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OFDM-MIMO based carrier frequency offset modulation for the multi-carrier transmission

Sanjay Singh* and Bhagwat Kakde
Madhyanchal Professional University (MPU) Bhopal, India

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Abstract
In this paper a hybrid framework has been developed which is based on OFDM-MIMO system. This system adopted carrier frequency offset (CFO) modulation scheme for the multi-carrier transmission. Different subcarriers have been considered with quadrature amplitude modulation (QAM). Different channel capacity along with the subcarrier and lengths have been considered for the system performance estimation. CFO with different channel consideration is found to be helpful in the improvement of the system. The results show the variations in subcarrier, length and variations. The results show the improvement in bit error rate (BER) in case of increasing the number of systems, subcarriers and variations in correlation.

Keywords
OFDM, MIMO, CFO, QAM, BER.

1.Introduction
Orthogonal frequency division multiplexing (OFDM) is a frequency division multiplexing (FDM) scheme for the multi carrier frequency system [1, 2]. For the enhance flexibility of multiple transmitter and receivers, multiple inputs and multiple outputs (MIMO) can be used [3].

For the communication system different combinations were used like quadrature amplitude modulation (QAM)) and quadrature phase shift keying (QPSK) for the better communication and the reduction of the error rate [4, 5]. The performance of the OFDM and MIMO system may degrade in case of inter carrier interference (ICI). Then the other measure is the carrier frequency offset (CFO) [6]. The performance factor may be affected by the sub channels, frequency fading and timing jitters. Time-division multiplexing (TDM) and space-division multiple access (SDMA) are capable in improvement of the performance based on different timing jitters [1, 2]. For synchronized communication system code division multiple access (CDMA) can be used [3]. Multiple access interference (MAI) can be helpful in the data rates optimization [2, 3].

Different error correction codes have been used in the previous work like Reed-Solomon-code, Alamouti-code, turbo-code [7, 8]. It has been used in different system for the reduction of error rates. For the block synchronization cyclic prefix can be helpful with the inter-symbol-interference (ISI) [9, 10]. For the spectral efficiency windowing techniques were used [10, 11].

The objective of this paper is to show the modulation based on varying parameters like system model and bandwidth considering different channel modes. This paper is organized and explored in the following sections. Literature discussion in section 2. Methods have been explored in section 3. Results investigation and discussion have been presented in section 4. The concluding remark has been elaborated in section 5.

2.Literature review
In 2021, Linnartz and Deng [11] discussed about the intensity modulated optical communication. Non-negative signal is required for the communication in case of light emitting diode (LED) channel. It is helpful in the low pass nature. For this purpose, they have proposed the combination of flip and asymmetrical clipped optical-OFDM.

*Author for correspondence

In 2022, Badran et al. [12] proposed CAZBAR sequence. It is based on zero autocorrelation. It is helpful in zero shift, better autocorrelation and higher peak. The results shows that the bit error rate (BER) has been reduced in comparison to MIMO-OFDM combination with single-carrier frequency-division multiple access (SC-FDMA).

In 2022, Huang et al. [13] discussed about RadCom. They have suggested that the traditional RadCom which is based on OFDM system have low efficiency due to high peak-to-average power ratio (PAPR) and improper bandwidth allocation. So, they have proposed cyclic algorithm combination with the traditional system. The results show significant improvement in comparison to the traditional system in terms of communication and radar functions.

In 2021, Reddy et al. [14] discussed about forward error-correcting codes. They have developed a concatenated version of MIMO and OFDM. It is helpful in the reduction of inference. It can be helpful in the improvement of data rate. Turbo code found to be better in the result analysis.

In 2022, Ahmad and Shin [15] discussed about the wavelet-OFDM. They have proposed a 6G network. It is based on wavelet-OFDM and MIMO system. It is mainly based on non-orthogonal-multiple-access. The performance parameters consider are PAPR, symbol error rate and spectral efficiency. The results show the improvement in terms of traditional Fourier transform based system.

In 2022, Khosravy et al. [16] discussed regarding the combination of OFDM-MIMO system. Due to the advantage in data rate and energy consumption, they have suggested a blind structure of MIMO. They have also used the combination of independent component analysis. Their approach is found to be proficient in efficiency and complexity.

In 2019, Chow [17] proposed a modified OFDM using asymmetrical model. For the bandwidth efficiency they have used direct-current biased optical OFDM. The results show reduction improvement in PAPR. It is also helpful in index modulation.

In 2019, Mizutani et al. [18] proposed a function based on time-domain windowing. It has been used with long-term evolution (LTE) uplink parameters. They have used several performance parameters for the proper comparison of the results and found to be satisfactory.

In 2018, Dan et al. [19] discussed about N-continuous-OFDM. They have analysed the inference in the N-continuous-OFDM. It has been used in terms of frequency domain and power distribution system. The results show better BER as compared to out-of-band suppression.

In 2022, Attiah et al. [20] proposed an approach based on deep learning. It has been proposed for the MIMO system for channel sensing and hybrid beamforming. It reduces the intermediate channel estimation. The results show less training overhead in comparison to the traditional approaches.

In 2020, Nguyen et al. [21] discussed about OFDM in terms of single-carrier modulation. Multi-LED system has been adopted due to the improvement in the data frate.

In 2017, Rakhi and Jayakumari [22] discussed about the optical wireless communication. It has been discussed as it is beneficial in the deployment of LEDs. They have designed a flip-OFDM system for the same purpose. The results show significant improvement in BER.

In 2016, Yu et al. [23] discussed about the fast Fourier transform based OFDM system. They have investigated the impact of impulsive noise. It has also been discussed in additive white Gaussian noise (AWGN) channel. The result shows that the impulsive noise is more in wavelet-based OFDM in comparison to fast Fourier transform based OFDM system.

3.Methods

In this paper a hybrid OFDM-MIMO correlation system has been developed for the estimation of the performances using BER considering different system specifications. The working mechanism is clearly depicted in *Figure 1*.

The system development steps are as under:

1. Transmit and receive Antenna (System model)
2. Data stream selection
3. Selection and identification of channels
4. Performance measures

The first phase is the system model. In this phase different system configurations have been checked and analysed. The transmit and receive antenna considered here are 2, 3, 4 and 5. The configuration systems considered here are 2×2, 3×3, 4×4 and 5×5.

AWGN channel has been considered for the data stream selection. The number of iterations is fixed to 1000. It has been considered as it is helpful in the confidence and estimation assurance.

The next phase is selection and identification of channels. Subcarrier is selected first. It varies from 8-512 subcarriers. The code length considered was 2^n with the timing jitters. The subcarrier capacity is denoted by n. Then the related subcarrier distance has been calculated for the nearest jitters based on the Euclidean distance. The channels considered here are AWGN and Rayleigh. Quadrature amplitude modulation (QAM) and QAM have been considered for the modulation.

The BER has been calculated as shown below.

$$BER = \frac{Error\ number}{Number\ of\ bits}$$

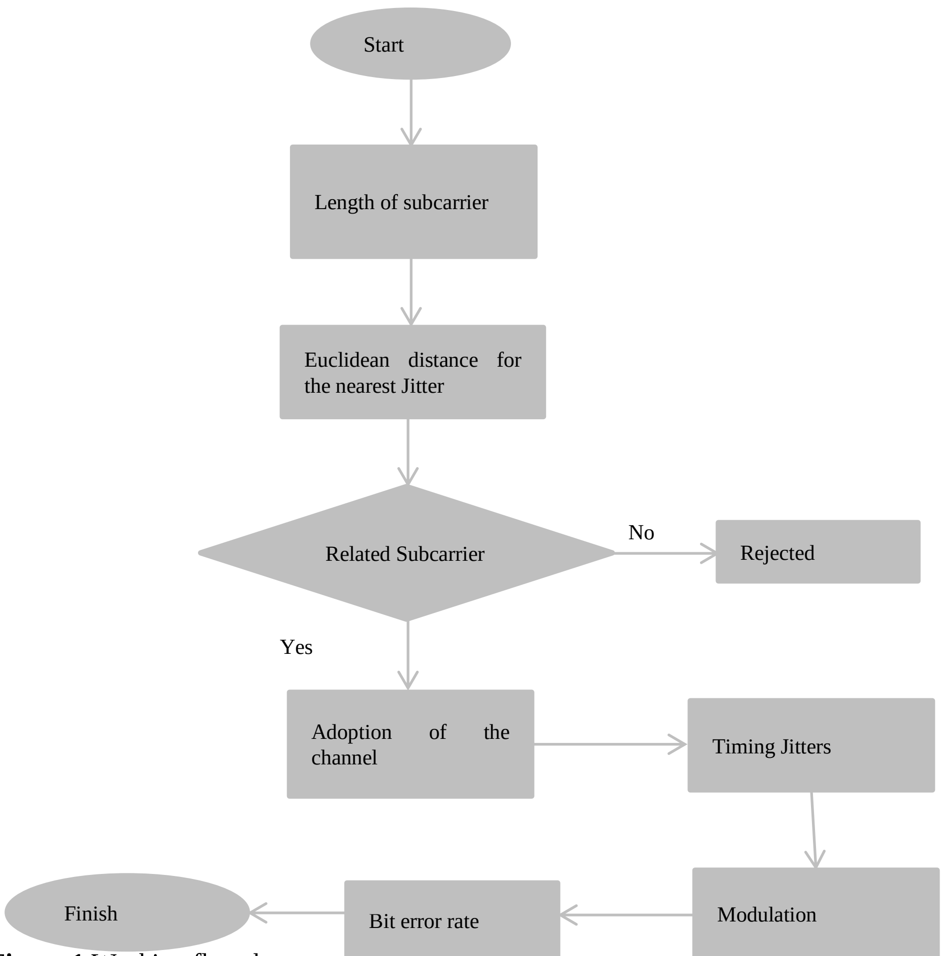

Figure 1 Working flowchart

4. Results and discussion

In this section results have been explored with variable paraments. Different cases have been considered for the experimentation which are shown in *Table 1* and *Table 2*.

Table 1 Notation and representation used in the results

S. No.	Symbol	Representation
1	Circle-dash line	Jitters affected bit error rates
2	Star-dash line	Correlated Jitters affected bit error rates
3	+-dash line	Uncorrelated-Zero Jitters
4	X-dash line	Bit error rate (Ideal)

Table 2 Parameters used in the experimentation

S. No.	Parameter	Ranges
1	System model	AWGN
2	Bandwidth estimation	5MHZ
3	Iteration	1000
4	MIMO-OFDM	Iterative approach
5	Time slot	Time division
6	Modulation	QPSK

The result shown in *Figure 2 to Figure 7* clearly depicts the performance evaluation on different system. The results show the variations in subcarrier, length and variations. The results show the improvement in BER in case of increasing the number of systems, subcarriers and variations in correlation.

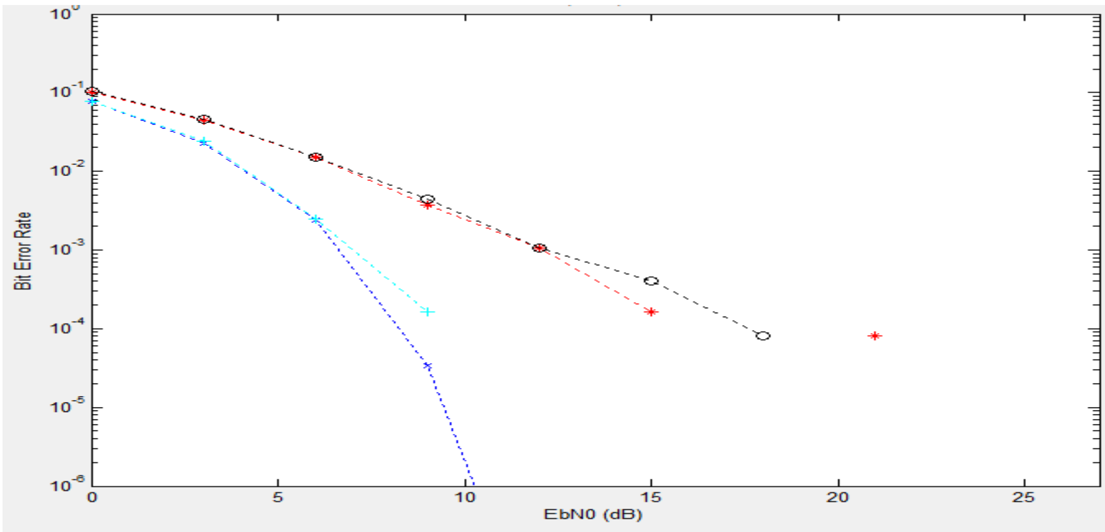

Figure 2 BER performance evaluation (4×4 system) [Subcarrier−7 (length=4, variation =0.1)]

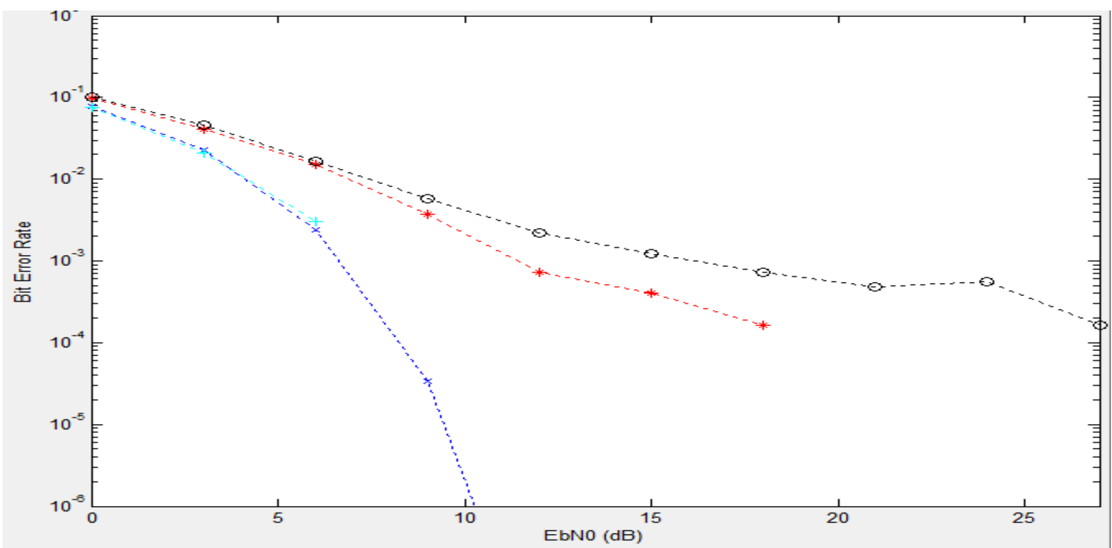

Figure 3 BER performance evaluation (4×4 system) [Subcarrier−7 (length=4, variation =0.5)]

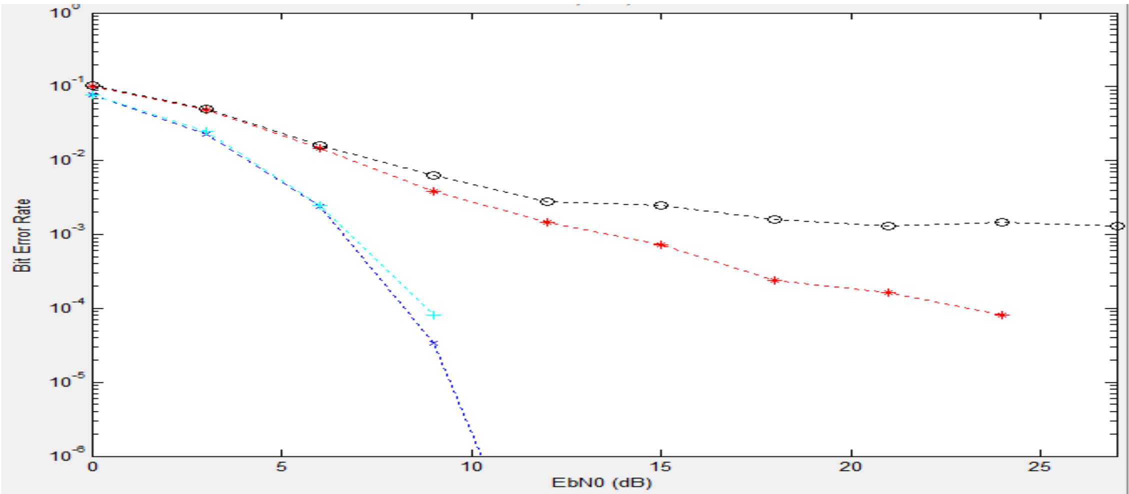

Figure 4 BER performance evaluation (4×4 system) [Subcarrier−7 (length=4, variation =0.9)]

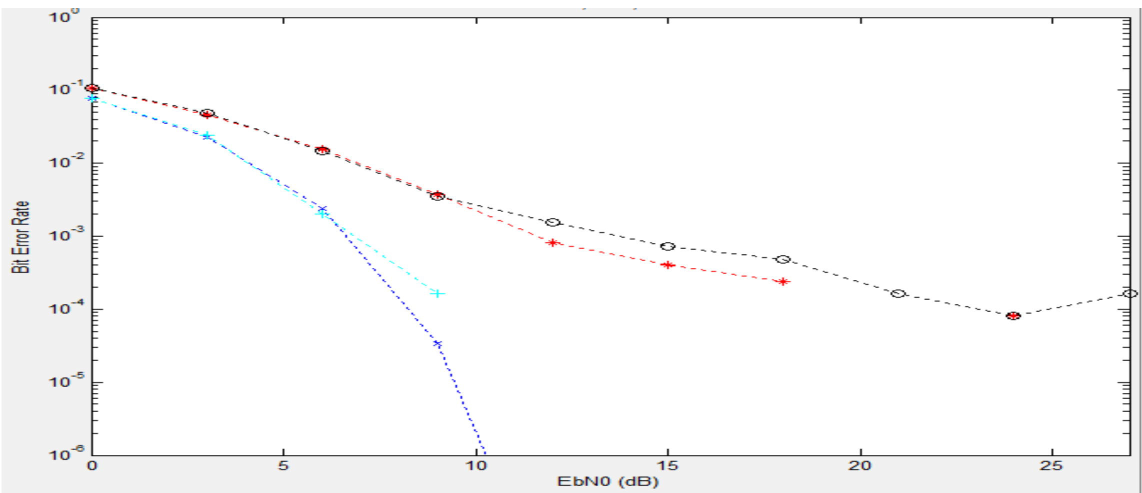

Figure 5 BER performance evaluation (4×4 system) [Subcarrier−7 (length=8, variation =0.1)]

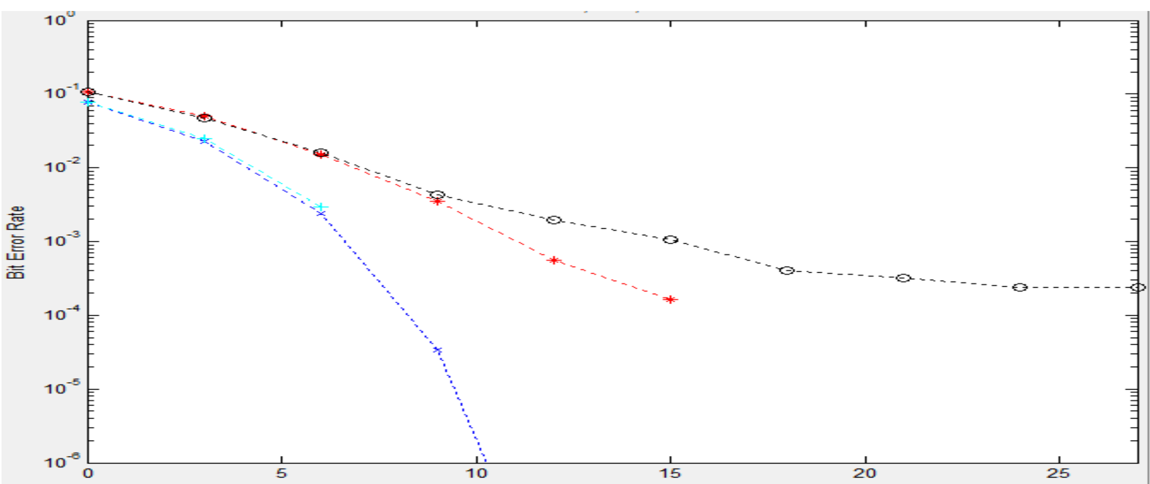

Figure 6 BER performance evaluation (4×4 system) [Subcarrier−7 (length=8, variation =0.5)]

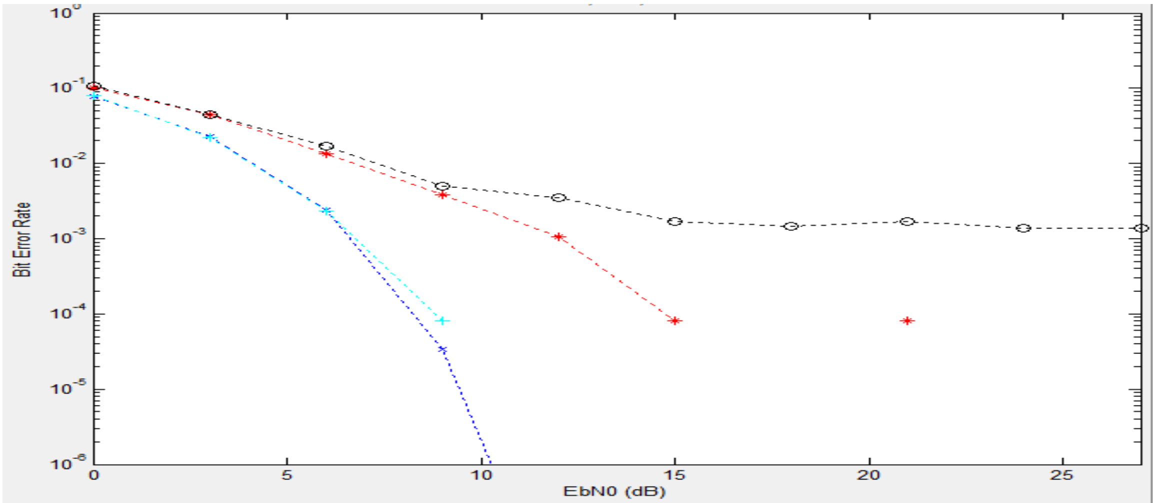

Figure 7 BER performance evaluation (4×4 system) [Subcarrier−7 (length=8, variation =0.9)]

5. Conclusion

In this paper OFDM and MIMO has been analysed and explored in terms of its performance parameters. Different system has been discussed for the performance improvement and its correlation. The considered parameters are channel efficiency, error rates, subcarrier, length etc. This paper also explores a hybrid design which is based on OFDM and MIMO system. The transmit and receive antenna considered here are 2, 3, 4 and 5. The configuration systems considered here are 2×2, 3×3, 4×4 and 5×5. The experimentation performed on 4×4 system and its shows that the results have been improved significantly in case of increasing subcarrier and length variations.

Acknowledgment

None.

Conflicts of interest

The authors have no conflicts of interest to declare.

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Sanjay Singh is doing M.Tech in Digital and Communication from Madhyanchal Professional University, Bhopal (M.P.) and completed his Bachelor of Engineering degree in Electronic and Communication. His areas of interest are VLSI, Image processing and OFDM Communication.

Dr. Bhagwat Kakde is an Associate Professor in the Department of Electronics and Communication Engineering at Madhyanchal Professional University (MPU), Bhopal, Madhya Pradesh, India. He received his Ph.D. in Electronics and Communication Engineering from Sarvepalli Radhakrishnan University (SRKU), Bhopal (MP) and his Master of Engineering in Digital Communication Engineering from Technocrats Institute of Technology, Bhopal (MP) and BE from Samrat Ashok Technological Institute (SATI) Vidisha (M.P). His areas of interest are Digital Communication Engineering, Digital Image Processing, Wireless Communication, VLSI and OFDM communication. He has more than 70 research papers published in national and international journals and conferences. He has 15 years of Experience in teaching and administration.
Email: bhagwatkakde@gmail.com