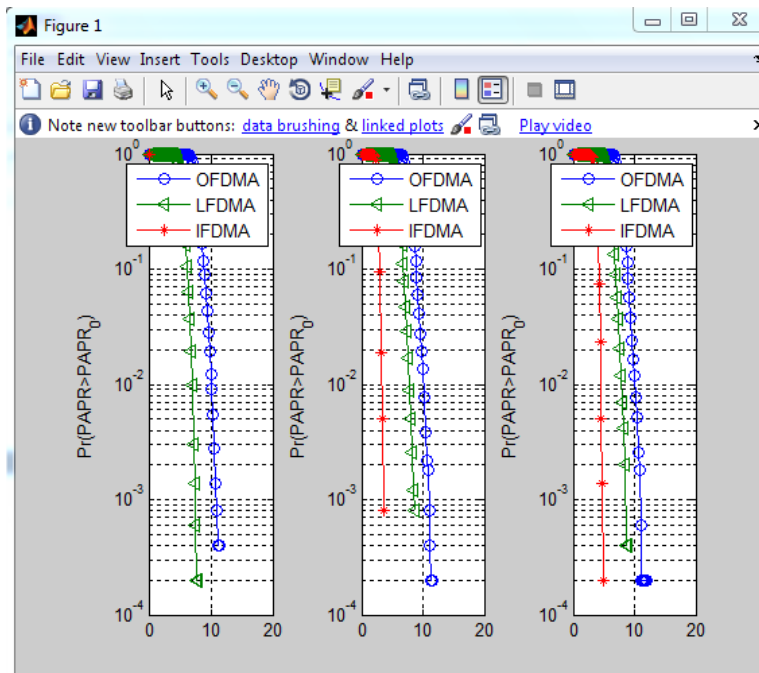


Fig 6 PAPR reduction after the proposed method

The OFDM block consists of 64 bits. In the 1024 QAM OFDM trellis-coded system with shell mapping, the first 32 bits

are used to select the shell using an algorithm that determines the 1024 QAM indexes. Subsequently, the selected 16 symbols using 1024 QAM are transmitted using the space-frequency OFDM scheme. The BER performances are evaluated for both the 1024 QAM-OFDM trellis-coded system with shell mapping and its corresponding 1024 QAM reference system, both achieving a spectral efficiency of 4 b/s/Hz per subcarrier, as a function of the average SNR. The 1024 QAM-OFDM trellis-coded system with shell mapping demonstrates superior performance over the reference system at high SNR values. The coding gain of the proposed system compared to the reference system is approximately 5 dB for channel 1 and about 4 dB for channel 2, at a BER of  $10^{-4}$ , with increasing gains observed for lower BER values. Furthermore, the proposed system outperforms the reference system by more than 4 dB (for channel 1) and by more than 2 dB (for channel 2) at a FER rate of  $10^{-2}$ , with increasing gains for lower BER values. The reduced BER performance of the proposed system in channel 2, compared to channel 1, can be attributed to the increased frequency selectivity present in channel 2, characterized by significant differences in channel coefficients between neighboring carriers. It is worth noting that the performance of the reference system remains unaffected by the channel model, resulting in identical BER results for both channel models.

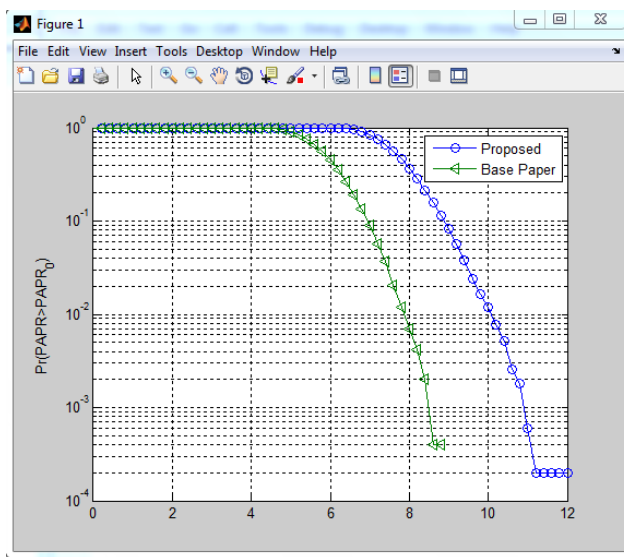


Fig 7 PAPR Graph for 1024 QAM

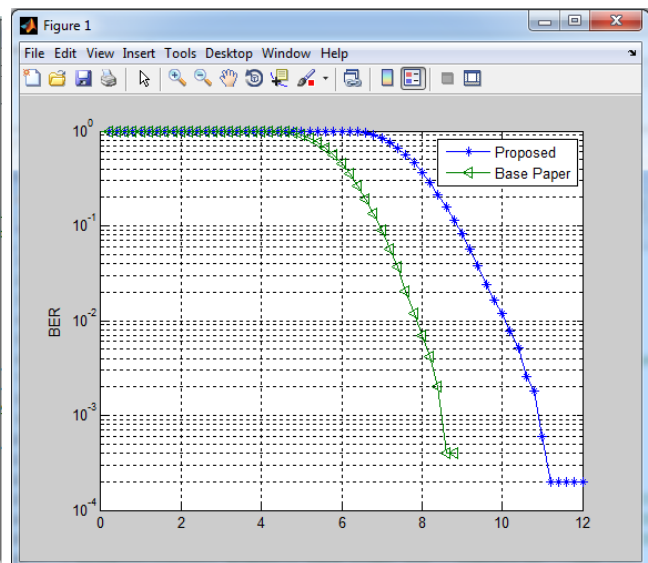


Fig 8 BER graph for 1024 QAM

Table II Comparative results of Base Paper and Proposed Work

S. NO	Base Paper		Proposed Work
	SNR (dB)	BER	BER
1	0	0.648	0.568
2	5	0.645	0.561
3	10	0.451	0.593
4	15	0.645	0.511

Here the BER of 0.5511 is obtained for SNR of 15 db for simulated results verifies the proposed technique is better as compared to previous works.

### V. CONCLUSION

We propose a modified constellation shaping algorithm for Orthogonal Frequency Division Multiplexing (OFDM) to reduce the Peak-to-Average Power Ratio (PAPR) in the transmitted OFDM frames. Extensive computer simulations using different channel models demonstrate the significant improvement achieved by our approach compared to a reference uncoded system. To further enhance performance, we suggest incorporating super-orthogonal space-frequency trellis codes with larger memory and exploring alternative techniques for PAPR reduction. Our research offers an effective solution to address equalization challenges in broadband channels, resulting in enhanced PAPR reduction in OFDM communication.

Additionally, we introduce an improved OFDM architecture with 1024-QAM modulation and 2048-IFFT/FFT techniques, which effectively reduces the Bit Error Rate (BER) and improves the Signal-to-Noise Ratio (SNR). Our findings show a satisfactory decrease in BER compared to previous works, indicating improved performance with increasing SNR. Moreover, we achieve PAPR reduction by utilizing a selective mapping method based on Discrete



Fourier Transform (DFT). The proposed OFDM architecture demonstrates enhanced performance in terms of BER reduction and improved SNR, offering a promising solution for high-quality OFDM communication.

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