JOURNAL OF NANO- AND ELECTRONIC PHYSICS
Vol. 16 No 3, 03007(5pp) (2024)

ЖУРНАЛ НАНО- ТА ЕЛЕКТРОННОЇ ФІЗИКИ
Том 16 № 3, 03007(5cc) (2024)

REGULAR ARTICLE

OPEN ACCESS

Integration of Binary Subcarrier Search with Hilbert Matrix (BSS – HBM) using 39 GHz MIMO Antenna in 5G Application

K. Duraisamy[1,*] ✉, R. Delshi Howsalya Devi[2], P. Chinniah[3], J. Mohandas[4], M. Alagarsamy[5]

[1] *Department of ECE, Jeppiaar Institute of Technology, Kunnam, Sriperumbudur, TN, India*
[2] *Department of AI&DS, Karpaga Vinayaga College of Engineering and Technology, Chengalpattu, TN, India*
[3] *Department of ECE, Karpagam College of Engineering, Coimbatore, TN, India*
[4] *Department of ECE, KSR Institute for Engineering and Technology, Namakkal, TN, India*
[5] *Department of ECE, K.Ramakrishnan College of Technology, Trichy, TN India*

(Received 15 April 2024; revised manuscript received 16 June 2024; published online 28 June 2024)

In the Multiple Output – Orthogonal Frequency Division Multiplexing (MIMO – OFDM) system, the Fifth Generation (5G) plays an important role due to the extraordinary features and advantages of mobile communication. These 5G works in any aspect of the industry to improve speed because of better capacity, frequency, and lower delay. The existing system Align Crow Search (ACS) algorithms are implemented in the uplink of the MIMO – OFDM system to reduce the Bit Error Rate (BER) from 10^{-1} to 10^{-4}. In the uplink, the Inter Symbol Interference(ISI) and Inter-Carrier Interference (ICI) are evolved due to the implementation of OFDM, which deals with the several number of subcarriers transferred. The Binary Subcarrier Search is proposed to detect and reduce the ISI and ICI, with Hilbert Matrix to avoid the Peak to Average Power Ratio (PAPR). Then, the 38 GHz MIMO antenna is implemented through the channel, which can reduce the Bit Error Rate (BER) in the downlink of the system. It provides 80% efficiency with higher gain and the 14 GHz bandwidth with grand parameters of 5G. Finally, the MIMO-OFDM system yields better performance by using BSS – HBM through the 39 GHz antenna with substrate size 3.039 mm × 2.548 mm in the 5G Application. Hence the conventional method ACS is compared with the BSS – HBM to enhance better signal-to-noise ratio (SNR), Lower BER, and reduction of ICI with high efficiency given in the simulated results.

Keywords: Binary Subcarrier Search with Hilbert Matrix (BSS – HBM), Multiple Input Multiple Output (MIMO) Antenna Fifth Generation (5G), the Inter-Carrier Interference (ICI), Peak to Average Power Ratio (PAPR).

DOI: 10.21272/jnep.16(3).03007 PACS number: 84.40.Ba

1. INTRODUCTION

In the Fifth Generation (5G), most of the wireless communication (WC) systems are evolved in the Multiple Input Multiple Output (MIMO) antenna to decrease the signal-to-noise ratio (SNR) through the channel. It avoids the scattering in the Line of Sight (LOS), which passes between the uplink and downlink antenna through the channel. MIMO Antenna always demands speed in data storage, low latency, and, better coverage in the variation of SNR. The reason to use MIMO antenna is the stability of the signal, and high throughput excluding the higher power and bandwidth during the transmission of the data information. 5G application provides better characteristics to develop the enormous technology in wireless communication without the fading occurring in the channel. The MIMO is familiar in the Long Term Evolution (LTE), which can operate between 100 MHz to 1 GHz with the high fading terms built in the Fourth Generation (4G) communication system. But the 5G has better spectrum efficiency, sufficient bandwidth and without fading interruption and also reduction of Inter Carrier Interference (ICI) [1]. Orthogonal Frequency Division Multiplexing (OFDM) is one of the technologies in the 4G, which yields a high Peak to Average Power Ratio (PAPR), Bit Error Rate (BER), and Inter-Carrier Interference (ICI). It has more challenges to achieve reliable high data rate transmission and it can overcome the multipath frequency selective fading [2]. To reduce the ICI, BER, and Peak to Average Power Ratio (PAPR) and to increase the SNR, the MIMO-OFDM system is organized and implemented by using SFBC [2] Combined Space Frequency Block Coding (SFBC – PTS) [3], and Hybrid Space Time Block Coding – Partial Transmit Sequence (STBC – PTS) with enhanced Artificial Bee Colony(ABC) in the uplink [4]. The Hilbert Fast-Sparsity Adaptive Matching Pursuit (HF-SAMP) is determined to succeed in reducing the BER and increasing the SNR through the channel estimation in the downlink [5] & [6]. In China and Korea, the 5G application brought from 3400 – 3600 bands for the sub 6 GHz [7], focused on the band from 3400 – 3600 MHz [8]. 5G always improvises the knowledge of the MIMO antenna in broadcasting the connectivity for better throughput, lesser latency, reliability, high efficiency, etc. [8]. In [9], the crow search algorithm (CSA)

* Correspondence e-mail: skvijaykumu@gmail.com

Cite this article as: K. Duraisamy et al., *J. Nano- Electron. Phys.* 16 No 3, 03003 (2024) https://doi.org/10.21272/jnep.16(3).03007

helps to determine to predict the hidden food in surroundings where the food is stored in a memory in the immediate procedure. It does not enable the stableness and motion in changes every time without equality and the search occurs in continues for finding netter probability. The Grey Wolf Optimizer with Crow Search Algorithm (GWOCSA) is an existing system, which is used to optimize the selection problem and to test the efficiency by ruling on 23 benchmark functions with 21 datasets. The classification accuracy is well analyzed and statistically significant, also implemented for faster and convergence speed [10, 11].

2. LITERATURE REVIEW

The 5G parameters are evolved to build for the MIMO antenna in the Wireless Communication system, i.e. the MIMO is connected with OFDM to yield better system performance. The PAPR is reduced to (**i**) 2.6 dB and 3.1 dB by using SFBC [2] (**ii**) 6.25 dB. 5.28 dB and 4.95 dB by using SFBC – PTS [3] (**iii**) 4.5 dB, 4,3 dB and 3.5 dB by using Hybrid STBC-PTS with ABC algorithm [4] (**iv**) 5.2 dB for 512 subcarriers and 9 dB for 1024 subcarriers by using Omar Pigeon Space Time (OPST) algorithm with Hybrid Space time-Hadamard Matrix [12] The BER is decreased up to (**i**) 10^{-7} dB by using HF-SAMP in the MIMO-OFDM system [5] (**ii**) 10^{-5} dB for 512 subcarriers and 10^{-7} dB for 1024 subcarrier by using OPST with HST-HM algorithm [12]. The fifth generation and beyond networks are utilized to transceiver through the MIMO-OFDM antenna to reduce the noise, BER by using the deep learning-based channel estimation. In the system, stability plays vital role in estimating the channel quality by using machine learning [13]. MIMO Antenna are important in many of the wireless communication systems without dropping the signal coverage and validation for the handheld devices.

The existing combination of mm-wave and 6 GHz antenna is determined by the design of frequencies from 11 – 27 GHz and 32.4 GHz bandwidth to yield. It is maintained 60% throughput with 29.1 dB gain in the handheld 5G communication system [14]. A 28/38 GHz mm-wave frequency is implemented to introduce two inverted F-shaped antenna and provide 11.35 GHz bandwidth with the compact size of $15.5 \times 6.8 \times 0.74$ mm^3 in the conventional methods [15]. In [16] the Inverted Matchstick Slotted Rectangular Patch (IMSRP) is exists to evolve at 38 GHz by the double band for 5G and the specifications of the antenna are $16.5 \times 20 \times 0.508$ mm [16]. Modified Crow Search Algorithm (MCSA) is passed to reach the destination of each crow, inspire with proper quality, robustness and to process very fast in the system [11].

3. PROPOSED SYSTEM: COMBINATION OF BINARY SUBCARRIER SEARCH WITH HILBERT MATRIX (BSS – HBM)

The proposed system is focused on the binary Subcarrier Search (BSS) algorithm with the Hilbert matrix to reduce the Inter Carrier interference (ICI) cancellation and reduce the PAPR in the uplink. The MIMO - OFDM system is analysed with the transmission of data bits based on the 5G parameters. The system is calculated the number of subcarriers with the symbol duration for each data transmission. The symbol period is less than twice of the data rate for initializing the orthogonality. The number of subcarriers always follows the orthogonal to each other.

The BSS algorithm is placed between the Quadrature Amplitude Modulation (QAM) modulator and Inverse Fast Fourier Transform (IFFT) to analyse the number of subcarriers and the data rate with the conversion of Serial to Parallel Converter as given. The IFFT helps to convert from the frequency domain to the time domain for further process to calculate the PAPR. Moreover, the BSS algorithm is used to reduce the ICI and ISI then focus on inserting the cyclic prefix.

The BSS algorithm is given in Table 1, how the number of subcarriers works step by step to avoid interference or distortion. The main disadvantage that occurs in the MIMO – OFDM system is PAPR, which is decreased by using the HBM techniques given in section 3.1. Both the ICI and PAPR are reduced, and the data information is passed through the channel to the downlink of the MIMO – OFDM system. In the downlink, the BER and SNR can be calculated in the sink. Thus, the MIMO – OFDM system is in demand with 5G parameters and specifications for developing and reducing the ICI and PAPR by using BSS-HBM algorithm.

Table 1 – Binary Sub-Carrier Search(BSS) Algorithm

Step 1	List the number of "n" Subcarrier with the values of X_0, X_1, X_2……X_{n-1}
Step 2	Set the ascending order for set of input values from X_0 to X_{n-1}, where the number of subcarriers (Sc) to forward in the given order within the time in msec.
Step 3	Set 0 and Sc to X_{n-1}
Step 4	If threshold values is greater than Sc, then the search binary subcarrier is terminating as not succeed.
Step 5	Set the subcarrier up to 1024, find the center position of the data symbols for $Tv + Sc/2$.
Step 6	If $X_n < P$, set Tv to "$n + 1$" and go to step 2.
Step 7	If $X_n < P$, set Sc to "$n – 1$" and go to step 2.
Step 8	Finally, $X_n = P$, subcarrier search is finish and return "n".

3.1 Hilbert Matrix (HBM)

The Hilbert matrix is used for using the unit of fraction because it is a square matrix. It is otherwise known as Legendre polynomials, which is a generalized orthogonal system to be performed by the moment matrices. It is well-suitable to derivatives of Legendre polynomials. These Hilbert matrices are traced for the approximation problem in its process. It is used for perturbations because it has to be ill-conditioned and can be defined as below equation (1)

$$\boldsymbol{H}_{ij} = \frac{\mathbf{1}}{\mathbf{1} + \boldsymbol{j} - \mathbf{1}} \tag{1}$$

3×3 Hilbert matrix can be written as in equation (2)

$$H = \begin{vmatrix} 1 & 1/2 & 1/3 \\ 1/2 & 1/3 & 1/4 \\ 1/3 & 1/4 & 1/5 \end{vmatrix} \qquad (2)$$

Syntax can be written as

$$H = hlib\ (n) \quad and \quad H = hlib\ (n, classname)$$

3.2 PAPR Calculation

The proportion of average power to peak instantaneous power. Equation (3) provides the signal's PAPR definition.

$$PARP = \frac{max_{0\le t\le T}|x(t)|^2}{E[|x(t)^2|]} \qquad (3)$$

The encoded input data transmission of two variables are A_1 and A_2

$$A_1 = [A(0), A^*(1) \dots \dots \dots A(M-2), -A^*(M-1) \qquad (4)$$

$$A_2 = [A(1), A(0) \dots \dots \dots A(M-1), X^*(M-2) \qquad (5)$$

After QAM modulation, the input signal is encoded with the Hilbert Matrix in the uplink is given as

$$H_l = \begin{matrix} H_0 & -H_1 * \\ H_1 & H_0 * \end{matrix} \qquad (6)$$

If the input data is moved through the IFFT waveform based on the time domain can be obtained as equation (7)

$$F(T) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} f_n\, e^{j2\pi\Delta ft} \qquad 0 \le t \le NT \qquad (7)$$

The BSS algorithm is used to convert the time domain with a number of subcarriers and the Hilbert matrix calculates with the OFDM signal is given in equation (8)

$$B(n) = \frac{1}{\sqrt{N}} \sum_{l=0}^{N-1} H(l) e^{\frac{j2\pi nl}{N}} \qquad (8)$$

Finally, the PAPR is calculates with proposed system as the combination of BSS-Hilbert Matrix is given in equation (9)

$$PAPR(x) = \frac{max\{|B(n)|^2\}}{E\{|B(n)|^2\}} \qquad (9)$$

4. RESULTS AND DISCUSSION

The ICI and PAPR are reduced by the proposed system's BSS-HBM algorithm since it results from the data input's with many subcarriers. During the transmission of OFDM symbols with several subcarriers for 1024, BSS decreases the ICI, and HBM reduces the PAPR abruptly in the uplink. Once PAPR and ICI are reduced during the transmission of data bits, then it forwards to the downlink to calculate the BER and SNR through the channel in the MIMO-OFDM system. All the parameters are gained by using the 39 GHz frequency band on the MIMO antenna in the 5G applications as given in Table [2]. 5G sticks on faster data rates, lower latency, higher device density, and improved energy efficiency.

The designed antenna is embedded over Rogers RT Duroid material operating at a 39 GHz frequency band for mm-wave application. The designed prototype is a miniature antenna of substrate size 3.039 mm × 2.548 mm. The antenna parameters such as gain, impedance matching, and efficiency are observed to be good. Fig. 1 gives the rearview and front view of the MIMO antenna with better performance than the conventional method. Fig. 2 shows the Antenna over the axis and Fig. 3 shows the dimensions of plots in the patch of the substrate.

Table 2 – Simulation Parameters

S.No	Parameters	Values
1	Modulation	QAM (256)
2	Subcarriers in MIMO-OFDM	1024
3	Frequency Band	39 GHz
4	Number of OFDM symbols	1000, 1100
5	Cyclic Prefix	64
6	Bandwidth (BW)	Several hundred MHz
7	Subcarrier Spacing	15 KHz to 240 KHz
8	Frequency at Subcarriar	20 GHZ
9	5G Speed	4.5 GHz
10	Delay	1 ms

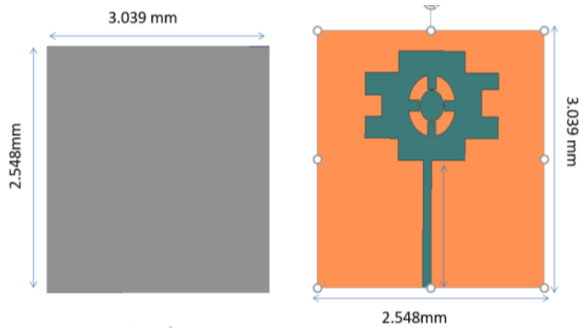

Fig. 1 – Rear view of antenna (a), Front view of antenna (b)

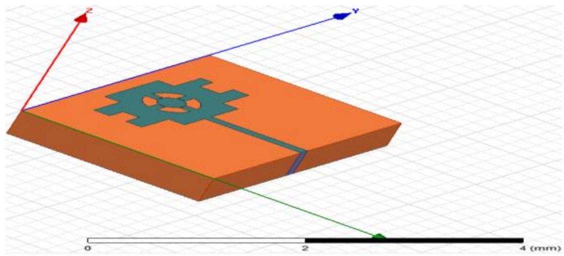

Fig. 2 – Antenna over the axis

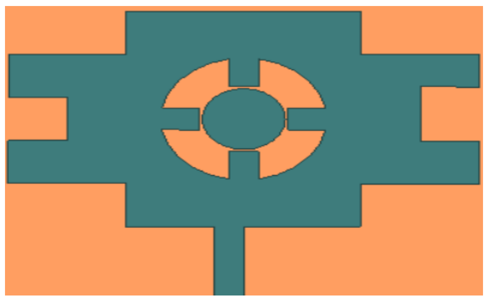

Fig. 3 – Dimensions of plots in the patch

With *e* = 0.03 as the error rate, the BER overall performance is purchased concerning the Signal to Noise Ratio (SNR) for ICI cancellation, as shown in Table 3.

Table 3 – Simulated Parameters against e = 0.03 for Existing and Proposed (BSS - HBM) system

	e = 0.03		
S.No	**MIMO-OFDM System**	**PAPR**	**BER**
1	SFBC(2)	3.1 dB	10^{-9}
2	SFBC-PTS(3)	6.25 dB	10^{-8}
3	Hilbert Fast SAMP(5)	4.95 dB	10^{-7}
4	OPST-HST-HM (12)	9 dB	10^{-7}
5	STBC-PTS- ABC(4)	3.5 dB	10^{-6}
6	BSS-HBM (Proposed)	3 dB	10^{-5}

The MATLAB simulated outcomes are proven for e = 0.03 in Fig. 5 using the implementation of the BSS-HBM algorithm in the 39 GHz MIMO antenna system.

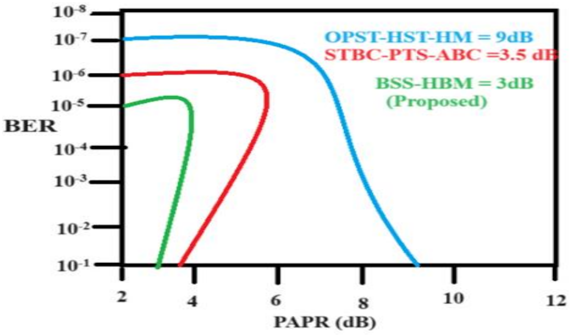

Fig. 4 – Simulated results for PAPR and BER with *ICI* = 0.03

Hence, the traditional technique acquired for PAPR is 9 dB with 10^{-7} BER by way of the usage of OPST-HST-HM and PAPR is 3.5 dB with 10^{-6} BER for STBC-PTS with ABC algorithm. Finally, the proposed BSS-HBM yields a higher overall performance of PAPR as 3 dB with BER as 10^{-5}, which is decided in Fig. 4.

5. CONCLUSION

The 5G specification is applied to enhance the overall performance of the MIMO – OFDM device for warding off ICI. It is delivered due to the large lengthened unfold with the simultaneous switch of the number of subcarriers with the OFDM symbol. Hence to keep away from the lengthening unfold in the transmission of an information bit, the BSS-HBM algorithm is proposed and decided with the analytical purpose. This algorithm decreases each ISI and ICI throughout the insertion of CP in the uplink of the MIMO – OFDM system. Hence the proposed device BSS-HBM algorithm is used to decide the time and amplitude of the information image with the range of subcarriers barring interference. This system makes the complete exchange to be steady inside the time length of the information symbol. Moreover, the error rate is calculated as e = 0.03 for identifying the SNR and BER through the Channel.

The MIMO antenna is demonstrated with the substrate size as 3.039 mm × 2.548 mm based on the 39 GHz as shown in Figs. 1 to 4. At this error rate, the SNR (20 dB) will increase by reducing the BER (10^{-5}) in the BSS-HBM algorithm on the MIMO – OFDM system. The SNR stages are between 0 to 20 dB and BER varies between 10^{-1} to 10^{-5} dB as proven by using Mat lab [6]. Hence, the proposed system BSS-HBM algorithm on the MIMO antenna is better than the conventional method performed well as shown in Table 2. Moreover, the 5G parameters are utilized to develop the communication system to be used for many applications strengthened by a 39 GHz MIMO antenna.

REFERENCES

1. O.A. Saraereh, I. Khan, Q. Alsafasfeh, S. Alemaishat, S. Kim, *Symmetry* **11** No 5, 713 (2019).
2. D. Kumutha, N.A. Prabha, *Indian Journal of Science and Technology* **9** No 32, 1 (2016).
3. D. Kumutha, N.A. Prabha, *ARPN J Eng Appl Sci*, **11** No 21, 12690 (2016).
4. D. Kumutha, N.A. Prabha, *Journal of Ambient Intelligence and Humanized Computing*, 1 (2017).
5. D. Kumutha, N.A. Prabha, *International Journal of Internet Technology and Secured Transactions* **8** No 2, 221 (2018).
6. D. Kumutha, J.P.R. Gnanaraj, V. Jayaprakasan, *In Advances in Automation, Signal Processing*, Instrumentation, and Control: Springer Select Proceedings of i-CASIC 2020 (pp. 3143-3158), (2021).
7. IMT-2020 (5G) Promotion Group. White Paper on 5G Concept. February. 2015. Available (accessed on 20 June 2023).
8. SK Telecom. SK Telecom 5G White Paper. October 2014. Available online: pdf.
9. S. Arora, H. Singh, M. Sharma, S. Sharma, P. Anand, *IEEE Access* **7**, 26343 (2019).
10. A. Javidi, E. Salajegheh, J. Salajegheh, *Soft Comput.* **77**, 274 (2019).
11. F. Mohammadi, H. Abdi, *Appl. Soft Comput.* **71**, 51 (2018).
12. K. Duraisamy, T. Thanarajan, M. Alharbi, *Traitement du Signal- IIETA* **39** No 5, 1631 (2022).
13. H.A. Le, T. Van Chien, T.H. Nguyen, H. Choo, V.D. Nguyen, *Sensors* **21** No 14, 4861 (2021).
14. R.M. Gomathi, M. Jeyabharathi, T. Islam, *J. Nano- Electron. Phys.* **15** No 4, 04027 (2023).
15. El Arrouch Tarik, Najiba El Amrani El Idrissi, S. Jeevitha, S. Das, *J. Nano- Electron. Phys.* **15** No 1, 01026 (2023).
16. K. Jayanthi, A.M. Kalpana*, J. Nano- Electron. Phys.* **15** No 3, 03022 (2023).

Інтеграція бінарного пошуку несучої з матрицею Гільберта (BSS – HBM) 5G MIMO-антени 39 ГГц

K. Duraisamy[1], R. Delshi Howsalya Devi[2], P. Chinniah[3], J. Mohandas[4], M. Alagarsamy[5]

[1] *Department of ECE, Jeppiaar Institute of Technology, Kunnam, Sriperumbudur, TN, India*
[2] *Department of AI&DS, Karpaga Vinayaga College of Engineering and Technology, Chengalpattu, TN, India*
[3] *Department of ECE, Karpagam College of Engineering, Coimbatore, TN, India*
[4] *Department of ECE, KSR Institute for Engineering and Technology, Namakkal, TN, India*
[5] *Department of ECE, K.Ramakrishnan College of Technology, Trichy, TN India*

Системи Multiple Output Orthogonal Frequency Division Multiplexing (MIMO – OFDM) п'ятого покоління (5G) відіграють важливу роль завдяки унікальним характеристикам і перевагам мобільного зв'язку. Мережі 5G працюють в різних галузях, покращуючи швидкість та пропускну здатність, частоту та зменшуючи затримку. Існуючі системні алгоритми Align Crow Search (ACS) реалізовані у висхідній лінії зв'язку системи MIMO – OFDM для зменшення коефіцієнту бітових помилок (BER) з 10^{-1} до 10^{-4}. У лінії зв'язку міжсимвольні перешкоди (ISI) і міжнесучі перешкоди (ICI) реалізуються завдяки OFDM. Двійковий пошук пропонується для виявлення та зменшення ISI та ICI, за допомогою матриці Гільберта, щоб уникнути відношення пікової до середньої потужності (PAPR). Потім через канал реалізується MIMO-антена 38 ГГц, яка може зменшити частоту бітових помилок (BER) у низхідній лінії зв'язку системи. Вона забезпечує ефективність 80% із вищим коефіцієнтом підсилення та смугою пропускання 14 ГГц з високими параметрами 5G. Крім того система MIMO-OFDM забезпечує кращу продуктивність завдяки використанню BSS – HBM через антену 39 ГГц із розміром підкладки 3,039 мм x 2,548 мм. Таким чином, звичайний метод ACS порівнюється з BSS – HBM для покращення кращого співвідношення сигнал/шум (SNR), нижчого BER та зниження ICI із високою ефективністю, наведеною в результатах моделювання.

Ключові слова: Двійковий пошук піднесучої за допомогою матриці Гільберта (BSS – HBM), Антена п'ятого покоління (MIMO), Інтерференція між несучими (ICI), Відношення пікової до середньої потужності (PAPR).