Group Members:_____

EE354 Lab 7: FM Demodulation

This lab will have you demodulate an FM waveform using Software-Defined Radio techniques.

Simulation

This part of the lab will step you through creating a FM receiver in Matlab.

Using Matlab, create an FM signal with center frequency of 4.7 MHz, modulating frequency of 1.0 kHz, and frequency deviation of 75.0 kHz. See the in class examples and/or homework solutions for ideas on how to generate the FM Signal.

To demodulate the FM Signal, you will be connecting Matlab software routines based on the following block diagram:

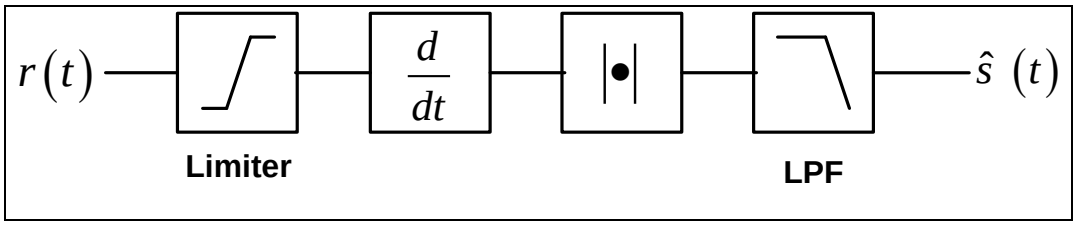

Figure 1: Implementation of the Instantaneous Frequency Equation

1. Limit the received signal to remove amplitude variations.
2. Differentiate the limited signal (Aside: differentiating the FM signal turns it into an AM signal).
3. Take the absolute value of the differentiated signal to recover the information signal from the envelope.
4. Low-pass filter to remove undesired high frequency terms.
5. Downsample the low-pass filter to an audio-level sampling frequency ($f_s < 44.1kHz$)
6. Output the resulting audio signal via the PC's speaker using the `sound` command.

In order to build your FM demodulator, you will need the following Matlab functions: `diff.m`, `filter_BB.m` (available on the course website) `and downsample.m`. The `diff.m` command is used to implement the time derivative, and instructions for its use can be found in the Matlab Help files.

Note: Because the sampling frequency is set based on the FM signal, it is many times larger than the PC's sound card can handle. To obtain an acceptable audio sampling frequency, we need to <u>decimate</u> the demodulated signal, as we did in earlier labs.

Create a meaningful plot of the frequency spectrum of your received FM Signal and the time-domain version of your demodulated information signal. **Include a copy of these figures with your report.**

<u>Demonstrate</u> the successful demodulation of your signal by playing the recovered baseband signal for the instructor.

Instructor Verification of Simulation Tone Demod:

Hardware Setup – Demodulation of a Single Tone

1. To begin, use one of the Agilent 33220A function generators to create a 4.7 MHz sine wave with an output level of 1.0 $V_{pk\text{-}pk}$. Configure the function generator to produce FM Modulation, with a frequency deviation of 75 kHz and an External source (see previous labs for instructions). This function generator will be known as the "FM Modulator".
2. Use a second Agilent 33220A function generator to produce a 1.0 kHz sine wave information signal with an amplitude of $5V_{pk\text{-}pk}$. This function generator will be known as the "Message Signal". Connect the output of Message Signal to the "Modulation In" input on the back of the FM Modulator.
4. Connect the output of the FM Modulator to the Anritsu Spectrum Analyzer. Configure the Spectrum Analyzer to observe the spectrum of your FM Waveform. Using the Markers, measure/estimate the center frequency and bandwidth of your FM Signal, and compare it to the Theoretical Carson's Rule Bandwidth.

Carson's Rule Bandwidth	
Measured Center Frequency	
Measured Bandwidth	

Question 1: How does the measured bandwidth compare to the predicted Carson's Rule Bandwidth?

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5. Use the Marker Demod functions to demodulate your FM Signal (see previous labs for instructions). Verify that you hear a 1.0 kHz tone output from the spectrum analyzer.

Record a copy of your FM Spectrum and include it with your report.

6. Connect the output of the FM Modulator to the Oscilloscope. Be sure the Function Generator is set for a 50Ω output impedance and the scope is set for a 50Ω input impedance.
7. Confirm that the FM signal is present by configuring the Scope to record 100,000 samples, and then adjusting the settings on the display as needed to see a few periods of the FM Waveform and to make sure the frequency deviation is present on the screen.
8. Adjust the sampling frequency of the oscilloscope to 1.0 MHz, and then configure the scope to generate the FFT of the waveform. Using the FFT plot on the scope, verify that the FM Spectrum appears centered around 300 kHz.
9. Adjust the oscilloscope to record 5.0 Million Samples, and reset the sampling frequency to 1.0 MHz. Your timebase on the scope screen should be 500 msec/division. Turn off the FFT and/or any measurement functions so that the scope is configured to **only display and record Channel 1**. Record the waveform to a Matlab .dat file.
10. Load the recorded file in Matlab and use your FM Demodulation routine from the Simulation section to successfully demodulate and play the 1.0 kHz tone signal.

Instructor Verification of Hardware Tone Demod:

Hardware Setup – Demodulation of a ActualAudio Signal

1. Using an adapter provided by the instructor, connect the PC Audio Output (from the speakers) to the oscilloscope input.

2. On the PC, open the PC Volume Control panel, and set both the Main and Wave volumes to Max, as shown in Figure 2. On the PC's front panel, set the volume control thumbwheel to about 70-80% of maximum. Using the PC, navigate to your favorite YouTube music video or MP3 location and select a song to play. Play the audio file and observe the result on the oscilloscope screen.

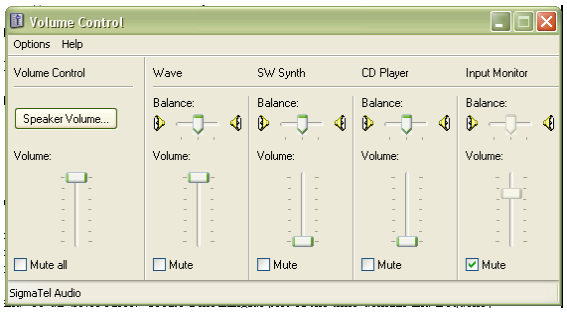

Figure 2: Volume Control Configuration

3. Adjust the timebase of the oscilloscope to display several tens of milliseconds of the audio signal. Adjust the amplitude (volume) of the audio signal until the peak falls between 2.5V and 3.0V. Use the scope to measure the RMS voltage of the audio waveform (**Note:** It will bounce around somewhat, so make a good guess as to the average value).

Record the Peak voltage of the audio signal: _____

Record the RMS voltage of the audio signal: _____

4. Disconnect the Information Generator from the MOD IN input on the FM Modulator, and instead, connect the PC Audio Output (from the speakers) to the MOD IN input using the adapter provided by the instructor, as shown below in Figure 3.

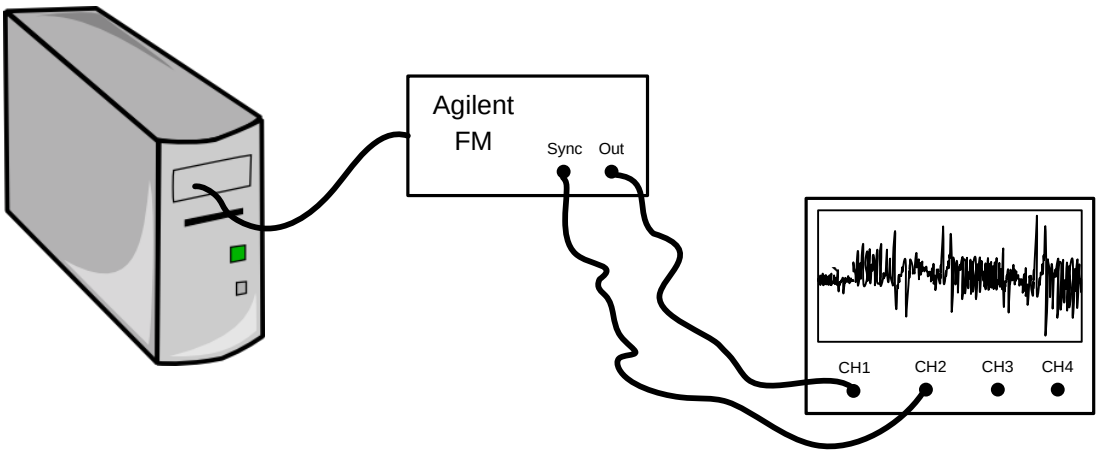

Figure 3: Measurement Setup Connections

5. Adjust the oscilloscope to record 5.0 Million Samples, and reset the sampling frequency to 1.0 MHz. Your timebase on the scope screen should be 500 msec/division. Turn off the FFT and/or any measurement functions so that the scope is configured to **only display and record Channel 1**. Record the waveform to a Matlab .dat file.

6. Create a meaningful plot of the time-domain and frequency spectra of the demodulated baseband signal. Using Matlab (via the software code you wrote for the simulation) demodulate the FM signal and play the baseband audio via the PC's speakers. **Demonstrate** the successful demodulation of your signal by playing the recovered baseband signal for the instructor.

Instructor Verification of Hardware Audio Demod: