Lab 4: Measuring Received Signal Power
EE 361 – Signal Propagation
Spring 2019

This is a one-week lab, plus an extra class period next week (tentatively) outside taking measurements. The lab period is 09-May, and the outdoor portion will take place some to-be-determined day next week (based on weather). You have two full weeks to write up the lab report (i.e., it's due before the start of lab two weeks later, on Thu 23-May). However, please note that we will start the final project during next week's lab session, so you are encouraged to finish the lab report as soon as possible. Remember to take good notes in your lab notebook. You will want to include screenshots in your lab report, as well.

In this lab, you will use a digital TV tuner USB stick for a purpose other than which it was intended. Instead of using it to receive and decode digital TV[1], you will use it to measure relative received powers of various signals in the frequency domain, which will be useful for the final project where you will be asked to characterize the behavior of an antenna that you build.

Objectives:

- Familiarize yourself with the operation of the RTL-SDR software defined radio, and the SDRSharp software.

- *Think* about how to measure receive signal power.

- Practice measuring relative received signal powers, and comparing them with theoretical expectations.

- Explore waterfall diagrams, and gain experience scanning for signals.

Components needed:

- RTL-SDR (containing RTL2832 and R820T chips)

- Whip antenna

- PC running SDRSharp software (you are encouraged to use a laptop)

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[1]This is difficult in Bellingham since the received power of the Seattle TV stations is generally too low!

Tasks:

1. **Installation of SDRSharp software**. You may skip this step if using a Western-furnished PC (e.g., desktop or loaner laptop), as SDRSharp is already installed. Note that this part is tricky, requires you to follow each step **precisely**, can vary a little due to differing hardware/software setups, and may require a couple of attempts.

   (a) Download `sdrsharp-x64.zip` from the course website, and unzip it into a directory at `c:\sdrsharp`.

   (b) In `c:\sdrsharp`, run the batch file `install-rtlsdr.bat` (for example, by double-clicking on this file when in the File Manager). A terminal window will pop up, and some stuff will happen. Just be patient. Eventually it will close.

   (c) Insert the RTL-SDR USB dongle into your laptop. If Windows tries to install a driver, try to stop the process.

   (d) In `c:\sdrsharp`, run the executable file `zadig.exe` (for example, by double-clicking on this file when in the File Manager). From the top menu bar within Zadig, select: Options → List all devices. From the drop-down box in the main Zadig window, select "RTL2832U". Click "Install driver". After it complete, close the Zadig window.

   (e) In `c:\sdrsharp`, run the executable file `SDRSharp.exe` (for example, by double-clicking on this file when in the File Manager).

   (f) Set the device to "RTL-SDR (USB)".

2. **Tuning in an FM Radio Station**. It is challenging, if not downright impossible to measure signals from within the depths of the Ross Engineering Technology Building. As such, you will want to do these remaining steps outside, if you have a laptop. In a real pinch, you can use the desktop computers in ET 338, but you will have a much harder time collecting data. You must complete these steps in exactly the order specified, or you may encounter problems. First, insert the USB dongle into the USB port on the front of the computer. Then, using the File Manager in Windows, navigate to the folder `c:\sdrsharp` and double-click the program called `SDRSharp.exe`. After the program loads, click on the gear icon to access the configuration settings. Deselect "Tuner AGC" (if selected), adjust the RF gain (i.e. the gain of the amplifier inside the software radio) to as near 20 dB as you can, and make sure that the sample rate is set to 2.4M samples per second. As always, take note of the exact values in your lab notebook, and include them in your lab report[2]. Back in the main program, ensure that "WFM" or wideband FM is selected in the radio demodulation options. Then, click on the frequency numbers on the top of the window, and type in your favorite FM radio station (e.g. KUGS 89.3 MHz, KISM 92.9, KZAX 94.9, KMRE 102.3, etc). Finally, click the play icon to start demodulating an FM station. Verify that you hear sound from the computer speaker. The top plot shows the relative magnitude spectrum in the frequency domain (in dB), and the bottom plot is a "spectrogram" or

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[2]Please always take note of settings and other details related to your experiment. This document does not always specifically ask for these details because it is expected lab practice.

"waterfall" plot that shows how the frequency changes with time. Do you see nearby stations? If you use the mouse to click and "grab" the frequency response plot and drag, you can easily change the frequency. Explore the FM frequency band... Make note of your observations.

3. **Antenna placement and orientation.** Note that the dB numbers reported on the frequency domain plot are *relative* power numbers since they are in dB and not in dBm. The reported values are not true power values since we would need to calibrate the RTL-SDR to establish what corresponds to 1 dBm of received power. However, the device is still very useful for measuring relative received powers (e.g. in establishing whether the received power of 89.3 FM is ten times as strong as 102.3 FM). Now, tune in a station. Think about how you would measure the relative received power.

In doing this, look in the top window and focus on the units shown on the axes. **Ignore the reported numbers near the cursor (if any).** Like the oscilloscopes in the lab, SDRSharp will attempt to make its own (often erroneous) measurement of various quantities. I want you to be able to estimate or compute these quantities on your own, from the graphical information (and not from the numbers "estimated" by the software).

So, how do you estimate the average received power? Over what range of frequencies do you make this determination? Would you simply take note of the largest dB value? How might you estimate the noise power from the figure? After reflecting on this, **you must get checked off that you've had a discussion with the instructor about this point**. You may find it useful to lower the "S-Attack" and "S-Decay" values in the FFT Display settings for purposes of estimating the power. **Important:** All measurements must be made with identical display settings in order to be comparable. So, if you adjust your settings, and you want to compare two measurements, you may need to repeat measurements. In any case, you should take note of all settings and measurements so that you or others can repeat your results (a screenshot of the relevant FFT display settings might suffice here).

Record your estimate of the *relative* received power in dB of the station that you have tuned in, and estimate the SNR (in dB) of the station you have tuned in. Explore the effect of antenna placement on signal power, and comment on what you see. Does the antenna orientation (horizontal versus vertical) change things? Are there sources of noise (e.g. 60 Hz harmonics) that may affect the signal? How does the SNR change? Does touching or being near the antenna change things? Is your antenna isotropic? In both 2-D and 3-D? How does the length of your antenna relate to the wavelength of transmission?

4. **Effect of RF Gain.** Again, tune to the station from the previous step. In the first step, you set the RF gain to 20 dB. Explore the effect of changing this value. How does the noise floor change? How does **your** measured (not SDRSharp's measured) SNR change? Can you audibly "hear" the SNR changing in the received audio signal? What is a "good" value of RF gain for the weak station you have tuned in? What happens if it is chosen to be too small? Too large? Why? Can you provide measurements and

data to back up any SNR claims? Remember to return the RF gain to the initial 20 dB value to permit comparison of all measurements you've taken with those you will take in the next step.

5. **Received power measurements of FM radio stations.** Find 3 different FM radio stations, and measure their relative received power. Try to include a mix of weak and strong stations. Describe your measurement procedure, and any other challenges or observations you make along the way. Put results in a table with the following headings: frequency, call letters, distance from campus, effective radiated power (ERP), measured relative receive power (dB). (In the interest of time, you may want to postpone finding some of this data until a later time, outside the designated lab period.) To find the distance from campus and ERP of each station you have chosen, you will find `radio-locator.com` very useful.

6. **Received power measurements of digital FM radio stations.** One challenge with measuring the received power of an analog radio station is that the received power is higher when the music is louder, and it is near zero (except possibly for the presence of a carrier signal) when the radio station is transmitting audio silence. Let's now consider an alternative method of measuring received power of FM radio stations. Some stations additionally transmit *digital* streams which appear ± 0.15 MHz from the carrier, as shown in this figure:
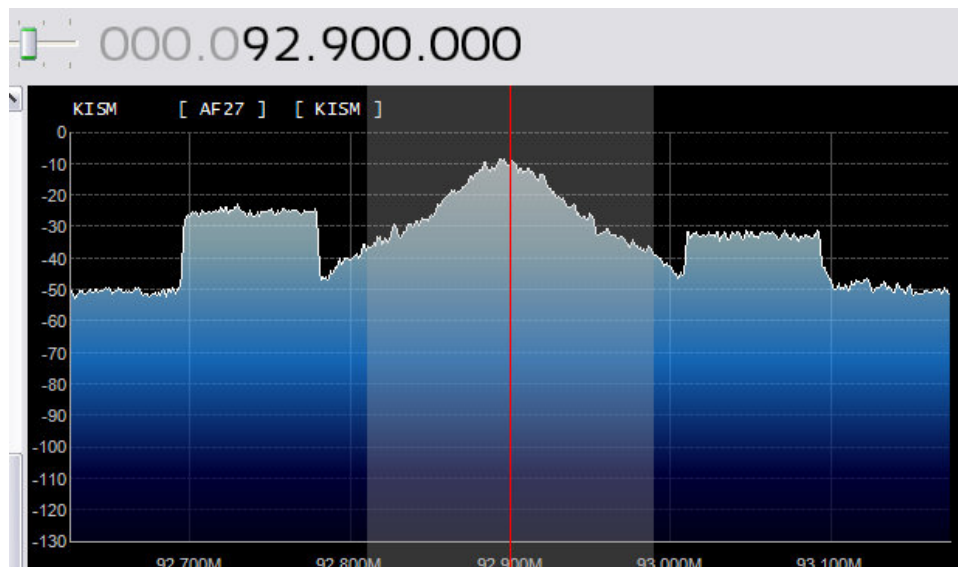

Figure 1: Analog FM transmission sandwiched between two digital streams.

Even when the radio station is "silent" from an audible point of view, it is always transmitting digital information. Furthermore, the digital signal is "white" since it contains energy at all frequencies across its band, and is flat. On the other hand, the analog transmission is "colored", is not flat, and adds an amount of guesswork to the received power measurements. Radio stations in Bellingham that transmit digital IBOC streams include: 90.3, 91.7, 92.9, 104.1, and 106.5. Make a second table just

like the previous step, but now measure the received power of the *digital* portion of at least 3 radio stations, including ERP, etc.

7. **Public service frequencies.** There are several frequency bands that are used for public services, such as local police and fire. See if you can estimate the received power of transmission on these public service channels by "scanning" the frequencies between 453.0–454.0 MHz, and monitoring the waterfall plot. Note that you will need to change the demodulation to "NFM" since narrowband FM is used for the handheld transmitters used by these services. You may need to be patient, and wait for someone to speak. While waiting, you will probably want to set the "squelch" setting as low as possible, but just high enough to silence the noise. You're likely to encounter transmission from Bellingham police and fire, WWU police, Whatcom County Sheriff, or maybe even the Washington State Patrol. You may find other public services 154-156 MHz. Report which frequencies you observed, the public service name (if possible), and the relative received power. Please do **not** report anything about the contents of the transmission.

8. **Foxhunting and path-loss modeling (at a later date).** Several portions of the radio spectrum have been allocated for use by amateur radio operators (or "ham" operators). In order to transmit in these bands, one must pass an exam and obtain a license. Your knowledge of EE 360 and EE 361 gives you excellent preparation for this exam, in case ham radio is a hobby you are interested in pursuing[3]. Indeed, there are several ham operators in the department, including students. Ham operators tend to refer to the frequency bands they're using more commonly in terms of their wavelength; for example, the 15m band operates between 21.025 and 21.2 MHz.
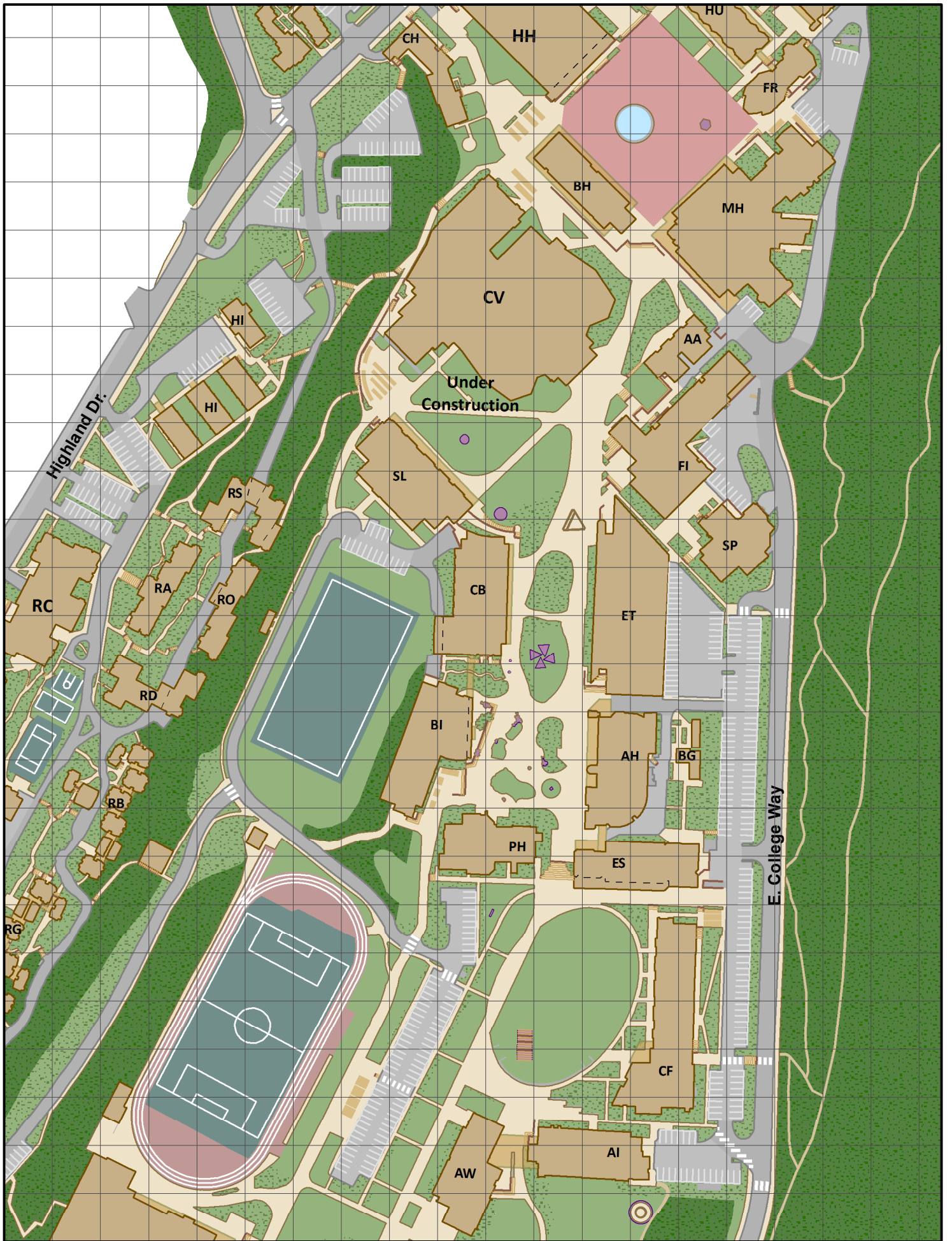
In this lab, a ham radio has been hidden somewhere on campus within the boundary of the attached map, and the transmitter is continuously broadcasting in the 2m band at 146.565 MHz. Using your laptop as a radio receiver, you are to travel across campus measuring the relative received power of the signal on that frequency (this activity is called "foxhunting" by ham operators, though it usually takes place over an area spanning many miles, and most hams use directional antennas). By following the signal to areas of higher intensity, you should be able to locate the source of the transmission.

For each received power measurement that you take, mark your map with the location at which you made the measurement, and write down the received signal in your notebook along with any related notes about the signal or interference. Take at least 10 measurements across campus, across a fairly wide location.

Once you have determined the location of the transmitter (or once it has been revealed by the instructor), identify it on your map, and take note of the distance of each of your 10 or more measurements from the transmitter. Now, take a few additional measurements at varying distances from the transmitter to make sure that you have measurements across a diverse range of transmitter-receiver distances. Once the foxhunting activity has concluded, accurately measure the distance between each measurement you took and the transmitter, using your map. Choose a nominal transmit

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[3]The Mount Baker Amateur Radio Club's website has more information on license exams.

power, and plot the attenuation as a function of distance from the transmitter. In this plot, your x-axis should be in meters, and your y-axis should be in dB. On the same axes, plot the predicted attenuation using the simplistic free-space path-loss model (without a reflecting path). Does the measured attenuation follow the same trend as the (single-path) free-space path loss propagation model predicts?

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