Learning Objective 3.3: I can implement an FM receiver in GNU Radio, demodulate a live broadcast FM signal, and decode its RDS data.

Learning Objective 3.4: I can explain and demonstrate the trade-off between bandwidth and noise performance for AM vs. FM.

Show your work. Write a **Documentation** line at the end (**None** if you did not collaborate).

1. **FM bandwidth.** Carson's rule, a rule of thumb for setting a channel filter, puts the width of an FM signal with peak deviation Δf and audio bandwidth W at about

$$B \approx 2(\Delta f + W)$$

(a) Fill in the table. For the AM row, the station sends the same audio as DSB-AM.

Service	Δf (kHz)	W (kHz)	Bandwidth (kHz)
Broadcast FM, mono	75	15	
Two-way radio, NBFM	5	3	
AM, broadcast audio	–	15	

(b) Open the FM Explorer on the Lesson 7 page and choose the broadcast preset, 75 kHz of deviation with a 15 kHz tone. Lower the deviation to 25 kHz and describe what happens to the spectrum. Then explain in words why the broadcast signal is wider than $2\Delta f$ = 150 kHz.

2. **The WBFM receiver.** A PlutoSDR records 2.4 MS/s centered on 98.8 MHz, and the station we want is at 99.1 MHz. The receiver is `L07-wbfm-rx.grc`.

   (a) Find the center frequency of the Frequency Xlating FIR Filter, and the sample rate after it decimates by 10.

   shift = ____

   rate = ____

   (b) A classmate decimates by 20 instead. Explain what goes wrong, using the channel filter's ±90 kHz passband and the 57 kHz RDS subcarrier.

   (c) Find the Quadrature Demod gain that makes 75 kHz of deviation produce an output of 1, and the output when the carrier sits 30 kHz above center.

   gain = ____

   output = ____

   (d) Find the decimation from the demodulator to a 48 kHz sound card, and the time constant to type into FM Deemphasis for a US station.

   decimation = ____

   τ = ____

   (e) Explain why the flowgraph needs no Throttle, whether it plays a file or receives from the PlutoSDR.

3. **RDS.** RDS sends 1187.5 bits per second on a 57 kHz subcarrier.

   (a) The RDS branch resamples to 19 kHz before Symbol Sync. Find the samples per bit that Symbol Sync is set for.

   (b) The RDS signal is BPSK, a DSB-SC signal. Name the block in `L07-rds-rx.grc` that recovers its carrier, and explain why a recovered carrier 180° off does no harm, given the differential coding.

   (c) A station's audio is clear, but the station name never appears. Explain why RDS needs a stronger signal than the audio does.

4. **AM and FM in the same noise.** `L07-am-vs-fm.grc` sends a 1 kHz tone as AM at $m = 1$ in a 10 kHz channel and as FM in a wider channel, with the same transmitted power and the same noise. Its Input SNR slider sets the noise, and two meters show each receiver's output SNR.

   (a) Run it at 15 kHz deviation with Input SNR at 25 dB, as in the lesson figure. Say which output is cleaner, on the meters and on the frequency sink, and explain in words how FM wins although its wider channel lets in more noise.

   (b) Keep 15 kHz deviation, put the speaker on FM, and drag Input SNR down slowly. Describe what you hear, and what the FM meter does compared with the AM meter.

   (c) You raise the deviation from 20 to 40 kHz. Say, in words, what happens to the FM meter while the signal is strong, and to where the clicks begin as the noise rises. Explain the trade.

   (d) Set Input SNR to 8 dB and listen to the FM output at 10, 20, and 40 kHz deviation. Say which sounds cleanest and why, in words. Then say which you would choose for a weak link to a distant receiver.

5. **An AM receiver for ATIS.** An airport broadcasts its ATIS on 119.25 MHz. The PlutoSDR runs at 2.4 MS/s centered on 119.0 MHz, and the receiver is `L07-am-rx.grc`.

   (a) Find the Frequency Xlating FIR Filter's center frequency, and the decimation that takes it straight to a 48 kHz sound card.

   shift = ____

   decimation = ____

   (b) Lesson 6 detected the envelope with Abs, a low-pass filter, and a gain of $\pi/2$. Explain why Complex to Mag replaces Abs and the $\pi/2$ gain.

   (c) Explain why the AM receiver needs an AGC and the FM receiver does not.

Documentation: _____