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Digital Modulation Techniques Using MATLAB Script file and Graphical Approach

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Abstract: The major building block of any communication system is modulation. In communication system, analog and digital modulation techniques are commonly used. But presently, analog modulation techniques are getting replaced by digital modulation techniques due to many advantages such as noise immunity and increasing shortage of wireless communication channels. Out of many popular digital modulation techniques, Quadrature amplitude modulation (QAM) has been widely adopted because of its large bandwidth and power efficiency. In this paper, M-ary QAM is implemented using simulink model with different setting of parameters for different blocks such as random generator, QAM modulation and demodulation, AWGN channel etc. Using same model, other different modulation techniques can be designed and implemented.
Keywords: modulation, communication, Quadrature amplitude modulation (QAM), MATLAB, simulink

Introduction

Communication stands for transferring of information from source to destination through some medium. It is necessary to strengthen the signal to travel long distance. This process of strengthen the signal is called modulation. The strengthening of signal is done by varying one of characteristics of carrier signal such as amplitude or frequency or phase according to the instantaneous amplitude of the baseband signal/modulating signal. Broadly modulation can be classified into analog and digital modulation. Baseband signal is converted to Radio Frequency (RF) modulated signal, but in analog modulation these RF communication signals are continuous range of values, whereas in digital modulation these are prearranged discrete states. Classification of analog and digital modulation techniques are illustrated in fig.1.

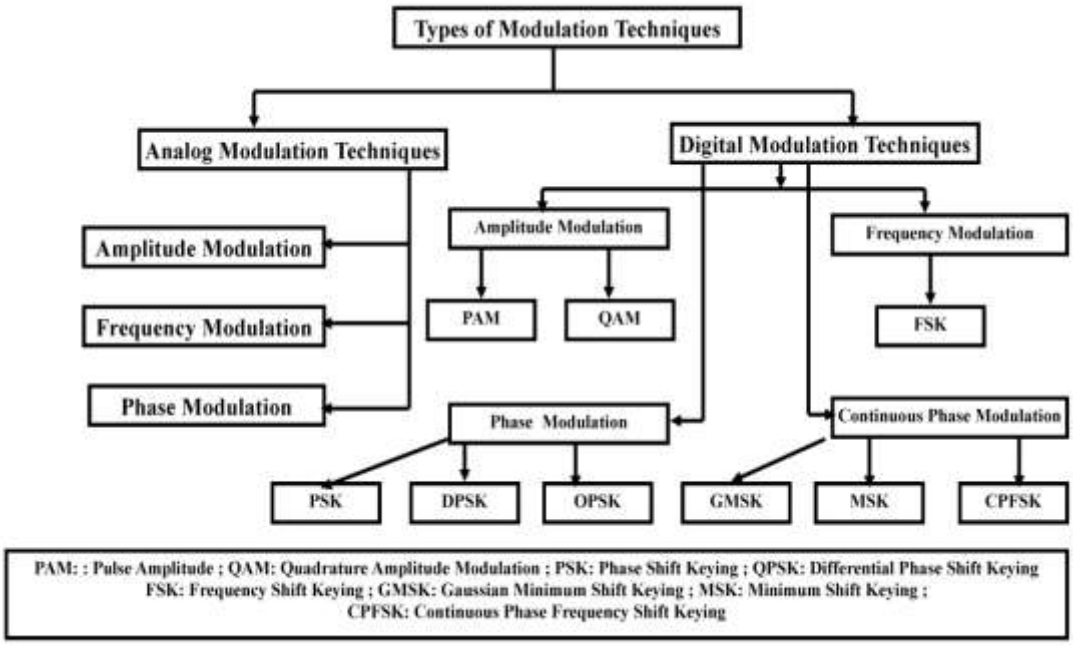

Figure 1. Classification of Analog and Digital Modulation Techniques

Teaching mathematical intensive modulation techniques to undergraduate students pose a great confront to instructors. Students have to indulge a lot of time to understand the mathematical concepts involved in these modulation techniques. However, traditional class room teaching method suffers from lower students' learning activity, poor education efficiency and poor understanding of mathematical concepts. To cope with this problem, different alternative techniques may be adopted to teach modulation techniques. In this paper, we

provide an efficient and effective method for teaching digital and analog modulation to undergraduate students which almost independent of strong foundation in mathematics. The method used in this paper is project based method (PBM) replacing traditional trainer kit laboratory method since simulation based experimental environment can play pivotal role towards the understanding of subject matter[1-2]. The approach used in this paper utilities MATLAB package, SIMULINK, and GUIDE to simulate modulation techniques avoiding the derivation of any mathematics formulations.

The rest of the paper is organized as follow: In section 2, review of some of analog and digital modulation techniques are presented. Section 3 discusses some of importance of utilizing MATLAB and SIMULINK offered in MATLAB to study modulation techniques. Section 4 shows simulated results and its Graphical User Interface (GUI) application to teach modulation techniques and section 5 concludes the paper.

Classification of Analog Modulation Techniques:

In this section, we will review some of most dominating analog and digital modulation techniques which are used in different fields such as communications, military and satellite communications. Modulation techniques can be classified into two categories i.e analog and digital modulation techniques are shown in fig.1. Table 1 illustrates major characteristics/ comparison of analog modulation techniques

Table1: Comparison between Different analog modulation techniques

Function	Amplitude Modulation	Frequency Modulation	Phase Modulation
Definition	The amplitude of the carrier signal varies in accordance with the message signal, and other factors like phase and frequency remain constant.	In this type of modulation, the frequency of the carrier signal varies in accordance with the message signal, and other parameters like amplitude and phase remain constant.	In this type of modulation, the phase of the carrier signal varies in accordance with the message signal.
Carrier Frequency	Phase and frequency of carrier signal remain constant	Phase and amplitude of carrier signal remain constant	amplitude of carrier signal remain constant but frequency is affected
Mathematical Expression	$v(t) = [A_c + A_M \cos(2\pi f_m t)] \cos(2\mu f_c t)$	$v(t) = A_c \cos(2\pi f_C t) + \beta \sin(2\mu f_M t))$	$v(t) = A_c \cos(2\pi f_C t) + \beta \cos(2\mu f_M t)$
Modulation index	Modulation index is the ratio of A_M and A_c. $\mu = \frac{A_M}{A_C}$	Modulation index is proportional to modulating signal m(t) as well as modulating frequency f_m. $\beta = \frac{K_f A_M}{f_M}$	Modulation index is proportional to modulating signal m(t). $\beta = K_p A_M$
MATLAB Inbuilt Function	ammod	fmmod	pmmod
Types	• Quadrature **Amplitude Modulation** (QAM) • Single sideband (SSB) • Vestigial sideband (VSB) • Double Sideband Suppressed Carrier(DSB SC)	• Narrow Band FM-modulation index is less than one • Wideband FM-modulation index is greater than one	• PSK - **Phase** Shift Keying. • BPSK - Binary **Phase** Shift Keying. • QPSK - Quadrature **Phase** Shift Keying. • 8 PSK - 8 Point **Phase** Shift Keying.
Applications	computer modems, VHF aircraft radio, and in portable two-way radio , AM Radio and TV broadcasting	FM broadcasting, Radio Broadcasting, Direct Satellite Broadcasting radar, radio and telemetry	Mobile Communications, WiFi, and satellite television

Classification of Digital Modulation Techniques:

Today, we have witnessed a major transition in communication field. It occurred because simple analog Amplitude Modulation (AM) and Frequency/Phase Modulation (FM/PM) is replaced by newly developed digital modulation techniques. In digital modulation technique, discrete signal is used for modulating the carrier signal. The digital modulation techniques can be classified as shown in figure 2.

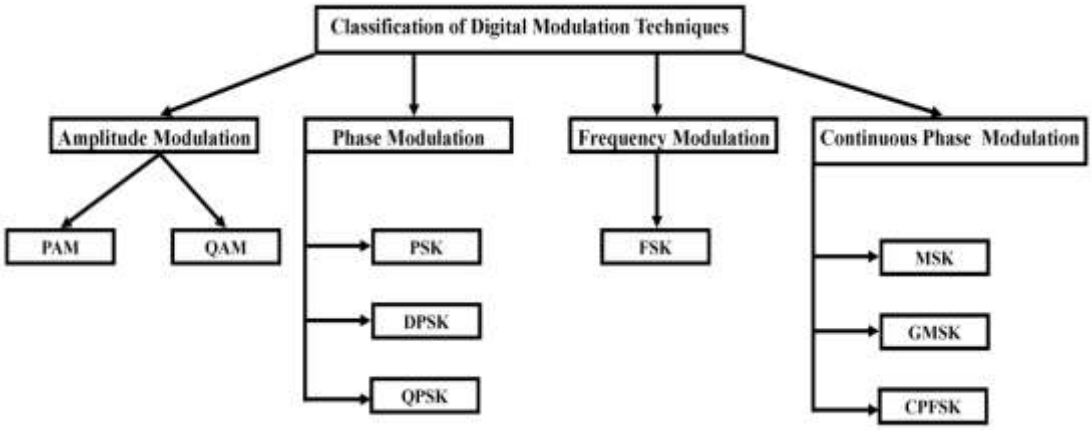

Figure 2. Classification of Digital Modulation Techniques

Digital modulation techniques are used for getting an efficient and better quality with high noise immunity as well as permissible power. In these techniques, a message signal is first converted into digital signal and then it is modulated by using carrier signal. The type of digital modulation is decided depending upon the various parameters of carrier signal like amplitude, phase and frequency.

Digital Modulation Techniques Teaching Using MATLAB Script/Simulink Model

MATLAB i s most widely used commercial mathematical software developed by Math Works Inc. mainly consists of two parts, MATLAB and Simulink. It has numerous function modules along with many tool boxes with following advantages such as programming efficiency, strong portability, simple language and efficient matrix and array operations making it popular among teachers and students to learn themselves. In this section, we will try to implement some of digital modulation techniques for better understanding which involves lots of mathematical in their theory which is difficult to understand by undergraduate students. These toolboxes widen MATLAB's capabilities into application specific domains. One of toolbox which will be used in this paper is communication toolbox which can be used in designing of various communications system such analog and digital communication system. Simulink also similar to toolbox in its functionality but Simulink is design tool. In the next paragraph, some examples using MATLAB and Simulink are presented for teaching principles of digital modulation techniques.

Implementation of Digital modulation Techniques

In this section, M-ary QAM modulation and demodulation techniques is studied using Simulink model. In M-ary QAM modulation, amplitude and the phase of the carrier signal are concurrently changed according to the message information needed to transmit. M-ary QAM can be mathematically represented as

$\boldsymbol{V_{k,l}(t) = A_k(2\pi f_c t + \theta_l)}$ **,** where the amplitude of signal isA_k, θ_l is phase of signal and f_c is the frequency of carrier signal. This digital technique is most widely used in radio communications with many variants such 16-QAM, 32-QAM and 64-QAM etc. Due to its large utility, M-ary QAM modulation technique is studied in this paper and factors which affect its performance are studied and compared with theoretical results. The Simulink model of M-ary QAM is shown in figure 3. The model is developed using various blocks present in various libraries of toolboxes. The model is simulated for 100 sec. The parameter setting of various blocks is done as per requirement of M-ary QAM with $M=2^k$ where k is an integer. The Simunik model simulated and the simulated results are shown in figure 4, 5 and 6 respectively.

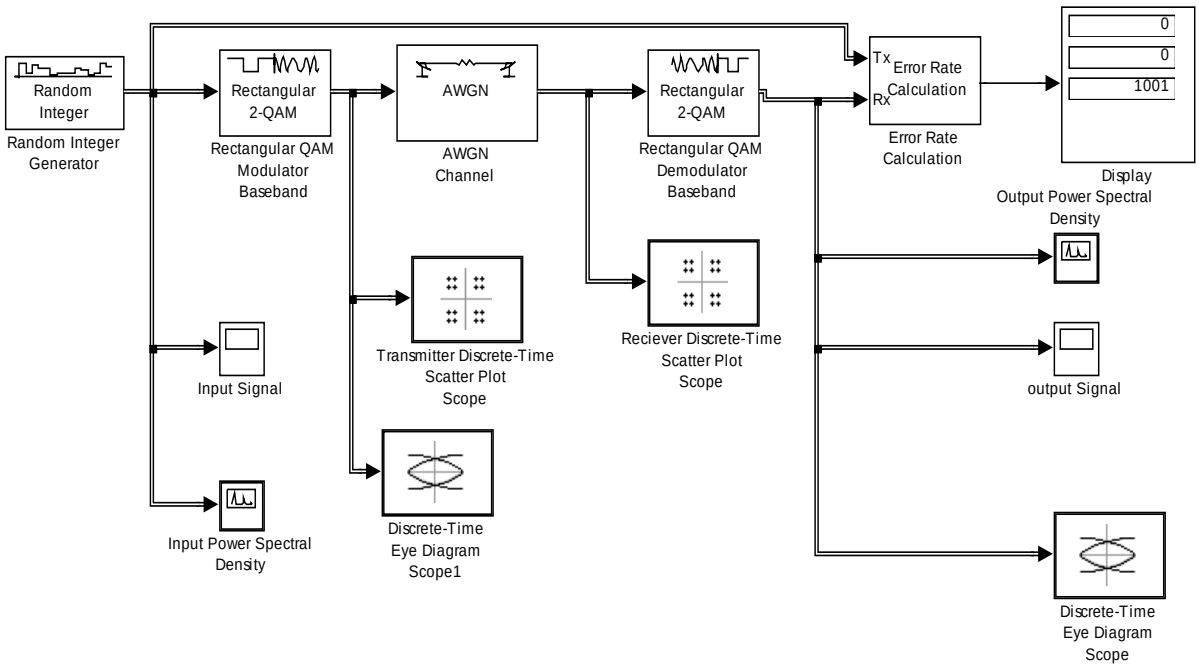

Figure 3. Simulink Model for Digital Modulation Technique

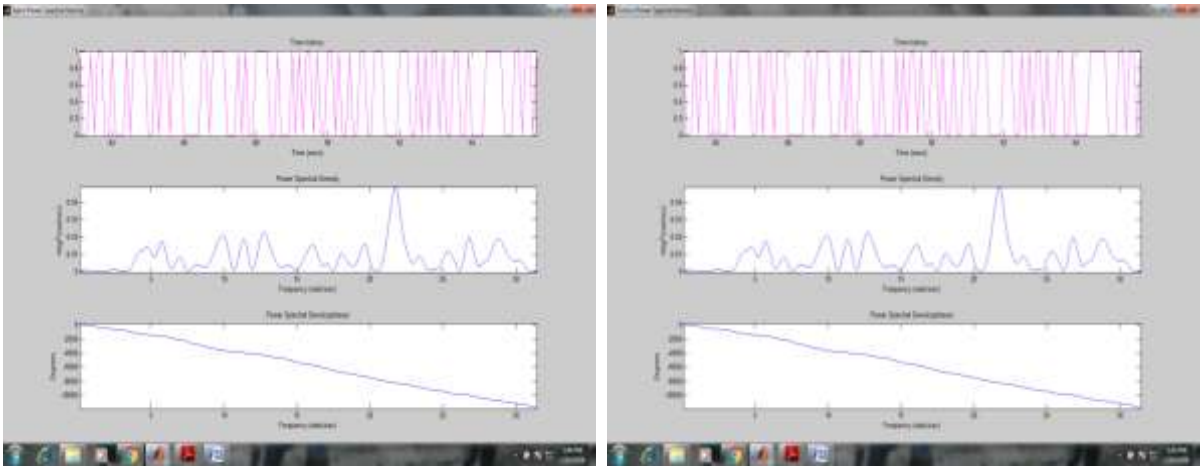

Figure 4. Input and Output Power Spectral Density for 2-QAM Modulation

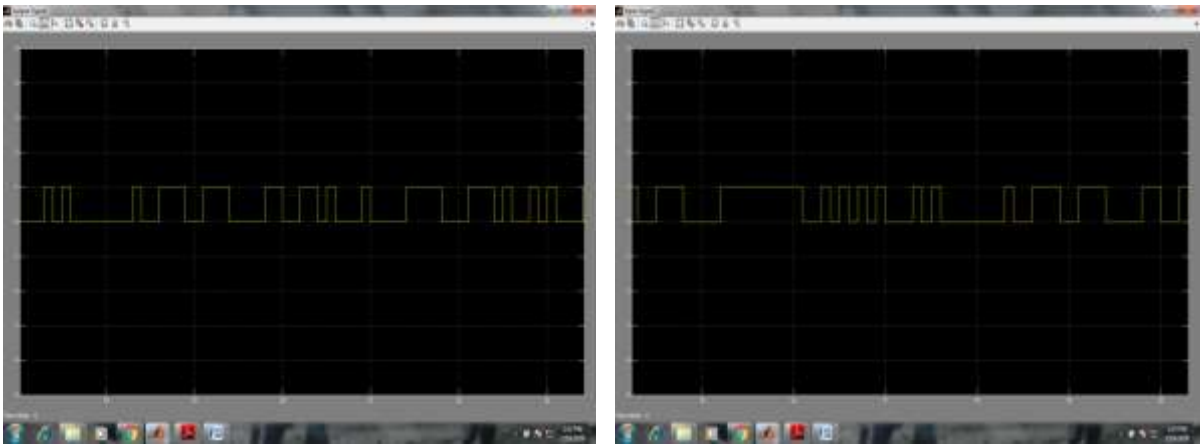

Figure 5. Output and Input message received after demodulation and modulation of M-ary QAM

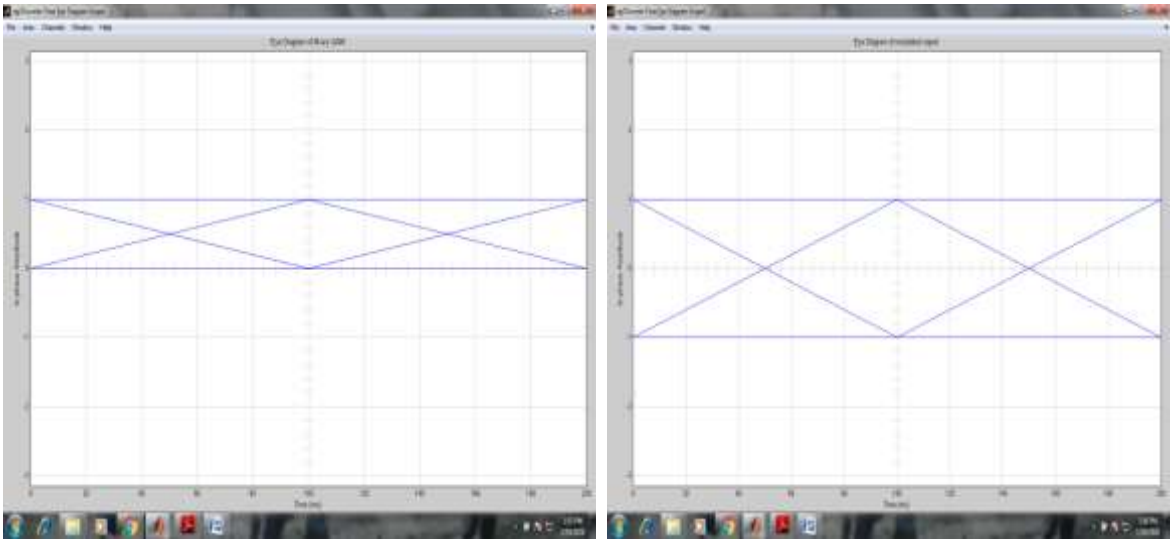

Figure 6. Eye Diagram after demodulation and modulation of M-ary QAM

Conclusion

One of most powerful tool used for simulation of various problems related to communication systems, control system, digital signal processing, mathematics, image processing etc is obviously MATLAB/Simulik. In this paper, we have build a simulink model to implement M-ary QAM and try to show that simulated results are almost comparable to theoretical results. This helps the students to understand the concepts of digital modulation techniques and same criteria may be used to design and implement other modulation techniques.

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