

PAPR Reduction in SLM–OFDM System Using Lehmer Sequence Without Explicit Side Information

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Abstract Selected mapping (SLM) is one of the promising techniques used for peak-to-average power ratio (PAPR) reduction in orthogonal frequency division multiplexing (OFDM) system. One of the major drawbacks in this technique is that, the transmitter is forced to transmit more amount of side information (SI) bits in order to recover the original data at the receiver, which leads to data rate loss and inefficient transmission. In this paper, a new phase sequence generation method using Lehmer Random Number Generator (LRNG) called Lehmer sequence is proposed for SLM technique. Using the periodicity property of this sequence, the SI bits are embedded within the transmitted data block for 16-PSK modulation, which ensures that SI bits are not explicitly sent. The simulation results show that the proposed SLM (PSLM) provides a slight improvement in PAPR reduction without compromising the bit error rate (BER) for higher values of an expansion factor when compared to conventional SLM (CSLM).

Keywords Orthogonal frequency division multiplexing (OFDM) · Lehmer random number generator (LRNG) · Peak to average power ratio (PAPR) · Side information (SI)

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1 Introduction

Orthogonal frequency division multiplexing (OFDM) is one of the most popular multi-carrier modulation techniques used by recent wireless standards such as WiMAX, Wi-Fi, LTE and LTE-A due to its high spectral efficiency, immunity to multipath fading and impulse noise. The major drawback of OFDM system is the high peak-to-average power ratio (PAPR) of transmitting signals, which degrade the efficiency of the high power amplifier at the transmitter [1].

To reduce the impact of high PAPR, numerous techniques are suggested in the literature such as clipping [2], selected mapping (SLM) [3], partial transmit sequence (PTS) [4] etc. Among them, selected mapping (SLM) is widely used to reduce PAPR in OFDM system without affecting bit error rate (BER) performance.

In SLM, for the given input data block the transmitter generates a set of alternative signals, all representing the same information with different PAPR value. Then, the signal having lowest PAPR is selected for transmission. The amount of PAPR reduction mainly depends on the construction of phase sequence set [5]. In literature, a number of phase sequence sets have been proposed for SLM technique which includes rows of Riemann matrix [6], normalized Riemann matrix [7], Hadamard matrix [8], Zad-off Chu matrix [9] and Chaotic sequence [10], etc.

These techniques require the transmission of explicit side information (SI) i.e. the index of the selected phase sequence corresponding to minimum PAPR to the receiver. This decreases the data rate and increases the transmitted power. Hence, it is crucial to concentrate on SLM techniques which do not require any explicit SI.

In [11–13], techniques have been proposed to embed SI within the phase sequence prior to multiplication with the original data sequence to generate the transmitted data block. In these techniques, the phase sequence is divided into multiple sub-vectors of equal length and the values at certain locations in each sub-vector are modified by a constant C , where $C > 1$ is called an expansion factor. At the receiver, SI is recovered by identifying the locations of constant C in the each sub-vector. The technique used in [13] modifies multiple locations in the phase sequence by the expansion factor, which leads to a considerable increase in average energy per transmitted data block while assuming perfect channel state information (CSI). In addition, the technique used in [12, 13] can be applied only when the number of sub-carriers equal to multiples of 5. In this paper, we propose a new technique, where the number of sub-carrier equal to 2^n (where n is any positive integer) is proposed to embed SI with the help of Lehmer sequence. In this technique, only certain locations in the first sub-vector (window) of phase sequences are modified with a constant $C > 1$ unlike in [13] and at the receiver, SI is recovered by identifying the value of the first sub-vector.

This paper is organized as follows. In Sect. 2, Review of Lehmer Random Number Generator (LRNG) and its auto correlation properties are given. In Sect. 3, the Proposed SLM is discussed in detail. In Sect. 4, simulation results are discussed. Finally, the conclusion is given in Sect. 5.

2 Review of Lehmer Random Number Generator (LRNG)

LRNG is a method of generating random numbers, invented by D.H. Lehmer in 1949 [14]. It is a special case of linear congruential generator (LCG) based on the recursive relation (1):

$$L_{n+1} = (a \cdot L_n + b) \bmod m, \quad n \geq 0 \tag{1}$$

where m is the modulus, $m > 0$, a is the multiplier, $0 < a < m$, b is the increment, $0 < b < m$, L_0 is the initial seed, i.e. the first state in the recursive relation ($0 \leq L_n < m$) and L_{n+1} is the sequence of random numbers.

In (1), if $b = 0$, then the relation is known as multiplicative congruential generator or LRNG. The parameters of (1) must be chosen properly in order to obtain sequence with maximum period. To generate a sequence with period $m - 1$, the conditions to be satisfied by the parameters are [15]:

1. m should be a prime or power of a prime number.
2. a should be a primitive root modulo m .
3. L_0 must be co-prime to m .

The above conditions can be satisfied if $\bmod m$ is a full repetend prime or proper prime in base a [16]. A number m is said to be a full repetend prime, if the remainder of (2) repeats after a period of $m - 1$.

$$L_{n+1} = a \cdot L_n \pmod{m} = (a^n) \bmod m, \quad n \geq 0 \tag{2}$$

Table 1 illustrates the property of full repetend prime and Lehmer random numbers generated for $m = 11$ and $a = 2$. In this case the remainder repeats after $m - 1 = 10$. There are $m - 1$ cyclic shifts possible for a sequence of period $m - 1$. It is evident that an infinite sequence with period $m - 1$ can be generated using the recursive relation (2).

In CSLM, phase sequences are generated randomly from the set $\{\pm 1, \pm j\}$ which possesses low autocorrelation properties. Figure 1 compares the autocorrelation magnitude of various sequences, namely Lehmer sequence, Random, Hadamard, Riemann, Zad-off Chu and Chaotic sequences with length 128. It is observed from the simulation results that Lehmer sequence has almost same correlation properties as random sequences. Thus, the Lehmer sequence can also be used for PAPR reduction. As it is possible to regenerate the sequence at the receiver by having the knowledge of LRNG parameters, the size of the lookup table required at the receiver is reduced.

This leads to the new deterministic random phase generation technique that has been proposed for the purpose of PAPR reduction. A detailed discussion on the transmission technique utilized for LRNG sequence is provided in the Sect. 3.

3 Proposed SLM Technique Without Explicit Side Information

In this section, the notation \mathbf{X}_k is used to express a frequency domain signal vector \mathbf{X} composed of N quantities such that $k \in \{0, 1, 2, 3, \dots, N - 1\}$ and the corresponding time domain signal vector is \mathbf{x} and $E [.]$ denotes the expectation.

3.1 Transmitter Design for the Proposed Technique

An OFDM system using N subcarriers and a data block \mathbf{X}_k composed of N complex data symbols is considered in this proposed technique. In CSLM, the original input data block is multiplied by U different random phase sequences \mathbf{B}^u , $u \in \{1, 2, \dots, U\}$ to obtain alternative signals \mathbf{X}_k^u as

Table 1 Property of the full repetend prime and Lehmer sequence generated for $m = 11, a = 2$ and $L_0 = 1$

<i>Number of iterations</i>	<i>n</i>	$(a^n) \bmod m$
1	0	$(2^0) \bmod 11 = 1$
2	1	$(2^1) \bmod 11 = 2$
3	2	$(2^2) \bmod 11 = 4$
4	3	$(2^3) \bmod 11 = 8$
5	4	$(2^4) \bmod 11 = 5$
6	5	$(2^5) \bmod 11 = 10$
7	6	$(2^6) \bmod 11 = 9$
8	7	$(2^7) \bmod 11 = 7$
9	8	$(2^8) \bmod 11 = 3$
10	9	$(2^9) \bmod 11 = 6$
11	10	$(2^{10}) \bmod 11 = 1$

$m-1=10$

$$\mathbf{X}_k^u = \mathbf{X}_k \cdot \mathbf{B}^u, \quad u \in (1, 2, \dots, U) \tag{3}$$

Then, the resultant signal in (3) is transformed into the time domain signal \mathbf{x}_n^u through inverse fast Fourier transform operation as

$$\mathbf{x}_n^u = IFFT(\mathbf{X}_k^u) = IFFT(\mathbf{X}_k \cdot \mathbf{B}^u), \quad u \in (1, 2, \dots, U) \tag{4}$$

Out of U signals, one with minimum PAPR $\mathbf{x}_n^{\bar{u}}$ is selected for transmission as shown in Fig. 2. In this case, to discover the original data block at the receiver, it is required to send $\lceil \log_2 U \rceil$ number of bits for each transmitted data block as SI from the transmitter.

Figure 3 depicts the PSLM structure. The proposed technique is used to generate phase sequence set with LRNG and embed the SI required for detecting the phase sequence at the receiver. In PSLM, random numbers are generated using LRNG and are converted into binary in such a way that each digit has $\gamma = \lceil \log_2^{m-1} + 1 \rceil$ number of bits in the binary representation; where m is the modulus parameter of LRNG. Later, the binary representation is divided into windows, each of size γ bits and zeros in the whole sequence are replaced with ‘-1’ and only ones in the first window are replaced by an expansion factor $C > 1$. Since any number occurs only once in the whole sequence, by identifying the first

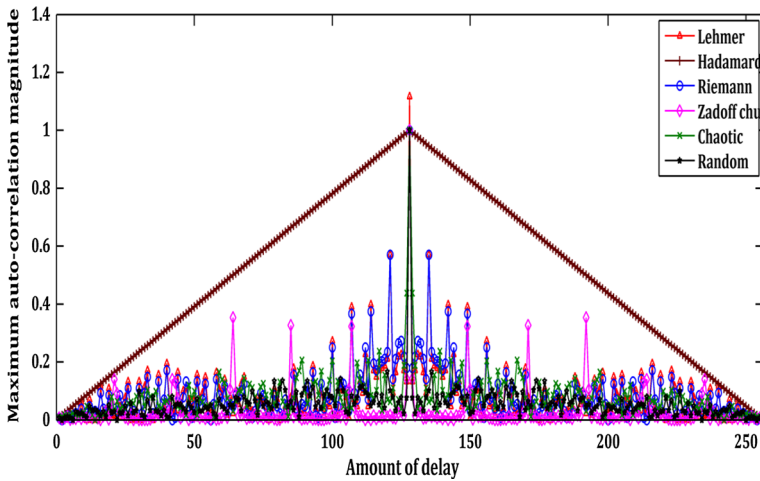


Fig. 1 Auto correlation magnitude of various sequences with length 128

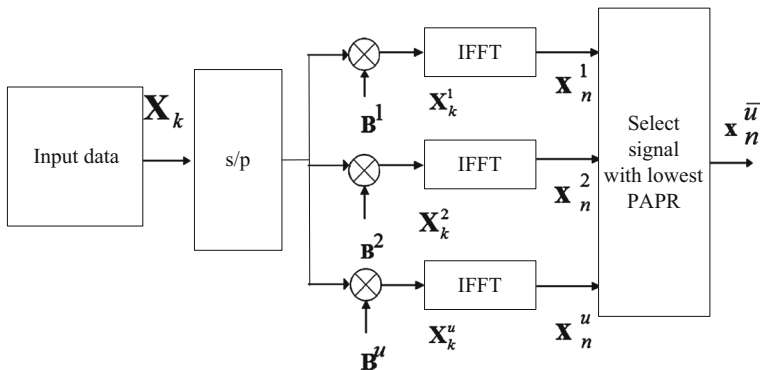


Fig. 2 Block diagram of conventional SLM

window value, the number of cyclic shifts applied at the transmitter can be obtained. The value obtained from the first window acts as SI at the receiver.

The procedure for generating Lehmer phase sequence is as follows:

Step 1 A Lehmer random sequence is generated using (2) based on the condition $\gamma \cdot (m - 1) \geq N$; where γ is the number of bits used for the binary representation of each number in the sequence, m is the modulus parameter of LRNG and N is the number of subcarriers used in OFDM system. This condition is explained with LRNG parameters $a = 2$, $m = 11$ and $X_0 = 1$ as seen in the Table 2. The maximum number of cyclic shifts possible is restricted by the period of the generated sequence.

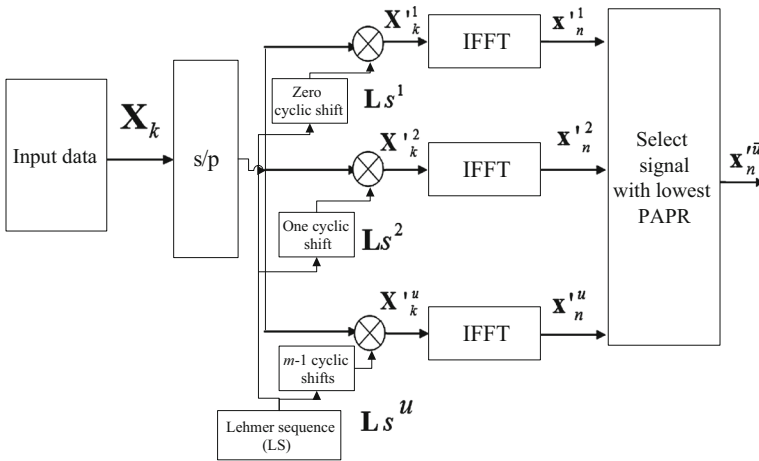


Fig. 3 Block diagram of the proposed SLM structure

Step 2 Random numbers generated in step 1 are converted into binary bits. The 4 bit binary equivalent of each number in the sequence is given in Table 3. Therefore, for $\gamma = 4$ and $m = 11$, it can be understood that the phase sequence generated in Tables 2 and 3 can be used for a maximum of $N = 40$ subcarriers.

Step 3 Divide the binary data obtained in step 2 into several sub-vectors of equal length called windows (W). In the proposed scheme, all zeros in the binary representation are replaced by -1 and the ones in the first window (W1) are replaced by a constant C, as shown in Table 4 to obtain the phase sequence to be used in SLM-OFDM

In Table 3, based on the required number of subcarriers, the sequence generated can be truncated to form the phase sequence, i.e. if the number of required subcarriers is 8, then the values available in Box 1 are used as a phase sequence and if the required number of subcarriers is 16, then the values available in Box 2 are utilized and so on.

Table 2 Random sequence generated using (2) with parameters $a = 2, m = 11$ and $X_0 = 1$

No. of iterations	0	1	2	3	4	5	6	7	8	9
No. of cyclic shifts										
0	1	2	4	8	5	10	9	7	3	6
1	2	4	8	5	10	9	7	3	6	1
2	4	8	5	10	9	7	3	6	1	2
3	8	5	10	9	7	3	6	1	2	4
4	5	10	9	7	3	6	1	2	4	8
5	10	9	7	3	6	1	2	4	8	5
6	9	7	3	6	1	2	4	8	5	10
7	7	3	6	1	2	4	8	5	10	9
8	3	6	1	2	4	8	5	10	9	7
9	6	1	2	4	8	5	10	9	7	3

Table 3 Binary representations of random sequence generated in Table 2

No. of iterations	0	1	2	3	4	5	6	7	8	9
No. of cyclic shifts										
1	0001	0010	0100	1000	0101	1010	1001	0111	0011	0110
2	0010	0100	1000	0101	1010	1001	0111	0011	0110	0001
3	0100	1000	0101	1010	1001	0111	0011	0110	0001	0010
4	1000	0101	1010	1001	0111	0011	0110	0001	0010	0100
5	0101	1010	1001	0111	0011	0110	0001	0010	0100	1000
6	1010	1001	0111	0011	0110	0001	0010	0100	1000	0101
7	1001	0111	0011	0110	0001	0010	0100	1000	0101	1010
8	0111	0011	0110	0001	0010	0100	1000	0101	1010	1001
9	0011	0110	0001	0010	0100	1000	0101	1010	1001	0111
9	0110	0001	0010	0100	1000	0101	1010	1001	0111	0011

Box 1

↓

Box 2

Another set of LRNG parameters which can be utilized for various numbers of sub-carriers i.e. 8, 16, 32, 64, 128, 256, 512 and 1024 are $a = 2$, $m = 131$ and $X_0 = 1$ as illustrated in Table 5. Similarly, the phase sequence set can be obtained by truncating the original sequence generated to suit the required number of subcarriers. Therefore, in the proposed technique, the input data block \mathbf{X}_k is multiplied by the Lehmer phase sequence formulated (\mathbf{Ls}) in Table 4, in which the average energy for each transmitted symbol is modified by a factor of either 1 or C .

Like CSLM, in the proposed method, the set of alternative signal $\mathbf{X}_k^{(u)}$ is obtained by multiplying the original input data block \mathbf{X}_k by Lehmer sequence (\mathbf{Ls}) generated in Table 4 as follows:

$$\mathbf{X}_k^{(u)} = \mathbf{X}_k \cdot \mathbf{Ls}^u, \quad u \in (1, 2, \dots, U) \tag{5}$$

These frequency domain sequences $\mathbf{X}_k^{(u)}$ are transformed into the time domain signals $\mathbf{x}_n^{(u)}$ through inverse fast Fourier transform (IFFT) operation as follows:

Table 4 Phase sequence generated using a random sequence in Table 3, where the first row denotes the window number

W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
-1-1-1C	-1-11-1	-11-1-1	1-1-1-1	-11-11	1-11-1	1-1-11	-1111	-1-111	-111-1
-1-1C-1	-11-1-1	1-1-1-1	-11-11	1-11-1	1-1-11	-1111	-1-111	-111-1	-1-1-11
-1C-1-1	1-1-1-1	-11-11	1-11-1	1-1-11	-1111	-1-111	-111-1	-1-1-11	-1-11-1
C-1-1-1	-11-11	1-11-1	1-1-11	-1111	-1-111	-111-1	-1-1-11	-1-11-1	-11-1-1
-1C-1C	1-11-1	1-1-11	-1111	-1-111	-111-1	-1-1-11	-1-11-1	-11-1-1	1-1-1-1
C-1C-1	1-1-11	-1111	-1-111	-111-1	-1-1-11	-1-11-1	-11-1-1	1-1-1-1	-11-11
C-1-1C	-1111	-1-111	-111-1	-1-1-11	-1-11-1	-11-1-1	1-1-1-1	-11-11	1-11-1
-1CCC	-1-111	-111-1	-1-1-11	-1-11-1	-11-1-1	1-1-1-1	-11-11	1-11-1	1-1-11
-1-1CC	-111-1	-1-1-11	-1-11-1	-11-1-1	1-1-1-1	-11-11	1-11-1	1-1-11	-1111
-1CC-1	-1-1-11	-1-11-1	-11-1-1	1-1-1-1	-11-1-1	1-11-1	1-1-11	-1111	-1-111

Table 5 Random sequence generated using LRNG with parameters $a = 2, m = 131$ and $X_0 = 1$

1	2	4	8	16	32	64	128
125	119	107	83	35	70	9	18
36	72	13	26	52	104	77	23
46	92	53	106	81	31	62	124
117	103	75	19	38	76	21	42
84	37	74	17	34	68	5	10
20	40	80	29	58	116	101	71
11	22	44	88	45	90	49	98
65	130	129	127	123	115	99	67
3	6	12	24	48	96	61	122
113	95	59	118	105	79	27	54
108	85	39	78	25	50	100	69
7	14	28	56	112	93	55	110
89	47	94	57	114	97	63	126
121	111	91	51	102	73	15	30
60	120	109	87	43	86	41	82
33	66						

$$\mathbf{x}_n^{iu} = IFFT(\mathbf{X}_k^{iu}) = \frac{1}{\sqrt{LN}} \sum_{k=0}^{LN-1} \mathbf{X}_k^{iu} \cdot e^{j2\pi nk/N}, \quad n = 0, 1, \dots, LN - 1, u \in \{1, 2, \dots, U\} \tag{6}$$

Then, PAPR is computed for all the U alternative signals and it is given by

$$PAPR[\mathbf{x}_n^{iu}] = \frac{\max \left[|\mathbf{x}_n^{iu}|^2 \right]}{E \left[|\mathbf{x}_n^{iu}|^2 \right]}, \quad n \in \{0, 1, 2, \dots, N - 1\}, u \in \{1, 2, 3, \dots, U\} \tag{7}$$

Finally, the signal \mathbf{x}_n^{iu} with minimum PAPR is selected for transmission.

3.2 Receiver Design for the Proposed Technique

In this paper, the PSLM technique is analyzed for Rayleigh channel. The time domain of each transmitted symbol denoted as $\mathbf{x}_{s,n}^{iu}$ after passing through the Rayleigh channel is given as [13]:

$$\mathbf{y}_{s,n} = \mathbf{h}_n \cdot \mathbf{x}_{s,n}^{iu} + \mathbf{n}_n \quad n \in \{0, 1, 2, \dots, N - 1\} \tag{8}$$

where $\mathbf{y}_{s,n}$ is the received time domain symbol, n_n is a complex noise sample that exhibits Gaussian noise for the desired signal to noise ratio, h_n is an n-tap channel with real and imaginary part of each tap being an independent Gaussian random variable.

It is assumed that the receiver must be aware of the LRNG parameters, the logic applied to embed SI and the window width (γ) used at the transmitter end. The SI bits of each OFDM block are extracted using the decimal representation of the corresponding binary values available in the first window (W1), which contains some non-unity symbols. To get

<u>-1-1-1C</u>	-1-11-1	-11-1-1	1-1-1-1	-11-11	1-11-1	1-1-11	-1111	-1-111	-111-1
1 st Window									

Fig. 4 Snippet of Table 4 used for minimizing PAPR

a better understanding of the detection process, we look into the periodicity property of LRNG and how it is exploited to embed SI.

3.2.1 Periodicity Property

A random sequence is generated using LRNG with parameters a, m and L_0 such that it has a period $m - 1$, i.e. a number generated would repeat only after a period of $m - 1$.

The numbers generated in one period are used to ensure that no number repeats. Therefore, the number of cyclic shifts performed can be identified by detecting the first number received. For example, in Table 4, if the first row was used at the transmitter to minimize the PAPR, then the sequence is identified by the value in the first window as shown in Fig. 4.

The SI detection by the receiver is performed as in the following steps:

Step 1 The value of receiving symbols from the first window of receiving data block is extracted i.e.

$$\mathbf{y}_{w_1} = \mathbf{y}_{s,n}(1 : \gamma), \quad n \in \{0, 1, 2, \dots, N - 1\} \tag{9}$$

where γ is the window width and w_1 denotes first window.

Step 2 Since the magnitude of the 16-PSK modulated symbol has been always one, the positions where magnitude is greater than one are identified using a threshold y_{th} . If m_{w_1} denotes the magnitude of the first window (W1) and y_γ denotes value at γ^{th} position of first window.

$$m_{w_1} = |y_{w_1}| = [|y_1|, |y_2|, \dots, |y_\gamma|], \quad w_1 \in \{1, 2, 3, \dots, \gamma\} \tag{10}$$

Then, the positions where the magnitude is greater than y_{th} (which is fixed based on the value of C) and the amount of noise in the channel are identified. After the positions of non-unity symbols are identified, the values in the corresponding positions are replaced with ‘1’ and values in the remaining positions with ‘0’. The obtained binary representation is converted into decimal value, which provides the index of the phase sequence applied at the transmitter. In case, the index is not identified, it is defaulted as ‘1’.

Step 3 The original data block is recovered by performing the reverse operation of SLM, i.e. the received frequency domain data block is multiplied by the conjugate of the phase sequence identified using the index obtained in step 2.

4 Simulation Results and Discussion

In this section, the metrics considered for the analysis of the proposed technique are complementary cumulative distribution function (CCDF) of PAPR, the probability of SI detection failure (P_{df}) and bit error rate (BER). The computer simulation results verify the PAPR reduction and BER performance of the PSLM with original OFDM, CSLM and SLM with other phase sequences. The P_{df} and BER performance is analyzed over Rayleigh channel for different values of an expansion factor 'C'. For simulation, 10^5 independent OFDM data blocks were randomly generated and data symbols were modulated using a 16-PSK constellation. The oversampling factor $L = 4$ is examined here for a different number of alternative signals ($U = 16, 32$ and 64). The number of subcarriers N is set as 128, 256 and 512. LRNG parameters for phase sequence generation are given in Table 5.

4.1 PAPR Reduction Performance

CCDF of PAPR is expressed as $CCDF = Pr(PAPR > PAPR_0)$, where $PAPR_0$ is the given threshold. The CCDF curve in Fig. 5 depicts the PAPR reduction performance of the PSLM in comparison with original OFDM, CSLM and SLM using other sequences, i.e. Riemann, Hadamard, Chaotic and Zad-off chu for $U = 16, 32$ and 64 with $N = 128$.

At $CCDF = 10^{-2}$, for $U = 16$ and $N = 128$, the PAPR is 10.1, 8.4, 8, 7.3, 7.3, 7.1 and 6.5 dB, for the original OFDM signal, SLM with Zad-off chu, Hadamard, Chaotic, Random, Lehmer and Riemann sequences respectively. The results in Fig. 6 clearly show that the PAPR reduction performance of the PSLM with $U = 16$ is slightly superior to CSLM by 0.2 dB. The Riemann sequence achieves 0.6 dB reduction with respect to CSLM due to change in the amplitude of input data symbols and achieves 0.4 dB PAPR reduction gain than the Lehmer sequence. Figure 7 compares the same for $N = 256$. At $CCDF = 10^{-2}$, for $U = 16$, the PAPR is 10.3, 8.9, 8.5, 7.8, 7.8, 7.6 and 7.2 dB for original OFDM signal, SLM with zad-off chu, Hadamard, Chaotic, Random, Lehmer and Riemann sequence

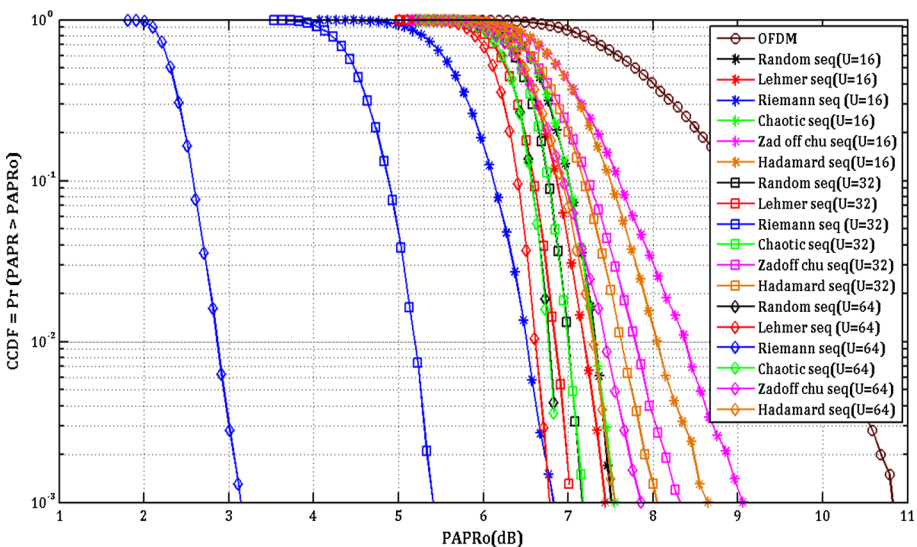


Fig. 5 CCDF of proposed SLM with a different number of alternative signals (U) with $N = 128$

respectively. According to the simulation results, for all N and U values, the PAPR reduction performance of the PSLM is slightly better than CSLM.

4.2 Probability of SI Detection Failure

The probability of SI detection failure P_{df} defines the probability that the receiver is unable to detect the SI which results in the loss of an entire OFDM block. The P_{df} versus expansion factor C has been plotted for a different number of subcarriers ($N = 256, 512$ and 1024) at $SNR = 0, 5, 15$ and 20 dB for Rayleigh channel. The signal to noise ratio (SNR) is defined as the ratio between the average energy per transmitted bit (E_b) and noise power spectral density (N_o). As SI is embedded only in the first window, SNR varies in the first window of every data sequence, and is detected by choosing an appropriate threshold. When $C \geq 3$, the receiver can easily distinguish modified and unmodified symbols. For simulation purpose, the threshold has been chosen as 2.5. It is observed from the Fig. 8 that, the P_{df} decreases for higher values of expansion factor C and SNR. In addition, the number of subcarriers N do not influence P_{df} performance.

4.3 BER Performance

The BER performance of the PSLM for different values of C , i.e. 2.6, 2.8, 3, 3.2 and 3.4 is depicted in Fig. 9. For the purpose of comparison, BER of original OFDM, CSLM, SLM with other sequences such as zad-off chu, Hadamard, Chaotic and Riemann sequence are plotted. The simulation results depict that the BER performance of SLM with Riemann, Zad off chu and chaotic sequences are worse than CSLM. Whereas, the PSLM shows the similar BER performance as CSLM for higher values of the expansion factor ($C \geq 3$). The CSLM, original OFDM, SLM with Hadamard and PSLM requires E_b/N_o of 15 dB to maintain a BER of 10^{-2} in Rayleigh channel. Whereas, SLM with Riemann sequence requires 26 dB to maintain the same BER. Hence it is not useful for practical communication system.

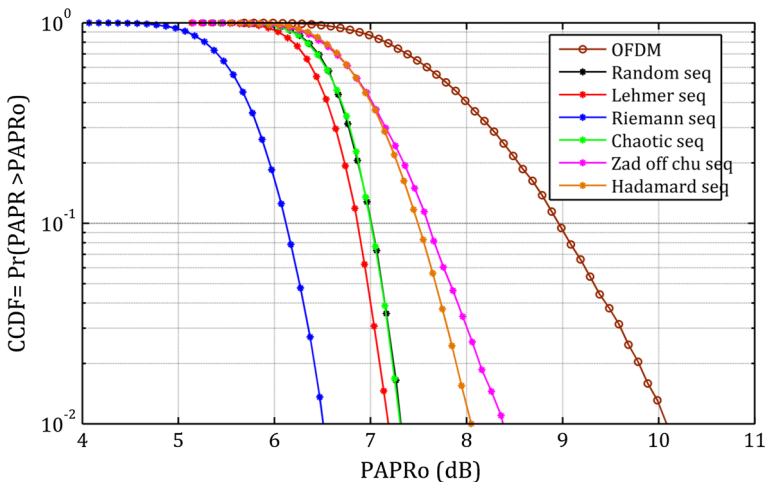


Fig. 6 CCDF comparison of PSLM and SLM with other sequences when $U = 16$ and $N = 128$

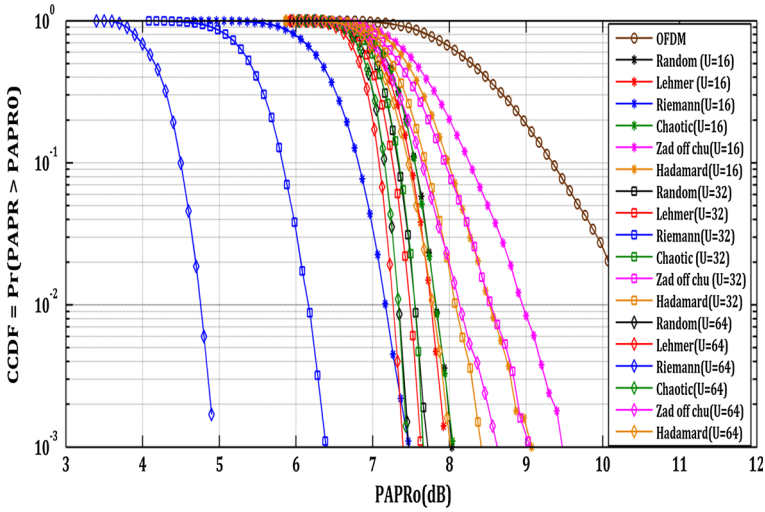


Fig. 7 CCDF of proposed SLM for a different number of alternative signals (U) with $N = 256$

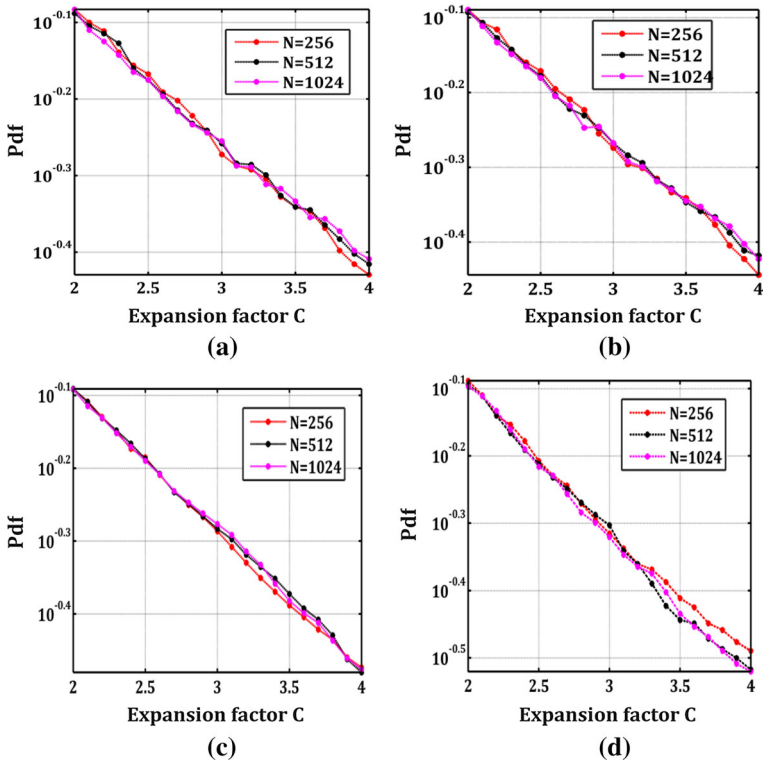


Fig. 8 Probability of SI detection failure a SNR = 0 dB, b SNR = 5 dB, c SNR = 15 dB and d SNR = 20 dB

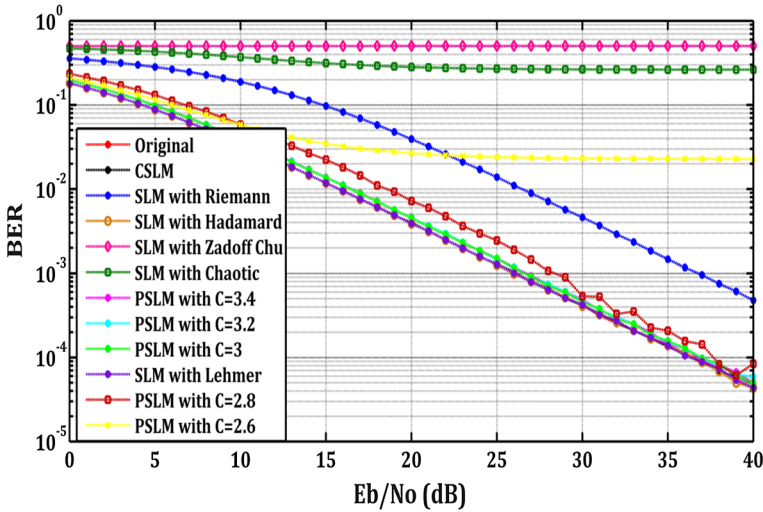


Fig. 9 BER performance comparison of proposed SLM and SLM with various phase sequences for $N = 256$

The BER performance of Hadamard sequence is same as CSLM but PAPR reduction is poor. Though Riemann sequence provides good PAPR reduction, the BER performance is worse than the proposed sequence. Therefore, Riemann sequence is not an acceptable choice for SLM-OFDM system. However, the proposed technique provides a slight improvement in PAPR reduction when compared with CSLM without BER degradation. Hence, the proposed sequence would be the best choice for an SLM-OFDM system.

5 Conclusion

In this paper, a new SLM scheme has been proposed using a sequence with similar auto correlation properties as a random sequence to reduce the PAPR without transmitting any explicit SI bits. In the proposed scheme, LRNG has been used to construct phase sequence, which ensures that the nature of phase sequence generated is random. The unique periodicity property of the sequence generated using LRNG enables us to embed the SI in the transmitted data block, which saves the bandwidth spent for SI transmission. As this technique modifies the magnitude of only a few symbols, it does not have a great impact on the transmitted power and BER performance. However, it marginally improves PAPR reduction performance when compared to conventional SLM. Hence, the proposed sequence can be a potential alternative for a random number with an advantage of embedded SI. However, it is applicable only for M-ary PSK modulated symbols, as all the bits have the same energy which enables us to embed SI.

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