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Selective Mapping Technique with Novel Symmetric Hankel Phase Sequences for PAPR Reduction in OFDM Systems

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Abstract: Various applications such as WiMAX, 3GLTE and Wireless local area networks, digital audio, radio and optical communications employ OFDM for data transmission because of its advantages such as excellent spectrum efficiency, easy channel equalization, robustness against different kinds of interference and noise induced by impulsive factors, etc., Increased peak to average power ratio (PAPR) is one of the major shortcomings which is encountered by OFDM systems. In this paper, we have proposed and investigated about the PAPR reduction performance of Novel Symmetric Hankel matrices as phase sequences for the Selective Mapping technique. Using MATLAB software, simulation results were obtained for different number of subcarriers using variety of modulation techniques. The obtained results were also compared with Hadamard, Hilbert, Random and Lehmer phase sequences. The results of the proposed SLM-Symmetric Hankel technique showed better reduction in the PAPR value compared to other works reported by the various literature works.

Keywords: Orthogonal Frequency Division Multiplexing,Peak to Average Power Ratio, Phase sequences, Selective Mapping, Novel Symmetric Hankel phasesequences.

1. Introduction

Over the previous few decades, the need for wireless communication has exploded. We're on our way to a society dominated by totally by the remote systems controlled remotely manner. Autonomous systems are gaining traction in a variety of fields, including health, industry, transportation, the space and oceans. In order to create a cloud nine life and robotic systems, zillions of sensors are incorporated into cities, vehicles, houses, food and other settings. As a result, a high level of reliability is required with high data rate. 5G communications will be extensively adopted in the future technology, with expressively more features than 4G communications. It is scheduled to be adopted in Between the year 2027 to2030 a new wireless communiqué the 6G system with full machine learning support paradigm. Advanced system capacity, high data rate, complex security, less latency and enhanced Quality of service are few disquiets that needs to be solved outside 5G.The quick development of new applications such as 3D media ,Internet Of Everything (IoE), Artificial Intelligence (AI) and the Virtual Reality (VR) has resulted in a large amount of complex traffic[1] . In 2010, international mobile commuter traffic was 7.462 EB/month, this commuter flow anticipated to be 5016 EB/month on 2030 [2]. The number demonstrates the precarious it is to improve communication network parameters.5G is scheduled to be completely operational worldwide by 2021. 5G networks won't be able to give a fully intelligent network with automated systems that offers great service with a fully tremendous experience. When compared to 4G network communication system 5G systems will offer prominent gains over an current systems, the 4G will not able to meet the loads of automation with fully intelligent systems beyond one decade [3]. By comparing with older communication systems the 5G network offer additional proficiencies and a higher value of network parameters as QoS[4-6]. The amalgamation of licensed and abandoned bands are all included in 5G communication system with optical spectra enhanced spectrum usage such as millimeter-wave and there management. Nonetheless, rapid expansion of data-centric and automated technologies may outstrip 5G wireless network capabilities. The confluence of intelligence, control, communication, sensing, and figuring functionalities were largely disregarded in 5G . on the other hand the applications of future IoE, will demand this convergence. Explicit gadgets, like as headsets with virtual reality, demand information rates of 10 Gbps, therefore they must move beyond 5G[1] .

Some 6G capabilities may not be supported by 5G devices, but the increased competence in 6G operating device may escalation the price. Few devices that will be available for 5G is projected to be in the billions. The operability of 5G network devices with 6G networks is a key issue as communication infrastructure transitions from 5G to 6G [7]. This inter communication creates it easy for end-users to utilise while also saving money. As Repercussion based on technical compatibility with 5G, 6G should prioritise computing devices with integrated communications, performance computing increase, and so on. In 6G the compactness will be extremely high as access networks is concerned. Furthermore, within a topographical place, diverse and extensive access networks will be offered for sorts of different customers, such an access networks offer connectivity with increased data rate. Because FSO and optical fiber networks offer backhaul connectivity with a high-capacity as an alternatives, any upsurge in their volume will be difficult to achieve the exponentially increasing demands of 6G. Several additional functions will be available with the 6G system. Smartphones, for example, should be capable of handling the new functionalities. Supporting integrated sensing T throughput, AI and XR, and with communication features utilizing separate policies is particularly difficult [8]. A large variety of communication systems with heterogeneity will be involved in 6G, including frequency bands, communication topologies, and service delivery. Furthermore, the hardware requirements for contact points and mobile terminals in a remote manner will be immensely different. Colossal MIMO will be progressed from present 5G to 6G, which requires a more complex design. While establish connectivity between the core network as well as access networks a logjam would be created It will also make the system of the communication protocol and algorithm more difficult in order to avoid and support user level with high data rates backhaul network of 6G must able to manage huge amount of data.

Artificial intelligence and Machine learning on the other hand, will be assimilated in the present systems. Advanced hardware architecture for various communication systems varies as per the requirement. Reinforcement and Unsupervised learning will constitute the complicated hardware.

For the introduction of 6G connectivity, the economic outlook is equally critical. A new 6G implementation will cost more for network infrastructure. By converting the infrastructure of 5G to a 6G system and by appropriate design, the cost can be condensed. To make the cost-effective potential 6G network parameters like infrastructure, data interoperability, and shared available spectrum must be thoroughly studied. To the enlargement of optimized 6G systems and business models, the interaction between expected 6G enabling technologies, multi modal applications, regulations regarding spectrum, and smooth changeover from 5G to 6G, is critical [9]. Inculcating optimized methods for lowering deployment costs and building long-term ecological business models for sharing network infrastructure, shared infra with public, the spectrum of radio, data could be extremely beneficial for the upcoming 6G systems. As a result, neutral hosting, infrastructure sharing and spectrum with different location, licensing can all be considered options for reducing deployment costs. Huge growth in usage of video traffic and the massive growth in Cloud computing will make an average customer is estimated to use about 11 GB/month using their smartphone by the end of 2022. 5G technology is driving global growth. The estimated global economic output is predicted to be 13.1$ trillion dollars. 22.8$ new jobs will be created and $265B global 5G CAPEX and R&D over the next 15 years will be done. 5G entire economic effect is likely to be realized by 2035 worldwide and it will also support industries, goods and services. 5G is designed for forward compatibility. Some of the advantages of 5G include increased download speeds, minimal latency, high capability critical communications (MCC) and Massive IoT. 5G technology is considered as the next stage of mobile networking technology. 5g has various advantages such as multi-Gbps peak data-rates, reduced energy consumption, improved traffic control process and bandwidth, increased battery life and capacity, ultra-low latency and high reliability and throughput and provides uniform user experience [10]. Some of the applications of 5G include increased speed in mobile network, entertainment and multimedia, IoT-connecting everything, smart homes, logistics and shipping, smart cities, Industrial IoT, smart farming, fleet management, healthcare and mission critical applications, autonomous driving, drone operation, security and surveillance and satellite imaging. Furthermore, 5Gtechnology can be made more flexible to make it employable for a wider range of use cases. [11]

Filter Bank Multicarrier (FBMC), Universal Filtered Multicarrier (UFMC) and Resource Block Filtered Orthogonal Frequency Division Multiplexing (RB-OFDM) are some of the reliable multicarrier modulation techniques introduced for 5G systems. FBMC employs a technique where the subcarrier streams are given as input to the filter bank and later overlapped. UFMC employs a technique which employs splittingofthesignalintovarioussubstreamsandiscarriedon different sub-carriers and filtering is applied to each of them separately. [12]

The method of RB-F-OFDM is splitting of the band into different orthogonal sub-bands. After this process of splitting, filtering is done. Out-Of-BandEmission(OOBE)androbustnessagainstICIand ISI are some of the factors by which these waveforms are compared with normal OFDM [13]. One of the issues faced by these multicarrier modulation schemes is their high PAPR. To overcome the PAPR problem, various methodologies were discussed. Some of them are Clipping and filtering, Partial Transmit Sequence (PTS), Selective mapping (SLM) andPulse Shaping or Pre-Coding and Tone Reservation (TR). Hybridmethods werealsoproposedtoreducePAPRbycombining minimum of 2 simple PAPR techniques. Similar to the OFDM technique, other multicarrier modulation scheme also have an important shortcoming which is the high PAPR and it needs to be solved.[14]

In this research, we introduce Novel Symmetric Hankel matrices as phase sequences to the SLM technique for minimizing the value of PAPR in multi-carrier modulation systems such as OFDM, FBMC and RB-F-OFDM. Simulation results indicate that by applying Symmetric Hankel matrices as phase sequences to the SLM technique, the PAPR is greatly reduced when compared to some existing phase sequences.

The remaining content of the manuscript is as follows. The various works done by various authors are listed under Section II. Section III brief about the role of phase sequences when SLM is applied to the Selective Mapping Technique. Novel symmetric Hankel phase sequence basedSelectiveMappingtechnique is described in Section IV. SectionVandVIexplains about the conclusion and future work of the proposed scheme.

2. Literature Survey

Gupta et al (2016) [15] proposed Novel Qth sub-optimal phase sequences based on circular shifting (QSCPM) with the discrete cosine transform. Design of the phase sequences were such that they required almost no transmitted side information. Thereby, due to this reason complexity was minimized as well as transmitted signal statistics was improved. Ohkubo (2003) [16] designed criteria for SLM phase sequences such that they had lower value of average and higher value of variance. Chanpokapaiboon (2011) [17] developed centering matrices for Single Input – Single Output -OFDM and MIMO-OFDM systems for minimizing the peak to average power ratio. These matrices outperformed Riemann and Hadamard matrices. Baig (2010) [18] proposed DCT precoded SLM in which the precoding the constellation symbols with DCT precoder after the multiplication of phase rotation factor and before the IFFT in SLM-OFDM systems. Lin (2012) [19] proposed Partial sequence SLM which was based on the concept of partition to reduce computational complexity and PAPR. It was based on the combination operation of phase rotation. By reducing the number of IFFT operations to reduce computational complexity. Jayamathi (2022) [20] proposed novel SLM and oppositional hosted cuckoo optimization algorithm to reduce PAPR in 5g UFMC systems. The convergence rate is also improved. It can be used in real time to accomplish high data rate communications.

Sudha et al (2015) [21] introduced the concept of Low complexity SLM and New Riemann sequences that are used to reduce PAPR and computational complexity. When compared to and also connectivity for billions of devices – in the areas of VR, IoT and AI. Applications of 5G includes connected services such as Enhanced Mobile broadband (eMBB), mission critical communications (MCC) and Massive IoT. 5G technology is considered as the next stage of mobile networking technology. 5g has various advantages such as Multi-Gbps peak data-rates, reduced energy consumption, improved traffic control process and bandwidth, increased battery life and capacity, ultra-low latency and high reliability and throughput and provides uniform user experience [10]. Some of the applications of 5G include increased speed in mobile network, entertainment and multimedia, IoT- connecting everything, smart homes, logistics and shipping, smart cities, Industrial IoT, smart farming, fleet management, healthcare and mission critical applications, autonomous driving, drone operation, security and surveillance and satellite imaging. Furthermore, 5Gtechnology can be made more flexible to make it employable for a wider range of use cases. [11]

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3. Phase Sequences

Phasesequencesplaysaveryimportantroleinthereduction of peak to average power ratio in OFDMsystems.

3.1 Hadamard Phase Sequences

Hadamard matrix is a square matrix whose entries are ± 1, and the rows are mutually orthogonal. Each pair of rows in a Hadamard matrix represents two perpendicular vectors. The Hadamard matrix of order 4 can be given as [34]

$$H = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \end{bmatrix} \tag{1}$$

3.2 Hilbert Phase Sequences

A Hilbert matrix is a square matrix with unit fractions as entries

$$H_{ij} = \frac{1}{i+j-1} \tag{2}$$

The Hilbert matrix can be regarded as derived from the integral

$$H_{ij} = \int_0^1 x^{i+j-2} dx \tag{3}$$

as a Gramian matrix for powers of x. This arises in least squares approximation of arbitrary functions by polynomials. The Hilbert matrices are examples of poorly-conditioned matrices, Because, it becomes difficult to use them in numerical calculations. The Hilbert matrix of order 4 can be given as [35, 36]

$$Hb = \begin{bmatrix} 1 & 1/2 & 1/3 & 1/4 \\ 1/2 & 1/3 & 1/4 & 1/5 \\ 1/3 & 1/4 & 1/5 & 1/6 \\ 1/4 & 1/5 & 1/6 & 1/7 \end{bmatrix} \quad (4)$$

3.3 Random Phase Sequences

A Random matrix is a matrix-valued in which few elements are random variables. The Random matrix of order 4 can be given by

$$R = \begin{bmatrix} 1 & 0 & 1 & 0 \\ 1 & -1 & 1 & 0 \\ -1 & -1 & -1 & 1 \\ 1 & 0 & 1 & -1 \end{bmatrix} \quad (5)$$

3.4 Lehmer Phase Sequences

A Lehmer matrix is the constant symmetric matrix defined by [37]

$$L = \begin{cases} s/t, & t \geq s \\ t/s, & t < s \end{cases} \quad (6)$$

This can also be written as

$$L_{st} = \frac{\min(s,t)}{max(s,t)} \quad (7)$$

The Lehmer matrix matrix of order 4 can be given by

$$L = \begin{bmatrix} 1.0 & 0.5 & 0.333 & 0.25 \\ 0.5 & 1.0 & 0.6667 & 0.5 \\ 0.33 & 0.6667 & 1.0 & 0.75 \\ 0.25 & 0.5 & 0.75 & 1.0 \end{bmatrix} \quad (8)$$

4. Proposed Novel Symmetric Hankel Phase sequences

A Hankel matrix is a square matrix in which each ascending skew-diagonal from left to right is constant. In this approach, the rows of the Hankel matrices are given as phase sequences to the SLM technique. [38]

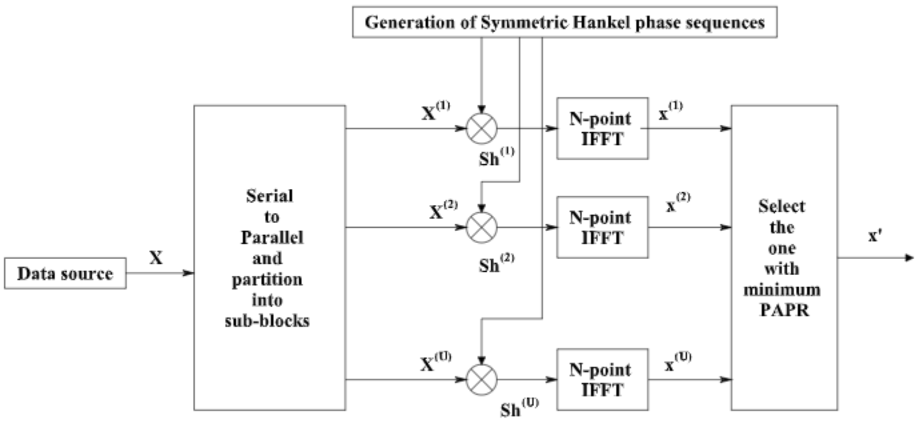

Fig 4.1. Block diagram of SLM-Symmetric Hankel technique

$$\begin{bmatrix} a & b & c & d \\ b & c & d & e \\ c & d & e & f \\ d & e & f & g \end{bmatrix} \quad (9)$$

A Hankel matrix is any $n \times n$ matrix *A* of the form

$$A = \begin{bmatrix} a_0 & a_1 & a_2 & \cdots & \cdots & a_{n-1} \\ a_1 & a_2 & & & & \vdots \\ a_2 & & & & & \vdots \\ \vdots & & & & & a_{2n-4} \\ \vdots & & & & a_{2n-4} & a_{2n-3} \\ a_{n-1} & \cdots & \cdots & a_{2n-4} & a_{2n-3} & a_{2n-2} \end{bmatrix} \quad (10)$$

In terms of the components, if the i, j element of A is denoted with A_{ij} , and assuming $i \leq j$, we have

$$A_{i,j} = A_{i+k,j-k} \quad (11)$$

for all $k = 0,1, \ldots . j - i$

5. Simulation Results and Discussion

MATLAB simulations were used to evaluate the PAPR reduction performances of SLM when applied with various phase sequences. Complementary Cumulative Distribution Function (CCDF) is used as a metric to measure the amount of reduction in PAPR. The simulation parameters are listed in Table 5.1. The phase weighting factors used are given by $\{\pm 1, \pm j\}$.

Table 5.1: Simulation Parameters

Parameter	Value
Number of symbols transmitted	10000
Number of sub-carriers	64,256
Modulation schemes	BPSK, QPSK, 16-QAM and 64-QAM
Number of candidate phase sequences	64,256
CCDF	10^{-4}
Number of sub-blocks	4
Number of phase weighting factors	4
Phase sequences used	Hadamard, Hilbert, Random, Lehmer and Symmetric Hankel

Figure 5.1 illustrates the PAPR reduction performances of C-OFDM, C-SLM, SLM-H, SLM-Hb, SLM-Random, SLM-Lehmer and SLM-SH when N=64 for BPSK modulation. The PAPR reduction of the proposed scheme with respect to SLM-H, SLM-Hb, SLM-Random and SLM-Lehmer are given by 3.143 dB, 5.63 dB, 1.668 dB and 4.471 dB respectively. The proposed scheme has a good PAPR reduction over the SLM-H, SLM-Hb and SLM-Lehmer techniques.

Figure 5.2 depicts the PAPR reduction performances of the SLM-H, SLM-Hb, SLM-Random and SLM-Lehmer techniques when N=64 for QPSK modulation. The PAPR values of the C-OFDM, C-SLM, SLM-H, SLM-Hb, SLM-Random, SLM-Lehmer and SLM-SH are given by 11.48 dB, 5.598 dB, 6.397 dB, 8.884 dB, 4.922 dB, 7.725 dB and 3.254 dB respectively. The PAPR reduction performances of the proposed scheme over the SLM-Hb, SLM-Lehmer, SLM-H, and SLM-Random are given by 5.63 dB, 4.471 dB, 3.413 dB and 1.668 dB respectively. The proposed scheme has a good PAPR reduction over the other schemes.

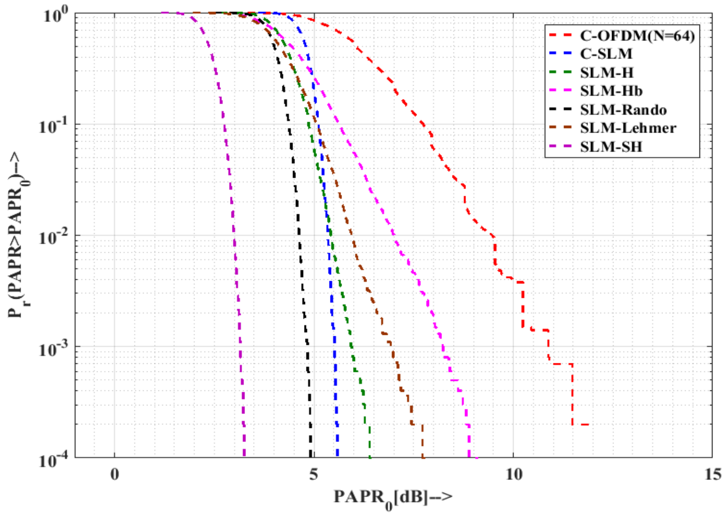

Fig. 5.1. PAPR performance comparison of SLM-H, SLM-Hb, SLM-Random, SLM-Lehmer and SLM-SH for 64 subcarriers with BPSK modulation

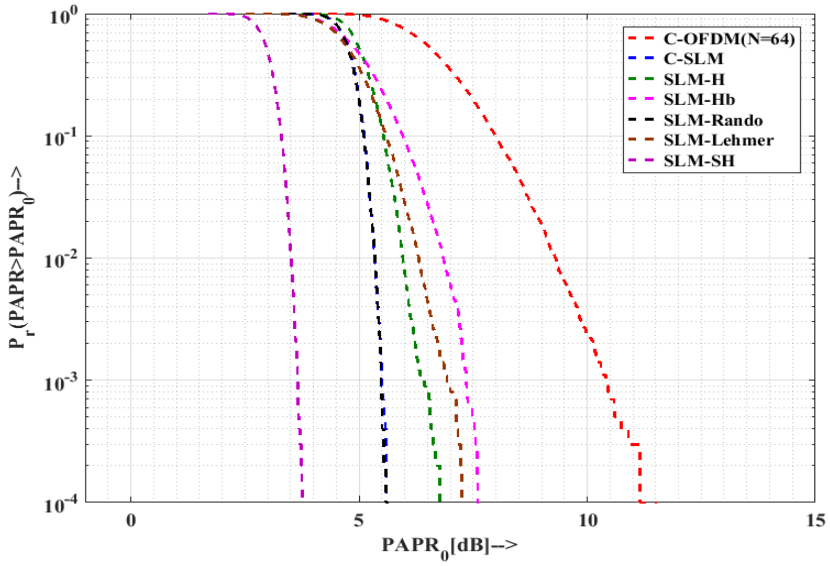

Fig 5.2. PAPR performance comparison of SLM-H, SLM-Hb, SLM-Random, SLM-Lehmer and SLM-SH for 64 subcarriers with QPSK modulation

From Figure 5.2 and Figure 5.3, it can be seen that the schemes SLM-H, SLM-Hb and SLM-Lehmer has a better PAPR reduction in the case of BPSK modulation scheme than QPSK modulation. SLM-Random has a better PAPR reduction in the case of QPSK modulation.

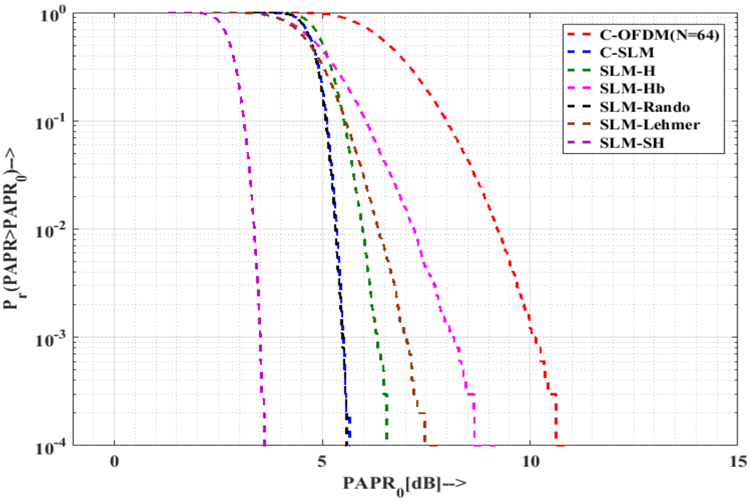

Fig 5.3 PAPR performance comparison of SLM-H, SLM-Hb, SLM-Random, SLM-Lehmer and SLM-SH for 64 subcarriers with 16-QAM modulation

Figure 5.3 shows the PAPR reduction performances of C-OFDM, C-SLM, SLM-H, SLM-Hb, SLM-Random, SLM-Lehmer and SLM-Symmetric Hankel schemes when N=64 for 16-QAM modulation. The PAPR reduction of the proposed scheme with respect to SLM-Hb, SLM-Lehmer, SLM-H, SLM-Random are given by 5.04 dB, 3.856 dB, 2.952 dB, and 1.975 dB respectively.The PAPR reduction performances of C-OFDM, C-SLM, SLM-H, SLM-Hb, SLM-Random, SLM-Lehmer and SLM-Symmetric Hankel schemes when N=64 for 64-QAM modulation are described in Figure 5.4. The PAPR reduction of the proposed scheme with respect to SLM-Hb, SLM-Lehmer, SLM-H, SLM-Hb are given by 5.13 dB, 3.856 dB, 3.274 dB, and 1.985 dB respectively. From Figure 5.4 and Figure 5.5, it can be inferred that the proposed scheme has a better PAPR reduction in the case of 64-QAM modulation than 16-QAM modulation.

Table 5.2 shows the comparison of the proposed scheme along with various other existing works in the literature. The proposed scheme has an improvement of 3.125%, 51.56 %, 52.30%, 53.73%, 58.66%, 60.25%, and 67.36% over the Fibonacci-Binary phase sequences, Hilbert phase sequences, Chaotic phase sequences, Lehmer phase sequences, Monomial phase sequences, gold phase sequences, Hadamard phase sequences and Modified Chu phase sequences respectively.

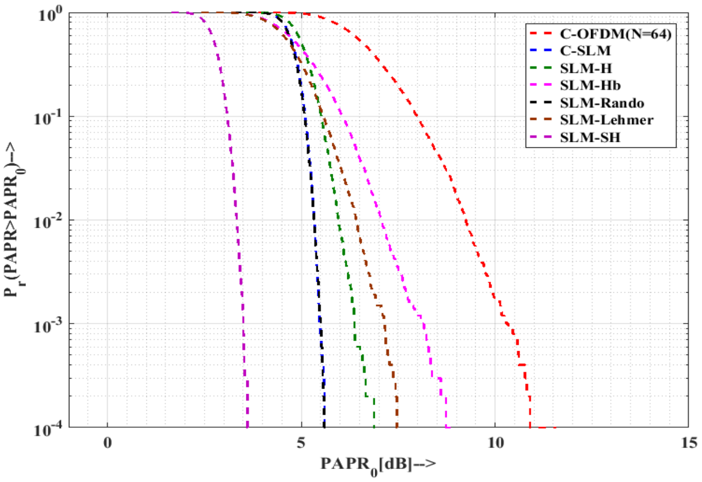

Fig 5.4. PAPR performance comparison of SLM-H, SLM-Hb, SLM-Random, SLM-Lehmer and SLM-SH for 64 subcarriers with 64-QAM modulation

Figure 5.5 depicts the PAPR performance comparison of SLM-H, SLM-Hb, SLM-Rando, SLM-Lehmer and SLM-SH for 256 subcarriers when BPSK modulation is employed. The PAPR values of the Conventional OFDM, Conventional SLM, SLM-H, SLM-Hb, SLM-Random, SLM-Lehmer and SLM-Symmetric Hankel techniques are given by 12.04 dB, 6.46 dB, 6.562 dB, 8.379 dB, 5.879 dB, 7.571 dB, and 3.126 dB respectively. The PAPR reduction of the proposed scheme SLM-SH with respect to SLM-H, SLM-Hb, SLM-Random and SLM-Lehmer are given by 3.436 dB, 5.265 dB, 2.753 dB, and 4.445 dB respectively.

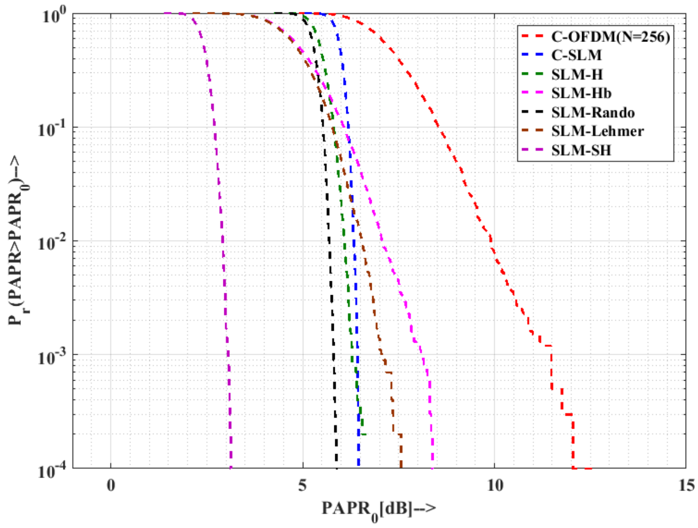

Figure 5.5 PAPR performance comparison of SLM-H, SLM-Hb, SLM-Random, SLM-Lehmer and SLM-SH for 256 subcarriers with BPSK modulation

Figure 5.6 describes the PAPR performance comparison of SLM-H, SLM-Hb, SLM-Random, SLM-Lehmer and SLM-SH for 256 subcarriers with QPSK modulation. nIn the case of QPSK modulation, when N=256, the PAPR reduction performances of the proposed scheme with respect to SLM-H, SLM-Hb, SLM-Random, SLM-Lehmer are given by 3.321 dB, 4.433 dB, 2.787 dB, and 3.979 dB respectively.

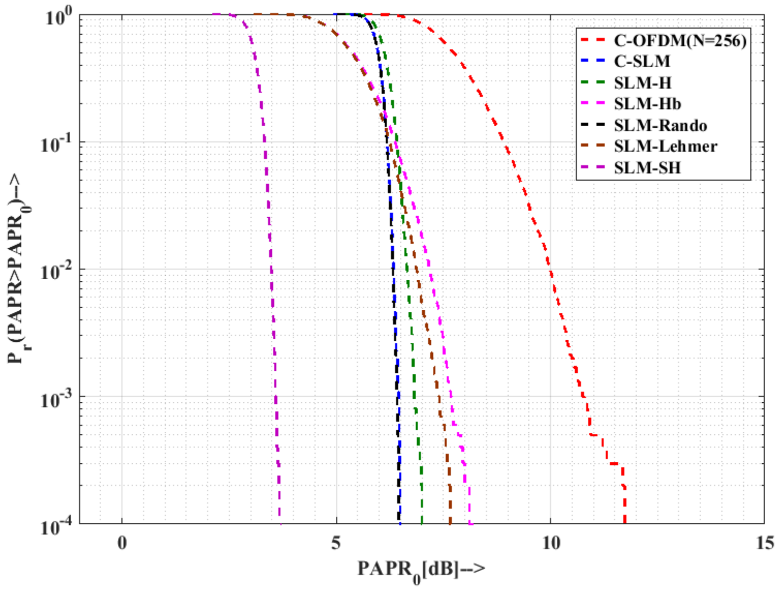

Figure 5.6 PAPR performance comparison of SLM-H, SLM-Hb, SLM-Random, SLM-Lehmer and SLM-SH for 256 subcarriers with QPSK modulation

Figure 5.7 depicts the PAPR performance comparison of SLM-H, SLM-Hb, SLM-Rando, SLM-Lehmer and SLM-SH for 256 subcarriers with 16-QAM modulation. When N=256, for 16-QAM modulation scheme, the PAPR reduction performances of the proposed scheme with respect to SLM-H, SLM-Hb, SLM-Random, SLM-Lehmer are given by 3.548 dB, 5.017 dB, 2.955 dB, and 4.289 dB respectively. The proposed scheme has a good PAPR reduction performance over the SLM-Hb and SLM-Lehmer techniques.

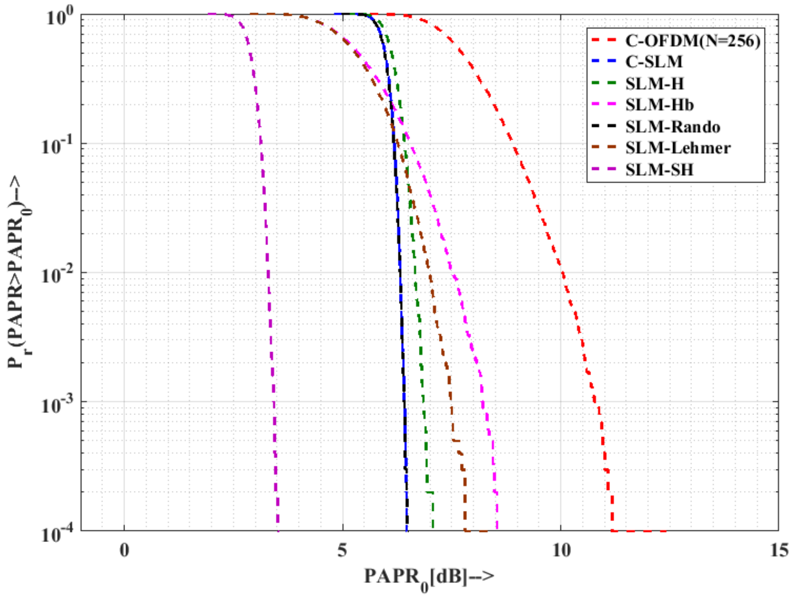

Figure 5.7 PAPR performance comparison of SLM-H, SLM-Hb, SLM-Random, SLM-Lehmer and SLM-SH for 256 subcarriers with 16-QAM modulation

Figure 5.8 depicts the PAPR performance comparison of SLM-H, SLM-Hb, SLM-Random, SLM-Lehmer and SLM-SH for 256 subcarriers with 64-QAM modulation.

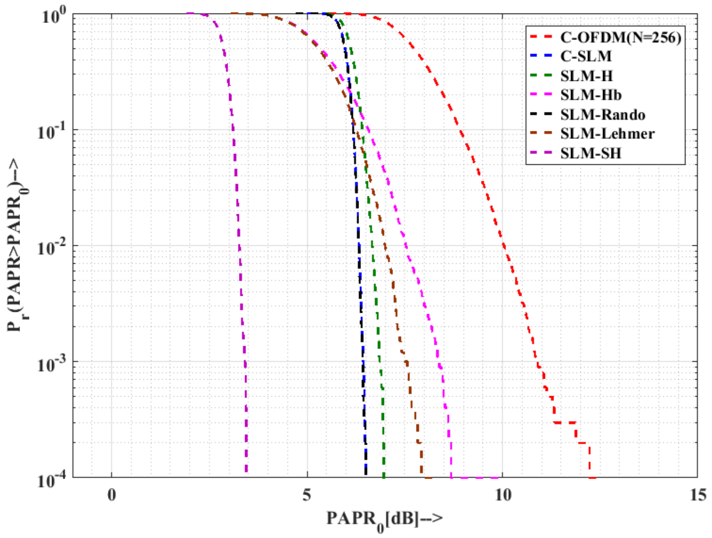

Figure 5.8 PAPR performance comparison of SLM-H, SLM-Hb, SLM-Random, SLM-Lehmer and SLM-SH for 256 subcarriers with 64-QAM modulation

In the case of 64-QAM modulation, when N=256, the PAPR values of the SLM-H, SLM-Hb, SLM-Random, SLM-Lehmer and SLM-SH are given by 6.959 dB , 8.687 dB, 6.502 dB, 7.924 dB, and 3.45 dB respectively. The PAPR reduction of the proposed scheme with respect to the SLM-Hb, SLM-Lehmer, SLM-H, and SLM-Random are 5.237 dB, 4.474 dB, 3.509 dB and 3.052 dB respectively. Figure 5.9 shows the PAPR reduction performances of SLM-SH over other schemes when N=256 over various modulation schemes. Figure 5.9 depicts the PAPR reduction performances of SLM-SH over other schemes when N=256 over various modulation schemes

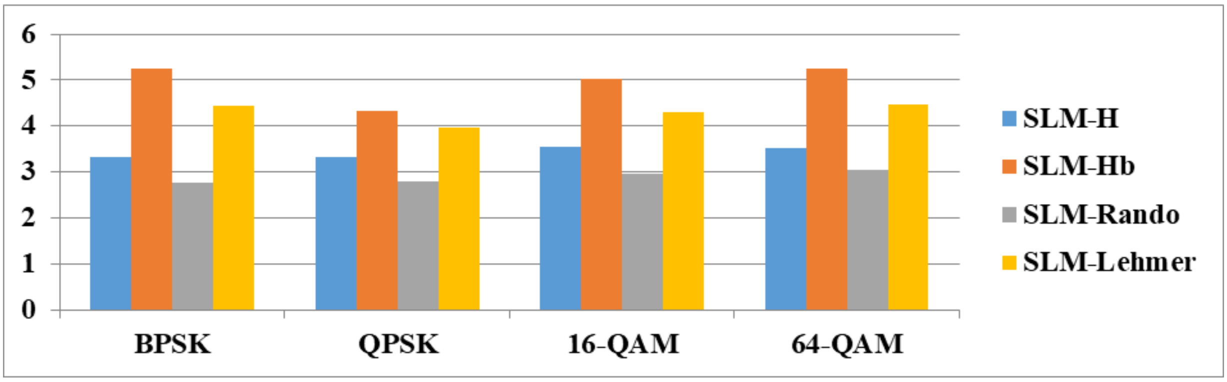

Figure 5.9 PAPR reduction performances of SLM-SH over other schemes when N=256 over various modulation schemes

From the simulation results, the following points can be inferred Hadamard phase sequences have better PAPR reduction when compared to the Hilbert phase sequences. Rando phase sequences perform better when compared to Lehmer phase sequences. As the number of sub-carriers increases, PAPR reduction also increases. The proposed scheme is independent of sub-carriers.

Table 5.2 shows the comparison of the proposed scheme along with various other existing works in the literature. The proposed scheme has an improvement of 3.125 %, 51.56 %, 52.30 %, 53.73 %, 58.66 %, 60.25 %, and 67.36% over the Fibonacci-Binary phase sequences, Hilbert phase sequences, Chaotic phase sequences, Lehmer phase sequences, Monomial phase sequences, Gold phase sequences, Hadamard phase sequences and Modified Chu phase sequences respectively.

Table 4.2: Comparison of SLM-Symmetric Hankel matrices with other existing works in the literature

Author name & Year	Phase Sequences used	Obtained PAPR value (dB)
Jayalath *et al.* (2000)	Monomial	7.5
Goel *et al.* (2012)	M-ary Chaotic	6.5
Namita *et al.* (2014)	Gold	7.5
	Hadamard	7.8
Adegbite *et al.* (2014)	Fibonacci-Binary	3.2
Sharma *et al.* (2012)	Modified Chu sequences	9.5
Vaiyamalai *et al.* (2017)	Lehmer	6.7
Palanivelan *et al.* (2011)	Hilbert	6.4
This work	**Symmetric Hankel**	**3.1**

6. Conclusion

OFDM systems are used in various applications such as WiMAX, 3GLTE and Wireless local area networks, digital audio radio and optical communications. The advantages of OFDM include increased spectral efficiency, simple channel equalization, immunity against co-channel interference, and impulsive parasitic noise. Though it has several advantages, one of the main issues faced by OFDM systems is its increased peak to average power ratio, which is caused by the summation of modulated sub-carriers. In this paper, we have proposed investigated and applied Novel Symmetric Hankel matrices as phase sequences for the Selective Mapping technique to reduce Peak to average power ratio in OFDM systems. The simulation results were executed for 64 subcarriers for various modulation schemes such as BPSK, QPSK, 16-QAM, and 64-QAM using MATLAB 2016 software. The results of the proposed method are compared with Hadamard, Hilbert, Random and Lehmer phase sequences. The proposed method shows better performance when compared with other works in the literature.

Conflicts of Interest

"The authors declare no conflict of interest."

Author Contributions

Conceptualization, Sanjana Prasad; methodology, Sanjana Prasad; software, Sanjana Prasad; validation, Sanjana Prasad, formal analysis, Sanjana Prasad; investigation, Sanjana Prasad; resources, Arun S; data curation, ; writing—original draft preparation, Sanjana Prasad; writing—review and editing, Arun S & Pradeep Kumar BP; visualization, Sanjana Prasad; etc.

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