Chapter 9

Commercial FM Radio

The frequency modulation (FM) and demodulation techniques were explained in detail in Chapter 5. In this chapter, with the help of concepts you learned earlier, you will build a receiver for commercial FM signals. The receiver will combine an analog front-end with a software-defined backend (see Figure 1.1).

9.1 Background

9.1.1 FM Stereo

Stereo multiplexing is a form of frequency-division multiplexing designed to transmit two different channels – Left (L) and Right(R) – on the same carrier. This is widely used in FM broadcasting to send different elements of a program. The FM stereo must be compatible with monophonic radio receivers. For this reason, the L and the R channels are algebraically encoded into the sum(L+R) and the difference (L-R) signals. A monophonic receiver will just use the L+R signal so the listener will hear both channels through a single speaker. The stereo receiver will add L+R and L-R to recover the L channel and subtract L-R from L+R to recover the R channel. The L+R channel places the baseband audio in the frequency range of 30 to 15000 Hz. The L-R channel is modulated onto 38 kHz DSBSC carrier occupying the baseband range 23 to 53 MHz. A pilot tone at 19 kHz can be used to recover the $19 \times 2 = 38$ kHz sub-carrier frequency; thus, the pilot is a reference used for coherent detection of the L-R signal at the stereo receiver. The compo-

nent at 57 kHz corresponds to the Radio Broadcast Data System (RBDS) signal, and the pilot can likewise be used as a reference for coherent digital demodulation of the RBDS signal. The FM broadcast signal is depicted in Figure 9.1.

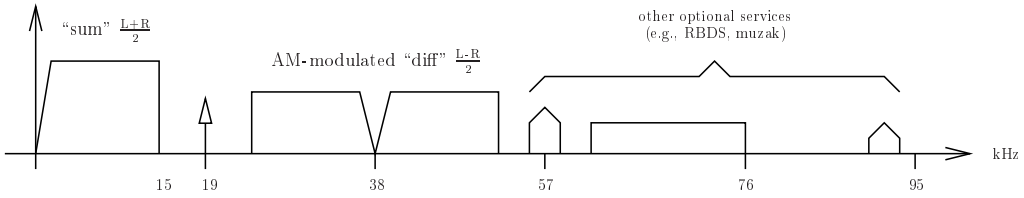

Figure 9.1: Spectrum of the FM broadcast signal.

9.1.2 Digital Implementation: FM Discriminator

You will be using an FM discriminator, shown in Figure 9.2, to demodulate the FM signal received. Refer to Chapter 5 for the digital implementation of an FM discriminator.

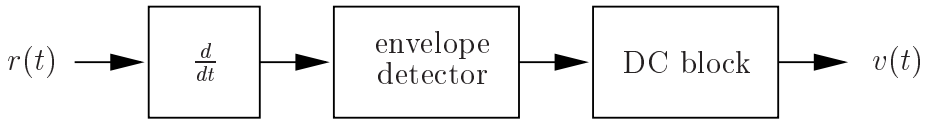

Figure 9.2: Discriminator for FM demodulation.

9.2 Exercise: RF Front End

In this exercise, you will construct the analog RF front end for operation in the FM band. A schematic is given in Figure 9.3.

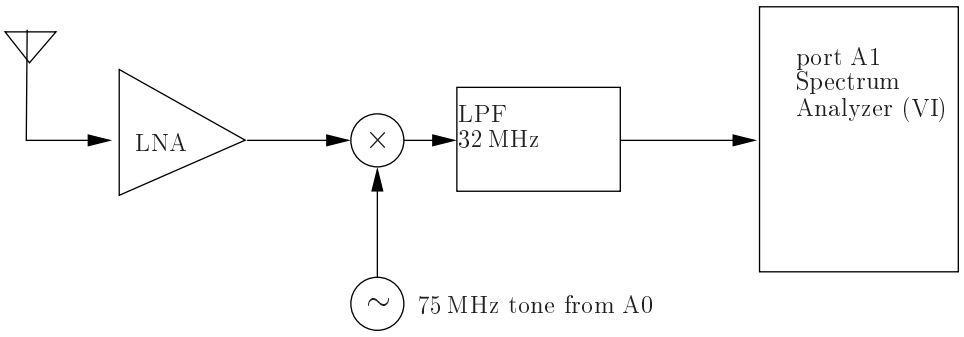

Figure 9.3: Schematic for analog RF front end.

Precaution! To prevent severe damage to the amplifier, turn the voltage supply on before connecting the amplifier. Do not connect the output signal to the NI board. Supply should be set to 15V. Connect the ground and then connect the supply voltage to the amplifier.

1. Build the circuit as shown in Figure 9.3.

2. Copy `TxStreaming.vi` to your workspace. Set the center frequency to 75 MHz and begin transmission of a tone to provide the local oscillator for the mixer.

   Precaution! Before connecting any signal source to the 5640-R analog input, first connect the output of the mixer to the oscilloscope and check the peak-to-peak voltage. Record your results (Amplitude). Make sure the value of the amplitude is less than 1V. If NOT, call the TA.

3. Use the oscilloscope to view the output of the analog lowpass filter.

- What is the peak-to-peak amplitude at the output of your lowpass filter?
- What does the mixer do? Explain its operation.
- Why do we use a low pass filter after the mixer?

Question 10.1: port p-p amplitu

Question 10.2: Explain mixing?

Question 10.3: Why LPF?

4. Next, use `RxStreaming.vi` to view the received signal and its spectrum. Connect the output of the analog low pass filter to the analog input at the IF transceiver board. From the spectrum you can observe several FM broadcast signals (each having 200 kHz bandwidth). Choose a strong FM signal and tune the digital downconversion ("center frequency") to demodulate that FM signal to 0 Hz.

   - What combination of local oscillator and digital-downconversion center frequency have you chosen to receive an FM broadcast signal?
   - What is the FM station corresponding to this frequency? (Hint: Google for the list of FM stations)

Question 10.4: Frequency selections?

Question 10.5: FM Station?

9.3 Exercise: FM Receiver

The following are suggested steps for implementing the software receiver.

1. Modify `RxStreaming.vi` to implement Figure 9.2, the FM discriminator. Refer to Chapter 5 for in-depth discussion.
2. On the `RxStreaming.vi` front panel, set the center frequency to the frequency determined previously in Question 10.4.
3. Set `IQrate` to `195K` and block size to a value greater than `300K`.
4. Using LabView, insert a low pass filter after the digital FM discriminator. The LPF should include only the L+R channel within the passband.

   - What is the purpose served by inserting a low pass filter following the discriminator?

Question 10.6: Why LPF?

5. Play the sound through the speakers. On the LabView front panel, cascade the lowpass filter, `BuildWaveform.vi` and `PlayWaveform.vi`. See `(Graphics and sound >> Sound >> Output)`.

6. Begin receiving. You should clearly hear a FM radio broadcast.

7. On the front panel, reduce the block size. Observe what happens with small block sizes.

   - Observe and explain your observation.

   Question 10.7: Observe?

8. Now rewire the front panel power spectrum to observe the input to the digital low pass filter.

   - What do the different peaks in the spectrum correspond to? Note the frequencies and give a sketch of the spectrum.

   Question 10.8: Spectrum