STRUCTURE, ANALYSIS, AND CLASSIFICATION OF THE OPTIMUM SYSTEM FOR ELECTRONIC COMMUNICATION

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Abstract: For a particular device or setup, a sound communication system made up of the required essential components is very important in the event of any practical communication-related problem formulation. As a result, the design and analysis of the various communication systems are crucial since they have a direct impact on the functionality of the device and expose the system's innate ability to deliver the required results. In this regard, the design and study of various digital communication systems is the subject of this essay. The goal is to identify the most efficient system, taking into account all relevant factors, and to apply it to significant communication-related issues and circumstances. In the next section, we'll mostly concentrate on the various systems' design procedures, the theory behind them, the findings of the simulations, a few unique error-correction strategies, and the systems' error performance.

Keywords: **Modulation, Electronic Communication Systems, Shift Keying, Error Performance, Optimum System**

1.0 Introduction

A crucial and essential component of today's study in the field of wireless communication is digital communication systems. This is because, when compared to the conventional systems currently in place, these digital systems typically display greater performance in terms of bandwidth, noise performance, power consumption, and, most crucially for digital transmission, the error performance involved. The modulation method and the related demodulation are important elements in a typical digital system. Binary Amplitude Shift Keying (BASK), Binary Phase Shift Keying (BPSK), Binary Frequency Shift Keying (BFSK), Quadrature Phase Shift Keying (QPSK), and some more modified variants of the aforementioned are some of the different digital modulation methods that are available. Given the abundance of these schemes, it is crucial to effectively design these systems and analyze their performance in terms of various parameters in order to determine the best communication system that would deliver the desired result with an optimized value for each of the performance parameters, i.e., the least amount of error at the lowest amount of signal to noise ratio (SNR) with the least amount of bandwidth for a noisy channel. The design and analysis of an optimum digital communication system for wireless applications will be the focus of this lecture. In order to choose the optimal scheme, we will primarily focus on the waveforms and designs of the BASK, BFSK, and BPSK schemes as well as a brief look at the QPSK system.

Following is a discussion of the report's flow. Section I provides a detailed explanation of the theoretical underpinnings of our research, including information on various communication systems and the modulation and demodulation algorithms involved. In section II, a review of the literature on the subject was covered. It also gave some insight into the concepts behind several pertinent publications. We have talked about the work that we have really completed, and in this regard, we have talked about the design practices that we have used for various systems and the crucial elements that are needed for them, which are listed in section III. In the next section, we have included a brief analysis of the various systems as well as the waveforms and different plots that we have obtained from each design. Finally, we have discussed our conclusions from the work we have done in the conclusion section.

1.1 Theoretical Context

The techniques of amplitude modulation (AM), frequency modulation (FM), and phase modulation (PM), which vary one of the fundamental properties of a high frequency carrier signal in accordance with the instantaneous changes in the low frequency message signal, have long dominated the field of communication. The task at hand, however, changes significantly as we get into the digital realm because in this situation, the data is in the form of bit streams (0s and 1s), and we must use a modulation or masking technique so that, at the transmitter end, we represent the 1s as a single entity and the 0s as a separate one. To ensure proper decoding of these masks at the receiver, we must additionally take additional precautions. But as they are closely related to the amplitude, phase, and frequency properties of the carrier, it is clear that the digital modulation schemes that are currently in use also retain some elements of the conventional methods. The most well-known modulation techniques include:

1.1.1) ASK, or Amplitude Shift Keying

Amplitude-shift keying (ASK) is a type of modulation that uses variations in a carrier wave's amplitude to represent digital data. The most basic and widely used type of ASK functions as a switch, employing the presence of a carrier wave to denote a binary "1" and the absence of one to denote a binary "0." On-off keying is a method of modulation that is employed at radio frequencies (also known as continuous wave operation) to transmit Morse code. Similar to AM, ASK is linear and susceptible to environmental factors such as ambient noise, distortions, and differing PSTN routes' propagation conditions. The procedures for ASK modulation and demodulation are both reasonably priced. Digital data transmission over optical fiber also frequently use the ASK method. Binary 0 and binary 1 are both represented by the absence of light in LED transmitters, respectively. Normal laser transmitters emit low light levels due to a fixed bias current in the device. This low level corresponds to binary 0, while the binary 1 light wave has a bigger amplitude. This modulation technique performs about averagely, and noise has a significant impact on it. The demodulator, which is created specifically for the symbol-set that the modulator uses, measures the received signal's amplitude and converts it back to the symbol it represents, retrieving the original data while maintaining the carrier's frequency and phase constants.

1.1.2) FSK, or Frequency Shift Keying

The frequency modulation technique known as frequency-shift keying (FSK) transmits digital information by discretely changing the frequency of a carrier wave. Binary FSK (BFSK) is the simplest kind of FSK. BFSK transmits binary (0s and 1s) data using a pair of discrete frequencies. The "1" in this technique is known as the mark frequency, while the "0" is known as the space frequency.

In comparison to phase modulated signals, demodulation of FSK signals is a little more challenging since the decision boundary is placed in a less-than-ideal location on the constellation plot, namely at 45 degrees on the complex plane (1st quadrant). As a result, locations that are close to the boundary run the risk of delivering inaccurate results, which makes the system unstable.

1.1.3) PSK, or Phase Shift Keying

Phase-shift keying (PSK) is a modulation technique that transmits data by modifying the phase of a carrier wave, which serves as a reference signal. There are a limited number of phases in PSK, each with its own particular bit pattern. Each phase typically encodes an equal number of bits. Each bit pattern creates a symbol that corresponds to a specific phase. Determining the phase of the received signal and mapping it back to the symbol it represents, the demodulator, which was created specifically for the symbol-set used by the modulator, recovers the original data. The PSK scheme known as M-ary PSK comes in a variety of forms. Here, we shall limit our investigation to one of two formats:

a) Binary Phase Shift Keying (BPSK)

BPSK is the most basic type of phase shift keying (PSK), also known as Phase Reversal Keying (PRK) or 2PSK. It utilizes two phases that are 180 degrees apart, and is hence also known as 2-PSK. It makes no difference exactly where the constellation's points are located. This modulation is the most durable of the PSKs because it requires the most noise or distortion to get the demodulator to make a bad judgment call. However, because it can only modulate at 1 bit per symbol (as seen in the diagram), it cannot handle high data rates. Here, M is equal to 2. The following equation is the general form for BPSK:

$$s_n(t) = \sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t + \pi(1-n)), n = 0, 1.$$

This yields two phases, 0 and π. In the specific form, binary data is often conveyed with the following signals:

$$s_0(t) = \sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t + \pi) = -\sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t)$$

For binary ‘0’

For binary ‘1’

where f_c is the frequency of the carrier-wave.

$$s_1(t) = \sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t)$$

b) QPSK, or Quadrature Phase Shift Keying

Quaternary PSK, quadriphase PSK, 4-PSK, and 4-QAM are some other names for it. (Although the fundamental ideas behind QPSK and 4-QAM are dissimilar, the modulated radio waves that arise are the same.) On the constellation diagram, QPSK makes use of four evenly spaced points. QPSK can encode two bits per symbol with four phases. M has a value of 4 in this case. The use of QPSK denotes the use of higher-order PSK and is more widespread than the use of BPSK. Writing the stars in the diagram’s symbols in terms of the sine and cosine waves that carried them:

$$s_n(t) = \sqrt{\frac{2E_s}{T_s}}\cos\left(2\pi f_c t + (2n-1)\frac{\pi}{4}\right), \quad n = 1,2,3,4.$$

This yields the four phases π/4, 3π/4, 5π/4 and 7π/4 as needed.

Because the M-PSK scheme has lower error probability than the other shift keying techniques because to the advantageous constellation plots and decision bounds, we have focused more on the phase shifting scheme in this discussion. Additionally, because di-bit systems like QPSK and others at a higher level of PSK offer larger data rates, they can be used for high-speed transmission while still maintaining the bandwidth of the signals. Additionally, by maintaining the same data rate as BPSK, we can cut the necessary effective bandwidth in half. We can see from the aforementioned comments that M-PSK systems have distinct benefits over the other shift keying strategies, which is why we have placed more emphasis on this system. The practical design of the systems has proven this theoretical description to be accurate.

2.0 Some Literature Review

There has been a great deal of research and work done over the years on this part of the design of a sound communication system because the design and analysis of digital modulation schemes is a very important issue of discussion in the field of communication. We have also read through some of these proposed works while conducting our design and analysis to obtain a sense of the various methodologies used:

The OFDM system combined with Trellis Coded Modulation (TCM) for TV broadcasting is a very significant modulation technique that has been presented by Mr. Saito and coauthors. This system has the ability to transmit a large number of bits at a higher rate while maintaining almost constant error performance. Additionally, the transmission has undergone testing in a variety of reception environments, and carrier recovery is not necessary.Mr. Smithson spoke on digital modulation techniques and provided a detailed overview of each one. In his presentation, he makes the argument that there is no such thing as the optimum communication system or scheme; rather, everything depends on factors including the channel characteristics, the needed error performance, the availability of BW, and the goal cost for creating the hardware. Any solution that best satisfies these criteria while minimizing trade-offs emerges as the final option for a specific communication issue.

Mr. Alfred O. Hero presented the Digital Modulation Classification Technique based on Power Moment Matrices and suggested a novel strategy based on the recently created pattern recognition system to distinguish between the various M-ary PSK systems with respect to noise performance. This method uses a matrix to facilitate the Eigen decomposition process. Images in greyscale have used the method. Applying noise to the photos in this case and then breaking them down into eigenvalues. Then, it is input into many systems, and analysis is done to see which system can restore the image the closest to its ideal form.

3.0 Consistent Work

As described in the previous part, we have created a sound system for communication that would best satisfy the requirements for noise, error performance, bandwidth demand, hardware difficulty, and the SNR requirement, among others. As a result, we have done the analysis and developing of the numerous systems for this. Additionally, we are working on building some additional systems that are pertinent as we attempt to compare them all to determine which is best. The AWGN channel is the one we've been using. The details of three of the schemes that we successfully carried out are as follows:-

B.)BASK System: Design Methodology:

• Data input takes the form of a bit stream.

• It is changed into a digital signal with a pulse shape.

• Use a sinusoidal carrier to modulate the pulse.

• At specific SNR ranges, the channel response is added to it.

• Coherent demodulation is used to isolate the message signal from the carrier.

• The output pulse for the receiver is decided using a certain threshold check logic.

• Bit streams from the input and output are compared.

C.) BPSK Bit Streams are Acceptable as Input in the System's Creation Procedure.

• Changed into a pulse-signal format.

• Changed into a signal with polar pulses.

• Modulated using the right sinusoid.

• The AWGN channel receives the signal at its maximum SNR.

Separating the message from the carrier by coherent demodulation.

• The energy corresponding to the symbols is computed over the bit period.

• We identify which symbol represents bit 0 and which one represents bit 1 using a threshold check logic.

• Bit streams from the input and output are compared.

D.) BFSK System: Design Methodology:

• The input terminals accept bit streams.

• Changed into a pulse-signal format.

• Encoding is complete, or we may say that a control switch activity is happening.

• The data is modulated using two separate frequencies, one high indicating high and the other low.

• One output including both modulation outputs.

• The AWGN channel receives the signal.

• The receiver performs comparable processes including coherent demodulation, symbol representation as a signed value, and threshold testing.

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It Compares the Input and Output Pulses.

Note: We are attempting to create a di-bit QPSK system in order to optimize BW. We are not revealing the design process in this discussion since we have not yet been successful in fully implementing this concept. However, we were pleased with the baseband QPSK version of the results. We have therefore provided the outcomes for them in the following section.

3.0 Result and Conversation

We have examined the output waveforms for the various systems we have designed thus far in this section, as well as performed a performance study on the various schemes.

BASK System, E.

After designing the BASK system, we obtained the following findings and examined the system's functionality, which are displayed in Figure 1:

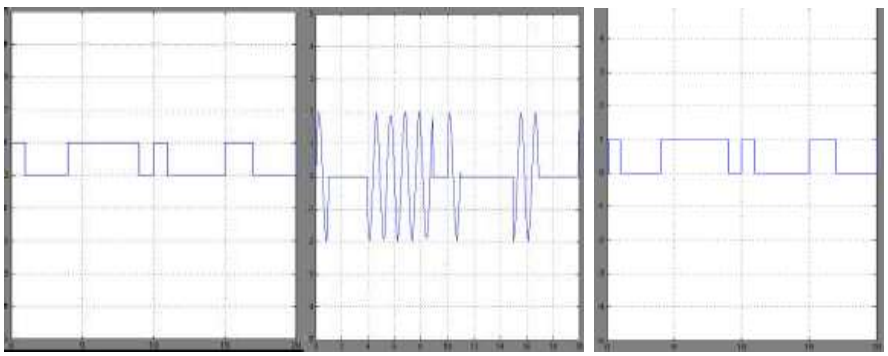

Figure 1.1 Figure 1.2 Figure1.3

Figure 1: 1.1: Input Signal, Modulated signal, Output signal

We can see from Figure 1 that the input and output pulses are identical. One KHz sinusoidal carrier is used for the modulation. The drawback of this system is that it performs poorly at low SNR levels and finds it challenging to function in real-world settings at very high SNR values. This occurs mostly because the existence or absence of a signal determines the output, and hence, during decoding, a small amount of noise can transform a bit 0 to a 1.

F. BPSK System: After designing the BPSK system, we evaluated its performance and obtained the findings displayed in Figure 2:

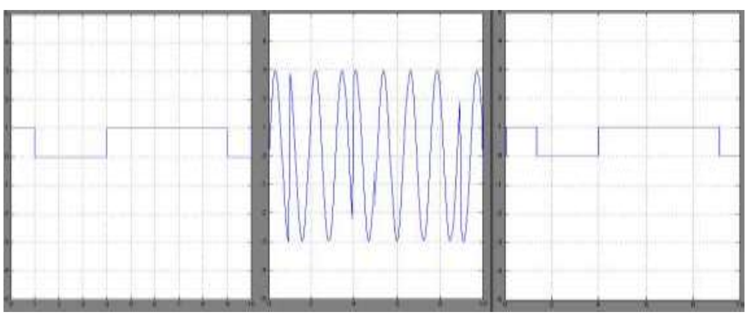

Figure 2.1 Figure 2.2 Figure 2.3

Figure 2: 2.1: Input Signal, Modulated Signal, Output Signal

1. The input and output pulses are identical as illustrated.

2. To account for an appropriate decision boundary, the bipolar pulse is generated with two different signed values of signal energy.

3. The modulation employs a carrier signal of 10 kHz.

4. The system has the advantage that the demodulation is accurate at low SNR since the decision boundary is extremely clear and depends on the sign assigned to each signal.

5. It is a single-bit system, hence the BW needed is larger.

6. The signal with the lowest error probability is the phase modulated signal.

G. BFSK System: After designing the BFSK system, we obtained the findings given in Figure 3 and performed an analysis of the system's efficiency:

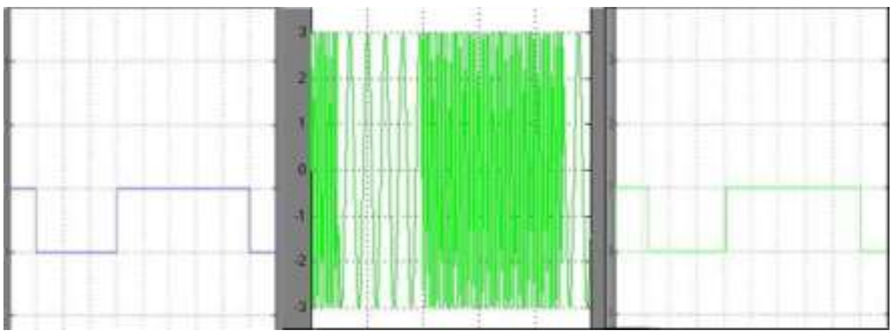

Figure3.1 Figure 3.2 Figure3.3

Figure 3: 3.1: Input Signal, Modulated signal, Output signal

The BFSK system has a performance that is ordinary. It performs better than the BASK system. However, compared to the BPSK system, the probability of error is higher. because its two extreme points are located on the y-axis and x-axis, respectively. Therefore, the odds of error are higher for BFSK than BPSK when the sign is near the diagonal. The system is therefore less stable. Additionally, it is a single-bit system with a high BW need.

H. QPSK Baseband Modulation: After developing the QPSK Baseband system, we examined its performance and obtained the results displayed in Figure 4, which are as follows:

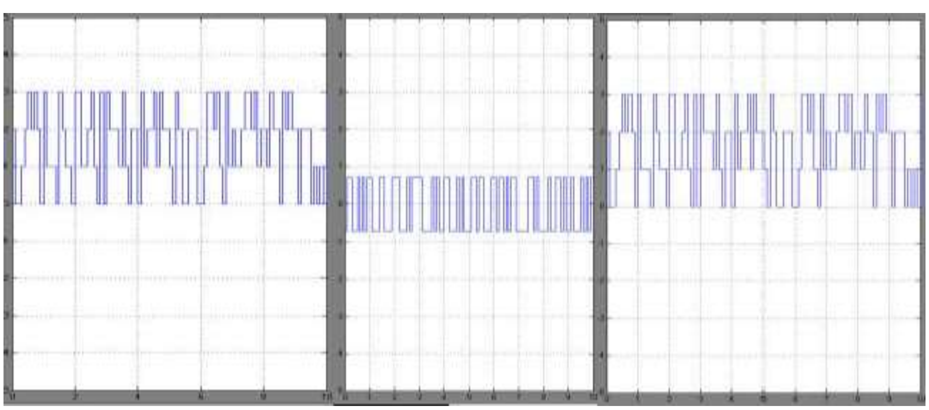

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Figure 4.1 Figure4.2 Figure 4.3

Figure4: 4.1: Input Signal, Modulated Signal, Output signal

- **Power spectral Density plot:**

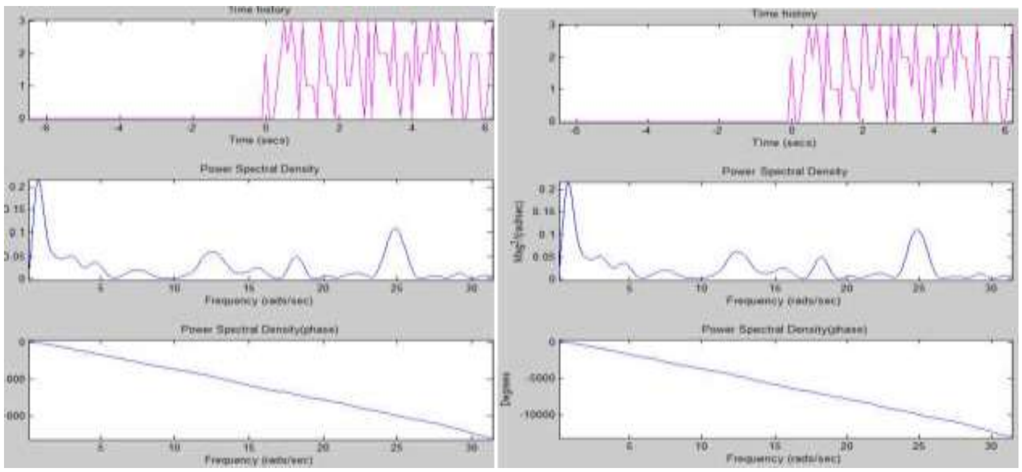

Figure5.1 Figure5.2

Figure5: Power Spectral Density plot

- **Constellation Plots:**

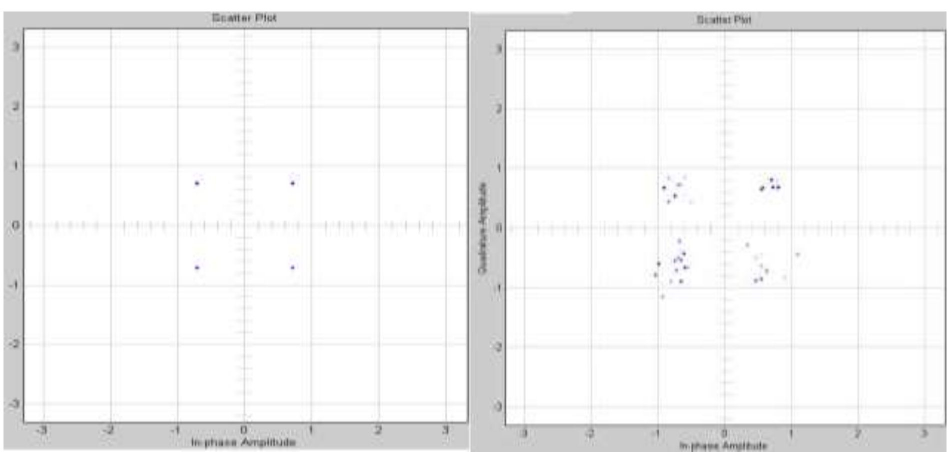

Figure6: 6.1: Coordinate of energy level6.2: Scatter Plot

Figures 5 and 6 indicate that the QPSK system exhibits very outstanding performance at baseband level analysis alone. As a result, it is simple to forecast how it would behave when a carrier modulation was added. We are attempting to develop the passband model for this communication system with this viewpoint in mind. But so far, we haven't been successful.

4.0 Conclusion

We want to make some inferences about our previous work in this section. As previously mentioned, we designed and studied the BASK, BPSK, BFSK, and partially the QPSK systems. After doing this, we can state that the Phase Shift Keying systems are more stable and perform better in terms of the likelihood of errors, the impact of noise, as well as bit rate and bandwidth. The BPSK system's appropriate constellation diagram and decision boundary, which lead to proper decoding, are substantially to blame for this. Additionally, the fact that QPSK is a two-bit system aids in nearly double the bit rate of BPSK.

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