EE 340: Communications Laboratory
Autumn 2015

Lab 5: Generation and Demodulation of FM signals with pre-emphasis and de-emphasis

Legends

 Question/Observation: Show it to the TA and explain (carries marks)

Recall/think about something

 Caution

 Additional information - weblink

Aim of the experiment

- To study how pre-emphasis and de-emphasis can be used to avoid boosting of high-frequency noise components in FM radio
- To implement FM modulator with pre-emphasis and FM demodulator with de-emphasis in GNU-Radio software
- To transmit frequency modulated dual-tone signal using IQ modulator board and demodulate received signal in GNU-Radio

Pre-lab Work

- Make sure that you had completed implementation of frequency modulation and demodulation in GNU radio in Lab 2.
- Make sure that you have read the supporting material uploaded along with this document

Important note for all parts

- Use the sample rate of 40 KHz for all un-modulated signals (this sample rate is termed as Audio Rate in FM blocks – however, you don't have to use the ready made blocks)
- Use the sample rate of 640 kHz for all frequency or phase modulated signals in GNU-Radio (this rate is termed as Quadrature Rate in GNU-Radio FM blocks)
  - However, for FM generation using AFG and IQ modulator board, the AFG sample rate could be 128 kHz.
- Use the sample rate of 2 MHz for RTL SDR block in the receiver
- Debugging steps:
  - If things are not working, trace the point of failure (by checking signal at various nodes).
  - If you're not able to get the display after a new GNU-Radio block was added in the schematic, most likely you've entered wrong parameters in the new block (check carefully!)
- IIR filter implementation:
  - FF coefficients: [b_0, b_1]; FB coefficients: [a_0, a_1]; Old Style of Taps = "True", implements the discrete time filter: $$\frac{b_0 + b_1 z^{-1}}{a_0 - a_1 z^{-1}}$$
  - In GNU-Radio's IIR filter block, the value of a_0 is fixed to 1.

Part 1: Generation of FM signals

Generate an FM signal with two sinusoidal tones of frequencies 1.1 kHz and 11 kHz, and each having an amplitude 0.5 (so that the peak amplitude of the two sinusoids added together is 1).

- Use the method provided in prelab document.
  - To implement an integrator, use the IIR filter with FF coefficient: [b_0]; FB coefficient: [1,1]; Old Style of Taps: “True”;
    - Show that this is an integrator (using the assumption given in pre-lab material)
    - What should be the value of b_0 so that the integrator has a gain of 1 at ω=1 rad/sec?
  - You can use the Phase Modulator block for FM generation (though not necessary)
    - What should be the value of phase modulator sensitivity (k_f) so that maximum frequency deviation is 75 kHz for the signal above.
    - Phase Modulator output should have the higher sampling rate. Therefore, you may need to use a Rational Resampler for upsampling (Interpolation: 16; Decimation: 1) before PM.
- Observe the modulated spectrum.

Part 2: Demodulation of FM signals

- Before demodulation, add random noise to the FM signal to emulate the noise added by the wireless channel.
  - Use ‘Noise Source’; Noise Type: Gaussian; Amplitude: 0.2
- Using the procedure mentioned in the lab-sheet, make the FM Demodulator.
  - You can use ‘Complex to Arg’ block to get the phase of a complex signal
  - You can use a ‘Low Pass Filter’ after demodulation to filterout out-of-band noise and down-sample to signal to Audio Rate (Decimation: 16; Gain: 1; Cutoff Freq=20kHz; Transition Width: 4kHz)

✓ Observe the demodulated spectrum.

Part 3: Adding pre-emphasis/ de-emphasis

After proper scaling, you must have observed that the noise floor is higher at high frequencies. Why?

- Implement pre-emphasis and de-emphasis:
  - Use IIR Filter block to implement $(1 - 0.95z^{-1})$ transfer function for pre-emphasis of the message signal at Audio Rate (before Phase Modulation).
  - Use IIR Filter block to implement $1/(1 - 0.95z^{-1})$ transfer function for de-emphasis of the message signal at Audio Rate (after demodulation and down sampling).

Now observe the demodulated signal spectrum. Has pre-emphasis/de-emphasis reduced high-frequency noise in the demodulated signal?

Part 4: Use of IQ modulator board to generate FM signals

- Before generating FM signal, adjust the DC offsets of two channels to minimize carrier feed-through, as you'd done in Exp-4. Note down these DC offset values and use the same for the rest of the experiment.
- Now use the IQ modulator board to generate an FM signal with two sinusoidal tones of frequencies 1.1 kHz and 11 kHz.
  - Use the skeleton Python code to generate the waveforms in .csv file. Use Arb-Express software to convert the waveform to *.tfw* format.
  - Use the carrier frequency assigned to your group for IQ modulator board (Same as Exp-4).
  - Set the Frequency=100 Hz, Amplitude=20mV for both the channels on AFG.

⚠ Make sure that the AFG output is in High-Z (i.e. high impedance) mode.

✓ Use the SDR dongle and the FM demodulator developed by you to demodulate the signal.

✓ Repeat the experiment after scaling the amplitudes of the two tones (Am1=0.5 and Am2=1 in the code) for pre-emphasis and implementing the de-emphasis using IIR filter. Adjust IIR filter feedback coefficient for De-emphasis filter such that two tones are of roughly same amplitude. This should reduce the high frequency noise in the demodulated signal spectrum.