A Performance Analysis of Digital Modulation Techniques under Simulation Environment

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***Abstract* – Digital modulation techniques are an important part of a digital and data communication course. Digital carrier modulation or simply digital modulation is the process by which digital symbols are transformed into waveforms that are compatible with the characteristics of the channel over which digital symbols are to be transformed. This becomes challenging when it is need to be incorporated within a technology course, where the focus is mainly with application rather than the theoretical aspects. We have presented impact of various modulation parameters towards the modulation and demodulation processes. In addition, it has been proven that a simulation environment can play an important role towards the understanding of subject matter. This paper presents the development of a highly interactive user-friendly environment for the simulation of digital modulation and demodulation techniques.**

***Keywords* - BPSK, BFSK, QPSK, QAM, BER**

I. INTRODUCTION

In communication systems, major requirement is to use such modulation/demodulation technique, which consumes less bandwidth of channel and made the receiver simple to estimate symbol timing so that optimal symbol decisions may be made. In digital communications, the modulating signal consists of binary wave with fixed frequency. Here modulation process involves switching or keying the amplitude, frequency or phase of the carrier I accordance with the input data.

Today with the development of high speed and computationally powerful digital signal processing (DSP) chips there is increasing interest in moving digital communication functions to the digital domain. Implementing modems with an all-digital design may reduce front-end analog circuitry and decrease the burden on the analog-to-digital (A/D) converter while increasing the computational burden of the DSP. All digital modulation blocks process only discrete-time signals and use the baseband representation. There are a number of digital modulation techniques that one can employ for electronic communication. In this paper, only four of these techniques for the transmission of digital data are being implemented within the simulation environment will be discussed.

The techniques are:

1. Binary Phase Shift Keying(BPSK);
2. Binary Frequency Shift Keying(BFSK);
3. Quadrature Phase Shift Keying(QPSK);
4. Quadrature Amplitude Modulation(QAM)

Binary Phase Shift Keying

Binary Phase Shift Keying (BPSK) is one of the simplest forms of digital modulation techniques. With BPSK, two output phases are possible for a single carrier frequency. The binary symbols '1' and '0'modulates the phase of the carrier.

As the input digital signal changes state, the phase of the output carrier shifts between two angles that are 180° out of phase. Figure 1 shows the binary input data and subsequent modulated signal.

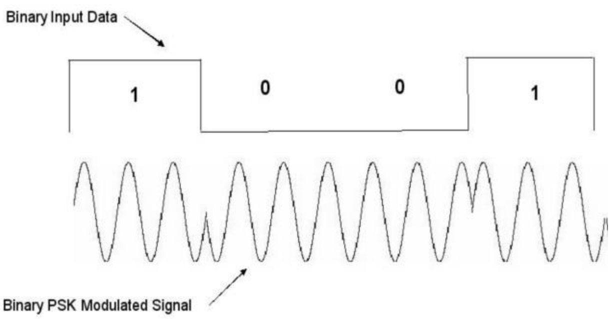

Figure 1: Input data and BPSK modulated signal.

Binary Frequency Shift Keying

Binary Frequency Shift Keying (BFSK) is a form of constant-amplitude angle modulation similar to the frequency modulation, except that the modulating signal is a binary signal that varies between two discrete voltage levels. The general expression for BFSK can be written as

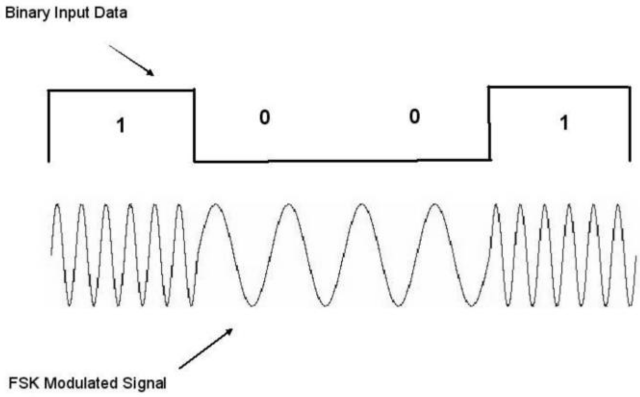

Figure 2: Waveform of a BFSK modulated signal.

Figure 2 shows the BFSK modulated waveform (continuous phase) for a binary signal. It can be seen that as the logic changes its state, the frequency shifts between the mark and space frequency values.

Quadrature Phase Shift Keying

Quadrature Phase Shift Keying (QPSK) is another form of angle-modulated, constant amplitude modulation. Here two or more bits are combined in some symbols hence signaling rate will be reduced. This reduces frequency as well as the transmission bandwidth of the channel.

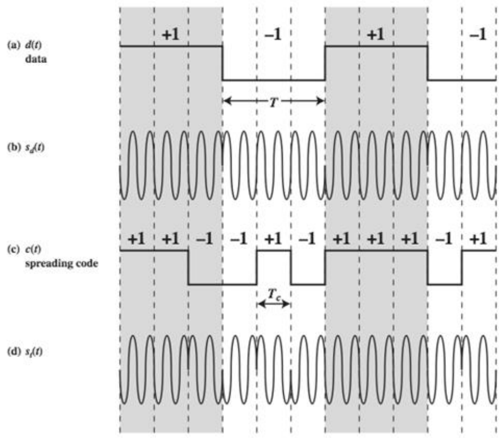

Figure 3: Waveform of a QPSK modulated signal.

There are four possible output phases for a single carrier frequency. The BPSK phase of the carrier is changed by 180◦ but QPSK encodes two bits at a time, which results in 4 different phase-combinations. The binary input data is combined into groups of two bits called dibits and clocked into the modulator. For every digit, a single output waveform is generated; hence, the baud rate for QPSK is half the input bit rate.

The signal shifts in increments of 90 degrees from 45 to 135, 135 to -45, -45 to -135 or -135 to 45 degrees.

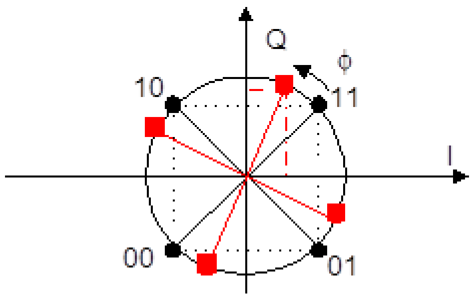

Figure 4: Effect of phase shift on Q/I Diagram

These points are chosen as they can be easily implemented using an I/Q modulator. Only two I values and two Q values are needed, and this gives two bits per channel. There are four states for QPSK. It is, therefore, a bandwidth-efficient modulation compared to BPSK and potentially twice as efficient. Figure 5 shows constellation diagram of QPSK modulation.

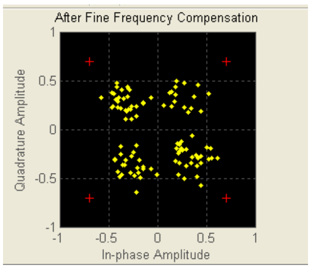

Figure 5: Constellation Diagram of QPSK

Quadrature Amplitude Modulation

Quadrature Amplitude Modulation (QAM) is a method for transmitting two separate (and uniquely different) channels of information using a single carrier.

QAM is both an analog and a digital modulation scheme. It conveys two analog message signals by modulating the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme. These two modulation inputs (analog or digital) are applied to two separate balanced modulators, each of which is supplied with the sine or cosine carriers.

The outputs of both modulators are algebraically summed and result in a single waveform containing the I and Q information. The output waveform of an 8-QAM modulator is shown in Figure 6.

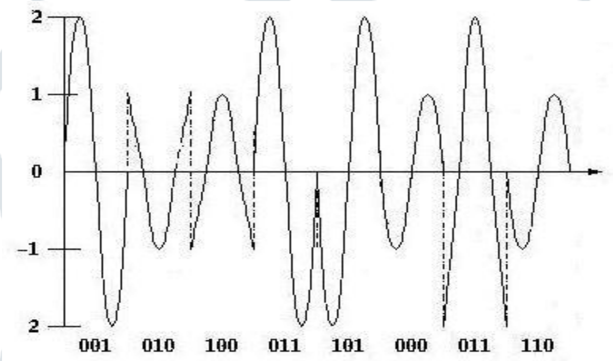

Figure 6: Typical 8-QAM modulated signal waveform.

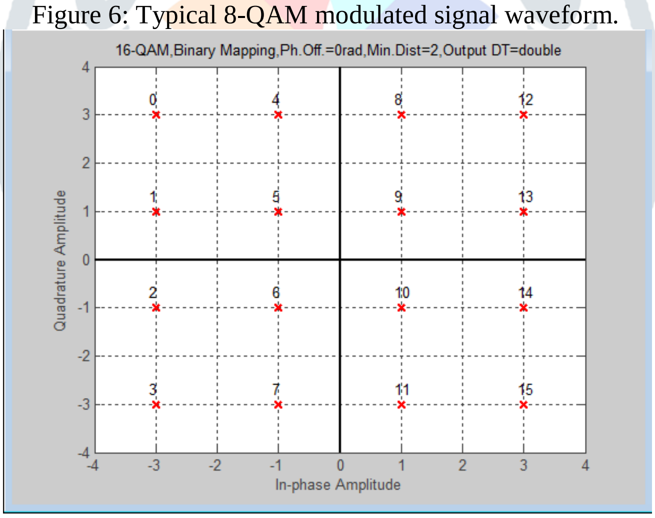

Figure 7: Constellation Diagram of 16-QAM

II. THE SIMULATION ENVIRONMENT

The simulation environment has been developed by using Matlab. Matlab and associated toolboxes provide the background computation for each of these implementations, while the user interacts with the environment through GUIs developed by using the Guide.

Four digital modulation and demodulation techniques are implemented. For each of these techniques, there are three Blocks. These are:

1. Transmitter
2. Channel
3. Receiver

At the very beginning of the process, the transmitter can be activated by entering the "transmitter" at the Matlab command prompt. BER performance has also been compared for various modulation schemes.

III. COMPARISION

There are mainly three factors that influence the choice of digital modulation system:

- Band width efficiency: number of bits per second that can be transmitted per Hertz of channel bandwidth
- Error performance: the probability of making a Bit error at the receiver, as a function of the signal-to-noise ratio
- Equipment complexity: which effectively corresponds to the cost of the system.

Table: 1 Theoretical BER over AWGN for various digital modulation techniques

$Modulation$	$Detection Method$	$Bit Error Rate\,(P_b)$
$BPSK$	$Coherent$	$0.5erfc(\sqrt{\frac{E_b}{N_0}})$
$QPSK$	$Coherent$	$0.5erfc(\sqrt{\frac{E_b}{N_0}})$
$M-PSK$	$Coherent$	$\frac{1}{m}erfc\left(\sqrt{\frac{mE_b}{N_0}}sin(\frac{\pi}{M})\right)$
$M-QAM(m=even)$	$Coherent$	$\frac{2}{m}\left(1-\frac{1}{\sqrt{M}}\right)erfc(\sqrt{\frac{3mE_b}{2(M-1)N_0}})$
$D-BPSK$	$Non-coherent$	$0.5e^{-\frac{E_b}{N_0}}$
$D-QPSK$	$Non-coherent$	$Q_1(a,b)-0.5I_0(ab)e^{-0.5(a^2+b^2)}$ $where\ a=\sqrt{\frac{2E_b}{N_0}\left(1-\frac{1}{\sqrt{2}}\right)}$ $b=\sqrt{\frac{2E_b}{N_0}\left(1+\frac{1}{\sqrt{2}}\right)}$ $Q_1(a,b)=$ Marcum Q -function $I_0(ab)=$ Modified Bessel-function

We took up some bandwidth-efficient digital modulation techniques (BPSK, QPSK and QAM) and compare its performance based on their theoretical BER over AWGN.

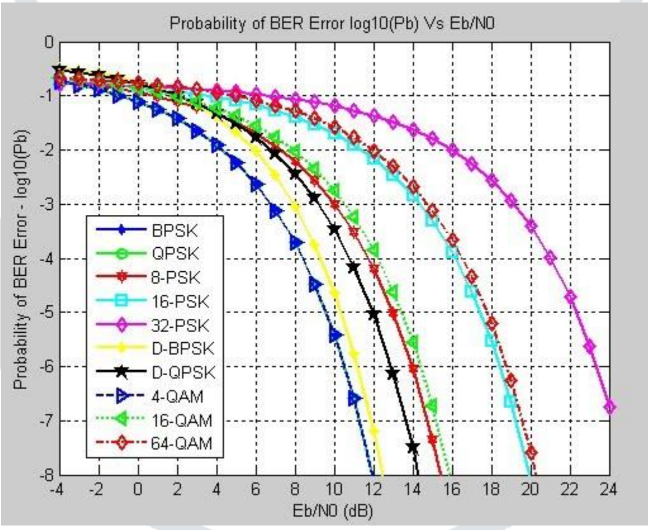

Figure 8:BER comparison of various techniques

IV. CONCLUSIONS

The development of an interactive and user-friendly environment for digital modulation systems has been presented. These techniques are compared on the basis of various parameters like bits transmitted per symbol, bandwidth efficiency, detection method, BER and SINR. Normally PSK and FSK methods have less noise interference.

The design of the developed environment is made flexible to accommodate any future modifications and enhancements to customize various teaching scenarios. Features, like bandwidth calculations, prompting the user for a particular input and reading data files from memory can be incorporated to make this GUI much more resourceful. The MATLAB also has a facility to provide the environment so that students can simulate the performance of various digital modulation techniques.

REFERENCES

[1] Taub & Schilling, Principles Of Communication Systems, Tata Mcgraw-Hill Publishing Company Limited

[2] Auslander, D.M., Ridgely, J. R. and Ringgenberg, J. D. (2002). Control Software for Mechanical Systems: Object- Oriented Design in a Real-Time World, Prentice-Hall.

[3] Azad, A. K. M. and Tokhi, M. O. (2003). An interactive environment for simulation and control of flexible manipulator systems, Proceedings of the 9th IEEE International Conference on Emerging Technologies and Factory Automation, Calouste Gulbenkian Foundation, Lisbon, Portugal, 16-19 September.

[4] Chen, Y-C and Naughton, J. M. (2000). An undergraduate laboratory platform for control system design, simulation, and implementation, IEEE Control System Magazine, June 2000, 12-20.

[5] Mathworks (2001). Creating Graphical User Interface, MathWorks Incorporated, MA, USA.

[6] Marchand, R. and Holland, O. T. (2003). Graphics and GUIs with MATLAB, Chapman and Hall/CRC.
[7] Miller, G. M. and Beasley, J. S. (2002). Modern Electronic Communication, 7th Edition, Prentice Hall, New Jersey.
[8] Penfield, P. and Larson, R. C. (1996). Education via advanced technologies, IEEE Transactions on Education, 39(3), 436-443.
[9] Tokhi, M.O., Azad, A.K.M. and Powrwanto, H. (1999). SCEFMAS: A simulink environment for dynamic characterization and control of flexible manipulators, International Journal of Engineering Education, 15(3), 213-226.