Register numbers: 23MEC0005 Name(s): Abhishek A M
23MEC0011 Yashika K
23MEC0015 Shreevatsa Kulkarni

Laboratory Assignment Report

Experiment Title: Signal Filtering Based on PSD, its Transmission and Reception with NI-USRP Interface.

Aim of the Experiment:

The primary aim is to delve into the intricacies of Power Spectral Density (PSD), its pivotal role in signal processing, and the practical application of these concepts through signal filtering. Additionally, the experiment seeks to demonstrate the transmission and reception of these filtered signals using the National Instruments Universal Software Radio Peripheral (NI-USRP) interface, all within the LabVIEW programming environment.

Hardware Required:

1. **NI-USRP Transmitter and Receiver Interfaces**: These are sophisticated devices that enable the transmission and reception of radio signals in a controlled laboratory setting.

Software Required:

1. **LabVIEW Software:** This graphical programming platform V.2020 is used for developing the signal processing algorithms and controlling the NI-USRP hardware.
2. **NI-USRP Drivers:** These drivers are crucial for the computer to interface with the NI-USRP hardware effectively.

Theory

Signal filtering based on Power Spectral Density (PSD) is a crucial aspect of signal processing, particularly in communication systems. PSD represents the amount of power contained in a signal across various frequencies. Filtering signals based on their PSD is a strategic approach to mitigate noise and enhance signal fidelity. This experiment leverages PSD to discern and filter out unwanted spectral components, thereby refining the signal quality before transmission.

Circuit/Block diagram in LabVIEW

Transmitter: The transmitter's LabVIEW block diagram encompasses several key components:

1. *Frequency and Amplitude:* The Basic Function Generator within the transmitter is configured to generate a sinusoidal signal. The frequency and amplitude of this signal are crucial parameters that define its characteristics. The frequency determines how fast the waveform repeats over time, while the amplitude indicates the strength or height of the signal.
2. *Standard deviation and Gaussian white noise:* To simulate real-world conditions, Gaussian White Noise is added to the signal. The standard deviation of this noise is a measure of its spread or variability around the mean value.

3. *FFT power Spectrum and PSD*: The signal, now a composite of the sinusoidal wave and Gaussian noise, is subjected to a *Fast Fourier Transform* (FFT) to convert it from the time domain to the frequency domain. The resulting Power Spectrum displays the strength of the various frequency components present in the signal.The *Power Spectral Density (PSD)* further refines this information by normalizing the power per unit frequency, providing a comprehensive view of the signal's power distribution across the frequency spectrum.
4. *Bandpass Filter:* To isolate the desired frequency components, this filter is designedto allow only a specific range *(lower frequency : 9 Hz and higher frequency :12 Hz)* of frequencies to pass while attenuating those outside the set bounds. The filtered signal, representing the PSD within the passband, is then ready for transmission via the NI-USRP interface.
5. *NI USRP Configuration Block*: This block configures the NI-USRP hardware for signal transmission.

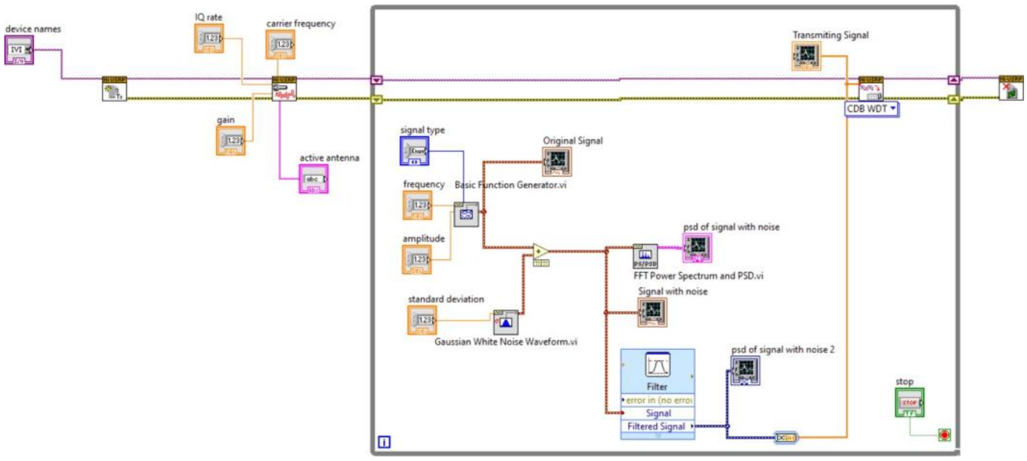

Fig 1.1
Transmitter Block

Receiver: The receiver's LabVIEW block diagram includes:

1. IQ Rate: This parameter sets the rate at which in-phase and quadrature components of the signal are processed.
2. Gain: It adjusts the strength of the received signal.
3. Active Antenna: Specifies the antenna used for signal reception.
4. Waveform Graph with USRP Block: Visualizes the received signal.
5. For Loop: A loop structure that allows continuous monitoring of the received signal.

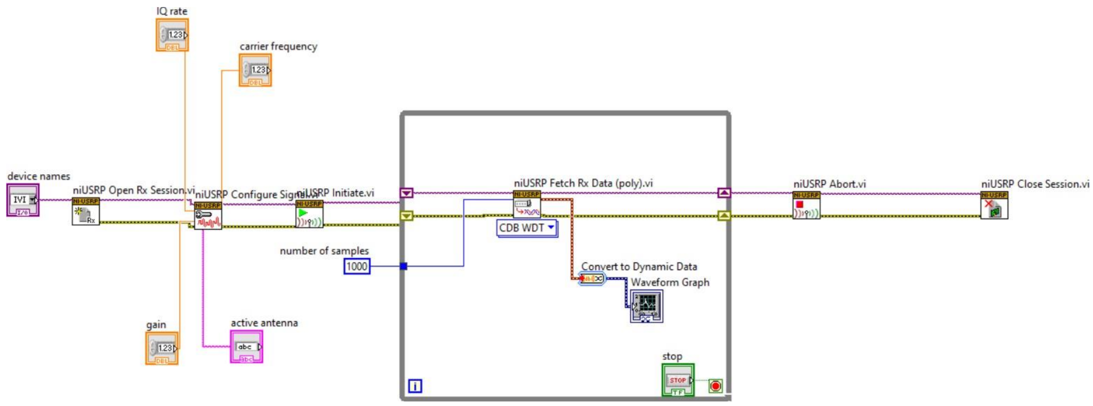

Fig 1.2
Receiver Block

Procedure:

1. Signal Generation:
   - Utilize the Basic Function Generator in LabVIEW to create a sinusoidal signal with predetermined frequency and amplitude.
   - Ensure the signal's parameters are accurately set to match the experiment's requirements.
2. Noise Addition:
   - Introduce Gaussian White Noise to the signal using LabVIEW's built-in functions.
   - Adjust the standard deviation of the noise to simulate various signal-to-noise ratio (SNR) conditions.
3. FFT and Power Spectrum Analysis:
   - Apply a Fast Fourier Transform (FFT) to the noisy signal to transition from the time domain to the frequency domain.
   - Analyze the resulting power spectrum to identify the strength of the signal's frequency components.
4. PSD Calculation:
   - Calculate the Power Spectral Density (PSD) of the signal post-FFT to obtain a normalized view of the power distribution over frequency.
5. Signal Filtering:
   - Implement a Bandpass Filter to isolate the desired frequency range of the PSD signal.
   - Configure the filter's passband to attenuate frequencies outside the desired spectrum.
6. Transmission Preparation:
   - Prepare the filtered signal for transmission by configuring the NI-USRP block with the transmitter's address and other relevant settings.
   - Verify that the signal is within the acceptable parameters for transmission.
7. Transmission via NI-USRP:
   - Transmit the processed signal through the NI-USRP interface.
   - Monitor the transmission process to ensure signal integrity and consistency.

8. Reception Setup:
    - Set up a separate NI-USRP interface for signal reception.
    - Configure the receiver with corresponding settings to match the transmitter’s parameters.
9. Signal Reception and Analysis:
    - Receive the transmitted signal using the configured NI-USRP receiver.
    - Employ LabVIEW tools to analyze the received signal characteristics, such as SNR, BER, and fidelity to the original signal.

Results and Analysis:

1. Power Spectral Density: The power spectral density plot of the generated signal is displayed on the LabVIEW GUI, showing the distribution of power across different frequency components.
2. Signal Filtering: LabVIEW implements the digital filter, and the filtered signal is observed to have attenuated frequency components as per the filter's characteristics.
3. Transmission and Reception: LabVIEW successfully controls the NI-USRP interfaces for both transmission and reception of signals. The received signal characteristics may vary due to channel effects and noise.

OUTPUT: Transmitted and Received Waveform

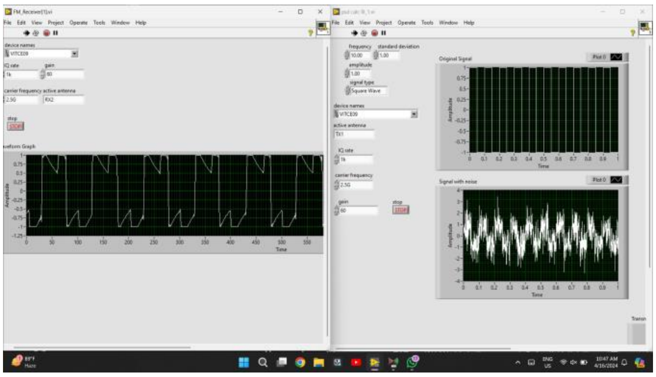

Fig 1.3
(a) Square signal transmission and reception

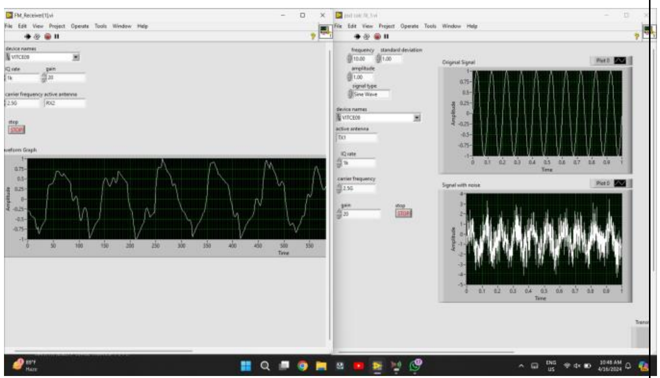

Fig 1.4
(b) Sine signal transmission and reception

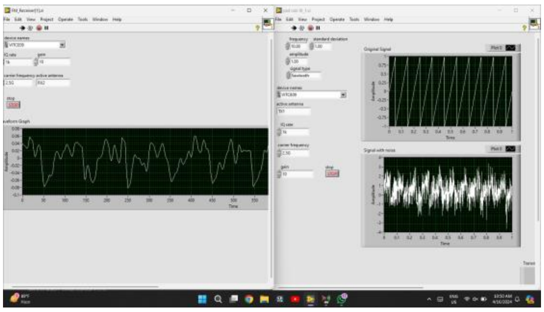

Fig 1.5
(c) Sawtooth signal transmission and reception

Conclusion:

This laboratory assignment has successfully elucidated the measurement of PSD, the process of signal filtering, and the practical aspects of signal transmission and reception using the

NI-USRP interface, all orchestrated through the LabVIEW software. The graphical programming capabilities of LabVIEW have proven instrumental in the design and execution of complex signal processing algorithms and communication system simulations. Mastery of these concepts and tools is indispensable for real-world applications in the domains ofwireless communication and advanced signal processing.

References:

1. LabVIEW User Manual. National Instruments.

2. NI-USRP Getting Started Guide. National Instruments.