

Laboratory Assignment: Exploring Spectrum



Names: _____

Objective

This laboratory assignment explores RF spectrum using the Spectrum Analyzer in the microwave laboratory. The exercises described here will help familiarize students with some of the basic test & measurement equipment used in microwave engineering.

Preparation

Before coming to the laboratory to perform this assignment, the students should prepare the following:

- Bring a WiFi-equipped laptop or PDA that can connect to the Georgia Tech LAWN (this will be used to generate a strong emitter in the 2.4 GHz band).

Write-Up

The students performing this laboratory do *not* need to prepare a stand-alone laboratory report for this assignment. All work may be neatly shown on this document, with any supplemental answers to questions attached. Be sure to include all group member names on this sheet.

Equipment Guide



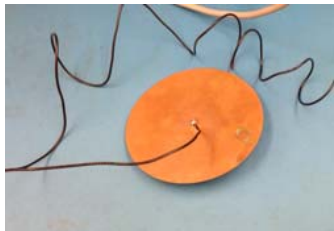
spectrum analyzer



connectors/adapters



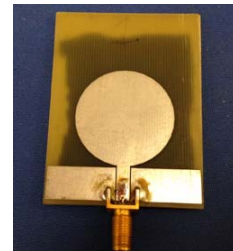
calibration kit



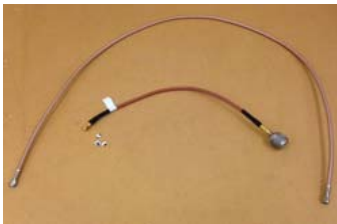
crude FM antenna



monopole antenna



2.4 GHz circle antenna



assorted coaxial cables

Procedure

Part I: Equipment Familiarization

1. Study the visual equipment guide above and locate all of these components in your laboratory benchtop and cupboard.
2. Place an N-type to SMA adapter on the input to the spectrum analyzer. Take out the SMA wrench from the calibration kit. Use this wrench to attach/detach all cables and adapters from one another as well as benchtop equipment. It is specially “torqued” so that the shaft will bend if you over-tighten an SMA connection. Practice using this wrench

Part II: FM Radio

3. Turn on the spectrum analyzer and allow several minutes for the equipment to initialize and warm-up. In your cupboard should be a connectorized copper disk with a long wire attached; this is a crude FM antenna. Connect this antenna to the input port of the spectrum analyzer.
4. Change the frequency range so that the analyzer is displaying the 200 kHz of bandwidth allocated to 91.1 MHz WREK (the closest FM transmitter to campus).

First change the center frequency of the display:

- Press the [**Freq. Cha.**] console button.
- Select [**Center Freq**] on the screen.
- Enter “91.1 MHz” from the console keypad.

Next change the span of the analyzer’s display:

- Press the [**Span**] console button.
- Select [**Span**] on the screen.
- Enter “200 kHz” from the console keypad.

You should now see sweeps of the FM modulated spectrum from WREK. Notices it changes from one moment to the next. To get a more complete view of this station’s spectral occupancy, we will need to do some averaging:

- Pres the [**BW/Avg**] console button.
- Select [**Res BW**] on the screen.
- Enter “1 kHz” from the console keypad.
- Select [**Average**] on the screen.
- Turn on the averaging.

Now the analyzer will average multiple sweeps together to provide a running average of the signal spectrum power. Also, by reducing the resolution bandwidth to 1 kHz, the analyzer will now calculate a spectral component using a much tighter filter. The *resolution bandwidth* of an analyzer refers to the bandwidth of the filter that the analyzer passes the signal through before calculating the total power in a spectral component. If it is set too large, then the displayed spectrum loses details (nearby components blur together) and the noise floor increases (since more thermal noise is allowed into the calculation instead of filtered); if, however, the resolution bandwidth is set too small, the sweep takes longer to calculate and (in zero-span mode) the analyzer may miss some of the total signal power of a source.

The *video bandwidth* specifies another filter that the video waveform is passed through before displaying on the screen. This is a cosmetic operation; it is usually set to the same value as the *resolution bandwidth*.

Now make some precise observations using a display marker:

- Press the [**Marker**] button on the console.

Use the console knob to move the marker to observation points in the spectrum.

What is the 10 dB bandwidth of the radio station's signal spectrum? Is WREK using the entire 200 kHz? Is there any evidence of a secondary signal in the sideband?

5. If the spectrum signal is not strong, adjust the sweep time:
Press the **[Sweep]** button on the console.
Select **[Sweep Time]** on the screen.
Increase the sweep time (start with 10 ms)

Observe the effects of increasing and decreasing the sweep time. Note particularly what happens to the noise floor and spectral resolution when sweep time is increased. There is important relationship between averaging, resolution bandwidth, and sweep time – they all trade-off against one another to achieve varying degrees of analyzer sensitivity.

Explore the trade-off between sensitivity and acquisition time (scanned MHz/sec) using your spectrum analyzer. Fill out the table below with either **increase** or **decrease**:

If you increase...	the Noise Floor...	the Acquisition Time...
Averaging		
Resolution Bandwidth		
Sweep Time		

6. Zero-span mode refers to a spectrum analyzer mode where the start and stop sweep frequencies are identical, resulting in zero-bandwidth sweeps on the display. Truthfully, the analyzer is actually sensing the power over the non-zero band determined by the *resolution bandwidth* parameter.

Place the analyzer's span in zero-span mode. Set the resolution bandwidth to the bandwidth of the FM signal that you measured in the previous step. The spectrum analyzer has an FM demodulation feature. Check to see if you can hear the radio signal coming in through the analyzer:

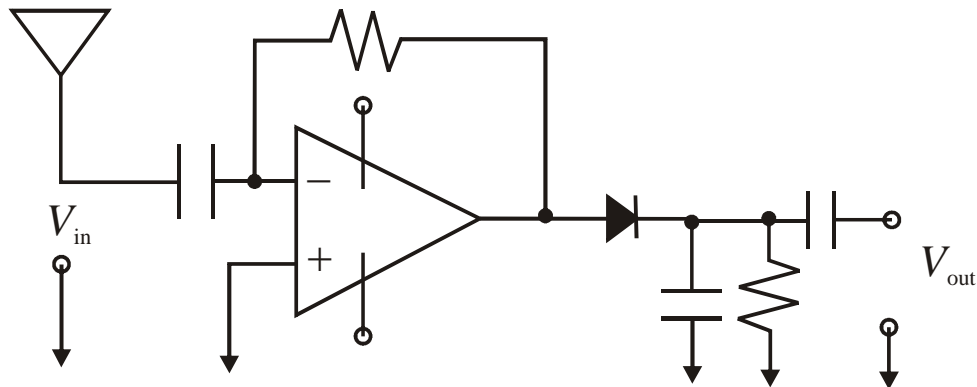
- Turn the averaging off.
- Press the **[Demod]** button on the console.
- Select the **[FM]** option on the display.

Make sure the [Speaker] is on.

Adjust the volume knob on the console if you cannot hear anything.

Were you able to hear the radio station? It should not sound continuous. Speculate as to why the analyzer demodulates intermittently.

FM Detection. The following circuit may be used to demodulate an FM signal (see mathematical form below). On an attached sheet of paper, explain step-by-step how this detector operates, describing the role of each component in the circuit.



$$x_{RF}(t) = A \cos \left(2\pi \int_0^t (f_c + k_f x(t')) dt' \right)$$

To the write is the mathematical description of a baseband signal $x(t)$ that has been modulated to an RF waveform $x_{RF}(t)$.

$$\text{Instantaneous Frequency: } f_i = f_c + k_f x(t)$$

$$f_{peak} = k_f \max(x(t))$$

Part III: Cellular Radio Band

1. Attach a quarter-wavelength 860 MHz monopole to the spectrum analyzer and view the output. In the United States, lower-end spectrum for cellular phones is allocated between 825 MHz and 890 MHz. Scan this area to find voice and control channels for the cellular network.

How many voice and/or control channels can you see? Are they GSM channels (200 kHz) or CDMA channels (1.25 MHz)? Other channels with different bandwidths? How many of each?

Part IV: WiFi Scanning

1. The goal of this exercise is to take a snapshot of a 2.4 GHz WiFi data packet. Turn on a WiFi-enabled laptop and logon to the Georgia Tech LAWN. Attach the circular antenna to the spectrum analyzer with an SMA cable – this will be the “sniffer” antenna.

WiFi network cards typically transmit in the 2.400-2.488 GHz microwave bands. The transmissions are *packetized*, which means that an analyzer sweep will not capture the signal spectrum unless the transmission happens to fall within the sweep period. This means that the students will have to adjust the sweep speed and resolution bandwidth in order to procure a good snapshot. It may also help to set the laptop or PDA to download/upload a very large file in order to ensure there are lots of data packets exchanged with the computer’s WiFi modem and the access point.

What is the bandwidth of the WiFi transmitted packet? How many non-overlapping channels would fit into this unlicensed spectrum?

2. The spectrum immediately below 2.4 GHz consists mostly of licensed bands. One of the strongest emitters in Atlanta are satellite radio repeater stations, which are used to relay the satellite radio signals to mobile users in urban environments where buildings may block the direct satellite signal.

At what center frequency is the satellite radio repeater? What is the bandwidth of this signal? If you do not see this radio spectrum, surmise why it might not be visible (hint: consider the propagation environment/location).