EE451 PROJECT PROGRESS REPORT 2

Students: Harun Durmuş **Student ID's:** 270206025 **Date:** 30.11.2023

Mustafa Eren Çelebi 270206053

Necmettin Yiğit Dübek 260206049

Abstract

This progress report heavily includes the theoretical parts of modulation, channel and demodulation explanations. Brief explanations for each part are made and strengthen with figures. Determining modulation type was the crucial part that effects next steps. Channel and demodulation decision is made according to the selected modulation type. Since it is decided to apply B-PSK modulation, which is also given in the lectures recently, channel is determined as wireless because of the effectiveness of bandpass transmission and B-PSK in wireless channels. Therefore, demodulation of the signal to be processed is choosen according to B-PSK for compatibility.

Modulation

Basic Concepts of Digital Modulation

Digital modulation[1] is a process used in telecommunications to transfer a digital bit stream over an analog communication channel. This method involves modifying the properties of a carrier wave - such as amplitude, frequency, or phase - to encode digital information. The primary aim of digital modulation is to translate digital data into a form suitable for reliable transmission through a physical medium, typically radio waves, cables, or optical fibers.

Overview of Different Modulation Types: ASK, FSK, and PSK

Digital modulation encompasses various techniques, each with its unique characteristics and applications.

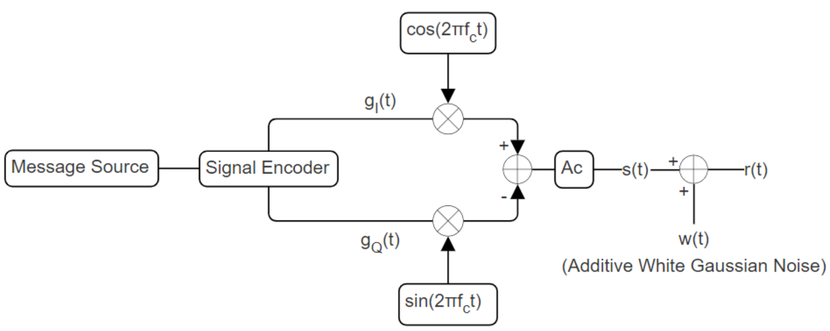

Figure 1: General Representation of Modulation

In the figure above, structure of the modulation part in bandpass transmission is shown. Considering binary transmission, three different methods are mentioned by handling an example of binary symbols $s_0(t)$ and $s_1(t)$ below:

- Bit 0, $s_0(t)$, where $0 \leq t \leq T_b$ and also $0 \leq t \leq T_s$, where $T_b = T_s$
- Bit 1, $s_1(t)$

In the cases below $A_c = 1$ and $f_c = 2000$ Hz assumptions are made for obtaining plot figures.

Amplitude Shift Keying (ASK): Amplitude Shift Keying (ASK) is a modulation technique where the amplitude of the carrier wave is varied in direct proportion to the digital data being transmitted. This method encodes binary data: a high amplitude of the carrier wave represents a binary '1', while a low amplitude represents a binary '0'. ASK is straightforward and cost-effective, making it suitable for applications where complexity and cost need to be minimized, such as in RFID systems and infrared remote controls. However, its major drawback is its susceptibility to noise and interference, as amplitude variations can be easily distorted, leading to errors in the received signal. This limitation makes ASK less ideal for noisy environments or long-distance transmission.

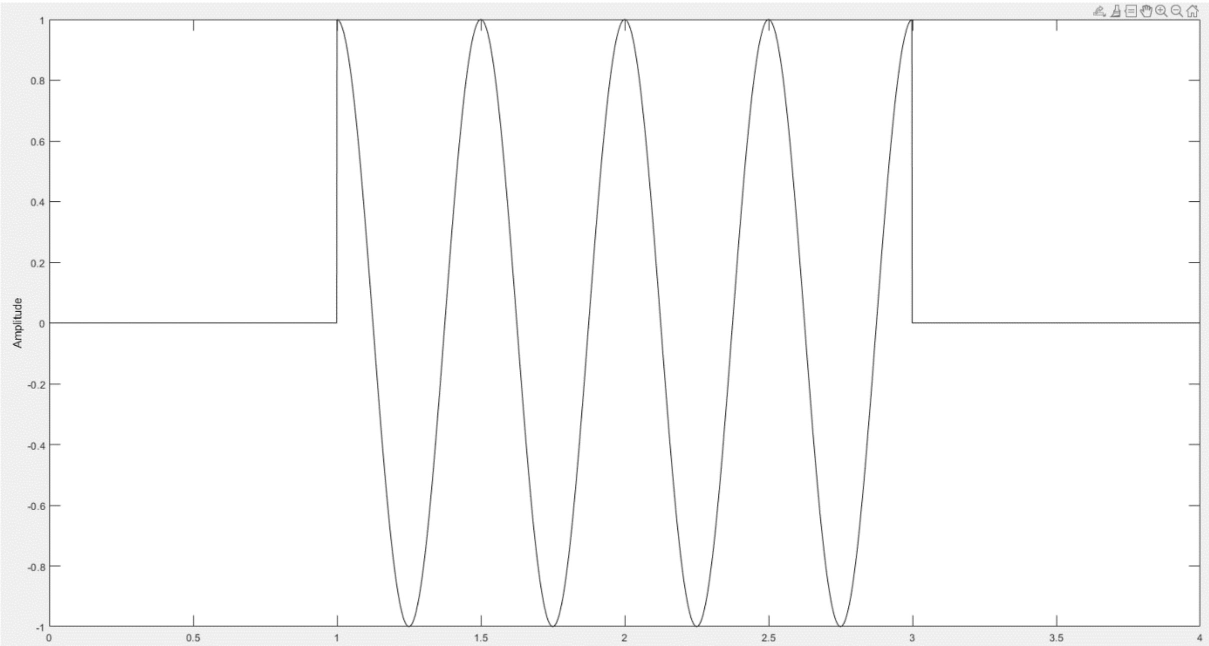

Figure 2: On-Off Keying with B-ASK[3]

Orthonormal basis functions for the case can be calculated as below and used for signal constellation in further steps:

- $Ø_1(t) = (2/T_b)^{1/2}\cos(2\pi f_c t)$

Frequency Shift Keying (FSK): Frequency Shift Keying (FSK) is a digital modulation technique in which the frequency of the carrier wave is varied to represent the digital data. Unlike ASK, FSK does not alter the amplitude but instead shifts between different frequencies to denote binary '1s' and '0s'. This feature makes FSK more resistant to signal amplitude noise, thus more reliable in noisy environments compared to ASK. FSK is widely used in applications like traditional radio systems, caller ID systems, and modem technology. Its resilience to noise and ability to operate effectively over various transmission media make it a versatile choice. However, it generally requires a larger bandwidth than ASK, which can be a limiting factor in bandwidth-constrained systems.

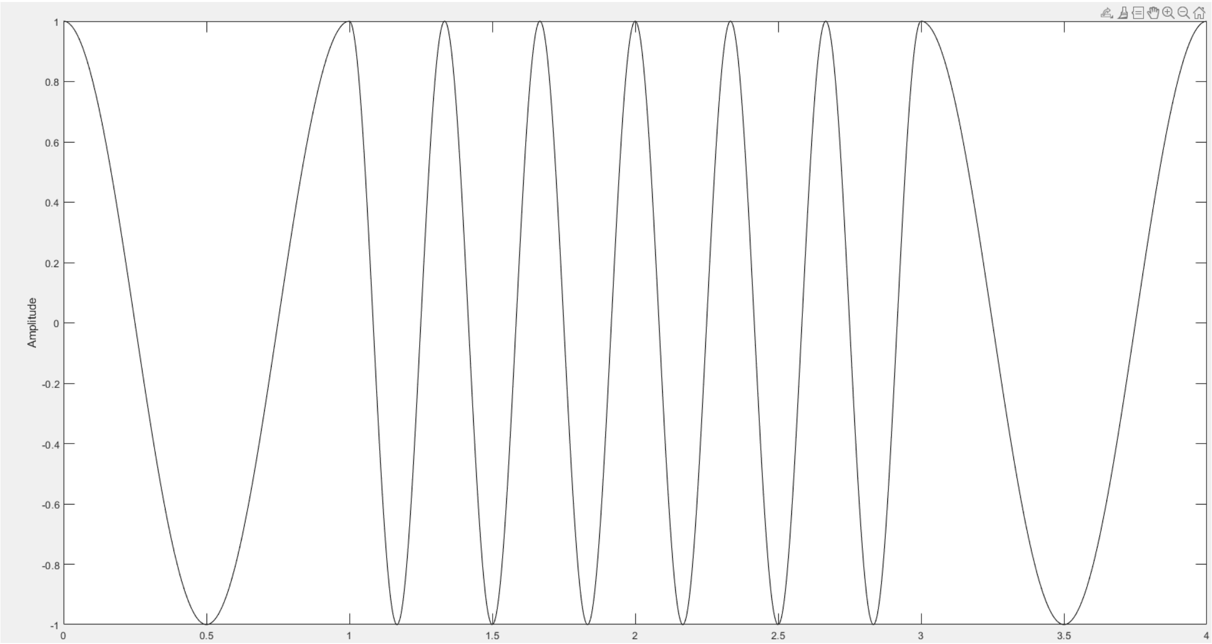

Figure 3: Signal Representation by using B-FSK[3]

- $\text{Ø}_0(t) = (2/T_b)^{1/2}\cos(2\pi f_0 t)$
- $\text{Ø}_1(t) = (2/T_b)^{1/2}\cos(2\pi f_1 t)$

There are two basis functions.

Phase Shift Keying (PSK): Phase Shift Keying (PSK) is a form of digital modulation that involves changing the phase of the carrier wave to convey information. The phase of the carrier signal is shifted in relation to the baseline or unmodulated signal to represent the digital data. PSK is more bandwidth-efficient than both ASK and FSK and offers a higher noise immunity, making it well-suited for high-data-rate applications in wireless communication. The simplest form of PSK is Binary PSK, where only two phase shifts are used, each representing a binary digit. PSK is widely used in technologies like Wi-Fi, RFID, and Bluetooth, where maintaining signal integrity in the presence of noise is crucial. Its main challenge is in the receiver design, which must accurately detect phase changes, a task that becomes more complex in environments with signal reflection and fading.

- $\text{Ø}_1(t) = (2/T_b)^{1/2}\cos(2\pi f_c t)$

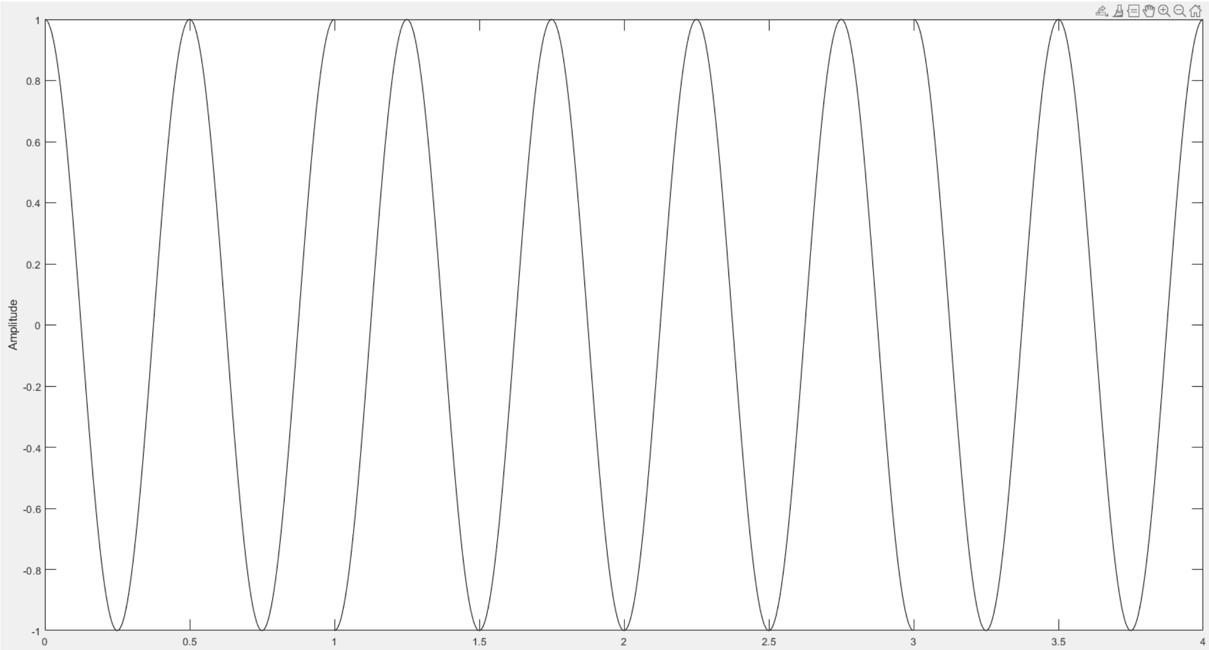

Figure 4: Signal Representation by using B-PSK[3]

Obtaining the signal constellation graphs from the calculated orthonormal basis functions for each method, it is observed that B-PSK is the best method since the probability of error is minimum in that case, assuming variance of the noise components are same.

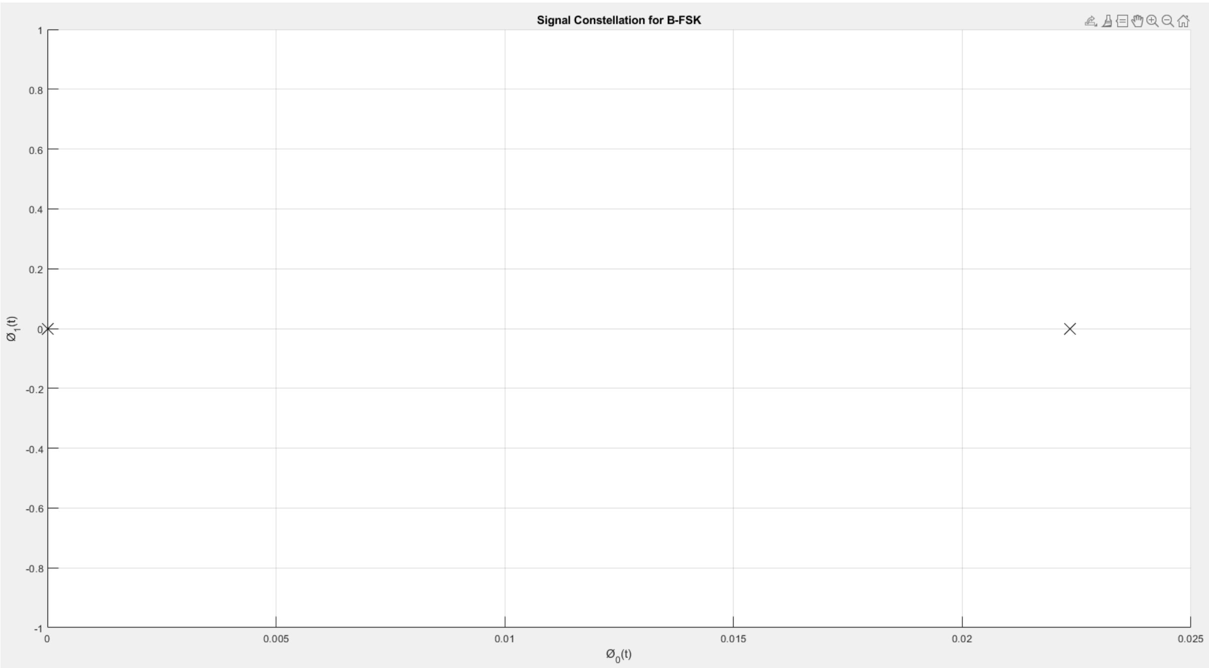

Figure 5: Signal Constellation for B-ASK[4]

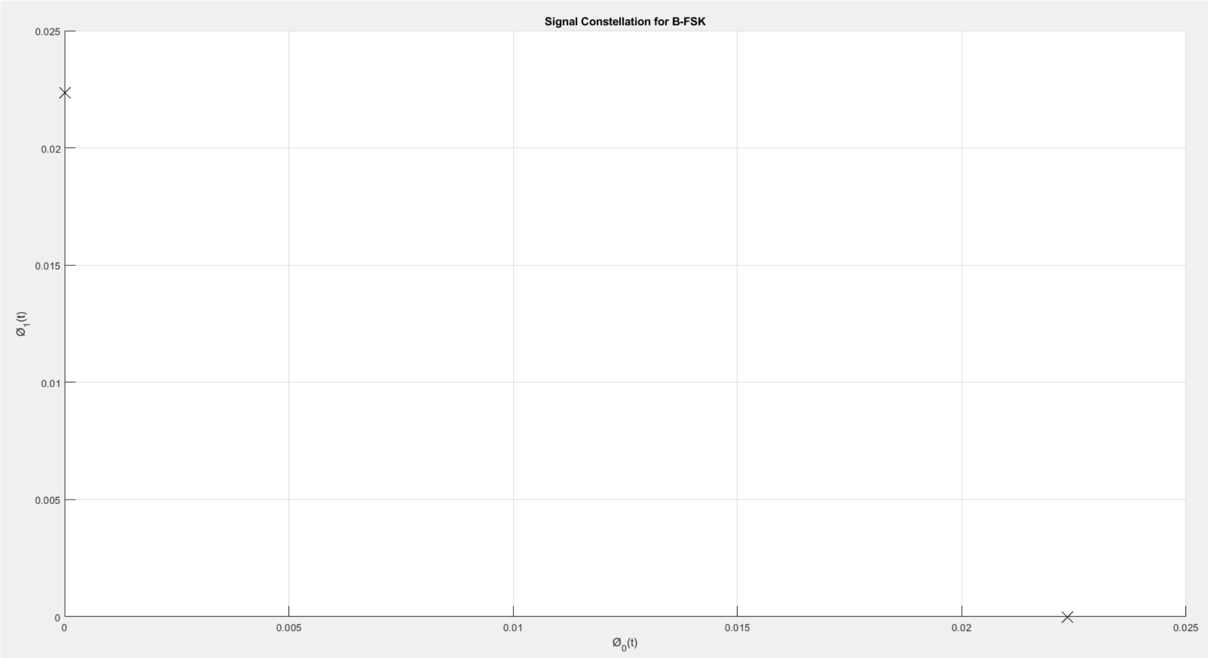

Figure 6: Signal Constellation for B-FSK[5]

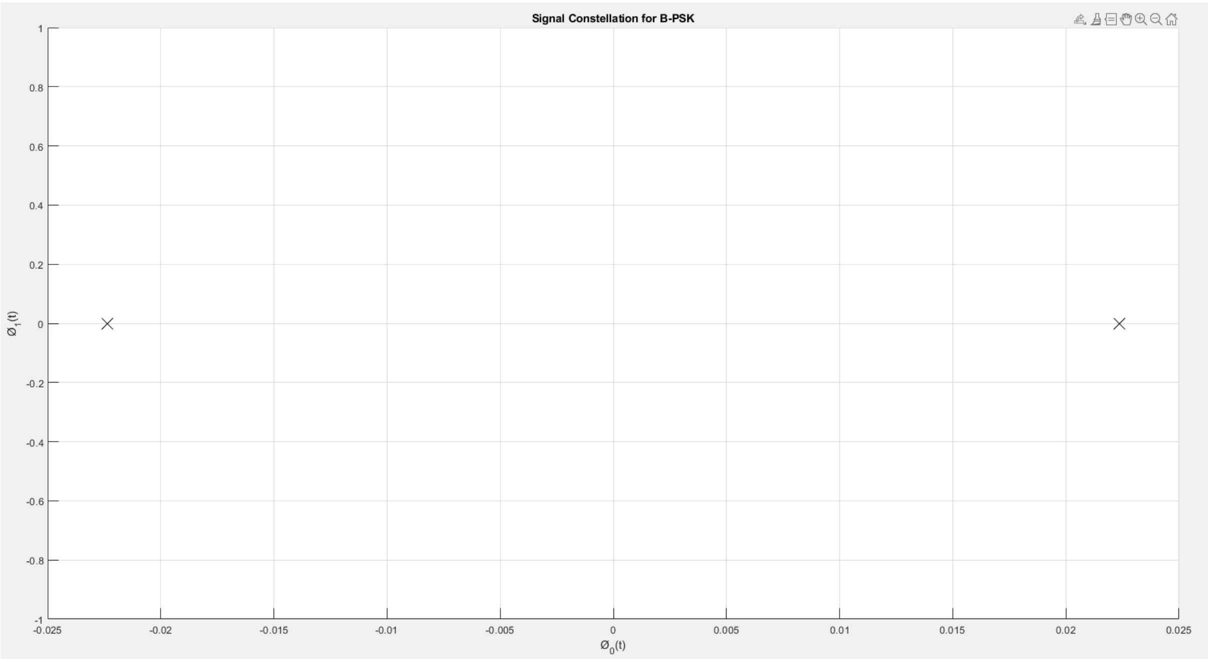

Figure 7: Signal Constellation for B-PSK[6]

- $\sqrt{Eb} < \sqrt{(2Eb)} < 2\sqrt{Eb}$

Since the maximum distance of between energies of two bits $s_0(t)$ and $s_1(t)$ in signal constellation is $2\sqrt{Eb}$ which is obtained with B-PSK, the minimum error will be occur. Probability of error can be calculated by using Q functions.

Channel

In communication systems [2], a channel refers to the medium through which information is transmitted from a sender to a receiver. This medium can take various forms, depending on the type of communication system. Here are a few examples:

Wire or Cable: In wired communication systems, such as traditional telephone networks or Ethernet connections, the channel is typically a physical wire or cable that carries electrical signals.

Wireless Medium: In wireless communication systems, like mobile networks or Wi-Fi, the channel is the air or space through which radio waves or electromagnetic signals travel.

Fiber Optic Cable: In optical communication systems, data is transmitted using light signals through fiber optic cables. Here, the channel is the optical fiber.

Satellite Link: In satellite communication, the channel involves the transmission of signals between ground stations and satellites or between different satellites.

Underwater Cable: In underwater communication systems, such as those used for submarine communication, the channel is the submerged cable.

The channel is a crucial concept in communication theory, and the characteristics of the channel can have a significant impact on the quality and reliability of the communication. Factors such as noise, interference, and bandwidth limitations can affect how well information is transmitted through the channel. Engineers and researchers study these factors to design communication systems that can effectively overcome challenges and deliver reliable and efficient communication.

AWGN Channel:

Characteristics: This channel introduces random additive noise to the transmitted signal, simulating the effects of various environmental interferences in communication systems.

Example: In digital communication systems, the AWGN channel can represent the cumulative impact of thermal noise, electronic interference, and other unpredictable factors. For instance, in wireless communication, AWGN may model the collective impact of atmospheric noise, electronic device interference, and other random disturbances that affect the clarity of the received signal.

Rayleigh Fading Channel:

Characteristics: This channel introduces random amplitude variations to the transmitted signal, simulating the effects of multipath propagation in wireless communication.

Example: Mobile communication in urban environments where signals can be reflected off buildings, causing variations in signal strength.

Rician Fading Channel:

Characteristics: Similar to the Rayleigh fading channel, but with the addition of a dominant line-of-sight signal component. It models scenarios where there is a strong direct signal along with scattered signals.

Example: Wireless communication in open spaces with some obstruction, where there is a clear line of sight to the transmitter.

Frequency-Selective Fading Channel:

Characteristics: This channel experiences varying levels of attenuation and phase shifts at different frequencies. It models scenarios where the channel response varies with the frequency of the signal.

Example: High-frequency radio communication in urban areas with varying building densities, causing different frequency components to experience different levels of fading.

Nakagami Fading Channel:

Characteristics: This channel is characterized by a fading envelope that follows a Nakagami probability distribution, which can exhibit different fading severity.

Example: Underwater acoustic communication, where the signal experiences different levels of attenuation due to water conditions.

Gilbert-Elliott Channel:

Characteristics: This channel model includes both "good" and "bad" states, representing periods of reliable and unreliable transmission, respectively.

Example: Communication in a mobile network where the channel conditions may switch between good and bad states due to factors like shadowing or signal blockage.

Multipath Fading Channel:

Characteristics: This channel simulates the effects of signals arriving at the receiver through multiple paths, causing constructive and destructive interference.

Example: Indoor wireless communication where signals may reflect off walls, floors, and other surfaces, leading to multipath propagation.

Slow Fading Channel:

Characteristics: This channel experiences variations in signal strength over a relatively long period, often due to factors like vehicle movement or slow changes in the environment.

Example: Communication in a vehicular network where the channel conditions change gradually as vehicles move.

These channel models help researchers and engineers analyze and design communication systems that can perform effectively in realistic and challenging conditions.

The AWGN (Additive White Gaussian Noise) channel introduces random noise to the received signal in a communication system. Here are the key effects of the AWGN channel on the received signal:

Additive Noise: The AWGN channel adds random noise to the transmitted signal during its journey from the sender to the receiver. This noise is independent of the original signal and is considered to be unrelated to the communication process.

burda bi conclusion yazp seçimi açklayp sonra balk atmak lazm
channel etkisi diye

Signal Degradation: The noise introduced by the AWGN channel can degrade the quality of the received signal. As the noise is added to the signal, it can make it more challenging for the receiver to accurately detect and interpret the original information.

Impact on Signal-to-Noise Ratio (SNR): The quality of the received signal is often measured by the Signal-to-Noise Ratio (SNR), which is the ratio of the signal power to the noise power. In the presence of AWGN, the SNR decreases, making it more difficult for the receiver to distinguish the signal from the noise.

Bit Errors: The presence of noise in the received signal can lead to errors in the detection of individual bits. In digital communication systems, this may result in bit errors, where the received bits do not match the transmitted bits.

Reduced Communication Performance: The random nature of the Gaussian noise in the AWGN channel means that the received signal experiences fluctuations that can impact communication performance. This is especially critical in scenarios where a high level of accuracy is required, such as in data transmission or digital audio/video communication.

Uncertainty: The randomness of the noise introduces uncertainty into the received signal. This uncertainty poses a challenge for the receiver to reliably reconstruct the original information sent by the transmitter.

Despite these challenges, engineers use various techniques, such as error-correcting codes, modulation schemes, and signal processing algorithms, to mitigate the effects of AWGN and improve the reliability of communication systems in the presence of noise.

Demodulation

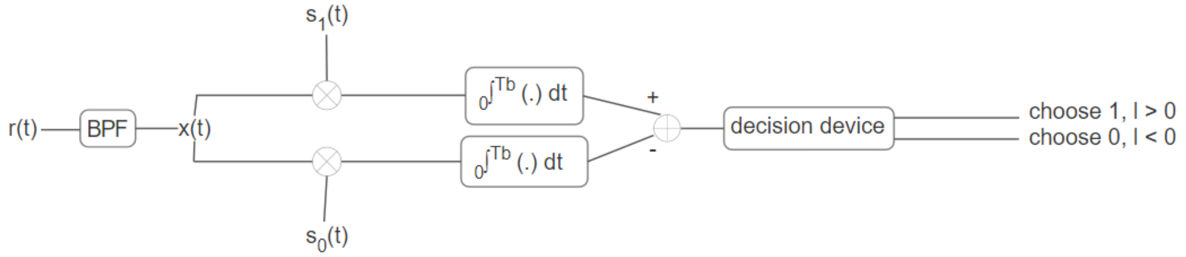

Figure 8: Demodulation Block Diagram

Considering two path correlation receiver a general case the demodulation of the B-ASK signal is described above. But for designing optimum receiver, coherent demodulation of the BPSK signal is performed at the receiver. The received signal is multiplied by a carrier with the same frequency and phase as at the transmitter, which is required for coherent demodulation. Phase synchronization is typically achieved using the Phase Locked Loop (PLL) in the receiver. However, perfect phase synchronization is assumed here, and PLL implementation is not undertaken. The block diagram of the BPSK modulator is depicted in the figure above. After multiplication with the carrier (orthonormal basis function), the signal is integrated and sampled over symbol time 'T'. Thresholding is then applied to determine whether a '1' is transmitted a '0' is transmitted.

Coherent receiver of B-PSK has only one branch for correlation since there is only one basis function.

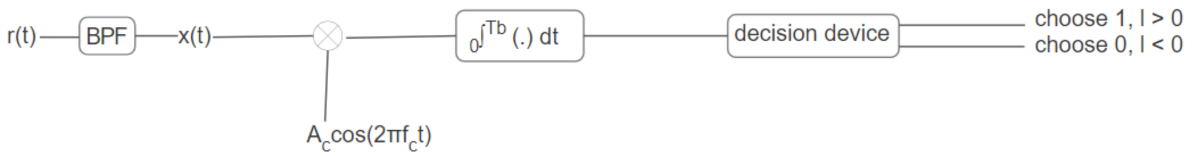

Figure 9: Coherent Detector of B-PSK

The demodulation of B-PSK signals involves several key steps. Initially, the demodulator detects the phase of the incoming signal and compares it against a reference phase. This comparison is critical to determine the binary value represented by each phase. Accurate demodulation requires precise synchronization between the transmitter and receiver to ensure that the phase comparison correctly interprets the data. Fluctuations in phase, known as phase noise, or any synchronization mismatches can lead to errors in interpreting the binary data. Despite these challenges, B-PSK remains a preferred choice due to its relative resistance to noise and efficient use of bandwidth compared to other modulation schemes like Amplitude Shift Keying (ASK).

References

[1] Proakis, John G. *Digital Communications*. 4th ed. New York: McGraw Hill, 2001.

[2] Fundamentals of Communication Systems, John G. Proakis and Masoud Salehi, 2nd edition, 2005.

Appendices

[3] MATLAB code for signal representations

```
clc;clear;close all;
tb = 1/1000;
ta= tb/1000;
t = 0:ta:(4*tb)-ta;
s=cos(2*pi*2000*t);
s(1:1000)=0;
s(3000:4000)=0;
plot(t,s,"black")
xlabel("Tb")
ylabel("Amplitude");
%%
clc;clear;close all;
tb = 1/1000;
ta= tb/1000;
t = 0:ta:(4*tb)-ta;
s1=cos(2*pi*3000*t(1001:3000));
s0_1=cos(2*pi*1000*t(1:1000));
s0_2=cos(2*pi*1000*t(3001:4000));
figure(1);
plot(t(1:1000),s0_1,"black")
hold on
plot(t(1001:3000),s1,"black")
hold on
plot(t(3001:4000),s0_2,"black")
xlabel("Tb")
ylabel("Amplitude");
%%
clc;clear;close all;
tb = 1/1000;
ta= tb/1000;
t = 0:ta:(4*tb)-ta;
s0_1= cos(2*pi*2000*t(1:1000));
s1= cos(2*pi*2000*t(1001:3000)+pi);
s0_2= cos(2*pi*2000*t(3001:4000));
figure(1);
plot(t(1:1000),s0_1,"black")
hold on
plot(t(1001:3000),s1,"black")
hold on
plot(t(3001:4000),s0_2,"black")
xlabel("Tb")
ylabel("Amplitude");
```

[4] MATLAB code for signal constellation with B-ASK

```
clc;
clear all;
%%
Fs = 1000;
Eb= (1/sqrt(2))*sqrt(1/Fs);
sz = 250;
figure(1)
scatter(0,0,sz,'x',"black");
hold on
scatter(Eb,0,sz,'x',"black");
```

```
grid on
xlabel("∅_0(t)");
ylabel("∅_1(t)");
title("Signal Constellation for B-FSK");
%%
```

[5] MATLAB code for signal constellation with B-FSK

```
clc;
clear all;
%%
Fs = 1000;
Eb= (1/sqrt(2))*sqrt(1/Fs);
fi2 = 0:0001:0.5;
fi1 = 0:0001:0.5;
sz = 250;
figure(1)
scatter(Eb,0,sz,'x',"black");
hold on
scatter(0,Eb,sz,'x',"black");
grid on
xlabel("∅_0(t)");
ylabel("∅_1(t)");
title("Signal Constellation for B-FSK");
%%
```

[6] MATLAB code for signal constellation with B-PSK

```
clc;
clear all;
%%
Fs = 1000;
Eb= (1/sqrt(2))*sqrt(1/Fs);
fi2 = 0:0001:0.5;
fi1 = 0:0001:0.5;
sz = 250;
figure(1)
scatter(-Eb,0,sz,'x',"black");
hold on
scatter(Eb,0,sz,'x',"black");
grid on
xlabel("∅_0(t)");
ylabel("∅_1(t)");
title("Signal Constellation for B-PSK");
%%
```