Lab 4: FM Modulation and Demodulation

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Aim of the experiment

- Implementing modulation – demodulation flow graphs for frequency modulation (FM) in GNU Radio
- Implementing pre-emphasis and de-emphasis.
- Using DVB – T (RTL – SDR) dongles to receive and demodulate locally transmitted FM signals.

Important Note

- Use the sample rate of 48KHz for all un-modulated signals (this sample is termed as Audio Rate in FM blocks-however,you don't have to use the ready made blocks)
- Use the sample rate of 960kHz for all the frequency or phase modulated signals in GNU-Radio (this rate is termed as Quadrature Rate in GNU radio FM blocks).
- Debugging steps:
  - If something is not working,trace the point of failure(by checking the 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 have entered wrong parameters in the new block(check carefully!)
  - **Make sure that you are consistently accounting for the sample rate whenever decimation(for downsampling) and interpolation(for upsampling) are used.**
- IIR filter block implementation:
  - FF coefficients=[b_0,b_1];FB coefficients=[a_0,a_1];Old Style of Taps=True, implements the discrete time filter:

$$\frac{Y(z)}{X(z)} = \frac{b_0 + b_1 z^{-1}}{a_0 - a_1 z^{-1}}$$

  - A bug in implementation always sets the value of $a_0 = 1$.
    Therefore, you must use $a_0 = 1$ in all your calculations for filter coefficients.

Task 1: Implementation of a Frequency Modulator

- 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).
- For making a Frequency Modulator, you need to first integrate the signal and then add the resultant signal to the phase of the carrier wave.
- To implement an integrator,use the IIR filter with:
  - FF coefficients=[b_0]; FB coefficients=[1,1]; Old style of Taps=TRUE;
  - Choose the sample rates judiciously,i.e. the Nyquist criterion should be satisfied comfortably.
  - Choose $b_0 = T$,i.e. the sampling period of the signal
- This output should go to the Phase Modulator: For an input Φ the Phase Modulator outputs $e^{jk_p\Phi}$, where k_p is the phase modulator sensitivity. ✓What should be the value of k_p so that maximum frequency deviation is 75kHz for the signal above?
- Phase Modulator output should have the higher sampling rate. Therefore, you may need to use a Rational Resampler for upsampling before PM. Remember that you've already scaled the signal using b_0.
- Observe the modulated spectrum.

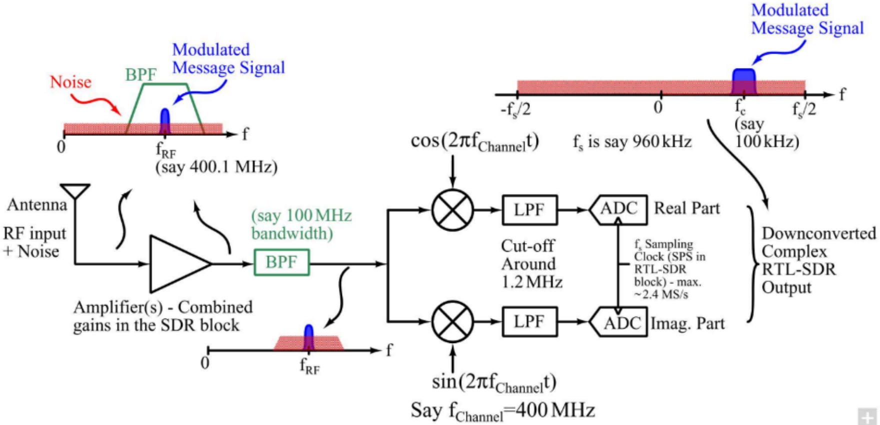
Task 2: Implementation of a Frequency Demodulator

- 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
- Implement the FM Demodulator.
  – You should use 'Complex to Arg' block to get phase after differentiating phase of the complex modulated signal, as in discrete-time implementation in GNU radio, the phase value obtained using the 'Complex to Arg' block has an ambiguity of $2n\pi$, where n is an integer (mentioned in the prelab).
- Observe the demodulated spectrum. Is the noise floor higher at higher frequencies? Why?

Task 3: Adding pre-emphasis/ de-emphasis

- 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 which is 44.1K (after demodulation and down sampling).
- Now observe the demodulated signal spectrum. Has pre-emphasis/de-emphasis reduced high-frequency noise in the demodulated signal?

RTL-SDR Dongle (What's inside the beast!)



Task 4: FM demodulation using RTL-SDR

To demodulate FM signals, you need to find the phase of the incoming sample and differentiate it with respect to time to obtain the transmitted signal.

- To use the signal received from RTL-SDR dongle, you need to use the **Soapy RTL-SDR** block. The sampling rate for this block must be **2.048 M samples/sec**.
- To demodulate the FM signal, tune your RTL-SDR block to the desired frequency **(950MHz)**. In this case, the frequency needn't be precise.
- Get the phase of the incoming signal: You can use **Complex to Arg** block for this operation.
- Take the difference between the arguments of n^{th} and $(n-1)^{th}$ samples to obtain the demodulated message signal.
- You can use the 'Low Pass Filter' block after demodulation to filter out the out-of-band noise and down-sample (using decimation value) the signal to 32 kHz (audio card sample rate). What would be the decimation factor? Observe the demodulated spectrum and listen to the Audio. The above steps have to be carried out for the signal generated by **your own FM modulator**, and for the **FM signal from your favourite FM station.**