Performance Analysis of OFDM System to Reduce PAPR using SLM Technique

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ABSTRACT

Orthogonal Frequency Division Multiplexing is an attractive technique for wireless high-rate data transmission. The basic principle of OFDM is to split a high-rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers. Because the symbol duration increases for lower rate parallel subcarriers, the relative amount of dispersion in time caused by multipath delay spread is decreased. Inter-symbol interference (ISI) is eliminated almost completely by introducing a guard time in every OFDM symbol .The major issue in OFDM system is high PAPR which causes peak overshoots. The paper deals with elaborate study of OFDM system and least crest method of reducing peaks. The crest factor or peak-to-average ratio (PAPR) is a measurement of a signal, calculated from the peak amplitude of the waveform divided by the RMS value of the waveform. The peak-to-average power ratio (PAPR) is a related measure that is defined as the peak amplitude squared (giving the peak power) divided by the RMS value squared (giving the average power).

$$PAPR = \frac{|x|_{\mathrm{peak}}^{2}}{x_{\mathrm{rms}}^{2}} = C^2$$

General Terms

Orthogonal Frequency Division Multiplexing, Selective level Mapping. Peak-to-Average Power Ratio

Keywords

SLM(Selective level mapping), CF(Crest factor), LCM(Low crest method)

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM), is one of multi-carrier modulation (MCM) techniques resulting in a considerable high spectral efficiency, multipath delay spread tolerance, immunity to the frequency selective fading channels and power efficiency [1], [2]. As a result, OFDM is used for high data rate communications and has been widely deployed in many wireless communication standards such as Digital Video Broadcasting (DVB) and based mobile worldwide interoperability for microwave access (mobile WiMAX) based on OFDM access technology[3].

However, some challenging issues still remain unresolved in the design of the OFDM systems. One of the major problems is high Peak-to-Average Power Ratio (PAPR) of transmitted OFDM signals. Therefore, the OFDM receiver’s detection efficiency is very sensitive to the nonlinear devices used in its signal processing loop, such as Digital-to-Analog converter (DAC) and High Power Amplifier (HPA), which may severely impair system performance due to induced spectral re-growth and detection efficiency degradation.

Moreover, various approaches have also been proposed to reduce the PAPR including clipping [7], coding schemes, phase optimization, nonlinear companding transforms , Tone Reservation (TR) and Tone Injection (TI) [9], constellation shaping, Partial Transmission Sequence (PTS) and Selective Mapping (SLM) [8][5] and other techniques such as pre-scrambles proposed in these schemes can be majorly classified into deterministic and probabilistic : deterministic schemes include clipping etc. and probabilistic schemes include PTS and SLM.

Section II indicates the description of the designed OFDM model. Section III details the problems associated with OFDM. Section IV elaborates the SLM block diagram and shows the designed SLM system

II. OFDM model and PAPR description:

The top level design contains simulink blocks for input, signal display and output. Input to the design is given from a sine wave generator or from a sound input stored in the workspace. The inputs are passed through a gateway in block to convert from floating point numbers to fixed point numbers compatible to Xilinx blockset. The data is then serialized using a parallel to serial converter and given to the OFDM transmitter. The transmitter is explained in detail in the later section. The transmitter outputs PAPR reduced serial data stream which is then given to the receiver to decode it. Also a certain amount is noise is added to the data stream. The receiver then decodes the stream and outputs original data bits. These data is displayed and compared on the scope and also output on the workspace for comparison. Also the BER is calculated by comparing the data before and after decoding.

Transmitter design

In the design presented, block length of 8 points and 4 different phase sequences are used. Transmitter subsystem design contains 4 independent OFDM modulators. In the modulator, the input data is multiplied by a look-up table from ROM before giving it to actual OFDM modulation process. This lookup table holds the phase sequences for each block. The output of each block is given to a PAPR calculator and selector. It transmits the data block with lowest PAPR and also transmits the selected block number.

Receiver design

The receiver is a normal OFDM receiver with a phase sequence selector block. The data stream is first given to FFT block for decoding. Then the data stream is passed to a lookup table multiplier which multiplies data with a phase sequence as indicated by the selected block number from transmitter.

Sr. no	specification	Values
1	OFDM Line rate	120khz
2	Sound input rate	4khz
3	Phase sequence length	8 bits
4	FFT points	64 point FFT
5	Number of phase sequences	4
6	BER performance	0.8 at 5dB

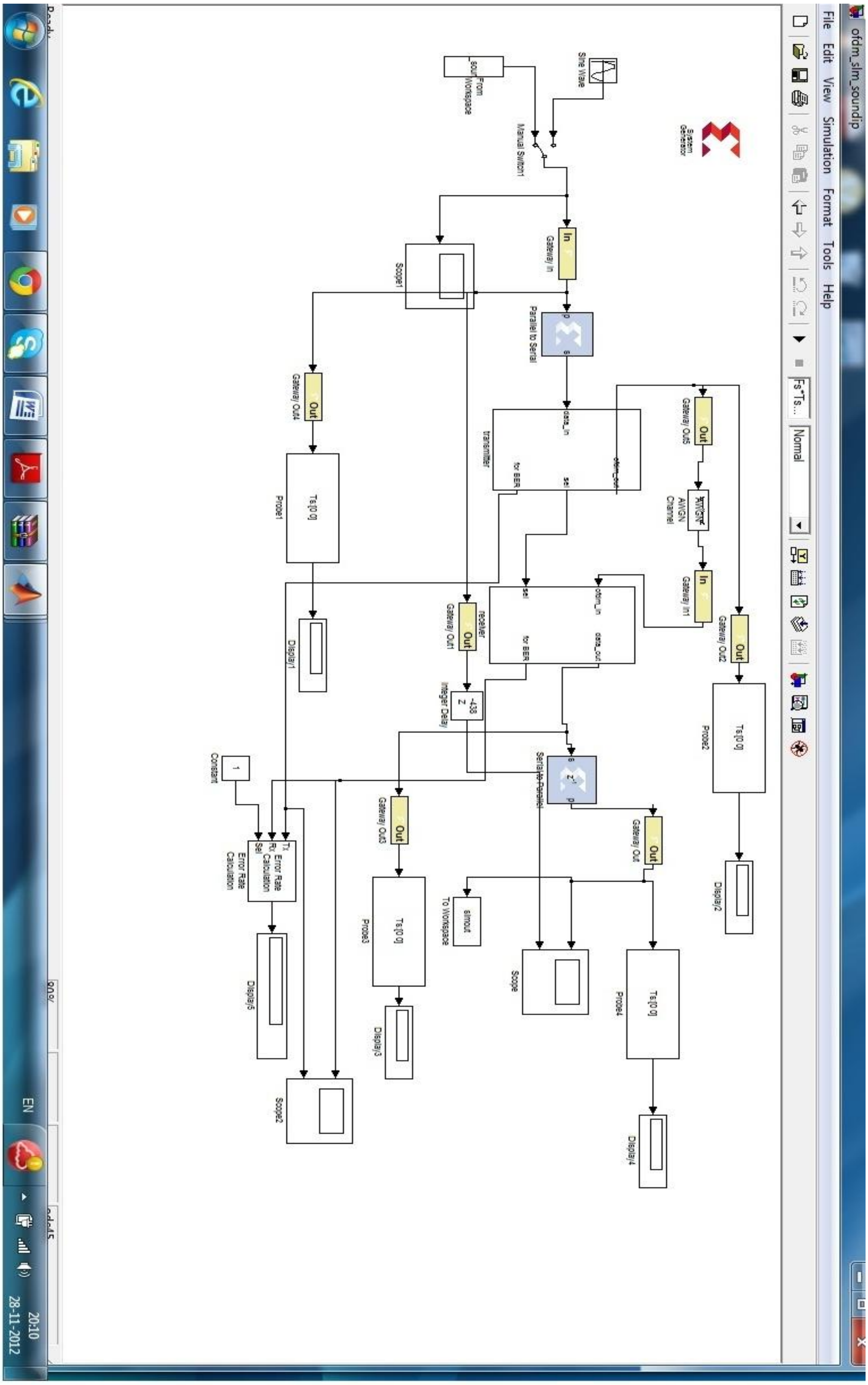

Fig1. Actual block diagram of the designed system

III. PAPR PROBLEM IN OFDM

Expression of one OFDM a symbol starting at t=ts is represent as

$s(t)=Re\{\Sigma di+Ns/2\exp(j2\pi(fc-i+0.5/T)(t-ts)\}$, (1)

$ts \le t \le ts+T$

S(t)=0, t< s(t) =0, $t < ts$+T

Where d_i are complex modulation symbols, N_S *is* the number of subcarriers, *T* the symbol duration, and f_C the carrier frequency.The Peak-to-Average power ratio is mathematically expressed as: $PAPR = \max \frac{(x_k)^\wedge 2}{E\{x_{k^\wedge 2}\}}$ = $P_{peak}/P_{average}$ (2)

Where P_{peak} represents peak output power, $P_{average}$ means average output power. $E\cdot$ denotes the expected value,x(k) represents the transmitted OFDM signals which are obtained by taking IFFT operation on modulated input symbols X_k.

For an OFDM system with *N* sub-carriers, the peak power of received signals is *N* times the average power when phase values are the same. The PAPR of baseband signal will reach its theoretical maximum at (dB) $=10\log_{10}N$. Another commonly used parameter is the Crest Factor (CF), which is defined as the ratio between maximum amplitude of OFDM signal $\boldsymbol{s(t)}$ and root-mean-square (RMS) of the waveform.

IV. PROPOSED SCHEME -SLM:

Selected mapping (SLM) is a well-known method for reducing the peak-to-average power ratio (PAPR) in orthogonal frequency-division multiplexing (OFDM) systems. The block diagram of SLM scheme is shown in Figure 2, *U* candidate sequence $\mathbf{x}^{(\mathbf{u})} = [x_0^u, x_1^u, \ldots, x_{N-1}^u]^T$ of length *N* (*u*=±1,...,*U* = ±1) are generated by multiplying original input $\mathbf{X} = [X_0, X_1, \ldots, X_{N-1}]^T$ component-wise with predetermined phase sequences **S(u)** ,whose length is also equal to *N* . Then, IFFT is applied to each sequence, transforming the signal from the frequency domain to the time domain. As a result, the candidate sequence is given by

x(u) = *IFFT*{**X*□S(u)**}
(3)

in which $\mathbf{S}^{(\mathbf{u})} = [S_0^{(u)}, S_1^{(u)}, \ldots, S_{N-1}^{(u)}]^T \ (u = 0,1,\ldots,U-1)$ phase weighting sequence usually selected from {□ □ □ ±, ±j for avoiding the complexity for complex multiplications. *U* is the number of predetermined phase sequences, and the character denotes a component wise multiplication. After the PAPR comparisons among the *U* candidate sequences x(*u*) , the optimal mapped one **x**ˆ with the minimum PAPR is selected for transmission. [8]
That is,

The main drawback of this technique being, each data block requires the transmission of several side information bits, which results in some data rate loss. These redundant bits are so critical to the error performance of the system that they need in practice to be protected by a powerful channel code. This increases the system complexity and transmission delay, and decreases the data rate even further. By considering the example of an OFDM system using 16-QAM modulation, it is shown that the proposed method performs very well both in terms of PAPR reduction and bit error rate at the receiver output.[8]

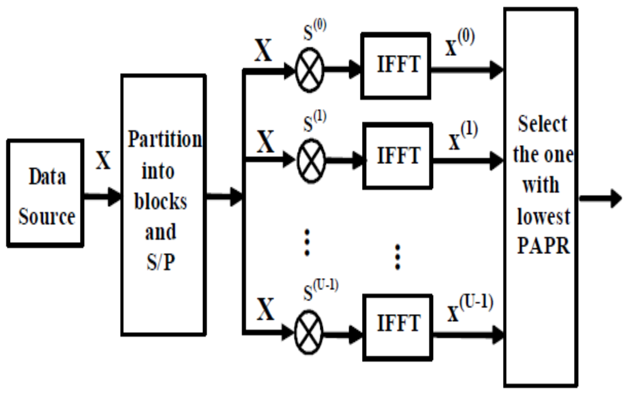

Fig 2: Block diagram of SLM technique

$$\hat{\mathbf{x}} = \arg \min_{0 \le u \le U-1} [PAPR(\mathbf{x}^{(\mathbf{u})})].$$ (4)

PAPR is given by: $C^2 = PAPR = \max \frac{(x_k)^\wedge 2}{E\{x_{k^\wedge 2}\}}$ (5)

$E\{X_K{}^\wedge 2\}$ is the expected or average value of the signal.

Crest factor [5] [8] is given by:

CREST FACTOR=√PAPR=C (6)

The reduction in crest factor results in a system that can either transmit more bits per second with the same hardware, or transmit the same bits per second with lower-power hardware (and therefore lower electricity costs) (and therefore less expensive hardware), or both.

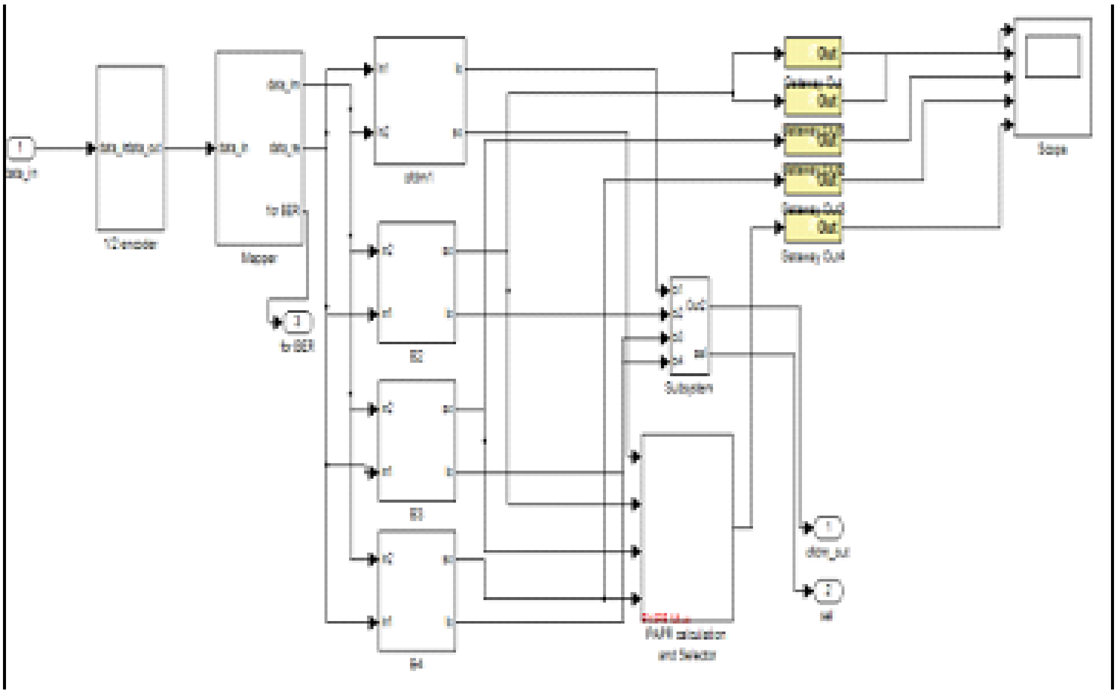

Fig 3: Designed SLM system

The SLM algorithm we have applied in this model uses 4 OFDM sequences of 8 point each and applies 4 different mask on each sequence. Blocks B1-4 are OFDM blocks which each multiply the input sequence with a predetermined mask. IFFT is calculated on the masked stream and the OFDM output is taken. The output is given to a PAPR calculator which calculates PAPR of each stream independently. The stream with the lowest PAPR is then selected for transmission. Along with the stream, the stream number is also transmitted for the receiver to know which mask to apply to decode the sequence.[5][8]

V.RESULTS AND DISCUSSION

The number of subcarriers is always less than the no FFT size. Considering a theoretical example of 64-point FFT its bifurcation is given below:

1. DC subcarrier (0th) not used as it causes problems in the DAC
2. -32 to -27 and 28 to 32 not used.(Guard band on both extremes)
3. Null subcarriers help in reducing out of band power.

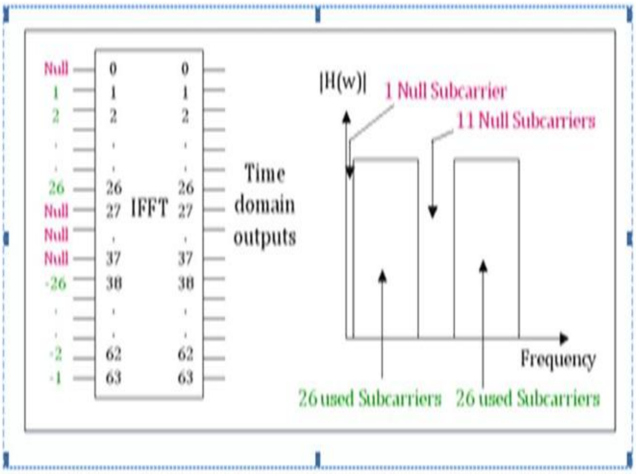

Fig 4: Data Subcarriers in 64-point FFT

No. of Subcarriers for different FFT point are as mentioned below.

Table I: Relation between FFT size and No. of sub-carriers

Sr. No.	No. of FFT Points	No. of Subcarriers
1	8	4
2	16	12
3	32	24
4	64	52

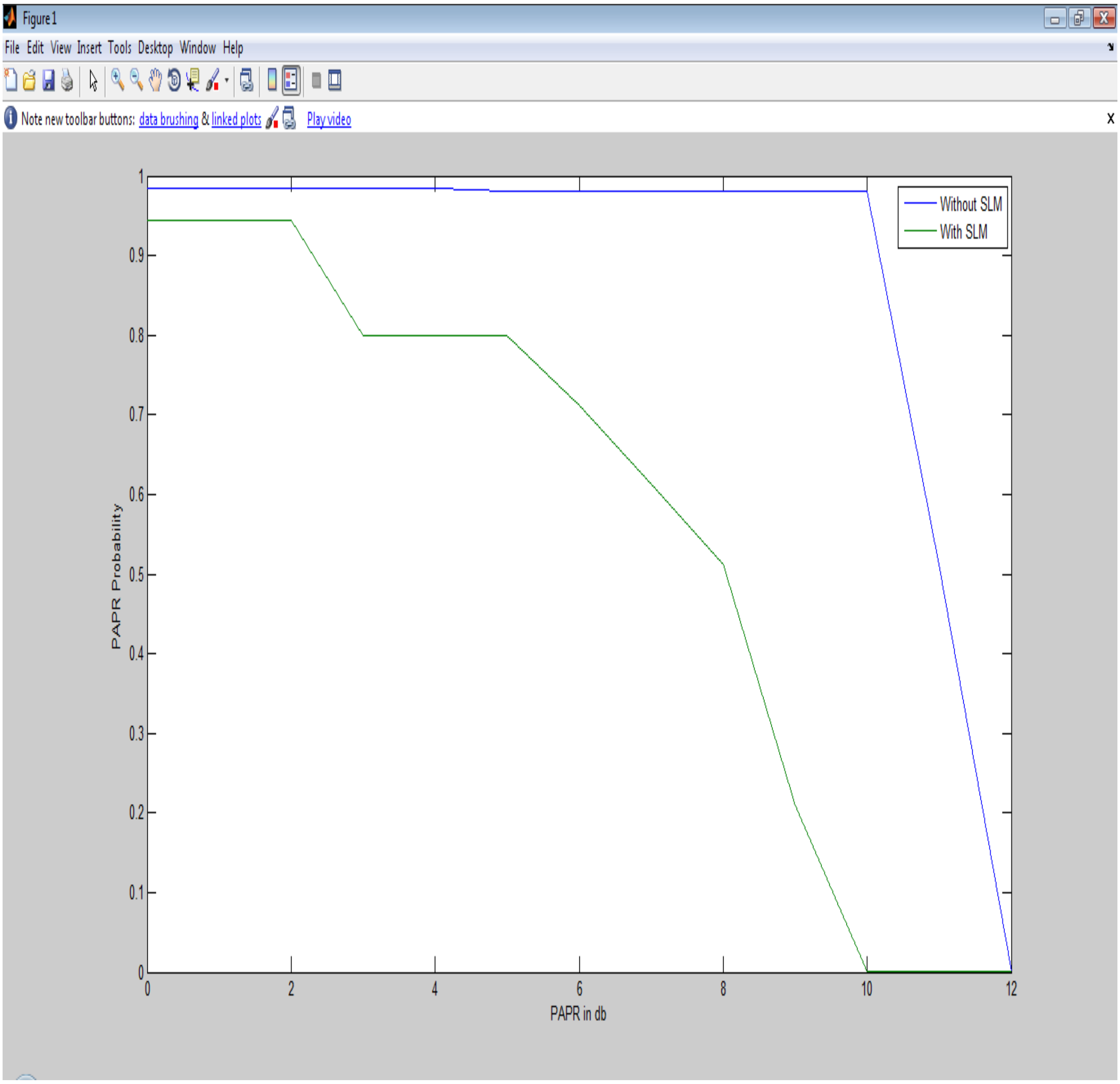

Fig 5: Graph showing the plot of the acquired readings

Conclusion from fig 5:

It is observed from fig.5 that in case of OFDM systems without employing SLM technique the PAPR that is evaluated is constant upto 10dB and it results in a steep slope after 10dB terminating at 12dB.

The OFDM system with SLM block for which the PAPR is calculated initially remains constant between 0 to 2dB and 3 to 5dB but varies between 5 to 10dB**.**

Thereby the final PAPR with SLM is 10db and without SLM is 12db resulting in overall PAPR reduction of 2db

Table II. PAPR and Crest Factor

Difference of PAPR in **dB** calculated for OFDM system with & without SLM	PAPR calculated as factor not in **dB**	Crest Factor as **Sqrt(PAPR)** as factor not in **dB** - **C^2**
2dB	**1.58483**	**1.2589**

Table III: Output obtained with and without SLM

PAPR	PAPR probability without SLM	PAPR probability with SLM
1	0.985	0.945
2	0.984	0.944
3	0.984	0.944
4	0.984	0.800
5	0.984	0.800
6	0.981	0.800
7	0.981	0.712
8	0.981	0.612
9	0.981	0.511
10	**0.981**	**0.210**
11	0.981	0.000
12	**0.512**	**0.000**
13	0.001	0.000

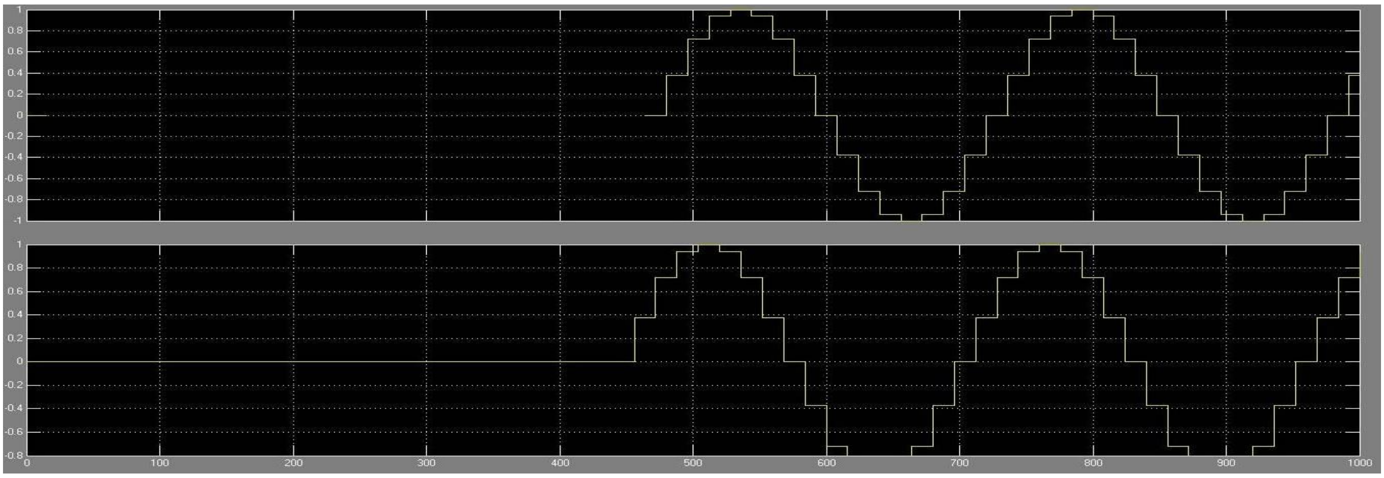

Fig 6. Final received Output chasing the direct input

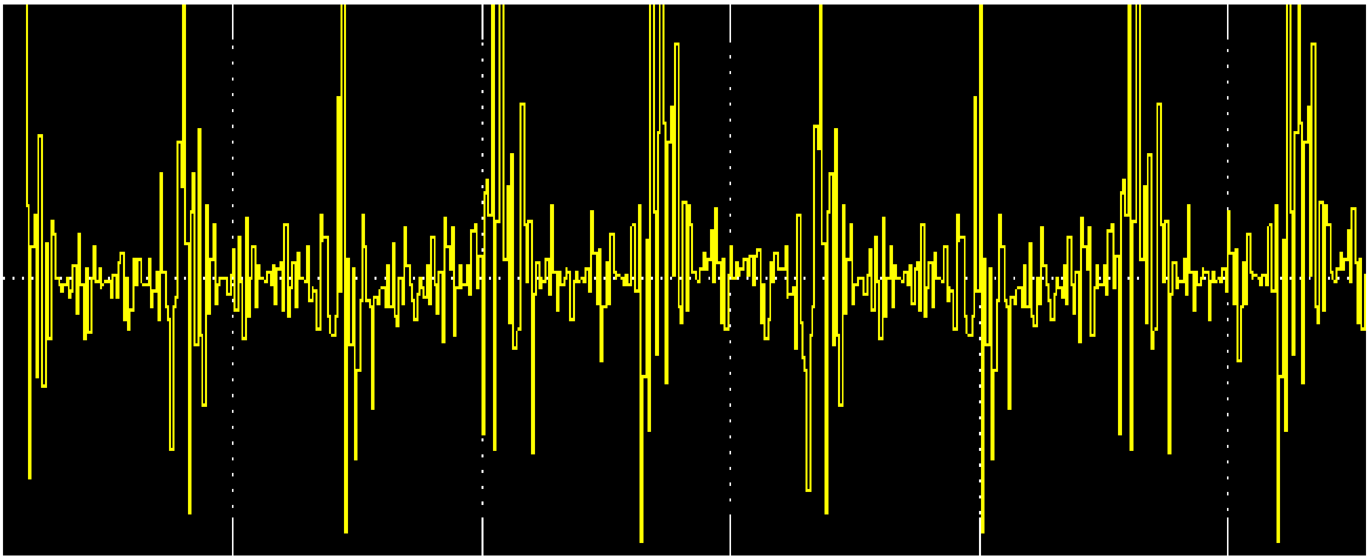

Fig 7. OFDM output spectrum

VI .CONCLUSION

OFDM is a very attractive technique for wireless communications due to its spectrum efficiency and channel robustness. One of the serious drawbacks of OFDM systems being the composite transmit signal can exhibit a very high PAPR when the input sequences are highly correlated. The PAPR obtained without SLM for OFDM system is 12dB and with SLM is 10dB resulting in overall reduction of 2dB. Thus SLM technique has the potential to reduce PAPR for OFDM systems and improve its performance in terms of low PAPR high SNR and improved BER.

ACKNOWLEDGEMENTS

Our thanks to the experts who have contributed towards development of the template.

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