

ECE 764 Lab 1

Familiarization with Radios and Spectrum Analyzers

Due Friday, Feb 8, 2019 @ close-of-business

Overview

In this lab, you will work with partners to learn about radio transmissions and associated frequency and signal strength measurements. Transmissions will be made using unlicensed-band handheld units and signal strength will be measured using the lab's spectrum analyzers. The main parts of the lab include:

0. Form your team of 3 to 4 students and collect contact info to help schedule when you will do the lab together.
1. Select the radio sets you personally want to investigate (CB, MURS, FRS, ISM band, or DECT 6.0 radios). **Each person in a team selects one radio-set/frequency-band so that performance comparisons can be made by the team.**
2. Research information on the radio service and band you personally selected, including allowable frequencies, signal bandwidth, and maximum transmission power. Each person does this independently for their band.
3. Measure the frequency of operation of the selected radios using a frequency counter or spectrum analyzer.
4. Compute the wavelength, and the ideal length of a $\lambda/4$ monopole antenna.
5. Measure/observe the bandwidth of the signals transmitted using the spectrum analyzer.
6. Measure the received power level versus distance and compare with theoretical "path-loss" in free-space.
7. Observe how received power is affected by obstructions such as building materials and people
8. Test the radio transmission range capabilities between the lab and various locations inside the building
9. Test the transmission range from inside the building to various points outside
10. Test the transmission range when operating outdoors (connecting the outdoor discone antenna to the spectrum analyzer)
11. Document your results in a team report (with two independent sections, one written by each teammate).
12. Document comparisons on transmission performance versus the two frequency bands tested.

Lab Partners and Writeups

After taking the measurements, you must writeup your results in the form of a report composed of 3 to 4 major sections - one for each radio-type/frequency-band. **Each student must do one section that covers their radios and frequency band.** **Do NOT** intermix the results as you go. A conclusions section at the end will be used for that.

Before the first major section, provide a brief introduction summarizing the goals above, and introducing the radios/frequencies involved. This can be written by one or more teammate(s). ***The key to good writing is to review and revise what you write before you release it, and your teammates can be useful for that here.***

Each individually written section should include its own introduction followed by subsections (with **narrative and pictures**) explaining the procedures, the results you got for that part, any problems you encountered (plus the resolution if any), and conclusions/observations relative to theory. For this section, you are required to do your own review and editing. You can let others read your section, but **Do NOT use others to rewrite your section.**

At the end, you should write up observations and comparisons about how the different radios/bands compare in terms of range, usability, etc. This section can and should be co-authored (and edited) by all teammate(s).

As described in the course syllabus, grades will be based on the Completeness, Correctness, and overall Quality (CCQ) of your writeups, so strive to provide a good engineering report.

Partner Selection

Record the names and contact information of your teammates below

Radio Service Band Selection

Each person in a two-person team must select a radio band to be responsible for (CB, MURS, FRS, or 900 MHz ISM band). In the lab, try-out the radios provided and make your selection, recording it below. *Don't be afraid of the "old" CB radios. You may find they outperform the newer fancy ones -- there's got to be some benefit to those absurdly long antennas !)*

Responsible Person

Service Band

_____	_____
_____	_____
_____	_____
_____	_____

Researching Information on Selected Service Band

Using the web and information provided on our class webpage, each teammate should determine and document the following for their selected radio-set:

- *The full name of the service band from the acronym (e.g. CB=citizens band) and who/what it is intended for*
- *The part and subpart of FCC CFR rules that govern that service. Wikipedia is likely a good resource here...*
- *The number of channels and associated frequency range for that service (listing every channel is **not** required)*
- *The type of modulation used (e.g. AM, FM, FSK/FHSS, etc.)*
- *The maximum legally allowed transmitter power and antenna height, or radiated field strength*

Measuring Frequency of Operation

You can measure the frequency of operation of your radios using either the frequency counter in the lab, or one of the spectrum analyzers. The frequency counter is the simplest to use for basic analog radios*. Be sure to configure it to provide the required resolution of at least 1 ppm (6 significant digits). If using the spectrum analyzer, be sure to zoom-in on the frequency axis (set to lower spans) as needed, since the resolution of frequency is about equal to the span over 480 or 1024 and it will not be accurate at wide span settings.

*NOTE: The frequency-counter may not work for the ISM band radios (since they use "frequency hopping" and don't stay on a frequency long enough). For the ISM band radios, an alternative is to use the spectrum analyzer and record the maximum and minimum frequencies you see, and quote the average value. You could try the "peak-hold" function in the Display menu for this...

Also be sure to record the channel you are on, if there is an option (***For the CB radios, use channel 15 which is setting A on the larger one. For the ISM band, leave the radios on the "public band" channel***)

Channel: _____ Frequency: _____

Wavelength and Antenna Size

As discussed in class, you can compute the wavelength for any given frequency if you know the speed of propagation. Using the speed of light (since we're in "open-air" which is close to the permittivity of vacuum), find the wavelength in meters. Record this computed value below to 3 significant digits. Using more than 3 significant digits is unnecessary for our purposes - since we are mainly interested in how long to make our receiving antenna. Such antennas work fine as long as you're within about 2 to 5 % of the correct length (which implies 2 to 3 significant digits is OK).

From the wavelength, find the length of a $\lambda/4$ antenna. You should use this length for configuring the receiving monopole antenna you connect to the spectrum analyzer; except for the CB case, which is too big - so use the loaded mag-mount monopole (white rod) antenna for that.

<u>Frequency</u>	<u>Wavelength in meters</u>	<u>Lambda/4 Antenna length in meters</u>
_____	_____	_____

Modulated Signal Bandwidth

Adjust the antenna connected to the spectrum analyzer to the proper length as found above and set the analyzer controls to monitor your transmitted signal (set frequency, span, amplitude reference level, etc.)

DO NOT let the antenna of your radio touch the spectrum analyzer's antenna, since the radios could be too powerful. Keep the antennas separated by a minimum of $\lambda/4$ at all times.

Transmit using one of your radios while monitoring your audio on the other radio and the display on the spectrum analyzer. Adjust the amplitude reference level if it is too close to the top of the display.

While speaking a continuous vowel sound (e.g. "eeeeee"), observe the spectrum bandwidth. Adjust the Span if needed to assess the bandwidth more clearly. Generally people may use either the "10 dB down" or "30 dB down" from maximum to ascribe a bandwidth value. Try talking close to the mic to get the widest bandwidth and record it. Adjust span and repeat to be sure you're seeing the signal bandwidth and not the spectrum analyzer's. Does the bandwidth agree with the FCC rules you researched previously?

NOTE: For the ISM band FHSS (frequency hopped spread spectrum) radio, this is a challenge. We want the modulation bandwidth, not the full range of frequencies hopped to. You should try setting the analyzer on one of the frequencies it hops to and use the Display>Peak-hold function (but be sure to return the analyzer to Clear/Write mode when done).

Record your result in kHz below, and **take photos of your setup and the spectrum observed** for use in your writeup.

_____ kHz

Received Power versus Distance

As above, tune the center frequency of the analyzer to the frequency you are using. Set the span to about 1 MHz (or 50 MHz for the ISM or DECT bands if it is easier). Then, using one of the radios, transmit a signal from various distances from the analyzer's antenna (***without modulating***), *recording the distance and the signal power displayed*. Keep the antennas in a "co-pole orientation" during your work (e.g. both vertical) !

Note that powers are displayed in dBm and the analyzer's default vertical scale is 10dB/division, relative to the "reference level" at the top of the screen. (Typically the top line is 0 dBm and the major divisions are 10dB, making the next line down -10 dBm, and so forth).

You may need to change the Amplitude>RefLevel to a higher value, especially for the case of the CB or MURS radio due to their higher power and longer antennas. If the signal level is at/over the top of the screen, it will not read correctly and you will need to adjust Amplitude>RefLevel. Similarly if the signal is "in the noise" near the bottom, you should adjust RefLevel, Span and/or Bandwidth to get a valid reading. This will be especially important in the next parts when you walk around inside/outside the building and check the range you can achieve with the radios.

<u>Distance (meters)</u>	<u>Received Power (dBm)</u>	<u>Received Power (Watts)</u>
<u>0.5</u>	_____	_____
<u>1</u>	_____	_____
<u>2</u>	_____	_____
<u>4</u>	_____	_____

As you vary the distance, does the received power decrease in accordance with $1/R^2$? (How many dB per doubling of distance should this be?) In your writeup, ***do a graph of these results to better understand and present them.***

Don't be too concerned if the measurements are not following theory well here. Measurements often don't, because theory is always simplified - ignoring additional factors we may not be modeling. For example, here there is lots of "multi-path" effects due to all the metal in the room, and windows ! Try this measurement set for a few different positions at each distance...

And as always, take photos and use them to help document your work. Remember - a picture is worth a thousand words. So use the photos to help you in writing and the reader in understanding your work.

Effects of Obstructions on Received Signal Level

Physical objects often interact strongly with radio signals, depending on their material composition. Metal blocks signals, or reflect signals, while some materials absorb them. Some are relatively "transparent" to radio. In this part you will attempt to determine the effects of various materials on received signal strength.

Move your radio about 1 meter away from the spectrum analyzer and transmit (without modulating), recording the received signal level in dBm. Then, without changing your radio's position, place one of the following objects between the radio and the analyzer and record the new signal level. Put the material just in front of the receiving or transmitting antenna so it blocks the path as fully as possible for the radio/antenna size. How many dB is the signal decreased by the presence of the material? I.e. what is the attenuation in dB relative to the unblocked path in the first measurement ?

<u>Case</u>	<u>Received power in dBm</u>	<u>Attenuation in dB</u>
No obstruction:	_____	<u>0</u> _____
Ceiling tile:	_____	_____
Plywood:	_____	_____
Drywall:	_____	_____
Person:	_____	_____
Metal sheeting:	_____	_____

Repeat each case a few times to be sure you get consistent results, since small variations in positions of the radio-to-analyzer path length can change the results significantly due to "multi-path" in the room. In particular, be sure the first measurement is not changing as you try different materials. In a multi-path environment, the signal bounces off objects, reaching the receiver via additional/different paths other than the direct path you are assuming when you place the obstruction between the antennas. The signals from the multiple paths then combine either constructively or destructively depending on the relative phase delays along those paths. If you move around, all this will change, even if you don't change the distance. Present your final results in a table (with associated narration) in your writeup.

In-Building Communication Performance

Our indoor propagation environment contains plenty of multi-path due to metal benches, etc - but it can get even worse when you go to other locations in the building. One would generally assume that larger distances will lead to decreased received power, but this is only true on a large scale. To get a feeling for what happens in the Engineering building, take the radio to various spots including those below and record the received signal power and estimated distance. Use the other radio of the pair (or your cell phone) to communicate from the person reading the spectrum analyzer, but of course, don't record measurements while the radio at the analyzer end is transmitting ! You may have to decrease the reference level and/or resolution bandwidth to keep the received signal from the distant radio above the "noise floor" as you go to more farther locations. (Also don't measure while talking, since modulation will spread the power and lower it.)

Outside Communication Performance

Finally, determine the range of the radios when operating fully outdoors, with relatively “line-of-sight” propagation. For this, connect the analyzer to the outside antenna (and make sure the lightning protection switch is in the correct position). Then go down to the ground floor and outside, right underneath the antenna to start. Walk south past all the nice greenery taking some measurements as you go. Then continue over to Denison (look both ways before crossing the street !). Keep going at least until you hit Anderson. (Again be mindful of traffic/etc)

Use a Google Maps screenshot or other map to help take and present this data:

<u>Radio location</u>	<u>Signal level (dBm)</u>	<u>Distance (radio-to-outside antenna)</u>
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Document / Writeup

See page 1 and class discussion for instructions on how to do your writeup. Do NOT turn in the instruction sheets. Writeup your procedures and results/conclusions in the form specified on page 1 and in a way that someone unfamiliar with these instructions would be able to follow what you did and understand the results you got and what they mean. I.e. provide a good narrative in addition to the data and discussions. Again - see page 1 (plus the instructions along the way).

As stated on page 1, each person does their own writeup as a separate “Section” for the team report. Include your name at the beginning of your section ! Then your team as a whole should do the Intro and Comparison/Conclusions* and combine your parts into a single report. Place a coverpage on it with your team name and list of team members and which radios they did.

Finall, rest and come back to it later and make sure it is all there and reads well before you turn it in. That’s why we will make “close of business” the following Monday morning :-)

*In the comparison/conclusions section, provide a brief summary of what you learned in the lab. For example: Which measurements agreed well with theory and which did not? Which radio band performed best. Why? Should you trust advertising that says these FRS radios can transmit “up to 14 miles” ? ; -)