ECE 764 Lab 1
Familiarization with Radios and Spectrum Analyzers
Due in-class, Wednesday

Overview

In this lab, you will work with a partner to learn about radio transmission and associated signal strength measurements. Radio transmissions will be made using unlicensed handheld units and signal strength will be measured using one of the lab's spectrum analyzers. The main parts of the lab include:

a. *Find a partner and exchange contact information so you can schedule time to do the lab.*
b. *Select two of the four options for radio sets: CB (27 MHz), MURS (150 MHz), FRS (465 MHz), or ISM band (900 MHz) . Each person in a team selects one band so that peformance versus band comparisons can be made by the team.*
c. *Research information on the service band(s) selected, including allowable frequencies and maximum transmission power*
d. *Measure the frequency of operation of the selected radios.*
e. *Compute the wavelength, and the ideal length of a lambda/4 monopole antenna from the radio frequency.*
f. *Measure/observe the bandwidth of the signals transmitted using the spectrum analyzer.*
g. *Measure the received power level versus distance.*
h. *Observe how received power is affected by obstructions such as building materials and people*
i. *Test the radio transmission range capabilities between the lab and various locations within the new Engineering Hall building*
j. *Test the transmission range from inside the building to outside*
k. *Test the transmission range when operating outdoors only*
l. *Document your results in a team report (with two independent sections, one written by each teammate).*
m. *Document general conclusions on transmission performance versus the two frequency bands tested at the end of the report.*

Lab Partners and Writeups

At the end of this lab you must writeup your results in the form of a report. Each student must do one "Section" that covers their radios. Do NOT intermix the results as you go.

Before the first section, provide a brief introduction summarizing the goals above, and introducing the radios/frequencies involved. This can be written by either teammate.

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

Partner Selection

Record the name and contact information of your teammate below

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Radio Service Band Selection

Each person in a two-person team should select a radio band to be responsible for (CB, MURS, FRS, or ISM band). In the lab, try-out the radios provided and make your selection, recording it below. Then "sign-up" for your band on the table posted in the lab. If your selected band is already taken, you will have to chose another. *(Sorry. This is to make sure we cover all bands. Don't be afraid of the "old" CB radios. You may find they outperform the newer fancy ones -- there's got to be some tradeoff against the 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 try to determine and document the following for their selected radio band:

- *The full text name of the service band from the acronym (e.g. CB=citizens band) and who/what it is for*
- *The number of channels and associated frequency* range *for that service (listing every channel is not needed)*
- *The modulation used (e.g. AM, FM, FHSS, etc.)*
- *The part and subpart of FCC CFR rules that govern that service*
- *The maximum legally allowed transmitter power 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. Be sure to configure the counter to provide the required resolution of at least 1 ppm (6 significant digits). 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***
______________________	______________________ MHz

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...

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

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 vaccuum), find the wavelength. 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 significant digits).

From the wavelength, find the length of a lambda/4 antenna in cm. You should use this for configuring your receiving monopole antenna for the remainder of this lab. (Except for the CB case, which is too big - so just set the antenna to its full extent)

Frequency	***Wavelength in meters***	***Antenna length in cm***
________________	________________	________________

Modulated Signal Bandwidth

Adjust the antenna on the spectrum analyzer to the proper length computed earlier and set it up to monitor your transmitted signal (set frequency, span, amplitude reference level, etc.)

Transmit using one of your radios while monitoring your audio on the other radio and the spectrum on the spectrum analyzer. While speaking a continuous vowel sound (e.g. "eeeeeee"), observe the spectrum bandwidth. Try talking close to the mic to get the widest bandwidth and record it. Does it agree with the information you researched previously?

NOTE: For the ISM band radio, this is at best a challenge. You could try setting the analyzer on one of the frequencies it hops to and using the Display>Peak-hold function...

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

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Received Power versus Distance

As above, tune the center frequency of the analyzer to the frequency you are using. Set the span to about 100 kHz or 1 MHz. Then, using one of the radios, transmit a signal from various distances from the analyzer's antenna, *recording the distance and the power of the signal displayed.* Do this for at least the following distances. 1 foot, 2 feet, 4 feet, and 8 feet.

Keep the antennas in a "co-pole orientation" during your work (e.g. both vertical) ! Note that powers are formatted in dB 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 be read correctly and you will need to adjust Amplitude>RefLevel. Similarly if the signal is "in the noise" at 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 and check the range you can achieve with the radios.

As you vary the distance from 1 foot to 2 feet, 4 feet, and 8 feet, does the received power decrease in accordance with $1/R^2$? How many dB per doubling of distance should this be?

(Don't be too concerned if the measurements are not following theory well here. Measurements often don't, because theory is always simplified to some degree - ignoring additional factors we didn't model...)

Effects of Obstructions on Received Signal Level

Physical objects sometimes interact strongly with radio signals, depending on their material composition. Metal blocks signals, or reflect signals, while other 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 2 feet 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 objects below between the radio and the analyzer and record the new signal level. How many dB is the signal decreased by the prescence of the material?

Case	***Received power in dBm***
No obstruction:	____________________
Ceiling tile:	____________________
Plywood:	____________________
Drywall:	____________________
Person:	____________________
Metal sheeting:	____________________

Repeat each case a few times to be sure you get consistent results, since small variations in position can change the results due to "multi-path" in the room. 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.

In-Building Communication Performance

The propagation environment contains plenty of multi-path within our lab 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 new Engineering Hall building, take the radio to various spots including those below and record the received signal power. Use the other radio of the pair to communicate, but of course don't record data when you are transmitting on the radio held by the person at the analyzer ! You may have to decrease the reference level and/or resolution bandwidth to keep the received signal above the "noise floor" as you go to more distant locations. (Use your cell phone if you lose contact in some locations.)

Case	***Received power in dBm***
In doorway of lab:	____________________
Top of stairs:	____________________
In new atrium at bottom of stairs:	____________________
In front of Radinas:	____________________
In old building atrium at north entrance from parking lot:	____________________
____________________:	____________________
____________________:	____________________

Inside Building to Outside Communication Performance

Continue the above measurements at the following locations as a minimum:

Outside old building at entrance from parking lot:	____________________
On west-side ground floor lobby in new building where the "competition team" rooms are	_____________
Outside, just beyond the doors	____________________
Within the "airlock" space between the inside and outside	__________________
____________________:	____________________
____________________:	____________________

Outside Communication Performance

If you like, try to determine the range of the radios when both are outside. You can't record signal levels here since you won't have the spectrum analyzer, but you can at least try some long-path cases if you're up for some hikes. See if you can get far enough away from each other to cause the communcation to fail, and record locations where you were at such times so that you can use Google maps (or Bing?) later to estimate the distance. Comment on the terrain and obstructions too.

Radio 1 location	***Radio 2 location***	***Estimated distance***
____________________	_____________________	___________________
____________________	_____________________	___________________

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. As stated on page 1, each person does their own writeup as a separate "Section" in the report. Place a coverpage on it and and include a summary as specified below after Section 2.

Document General Conclusions

At the end of the writeup of the procedures and measurements/results above, 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" ? ; -)

This summary section can be written by both teammates, or discussed by both and written by one.