CHAPTER 6

M-ARY CHAOTIC SEQUENCE BASED SLM-OFDM SYSTEM FOR PAPR REDUCTION

Selected mapping (SLM) [34] is a popular PAPR reduction scheme for OFDM systems. Like PTS [35], SLM provides good PAPR reduction capability without distorting the shape of the OFDM signal. As discussed in chapter 3, frequency domain OFDM signal, after multiplication with phase sequence set, generates a set of alternative OFDM signals and one of them with lowest PAPR is selected for transmission. But, like PTS scheme, it also suffers from the requirement of SI transmission, which results in data rate loss. As shown in chapter 3, in SLM based PAPR reduction schemes the PAPR reduction capability increases with the number of alternative OFDM signals. But, by increasing the number of alternative OFDM signals, the computational complexity of system increases due to the increase in number of IFFT operations and the number of multiplications required to multiply the frequency domain OFDM signal with phase sequence.

It has been reported in [93]-[94], that SLM based OFDM systems using different types of phase sequence sets, have different PAPR performances for same number of alternative sequences. Hence, for achieving good PAPR reduction and to limit the computational complexity, it is essential to select a good phase sequence set.

For SLM-OFDM system many phase sequence sets to achieve good PAPR reduction capability are proposed in [94]-[97]. A phase sequence set that achieves minimum correlation between alternative OFDM signal provide best PAPR performance, in [94], a phase sequence set is generated randomly from the set of four phase factors \{±1,±j\}, for achieving good PAPR reduction capability, but it requires large number of bits to encode the SI because in an OFDM system with \(N\) subcarriers, there are \(4^N\) possible combinations of phase sequences with length \(N\) and any one of them can be generated randomly; In order to encode the index of a phase sequence, \(\log_2 (4^N)\) bits per OFDM symbol are required, which results in high data rate loss. In [95], the PAPR reduction in SLM-OFDM system is performed by choosing
the rows of Hadamard matrix as phase sequence. The elements of Hadamard matrix are either 1 or -1, therefore they have only two phase factors \( \in \{1,-1\} \), but PAPR reduction capability of Hadamard matrix is very limited.

The binary chaotic sequence based phase sequence set generation scheme is proposed in [96], and PAPR reduction capability of this sequence is superior to that of Hadamard [95] and Shapario-Rudin [96] sequences. The PAPR reduction capability of SLM-OFDM system has been further improved by using rows of Riemann matrix as a phase sequence [97].

In all of the SLM-OFDM systems [94]-[97] described here, SI is required to recover the original OFDM signal. Therefore, SI has the prime importance in the transmitted OFDM signal because if it gets corrupted over communication channel, then due to incorrect SI detection, recovered OFDM symbol may be completely erroneous, which severely degrades the error performance of SLM-OFDM system.

In [98]-[101], many schemes for SI embedding have been proposed for SLM-OFDM systems. In [98], a scrambling based method is proposed by Breiling, Weinfurtner and Huber to embed SI in OFDM signal. Maruyama et al. proposed to use a new phase set generation scheme [99] based on m-sequences. In this scheme first phase sequence is generated by multiplication of two m-sequences and remaining phase sequences are generated by multiplication of a m-sequence with cyclic shifted m-sequences. At the receiver, correlation detectors are used for the detection of phase sequence utilized at the transmitter for PAPR reduction. Therefore, its receiver circuit becomes very complex and its computation complexity increases with the number of alternative OFDM signals.

Chen and Zhou proposed an SI embedding scheme in [100], which uses a high power pilot symbol whose location in data block depends on SI index. But its [100] performance is not found suitable in fading channel. In [101], S. Y. Le Goff et al. proposed an SI embedding for SLM–OFDM system, which increases the power level of the data transmitted on certain number (locations) of subcarriers, depending on SI index. In this scheme [101], the SI index i.e. the location of the high power data subcarriers has one to one mapping with the index of phase sequence, utilized to minimize the PAPR of OFDM signal. The receiver part of this scheme uses a maximum-likelihood detection technique to retrieve the SI. However, SI detection capability of this scheme over fading channel [101] is very poor at lower values of signal-to-noise ratio (SNR).
Here, we are motivated to deal with two major requirements of the conventional SLM-OFDM system together: (i) selection of good phase sequence (ii) SI transmission recovery.

In this chapter, a new phase sequence set generation based on \( M \)-ary chaotic sequence has been proposed for achieving better PAPR reduction capability. In this scheme, to generate the first phase sequence, an \( M \)-ary chaotic sequence of length equal to the number of subcarriers in an OFDM system is generated and then its elements are used as indices to select the phase factors from a predetermined phase set, containing \( M \) different phase factors. The remaining phase sequences of phase sequence set are generated by cyclic shifting of first phase sequence. Therefore, it avoids the requirement of generating remaining fresh phase sequences. Further, to eliminate the requirement of SI at the receiver, concentric circle constellation mapping [84], proposed in chapter 5, has been applied. In this chapter, we have also shown a comparison of PAPR and SER performances of proposed \( M \)-ary chaotic sequence with Riemann matrix based SLM-OFDM system because Riemann matrix based phase sequence has been claimed [97] to have achieved the best PAPR reduction capability. In order to show the SER performance degradation with increased number of alternative sequences, we have also done SER performance analysis of SLM OFDM system using Riemann matrix based phase sequence set. It has been shown that the proposed method provides good PAPR reduction capability and has better symbol error rate (SER) performance than its counterparts [94]-[97].

The remainder of this chapter is organized as follows. Section 6.1 describes the system model of the proposed SLM-OFDM system. The generation of Riemann matrix based phase sequence and its SER performance analysis are presented in section 6.2. In section 6.3, we discuss the proposed \( M \)-ary chaotic sequence based phase sequence set generation. The coupling of concentric circle constellation mapping with SLM, to eliminate the requirement of SI, is presented in section 6.4. In section 6.5, we present and discuss the results for PAPR and SER performances of the schemes under consideration. Finally, we conclude the chapter in section 6.6.

**6.1 System Model**

Fig. 6.1 shows the simplified block diagram of the proposed base band SLM-OFDM system. In this system, the serial binary data stream is first converted into quaternary data stream and concentric circle constellation mapping is applied to obtain the modulated data symbols. It is
then converted into parallel form by using serial-to-parallel (S/P) converter. After this, conventional SLM is applied to obtain the OFDM signal with minimum PAPR. The obtained OFDM signal is serialized by using a parallel-to-serial converter (P/S) and a cyclic prefix (CP) of sufficient duration is inserted to eliminate the effect of multipath propagation. The obtained digital signal is converted into analog signal using D/A converter and then amplified to the desired power level. Finally, the amplified signal is transmitted over the communication channel.

The received signal is first converted into digital signal by using A/D converter and then, CP is removed. The obtained signal is transformed into parallel streams by using S/P converter and then it is applied to the FFT block for subcarrier demodulation. The demodulated signal is de-mapped to quaternary data signal using CCM de-mapper and then quaternary to binary data conversion is performed to obtain the binary data signal.

![Diagram of SLM-OFDM transceiver](image)

**Figure 6.1:** $M$-ary chaotic sequence based SLM-OFDM transceiver
6.2 RIEMANN MATRIX PHASE SEQUENCE SET GENERATION AND ITS SER ANALYSIS

The Riemann matrix \([102]\) (R) of size \(N \times N\) is obtained by removing the first row and first column of matrix \(A\) of size \((N+1) \times (N+1)\),

\[
A(i, j) = \begin{cases} 
  i - 1 & \text{if } i \text{ divides } j \\
  -1 & \text{otherwise}
\end{cases}
\]  

(6.1)

The elements of \(v^{th}\) row in Riemann matrix (R) are either \(v\) or -1, \(1 \leq v \leq N\). In \(v^{th}\) row of Riemann matrix (R), \(c = \left\lfloor \frac{N}{v+1} \right\rfloor\) number of elements have value \(v\), whereas the remaining elements are -1, here, \(\lfloor . \rfloor\) is greatest integer function. Therefore, when \(v^{th}\) row, \((2 \leq v \leq U)\) of matrix \(R\) is used as phase sequence \(P^v\), it results not only in phase change but also amplitude change of the modulated data symbols.

Therefore, the average transmitted power of alternative frequency domain OFDM signals, \(X^u\), \(1 \leq u \leq U\) will not be the same as original OFDM signal \(X\). Here, \(X^u\) is the \(u^{th}\) alternative frequency domain OFDM signal.

Example 1: Consider an SLM-OFDM system with 8 subcarriers, which uses rows of Riemann matrix (R) as phase sequence. An \(8 \times 8\) Riemann matrix is given by

\[
R = \begin{bmatrix}
1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\
-1 & 2 & -1 & 1 & 2 & -1 & 1 & 2 \\
-1 & -1 & 3 & -1 & -1 & -1 & 3 & -1 \\
-1 & -1 & -1 & 4 & -1 & -1 & -1 & -1 \\
-1 & -1 & -1 & -1 & 5 & -1 & -1 & -1 \\
-1 & -1 & -1 & -1 & -1 & 6 & -1 & -1 \\
-1 & -1 & -1 & -1 & -1 & -1 & 7 & -1 \\
-1 & -1 & -1 & -1 & -1 & -1 & -1 & 8
\end{bmatrix}
\]

Here, Riemann matrix(R) serves as a phase sequence set with eight phase sequences because its rows are used as phase sequences to reduce the PAPR of the OFDM signal. Let, a \(M\)-ary PSK modulated frequency domain OFDM signal is applied to SLM-OFDM system and
suppose that the 3rd row of Riemann matrix as a phase sequence provides the best PAPR reduction. In the 3rd row of Riemann matrix the value of all the elements is -1 except 3rd and 7th element, which has a value of 3. Hence it has exactly \( c = 2 \) number of elements with value 3. When the elements with value -1 are used as phase factor, then they only produce the phase change whereas the two elements with value 3 produce the amplitude change. Therefore, the power level of two data subcarriers is increased by a factor of 9, which increases the average energy of the OFDM signal. Hence it has been verified by this example that when any row, except the 1st row is used for PAPR reduction in SLM-OFDM system then the average energy of the OFDM signal after multiplication with phase sequence increases.

**SER analysis of Riemann matrix based phase sequence**

Let the \( M \)-ary PSK constellation symbols have average symbol energy \( E_s \). Assume that \( v^{th} \) row, \( 2 \leq v \leq U \), of Riemann matrix (R) is the best available phase sequence to achieve maximum possible PAPR reduction for a particular OFDM signal. Therefore, after multiplication with \( v^{th} \) row, the symbol energy of \( c \) symbols is increased by a factor of \( v^2 \) and the symbol energy of remaining symbols remain unchanged \( (E_s) \). The average energy of alternative OFDM signal \( X^v \) (original frequency domain OFDM symbol after multiplication with \( v^{th} \) phase sequence) can be calculated as

\[
E_{av} = \frac{E_s(N - c) + cv^2E_s}{N}
\]  

(6.2)

If each of the \( M \)-PSK modulated subcarrier is transmitted over AWGN channel, the average probability of error \( P_e \) (SER) using Riemann matrix phase sequence in absence of any error in SI detection is given by

\[
P_e = \left( \frac{N - c}{N} \right) P_{e1} + \left( \frac{c}{N} \right) P_{e2}
\]  

(6.3)

where, \( P_{e1} \) and \( P_{e2} \) are the probability of errors when constellation symbols with energy \( E_s \) and \( v^2E_s \) respectively, are transmitted over AWGN channel and detected erroneously at the receiver. The error probabilities \( P_{e1} \) and \( P_{e2} \) for \( M \)-PSK modulated signals can be calculated as
\[ P_{e_1} = \text{erfc} \left( \frac{E_s}{N_o} \sin \left( \frac{\pi}{M} \right) \right) \]  

(6.4)

\[ P_{e_2} = \text{erfc} \left( \sqrt{\frac{v^2 E_s}{N_o}} \sin \left( \frac{\pi}{M} \right) \right) \]  

(6.5)

After substituting the values of \( P_{e_1} \) and \( P_{e_2} \) from (6.4) and (6.5) into (6.3), we have

\[ P_e = \left( \frac{N-c}{N} \right) \text{erfc} \left( \frac{E_s}{\sqrt{N_o}} \sin \left( \frac{\pi}{M} \right) \right) + \left( \frac{c}{N} \right) \text{erfc} \left( \sqrt{\frac{v^2 E_s}{N_o}} \sin \left( \frac{\pi}{M} \right) \right) \]  

(6.6)

After substituting the value of \( E_s \) from (6.2) into (6.3), we have

\[ P_e = \left( \frac{N-c}{N} \right) \text{erfc} \left( \frac{NE_{av}}{((N-c) + cv^2)N_o} \sin \left( \frac{\pi}{M} \right) \right) + \left( \frac{c}{N} \right) \text{erfc} \left( \sqrt{\frac{v^2 NE_{av}}{((N-c) + cv^2)N_o}} \sin \left( \frac{\pi}{M} \right) \right) \]  

(6.7)

In Fig. 6.2 we have shown the SER of QPSK modulated SLM-OFDM system using a phase sequence set generated from phase factors \( \{±1, ±j\} \). It is assumed that perfect side information is available at the receiver and is denoted by “SLM-OFDM with perfect SI”.

The SER performance of SLM-OFDM system using Riemann matrix based phase sequence is also shown in Fig. 6.2. The SER performance denoted by “Riemann v=4” and “Riemann v=8” represents the SER performances of SLM-OFDM system when 4\(^{th}\) and 8\(^{th}\) rows of Riemann matrix are used for achieving low PAPR. These results are obtained from (6.7) for \( v = 4 \) and 8. It can be seen from Fig. 6.2 that the SER performance denoted by “SLM-OFDM with perfect SI” is the best in all the three cases. It can be easily observed from Fig. 6.2 that average probability of error increases with \( v \), \( 2 \leq v \leq U \). The main reason behind it is that the data symbols, after multiplication with Riemann matrix phase sequence \( (X_0^u, X_1^u, X_2^u, ..., X_{N-1}^u) \), no longer have equal powers and therefore, symbols with low power can be easily corrupted during the transmission over AWGN channel. Hence, in case of Riemann matrix phase sequence SER performance degrades by increasing the value of \( U \).
In the above analysis, we have assumed that SI is known to the receiver or detected without error. But in general, exact SI is required at the receiver to recover the original OFDM signal because the received signal has to be multiplied with the reciprocal of the phase sequence \( uP \) (used by the transmitter to provide least PAPR) to recover the original OFDM signal. The SER performance of scheme [97] will further degrade, if SI gets corrupted. The results of Fig. 6.2 are therefore, the best achievable performances, for the given cases, under the assumption of ideal SI knowledge.

### 6.3 M-ARY CHAOTIC SEQUENCE BASED PHASE SEQUENCE SET GENERATION

Chaotic sequence [96] is a non-converging and non-periodic sequence that exhibits random behavior. The \( M \)-ary chaotic sequence \( C_n \in \{0,1,2,\ldots,M-1\} \), \( 1 \leq n \leq N \), of length \( N \), is generated by

\[
C_n = \left[ \frac{My_{n+1}}{2} \right] + \frac{M}{2}, \quad y_{n+1} = f(y_n) = 1 - \alpha y_n^2, \quad \alpha \in [1.4015,1.99], \quad y_n \in (-1,1)
\]  

\( (6.8) \)
where, \( \lfloor \cdot \rfloor \) is greatest integer function and \( C_r \), \( r^{th} \) element of first phase sequence becomes \( P^1_r = \exp(j2\pi C_r / M) = \phi_{C_r} \), e.g., if \( C_2 = 3 \), then \( 2^{nd} \) element of the first phase sequence \( P^2_2 = \phi_3 \). Therefore, the first phase sequence is constituted as \( P^1 = [\phi_{C_0}, \phi_{C_1}, \phi_{C_2}, \ldots, \phi_{C_{N-1}}] \) and \( u^{th} \) phase sequence \( P^u, 2 < u \leq U \) can be easily obtained from \( P^1 \) after \( u-1 \) right circular shifts.

**Example 2:** Consider an SLM-OFDM system with 8 subcarriers and \( M \)-ary chaotic sequence with \( M=4 \), to generate the phase sequence set with 8 phase sequences. Let, \( \{3, 2, 0, 1, 2, 3, 0, \text{ and } 1\} \) be the quaternary chaotic sequence of length 8 generated using (6.8) for \( M=4 \), \( \gamma_0 = 0.1 \) and \( \alpha = 1.5 \). The first phase sequence \( (P^1) \) is generated by using elements of quaternary chaotic sequence as an index for selecting the phase factors from set \( \{1, j, -1, -j\} \). In this particular case, the generated phase sequence is \( \{j, -1, 1, j, -1, 1, j\} \), which after multiplication with frequency domain OFDM signal produces only phase change and keeps the average power of OFDM signal fixed. The remaining phase sequences are generated by right circular shift of \( P^1 \), e.g. if we have to generate the second phase sequence then we shift \( P^1 \) by one and it becomes \( P^2 \).

As discussed earlier The PAPR reduction capability of SLM scheme mainly depends on the correlation between alternative OFDM signals generated by SLM, lower is the value of the correlation better is the PAPR reduction. As reported in [96], a phase sequence set that provides minimal variance of correlation (VC) is said to achieve the best PAPR reduction capability. The variance of correlation can be calculated as follows

\[
VC = \frac{\sum_{0 \leq v < u \leq U} \left\{ \left( R_{uv}(\tau) \right)^2 \right\}_{\tau = 0}^{N-1}}{\left( \begin{array}{c} U \\ 2 \end{array} \right)}
\]  

(6.9)

where \( R_{uv}(\tau) \) is the correlation in between two alternative sequences and denominator of (6.9) represents the total number of combinations that can be formed when two sequences are chosen out of \( U \) possible sequences.

In table 6.1, variance of correlation (VC) is calculated for Hadamard, Riemann and chaotic sequences for \( U=N=64 \) and 256.
<table>
<thead>
<tr>
<th></th>
<th>(N=64)</th>
<th>(N=256)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hadamard Sequence</td>
<td>6.02*10^{-3}</td>
<td>1*10^{-3}</td>
</tr>
<tr>
<td>Riemann Sequence</td>
<td>9.75*10^{-14}</td>
<td>7.05*10^{-17}</td>
</tr>
<tr>
<td>Chaotic Sequence</td>
<td>5.04*10^{-4}</td>
<td>5.62*10^{-4}</td>
</tr>
</tbody>
</table>

It can be observed from Table 6.3 that Riemann Sequence possesses low variance of correlation as compared to Hadamard and Chaotic Sequence. But, Riemman matrix based phase sequence set generation scheme [97] proposed by Irukulapati et al. achieves good PAPR reduction capability by producing an amplitude change in the modulated data symbols, which degrades the SER performance of the system, therefore Riemann sequence is not a good choice from SER performance point of view. However, in the proposed scheme phase vectors of phase sequence set do not produce any amplitude change and therefore keeps SER performance same for different values of \(U\). Hence, M-ary chaotic sequence is a viable choice from both SER and PAPR performance point of view.

### 6.4 COUPLING OF CCM WITH SLM-OFDM SYSTEM

In order to eliminate the requirement of SI transmission, we have combined SLM-OFDM with concentric circle constellation mapping introduced by us in chapter 5. Referring to the system model shown in Fig. 6.1, first binary data stream is converted in quaternary data stream and the quaternary data points are initially mapped to four different points of concentric circle constellation using Table 5.1. After that \(M\)-ary chaotic sequence based SLM scheme is applied to reduce the PAPR of OFDM signal. As discussed earlier in SLM scheme, frequency domain OFDM signal is multiplied with a set of phase sequence to get a set of alternative OFDM signals. Therefore, after multiplication, the initially mapped constellation points rotate and produce 13 different points as shown in Fig. 5.4. At the receiver, after subcarrier demodulation, the de-mapping scheme given in Table 5.2 is utilized to convert 13 different constellation points into quaternary data points and then, quaternary to binary data conversion scheme is used to obtain the binary data signal.
6.5 RESULTS AND DISCUSSION

Here, an OFDM system with $N = 64$ subcarriers and 10,000 OFDM symbols are considered to evaluate the SER and PAPR performance of the proposed scheme as shown in Fig. 6.1. The PAPR reduction capability of the chaotic sequence remains same $\forall y_0 \in (-1,1)$ and $\forall \alpha \in [1.4015,1.99]$. In this chapter, $y_0 = 0.1$ and $\alpha = 1.99$ are used to generate $M$-ary chaotic sequence. To evaluate the SER performance of the schemes under consideration, we have taken both AWGN channel and SUI-5 fading channel with average path gains [0dB, -5dB, -10dB], and path delays [0 µs, 4 µs, 10 µs]. To mitigate the effect of multipath propagation, cyclic prefix of length $1/8$ OFDM symbol duration is used. In order to evaluate the PAPR and SER performances of various schemes under consideration we have considered an SLM-OFDM system using Riemann matrix based phase sequence without coupling with CCM and perfect SI, whereas SLM-OFDM system using Hadamard matrix and $M$-ary chaotic sequences are coupled with CCM. Fig. 6.3 shows the PAPR reduction capabilities of Hadamard sequence [95], Riemann matrix based phase sequence set [97] and proposed $M$-ary chaotic phase sequence for $U=8$ and 32. The complementary cumulative distribution function (CCDF) of original OFDM signal (without PAPR reduction) is also shown for comparison. Fig. 6.4 shows the SER performance comparison for above systems i.e. Riemann matrix and $M$-ary chaotic phase sequence based schemes for $U=8$ and 32.

The SER performance of SLM-OFDM system using Hadamard sequence is identical to SLM-OFDM system using $M$-ary chaotic sequence because both the sequences keep the average power of OFDM signal before and after multiplication of phase sequence, unchanged.

In order to avoid hindrance in Fig. 6.4 and 6.5, we have not shown the SER performance of SLM-OFDM system using Hadamard sequence. In SLM-OFDM systems, a phase sequence set which provides low PAPR without SER performance degradation is considered to be the best. As seen from Fig. 6.3, Riemann matrix phase sequence set for $U=32$ provides best PAPR reduction capability among all phase sequence sets under consideration but its SER performance even at 20dB signal-to-noise ratio (SNR) is above $10^{-1}$, which is unacceptable for any practical communication system, therefore it cannot be a good choice for SLM-OFDM systems.
As seen from Fig. 6.4, the SER performance of $M$-ary chaotic phase sequence for $U = 8$ and 32 are coinciding and provide significantly low SER=$2 \times 10^{-4}$ at 18dB SNR whereas, it degrades in case of Riemann matrix phase sequence set on increasing the value of $U$. The PAPR reduction capabilities of Riemann matrix and $M$-ary chaotic phase sequences for $U = 8$ are almost equal but $M$-ary chaotic phase sequence requires 2dB less SNR to achieve an SER of $2 \times 10^{-4}$ and hence, the suggested sequence provides a better SER performance than Riemann matrix phase set sequence.

As seen from Fig. 6.3, the $M$-ary chaotic phase sequence with $U = 8$ provides 2.8dB PAPR reduction whereas, Hadamard sequence with $U = 8$ provides 1.2dB PAPR reduction for CCDF of PAPR=0.002. Lower variance of correlation is the main reason behind $M$-ary chaotic phase sequence to achieve better PAPR reduction capability in comparison to Hadamard sequence.
Further, the PAPR reduction capability of the $M$-ary chaotic phase sequence can be improved by increasing the value of $U$ without affecting the SER performance. Hence, the proposed $M$-ary chaotic phase sequence based scheme provides low PAPR and SER in comparison to all schemes under consideration.

The SER performance of the proposed scheme is also evaluated over fading channel, here we have considered a three tap frequency selective fading channel (SUI-5). The results of the SER performance of Riemann matrix phase sequence and proposed scheme over SUI-5 channel are shown in Fig. 6.5.
In the proposed scheme for $U=8$, the required $E_b/N_o$ to achieve an SER of $10^{-4}$ is 17.2 dB and its value remains same for $U=32$, i.e. the SER performance of the proposed scheme is independent of the number of alternative OFDM signals. If we compare the proposed scheme for $U=8$ with Riemann matrix based phase sequence then it is found that the required $E_b/N_o$ in the proposed scheme is about 4.5 dB lesser than the required $E_b/N_o$ for Riemann matrix based phase sequence to achieve an SER of $10^{-4}$ but its PAPR reduction capability is merely 0.3 dB worse. For $U=32$, Riemann matrix based phase sequence requires about $E_b/N_o=17.0$ dB to achieve an SER of $10^{-1}$ which is about 6.2 dB worse than the same phase sequence with $U=8$. In contrast to the proposed scheme, the SER performance of the Riemann matrix based phase sequence degrades rapidly by increasing the value of $U$. Hence, the proposed scheme has better SER performance in comparison to Riemann matrix based phase sequence with $U=8$ and 32.
6.6 CONCLUSION

In this chapter, $M$-ary chaotic sequence based phase sequence generation scheme for SLM-OFDM system, combined with concentric circle mapping is proposed which completely eliminates the need of conveying SI to the receiver and achieves good PAPR reduction capability. The PAPR performance of proposed $M$-ary chaotic sequence based phase sequence is better than that of the original OFDM signal and SLM-OFDM system using Hadamard sequence and it is very close to that of the Riemann matrix based phase sequence for $U=8$. The PAPR reduction capability of all schemes under consideration increases by increasing the number of alternative OFDM signals but it also increases the computational complexity of the system. Over AWGN channel as well as SUI-5 fading channel, the SER performance of the proposed scheme is superior to Riemann matrix phase sequence and no SI is required. The performance of the proposed scheme remains same for any number of alternative OFDM signals whereas, it degrades in case of Riemann matrix phase sequence.