Dept. of Electronics and Electrical Communication Engineering
Indian Institute of Technology Kharagpur

DIGITAL COMMUNICATION LAB (EC39001)

Author: Aryan Satpathy

Roll Number: 20EC10014

Group Number: 10
Experiment Number: 3

TA Instructor:

Experiment Number: 3
Title Of Experiment: Binary Phase Shift Keying
Date Of Submission: February 5, 2023

Introduction

This experiment involves modulating a digital message signal(PN Sequence in this case) and making it comaptible for the channel. The modulation technique that we will study in particular here is **Binary Phase Shift Keying**.

Key Objectives

For this experiment, out key objectives are:

- Generate inverse of a Analog Signal(Carrier Signal).
- Use a Switching IC in order to chose between the Carrier Signal and its inverse, in order to generate the modulated signal.

Circuit Components Used

The components used for this experiment were:

- IC 74LS95B Shift Register
- IC 7486 Quad 2 input ExOR
- IC 7427 Triple 3 input NOR
- IC 7432 Quad 2 input OR
- 4 x 330Ω Resistors
- 4 LEDs
- IC 4016 Switch
- IC 741 Op-Amp
- 2 x 1KΩ Resistors

Theory

Although storing and processing digital data is very convenient for us, transmitting it is kind of an issue. Channels are only compatible to particular frequency range of signals. Other frequencies get attenuated by the channel. Additionally, Modulation and converting to an Analog Signal gives us better noise immunity than the Digital counterpart. Therefore, we need to modulate the Digital Signal using an Analog Carrier signal.

Binary Phase Shift Keying(BPSK) refers to the representing Binary digits by phase shifts in the Carrier Signal. In order to get maximum error correction capabilities, we need to keep the Phases as far as possible(more on this in the discussion). In order to represent two values: **0** and **1**, the furthest possible phase shift is 180° (π). Therefore, in this experiment we proceed with a phase shift of π.

A phase shift of π implies that the signal is inverted(or negated).

$$cos(wt + \pi) = -cos(wt)$$

Therefore first we **invert the Carrier Signal**, and then we use the **Switching IC(4016)** in order to chose between the Carrier Signal and the inverted Carrier Signal, depending on whether the digital signal is 0 or 1. An analog signal can be inverted using a Differential Amplifier(Op-Amp). Let us have a look at how it can be done.

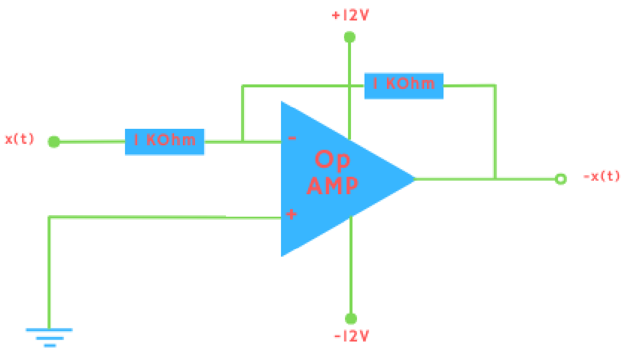


Figure 1: Inverter Circuit

Now that we have the inverted carrier signal, all we need to do is feed the Carrier Signal($x(t)$) and the inverted Carrier Signal($-x(t)$) into **IC 4016**, and use the **PN Sequence** input to **chose which output** to pick up.

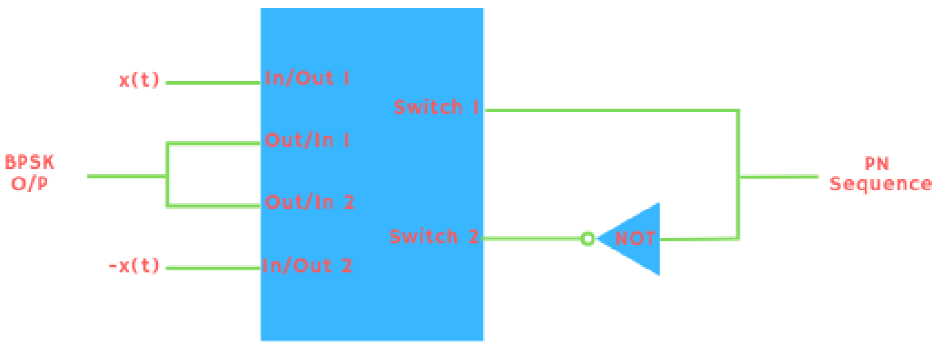
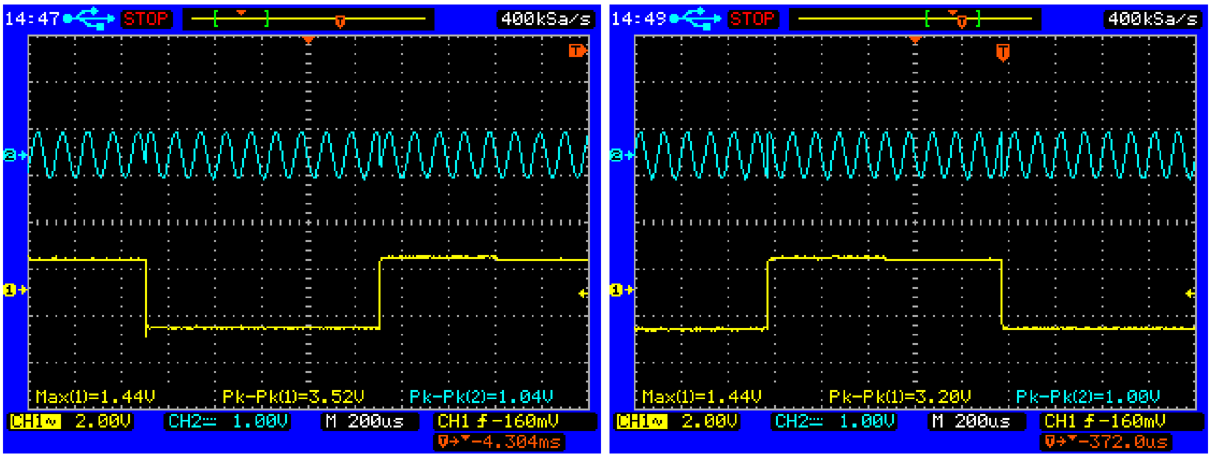


Figure 2: Overall Circuit

Results

Green Signal represents the **PN signal** which serves as our Input Digital Signal, whereas **Blue Signal** is the **Modulated/BPSK Signal**.



(a) Carrier Frequency integral multiple of Clock Frequency (b) Carrier Frequency not an integral multiple of Clock Frequency

Figure 3: Output

As we can see, when the frequency of Carrier Signal is an **integral multiple** of clock frequency, the **Phase shift occurs at 0 level**. Whereas when the Carrier Signal is **not an integral multiple** of clock frequency, the **Phase shift occurs at any random level**, and that may cause problems during demodulation.

Discussion

From this experiment, our key takeaways were:

- **Modulation**

  Modulation is defined as an operation on the Message Signal, in order to increase its compatibility the channel, and should be invertible at the Receiver's End. Inverse of the operation is called Demodulation. As we can see, BPSK is a modulation technique that modulates an Analog Signal with a Digital Signal. It introduces abrupt changes which come by in the form of **Non Differentiability**.

- **Why Phase Shift Of π?**

  The states in Modulated Signal that represent the Bits in Message Signal, need to be placed as far away from each other, as possible. This is done in order to **reduce the error probability**. Think of a **Maximum Aposterior Probability(MAP) detector**. As discussed in the class, it is established that **in order to reduce the probability of error** of the Detector's prediction, we need to either **reduce Variance of the message(Proxy for Noise)** or **separate the States further from decision threshold**. Since we cannot control the Noise, we need to try and keep the States representing the Bits, as far away from each other as possible. Maximum possible difference in phase is π.

- **Demodulation**

  This signal can be demodulated by **subtracting the signal** from the Carrier Signal, and then passing it through an **Envelope Detector**. That signal is already digital but in order to **fully Digitalize and remove error**, it can be optionally passed through a **MAP Detector**. However, we would need to generate the Carrier Signal at Receiving End.

Conclusion

In this experiment, we learnt about Binary Phase Shift Keying, circuit required to generate it, its properties and importance.

References

- Digital Communication Theory Class Notes
- Wikipedia
- ChatGPT
- Lab Manual