An analysis of the Analog and Digital Communication using Simulink

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In this document, a detailed report of the various aspects of the communication systems including its components and methods of signal modification using Matlab's Simulink tool.

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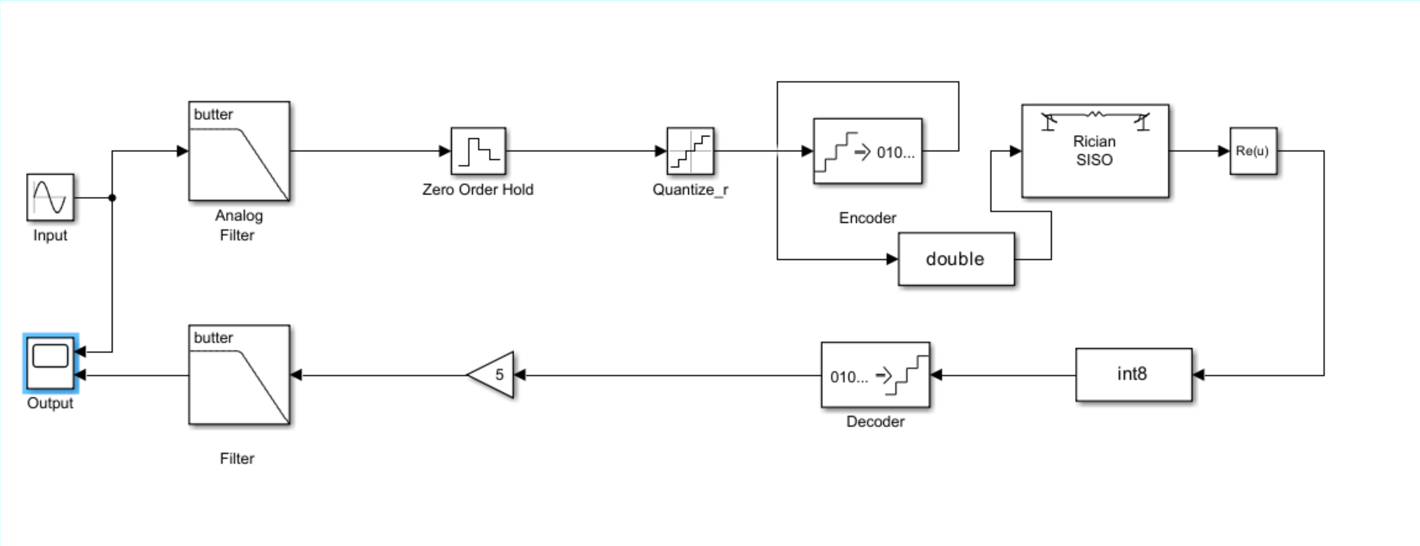
EXPERIMENT-1

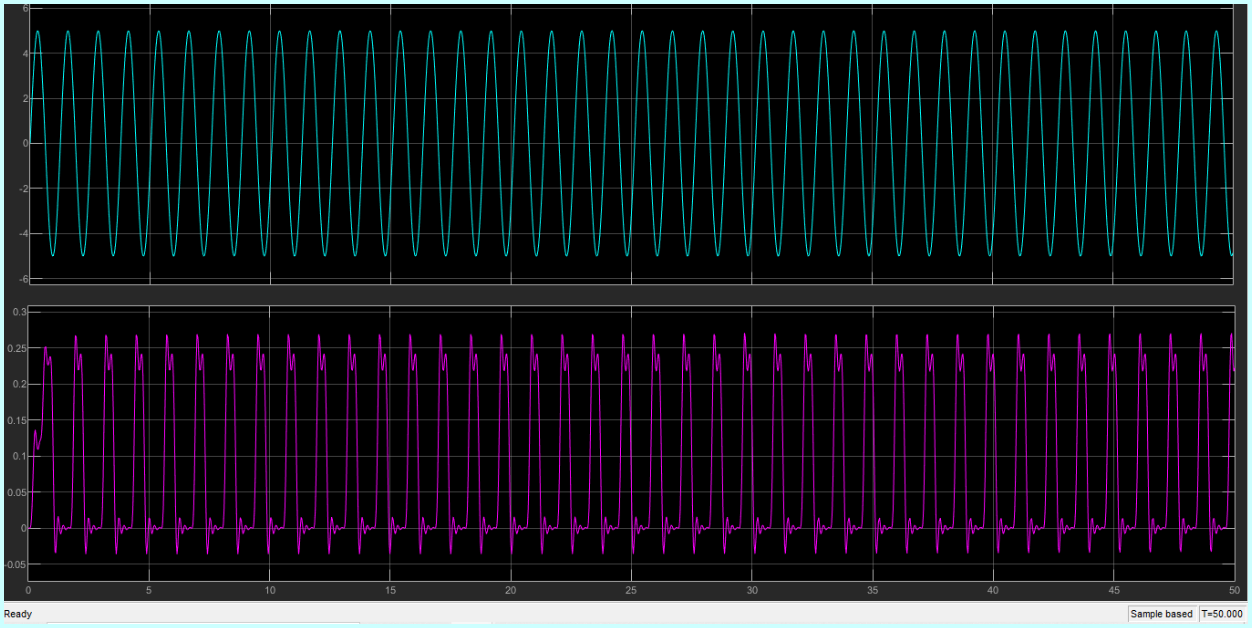
Aim: To analyze Analog Communication System.

Simulink Block Diagram:



Simulation:

Input



Output

Learning:

Using various modules such as the Zero Order Hold, Filters and Encoder, decoders a sample of an advanced Analog Communication System can be illustrated.

It contains all the basic elements required. i.e: Source, Sink, Channel, encoder and decoder.

Control Parameters:

- Input:
  - Frequency
  - Phase
  - Amplitude
- Analog Filter:
  - Filter Order
  - Bandpass/Lowpass/Highpass
  - Design Method
- Zero order Hold
- Quantizer
- Encoder
- Channel:
  - Input Power:
  - Gain:
  - Loss:
  - Noise

- **Input: Frequency, Phase, Amplitude -** Essential parameters dictating the characteristics of analog signals, influencing transmission quality and reception fidelity.

- **Analog Filter:** Filter Order, Bandpass/Lowpass/Highpass, Design Method - Determine the frequency response and attenuation characteristics crucial for shaping and refining analog signals, ensuring desired bandwidth and signal integrity.

- **Zero Order Hold:** A method for converting continuous signals into discrete form, preserving signal values at specific intervals, crucial for accurate representation and transmission in analog systems.

- **Quantizer:** Converts analog signals into digital format by discretizing amplitude levels, affecting signal resolution and fidelity during transmission and reception.

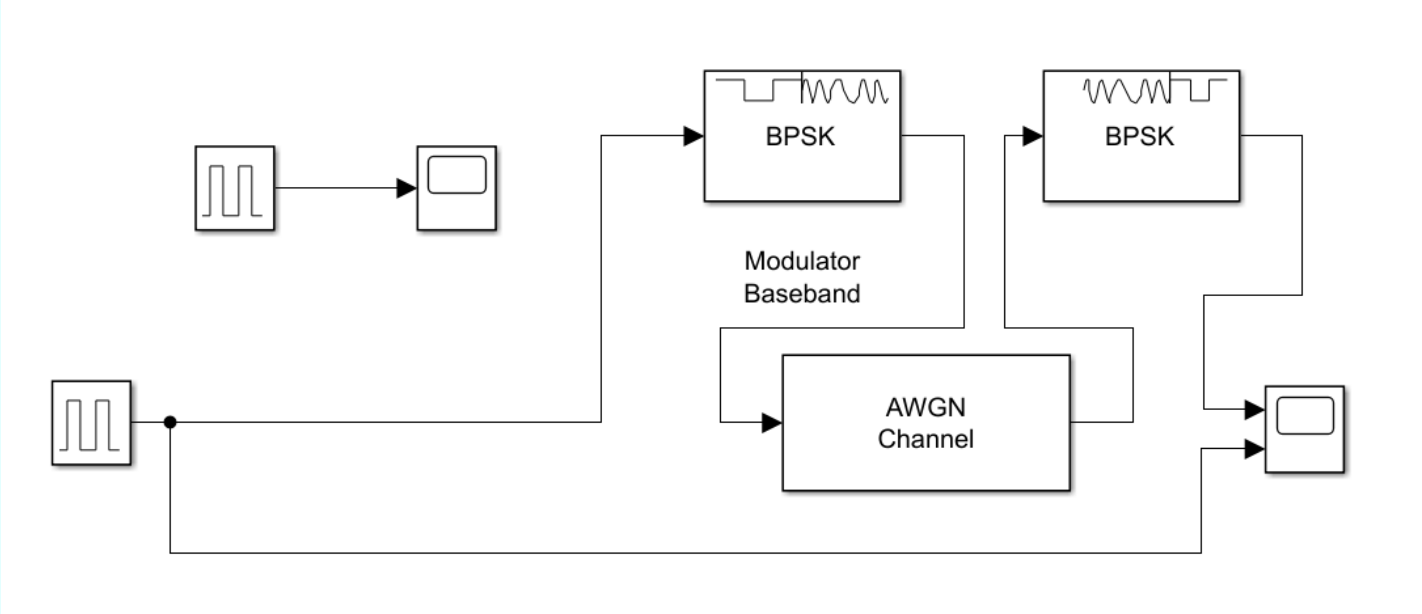
- **Encoder:** Encodes analog signals into digital data, employing various techniques like pulse code modulation (PCM) or differential pulse code modulation (DPCM), facilitating efficient transmission and decoding.

- **Channel: Input Power, Gain, Loss, Noise -** Parameters defining the behavior of the communication medium, influencing signal strength, fidelity, and susceptibility to noise, crucial for reliable analog signal transmission.

EXPERIMENT-2

Aim: To analyze Digital Communication System.

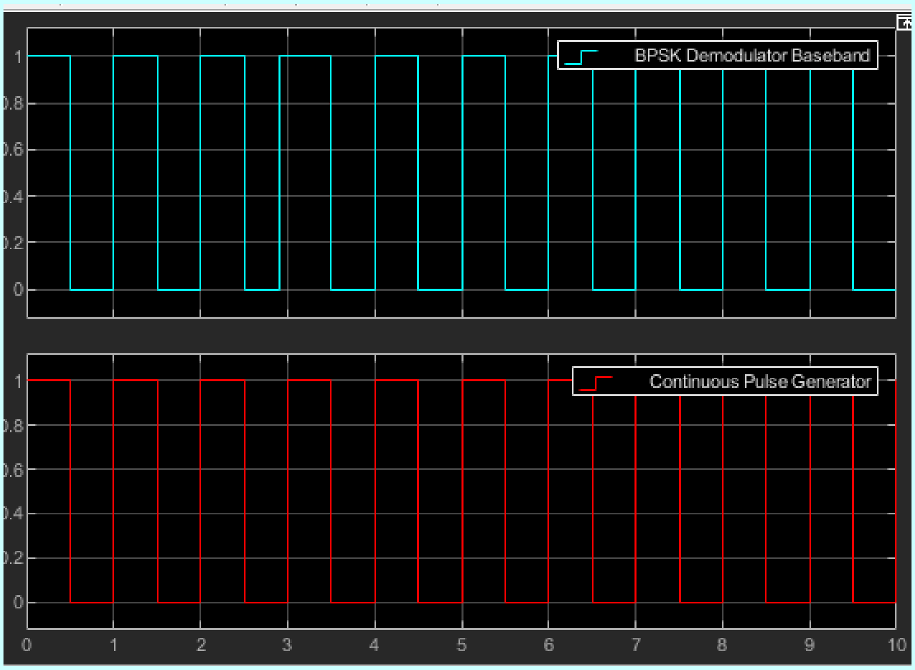
Simulink Block Diagram:



Simulation:

Input

Output



Learning:

Unlike Analog Communication, Digital Communication system is pretty simple and more efficient in terms of error free output. Also, it requires far less components and energy to transmit the same amount of informa6ion.

Control Parameters:

- Input:
  - Pulse Width
  - Pulse Rate
  - Amplitude
- Modulation
- Channel
- Repeaters

- **Pulse Width:** Shorter pulse width enables faster data transmission but increases susceptibility to noise, necessitating robust error correction methods.

- **Pulse Rate:** Higher pulse rates allow for more data transmission within the same time frame, but may require more bandwidth and can be more prone to interference.

- **Amplitude:** Increased amplitude improves signal strength and extends communication range, yet it demands more power and raises the risk of distortion.

- **Modulation:** Encoding digital data onto carrier signals optimizes transmission efficiency, with choices like AM, FM, or PM influencing data rates and noise resilience.

- **Channel:** The medium through which signals travel, channels vary in characteristics like bandwidth and noise, impacting signal quality and transmission reliability.

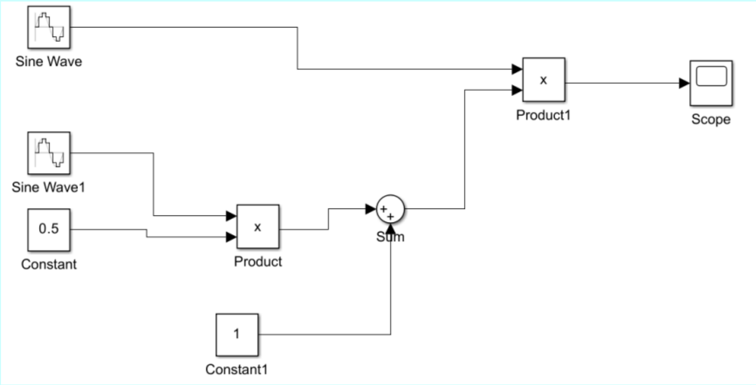
- **Repeaters:** Vital for extending signal range, repeaters regenerate and amplify signals, but introduce delays and noise, requiring strategic placement for optimal performance.

EXPERIMENT-3

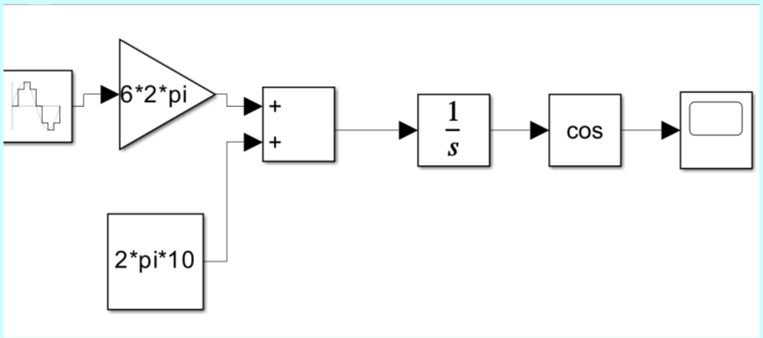
Aim: To analyze AM, FM, PM

Simulink Block Diagram:

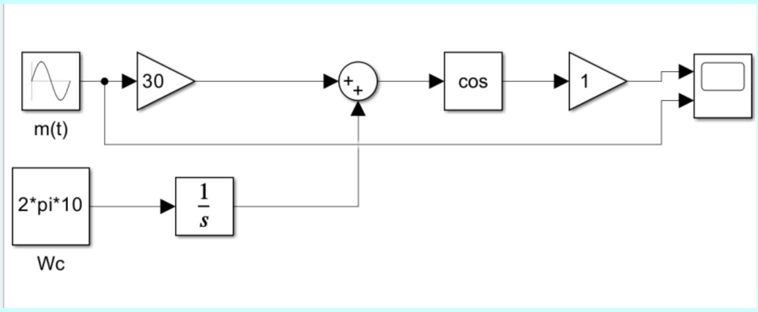
AM:



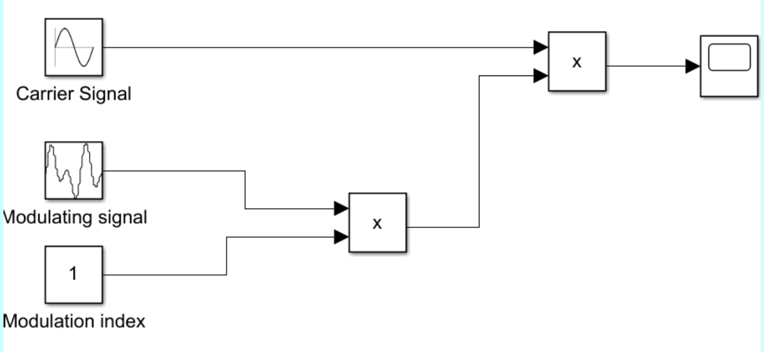
FM:



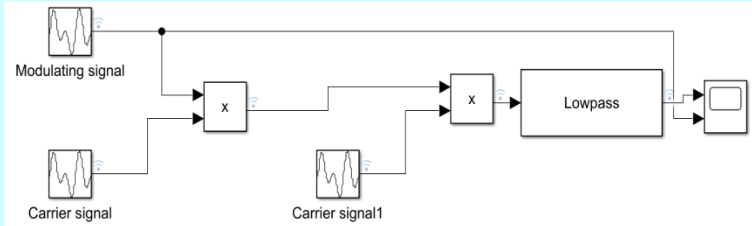
PM:



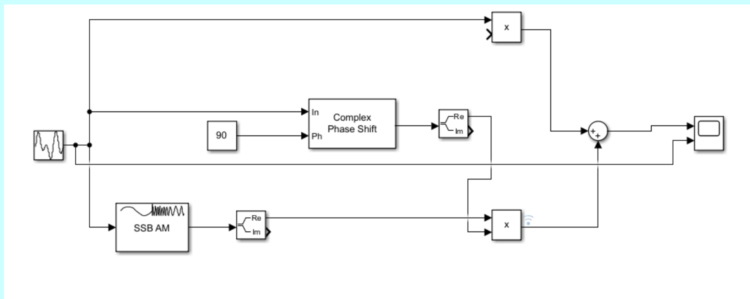
DSBFC:



DSBSC:

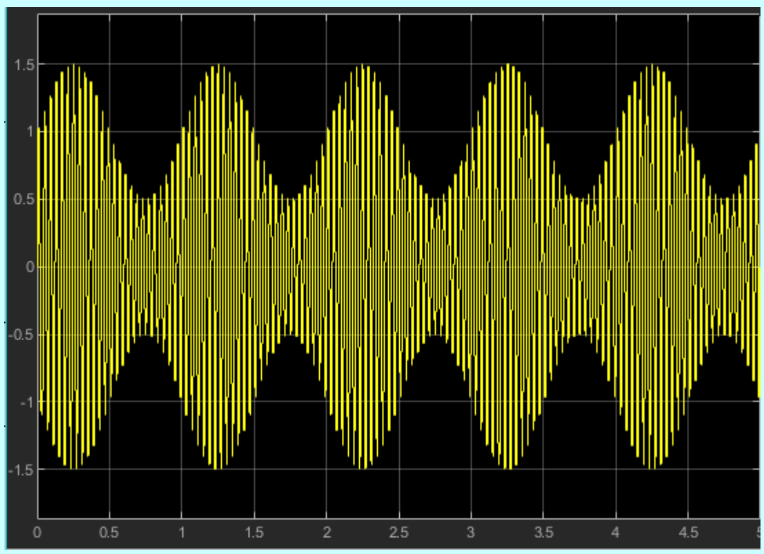


SSBSC:

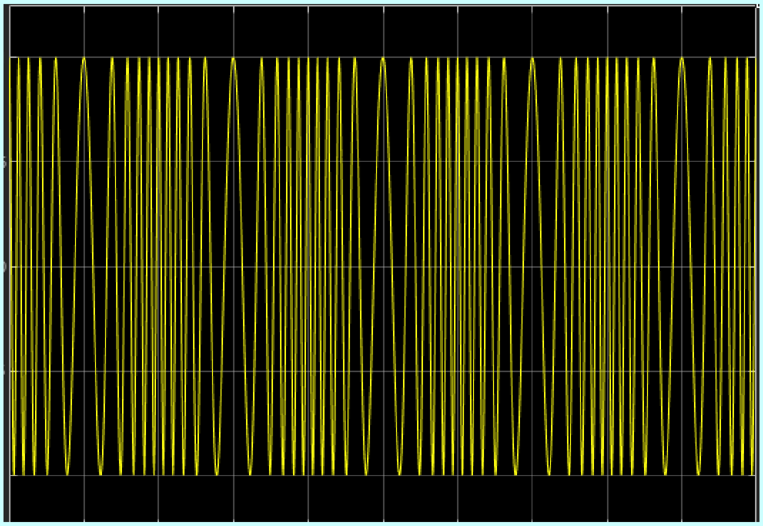


Simulation:

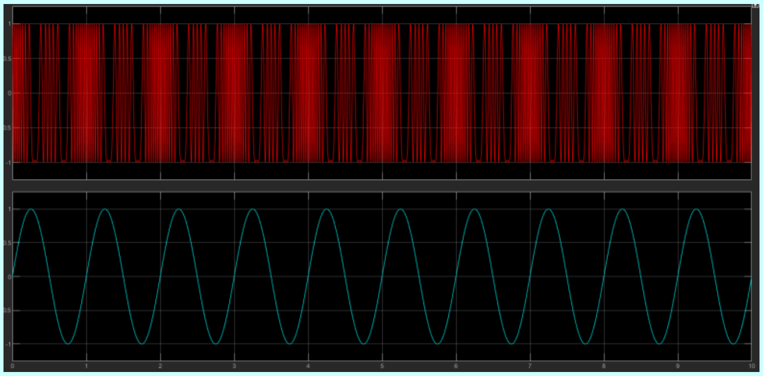
AM:



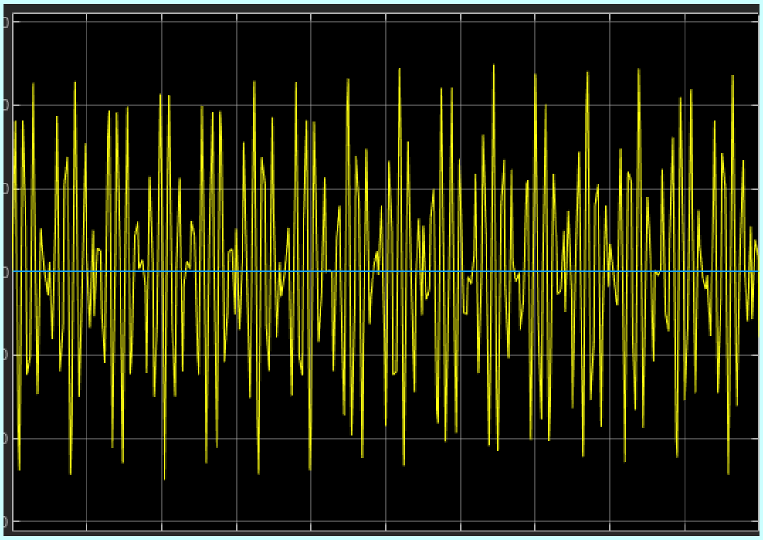
FM



PM:



DSBFC:



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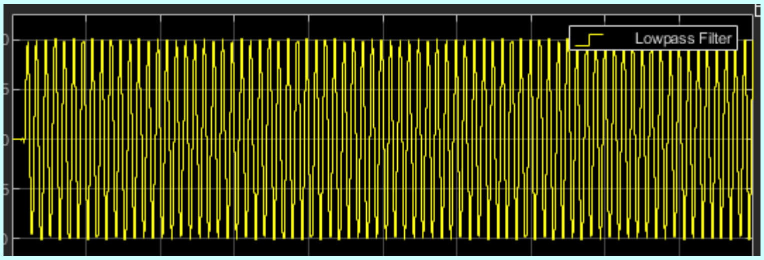

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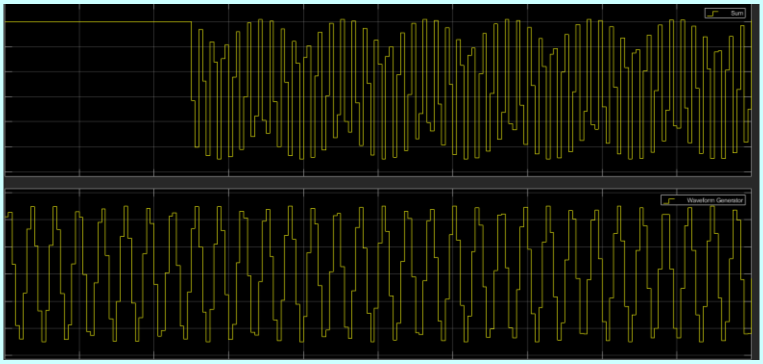


Learning:

Through this simulation, the different methods of modulation, their specific requirements and the flaws in each of them were highlighted to me. Of all, I did find the PM and FM to be more efficient in terms of noise interference and bandwidth efficiency.

Control Parameters:

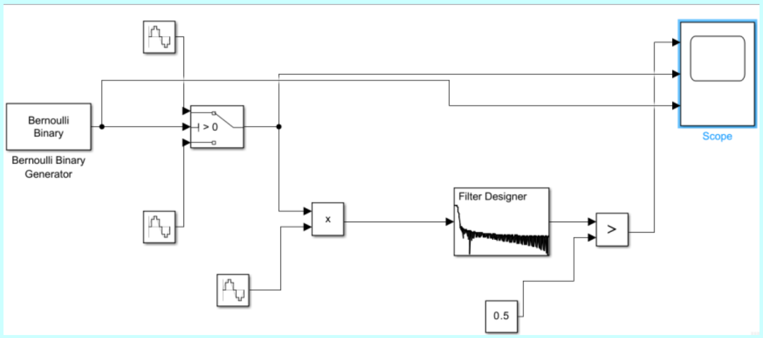
- **Amplitude Modulation (AM)**:
  - **Modulation Index**: A higher modulation index increases the amplitude variations in the modulated signal, providing better signal-to-noise ratio (SNR) but also increasing bandwidth.
  - **Carrier Frequency**: The carrier frequency determines the center frequency of the modulated signal and affects the bandwidth occupied by the modulated signal.
  - **Bandwidth**: AM bandwidth is directly proportional to the modulation frequency and the highest frequency component in the modulating signal.
- **Frequency Modulation (FM)**:
  - **Deviation Ratio**: Increasing the deviation ratio widens the frequency swing, allowing for more information to be encoded but also increasing the bandwidth requirements.
  - **Modulation Frequency**: The frequency of the modulating signal determines the rate of frequency changes in the FM signal, affecting the signal's bandwidth and spectral characteristics.
  - **Bandwidth**: FM bandwidth is directly related to the maximum frequency deviation and the highest frequency component in the modulating signal.
- **Phase Modulation (PM)**:
  - **Phase Deviation**: A higher phase deviation results in larger phase shifts, allowing more information to be encoded but also increasing bandwidth.
  - **Modulation Frequency**: Similar to FM, the modulation frequency in PM affects the rate of phase changes and therefore the bandwidth of the modulated signal.
  - **Bandwidth**: PM bandwidth is directly related to the modulation frequency and the maximum phase deviation.

EXPERIMENT-4

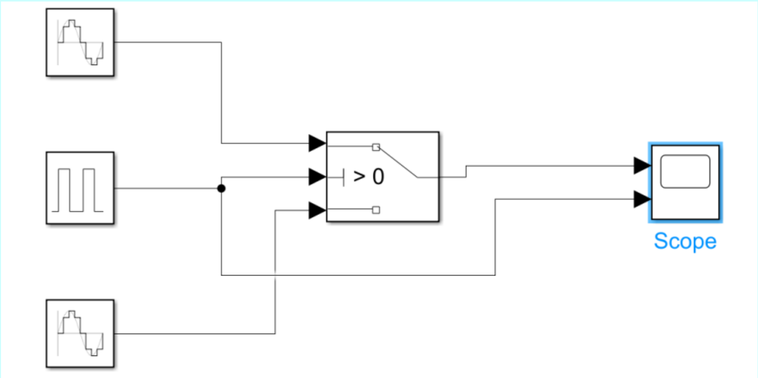
Aim: To analyze ASK,FSK,PSK,BPSK, QPSK, QAM.

Simulink Block Diagram:

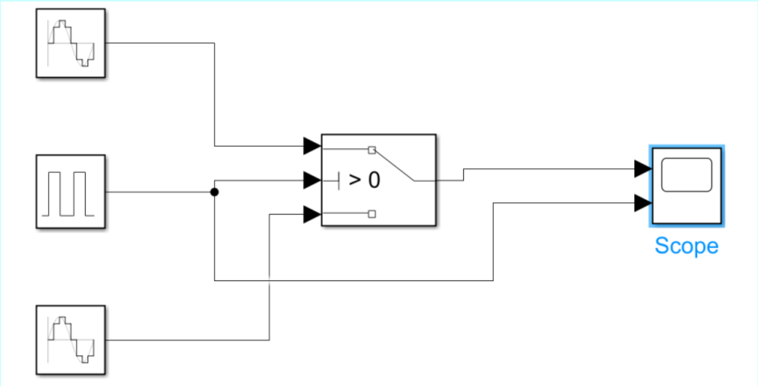
ASK:



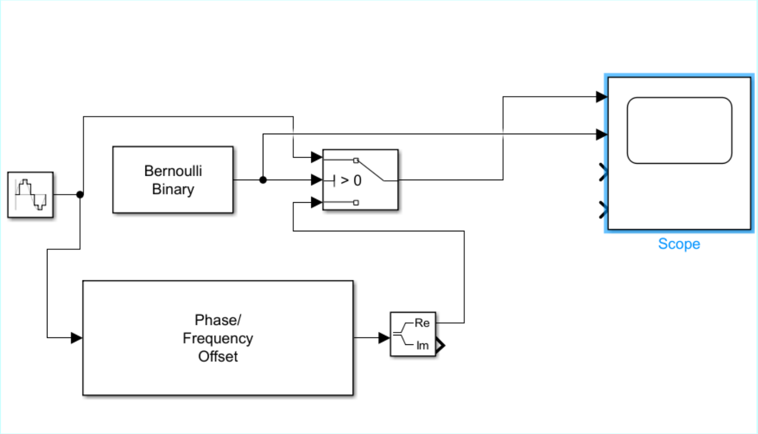
FSK:



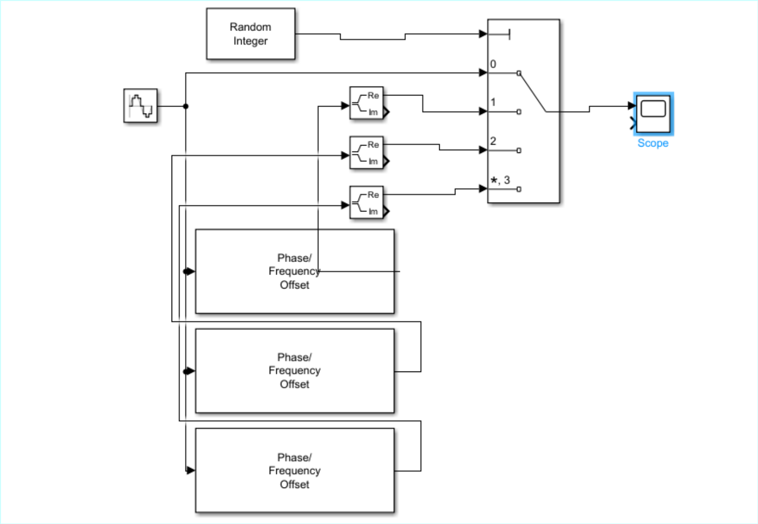
PSK:



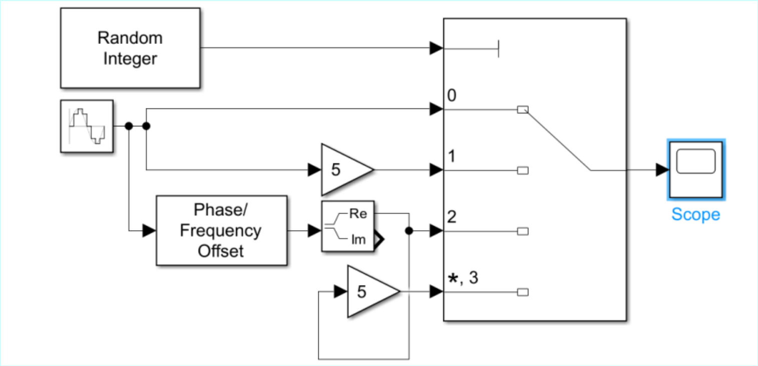
BPSK:



QPSK:

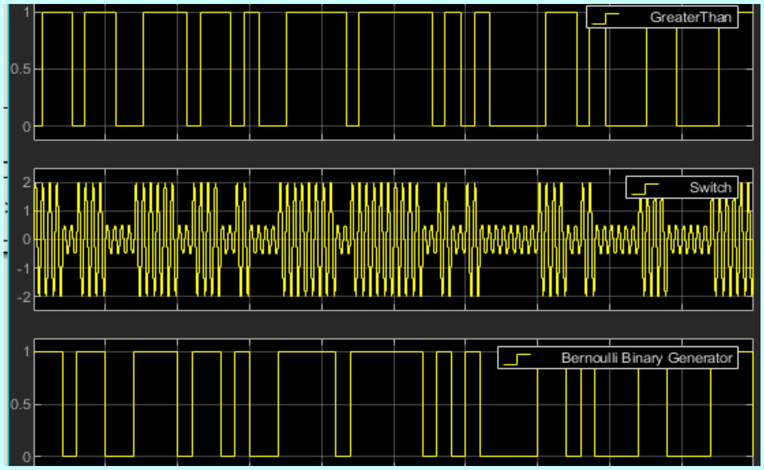


QAM:

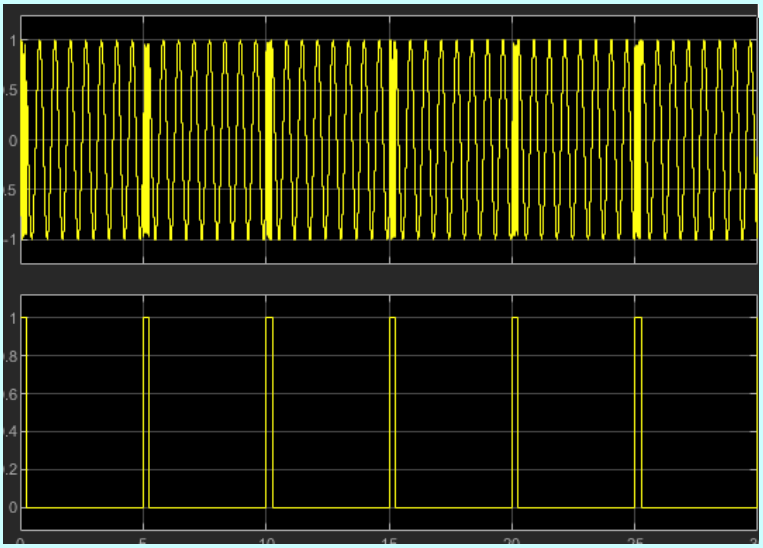


Simulation:

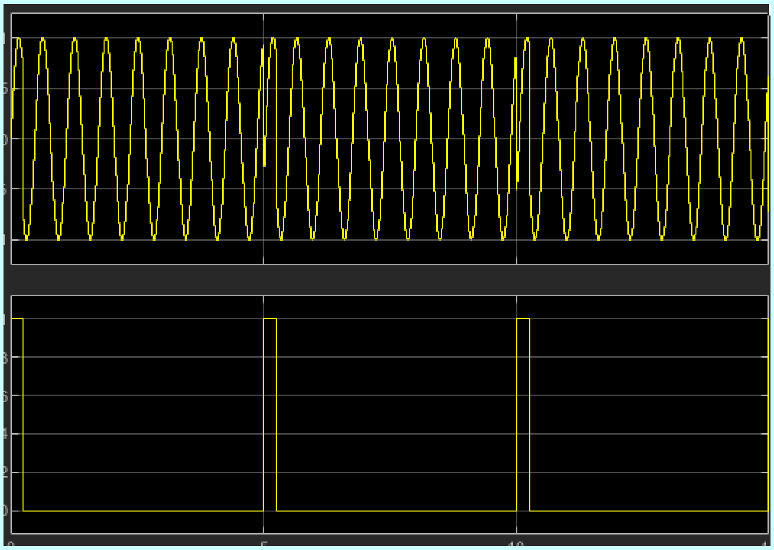
ASK:



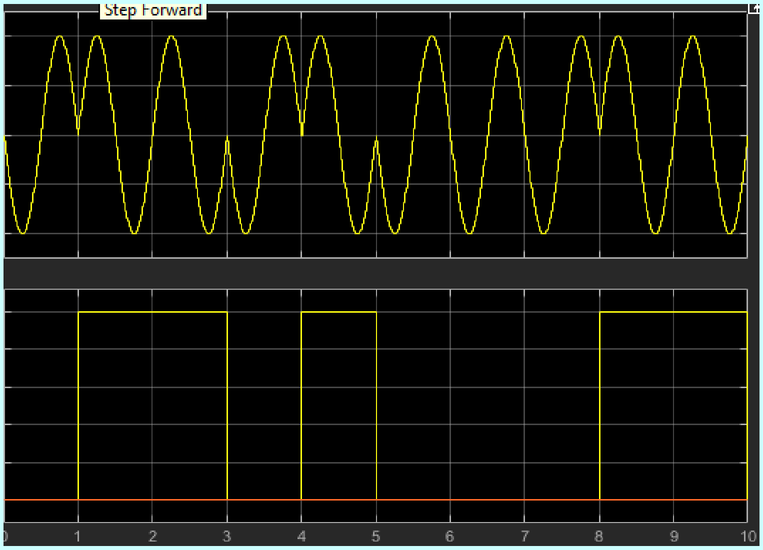
FSK:



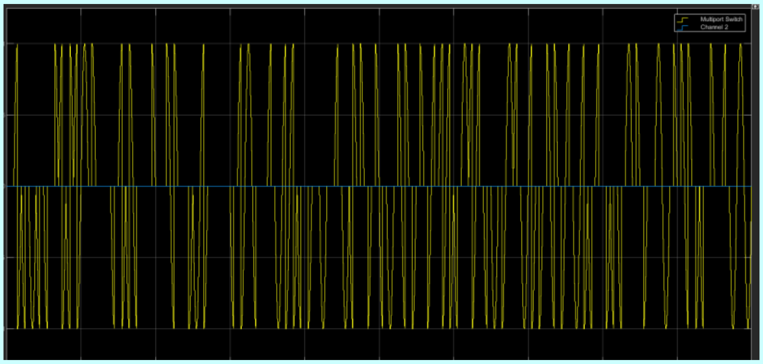
PSK:



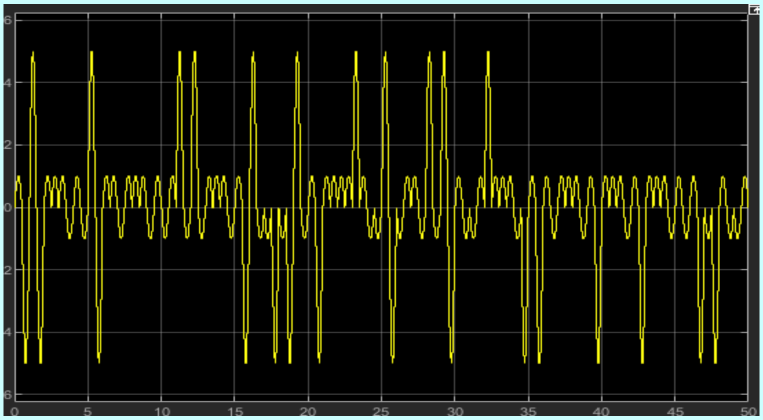
BPSK:



QPSK:



QAM:



Learning:

In this experiment, various techniques of line coding were analyzed and their parameters compared. What was seen is that higher forms of line coding such as BPSK and QPSK were excellent at noise-free, low-latency, high-bandwidth signals. However, even advanced forms of the line coding such as QAM were even more efficient due to their complex design,

Control Parameters:

- **Frequency Shift Keying (FSK)**:
  - **Frequency Separation:** Larger frequency separations allow for easier discrimination between symbols but may require more bandwidth.
  - **Modulation Rate:** Higher modulation rates enable faster data transmission but may increase the complexity of the system.
  - **Bandwidth:** Bandwidth increases with higher modulation rates and wider frequency separations.
- **Phase Shift Keying (PSK)**:
  - **Phase Difference:** Larger phase differences between symbols enable more distinct representations but may require more precise phase synchronization.
  - **Modulation Rate:** Higher modulation rates allow for faster data transmission but may increase the susceptibility to phase noise.
  - **Bandwidth:** Typically narrower than FSK due to the modulation being based on phase changes rather than frequency shifts.
- **Amplitude Shift Keying (ASK)**:
  - **Amplitude Levels:** More amplitude levels allow for denser symbol encoding but may increase susceptibility to noise.
  - **Modulation Depth:** Higher modulation depths provide greater signal strength variations but may also increase power consumption.

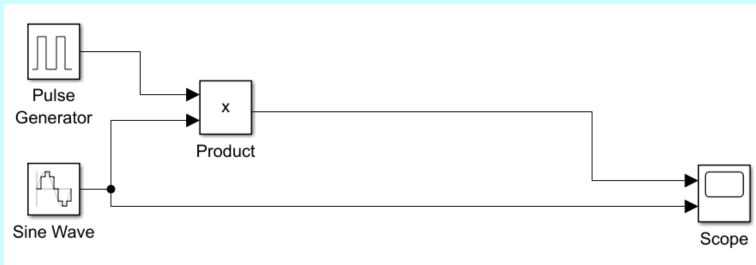
   - Bandwidth: Increases with higher modulation depths and symbol rates.
- **Quadrature Phase Shift Keying (QPSK)**:
   - **Phase States:** Four distinct phase states allow for two bits per symbol, enabling higher data rates but also increasing complexity.
   - **Modulation Rate:** The modulation rate is typically twice the symbol rate due to the need for two phase transitions per symbol.
   - **Bandwidth:** Generally wider than BPSK due to the increased symbol rate.
- **Binary Phase Shift Keying (BPSK)**:
   - **Phase Difference:** The angular separation between two phase states affects the robustness of the modulation against phase noise.
   - **Modulation Rate:** Higher modulation rates enable faster data transmission but may increase susceptibility to noise and errors.
   - **Bandwidth:** Typically narrower compared to QPSK due to representing one bit per symbol.
- **Quadrature Amplitude Modulation (QAM)**:
   - **Amplitude Levels:** More amplitude and phase levels allow for denser symbol encoding, enabling higher data rates but also increasing susceptibility to noise and distortion.
   - **Modulation Depth:** The degree of amplitude and phase variation affects the signal-to-noise ratio and power efficiency.
   - **Bandwidth:** Generally wider than PSK due to the increased complexity of symbol representation.

EXPERIMENT-5

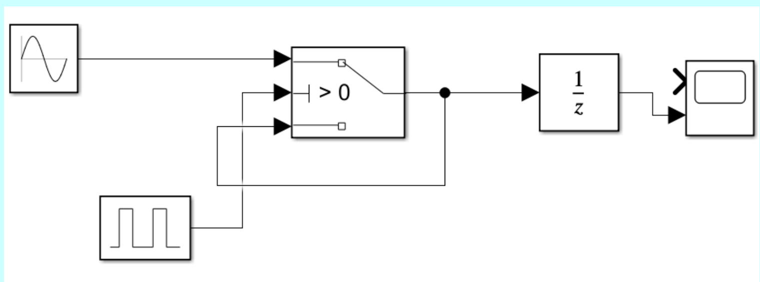
Aim: To analyze the effects of Sampling and Quantization.

Simulink Block Diagram:

Sampling:

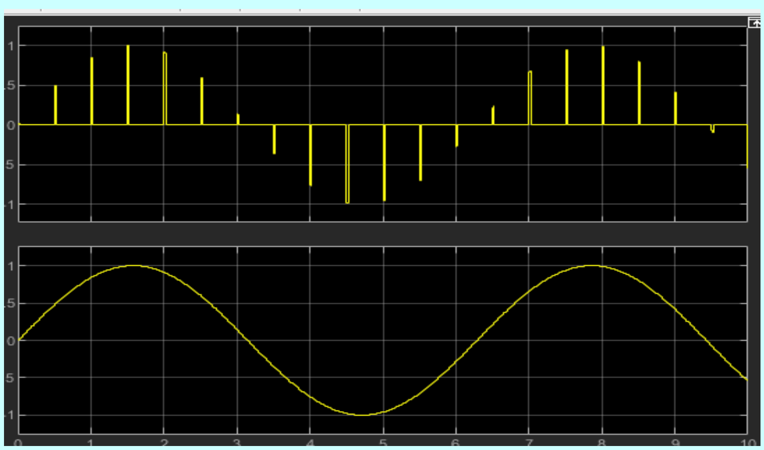


Quantization:

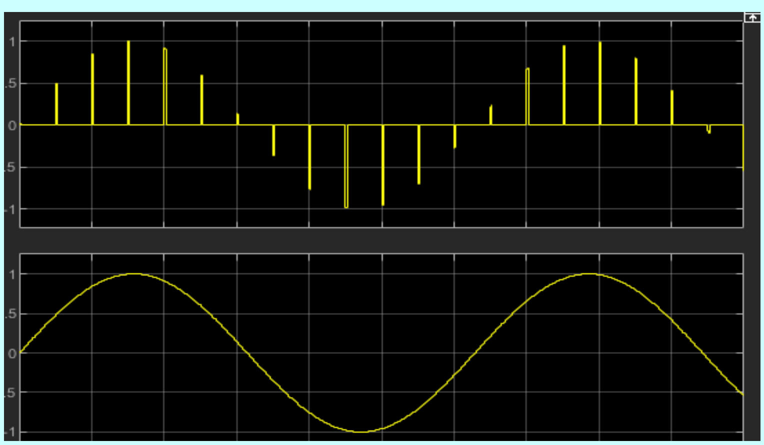


Simulation:

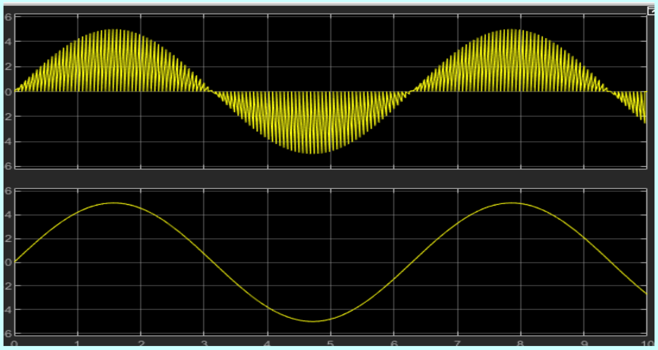
Flat-Top Sampling:



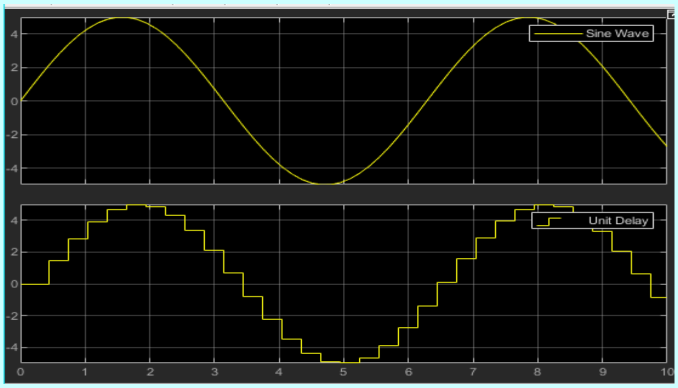
Ideal Sampling:



Natural Sampling:



Quantization:



Learning:

In this experiment, different forms of sampling and how to perform quantization was observed. Interestingly, the three categories of sampling, i.e. ideal, natural and flat-top all vary in terms of the output waveform but have the same circuit. What is changing is the pulse_rate at which sampling is performed. Once cannot help but think of an analogy to the modulation index and its effects on the output for eg: Under-, over and perfect modulation.

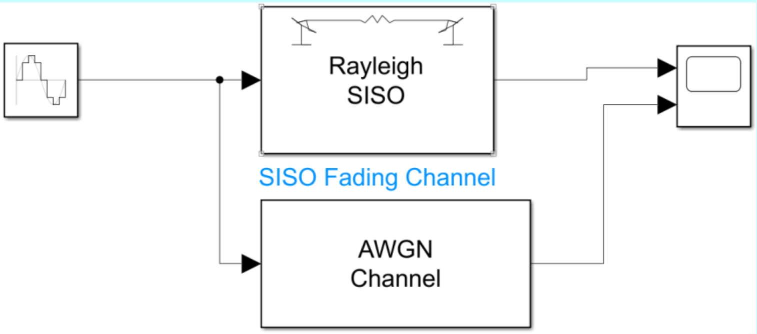
Control Parameters:

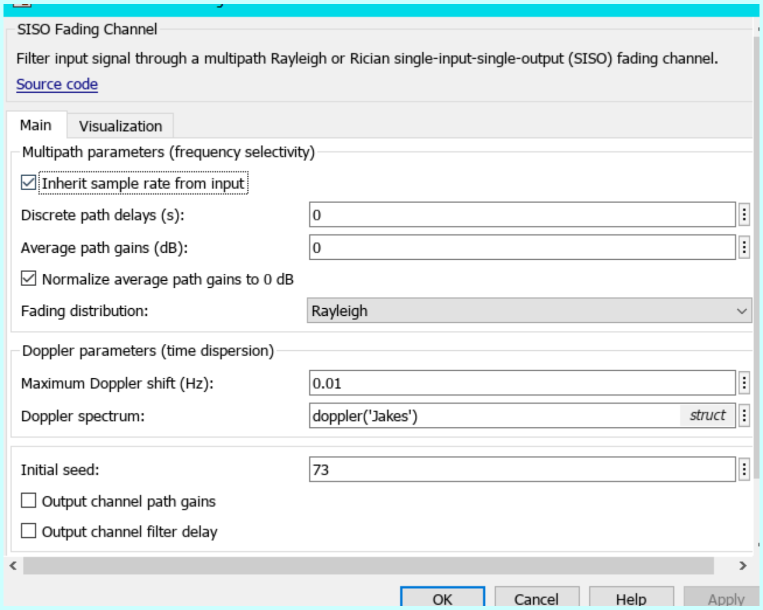
- **Sampling:**
  - **Ideal Sampling: In AM, ideal sampling preserves the modulation depth and faithfully reconstructs the modulated signal without distortion.**
  - **Flat-Top Sampling: Flat-top sampling can help reduce aliasing effects in FM and PM signals by providing a flat frequency response within the sampling interval.**
  - **Natural Sampling: Natural sampling in FM and PM allows for simpler implementation by aligning sampling instants with natural waveform features, potentially reducing distortion.**
- **Quantization:**
  - **Quantization Levels: More quantization levels in AM improve the fidelity of the demodulated signal, preserving the original modulation depth and reducing quantization noise.**
  - **Quantization Error: Minimizing quantization error in FM and PM ensures accurate reproduction of frequency or phase variations, maintaining signal fidelity.**
  - **Quantization Step Size: Smaller quantization step sizes in AM, FM, and PM result in finer resolution and reduced quantization noise, enhancing signal quality but increasing data rate and complexity.**

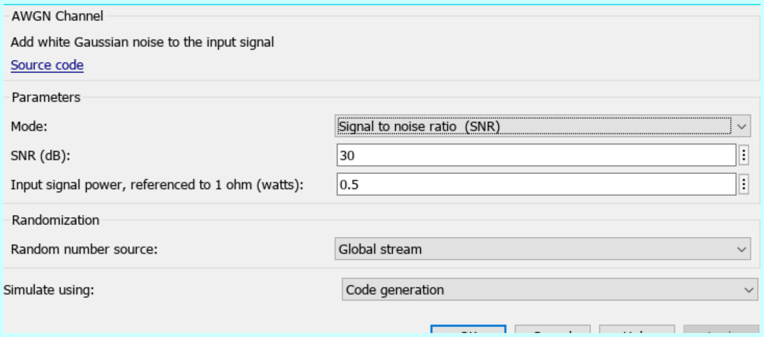
EXPERIMENT-6

Aim: To analyze the effects of noise into communication.

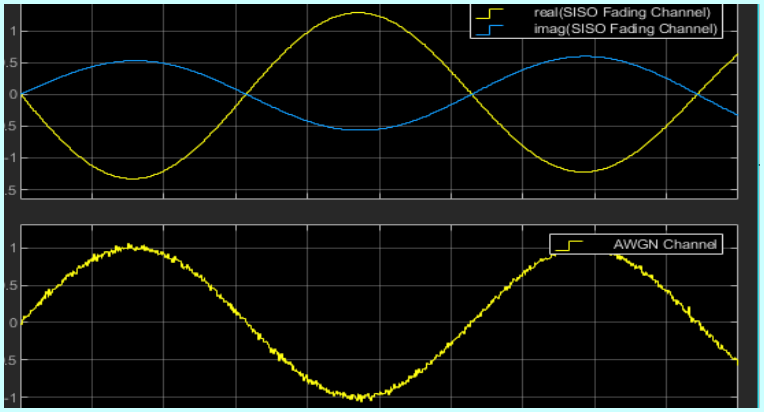
Simulink Block Diagram:







Simulation:



Learning:

In this experiment, various error were introduced wthin the channels and their effects observed. Of many, a few of the errors were: Fading(attenuation), Power gain(theoretical only), Distortion, Doppler shift(very affective to QOS), delay, high freq components due to SNR, etc.

Control Parameters:

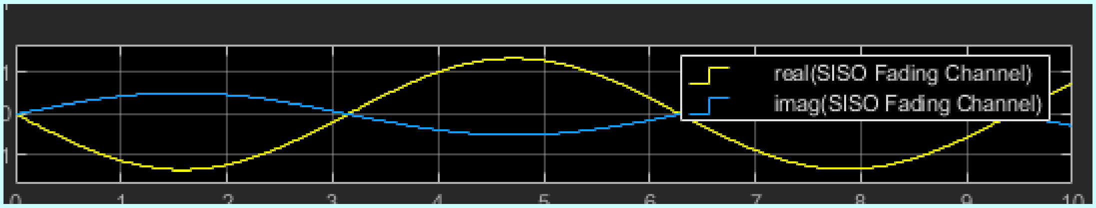
- **Fading (Attenuation)**:
  - Fading causes signal strength variations, impacting the received signal quality and introducing amplitude, frequency, or phase distortions.
- **Power Gain (Theoretical Only)**:
  - Theoretical power gain relates to the modulation index, frequency deviation, or phase deviation, depending on the modulation technique, determining signal strength variations and power efficiency.
- **Distortion**:
  - Distortion occurs due to nonlinearities in the modulation process or transmission medium, leading to signal degradation, harmonic distortion, and intermodulation products.
- **Doppler Shift (Very Affective to QoS)**:
  - Doppler shift results from relative motion between transmitter, receiver, and reflecting surfaces, causing frequency or phase variations in the received signal, impacting modulation accuracy and signal reception quality.
- **Delay**:
  - Delay introduces temporal shifts in the transmitted signal, causing phase distortions, intersymbol interference, and signal degradation, affecting demodulation accuracy and signal quality.
- **High-Frequency Components due to SNR**:
  - High-frequency components contribute to signal fidelity, noise immunity, and modulation accuracy, enhancing the ability to recover modulating information and improving overall signal quality.

EXPERIMENT-7

Aim: To analyze the Characteristics of wireless channels.

Simulink Block Diagram:

Simulation:



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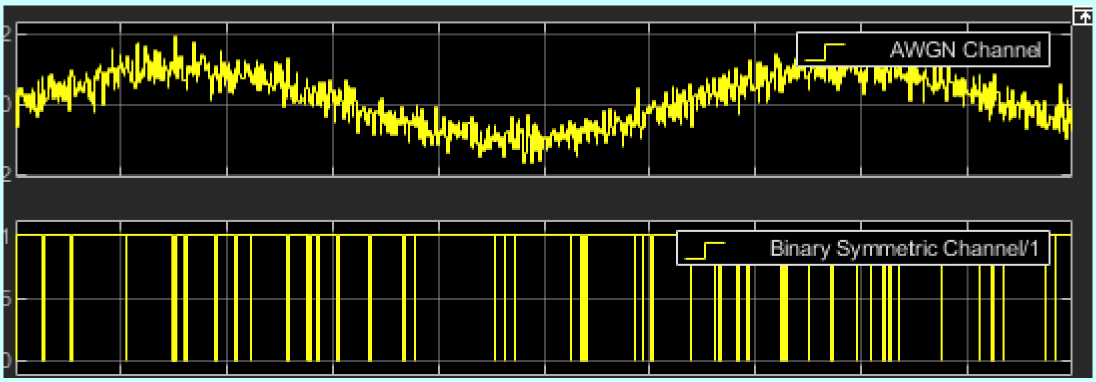

Conclusion/Learning, circuit and control parameters same as above..

EXPERIMENT-8

Aim: To analyze Bit Error Rate.

Simulink Block Diagram:

Simulation: