Lab 2

RSSI

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[GitHub Repository]

Introduction

This lab explores XBee radio communication using the IEEE 802.15.4 standard, focusing on signal strength, packet error rate (PER), and range testing. The experiment includes configuring XBee modules, measuring RSSI variations over distance, and analyzing the impact of different materials on signal attenuation. By comparing theoretical and experimental results, we determine the path loss exponent (α\alphaα) and assess environmental effects on wireless transmission.

Part 1: XBee Radio and Software Configuration

a. Define loopback
   - Loopback refers to a process or feature where a signal, message, or data that is sent out is returned back to its source without being modified.

b. What is the difference between the IEEE 802.15.4 standard, Zigbee, and Xbee?
   - IEEE 802.15.4 is a standard that defines the physical (PHY) and (MAC) layers for low-power wireless communication. Zigbee is a protocol built on top of IEEE 802.15.4, adding network, security, and application layers. Xbee is a family of wireless modules that support multiple protocols, including Zigbee.

c. Research Packet Error Rate and address the following:
   i. Define what it means
   - Packet Error Rate (PER) is the percentage of data packets that are received incorrectly compared to the total number of packets transmitted over a communication network.

   ii. What steps would you take to measure and calculate it?
   - Send a known number of packets, and observe how many are received, then calculate the PER.

   iii. Write the equation used
   - 100 x (# error)/(# sent)

d. Research RSSI and address the following:
   i. What is RSSI? What does it mean?
   - RSSI is a measurement of the power level that an RF device receives from a signal. It is commonly used to assess the signal quality of a wireless connection. RSSI values are usually negative and use dBm.

   ii. What is its formula?
   - 10log(Pr/Pref)

   iii. Describe the steps to find the RSSI of your own device. Give the model and manufacture of your device, e.g., T-Mobile Sidekick😊 and write the value.

- Dell Inspiron with Windows 11, ran command prompt and the command {netsh wlan show interfaces}, find the signal parameter. Then use RSSI = (Signal Percentage/2)-100. Found value was 57%, or -71.5 dBm.

e. The local module (XBEE_A) can also work in transparent mode, but the value of the remote RSSI will not be read. Explain why this happens.
   - In transparent mode on Xbee modules, the communication link between the local module and the remote module is simplified for straightforward data transmission without data processing. In this mode, the modules don't handle network-level features like RSSI reporting. The remote module's RSSI value will not be read or transmitted since the transparent mode does not provide feedback on the quality of the link.

Part 2: Executing a Range Test

f. Write the MAC address of the local XBee
   - 0013A20041CFE9A1

g. Write the MAC address of the remote XBee
   - 0013A20041D00CF1

h. Did the RSSI change when the remote XBee was moved? By how much?
   - Yes, at the further distance the RSSI got more negative (decreased by 17 between 1.5m and 12m).

i. At what distance does a noticeable change first occur?
   - The signal gets exponentially better when they are brought closer together, at around 7 inches.

j. How many packets are sent for the test?
   - 5

k. How many packets were received?
   - 5

l. What is the PER?
   - 0%

Part 3: RSSI Experiments

a. Include a screenshot of at least one of your experimental setups. Clearly label the local and remote radio and include your distance measurement tool.
   - See Figure 4.

b. For each condition what shape does the plot have from d0 to dmax?
   - See Figure 8. The plots have a slight decay shape, almost linear decrease.

c. Discuss the impact of changing conditions on the path range results. Rank the conditions from quickest decline or growth to slowest decline or growth and support your answer with the results of your experiments.

- By placing materials over the XBEE devices, the received power decreased as well as the range. Using Figure 8, we can see that generally using materials more absorbent of electromagnetics caused the greatest decline. For our trials, the metal was the worst and the free space was best.

d. Plot the theoretical power, power received, Pr, [in dBm] versus log[(distance[meters])]. Determine the appropriate value for Po to use in your equation and state how you arrived at the value. Hint: a section in XCTU
   - See Figure 9. Po to be used will be the Pr at 1m.

e. On the same graph, plot your experimental values for power received, Pr, at the local radio [in dBm] versus log[(distance[meters])]. One plot should be added for these results and clearly labeled. All RSSI values must be expressed in dBm, and the scale of the plot should allow the data and trends to be clearly observed. There should be one graph/figure for each condition.
   - See Figure 9.

f. Determine the values of alpha, the path loss exponent, from the three experimental plots.
   - Trial 1: 1.82
   - Trial 2: 2.74
   - Trial 3: 4.26

g. How would you calculate the power loss using the RSSI results? Calculate the power loss for each condition and include the results in your report.
   - Po-Pr(d), using d=6m
     - Trial 1: 29dBm
     - Trial 2: 24dBm
     - Trial 3: 39dBm

<u>Extra credit</u>

1. Explain how you would use two XBee modules to determine the distance between two buildings. When would using your method become ineffective?
   - To estimate the distance between two buildings using XBee modules, one module is placed in each building, with one acting as a transmitter and the other as a receiver. The receiver measures the RSSI, and the distance is estimated using the Log-Distance Path Loss Model. This method becomes ineffective when obstructions, interference, or multi-path fading cause signal variations, especially in non-line-of-sight conditions, making precise distance estimation difficult.
2. Repeat the range test for one of the parts of the conditions in a way to generate a plot that shows fading has occurred in the transmission path. Clearly explain your process.
   - To test fading, we tried different distances with different objects in the way as we went. This demonstrated fading by showing less received signal power with obstacles (see Figure 11).
3. Repeat the experimental procedure for a condition of your preference, but this time, use two different values of Pt. Describe any modifications made to your process. Include graphs illustrating the power received at the local radio versus log[(distance[meters])]. Compare all three

graphs (extra credit two plus initial one) and recalculate the values of alpha for the extra credit graphs and provide an explanation for any observed differences or trends.

- See Figure 14.
    - Alpha medium = 1.57
    - Alpha low = 1.5
- The path loss exponent (α) for both cases is relatively low, suggesting minimal environmental obstructions and a mostly free-space propagation condition. The slight difference in α between the two power levels could be due to variations in hardware sensitivity or minor environmental factors affecting signal attenuation differently at different power levels.

Conclusion

The lab demonstrated how RSSI and PER reflect wireless signal performance, showing a logarithmic decline in signal strength with distance. Different materials impacted attenuation, with metal causing the highest signal loss. The calculated path loss exponents aligned with expected trends, confirming environmental effects on wireless communication. These findings highlight key factors in optimizing XBee deployment and wireless network performance.

Appendix

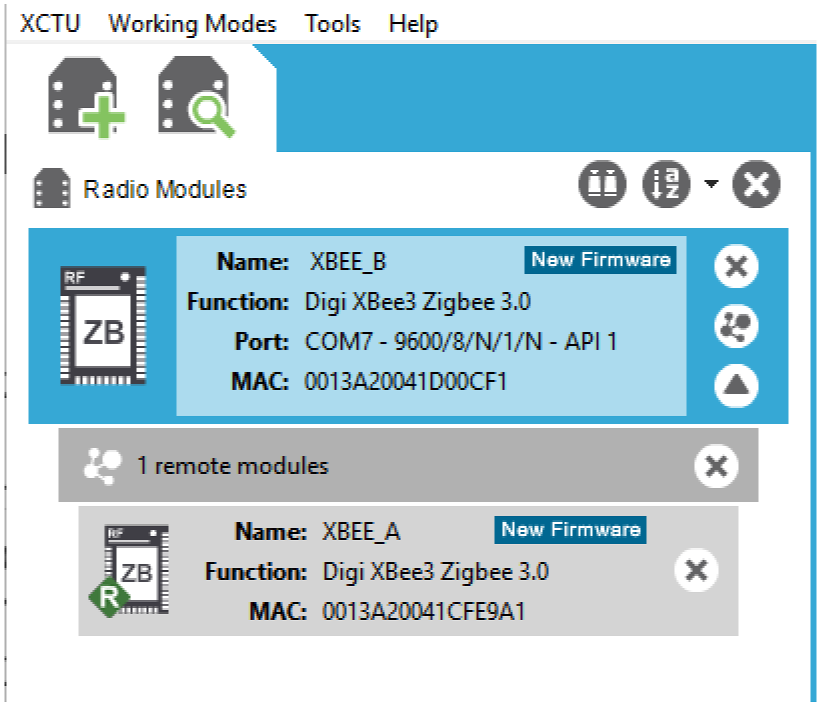

Figure 1: Setup XBEE_A and XBEE_B for network test.

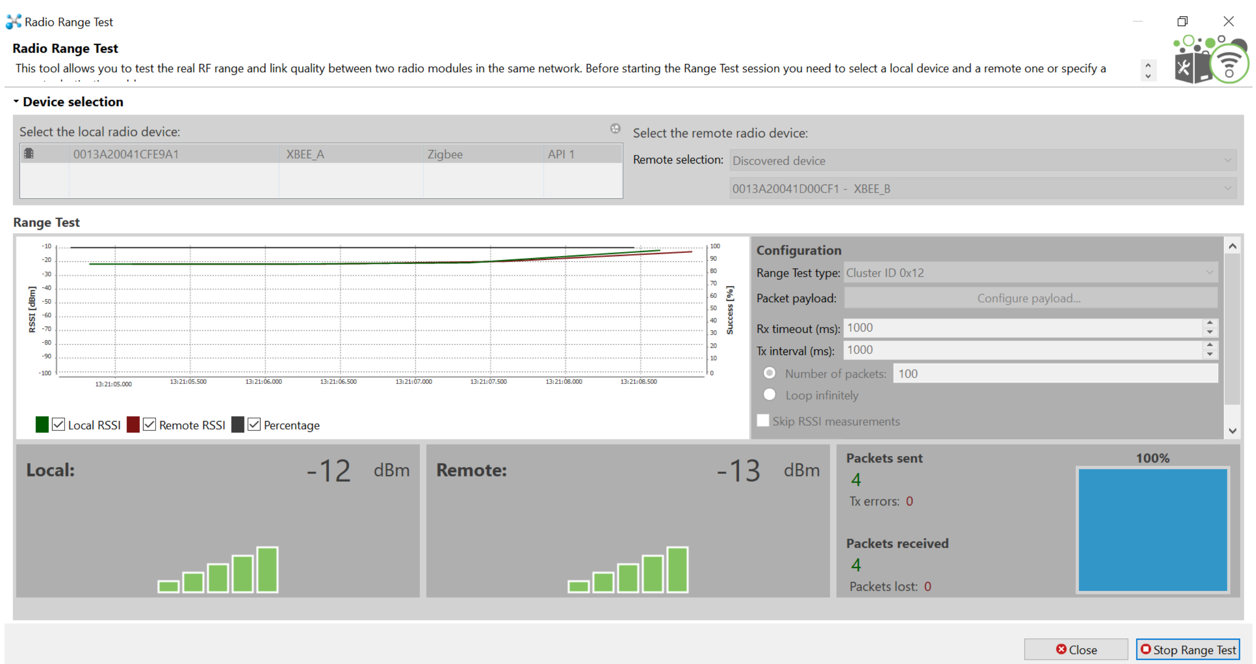

Figure 2: Tables and figures from test at 7ft.

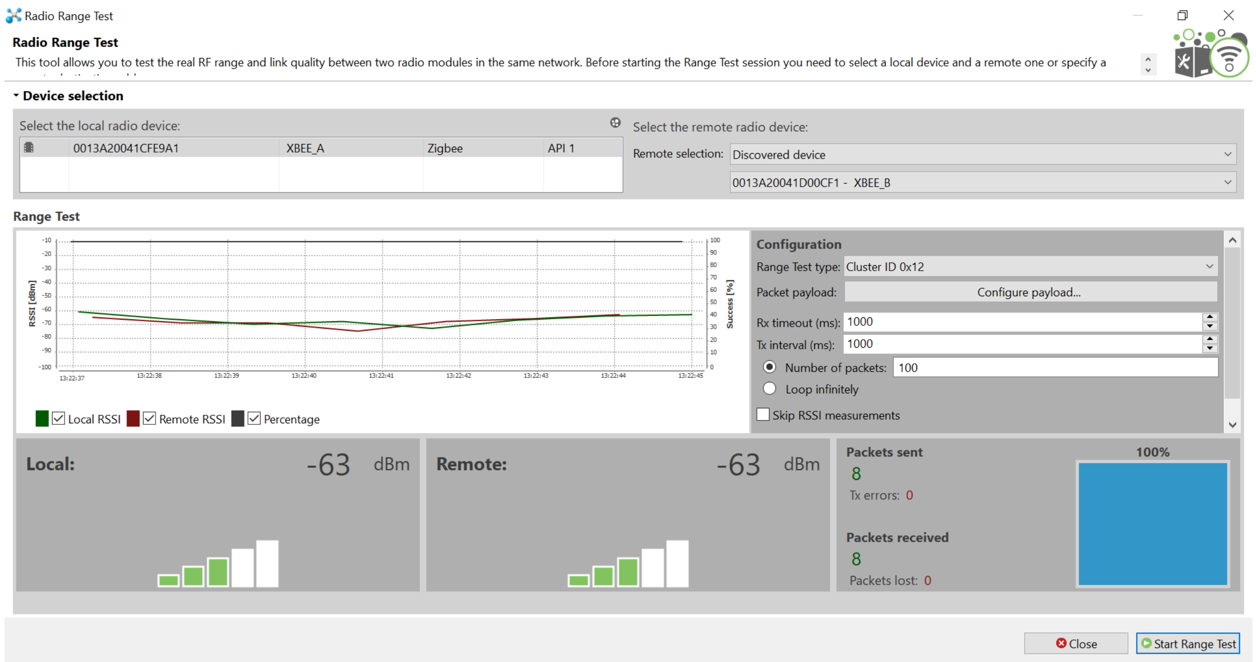

Figure 3: Tables and figures from test at 3.5ft.

Figure 4: Experimental setup. Far XBEE is XBEE B, and close is XBEE A. Distance measured with lidar sensor on a mobile phone.

Trials:	Distance (m)	RSSI local (dBm)	RSSI Remote (dBm)	Packets Sent	Packets Received	Packet Error Rate (received)
Trial 1	0.1524	-12	-13	4	4	0
Trial 2	1.5	-35	-34	5	5	0
Trial 3	3	-50	-55	9	9	0
Trial 4	4.5	-46	-54	7	7	0
Trial 5	6	-41	-42	8	8	0
Trial 6	7.5	-50	-52	8	8	0
Trial 7	9	-52	-56	6	6	0
Trial 8	10.5	-44	-46	5	5	0
Trial 9	12	-52	-54	4	4	0
Trial 10	36.85	-63	-63	8	8	0

Figure 5: Test 1 (Free Space)

Trials:	Distance (m)	RSSI local (dBm)	RSSI Remote (dBm)	Packets Sent	Packets Received	Packet Error Rate (received)
Trial 1	0.1524	-32	-33	5	5	0
Trial 2	1.5	-38	-37	5	5	0
Trial 3	3	-49	-48	5	5	0
Trial 4	4.5	-52	-50	5	5	0
Trial 5	6	-56	-55	5	5	0
Trial 6	7.5	-55	-58	5	5	0
Trial 7	9	-54	-53	5	5	0
Trial 8	10.5	-62	-59	5	5	0
Trial 9	12	-72	-69	5	5	0
Trial 10	13.5	-46	-46	5	5	0

Figure 6: Test 2 (Cardboard Box)

Trials:	Distance (m)	RSSI local (dBm)	RSSI Remote (dBm)	Packets Sent	Packets Received	Packet Error Rate (received)
Trial 1	0.1524	-30	-42	5	5	0
Trial 2	1.5	-44	-58	5	5	0
Trial 3	3	-50	-64	5	5	0
Trial 4	4.5	-52	-66	5	5	0
Trial 5	6	-69	-82	5	5	0
Trial 6	7.5	-60	-72	5	5	0
Trial 7	9	-64	-76	5	5	0
Trial 8	10.5	-60	-73	5	5	0
Trial 9	12	-74	-86	5	5	0
Trial 10	13.5	-65	-77	5	5	0

Figure 7: Test 3 (Metal Bowl)

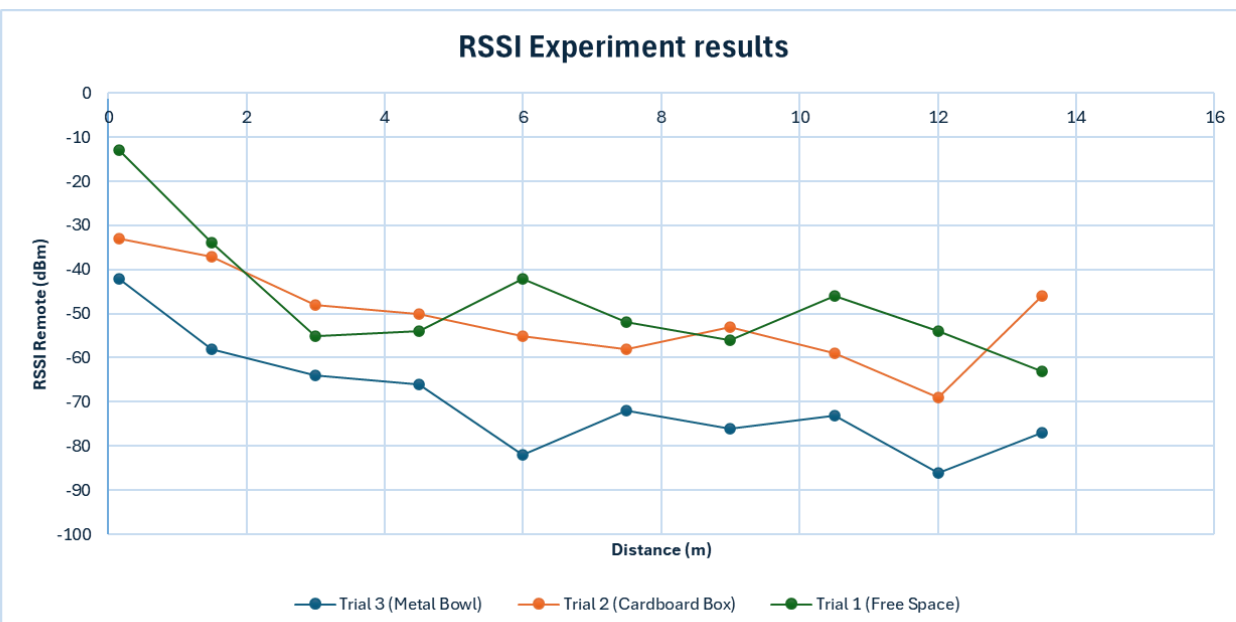

Figure 8: Plot of Distance vs RSSI (remote)

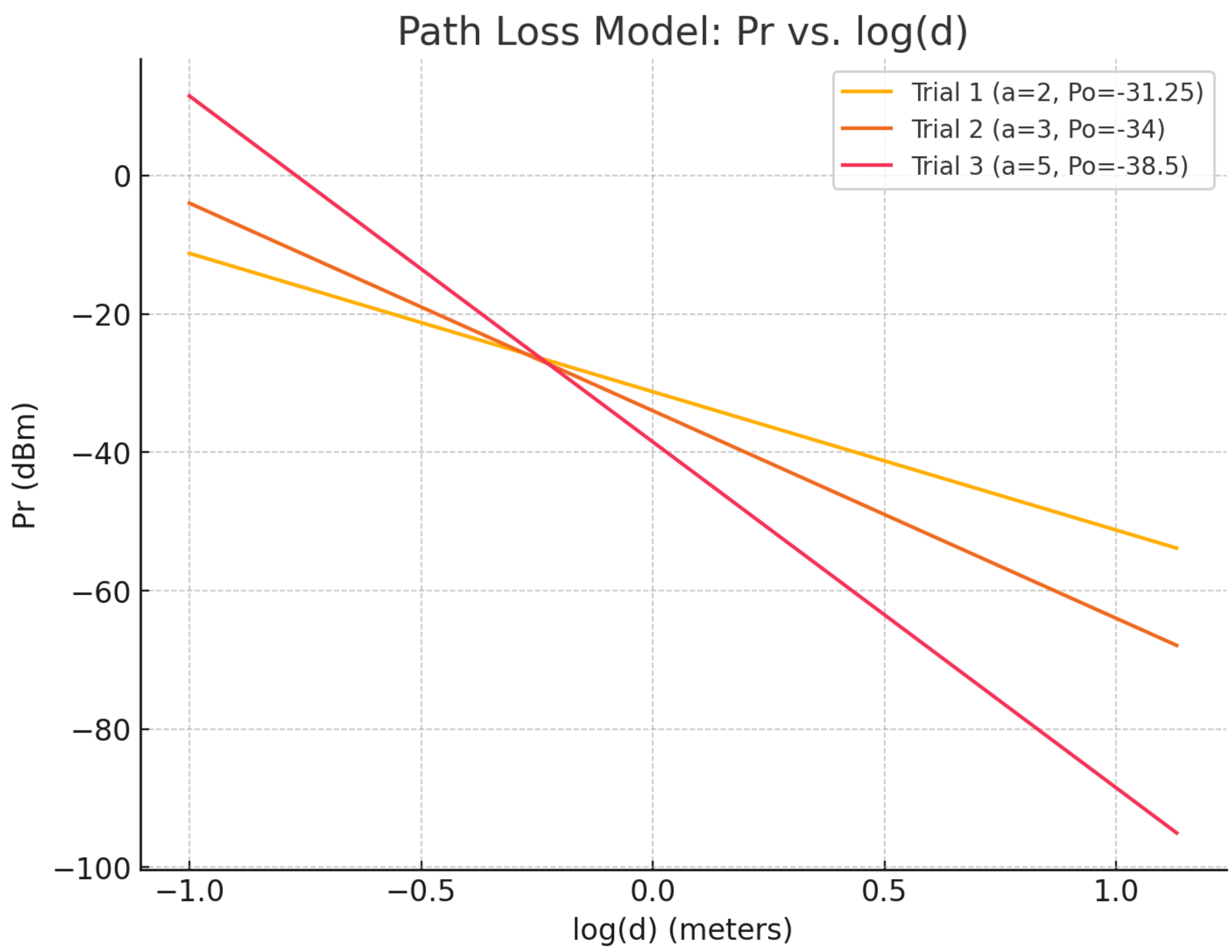

Figure 9: Ideal Pr for each trial.

EC (Fading)

Trials:	**Distance (m)**	**RSSI local (dBm)**	**RSSI Remote (dBm)**	**Packets Sent**	**Packets Received**	**Packet Error Rate (received)**
Trial 1	0.1524	-47	-44	5	5	0
Trial 2	1.5	-53	-54	5	5	0
Trial 3	3	-77	-78	6	4	33%
Trial 4	4.5	-71	-64	5	5	0
Trial 5	6	-71	-75	6	6	0

Trial 6	7.5	-70	-68	9	9	0
Trial 7	9	-70	-72	5	5	0
Trial 8	10.5	-84	-81	5	5	0
Trial 9	12	-82	-78	5	5	0
Trial 10	13.5	-89	-86	5	5	0

Figure 10: Extra credit 2 (Fading).

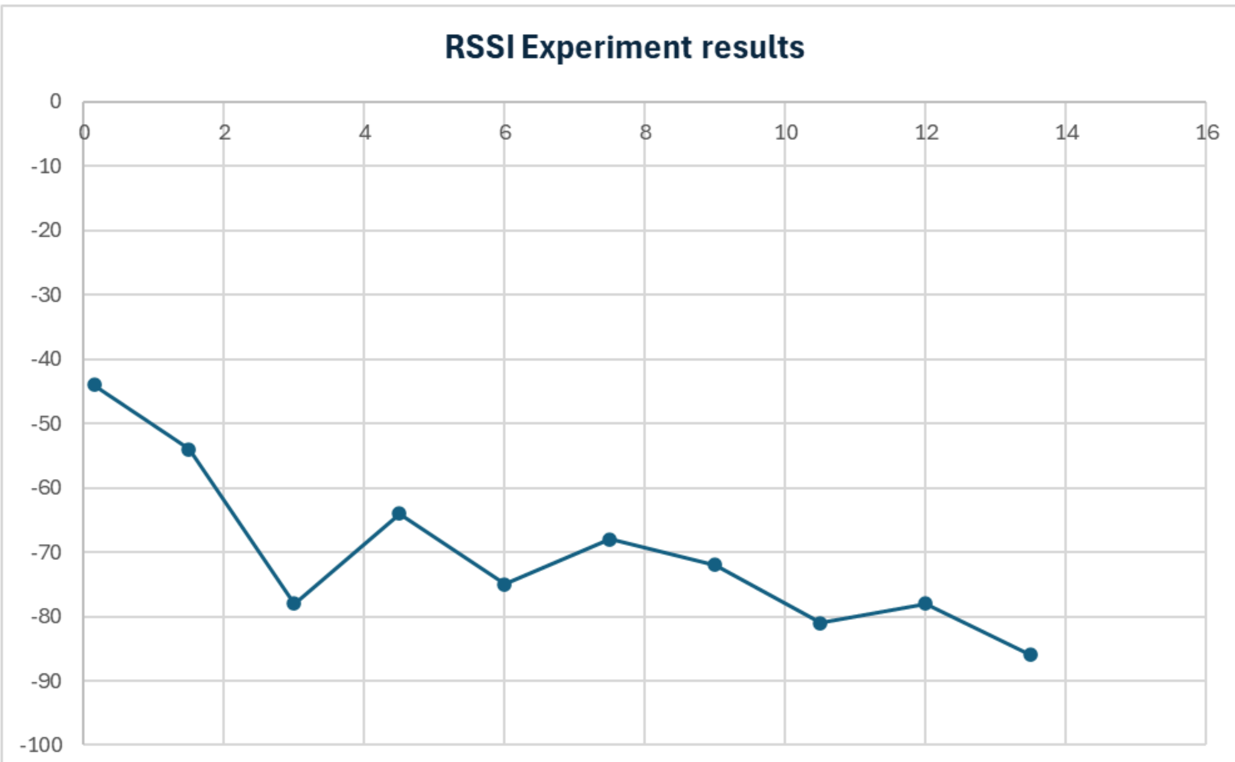

Figure 11: Plot of EC2.

Trials:	Distance (m)	RSSI local (dBm)	RSSI Remote (dBm)	Packets Sent	Packets Received	Packet Error Rate (received)
Trial 1	0.1524	-29	-42	5	5	0
Trial 2	1.5	-35	-42	5	5	0
Trial 3	3	-46	-53	5	5	0
Trial 4	4.5	-44	-51	5	5	0
Trial 5	6	-54	-64	5	5	0

Trial 6	7.5	-46	-53	5	5	0
Trial 7	9	-53	-58	5	5	0
Trial 8	10.5	-58	-67	5	5	0
Trial 9	12	-58	-64	5	5	0
Trial 10	13.5	-58	-66	5	5	0

Figure 12: Extra Credit 3 (pt = medum)

Trials:	**Distance (m)**	**RSSI local (dBm)**	**RSSI Remote (dBm)**	**Packets Sent**	**Packets Received**	**Packet Error Rate (received)**
Trial 1	0.1524	-26	-38	5	5	0
Trial 2	1.5	-34	-46	5	5	0
Trial 3	3	-37	-50	5	5	0
Trial 4	4.5	-43	-56	5	5	0
Trial 5	6	-47	-51	5	5	0
Trial 6	7.5	-46	-60	5	5	0
Trial 7	9	-51	-70	5	5	0
Trial 8	10.5	-52	-64	6	6	0
Trial 9	12	-48	-61	6	6	0
Trial 10	13.5	-58	-77	5	5	0

Figure 13: Extra Credit 3 (pt = low)

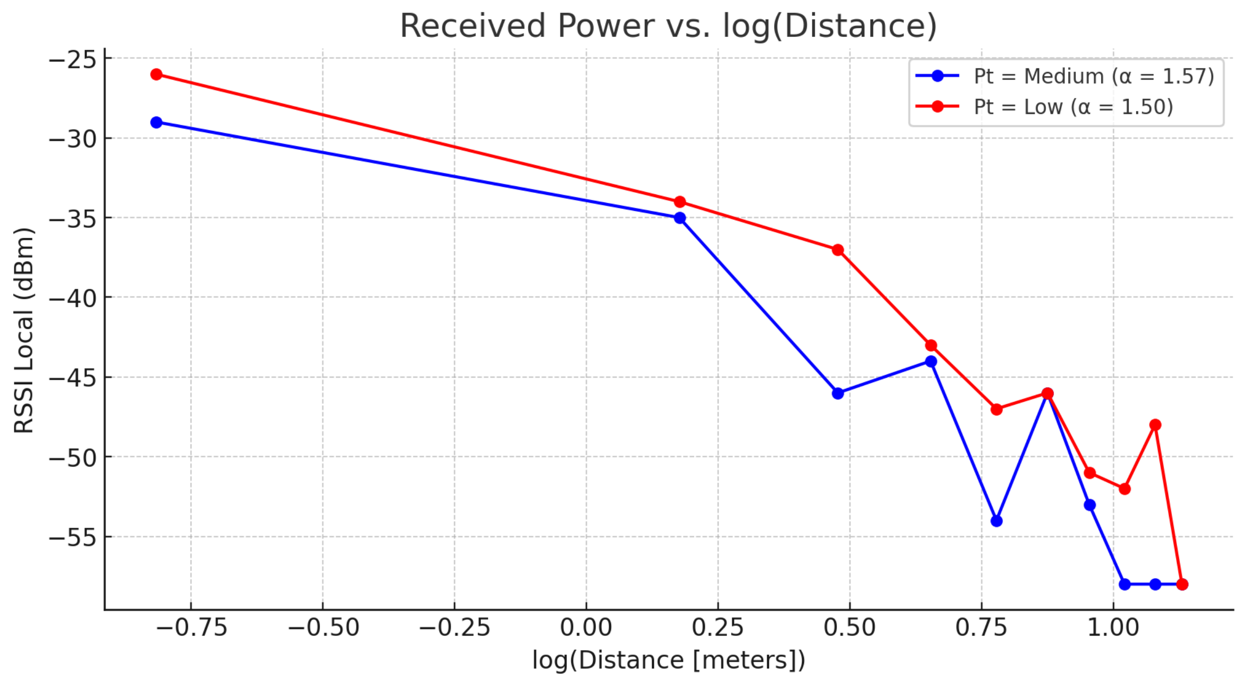

Figure 14: Extra Credit 3 Graphs

References:

[1] “IEEE SA - IEEE standard for low-rate wireless networks,” IEEE Standards Association, https://standards.ieee.org/ieee/802.15.4/7029/.

[2] “What is zigbee? learn about zigbee wireless mesh technology,” What is Zigbee? Learn About Zigbee Wireless Mesh Technology | Digi International, https://www.digi.com/solutions/by-technology/zigbee-wireless-standard.

[3] Radio Communication Protocols, https://www.digi.com/resources/documentation/digidocs/90001942-13/concepts/c_xbee_radio_comm_protocols.htm?TocPath=Additional+resources%7CXBee+buying+guide%7C_____5.