EE 340: Communications Laboratory
Autumn 2018

Lab 2: Implementation of Analog Modulation schemes in GNU Radio

Aim of the experiment

- To understand the basics of analog communication (i.e., amplitude and frequency modulation schemes)

- Implementing modulation – demodulation flow graphs for both amplitude modulation (AM) and frequency modulation (FM) in GNU radio.

- Using DVB - T (RTL – SDR) dongles to receive and demodulate locally transmitted AM signals.

- 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 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 960kHz for all frequency or phase modulated signals in GNU - Radio (this rate is termed as *Quadrature Rate* in GNU radio FM blocks)
- Debugging steps:

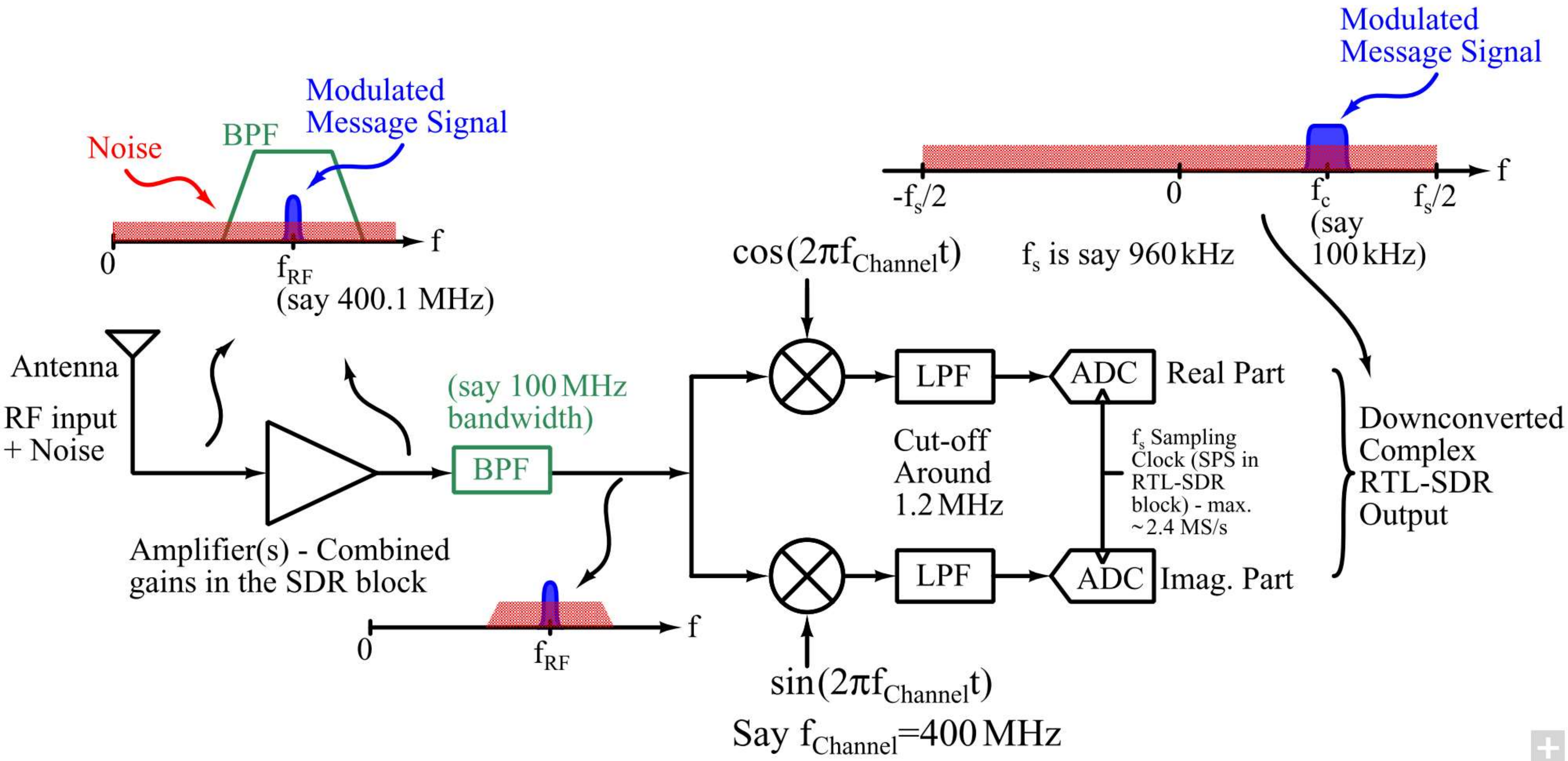
  \- If something is not working, trace the point of failure (by checking the signal at various nodes)

  - If you're not able to get the display after a new GNU-Radio block was added in the schematic, most likely you've 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 the implementation always sets the value of $a_0 = 1$. Therefore, you must use $a_0 = 1$ in all your calculations for filter coefficients.

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



Task 1: Implementation of DSB-FC

- Implement an entire DSB-FC AM modulation-demodulation flow graph in GNU radio.

  Note: You cannot use the built-in blocks for demodulation like AM-demod
- Parameters to be used:

  - Message signal (single-tone): 10 kHz
  - Carrier signal: 100 kHz
- You are allowed to use the ready-to-use Low Pass Filter block from GNU radio library for this

- Observe the message signal and modulated signal for DSB-FC in time and frequency domains

Task 2: Demodulation of AM

- Use the DVB–T (RTL-SDR) dongle to receive and demodulate the locally transmitted DSB-FC AM signal in the lab using the multiplier technique which works for DSB-FC signals as well (however it has an additional DC component, which can be removed by the `DC Blocker' block in GNU radio)
- Parameters required:
  - Transmitted carrier frequency: 850 MHz with 100 kHz offset (i.e. 850.1 MHz)
  - AM carrier frequency after reception by RTL-SDR: 100 kHz (i.e. use 850 MHz as the channel frequency)
  - Message signal (audio signal) bandwidth 20 Hz to 15 kHz

Note:

The transmit frequency and RTL-SDR frequencies have a small offset between them. A USRP kit is used for local AM transmission at 850 MHz (with a small offset in the actually transmitted frequency). Similarly, RTL–SDR will not tune to precisely 850 MHz (if you specify 850 MHz as the channel frequency), as the frequency references are not precise.

For better tuning, use a slider for compensating the offset between the two frequencies. Observe the FFT of received signal (by directly connecting FFT sink and RTL–SDR) and play with the slider to tune correctly.

- Feed the demodulated signal to the Audio Sink block. If the demodulation is done properly, you should be able to listen to the transmitted music signal. Observe the demodulated spectrum.

Task 3: Implementation of a Frequency Modulator

- 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 $\exp(jk_p\phi)$, where $k_p$is the phase modulator sensitivity.

  What should be the sensitivity for achieving modulation index =1 (it should be of the order of 1)? Remember that you've already scaled the signal using b_0

  Observe the modulated spectrum

Task 4: Making your own FM demodulator flow-graph

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 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.