Hands-On Lab 1: Simulating Digital Communication Chains Using Simulink

Objective

The objective of this lab is to familiarize students with Simulink's Communication Blockset by simulating a basic digital communication system. By the end of the lab, students will understand how to model, simulate, and analyze digital communication systems using Simulink.

Prerequisites

- Basic understanding of digital communication concepts such as modulation, demodulation, and noise.
- Familiarity with MATLAB and Simulink environments.

Lab Structure

1. **Introduction to Communication Blockset in Simulink**
    - Overview of Simulink and the Communication Blockset.
    - Understanding signal terminology: Frame vs. Sample.
    - Exploring source and sink libraries.
2. **Step-by-Step Simulation of a Digital Communication Chain**
    - Setting up the simulation environment.
    - Modulating a digital signal.
    - Introducing noise and simulating channel effects.
    - Demodulating and analyzing the received signal.
3. **Analysis and Interpretation of Results**
    - Measuring performance metrics such as Bit Error Rate (BER).
    - Visualizing signals using scopes and constellation diagrams.
    - Understanding the impact of noise and channel conditions.

Detailed Steps

1. Introduction to Communication Blockset in Simulink

Objective: Get familiar with the basic blocks and signal terminology.

- **Frame vs. Sample**:
  - **Sample**: Represents a single data point at a specific time.
  - **Frame**: A collection of samples over a period, representing a segment of a signal.
- **Source and Sink Libraries**:
  - **Source**: Blocks that generate input signals (e.g., Random Integer Generator, Sine Wave).
  - **Sink**: Blocks that capture output (e.g., Scope, To Workspace).

2. Simulation of a Digital Communication Chain

Objective: Build and simulate a simple digital communication system.

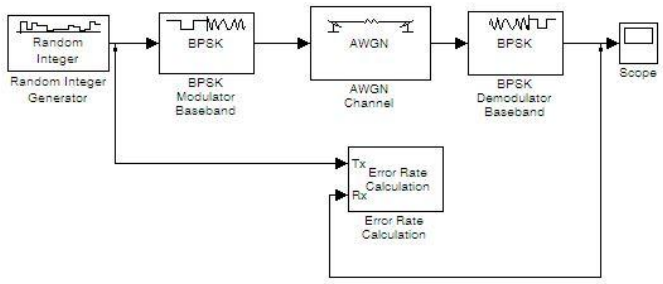

Figure 01

Step-by-Step Guide to Building the Scheme

1. **Open MATLAB and Simulink:**
   - Launch MATLAB.
   - Open Simulink by typing simulink in the MATLAB Command Window.
2. **Create a New Model:**
   - In Simulink, click on File > New > Model to create a new model.

3. **Add Blocks to the Model:**

a. Add the Random Integer Generator:

- In the Simulink Library Browser, navigate to Communications System Toolbox > Comm Sources.
- Drag and drop the **Random Integer Generator** block into your model.
- Double-click the block to configure it. Set the M-ary number to 2 (for binary signals).

b. Add the BPSK Modulator:

- In the Library Browser, go to Communications System Toolbox > Modulation > Digital Baseband Modulation.
- Drag the **BPSK Modulator Baseband** block into the model.

c. Add the AWGN Channel:

- Navigate to Communications System Toolbox > Channels.
- Drag the **AWGN Channel** block into the model.
- Double-click the block and set the Eb/No (dB) to your desired value (e.g., 10 dB).

d. Add the BPSK Demodulator:

- Go back to Communications System Toolbox > Modulation > Digital Baseband Modulation.
- Drag the **BPSK Demodulator Baseband** block into the model.

e. Add the Scope for Visualization:

- Go to Simulink > Sinks.
- Drag and drop the **Scope** block into the model.

f. Add the BER Calculation:

- In Communications System Toolbox > Utilities, find and drag the **Error Rate Calculation** block into the model.

4. **Connect the Blocks:**
   - Connect the blocks as follows:
     - **Random Integer Generator → BPSK Modulator Baseband → AWGN Channel → BPSK Demodulator Baseband → Scope**.
     - Also, connect the output of the **Random Integer Generator** directly to the first input of the **Error Rate Calculation** block.
     - Connect the output of the **BPSK Demodulator Baseband** to the second input of the **Error Rate Calculation** block.
5. **Configure the Simulation:**
   - Set the simulation time to a suitable value (e.g., 1000).
   - Save your model with an appropriate name.
6. **Run the Simulation:**
   - Click on the "Run" button to start the simulation.
   - Open the Scope to observe the transmitted and received signals.
   - Check the results in the **Error Rate Calculation** block to see the Bit Error Rate (BER).

3. Analysis and Interpretation of Results

Objective: Analyze the simulated communication system's performance.

- Run the simulation and observe the output on the Scope.
- Measure the Bit Error Rate (BER) using the BER Calculator.
  - Experiment with different SNR values and observe how noise impacts the BER.
- Visualize the signal constellation using a **Constellation Diagram** block.
  - Analyze how noise distorts the constellation points.

4- Effect of the modulation on the BER

- In the system (figure 01) replace BPSK by **QPSK modulator** then **16-QAM modulator using** adequate demodulator for each example (set M=16 for 16QAM).
- Compute BER with different SNR in each modulation and compare

Questions for Students

1. How does increasing the SNR affect the Bit Error Rate?
2. What is the difference between the signals observed at the transmitter and receiver?
3. How does the channel impact signal quality in the given communication system?