Performance Evaluation and Simulation of M-Ary QAM Modulation Schemes With VisSim/Comm Software

By

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Introduction

- **Information such as sound (audio), images (video), and digital data can be transmitted from one point to another using radio waves**

- **This is done by modulating an RF signal—a carrier—with the information to be transmitted**

- ***Modulation* is the variation one or more properties of an RF signal to represent the information being transmitted**

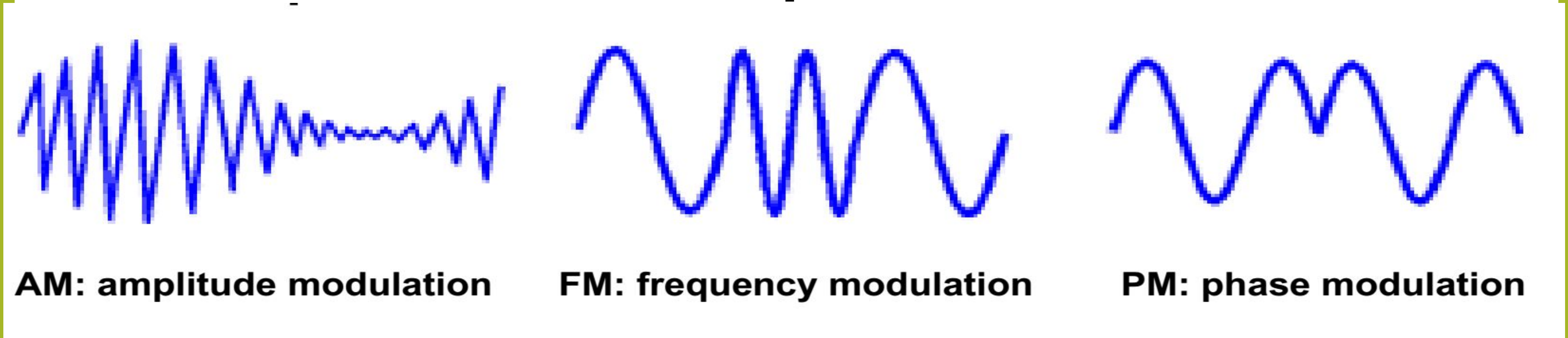
- **One or more of the following properties of an RF signal may be varied to convey information:**
  ***Amplitude*—Amplitude of a carrier is varied.This is called amplitude modulation (AM).**

- ***Frequency*—Frequency of a carrier is varied. This is called frequency modulation**

- **(FM).*Phase*—Phase of a carrier is varied. This iscalled phase modulation (PM).**

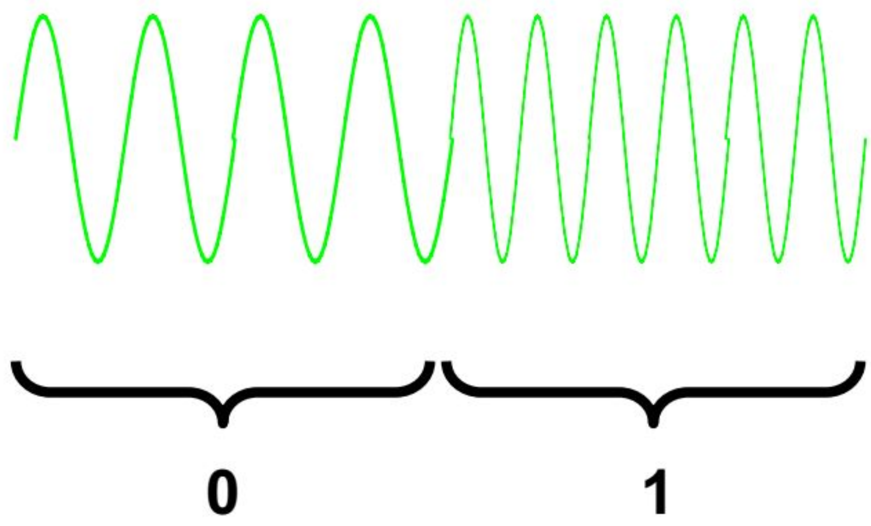
Modulation

AM: amplitude modulation FM: frequency modulation PM: phase modulation

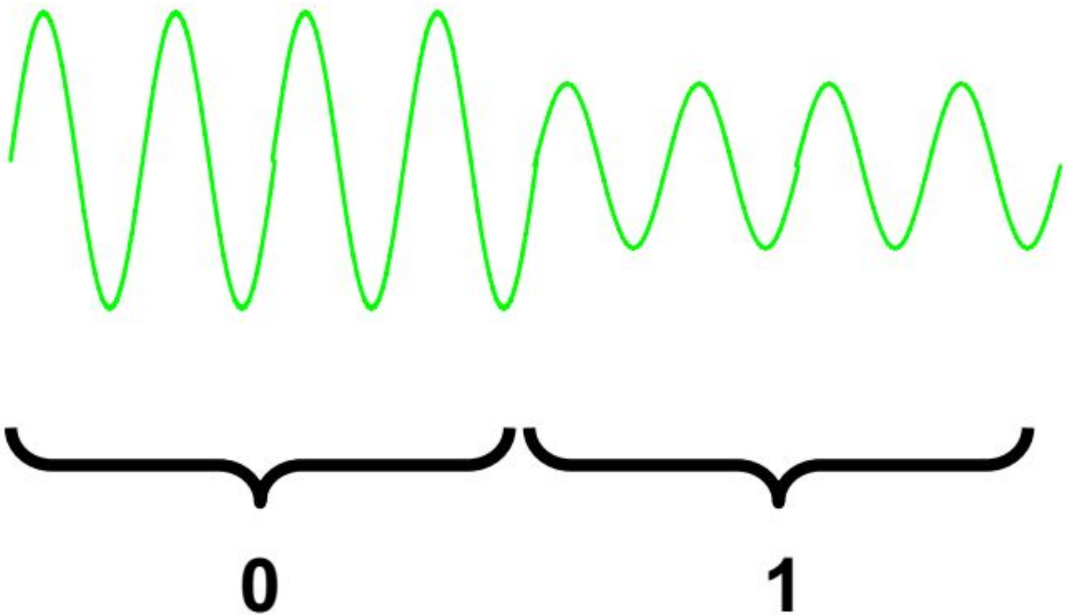


Basic Digital Modulation Formats

- **FSK—Frequency shift keying: Information is transmitted by shifting between two frequencies to represent zeroes and ones**

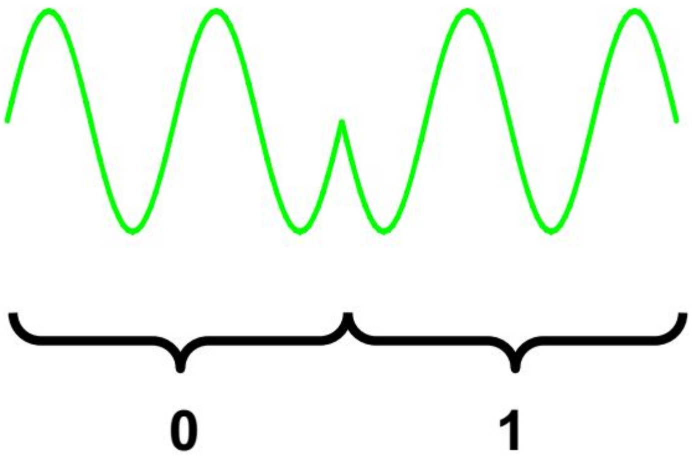


- **ASK—Amplitude shift keying: The amplitude of a carrier is shifted between two states to represent zeroes and ones**



- **PSK—Phase shift keying: The phase of a carrier is varied between two states to represent zeroes and ones**

If the phase shift between the two states is 180 degrees, the modulation is called BPSK, or biphase shift keying

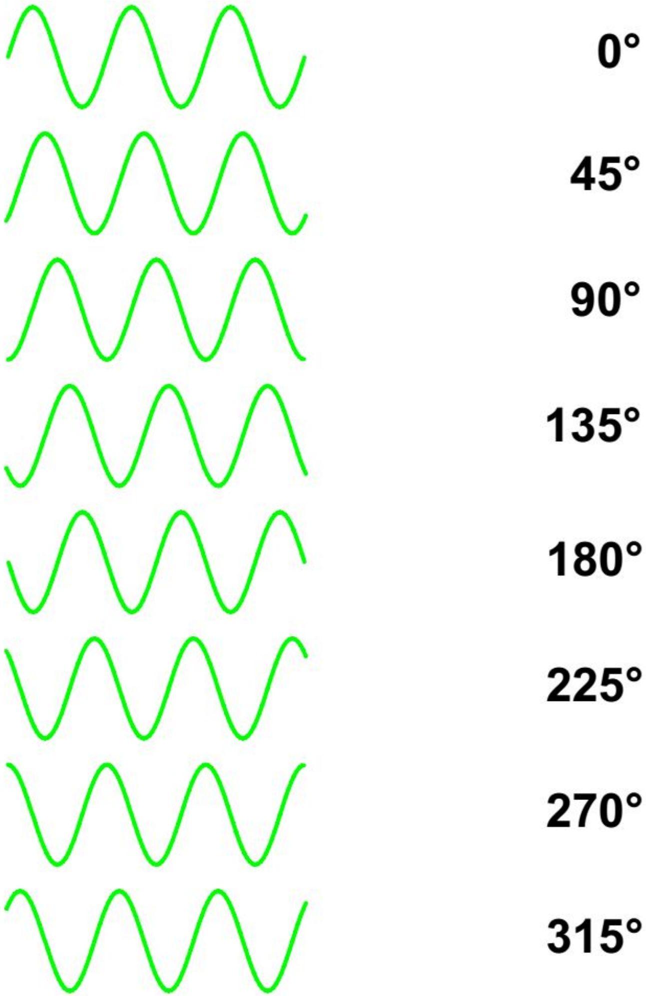


More About Carrier Phase

- These graphics represent RF carriers in the time domain with different phases relative to one another. They all have the same frequency and the same amplitude.

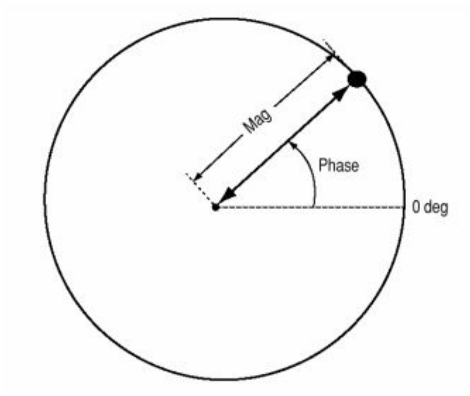
- Assume that the top carrier is assigned an arbitrary phase value of 0°

- The second carrier's phase relative to the first one is delayed 45°, the third carrier is delayed 90°, the fourth carrier 135° and so on

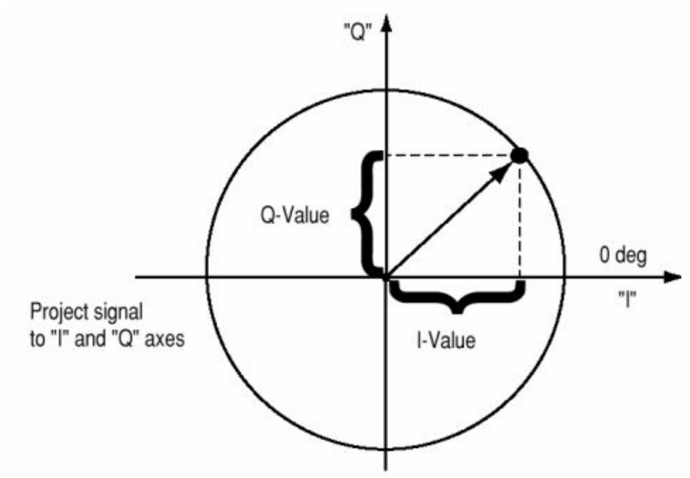


I/Q Modulation

- Amplitude and phase can be modulated simultaneously and separately to convey more information than either method alone, but is difficult to do
- An easier way is to separate the original signal into a set of independent components or channels: I (In-phase) and Q (Quadrature)
- The I and Q components are considered *orthogonal* or *in quadrature* because they are separated by 90 degrees
-

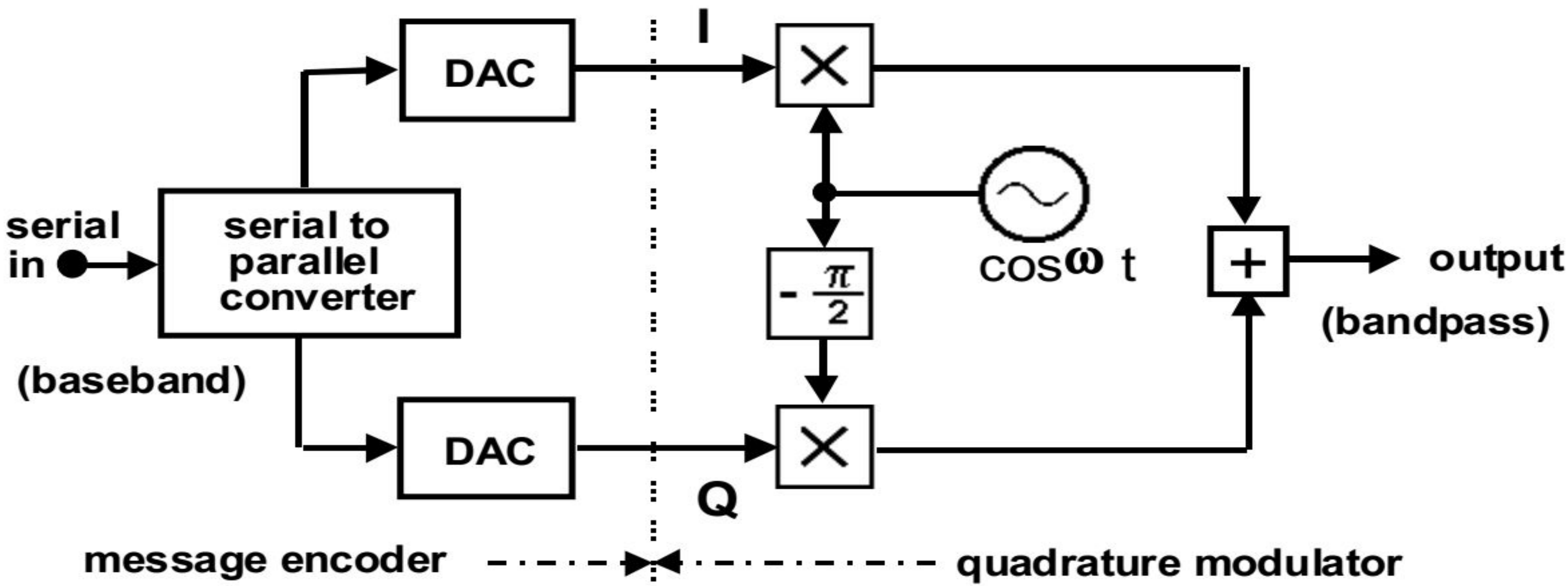


Polar display—Magnitude and phase represented together

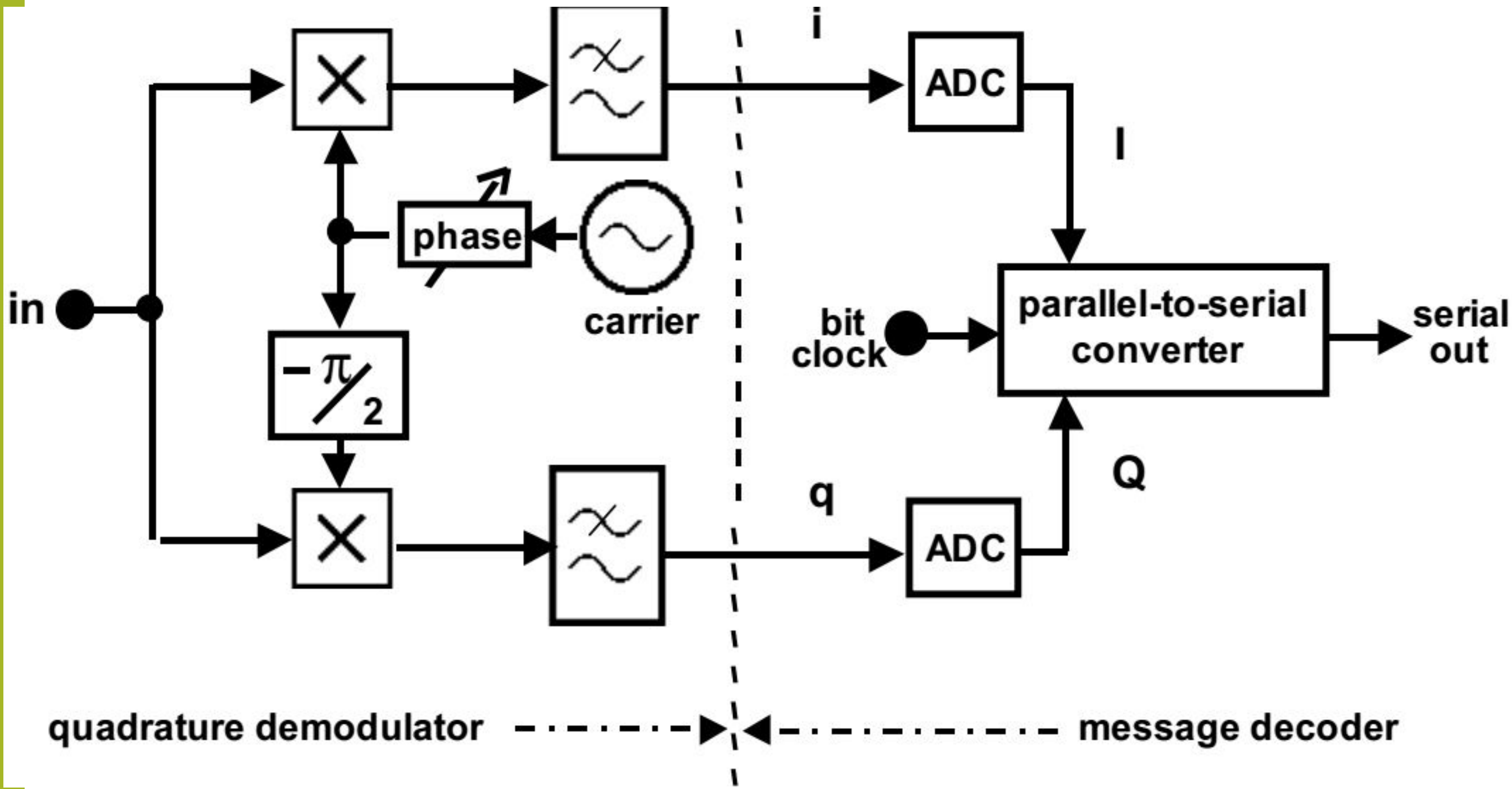


"I-Q" format—Polar to rectangular conversion

I/Q Modulator

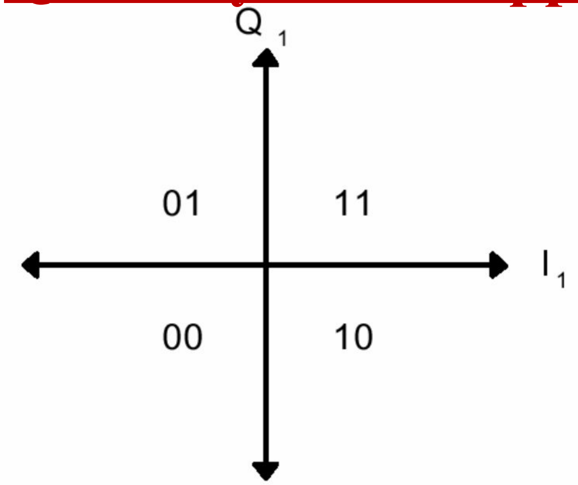


QAM demodulator

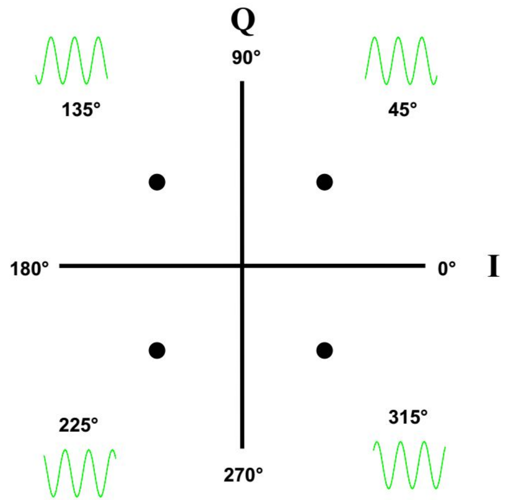


QPSK

QPSK Symbol Mapping



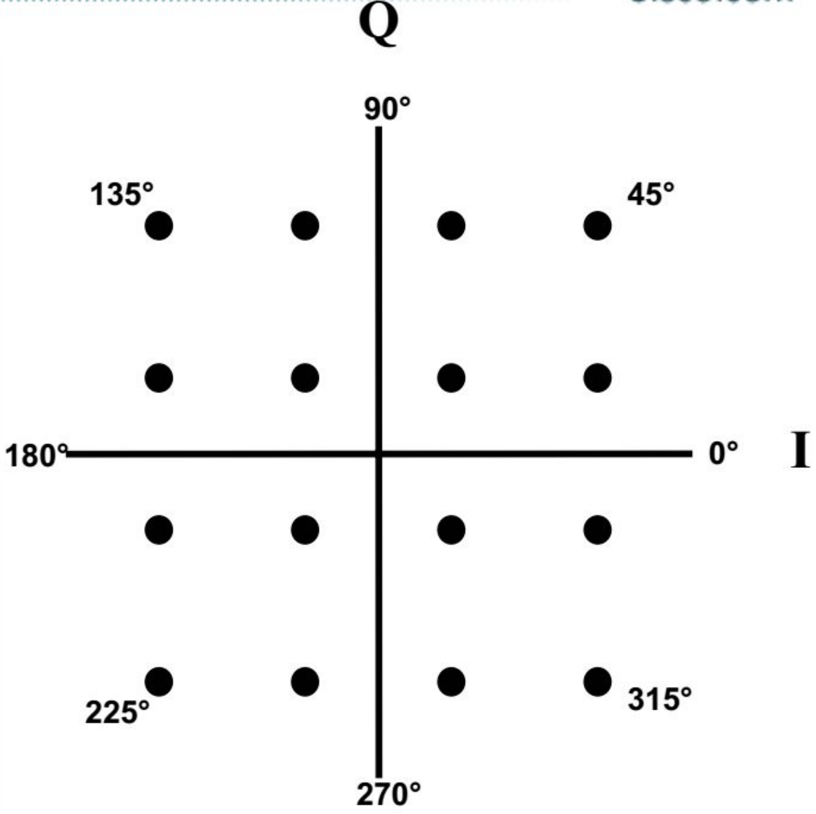
QPSK Constellation



Symbol Transmitted	Carrier Phase	Carrier Amplitude
00	225°	1.0
01	135°	1.0
10	315°	1.0
11	45°	1.0

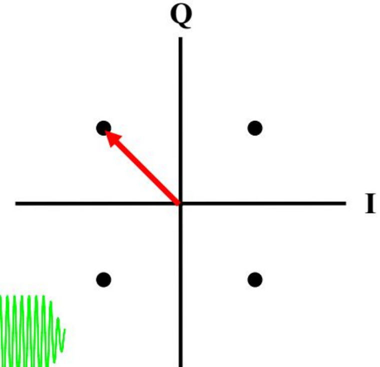
16-QAM Constellation

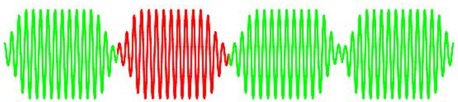
Symbol Transmitted	Carrier Phase	Carrier Amplitude
0000	225°	0.33
0001	255°	0.75
0010	195°	0.75
0011	225°	1.0
0100	135°	0.33
0101	105°	0.75
0110	165°	0.75
0111	135°	1.0
1000	315°	0.33
1001	285°	0.75
1010	345°	0.75
1011	315°	1.0
1100	45°	0.33
1101	75°	0.75
1110	15°	0.75
1111	45°	1.0



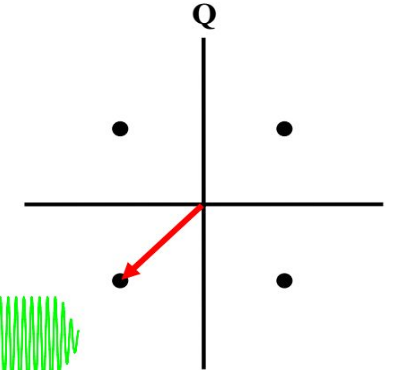
Modulated Signal Waveforms M=4

Symbol Transmitted	Carrier Phase	Carrier Amplitude
00	225°	1.0
01	135°	1.0
10	315°	1.0
11	45°	1.0

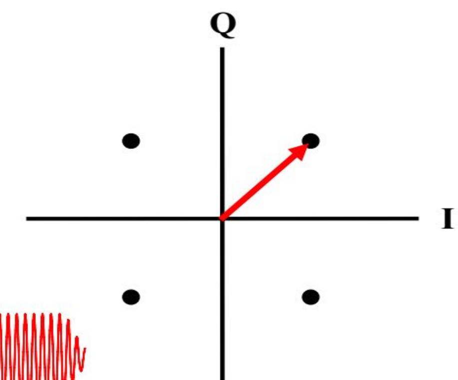




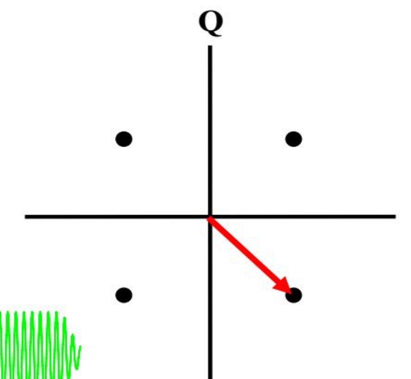
Symbol Transmitted	Carrier Phase	Carrier Amplitude
00	225°	1.0
01	135°	1.0
10	315°	1.0
11	45°	1.0

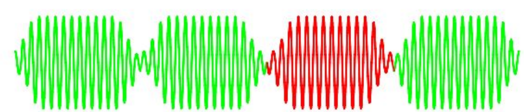


Symbol Transmitted	Carrier Phase	Carrier Amplitude
00	225°	1.0
01	135°	1.0
10	315°	1.0
11	45°	1.0



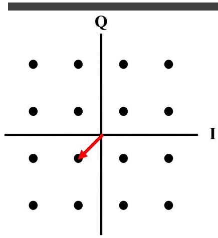
Symbol Transmitted	Carrier Phase	Carrier Amplitude
00	225°	1.0
01	135°	1.0
10	315°	1.0
11	45°	1.0



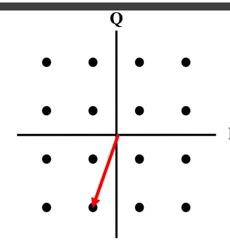


Modulated Signal Waveforms M=16

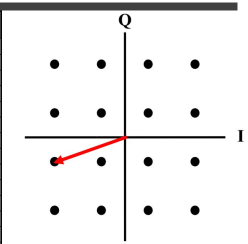
Symbol Transmitted	Carrier Phase	Carrier Amplitude
0000	**225°**	**0.33**
0001	255°	0.75
0010	195°	0.75
0011	225°	1.0
0100	135°	0.33
0101	105°	0.75
0110	165°	0.75
0111	135°	1.0
1000	315°	0.33
1001	285°	0.75
1010	345°	0.75
1011	315°	1.0
1100	45°	0.33
1101	75°	0.75
1110	15°	0.75
1111	45°	1.0



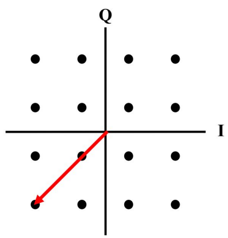
Symbol Transmitted	Carrier Phase	Carrier Amplitude
0000	225°	0.33
0001	**255°**	**0.75**
0010	195°	0.75
0011	225°	1.0
0100	135°	0.33
0101	105°	0.75
0110	165°	0.75
0111	135°	1.0
1000	315°	0.33
1001	285°	0.75
1010	345°	0.75
1011	315°	1.0
1100	45°	0.33
1101	75°	0.75
1110	15°	0.75
1111	45°	1.0



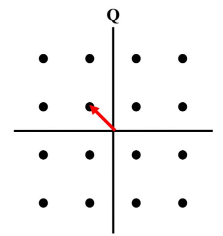
Symbol Transmitted	Carrier Phase	Carrier Amplitude
0000	225°	0.33
0001	255°	0.75
0010	**195°**	**0.75**
0011	225°	1.0
0100	135°	0.33
0101	105°	0.75
0110	165°	0.75
0111	135°	1.0
1000	315°	0.33
1001	285°	0.75
1010	345°	0.75
1011	315°	1.0
1100	45°	0.33
1101	75°	0.75
1110	15°	0.75
1111	45°	1.0



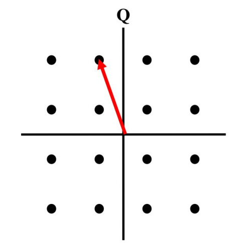
Symbol Transmitted	Carrier Phase	Carrier Amplitude
0000	225°	0.33
0001	255°	0.75
0010	195°	0.75
0011	**225°**	**1.0**
0100	135°	0.33
0101	105°	0.75
0110	165°	0.75
0111	135°	1.0
1000	315°	0.33
1001	285°	0.75
1010	345°	0.75
1011	315°	1.0
1100	45°	0.33
1101	75°	0.75
1110	15°	0.75
1111	45°	1.0



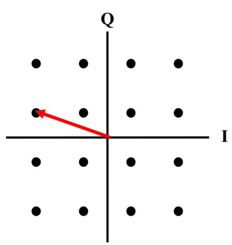
Symbol Transmitted	Carrier Phase	Carrier Amplitude
0000	225°	0.33
0001	255°	0.75
0010	195°	0.75
0011	225°	1.0
0100	**135°**	**0.33**
0101	105°	0.75
0110	165°	0.75
0111	135°	1.0
1000	315°	0.33
1001	285°	0.75
1010	345°	0.75
1011	315°	1.0
1100	45°	0.33
1101	75°	0.75
1110	15°	0.75
1111	45°	1.0



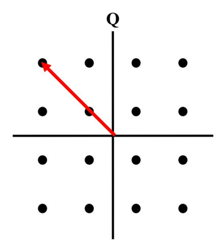
Symbol Transmitted	Carrier Phase	Carrier Amplitude
0000	225°	0.33
0001	255°	0.75
0010	195°	0.75
0011	225°	1.0
0100	135°	0.33
0101	**105°**	**0.75**
0110	165°	0.75
0111	135°	1.0
1000	315°	0.33
1001	285°	0.75
1010	345°	0.75
1011	315°	1.0
1100	45°	0.33
1101	75°	0.75
1110	15°	0.75
1111	45°	1.0



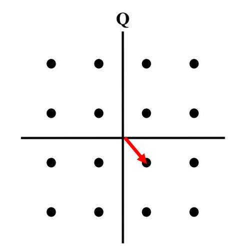
Symbol Transmitted	Carrier Phase	Carrier Amplitude
0000	225°	0.33
0001	255°	0.75
0010	195°	0.75
0011	225°	1.0
0100	135°	0.33
0101	105°	0.75
0110	**165°**	**0.75**
0111	135°	1.0
1000	315°	0.33
1001	285°	0.75
1010	345°	0.75
1011	315°	1.0
1100	45°	0.33
1101	75°	0.75
1110	15°	0.75
1111	45°	1.0



Symbol Transmitted	Carrier Phase	Carrier Amplitude
0000	225°	0.33
0001	255°	0.75
0010	195°	0.75
0011	225°	1.0
0100	135°	0.33
0101	105°	0.75
0110	165°	0.75
0111	**135°**	**1.0**
1000	315°	0.33
1001	285°	0.75
1010	345°	0.75
1011	315°	1.0
1100	45°	0.33
1101	75°	0.75
1110	15°	0.75
1111	45°	1.0

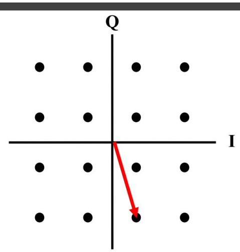


Symbol Transmitted	Carrier Phase	Carrier Amplitude
0000	225°	0.33
0001	255°	0.75
0010	195°	0.75
0011	225°	1.0
0100	135°	0.33
0101	105°	0.75
0110	165°	0.75
0111	135°	1.0
1000	**315°**	**0.33**
1001	285°	0.75
1010	345°	0.75
1011	315°	1.0
1100	45°	0.33
1101	75°	0.75
1110	15°	0.75
1111	45°	1.0

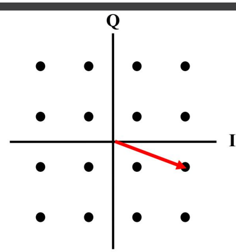


Modulated Signal Waveforms M=16 (Cont.)

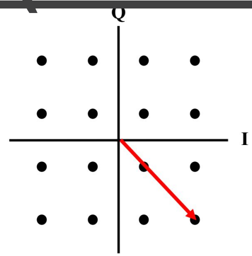
Symbol Transmitted	Carrier Phase	Carrier Amplitude
0000	225°	0.33
0001	255°	0.75
0010	195°	0.75
0011	225°	1.0
0100	135°	0.33
0101	105°	0.75
0110	165°	0.75
0111	135°	1.0
1000	315°	0.33
1001	**285°**	**0.75**
1010	345°	0.75
1011	315°	1.0
1100	45°	0.33
1101	75°	0.75
1110	15°	0.75
1111	45°	1.0



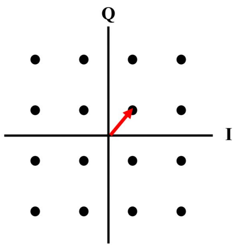
Symbol Transmitted	Carrier Phase	Carrier Amplitude
0000	225°	0.33
0001	255°	0.75
0010	195°	0.75
0011	225°	1.0
0100	135°	0.33
0101	105°	0.75
0110	165°	0.75
0111	135°	1.0
1000	315°	0.33
1001	285°	0.75
1010	**345°**	**0.75**
1011	315°	1.0
1100	45°	0.33
1101	75°	0.75
1110	15°	0.75
1111	45°	1.0



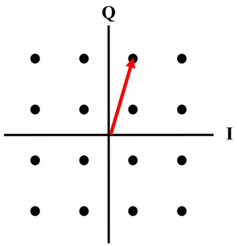
Symbol Transmitted	Carrier Phase	Carrier Amplitude
0000	225°	0.33
0001	255°	0.75
0010	195°	0.75
0011	225°	1.0
0100	135°	0.33
0101	105°	0.75
0110	165°	0.75
0111	135°	1.0
1000	315°	0.33
1001	285°	0.75
1010	345°	0.75
1011	**315°**	**1.0**
1100	45°	0.33
1101	75°	0.75
1110	15°	0.75
1111	45°	1.0



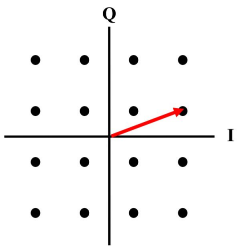
Symbol Transmitted	Carrier Phase	Carrier Amplitude
0000	225°	0.33
0001	255°	0.75
0010	195°	0.75
0011	225°	1.0
0100	135°	0.33
0101	105°	0.75
0110	165°	0.75
0111	135°	1.0
1000	315°	0.33
1001	285°	0.75
1010	345°	0.75
1011	315°	1.0
1100	**45°**	**0.33**
1101	75°	0.75
1110	15°	0.75
1111	45°	1.0



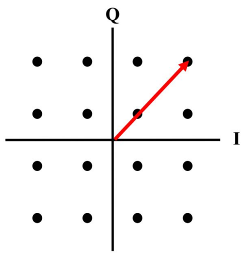
Symbol Transmitted	Carrier Phase	Carrier Amplitude
0000	225°	0.33
0001	255°	0.75
0010	195°	0.75
0011	225°	1.0
0100	135°	0.33
0101	105°	0.75
0110	165°	0.75
0111	135°	1.0
1000	315°	0.33
1001	285°	0.75
1010	345°	0.75
1011	315°	1.0
1100	45°	0.33
1101	**75°**	**0.75**
1110	15°	0.75
1111	45°	1.0



Symbol Transmitted	Carrier Phase	Carrier Amplitude
0000	225°	0.33
0001	255°	0.75
0010	195°	0.75
0011	225°	1.0
0100	135°	0.33
0101	105°	0.75
0110	165°	0.75
0111	135°	1.0
1000	315°	0.33
1001	285°	0.75
1010	345°	0.75
1011	315°	1.0
1100	45°	0.33
1101	75°	0.75
1110	**15°**	**0.75**
1111	45°	1.0

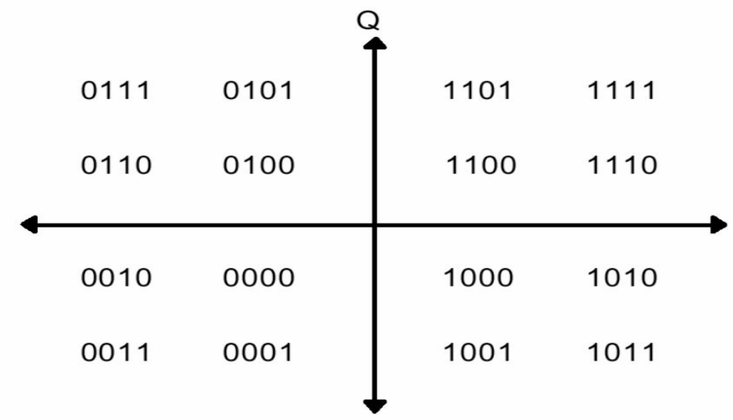


Symbol Transmitted	Carrier Phase	Carrier Amplitude
0000	225°	0.33
0001	255°	0.75
0010	195°	0.75
0011	225°	1.0
0100	135°	0.33
0101	105°	0.75
0110	165°	0.75
0111	135°	1.0
1000	315°	0.33
1001	285°	0.75
1010	345°	0.75
1011	315°	1.0
1100	45°	0.33
1101	75°	0.75
1110	15°	0.75
1111	**45°**	**1.0**

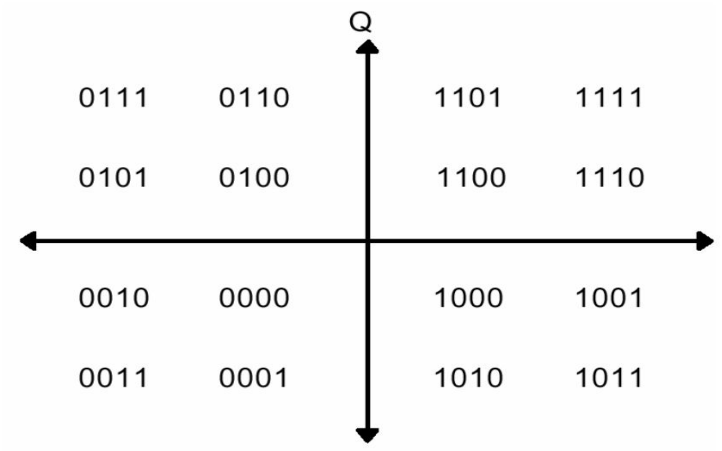


16-QAM Symbol Mapping

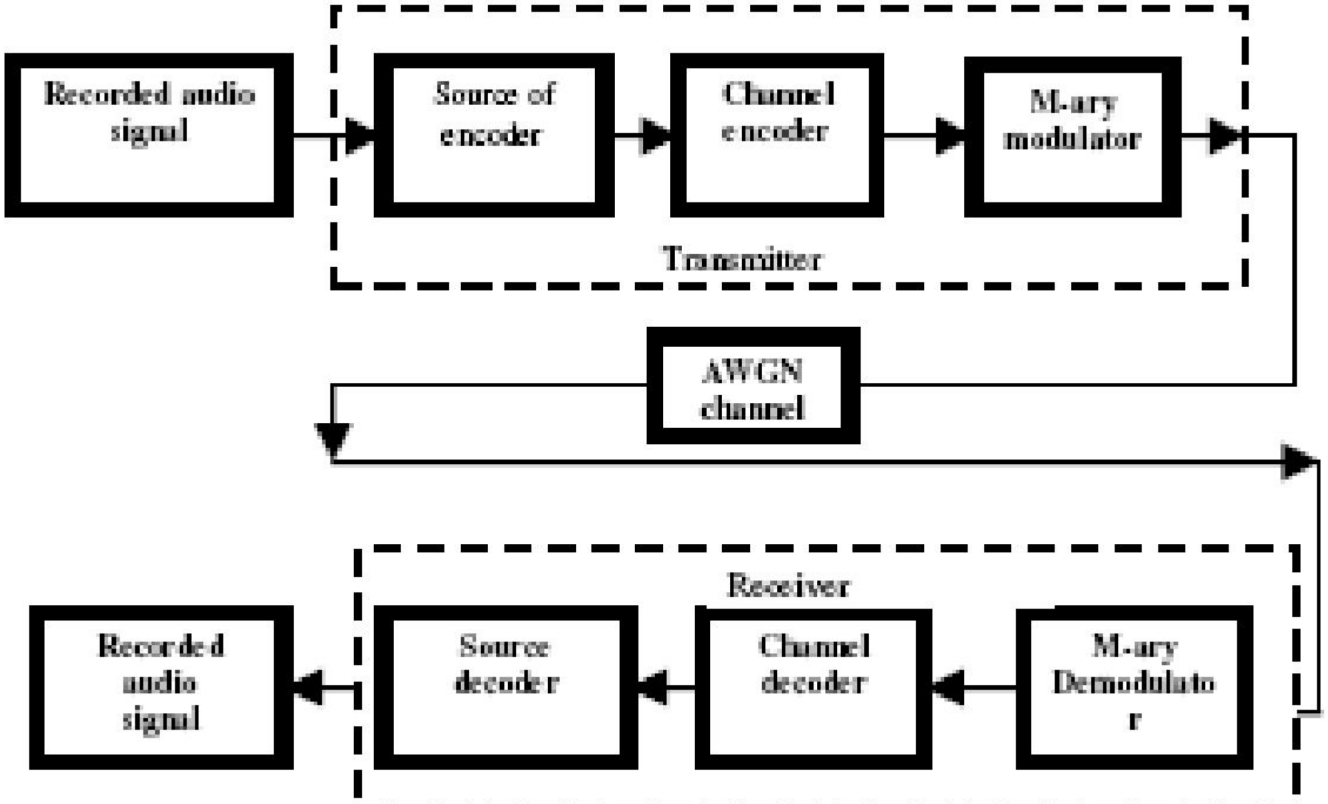
Gray-Coded Symbol Mapping



Differential-Coded Symbol Mapping



DIGITAL COMMUNICATION SYSTEM MODEL



Spectral Efficiency and Power Efficiency In Digital Modulations

The spectral efficiency of a digital modulation is the ratio between the transmitted bit rate R_b and the occupied bandwidth B, that is,

$$\rho = \frac{Rb}{B} \qquad , bits/sec/Hz$$

MATHEMETICAL MODEL

In general a modulated signal can be represented by:

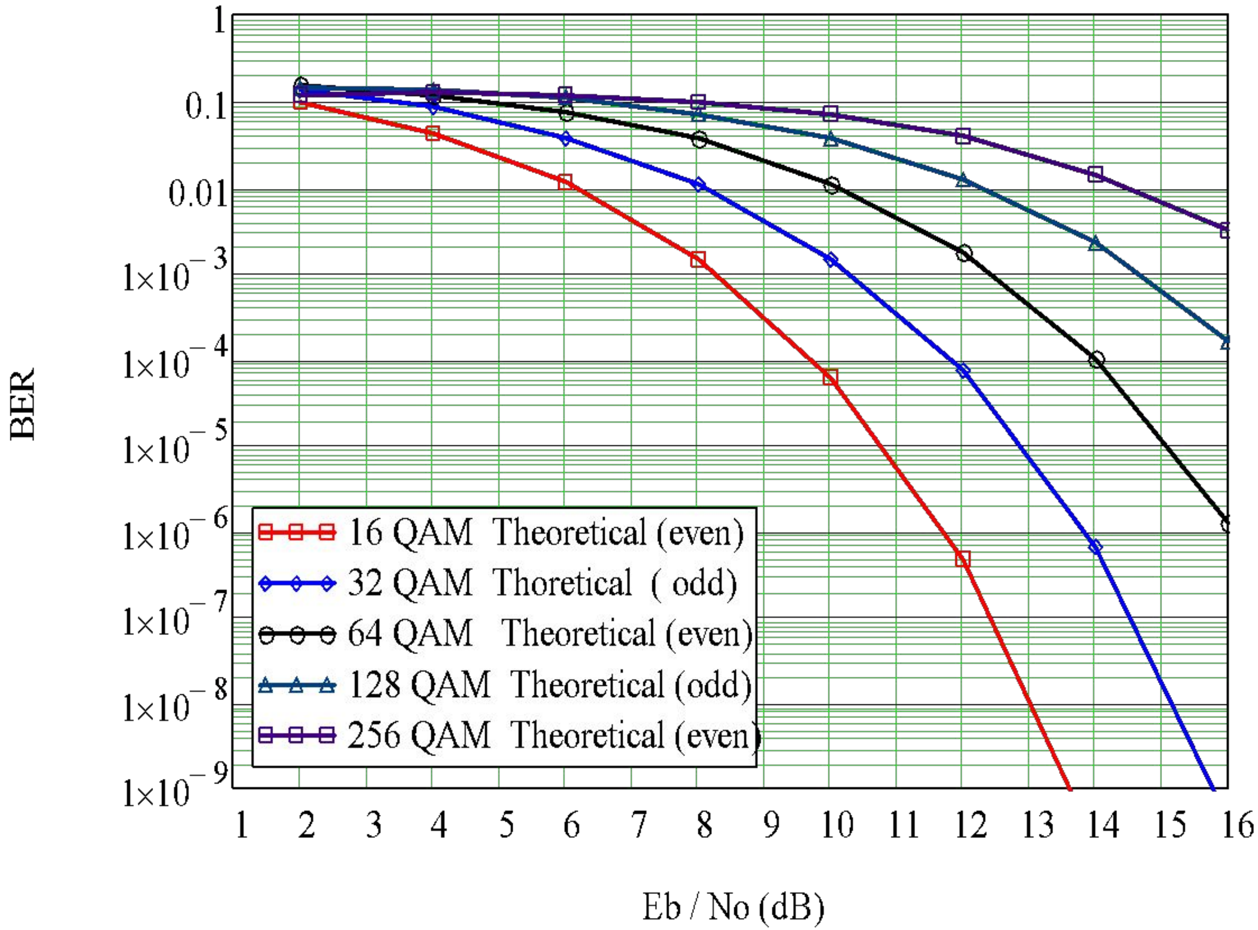
$$s_i(t) = \sqrt{\frac{2E_{min}}{T_s}} a_i \cos(2\pi f_c t) + \sqrt{\frac{2E_{min}}{T_s}} b_i \sin(2\pi f_c t) \quad 0 \le t \le T; i = 1,2...$$

CALCULATING THE BIT ERROR RATE (BER)

$$Pev_b = \frac{2}{\log2(M)} \cdot \left(1 - \frac{1}{\sqrt{M}}\right) \cdot \sum_{n=0}^{\frac{\sqrt{M}}{2}-1} \text{erfc}\left[(2 \cdot n + 1) \cdot \sqrt{\frac{3\log2(M)}{2 \cdot (M-1)} \cdot \frac{Eb}{No}}\right]$$

$$Pod_b = \frac{1}{\log2(M)} \cdot \left[1 - \left[\left(1 - 2\,\text{erfc}\left(\sqrt{\frac{3 \cdot \log2(M) \cdot EbNo}{M-1}}\right)\right)^2\right]\right]$$

Results of Theoretical Calculation of the Bit Error Rate (BER)



Bandwidth Efficiency

Shannon's formula's described as follows:

Bandwidth Efficiency

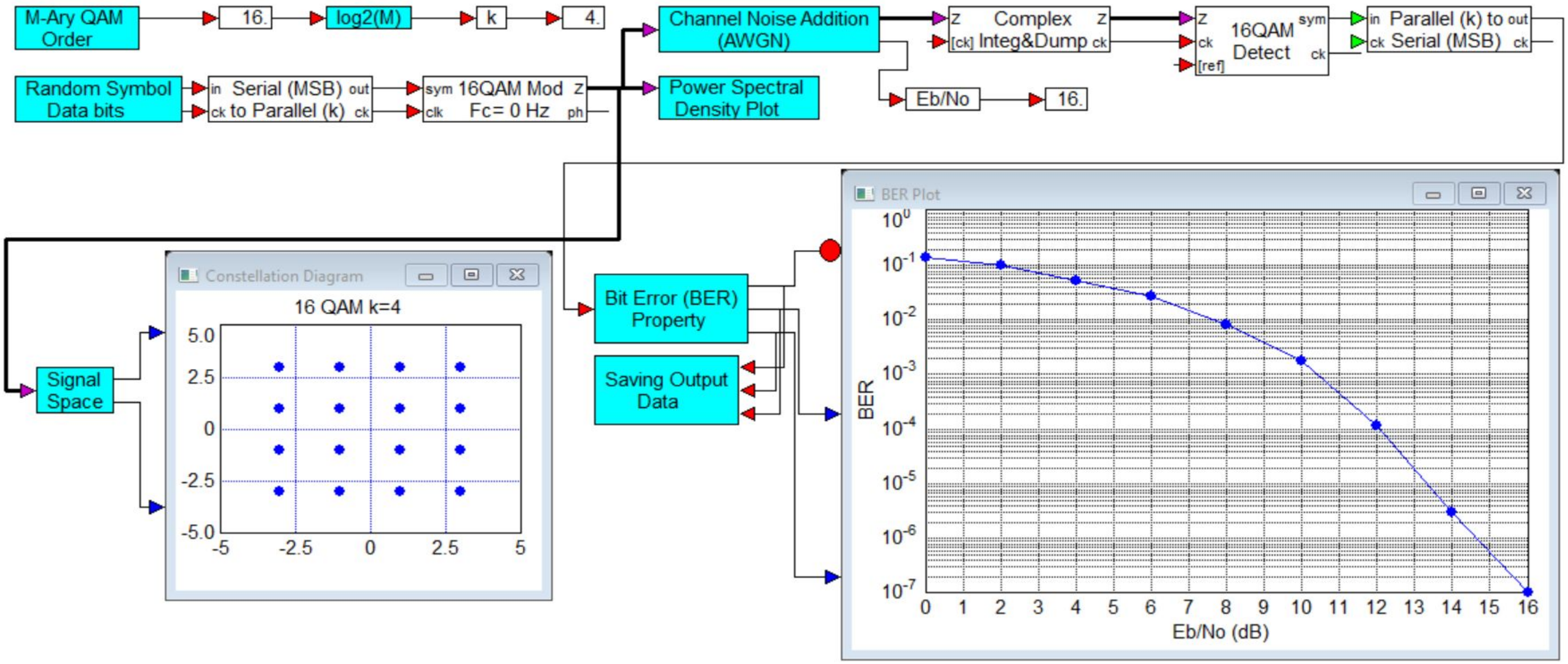
$$\eta = \log_2(1 + S/N) \quad [\text{bit/s/Hz}]$$

M- ary QAM (Quadrature Amplitude Modulation) Bandwidth Efficiency

M-QAM	Bits/Symbol (k) (even & odd)	Bandwidth Efficiency (Mb/s)
16	**4**	**80**
32	**5**	**100**
64	**6**	**120**
128	**7**	**140**
256	**8**	**160**

Note :The above alues based on assuming 20 MHz which is acommonly allocated bandwidth for channels in 4G cellular communications systems such as LTE-A and WiMAX [32, 33].

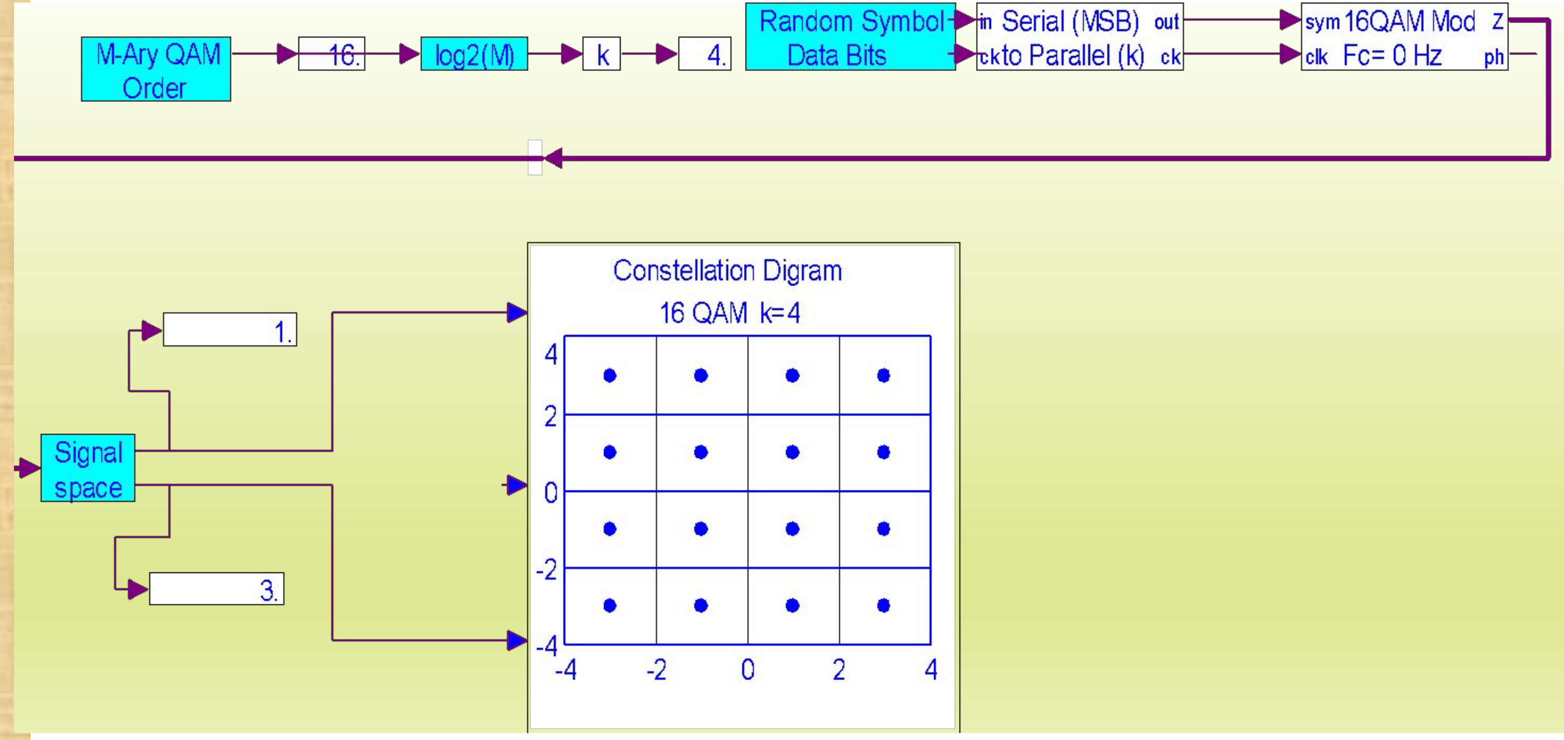
M-QAM Simulation Model With VisSim/Comm Software

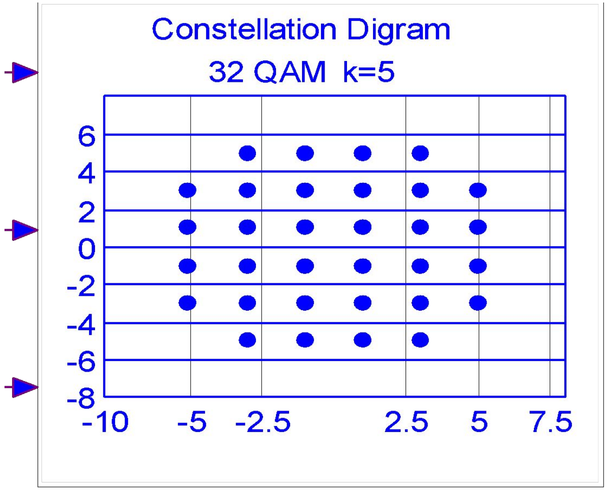


MQAM Dr. Husham J.A. File.vsm

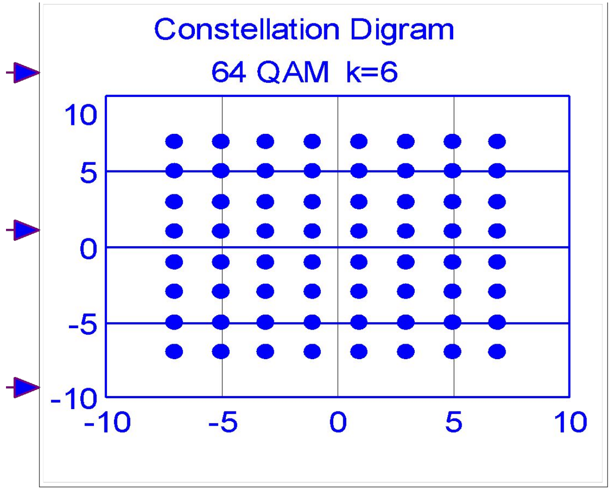
Simulation Results

Constellation Diagram with VisSim/Comm software (case 8 QAM, k=4)

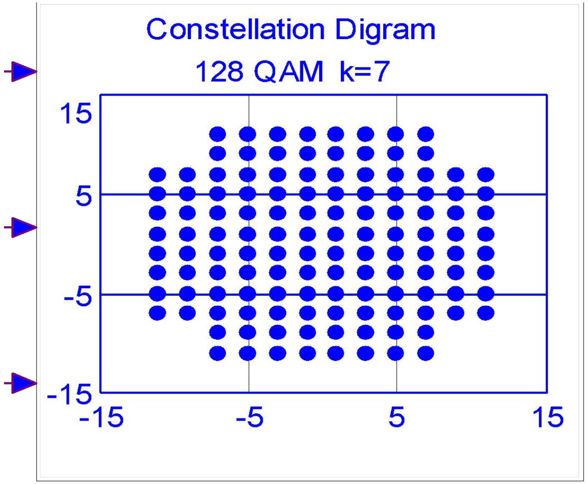




Constellation Digram
32 QAM k=5
6
4
2
0
-2
-4
-6
-8
-10
-5
-2.5
2.5
5
7.5

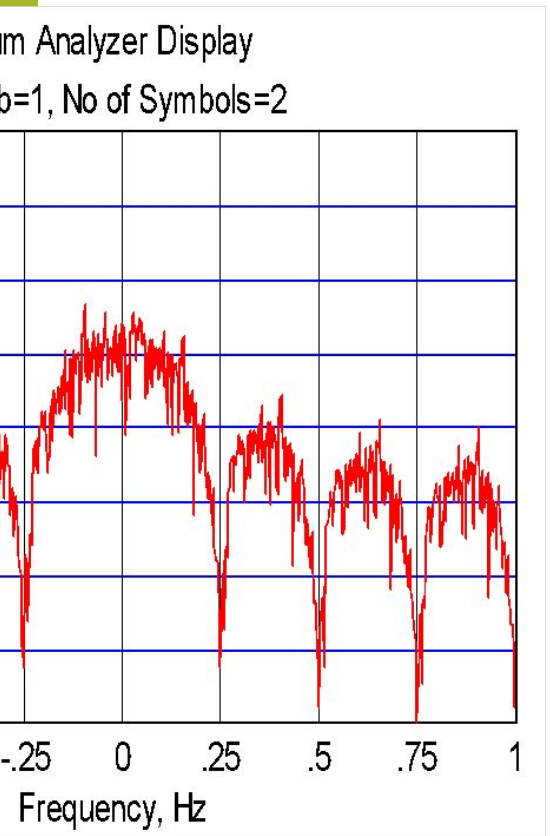


Constellation Digram
64 QAM k=6
10
5
0
-5
-10
-10
-5
0
5
10

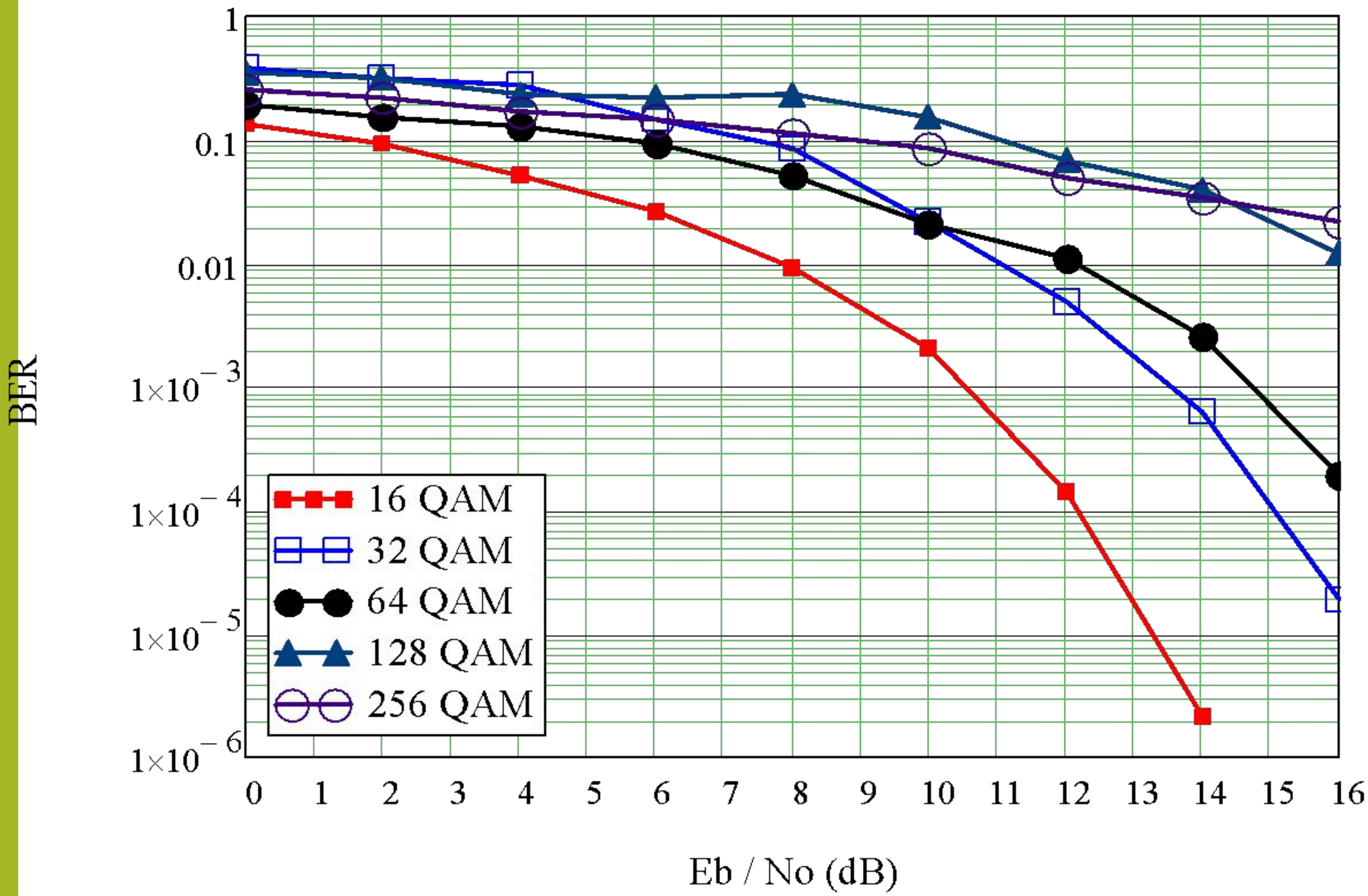


Constellation Digram
128 QAM k=7
15
5
-5
-15
-15
-5
5
15

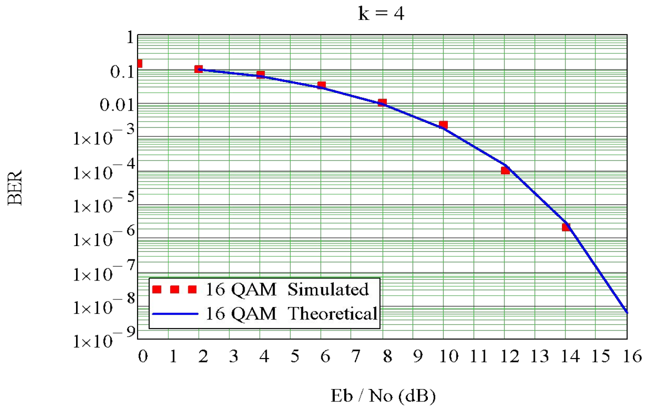
Power spectrum density (PSD) of 16-QAM.

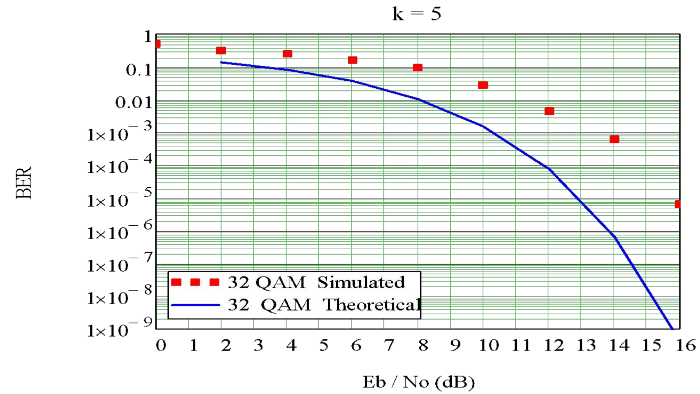


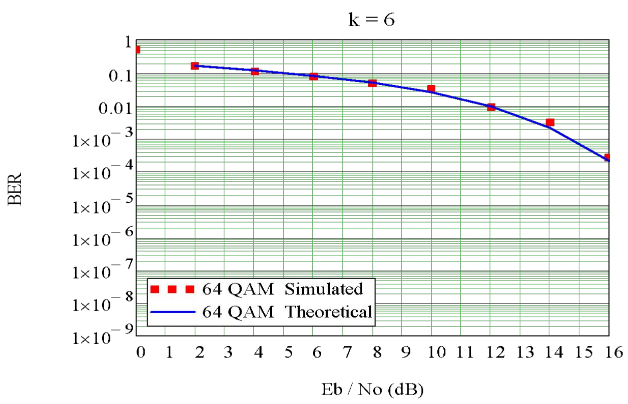
Simulated results of BER using VisSim/comm model

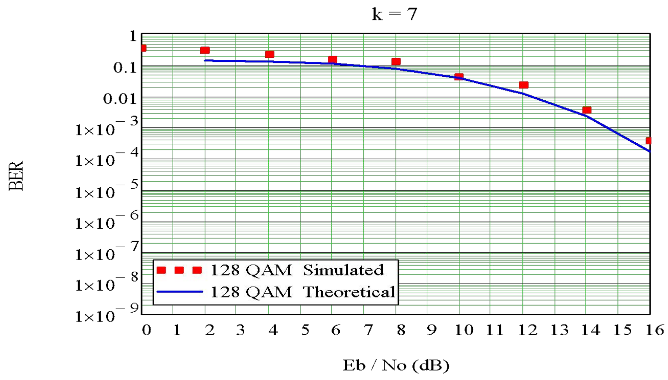


RESULTS AND COMPARATIVE EVALUATION.

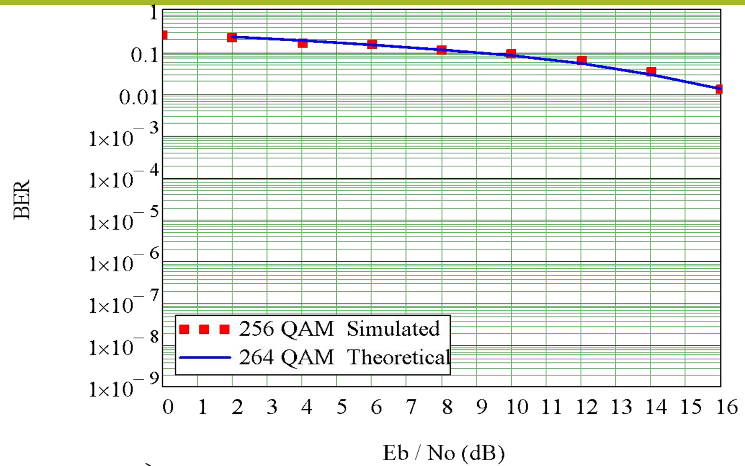






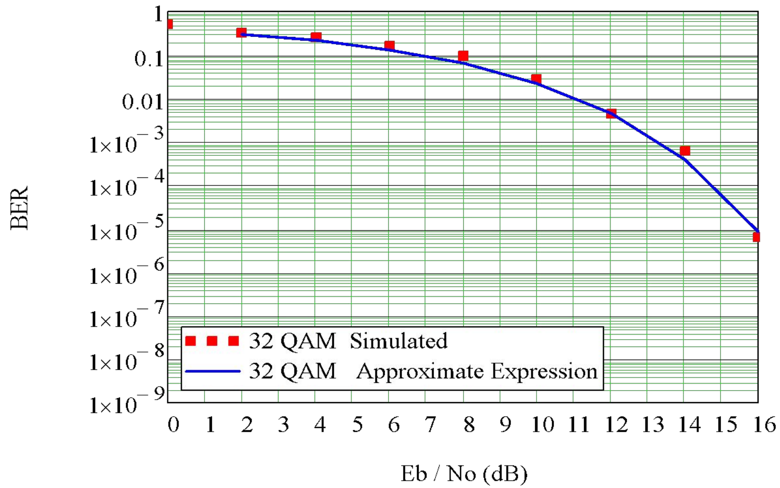


k = 8



$$P_b = 0.78 \cdot \mathrm{erfc}\left(\sqrt{\frac{15}{62} \cdot EbNo}\right)$$

k = 5



CONCLUSIONS

- In this paper, five M-QAM modulation schemes (16-QAM, 32-QAM, 64-QAM, 128-QAM and 256-QAM) are studied in order to find appropriate expressions to calculate and evaluate their BER performances in AWGN channe.

- Theoretical results are compared with the simulation results as well as approximate expression of BER is established for non-square constellation diagram (M=32). It is observed that in all cases that the BER decreases when the values of Eb/No are increased.

- It can be stated that VisSim/Comm software can be successfully used in evaluating the performance not only of M-QAM modulation, but of other digital modulation techniques, such as MPSK, MFSK, MSK, DQPSK, OQPSK, etc. Evaluate BER data, can be helpful for many researchers, in the field of digital modulation techniques, in simplifying the process of passing from simulation to implementation without the necessity of being specialized hardware engineers.

Thank You...