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Performance Analysis of OFDM System [Case study of optimize IFFT size for M-PSK technique]

Prashant Tavde[a],Anupam Dubey[b],Dr.K.D. KULAT[c]
[a,b]M.Tech Student, ECE, V.N.I.T. Nagpur
[c]Professor, ECE, V.N.I.T. Nagpur

ABSTRACT

In wireless communication, concept of parallel transmission of symbol is applied to achieve high throughput and better transmission quality. Orthogonal Frequency Division Multiplexing (OFDM) is one of the method of parallel transmission. The idea of OFDM is to split the total transmission bandwidth in to a number of orthogonal subcarriers in order to transmit the symbols using these subcarriers in parallel. In this paper M-ary PSK OFDM system has been simulated in MATLAB 7.6 to evaluate the performance of OFDM system. For this various modulation scheme such as BPSK,QPSK,16PSK and 256 PSK used in OFDM system with appropriate IFFT size, based upon the requirement of power and Bit Error Rate(BER) analysis. For selected modulation technique with a required power and BER, lookup table type arrangement has been provided to know the optimum size of IFFT.

Keywords—***OFDM, BER** ,**M**-***ary PSK ,SNR(Eb/No).**

I. INTRODUCTION

In Wireless communication multipath is propagation phenomenon. The effect of multipath including constructive and destructive interference and phase shifting of signal. Many methods are proposed to fight with multipath effect of wireless communication. One of the solution of Inter Symbol Interference(ISI) is use multicarriers (which is orthogonal to each other) modulation for data transmission [1],[3],[11],[13]that is Orthogonal Frequency Division multiplexing. The analysis of BER suggest that OFDM is better than CDMA which is widely comprise in existing 3G system[3],[11].

In 802.11 and 802.16, there are several data modulation schemes that are used with OFDM, such as binary phase shift keying (BPSK), quaternary phase shift keying (QPSK), 16-PSK, and 256- PSK to cover different data rates for different needs. The aim of OFDM is to divide the wide frequency selectivity of fading channels into multiple flat fading channels [1], [11]. The theme of using a Discrete Fourier Transform (DFT) for the generation and reception of OFDM signals reject the necessity of banks of analog subcarrier oscillators [5] [10]. Due to Orthogonality property of carriers all multiple information signals to be transmitted in parallel over a common channel and detected, without interference. If OFDM symbol period is Ts than carrier spacing $\Delta f = 1/Ts$ [1],[2],[5]. Another characteristic of orthogonality is that each carrier has an integer number of sine wave cycles in one bit period [8].

II. *M*-ary PSK OFDM Model

The general analytic expression for M-ary PSK waveform is:

$$S_i(t)=A.\cos(w_c t+\phi_i(t)); \quad i=0,1,2,\dots,M-1$$

$$\text{Where } A=\sqrt{\frac{2E}{Ts}}\,;\ \phi_i=\frac{2m\Pi}{M},\quad i=0,1,2,\dots,M-1$$

The parameter E is symbol energy, Ts is symbol time duration, and $0 \le t \le Ts$. For BPSK modulation, M=2, for QPSK modulation, M=4, for 16 PSK modulation M=16,and for 256 PSK modulation=256 and the modulation data signal shifts he phase of the waveform $s_i(t)$.The BPSK bandwidth efficiency is 1 bit/Hz, QPSK bandwidth efficiency is 2 bit/Hz,16 PSK has bandwidth efficiency is 4 bit/Hz, while 256 PSK has bandwidth efficiency is 16 bit/Hz.

A. Transmitter:

The OFDM transmitter can be implemented by using a regular IFFT, but without dividing the outputs by N:

$$Xk=\sum_{n=0}^{N-1} dn\, e^{j\frac{2\Pi}{N}nk} \quad ; \qquad k=0,1,2.........\,..N-1$$

where d_n is the predefined data symbol and $e^{\frac{j2\Pi kn}{N}}$,$k=0,1,\dots,N-1$,represents the corresponding orthogonal frequencies of the N sub-carriers. Fig. 1 shows simplified transmitter architecture.

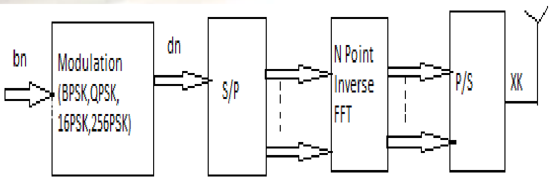

Fig.1 Architecture of a simplified OFDM transmitter

B. Receiver:

Assuming that the synchronization has completed, the received signal of the mP th OFDM symbol in general is:

$$r_k = r_{k,m} = \sum_{n=0}^{N-1} dn.e^{-j\frac{2\Pi}{N}nk} + w_{k,m} \quad (2)$$

The simplified diagram is shown in Fig 2

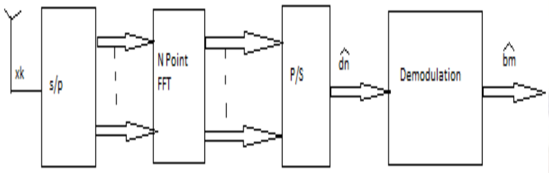

Fig.2 Architecture of a simplified OFDM receiver

The length of cycle prefix, N/4,we can find out the immunity of OFDM for errors caused by multi-path channels. N is chosen so that 0.25T is much larger than the maximum delay time of echo components in the received multi-path signal, where $T = NT_s$ is the OFDM symbol period and T_s is the data sample period.

C. System Configurations and Parameters

The OFDM system is modelled using MATLAB to allow various parameters of the system to be varied and tested. The following OFDM system parameters are considered for the simulation.

1) Input file – an 8-bit grayscale chessboard (256 gray levels) bitmap file (*.bmp);
2) IFFT size – an integer of a power of two (128,256,512-,1024,2048);
3) Number of carriers – not greater than [(IFFT size)/2 – 2];
4) Digital modulation method – BPSK, QPSK, 16-PSK, or 256-PSK;
5) Signal peak power clipping – 0dB
6) Signal-to-Noise Ratio –It should be varied from 4 dB to 28dB in the difference of 4(i.e. 4,8,12,16,20,24 and 28(all in dB))

BPSK: BPSK uses two phases which are separated by 180° and so also called as 2-PSK.The position of constellation points are shown on the real axis, at 0° and 180°. This modulation is the most strong than all the PSKs since it takes the highest level of noise or distortion to make the demodulator arrive an incorrect decision.

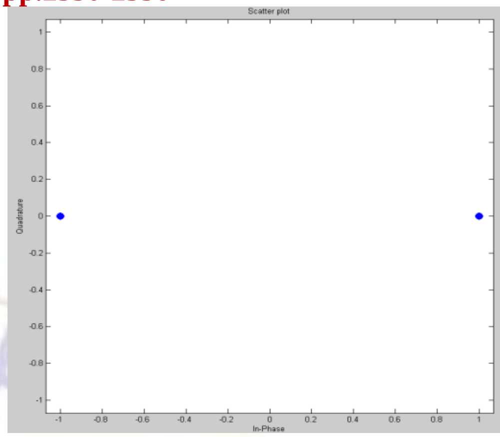

Fig.3 BPSK Signal Constellation with Gray Coding

QPSK: QPSK uses four points on the constellation diagram, equispaced around a circle. With four phases, QPSK can encode two bits per symbol, shown in the diagram with gray coding to minimize the bit error rate (BER). The mathematical analysis shows that QPSK can be used either to double the data rate compared with a BPSK system while maintaining the *same* bandwidth of the signal.

Input, decimal	Input, binary	Gray, decimal	Gray, Binary
0	00	0	00
1	01	1	01
2	10	3	11
3	11	2	10

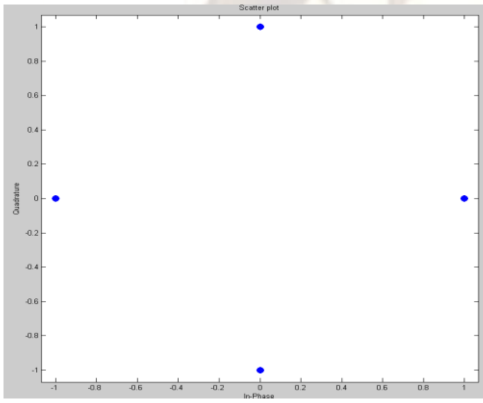

Fig.4 QPSK Signal Constellation with Gray Coding

16PSK:16 PSK uses 16 points on the constellation diagram, equispaced around a circle With 16 phases, QPSK can encode four bits per symbol, shown in the diagram with gray coding to minimize the bit error rate (BER).

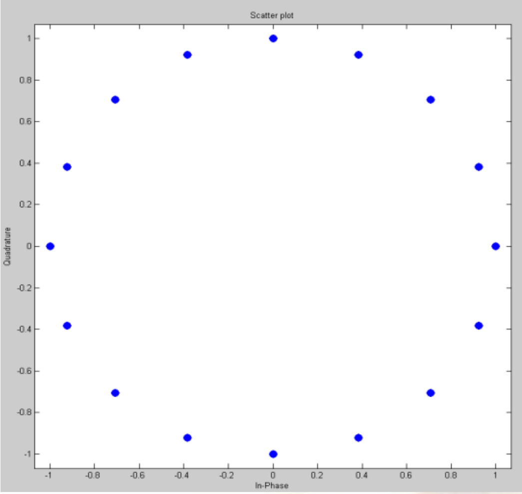

Fig.5 16PSK Signal Constellation with Gray Coding

Input, decimal	Input, binary	Gray, decimal	Gray, Binary
0	0000	0	0000
1	0001	1	0001
2	0010	3	0011
3	0011	2	0010
4	0100	6	0110
5	0101	7	0111
6	0110	5	0101
7	0111	4	0100
8	1000	12	1100
9	1001	13	1101
10	1010	15	1111
11	1011	14	1110
12	1100	10	1010
13	1101	11	1011
14	1110	9	1001
15	1111	8	1000

256PSK: 256PSK uses 256 points on the constellation diagram, equispaced around a circle With 256 phases, QPSK can encode 8 bits per symbol, shown in the diagram with gray coding to minimize the bit error rate (BER). Fig (7) shows a block diagram of a generic OFDM system. ADC, DAC, and RF front-ends (Amplification, RF upconversion/downconversion, etc.) are not simulated in this paper. Firstly source data for this simulation is taken. Data will then be converted to the symbol size (bits/symbol) determined by the choice of M-PSK from four variations provided by this simulation. The converted data will then be separated into multiple frames by the OFDM transmitter. The OFDM modulator modulates the the data frame by frame. Before the exit of the transmitter, the modulated frames of time signal are cascaded together

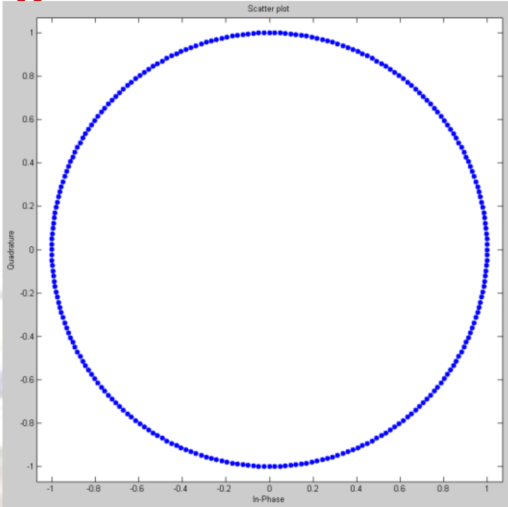

Fig.6 256-PSK Signal Constellation with Gray Coding

along with frame guards inserted in between as well as a pair of identical headers added to the beginning and end of the data stream. The communication channel is modeled by adding Gaussian white noise and amplitude clipping effect. The receiver detects the start and end of each frame in the received signal by an envelope detector. Each detected frame of time signal is then demodulated into useful data. Error calculations are performed at the end of the program. Representative plots are shown throughout the execution of this simulation.

III. EXPERIMENT RESULT

The performance of a data transmission system is usually analyzed and measured in terms **of** the probability of error at given bit rate and SNR. The parameter E_b/No, where E_b is bit energy and No is noise energy, is adjusted every time by changing noise in the designed channel.

The proposed scheme is tested on AWGN channel for a given channel given channel value of BER = 0.001, for 256×256 gray-scale chess board image[12]. By analysis of different result we observe that BER=0.001 is achieved in case(IFFT SIZE =128) ,for BPSK at SNR = 21dB,for QPSK at SNR=23dB,for 16 PSK at SNR=27dBand for 256 PSK SNR=52dB.By varying the IFFT size for different techniques(BPSK,QPSK,16PSK,256PSK) we observe that where BER=0.001 achieved and at which value of SNR BER is zero. Variation of IFFT size is shown below where each value of IFFT,BER vs SNR is shown.

For particular Eb/No value, system is simulated and corresponding probability of error is noted. The proposed design is simulated with necessary parameter changes for BPSK, QPSK, 16-PSK and 256-PSK. As shown in Figure 9, if we go on increasing the E_b/No value, BER reduces. In comparison of BER performance for M-PSK, it is observed that use of a higher M-ary constellation is better for high capacity transmission but the drawback is that the points on

.

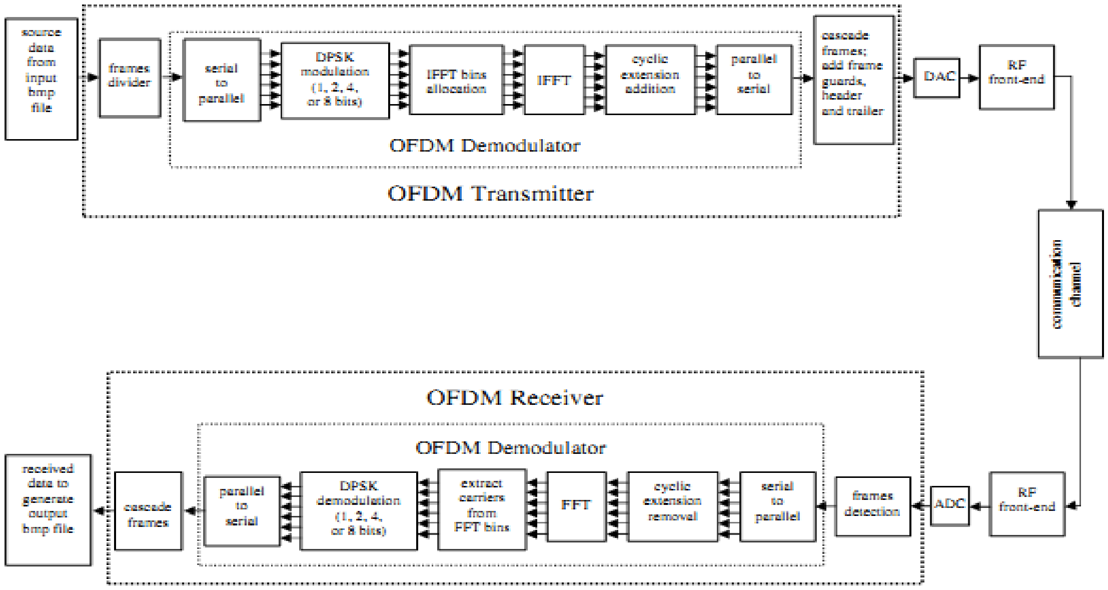

Fig.7 Block Diagram of an OFDM system

Constellations are closer which makes the transmission less robust to errors with same SNR.

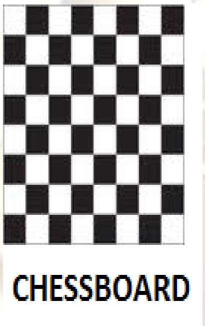

Fig.8 chess board(256×256)

For IFFT =128 and SNR=4 what changes occur in image with different modulation techniques as shown in figure (9) below.

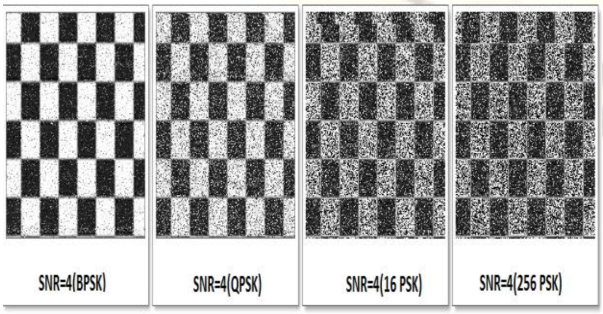

Fig.9 Diagram of chessboard with different technique for SNR=4

For BPSK and SNR=4 what changes occur in image with different IFFT size as shown in figure below-

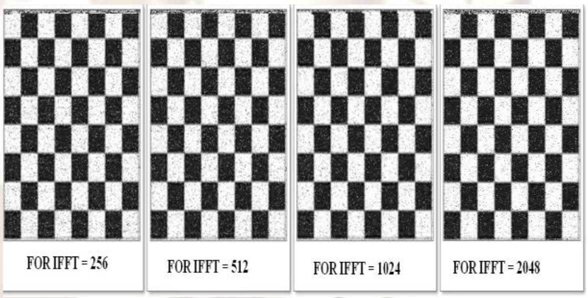

Fig.10 Diagram of chessboard with different IFFT size for BPSK with SNR=4

Here by varying the IFFT size, BER vs SNR plot is shown in fig for different modulation technique.

A) FOR IFFT SIZE= 128

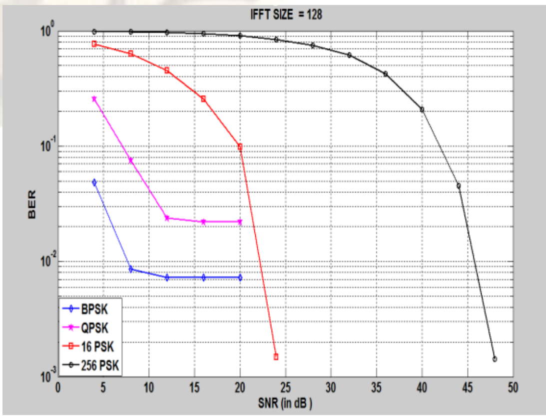

Fig.11 for IFFT size = 128

DIFFERENT TECHNIQUES WITH BER				
SNR	BPSK	QPSK	16PSK	256 PSK
4	0.048347	0.254763	0.769551	0.985900
8	0.008576	0.074763	0.635449	0.976089
12	0.007235	0.023792	0.451681	0.962966
16	0.007213	0.021905	0.255232	0.941268
20	0.007211	0.021901	0.098685	0.908477
24	0.000000	0.000000	0.001485	0.842269
28	0.000000	0.000000	0.000000	0.752716
32	0.000000	0.000000	0.000000	0.617324
36	0.000000	0.000000	0.000000	0.426330
40	0.000000	0.000000	0.000000	0.207031
44	0.000000	0.000000	0.000000	0.045410
48	0.000000	0.000000	0.000000	0.001434
52	0.000000	0.000000	0.000000	0.000000

B) FOR IFFT SIZE= 256

DIFFERENT TECHNIQUES WITH BER				
SNR	BPSK	QPSK	16PSK	256 PSK
4	0.047892	0.266358	0.775404	0.985656
8	0.008726	0.079907	0.644876	0.977249
12	0.008250	0.025852	0.463457	0.964309
16	0.008249	0.023223	0.257950	0.945678
20	0.000000	0.000000	0.052466	0.902664
24	0.000000	0.000000	0.005891	0.844757
28	0.000000	0.000000	0.000000	0.756179
32	0.000000	0.000000	0.000000	0.623306
36	0.000000	0.000000	0.000000	0.479791
40	0.000000	0.000000	0.000000	0.212371
44	0.000000	0.000000	0.000000	0.048294
48	0.000000	0.000000	0.000000	0.001480
52	0.000000	0.000000	0.000000	0.000000

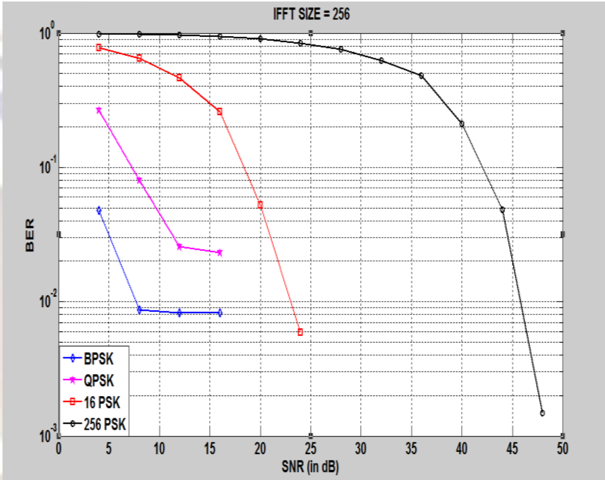

Fig.12 for IFFT size = 256

C) FOR IFFT SIZE= 512

DIFFERENT TECHNIQUES WITH BER				
SNR	BPSK	QPSK	16PSK	256 PSK
4	0.047078	0.260026	0.778478	0.985641
8	0.009013	0.078116	0.643877	0.977005
12	0.008175	0.024630	0.465774	0.964401
16	0.008137	0.022455	0.259472	0.942581
20	0.008102	0.020149	0.102087	0.911621
24	0.000000	0.000000	0.001304	0.847076
28	0.000000	0.000000	0.000000	0.767288
32	0.000000	0.000000	0.000000	0.616592
36	0.000000	0.000000	0.000000	0.429458
40	0.000000	0.000000	0.000000	0.207748
44	0.000000	0.000000	0.000000	0.046142
48	0.00000	0.0000	0.00000	0.00155

	0	00	0	6
52	0.00000 0	0.0000 00	0.00000 0	0.00000 0

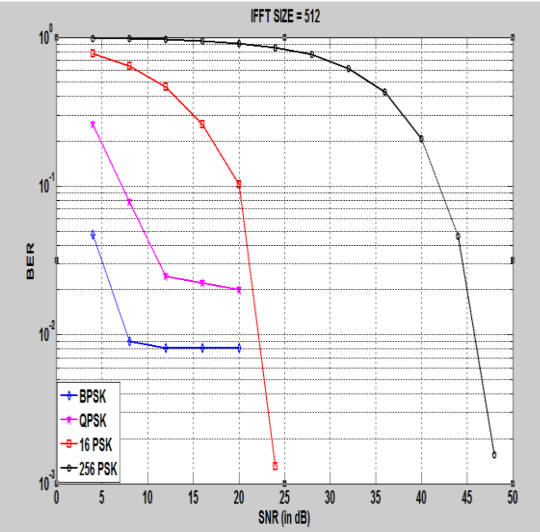

Fig.13 for IFFT size = 512

D) FOR IFFT SIZE= 1024

DIFFERENT TECHNIQUES WITH BER				
SN R	BPSK	QPSK	16PSK	256 PSK
4	0.0423 13	0.2457 55	0.7645 42	0.98576 3
8	0.0092 17	0.0679 90	0.6277 55	0.97662 3
12	0.0086 76	0.0193 76	0.4443 22	0.96321 1
16	0.0086 74	0.0177 02	0.2379 28	0.94180 2
20	0.0086 50	0.0175 10	0.0902 97	0.90977 4
24	0.0086 20	0.0172 02	0.0580 44	0.85560 6
28	0.0084 72	0.0171 12	0.0536 85	0.77853 3
32	0.0000 00	0.0000 00	0.0000 00	0.60585 0
36	0.0000 00	0.0000 00	0.0000 00	0.41282 6
40	0.0000 00	0.0000 00	0.0000 00	0.19487 0

44	0.0000 00	0.0000 00	0.0000 00	0.04167 1
48	0.0000 00	0.0000 00	0.0000 00	0.00117 4
52	0.0000 00	0.0000 00	0.0000 00	0.00000 0

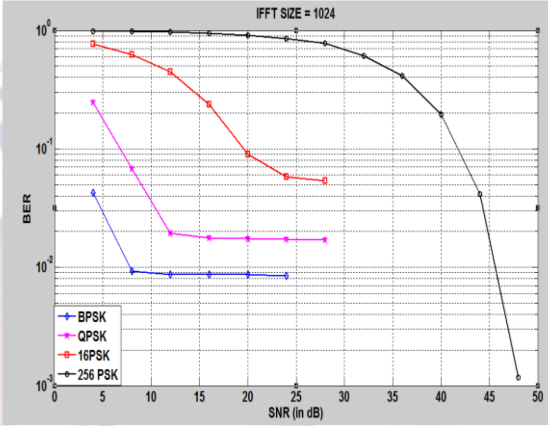

Fig.14 IFFT size = 1024

E) FOR IFFT SIZE = 2048

DIFFERENT TECHNIQUES WITH BER				
SN R	BPSK	QPSK	16PSK	256 PSK
4	0.03698 2	0.236037	0.760069	0.98481 7
8	0.00886 0	0.067940	0.623043	0.97547 9
12	0.00858 0	0.026201	0.436234	0.96151 7
16	0.00851 8	0.024993	0.230644	0.93968 2
20	0.00848 3	0.024917	0.094289	0.90454 1
24	0.00842 0	0.024857	0.063343	0.85084 5
28	0.00000 0	0.000000	0.000000	0.72236 0
32	0.00000 0	0.000000	0.000000	0.59020 9
36	0.00000 0	0.000000	0.000000	0.39396 6
40	0.00000 0	0.000000	0.000000	0.17872 6
44	0.00000 0	0.000000	0.000000	0.03388 9
48	0.00000 0	0.000000	0.000000	0.00074 7
52	0.00000	0.000000	0.000000	0.00000

	0			0

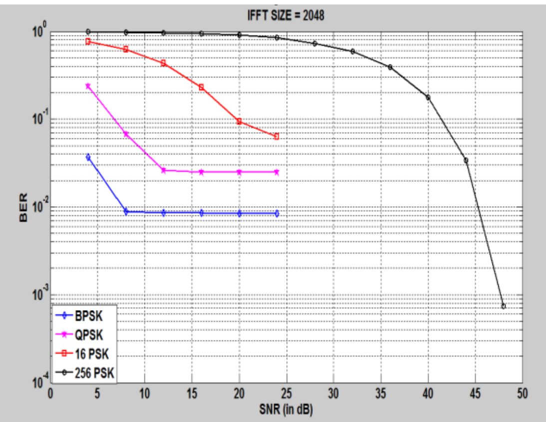

Fig 15 for IFFT size = 2048

IV. Conclusion

OFDM is a powerful modulation technique used for high data rate, and is able to eliminate ISI. It is computationally efficient due to the use of FFT techniques to implement modulation and demodulation functions. The performance of OFDM is tested for one digital modulation techniques namely M-PSK using MATLAB. It is observed from M-PSK BER plot that BER is less in case of BPSK for low Eb/No as compared to QPSK, 16-PSK and 256-PSK. Hence, high value of M-ary increases spectrum efficiency, but easily affected by noise. So OFDM system with BPSK, QPSK scheme is suitable for low capacity, short distance application. While the OFDM with higher M-ary modulation scheme is used for large capacity, long distance application at the cost of slight increase in Eb/No.

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