Project-1 Report

Modelling a Wireless Channel at Different Propagation Scenarios

Spring 2025

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Significance

Modeling the wireless channel is important for both signal power and connectivity. Wireless signals are affected by attenuation, interference, and multipath effects caused by obstacles, distance, and atmospheric conditions. Understanding these factors allows us to predict signal behavior, reduce losses, and improve network performance.

Objective

The objective of this project is to measure and analyze signal power in two different scenarios: one in direct Line of Sight (LOS) conditions and the other in Non Line of Sight (NLOS) conditions. For each scenario we will be collecting 30 power distance pairs which will be used to compute the path loss component(n). By comparing the results from both scenarios, we aim to understand how obstacles and environmental factors influence signal propagation.

Approach

For this study, we selected two routers, one for each scenario. In the Line of Sight (LOS) scenario, we used a router positioned in the hallway on the third floor of the Potter Building (Figure 1). For the Non-Line of Sight (NLOS) scenario, we used a router located in the hallway of the Classroom Office Building (Figure 2), where walls introduced signal obstructions.

To measure signal strength, we initially explored using the Airport Utility app. However, this method proved to be time-consuming, as it required manually running the “Scan” function at each measurement point and sometimes there was a delay in showing the updated power. We came up with a better approach of using the network measurement features available on a mobile phone through Siri Shortcuts. We created a custom shortcut (Figure 8) that allowed us to input the distance, then automatically retrieve the signal strength at the current location and append the data to the device’s Notes (Note: the input distance was not used in calculating the signal power). This collected data was later transferred to a spreadsheet for further analysis and calculations.

Figure 1: *Router location at Potter hallway*

Figure 2: *Router location at CLO hallway*

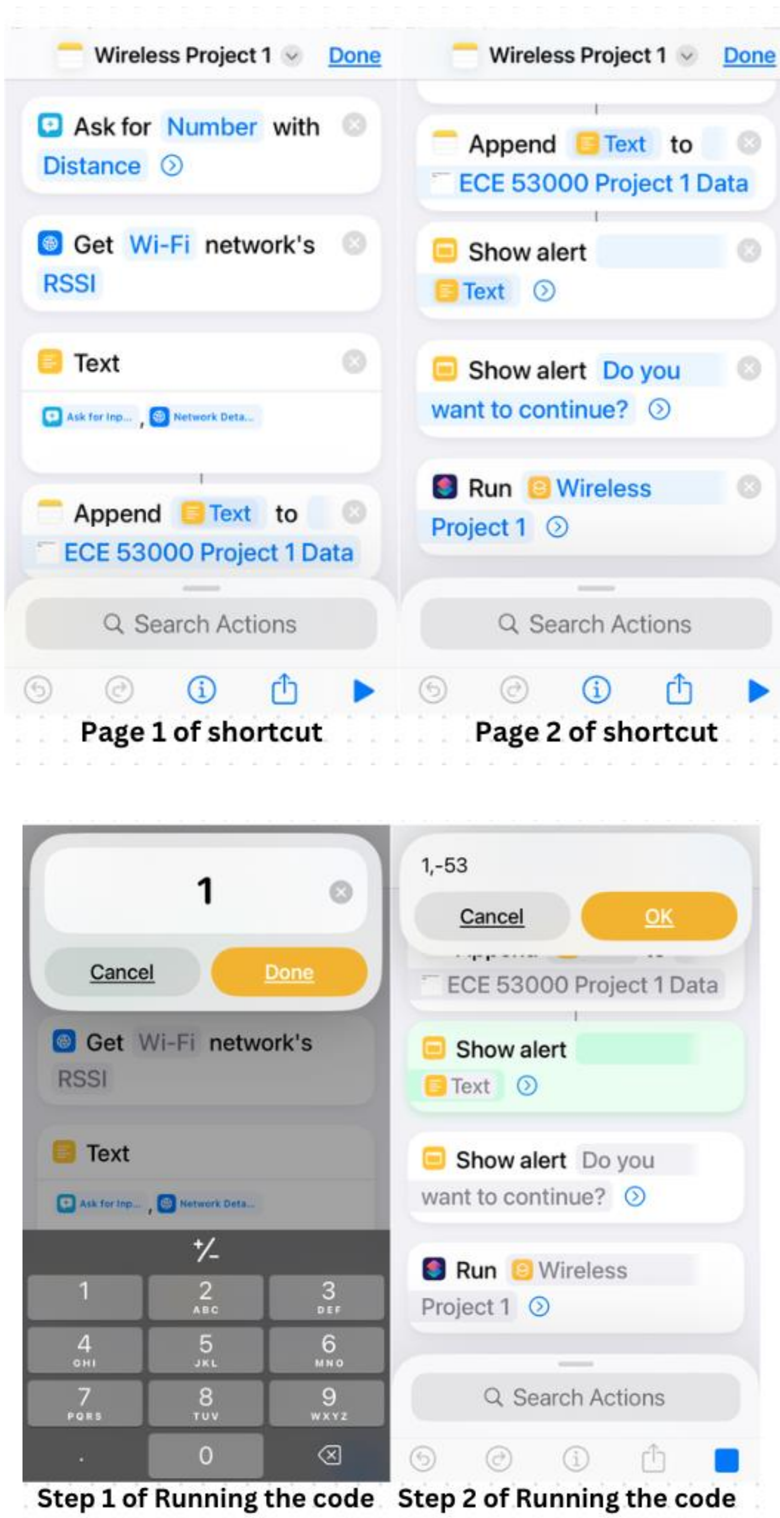

Figure 8: *Screenshots of the code at Siri Shortcuts*

Case 1: Power measurements at under direct line of sight

We began by measuring the signal strength at a reference distance of 0.1 meters from the router, denoted as d0. We then measured the signal strength at intervals of 0.25 meters apart covering 42 points along the hallway (Figure 3, 4). We then made an Excel spreadsheet to record all the points at different distances and made the following calculations.

We calculated the estimated power using the following formula. Assuming n = 2 as the path loss component, d_0 = 0.25m and $P(d_0)$ = -70 for each point.

$$P_{est} = P(d_0) - 10n\log_{10}\left(\frac{d_i}{d_0}\right)$$

Later used the following formula to get the estimated variance J(n),

$$J(n) = \frac{1}{N}\sum_{i=1}^{N}(n_i - \overline{n})^2$$

N = Total path loss component values

n_i = individual path loss expoenet values

$\overline{n}$ = mean path loss exponent,

$$\overline{n} = \frac{1}{N}\sum_{i=1}^{N} n_i$$

Calculating J'(n),

$$J'(n) = \frac{1}{N}\sum_{i=1}^{N}\left(P_{measured}(d_i) - P_{estimated}(d_i)\right)^2$$

Attached Appendix I & Appendix III, shows the calculations for path loss component, estimated variance, cost function for the powers measured in line of Sight scenario.

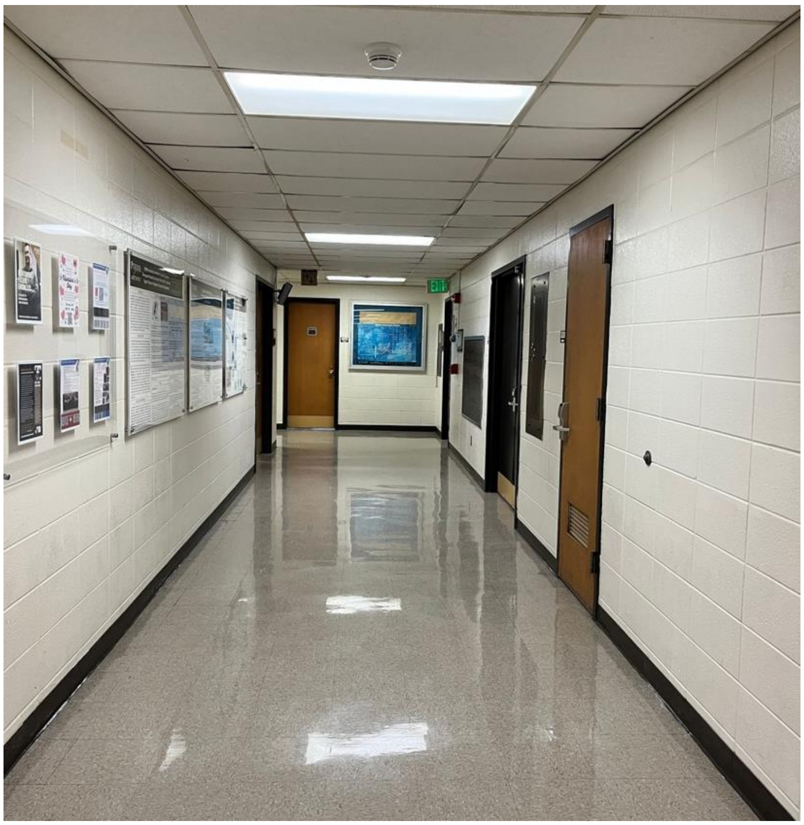

Figure 3: *Hallway at Potter*

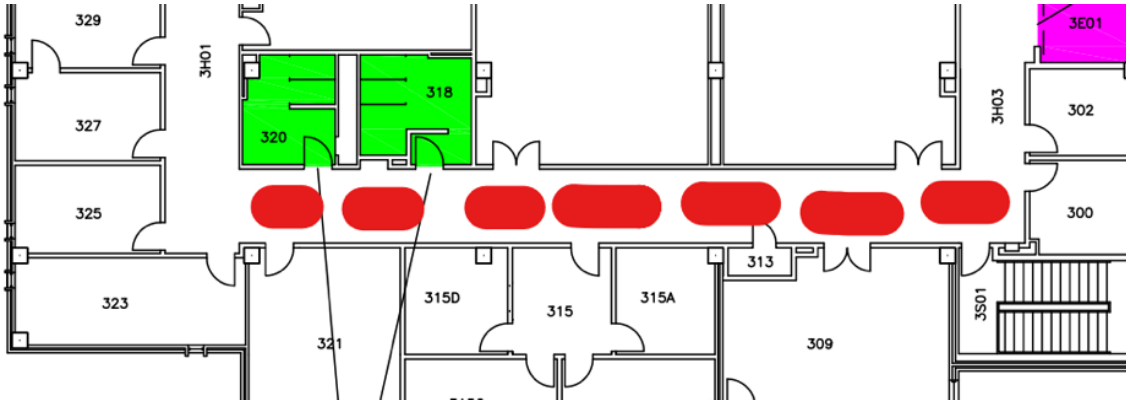

Figure 4: *Measurement points along the Potter hallway*

Case 2: Power measurements at under non line of sight

We measured the signal power at various distances shown in below figure 5. A similar approach was used to calculate the path loss component, estimated variance, cost function for the powers measured in line of Sight scenario (shown in Appendix II, Appendix IV). Assuming n = 3 as the path loss component, d_0= 0.25m and $P(d_0)$= -53 for each point.

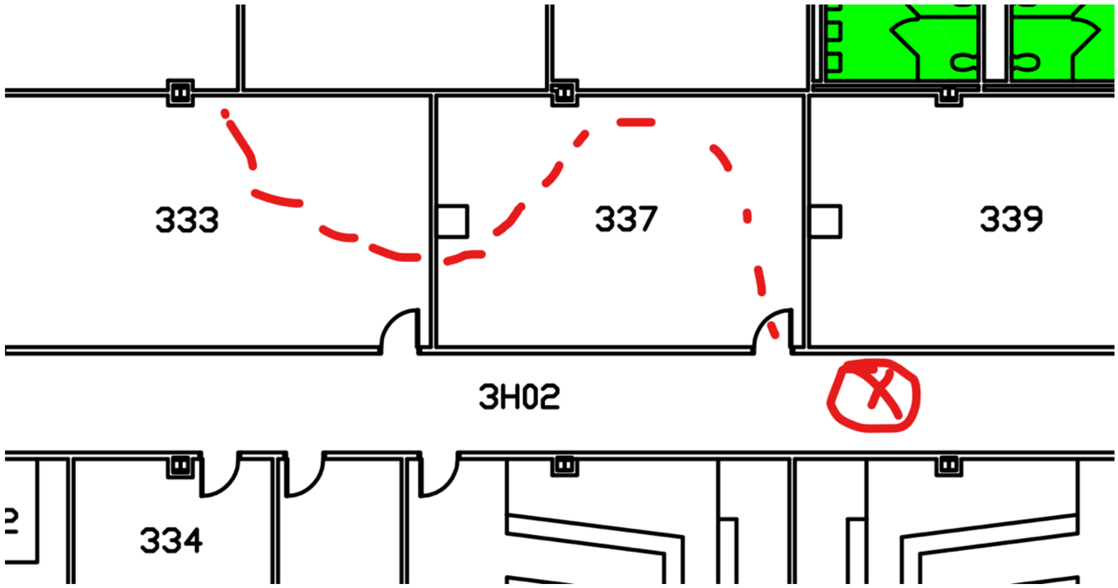

Figure 5: *Measurement points along the CLO hallway*

Outcomes

As explained in the previous section, the calculations were made using Excel spreadsheet.

Line of Sight (LOS) Scenario:

Analyzing the measured power values in this scenario, the signal fluctuated between a high of -56 dB and a low of -72 dB. Interestingly, the recorded signal strength at LOS distances was higher than the expected values based on theoretical calculations (Figure 6). The router demonstrated strong performance, maintaining reliable reception even as the distance increased. At 5.25 meters, the signal strength reached its lowest recorded value of -72 dB, which appeared to be the weakest signal the router could achieve before the mobile device likely switched to a closer router, leading to an improvement in signal strength. The average value for path loss component was found to be 0.6 showing strong signal retention, J(n) = 0.6041, J'(n) = 33.72.

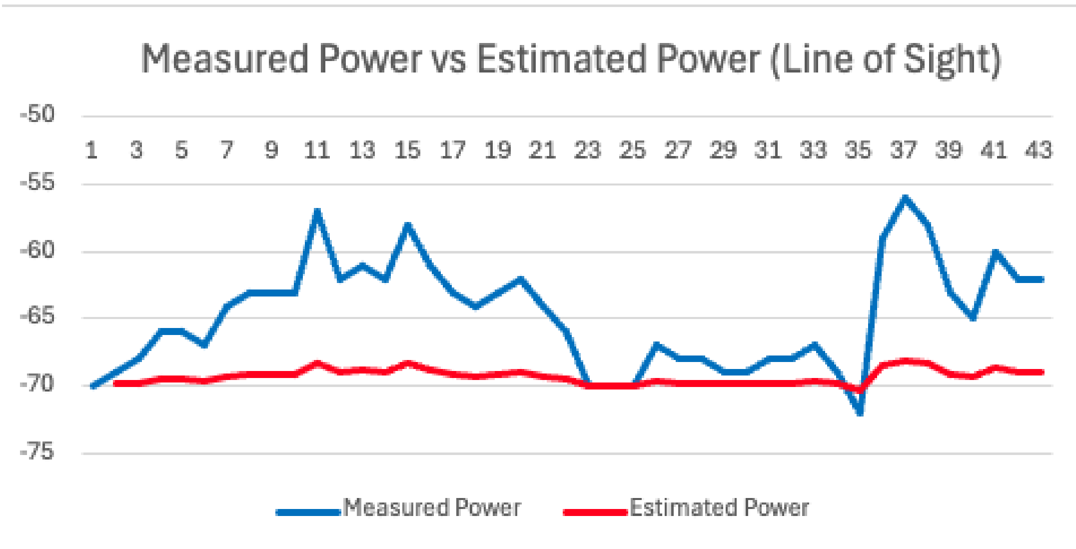

Figure 6: *Measured vs Estimated Power for LOS*

Non Line of Sight Scenario:

On the other hand, the signal power in this scenario showed a gradual decline in the measured signal strength with the least value of –72db at 8.2 meters (above Figure 7). This drop in signal strength was likely due to the obstructing wall, which interfered with the direct connection between the mobile phone and the router. Unlike the Line of Sight (LOS) scenario, the measured signal power at various Non Line of Sight (NLOS) distances was consistently lower than the theoretical calculations, highlighting the significant impact of obstacles on wireless signal propagation. The calculated value in this scenario were n = –0.007, J(n) 0.03 and J'(n) = 200.191.

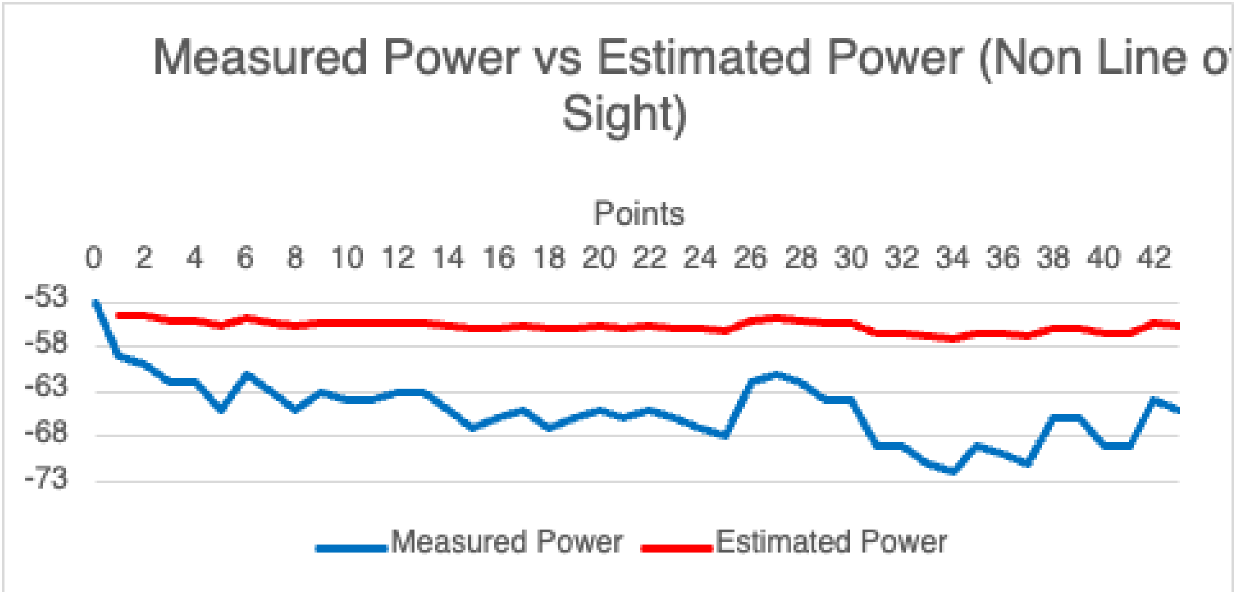

Figure 7: *Measured vs Estimated Power for NLOS*

Analyzing both scenarios, we observe that the lower values in n and J'(n) combined with higher values of J(n) indicated a stronger connection between the mobile phone and the router.

Appendices

Appendix I: Calculations for Line of Sight (LOS)

Appendix II: Calculations for Non Line of Sight (NLOS)

Appendix III: Written Calculations for Line of Sight (LOS)

Appendix IV: Written Calculations for Non Line of Sight (NLOS)

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Appendix I: Calculations for LOS

Name	Distance	Measured Power	Estimated Power	Path loss component (n)	(n - n_bar)^2	(Pmsd - Pest)^2
Formula	*d*	*Pmsd*	*(Pest = Prd0 - 10n log10(d/d0))*	*n = (P(d) - P(d0)) / (10 Log10(d/d0))*		
0	0.3	-70				
1	0.6	-69	-69.87502101	0.332192809	0.07732232	0.765661776
2	0.75	-68	-69.74821745	0.502588319	0.07732232	3.056264266
3	0.9	-66	-69.48891791	0.83836131	1081.24006	12.17254819
4	1.05	-66	-69.48891791	0.735202157	0.54052221	12.17254819
5	1.2	-67	-69.61953525	0.498289214	0.24829214	6.861964946
6	1.35	-64	-69.22163868	0.91853721	0.84371061	27.2655105
7	1.5	-63	-69.08485019	1.001473591	1.00294935	37.02540182
8	1.65	-63	-69.08485019	0.945482545	0.89393724	37.02540182
9	1.8	-63	-69.08485019	0.899568046	0.80922267	37.02540182
10	1.95	-57	-68.21553631	1.599186419	2.5573972	125.7882548
11	2.1	-62	-68.94587299	0.94663573	0.89611921	48.24515159
12	2.25	-61	-68.8046359	1.028499418	1.05781105	60.91234153
13	2.25	-62	-68.94587299	0.914221705	0.83580133	48.24515159
14	2.4	-58	-68.36659907	1.328771238	1.765633	107.4663763
15	2.55	-61	-68.8046359	0.968346969	0.93769585	60.91234153
16	2.7	-63	-69.08485019	0.733566146	0.53811929	37.02540182
17	2.85	-64	-69.22163868	0.613670363	0.37659131	27.2655105
18	3	-63	-69.08485019	0.7	0.49	37.02540182
19	3.15	-62	-68.94587299	0.783400297	0.61371603	48.24515159
20	3.3	-64	-69.22163868	0.576151541	0.3319506	27.2655105
21	3.45	-66	-69.48891791	0.377110224	0.14221212	12.17254819
22	3.6	-70	-70	0	0	0
23	3.75	-70	-70	0	0	0
24	3.9	-70	-70	0	0	0
25	4.05	-67	-69.61953525	0.265408332	0.07044158	6.861964946
26	4.2	-68	-69.74821745	0.174500574	0.03045045	3.056264266
27	4.35	-68	-69.74821745	0.172210703	0.02965653	3.056264266
28	4.5	-69	-69.87502101	0.085027415	0.00722966	0.765661776
29	4.5	-69	-69.87502101	0.085027415	0.00722966	0.765661776
30	4.65	-68	-69.74821745	0.168020393	0.02823085	3.056264266
31	4.8	-68	-69.74821745	0.166096405	0.02758802	3.056264266
32	4.95	-67	-69.61953525	0.24640982	0.0607178	6.861964946
33	5.1	-69	-69.87502101	0.081271151	0.006605	0.765661776
34	5.25	-72	-70.24468913	-0.160896121	0.02588756	3.081116256
35	5.4	-59	-68.51507943	0.876303747	0.76790826	90.53673661
36	5.55	-56	-68.06179974	1.104822629	1.22063304	145.487013
37	5.7	-58	-68.36659907	0.93841378	0.88062042	107.4663763
38	5.85	-63	-69.08485019	0.5426211	0.29443766	37.02540182
39	0.6	-65	-69.35630633	1.660964047	2.75880157	18.97740486
40	6	-60	-68.66106421	0.768621787	0.59077945	75.0140332
41	6.15	-62	-68.94587299	0.609870513	0.37194204	48.24515159
42	6.3	-62	-68.94587299	0.605043356	0.36607746	48.24515159

	n_bar	0.610261721
Estimated Variance	**J(n)**	0.604193376
Modified Cost Function	**J'(n)**	33.72057625

Appendix II: Calculations for NLOS

Name	Distance	Measured Power	Estimated Power	Path loss component (n)	(n - n_bar)^2	(Pmsd - Pest)^2
Formula	*d*	*Pmsd*	*(Pest = Prd0 - 10n log10(d/d0))*	*n = (P(d) - P(d0)) / (10 Log10(d/d0))*		
0	0.1	-53				
1	1.2	-59	-54.39728426	-0.555977045	0.3013572	19.21716391
2	1.4	-60	-54.61626142	0.502588319	0.252595	24.56714407
3	1.6	-62	-55.0434746	-0.166096405	0.027588	48.39324568
4	1.8	-62	-55.0434746	-0.159327954	0.0253854	40.2067007
5	2	-65	-55.65912461	-0.230586536	0.0531702	103.3959729
6	2.2	-61	-54.83161896	0.074492186	0.0055491	33.04018922
7	2.4	-63	-55.2519404	-0.144905355	0.0209976	53.88845147
8	2.6	-65	-55.65912461	-0.282690837	0.0799141	95.02466605
9	2.8	-63	-55.2519404	0.138201907	0.0190998	56.89499145
10	3	-64	-55.45712313	0.067699249	0.0045832	72.98074519
11	3.2	-64	-55.45712313	0	0	76.52854684
12	3.4	-63	-55.2519404	0.065296361	0.0042636	60.03242763
13	3.6	-63	-55.2519404	0	0	53.88845147
14	3.8	-65	-55.65912461	-0.126599618	0.0160275	80.03148867
15	4	-67	-56.05396799	-0.12483927	0.0155848	124.1432286
16	4.2	-66	-55.85804198	-0.061604832	0.0037952	106.9337038
17	4.4	-65	-55.65912461	0.060847508	0.0037024	80.03148867
18	4.6	-67	-56.05396799	-0.060141049	0.0036169	124.1432286
19	4.8	-66	-55.85804198	0.059479864	0.0035379	106.9337038
20	5	-65	-55.65912461	0.058859191	0.0034644	83.57539647
21	5.2	-66	-55.85804198	0	0	106.9337038
22	5.4	-65	-55.65912461	0.057723597	0.003332	83.57539647
23	5.6	-66	-55.85804198	0	0	98.92355268
24	5.8	-67	-56.05396799	-0.056707731	0.0032158	115.6271962
25	6	-68	-56.24699129	-0.112476371	0.0126509	167.8715505
26	6.2	-62	-55.0434746	0.33474826	0.1120564	51.3856867
27	6.4	-61	-54.83161896	0.387558278	0.1502014	35.48019488
28	6.6	-62	-55.0434746	-0.054958827	0.0030205	42.80923772
29	6.8	-64	-55.45712313	-0.163709981	0.026801	72.98074519
30	7.8	-64	-55.45712313	0	0	57.19599475
31	7.6	-69	-56.43719663	-0.2658424	0.0706722	157.8240284
32	7.5	-69	-56.43719663	0	0	148.608915
33	8	-71	-56.80947437	-0.105092245	0.0110444	196.2325024
34	8.2	-72	-56.9916988	-0.052251686	0.0027302	242.2008486
35	8.4	-69	-56.43719663	0.103935017	0.0108025	153.1489136
36	8.6	-70	-56.62466511	-0.051692985	0.0026722	173.9899663
37	8.8	-71	-56.80947437	-0.102855121	0.0105792	229.2788927
38	9	-66	-55.85804198	0.25585361	0.0654611	102.8593125
39	9.2	-66	-55.85804198	0.25460999	0.0648262	91.44720821
40	9.4	-69	-56.43719663	-0.152042859	0.023117	157.8240284
41	9.6	-69	-56.43719663	-0.15134155	0.0229043	183.4095139
42	9.8	-64	-55.45712313	0.251101573	0.063052	69.57020225
43	10	-65	-55.65912461	0.2	0.04	4225

	n_bar	-0.007016949
Estimated Variance	**J(n)**	0.035076622
Modified Cost Function	**J'(n)**	200.1911554

APPENDIX III

For Line of sight

$d = 0.3$ $\quad n = 2$ $\quad P_{rd_0} = -70\ dB$

(1) $d = 0.6$, $P_{rdi} = -69$

$$\text{Estimated Power } (P_{est}) = P_{rd_0} - 10\, n \log_{10}\left(\frac{d}{d_0}\right)$$
$$= -70 - 10(2)\left(\log_{10}\left(\frac{0.6}{0.3}\right)\right)$$
$$= -69.87$$

P_{rd_1} is close to P_{est}.

[Similar approach was used to calculate the remaining] ↓
[Appendix I]

$$\bar{n} = \frac{1}{N}\sum_{i=1}^{42} n_i = \frac{1}{42}\sum_{i=1}^{42}(n_i)$$

$$= \frac{1}{42}\left[0.3 + 0.5 + \dots 0.6\right] = 0.61$$

$$J(n) = \frac{1}{N}\sum_{i=1}^{42}(n_i - \bar{n})^2 = \frac{1}{42}\sum_{i=1}^{42}(n_i - 0.61)^2 = 0.6041$$

$$J'(n) = \frac{1}{N}\sum_{i=1}^{42}\left[P_{measured}(d_i) - P_{estimated}(d_i)\right]^2 = 33.72$$

APPENDIX IV

For Non Line Of Sight:

~~Calculating~~ Assume,

$d_0 = 0.1$ $\qquad P_{rd} = -59$ $\qquad n = 3$

Estimated Power (P_{est}) for $d = 1.2$

$$P_{est} = P_{rd_0} - 10n \log_{10}\left(\frac{d}{d_0}\right)$$

$$= -59 - 10(3)\left[\log\left(\frac{1.2}{0.1}\right)\right]$$

$$= -54.39$$

[Similar approach was used to get the remaining P_{est} values] [Appendix II]

$$\bar{n} = \frac{1}{N}\sum_{i=1}^{44} n_i = \frac{1}{44}\sum_{i=1}^{44}(n_i) = \frac{1}{44}[-0.5 + 0.5 - 0.1 \ldots]$$

$$\therefore \bar{n} = -0.00701$$

$$J(n) = \frac{1}{N}\sum_{i=1}^{44}(n_i - \bar{n})^2 = \frac{1}{44}[0.3 + 0.2 + \ldots]$$

$$J(n) = 0.035$$

$$J'(n) = \frac{1}{N}\sum_{i=1}^{44}\left[P_{measured}(d_i) - P_{estimated}(d_i)\right]^2 = 200.19$$

$$J'(n) = 200.19$$