VANIER COLLEGE – Computer Engineering Technology – Winter 2021

Telecommunications (247-410-VA)

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LABORATORY EXPERIMENT #8

Antennas and Propagation Loss

NOTE:
To be completed in one lab session of 3 hrs.
To be submitted using the typical lab format, one week later – **at the start** of your respective lab session.
This exercise is to be done **individually** except where specified in the procedure. **Each** student must submit a lab report with original observations and conclusions.

OBJECTIVES:

After performing this experiment, the student will be able to:

1. Become familiar with the inSSIDer wireless network survey software.
2. Observe how received signals fluctuate depending on distance, obstructions, reflections, antenna type and orientation.
3. Explain the phenomenon of electromagnetic polarization.
4. To calculate the transmission path attenuation in dB.

DISCUSSION OF THEORY

Wireless Transmission

Compared to wired media, wireless transmission presents several important challenges including:

- Huge signal attenuation.
- Fluctuating signal strength.
- Reflections and echo.
- Interference and noise.

The maximum transmit power rating of a wireless router is 15 dBm (30 mW) and a Wi-Fi receiver can operate with a received signal as weak as about -80 dBm or sometimes even -90 dBm (depending on the interference). For example, -90 dBm is one billionth of a milliwatt (or one trillionth of a watt!). If we transmit at 15 dBm and receive at -85 dBm, that means that we lost 100 dB along the way between the transmit antenna and the receive antenna. 100 dB attenuation means that we only received 1/10,000,000,000th of the power transmitted and lost 99.99999999% along the way.

Frequency and Wavelength

Frequency = Speed of Light / Wavelength

$f = c / \lambda$

Where: f = Frequency of signal in Hertz

c = Speed of light in m/s (3×10^8 m/s)

λ = Length of one wave cycle in m

Polarization

The term *Polarization* refers to the orientation of the Electric Field produced by the antenna. For mobile applications, vertical polarization is most common. Horizontal polarization is sometimes used for point-point links

Antenna Radiation Pattern

Real antennas don't radiate equally in all directions in 3 dimensions. The radiation pattern is a polar plot of the antenna's relative efficiency in different directions.

Free Space Loss

$$L = 20\ \log_{10}\left(\frac{4\pi d}{\lambda}\right)$$

There are many causes for signal attenuation over a wireless path but one of the most important is Free Space Loss, caused by the spreading of the signal as it gets farther away from the source. FSL is proportional to the square of the distance.

MATERIALS AND EQUIPMENT REQUIRED:

1 PC with Windows	inSSIDer Software
Paper and aluminum foil	1 Rosewill Wireless Adapter per group

PROCEDURE

1) Preparation

   a) Connect the Rosewill USB Wireless adaptor to the computer's USB port. Orient the antennas so that they are both vertical. You may need to install driver for the USB wireless Adaptor (available in CD in the box).

   b) There are two wireless routers (Access Points) in the Lab AP 1 and AP 2 (the instructor will indicate which is which). Launch the inSSIDer software Adjust the window size to make it as tall as possible on your screen.

   c) The table in the top half of the window shows all the wireless networks that your adapter hears. Click twice on the RSSI title at the top of the table in the upper half of the window. This will sort the list according to received signal strength (strongest to weakest). RSSI stands for Receive Signal Strength Indication and it is measured in dBm. Remember that -40 dBm is 1000 times stronger than -70 dBm.

   Click on one of the four APs (e.g. AP1A, AP1B, AP2A or AP2B) and a chart on the right will show how the received signals vary over time. Here are the characteristics of the APs:

   - *AP1A (2.4 GHz)*
   - *AP1B (5 GHz)*
   - *AP2A (2.4 GHz)*
   - *AP2B (5 GHz)*

2) Note the received signal strengths under different conditions. For each measurement, wait at least 1 minute for the signal to trace a certain length on the display, and then take a visual average of the signal over that minute. If you wish, right-click on graph to copy it and past it into your report.

   - See excel spreadsheet attached to this submission for complete results (see Q2-Q10 sheet in excel document). For this question and the ones that follow, unique colors show which parts belong to which question. This is like this for every sheet in the excel document.

3) Note the initial average signal strength (RSSI) in dBm for each of the 4 networks. Record these results in a table with one column for each AP and several rows (one row for each measurement or calculated result that you will perform in the steps below). Also note down any other technical related information about each of these networks.

   - See excel spreadsheet attached to this submission for complete results (see Q2-Q10 sheet in excel document). From the results, it is shown that my antenna can pick up AP2A and AP2B stronger than AP1A and AP1B. This is because AP2A and AP2B were in the same lab room as I and AP1A and AP1B were across the corridor in the other lab room, further away from my antenna. Each AP was laying on top of the instructor's desk in the two lab rooms. For AP1A the average signal strength was -60dBm, AP1B was around -50dBm, AP2A was -40dBm and AP2B was -35dBm.

4) Assuming the routers are transmitting with 15 dBm of power, use the measured signal strength to calculate the actual path attenuation in dB for each of the 4 networks. Add these measured values to the table.

- See excel spreadsheet attached to this submission for complete results (see Q2-Q10 sheet in excel document).

$$Path\ attenuation = P_r - P_t$$

$$P_r = received\ power$$

$$P_t = transmitted\ power$$

5) Estimate the distance between your antenna and each AP (you can pace it out). Calculate the theoretical Free Space Loss (FSL) from each AP and frequency (2.4 GHz and 5 GHz). Compare the theoretical and measured results and comment in your report (never use percentage to compare values in dB because dB is already a comparison. Simply show the difference in dB). If the difference is large, speculate on what might be the cause.

Distance from my antenna to AP1A/AP1B: 33 feet = 388 inches = 9.8552 meters.

Distance from my antenna to AP2A/AP2B: 11 feet = 132 inches = 3.3528 meters.

$$FSL = 20log_{10}\left(\frac{4\pi d}{\lambda}\right)$$

$$d = distance\ in\ meters$$

$$\lambda = \frac{3 * 10^8}{f}$$

- See excel spreadsheet attached to this submission for complete results (see Q2-Q10 sheet in excel document).

6) Remove both antennas from your Rosewill adaptor. After about a minute, estimate by how many dB each of the signals dropped.

- See excel spreadsheet attached to this submission for complete results (see Q2-Q10 sheet in excel document). For AP1A and AP1B, the signal has dropped by about 30dBm, the signal for AP2A dropped by about 33dBm and the signal for AP2B dropped by about 24dBm. The reason why AP1A and AP1B have worse results is because they were in the other lab room across the corridor and were further away than AP2A and AP2B to my antennas.

7) Re-attach only one of the antennas. Record the signal strengths again. Did all signals return to their original strength?

- See excel spreadsheet attached to this submission for complete results (see Q2-Q10 sheet in excel document). With only one antenna re-attached, all signals almost came back to normal. For AP1A, the signal strength came back up to -55dBm, the signal strength for AP1B came back up to -53dBm, the signal strength for AP2A came back up to -45dBm and the signal strength for AP2B came back up to -33dBm (all close to what the original signal strength was). From what the results show, it is possible to operate with only one antenna to achieve acceptable results.

8) Wrap the antenna in a sheet of paper. After about a minute, record the signal strengths and calculate by how many dB each of the signals dropped. Do radio waves go through paper very well?

   - See excel spreadsheet attached to this submission for complete results (see Q2-Q10 sheet in excel document). With the sheet of paper wrapped around the two antennas, there is no real visible difference in signal strength (it is still close to the original signal strength). This means that radio waves have no real problem going through paper. For AP1A, the signal strength slightly increased by 7dBm, the signal strength for AP1B stayed the same, the signal strength for AP2A dropped by 3dBm and the signal strength for AP2B stayed the same.

9) Repeat step 8 with aluminum foil instead of paper.

   - See excel spreadsheet attached to this submission for complete results (see Q2-Q10 sheet in excel document). With aluminum foil wrapped around the two antennas (covered), there is a visible difference in the signal strength. The results are not as pleasing as seen when there was paper wrapped around the two antennas. This means that radio waves do not go through aluminum foil as good as paper does when it covers the two antennas completely. For AP1A, the signal strength dropped by about 10dBm, the signal strength for AP1B dropped by 20dBm, the signal strength for AP2A dropped by 10dBm and the signal strength for AP2B dropped by 10dBm as well.

10) Repeat step 8 with wrapping your hands around the antennas.

   - See excel spreadsheet attached to this submission for complete results (see Q2-Q10 sheet in excel document). Like with the aluminum foil, when both hands are covering the two antennas, there is a visible difference in the signal strength. Since the results are like the results with the aluminum foil therefore, this means that radio waves do not go through human hands as good as paper does. For AP1A, the signal dropped by about 15dBm, the signal dopped by 35dBm for AP1B and the signal dropped by around 25dBm for AP2A and AP2B.

11) Flip the antenna so that it is horizontal and broadside to the APs (i.e., side of antenna facing AP). Record the signal strength from each network in your results table. Which orientation (horizontal or vertical) works best for each network, and why?

   - See excel spreadsheet attached to this submission for complete results (see Q11-Q12 sheet in excel document). The results show that is no major improvement when the position of the antenna changes. Regardless, there are still some things that can be noticed. For the APs operating on the 2.4GHz band, when the antenna is changed to point horizontally, the received signal is slightly stronger compared to when the antennas were positioned in the vertical position. But this is not the case for the APs operating on the 5GHz band; the results show that the received signal strength for the APs operating on the 5GHz band become slightly weaker. Therefore, for better performance on the 2.4GHz band, the antennas should be pointed horizontally but for better performance on the 5GHz band, the antennas should remain vertical.

12) Repeat step 11 with the tip of the (still horizontal) antenna pointing directly toward each AP.

   - See excel spreadsheet attached to this submission for complete results (see Q11-Q12 sheet in excel document). The results show the same behavior that was described in the previous question above. In this case, when the two antennas are pointed horizontally directly towards the APs, the antennas pick up better signal strength for the APs operating on the 2.4GHz band but does not pick up a better signal strength for the APs operating on the 5GHz band. For optimal performance, the same as what was said above before, for better performance on the 2.4GHz band, the antennas should be pointed horizontally but for better performance on the 5GHz band, the antennas should remain vertical.

13) Put the antenna back to vertical. Lift the Rosewill adapter as high as you can into the air. Record the signal strength after about 1 minute (or unless if your arms get tired). Did this help or make it worse? Why?

- See excel spreadsheet attached to this submission for complete results (see Q13-Q14 sheet in excel document). The results show that when the antenna was raised to as high as much I can reach, there were signs of improved signal strength (mainly for AP2A and AP2B since they were the closest to my antennas). For AP1A, the signal strength increased by about 3dBm, the signal increased by 9dBm for AP1B, the signal increased by 13dBm for AP2A and the signal increased by 6dBm for AP2B. When the antenna is placed very high, there are usually no obstructions that can hinder the antenna's ability to pick up signals, so in the case with our experiment there will be improvement in the received signal strength for all the APs.

14) Hold the Rosewill adaptor as low to the floor as possible. Note any change in the signal strength after about 1 minute (or less if your arms get tired). Did this help or make it worse, and why?

- See excel spreadsheet attached to this submission for complete results (see Q13-Q14 sheet in excel document). The results show that when the antennas were placed very low (on the floor), the received signal strength was worse than what was seen in the previous question (especially for AP1A and AP1B). For AP1A the signal strength worsened by 4dBm, for AP1B the signal strength worsened by 18dBm, for AP2A the signal strength worsened by 6dBm and for AP2B the signal strength worsened by 6dBm as well. When the antennas are placed very low, they will not pick up the signals as strong because there are more obstacles in the way unlike when the antennas were placed up high (picking up strong signals and away from most obstacles as seen above in the previous question).

15) Summarize what you have noticed from the above measurements. For example, under what conditions are the 2.4 GHz signals stronger than the 5 GHz signals?

- To summarize and give the best results for performance, these guidelines should be followed: do not obstruct the antenna(s) (as they will possibly hinder performance), properly position the antenna(s) (as they will also possibly hinder performance) and place the antenna(s) properly as well – not too high or not too low (if not, it will also possibly hinder performance). If these guidelines are not followed, signal strength for 2.4GHz and 5GHz APs will not be optimal and problems may even occur. From what was seen above, for example: if the antennas were covered by some material, most likely the signal strength will not be as expected (= poor performance). The same thing occurs when the antennas are not positioned correctly and when the antennas aren't placed correctly.