

# GNU Radio Lab 1: FM Broadcasting & WiFi Signals

EE 451: Communications Systems

Name: \_\_\_\_\_ Date: \_\_\_\_\_

## Objectives

1. Use RTL-SDR to receive and demodulate FM broadcast signals
  2. Understand frequency deviation and audio bandwidth in FM
  3. Observe WiFi signals in the 2.4 GHz spectrum
  4. Analyze real-world RF spectrum characteristics
  5. Build GNU Radio flowgraphs for signal reception
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## Equipment Required

- Computer with GNU Radio Companion installed
  - RTL-SDR USB dongle
  - Antenna (included with RTL-SDR)
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## Part 1: RTL-SDR Setup and Verification (15 points)

### Task 1.1: Verify RTL-SDR Connection

1. Connect the RTL-SDR dongle to your computer
2. Open a terminal and run:

```
rtl_test
```

3. Verify the dongle is detected

**Screenshot 1.1:** Paste a screenshot of successful `rtl_test` output here.

*[Insert screenshot]*

### Task 1.2: Launch GNU Radio Companion

1. Open GNU Radio Companion:  

```
gnuradio-companion
```
2. Create a new flowgraph
3. Add the following blocks:
  - **RTL-SDR Source** (from `osmocom` category)
  - **QT GUI Frequency Sink**
  - **QT GUI Waterfall Sink**
4. Configure the RTL-SDR Source:

- Sample Rate: 2.4 MHz (2400000)
- Center Frequency: 100 MHz (for FM band)
- RF Gain: 40 dB
- IF Gain: 20 dB

5. Connect the source to both sinks

**Screenshot 1.2:** Paste a screenshot of your flowgraph here.

*[Insert screenshot]*

### Question 1.1 (5 points)

- What is the frequency range of the RTL-SDR dongle you're using?
- What is the maximum sample rate supported?

**Your Answer:**

*[Write your answer here]*

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## Part 2: FM Broadcast Reception (30 points)

### Task 2.1: Build FM Receiver Flowgraph

Create a flowgraph with the following blocks:

#### 1. RTL-SDR Source

- Sample Rate: 2.4 MHz
- Center Frequency: [Your local FM station, e.g., 91.5 MHz]
- Gains: Adjust as needed

#### 2. Low Pass Filter

- Cutoff Frequency: 100 kHz
- Transition Width: 10 kHz
- Decimation: 10

#### 3. WBFM Receive (Wideband FM demodulator)

- Quadrature Rate: 240 kHz (after decimation)
- Audio Decimation: 5

#### 4. Rational Resampler (if needed to get 48 kHz audio)

#### 5. Audio Sink

- Sample Rate: 48000

#### 6. Add visualization:

- QT GUI Frequency Sink (after RTL-SDR)
- QT GUI Frequency Sink (after audio)

**Screenshot 2.1:** Your complete FM receiver flowgraph.

*[Insert screenshot]*

**Task 2.2: Tune to Different Stations**

1. Run the flowgraph
2. Tune to at least 3 different FM stations
3. Record observations in the table below:

| Station Frequency | Call Sign (if known) | Signal Strength | Audio Quality |
|-------------------|----------------------|-----------------|---------------|
|                   |                      |                 |               |
|                   |                      |                 |               |
|                   |                      |                 |               |

**Task 2.3: Observe FM Spectrum Characteristics**

1. Zoom in on a single FM station in the frequency sink
2. Observe the occupied bandwidth

**Screenshot 2.3:** Spectrum of a single FM broadcast station showing bandwidth.

*[Insert screenshot]*

**Question 2.1 (15 points)**

- a) What is the approximate bandwidth occupied by an FM broadcast station (measure from your spectrum display)?
- b) The FCC allocates 200 kHz per FM station. Why is this more than the audio bandwidth (15 kHz)?
- c) Compare the spectrum of a station playing music vs. speech. What differences do you observe?

**Your Answer:**

*[Write your answer here]*

**Task 2.4: Explore Stereo FM (Optional Bonus)**

FM stereo uses a 19 kHz pilot tone and L-R difference signal at 38 kHz.

1. Add an **FFT** block after the FM demodulator
2. Look for the 19 kHz pilot tone and 38 kHz subcarrier

**Screenshot 2.4:** Spectrum showing stereo pilot tone (if visible).

*[Insert screenshot]*

## Part 3: Frequency Deviation Measurement (20 points)

### Task 3.1: Measure Frequency Deviation

The FM broadcast standard uses  $\pm 75$  kHz maximum deviation.

1. Observe the spectrum during loud audio passages
2. Observe the spectrum during quiet passages
3. Note how the occupied bandwidth changes

### Question 3.1 (10 points)

- a) During loud audio, does the FM signal's occupied bandwidth increase or decrease?
- b) FM stations use "pre-emphasis" to boost high frequencies before transmission. Why is this done?
- c) What is the modulation index ( ) for an FM station with 75 kHz deviation and 15 kHz audio bandwidth? Use:  $\beta = \Delta f / f_m$

**Your Answer:**

*[Write your answer here]*

### Task 3.2: Compare NBFM vs WBFM

Try receiving a narrowband FM signal (if available): - Public safety or amateur radio: 144-148 MHz or 440-450 MHz - NBFM uses  $\pm 5$  kHz deviation

### Question 3.2 (10 points)

- a) What is the bandwidth difference between WBFM (broadcast) and NBFM?
- b) Why do mobile radios use NBFM instead of WBFM?

**Your Answer:**

*[Write your answer here]*

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## Part 4: WiFi Spectrum Observation (25 points)

### Task 4.1: View 2.4 GHz WiFi Spectrum

**Note:** RTL-SDR typically covers up to  $\sim 1.7$  GHz. For 2.4 GHz, you may need to: - Use a downconverter, or - Use a different SDR (HackRF, USRP), or - Observe the spectrum using `hackrf_sweep` or similar tool

If RTL-SDR cannot reach 2.4 GHz, complete this section using: 1. WiFi analyzer app on your phone, or 2. Spectrum screenshots from instructor materials

### WiFi Channel Allocation

| Channel | Center Frequency | Notes          |
|---------|------------------|----------------|
| 1       | 2.412 GHz        |                |
| 6       | 2.437 GHz        | Common default |
| 11      | 2.462 GHz        |                |

**Screenshot 4.1:** 2.4 GHz WiFi spectrum showing multiple access points.

*[Insert screenshot or describe observations]*

#### Task 4.2: Identify WiFi Characteristics

Observe and record:

1. **Channel width:** \_\_\_\_\_ MHz
2. **OFDM subcarrier spacing visible?** Yes / No
3. **Approximate power level difference between channels:** \_\_\_\_\_ dB

#### Question 4.1 (15 points)

- a) Standard 802.11n WiFi channels are 20 MHz wide. Why don't adjacent channels (e.g., 1 and 2) interfere with each other if they're only 5 MHz apart?
- b) How many non-overlapping 20 MHz channels exist in the 2.4 GHz band?
- c) Modern 802.11ac/ax uses 80 MHz or 160 MHz channels in the 5 GHz band. What is the trade-off between wider channels and coverage?

**Your Answer:**

*[Write your answer here]*

#### Task 4.3: Observe WiFi Traffic Patterns

1. Watch the spectrum while:
  - Streaming video
  - No network activity
  - Downloading a large file
2. Note the difference in spectrum activity

**Observations:**

*[Describe what you observed]*

### Part 5: Advanced Exploration (10 points)

#### Task 5.1: Explore Other Signals (Choose One)

Using your RTL-SDR, find and observe one of the following:

- ☐ **ADS-B aircraft signals** (1090 MHz)
- ☐ **NOAA weather satellites** (137 MHz)

- ☐ **Amateur radio** (144-148 MHz or 420-450 MHz)
- ☐ **Pager signals** (~929 MHz)
- ☐ **Weather radio** (162.4-162.55 MHz)

**What signal did you find?** \_\_\_\_\_

**Screenshot 5.1:** Spectrum of the signal you discovered.

*[Insert screenshot]*

**Description:** Describe the signal characteristics (bandwidth, modulation type if known, activity pattern).

*[Write your description here]*

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## Lab Summary

### Key Concepts Learned

1. **FM Broadcasting:**  $\pm 75$  kHz deviation, 200 kHz channel spacing
2. **SDR Architecture:** RTL-SDR samples RF directly, software does demodulation
3. **WiFi Spectrum:** 20/40/80 MHz channels, OFDM modulation, overlapping channels
4. **Real-world signals:** Impairments, interference, varying signal strengths

### Practical Skills Developed

- ☐ Built working GNU Radio flowgraph
  - ☐ Tuned and received FM broadcast signals
  - ☐ Analyzed RF spectrum characteristics
  - ☐ Identified different signal types in spectrum
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### Submission Checklist

- ☐ All screenshots inserted
- ☐ All questions answered
- ☐ All tables completed
- ☐ Flowgraph files (.grc) attached
- ☐ Document saved as PDF

**Files to Submit:** 1. This completed worksheet (PDF) 2. fm\_receiver.grc (your FM receiver flowgraph) 3. Any additional flowgraphs created

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*Submit to Brightspace by due date.*