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Richmond, B.C. V6V-2B2

April 11, 2005

Dr. David Michelson, Assistant Professor
University of British Columbia
Department of Electrical and Computer Engineering
2356 Main Mall
Vancouver, B.C. V6T-1Z4

Re: EECE 496 Final Report: Measurement-based Modeling of Propagation in Vehicular Environments – Part III. Results and Data Analysis

Dear Dr. Michelson:

Enclosed you will find my EECE496 report entitled "Measurement-based Modeling of Propagation in Vehicular Environments – Part III. Results and Data Analysis"

This report is part III of the final report for the project, "Measurement-based Modeling of Propagation in Vehicular Environments". There are in total three parts to the final report: "Part I. Overview and Literature Survey", "Part II. Measurement Methodology and Tool Development" and "Part III. Results and Data Analysis".

Stanley Ho is the main author for part I, Antonio Lau is the main author for part II, and I am the main author for part III.

Sincerely,

Kelvin Chu

Enclosure: EECE 496 Final Report: Measurement-based Modeling of Propagation in Vehicular Environments – Part III. Results and Data Analysis

The University of British Columbia
Department of Electrical and Computer Engineering

EECE 496
Engineering Project

DM3: Measurement-based Modeling of Propagation in Vehicular Environments – Part III. Results and Data Analysis

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EECE 496
The University of British Columbia
April 11, 2004

ABSTRACT

Radiowave propagation models are essential to wireless network designs in vehicular environments. Before a general propagation model can be developed, a large amount of data should be collected and compared to the hypotheses. Therefore, data reduction methodologies that allow easy and effective comparisons between our experimental results and theoretical predictions were developed and reported. Moreover, any similarities and discrepancies between our results and hypotheses were examined. Finally, conclusions were drawn regarding the validity of our original hypotheses. Results showed that S21 parameter generally decreased with distance in a straight-line fashion with different pathloss coefficients. The pathloss coefficients for Bluetooth receivers placed at roof height were around 2, signifying the characteristic of free space propagation that we have predicted. In addition, the hypothesis of higher initial insertion loss for receiver placed at bumper height than roof height was validated. However, the pathloss coefficients at bumper height were smaller than what we have expected. Finally, the coverage when the Bluetooth transmitter was placed near the dome light was found to have the best coverage around a vehicle.

TABLE OF CONTENTS

GLOSSARY

Pathloss:	Wave energy loss through propagation.
Vehicular environment:	Includes the inside and the area around a vehicle as well as the radio link between the interiors of two vehicles in a short distance.
S21 Parameter:	Forward transmission coefficients between the incident and reflected waves.
Vector Network Analyzer:	A “stimulus-response” test set that is used to determine the characteristics of an unknown device or system
Multipath Fading:	Signal attenuation due to collisions between signals with different delay spreads.
Noise floor:	The signal strength of all the noise. A signal must be above the noise floor in order to be distinguishable.

LIST OF ABBREVIATIONS

VNA – Vector Network Analyzer

dB – Decibel

GHz – Gigahertz

RF – Radio Frequency

1.0 INTRODUCTION

In the first and second part of this project report, the background and motivations, anticipated outcomes, research methodology and tool development have been discussed. The measurement procedure yielded a huge amount of data which must be reduced before our hypotheses are validated, models developed, and conclusions drawn.

Therefore, part 3 of the report will investigate into the experimental results that we obtained from our production runs. The objective is to compare these results with our anticipated outcomes. A strong agreement between the experimental data and our hypotheses will allow us to develop a Bluetooth propagation model for any automotive environment. Such a propagation model is an essential tool for wireless network design in vehicular environments, and it has not been explored in detail previously.

In this report, sample of raw data will first be shown and discussed. Moreover, the methodology for data reduction is presented followed by sample processed data for different cases (*i.e.* Different vehicle types). For brevity, only reduced data that have significant conclusions are presented. Any discrepancy between our experimental data and our expected results will be discussed. Finally, several conclusions will be drawn regarding our original hypotheses.

This report is divided into the following primary sections: Raw Measurement Data, Data Reduction Methodology, Results, Conclusions, References, and Appendix.

2.0 RAW MEASUREMENT DATA

From our pre-development and production runs, we have collected a very large amount of data. To be exact, we have collected 107 and 628 sets of data for pre-development runs and production runs respectively. In the production runs, we have collected data from three different vehicles according to the measurement plan specified in part 2 of the report. The three vehicles were a Neon Sedan, a Rav4 and a Sundance.

Each set of data that we have collected essentially was the frequency response for a specific position of the Bluetooth transmitter and the Bluetooth receiver. In the vector network analyzer (VNA), the data was represented by a graph that plots the S21 coefficients with a range of frequency values. S21 coefficients were measured in decibel (dB), and frequency values were in gigahertz (GHz). The frequency range was set to be between 2.4GHz and 2.55GHz because we know that the operational frequency for Bluetooth is around 2.45GHz. Moreover, we have set the VNA to collect 1601 data points in the frequency range in order to get a more accurate frequency response.

When we saved the data to the floppy disks, the VNA would create a file with an extension of .dat. This file did not show the plot that we observed from the VNA. Instead, it was a text file that begins with some texts describing the settings of the VNA. Some of the settings were the start and stop frequency values, the parameter measured and the reference plane value. Following the VNA settings, 1601 different frequency values with their corresponding S21 values were listed. A sample of the data file that we saved is shown in Exhibit 1 in the Appendix. Note that only the first 2 pages of data are shown.

From Exhibit 1, we can see that there are texts in between the data at the end of each page of the file. In order to plot the data in Matlab, we need to delete all the text and input only the 1601 pairs of data points to the program. To do this, one of Dr. Michelson's assistants, Chris, has helped us to develop a Matlab function that would extract the numerical data from the file effectively. This function is named "load_data", and its Matlab script is shown in Exhibit 2 in the Appendix.

In this Matlab script, Chris first counted the number of rows for the header, data blocks and the texts between the data blocks. Using this information, Chris could then skip all the undesired content in the data file and input all the frequency and S21 values into two 1601x1 matrixes. Since the formats of all data files were exactly the same, this Matlab function can be used for all data files that we have collected in the production runs. To use this function, we just have to input the file name that we want to extract the data from. For example, to extract the data from the "PORT130.dat" file in Exhibit 1, this command should be input in Matlab:

```
[freq, mag] = load_data(PORT130.dat)
```

After that, two 1601x1 matrixes, “freq” and “mag”, will be created. “freq” will contain 1601 different frequency values from 2.4GHz to 2,55GHz while “mag” will contain 1601 S21 values in dB. Using the “plot(freq, mag)” Matlab command, a plot of S21 vs. frequency can be produced, and it is very similar to the plot that we saw in the VNA. A sample of such a plot for the “PORT130.dat” file is shown below:

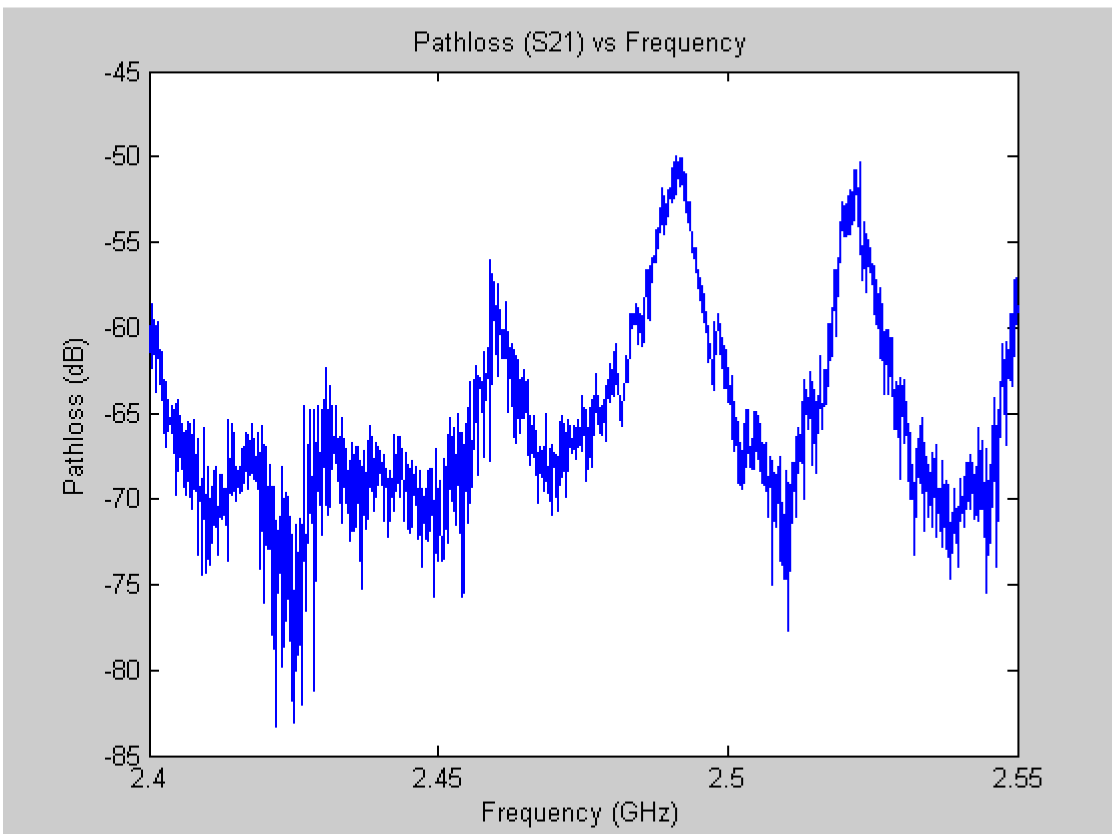

Figure 1. Pathloss vs. Frequency Plot for “PORT130.dat”

The peaks and dips in the plot above are the result of interference between multipath replicas of the original signal that arise from reflections in and around the vehicle.

Another interesting fact that we noticed from the plots of frequency responses is that the frequency response would have more distortion as the receiver moves further away from the transmitter. The plot above used data of "PORT130.dat", which represented a distance of 2 meters between the Bluetooth transmitter and receiver. Another data plot of S21 vs. frequency is plotted below at a distance of 12 meters from the "PORT134" file:

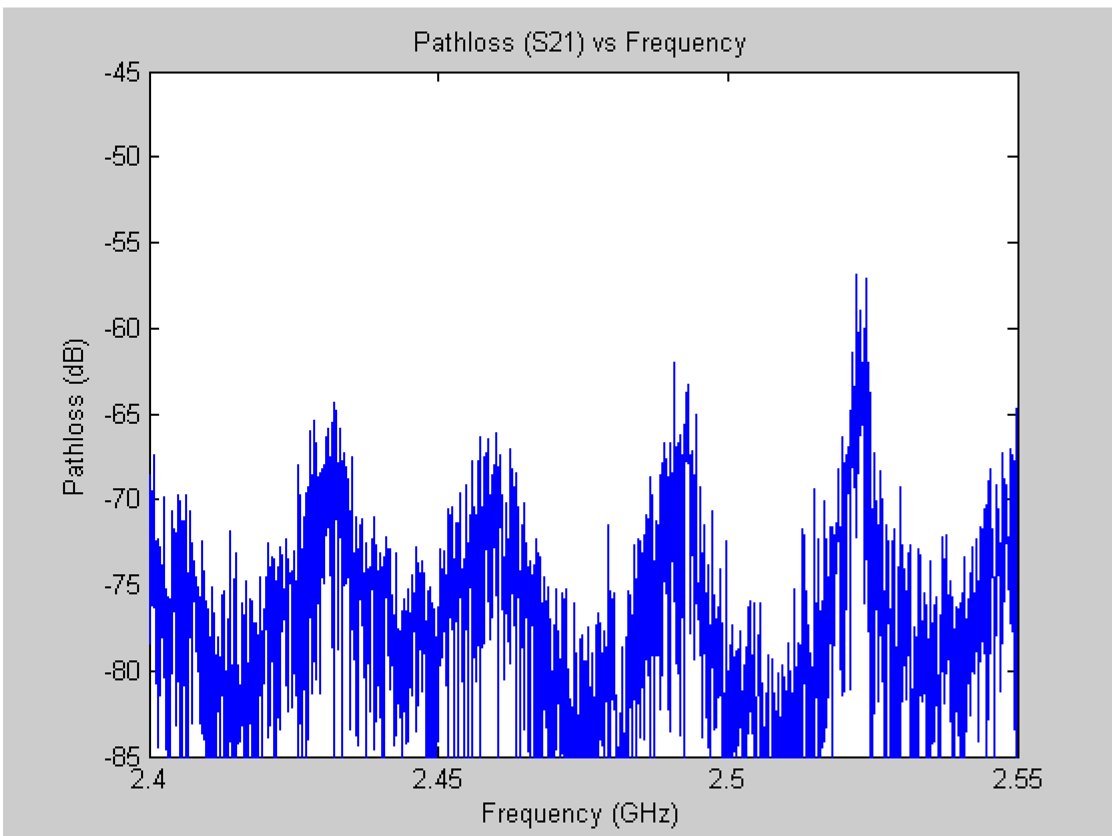

Figure 2. Pathloss vs. Frequency Plot for "PORT134.dat"

From the plot above, we can notice that there are more fluctuation and distortion for the S21 values at a distance of 12 meters than at 2 meters. This is due to multipath fading that attenuates and distorts the signal more as the distance increases. Beside the distortion, we can also notice that the average value of S21 decreases as the distance increases. However, the questions of how much it decreases as well as how the decrease relates to different positions and heights of the Bluetooth transmitter and receiver still remain unanswered. In order to find the answers to the questions and to verify our hypotheses, an effective way to reduce the data into a format that can be easily analyzed was developed. In the following section, this methodology of data reduction will be demonstrated.

3.0 DATA REDUCTION METHODOLOGY

3.1 S21 vs. DISTANCE PLOTS (for each transmitter position, angle and receiver height)

3.1.1 DATA PRESENTATION

In order to analyze the data that we collected in the production runs effectively, we organized the data in a special manner. The data was reduced and put into plots that show the relationship between pathloss (S21) and distance at every angle, transmitter position and receiver height. In the production runs, our measurements were done at five different angles, four different transmitter positions and two different receiver heights for each car. Therefore, there would be a total of 40 plots for each automobile. In addition, the pathloss values in dB were plotted against log distance. A linear regression line was also drawn in order to find the pathloss coefficient easily. As discussed earlier in part 1 of the report, the relationship between pathloss and the distance from the RF transmitter to the receiver is given by:

$$Pathloss(dB) = -10\log\left(\left(\frac{\lambda}{4\pi R}\right)^{\alpha}\right) \qquad (1)$$

Hence, it is clear that the pathloss coefficient α can be found simply by dividing the slope of the regression line in the graphs by –10. Along with the slope, the y-intercept, which represents the initial insertion loss, was also shown at the upper right corner for each graph. Moreover, the range of values in the pathloss axis was set to be consistent across all plots to allow easier comparison.

3.1.2 MATLAB SCRIPT DESCRIPTION

To reduce the data in the way described above, we have developed a Matlab script. This script is shown in Exhibit 3 in the Appendix. Note that only one part of the script is shown, and this part would only yield one plot out of the 40 plots that we obtained. In this Matlab script, we first defined the different distance values that we did the measurements at. Since there were some points that we could not do the measurements because the vehicle body was in the way, we have defined 3 different vectors of distances. One vector contained four terms from a distance of 4m to 12m while the second one contained five terms from 2m to 12m. The last vector contained all six terms from 1m to 12m. Therefore, different vectors would be used according to the data collected. After defining the distance vectors, we found the logarithmic values for the distances because we wanted to plot S21 in dB with log distance values. After that, we used the "load_data" function to extract the numerical data from the files that had the same angle, transmitter position, and receiver height. In this case, the transmitter position was at the dashboard, and the receiver was at bumper height. Moreover, the angle was at zero degree, which corresponded to the axis pointing towards the back of the car. Under such conditions, we only did 4 measurements along the axis. Therefore, we only loaded

4 files using the "load_data" function. Then, we used the "mean" function to find the linear average of S21 values for each distance value. Therefore, a vector of 4 different means of S21 was then created. We also used the "std" function to find the standard deviations for each distance value, but we did not show them in the plots. Using the "regress" function, the slope and intercept of the regression line were obtained. For this function, we should input the vertical and horizontal parameters that we want to draw the regression line with, which were the S21 mean vector and the log distance vector. We then input the S21 mean vector and the log distance vector to the "plot" function, and the original data were plotted. We also used the "axis" function to make sure that the vertical axis was consistent throughout all the 40 plots. Finally, we used the obtained slope and intercept to plot the regression line using the "plot" command. We also used the color of red for the regression line, and we also have put legend that shows the slope and intercept of the regression line at the upper right corner of each plot. Here is an example of the plot created by the Matlab script in Exhibit 3:

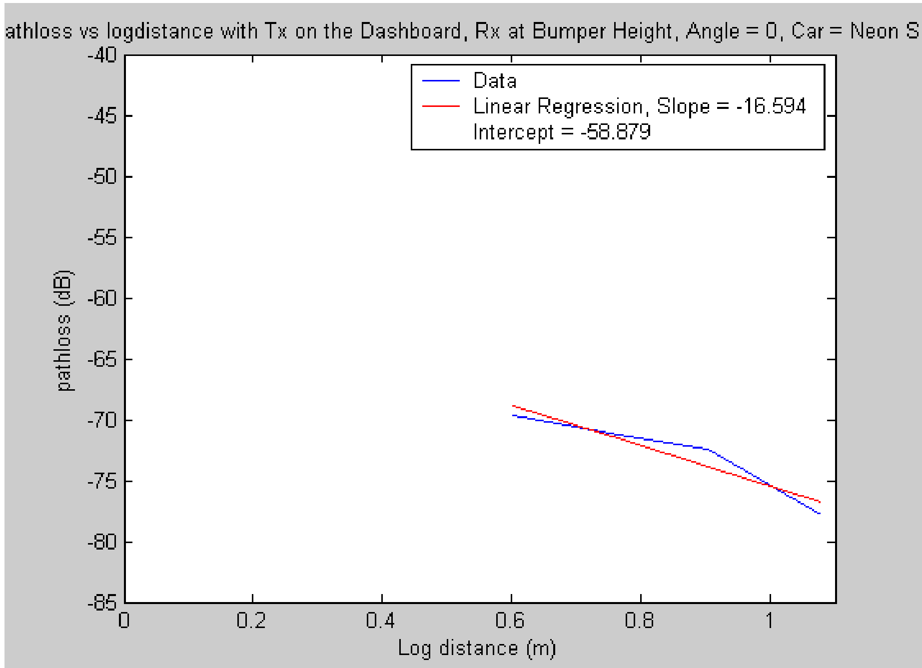

Figure 3. Pathloss vs. Log Distance Plot for Exhibit 3

Using similar Matlab code with different log distance vectors and data files, all 40 plots were created.

3.2 S21 vs. DISTANCE PLOTS (for each transmitter position and receiver height)

3.2.1 DATA PRESENTATION

After obtaining the 40 plots of pathloss vs. log distance, the data was further reduced to show pathloss vs. log distance without the angle factor. In this presentation, the pathloss values at different angles for each distance, transmitter position and height were averaged. Therefore, there would be a total of 8 plots for 4 different transmitter positions and 2 different heights for each vehicle. The format of these plots was the same as the previous plots which showed the slopes and intercepts of the regression line.

3.2.2 MATLAB SCRIPT DESCRIPTION

The Matlab code for one of these 8 plots is shown in Exhibit 4 in the Appendix. This code was very similar to the previous one in Exhibit 3. The only difference was that it had to take the linear average of S21 at the five different angles for each particular distance, transmitter position, and receiver height at the beginning of the code. After that, the rest of the code was the same except different parameters were used. The 8 different plots were created for each vehicle using similar code with different parameters. Here is the plot that was created with the code in Exhibit 4:

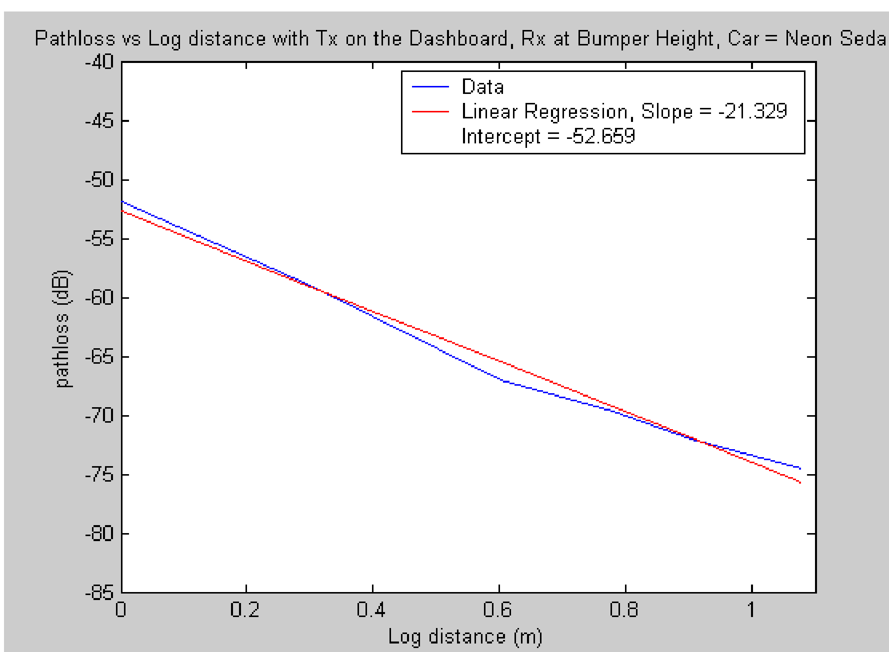

Figure 4. Pathloss vs. Log Distance Plot for Exhibit 4

3.3 SCATTER PLOTS

3.3.1 DATA PRESENTATION

The main purpose of our data analysis is to identify trends in the slopes and intercepts of our graphs, so that we can prove or disprove our hypotheses. Therefore, it is very convenient if all the slopes and intercepts are shown in one graph. Using the 8 plots above, the values of slopes were plotted against their respective values of intercepts for each transmitter position and height in a scatter plot. This scatter plot had 8 data points, and the 4 different transmitter positions were represented by 4 unique symbols, "x" for dashboard, "+" for gearbox, "*" for dome light and "Δ" for under dash. On the other hand, the 2 different heights were represented by two different colors, blue for bumper height (0.5m) and black for roof height (1.5m).

3.3.2 MATLAB SCRIPT DESCRIPTION

The Matlab code for this scatter plot is shown in Exhibit 5 in the Appendix. This code simply used the slopes and intercepts obtained in the code of Exhibit 4 and plotted them all in one graph. Therefore, 8 data points were plotted with different symbols and colors in the plot representing 4 different transmitter positions and 2 different receiver heights. The scatter plot created by the code in Exhibit 5 is shown here:

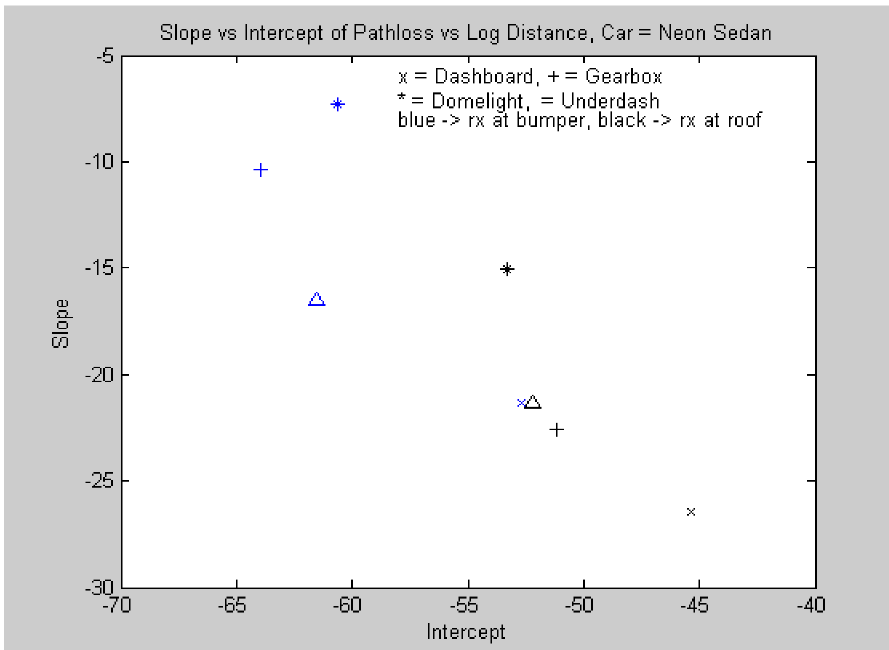

Figure 5. Scatter Plot of Slopes and intercepts for Exhibit 5

4.0 RESULTS

All of the processed data plots for the three cars that we measured in the production runs are shown in the Appendix (refer to Exhibit 10). This section will only show some significant findings and thus, only some plots are used for illustration.

4.1 GENERAL OBSERVATIONS from REDUCED DATA

Our first observation was that the values of the slopes in the reduced data graphs were generally negative (refer to Exhibit 6 in the Appendix). Moreover, many graphs showed that the pathloss values decline in a straight-line fashion. As an example, one of the pathloss vs. distance plots is shown below:

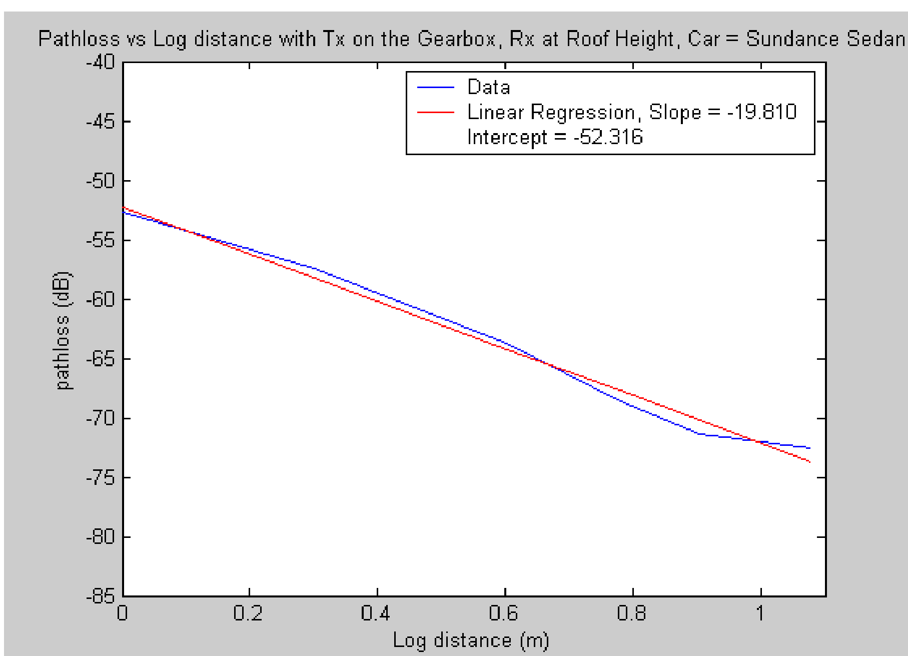

Figure 6. Pathloss vs. Log Distance Plot (TX at Gearbox, Rx at Roof Height, Car = Sundance)

The original data points can be seen to be very close to the values of its linear regression line, meaning that the pathloss values were declining in a straight-line manner. Although most of the slopes were negative, indicating that S21 generally decreased with distance, there were some specific instances where S21 actually increased with distance. For example,

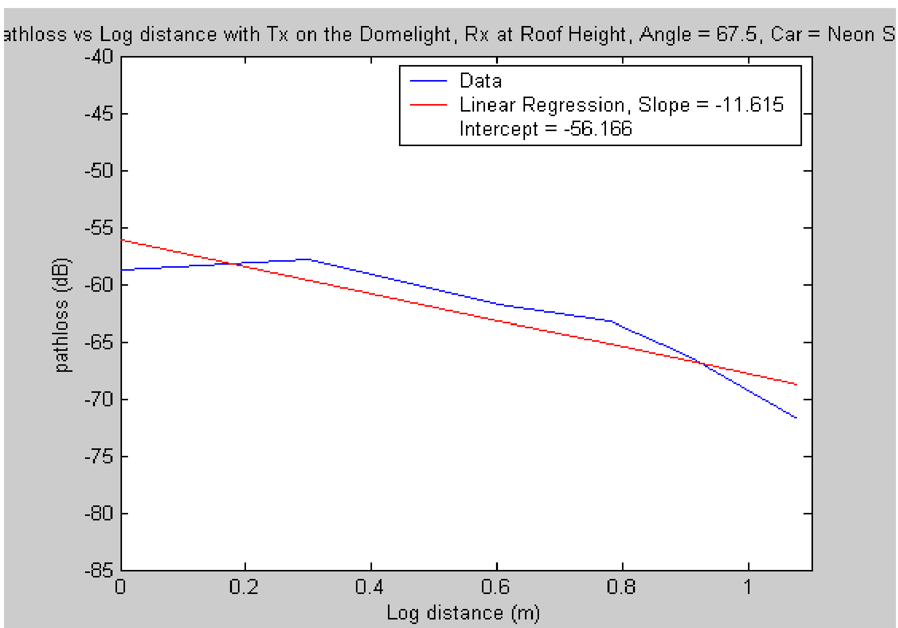

Figure 7. Pathloss vs. Log Distance Plot (TX at Dome Light, Rx at Roof Height, Angle =67.5, Car = Sundance)

In this plot, we can see that S21 increased initially and gradually declined, resulting an overall negative slope. This behavior might be due to the lack of line-of-sight between the Bluetooth transmitter and receiver when the receiver was placed very close to the vehicle; as a result the vehicle body blocked the direct path. As the receiver was moved further away from the vehicle, line-of-sight appeared again causing S21 to increase temporarily. Also, this behavior might be due to the large RF penetration into the metallic material of the automobile body, which significantly decreased the level of S21 when the receiver was close to the vehicle.

From Exhibit 6 in the Appendix, two plots out of a total of 160 pathloss vs. distance plots actually had positive slopes but the slopes were both close to zero. These 2 positive slopes occurred at plots with transmitter placed near the dome light in the Neon with an angle of zero, meaning that the measurements were done on the axis pointing to the back of the car. Both plots only contained 4 data points since measurements at a distance of 1m and 2m were not made due to the obstruction from the vehicle body. Therefore, the signals might have already reached the noise floor when the measurements started at the distance of 4, and a little bit of fluctuation in the signal could result in a positive slope. For more accurate results, more measurements should be taken at a smaller distance than 4m to compensate for any fluctuations around the noise floor after 4m. However, since there were only 2 positive slope values and the accuracy of the data was dubious, we still concluded that S21 decreased with distance around an automobile.

4.2 ANGULAR DEPENDENCY of the REDUCED DATA

After observing that S21 generally decreased with distance, we also looked into the angular dependency of the pathloss vs. distance plots. From Exhibit 6 in the Appendix, we noticed that the intercept values were fairly close together for measurements at different angles with same transmitter location and receiver height in the same vehicle. For example, the largest difference in the intercept values for measurements conducted in the Rav4 at a transmitter location near dome light and the receiver at bumper height was only around 5dB. Therefore, initial insertion losses were quite consistent for different angles. However, we noticed more differences in the values of slope for different angles. At some instances, the largest difference between the values of slope was around 20 for measurements at different angles with same transmitter location and same receiver height in the same car. This was equivalent to a difference of 2 in pathloss coefficient. This was not expected in our hypotheses since our hypotheses predicted that the pathloss coefficients would be affected mainly by different receiver heights. With further investigation, we found that the discrepancies were sometimes due to the inaccuracy of measurements conducted at zero degree since these values were generally quite different from the values at other angles. The inaccuracy was caused by inadequate measurements that were discussed before. For the measurements conducted in the Neon with a transmitter location near dome light and receiver at roof height, the slope at zero degree was 0.713 and the slopes at other angles were all between 10 and 20. If we ignore the values of slope at zero degree in some cases, the differences in the slopes were within reasonable range. Moreover, there was not a clear trend for angular dependency since we could not find any similar trends even when we compared the pathloss behavior under same conditions in the two sedans, the Neon and the Sundance. Therefore, we insisted that pathloss behavior did not depend on angles, but rather on the structures of the vehicles. Different structures include different placements and sizes of doors, passenger seats and windows. A slight change in the structure from the Neon to the Sundance would yield different angular pathloss behaviors. Therefore, more data should be collected in order to incorporate the angular factor in a general propagation model for a certain vehicle class.

Now, we have proven that S21 decreased with distance, and the relationship between pathloss and distance was generally not angular dependent; we were justified to take the linear averages for slope and intercept values at different angles to create the scatter plots. In the following 3 sections, we will investigate into the pathloss coefficient and initial insertion loss for each vehicle by examining the slopes and intercepts respectively from the scatter plots without the angular factor.

4.3 SCATTER PLOT of NEON

For the first vehicle that we measured, the Neon, here is the scatter plot of the slopes and intercepts for each transmitter position and receiver height (refer to Exhibit 7 in the Appendix for exact values of slope and intercept):

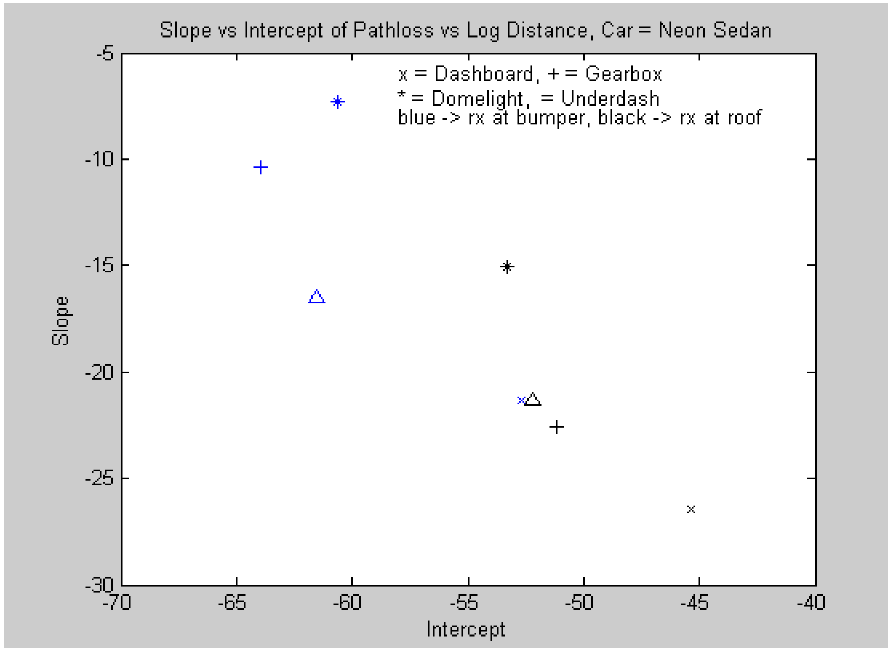

Figure 8. Slope vs. Intercept Scatter Plot (Car = Neon)

From this plot, we can observe that for all of the transmitter positions at roof height, the values of the slope were between -15 and -25. This corresponds to pathloss coefficients from 1.5 to 2.5. This was close to our hypothesis, which we expected the pathloss coefficient to be 2 for receiver at roof height since we have assumed free space propagation at this height. However, when the receiver was at bumper height, we expected the coefficient to be 4 but all of the experimental values were nowhere near that value. In fact, the experimental values for pathloss coefficient at bumper height were generally smaller than the ones at roof height. The smallest pathloss coefficient, which was around 0.73, occurs when the transmitter was placed at the dome light and the receiver was at bumper height. This experimental result contradicted our hypothesis, which predicted that the pathloss coefficient would get closer to 4 as the receiver became closer to the ground.

For the other hypothesis, we have predicted that the initial insertion loss should be less for the receiver at roof height than at bumper height. From our experimental data, we observed that the intercepts at roof height were generally higher than the intercepts at bumper height. Therefore, the experimental results support our hypothesis.

In addition, we also predicted that the coverage would be best with the lowest initial insertion loss when the transmitter is placed near the dome light. This was not true for the Neon, as the intercepts for transmitter near dome light at both bumper height and roof height were relatively low compared to other transmitter positions. For the 4 different transmitter positions at roof height, the highest initial insertion loss actually occurred when the transmitter was placed near the dome light. Surprisingly, at both heights, the initial insertion loss was minimal when the transmitter was placed at the dashboard. Although there was a low initial insertion loss for transmitter placed at the dashboard, it was not necessary for this position to provide the best coverage outside a vehicle. It is because the pathloss coefficients for transmitter placed at dashboard were also the greatest among other transmitter positions. This means that S21 would decline most rapidly with distance when the transmitter was placed at the dashboard. Although the initial insertion loss for transmitter placed at dome light was large, its pathloss coefficients were smallest among the others. In fact, the S21 value for transmitters at dome light at a distance of 12 meters was around –70 dB while the S21 values for other transmitter positions were all around –75 dB. For transmitters placed under dash and at gearbox, they had higher initial insertion loss than transmitter placed at dashboard, and they also had a higher pathloss coefficient than the transmitter near dome light. Therefore, their coverage was even worse.

4.4 SCATTER PLOT of RAV4

The second vehicle that we measured was the Rav4. Since the structure of a Rav4 is completely different than the Neon, we expect to find some differences in the collected data. Here is the scatter plot of the slopes and intercepts for each transmitter position and receiver height (refer to Exhibit 8 in the Appendix for exact values of slope and intercept):

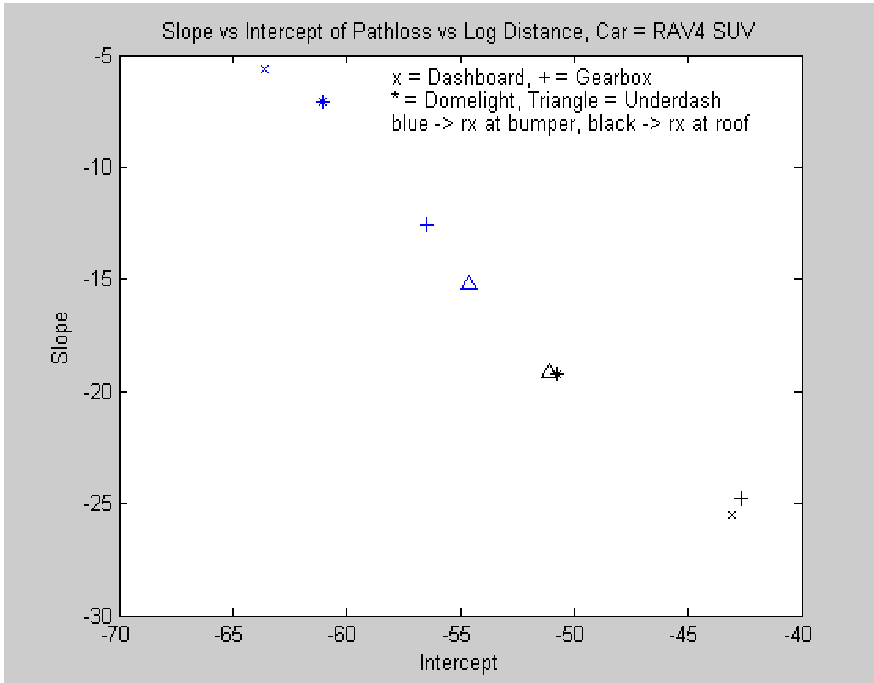

Figure 9. Slope vs. Intercept Scatter Plot (Car = RAV4)

From this plot, we observed some similarities with the Neon. For example, we noticed that the slopes were generally steeper for transmitters at roof height than at bumper height. The scatter plot of the Neon also showed similar behavior. This illustrated that the pathloss coefficients at roof height were greater than those at bumper height, and this contradicted our hypothesis. The only thing that met our predictions was that the pathloss coefficients at roof height were around 2, which represents the pathloss coefficient in free space. On the other hand, the pathloss coefficients at bumper height were again nowhere near its predicted value of 4.

Beside the pathloss coefficients, the Rav4 showed similar behavior with the Neon as the initial insertion loss at bumper height were generally greater than the loss at roof height. This experimental result coincides with our prediction.

For transmitter at dome light in the Rav4, the pathloss coefficient was small while the initial insertion loss was large compared to other transmitter positions. This behavior is consistent with the results for the Neon. For transmitter at dashboard and under dash, strange behavior was observed for the Rav4. When the dashboard transmitter was coupled with a receiver at roof height, it resulted in very low initial insertion loss and very high pathloss coefficient. However, when the dashboard transmitter was coupled with a receiver at bumper height, it resulted in a very low pathloss coefficient and a very high insertion loss. In addition, the transmitter under dash displayed a completely reverse behavior to the dashboard transmitter. For the gearbox transmitter, the result showed that it had the second lowest initial insertion loss and the second highest pathloss coefficient for both receiver heights.

4.5 SCATTER PLOT of SUNDANCE

The last vehicle that we measured was a sedan, the Sundance. Since the structure of the Sundance is very similar to the Neon, we expect to find many similarities in the collected data. Here is the scatter plot of the slopes and intercepts for each transmitter position and receiver height (refer to Exhibit 9 in the Appendix for exact values of slope and intercept):

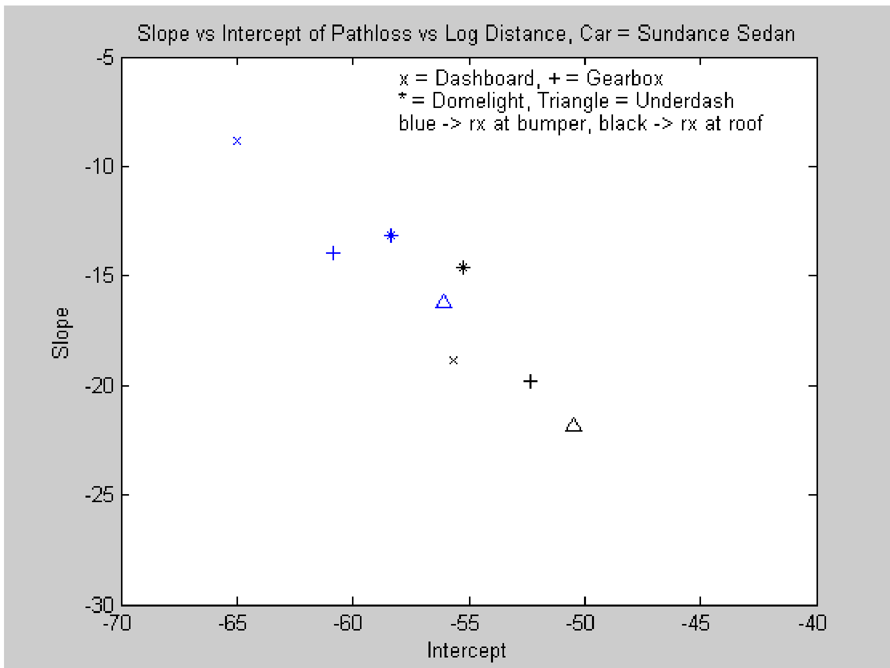

Figure 10. Slope vs. Intercept Scatter Plot (Car = Sundance)

From this scatter plot, we again noticed that the pathloss coefficients were higher and the initial insertion losses were lower at roof height than at bumper height. This behavior is consistent for all 3 vehicles tested. Another observation of the scatter plot w that the data points were closer together both vertically and horizontally when compared to the two other plots for the other cars. The pathloss coefficients at bumper height were again not close to what we have predicted. The low values of pathloss coefficients might be due to the high initial insertion loss at bumper height, and S21 was hitting the noise floor too rapidly. This would then result in a flat regression line. Since the values of initial insertion loss when the receiver was at bumper height were around –60dB, it was impossible to result in a slope of –40 since the noise floor was around –80dB. For example,

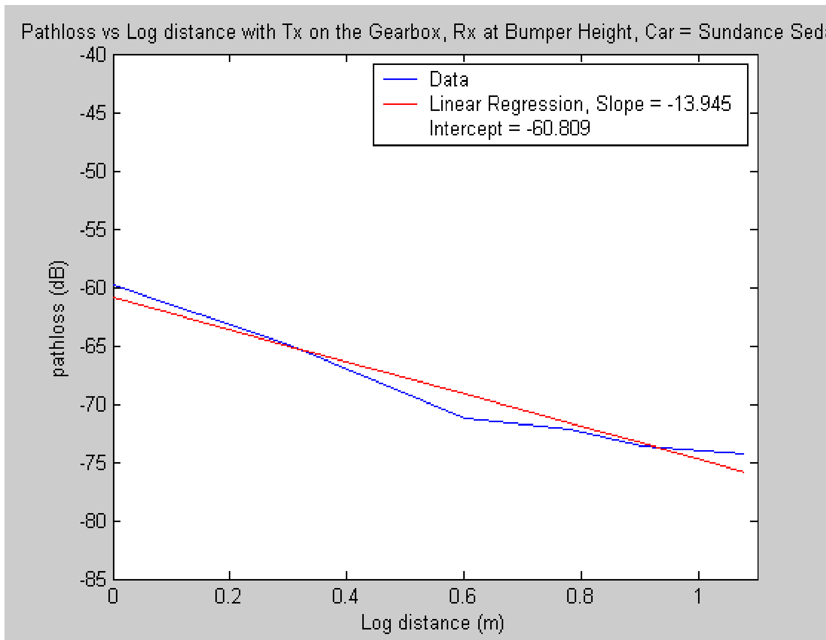

Figure 11. Pathloss vs. Log Distance Plot (TX at Gearbox, Rx at Bumper Height, Car = Sundance)

In this plot, we can notice that S21 decreased rapidly at first and settled for a less decline when it reached the noise floor. For a more accurate estimate of pathloss coefficient at bumper height, we should use the first few distance points only to plot the regression line. However, the exact number of points to be used in different situations is difficult to be determined.

For transmitter at dome light in the Sundance, it had relatively low pathloss coefficients for both bumper and roof height, similar to the results obtained from the other two cars. Moreover, it had a high insertion loss when the receiver was placed at roof height just like the other 2 previous cases. However, the only difference occurred at bumper height while it resulted a relatively low insertion loss.

The initial insertion loss was minimal when the transmitter was placed under dash for the Sundance. In addition, the pathloss coefficient was at its maximum at this transmitter position. Compared to the data for the Neon, similar behavior was found with the transmitter at the dashboard of the Neon. With further investigation, we also noticed that the behavior for under dash transmitter in the Neon is similar to the behavior for transmitter at the dashboard in the Sundance. This behavior swap might be due to the difference in mounting angles when we did the measurements. For example, when we mounted the transmitting antenna at the dashboard, we might have aimed the antenna upward for the Neon but aimed the antenna downward for the Sundance. As for the transmitter at gearbox, it had relatively high pathloss coefficients and medium initial insertion loss.

5.0 CONCLUSIONS

This report investigated into the experimental results and compared them to our original hypotheses. The hypothesis that S21 would decrease with distance in a straight-line manner was validated. In addition, the relationship between pathloss and distance did not depend on angles, but rather on the structures of the vehicles. The experimental results also proved that the initial insertion loss was higher at bumper height than at roof height. Moreover, it was also shown that propagation at roof height could be assumed to be free space as the pathloss coefficients were all around the value of 2. However, the measured pathloss coefficients for receivers placed at bumper height were nowhere near what we have expected. For transmitters at different positions, transmitter near the dome light generally had a high initial insertion loss, but it was offset by a very low pathloss coefficient. Therefore, the coverage of the transmitter at dome light was pretty good. The coverage of the transmitter placed on and under the dashboard was similar. It is characterized by low initial insertion loss and high pathloss coefficient. Finally, the coverage of the transmitter at gearbox was generally the worst among the four.

6.0 REFERENCES

[1] D. Michelson, “Introduction to Vector Network Analyzers,” class notes for EECE 483 – Antennas and Propagation, Department of Electrical Engineering, University of British Columbia, Fall 2004.

7.0 APPENDIX

Exhibit 1. Sample raw data file (PORT130.dat)

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##2□□□□□□□□□□□□□□□□□□□□□□□
37225A
##1□□□□□□□□□□□□□□□□□□□□□□□

MODEL:                 DATE:                 Page    1
DEVICE ID:              OPERATOR:

START:     2.400000000 GHz  GATE START:      -      ERROR CORR: 12-TERM
STOP:      2.550000000 GHz  GATE STOP:       -      AVERAGING:   1 PT
STEP:      0.000093750 GHz  GATE:            -      IF BNDWDTH: 1 KHz
                            WINDOW:          -

           ---CH1---
PARAMETER:            -S21-
NORMALIZATION:          OFF
REFERENCE PLANE:      11.3386cm
SMOOTHING:          0.0 PERCENT
DELAY APERTURE:          -

MARKERS:

MKR    FREQ        MAGNITUDE
#      GHz            dB


FREQUENCY POINTS:

PNT    FREQ        MAGNITUDE
#      GHz            dB
```

1	2.400000000	-48.417
2	2.400093750	-48.324
3	2.400187500	-48.591
4	2.400281250	-48.513
5	2.400375000	-48.597
6	2.400468750	-48.661
7	2.400562500	-48.811
8	2.400656250	-48.668
9	2.400750000	-48.770
10	2.400843750	-49.251
11	2.400937500	-49.000
12	2.401031250	-49.187
13	2.401125000	-49.202
14	2.401218750	-49.310
15	2.401312500	-49.578
16	2.401406250	-50.146
17	2.401500000	-49.955
18	2.401593750	-50.014
19	2.401687500	-50.168
20	2.401781250	-50.026
21	2.401875000	-50.296
22	2.401968750	-50.225
23	2.402062500	-50.395
24	2.402156250	-50.483
25	2.402250000	-50.678
26	2.402343750	-51.493

MODEL: DATE: Page 2
DEVICE ID: OPERATOR:

---CH1---

FREQUENCY POINTS:

PNT #	FREQ GHz	MAGNITUDE dB
27	2.402437500	-51.107
28	2.402531250	-50.730
29	2.402625000	-51.567
30	2.402718750	-51.490
31	2.402812500	-51.473
32	2.402906250	-51.819
33	2.403000000	-51.811

34	2.403093750	-52.358
35	2.403187500	-52.172
36	2.403281250	-51.673
37	2.403375000	-52.611
38	2.403468750	-52.005
39	2.403562500	-51.977
40	2.403656250	-52.478
41	2.403750000	-52.397
42	2.403843750	-52.528
43	2.403937500	-52.541
44	2.404031250	-53.095
45	2.404125000	-53.167
46	2.404218750	-52.885
47	2.404312500	-52.938
48	2.404406250	-53.061
49	2.404500000	-52.822
50	2.404593750	-52.944
51	2.404687500	-53.506
52	2.404781250	-53.645
53	2.404875000	-53.839
54	2.404968750	-53.854
55	2.405062500	-54.308
56	2.405156250	-54.077
57	2.405250000	-54.006
58	2.405343750	-54.699
59	2.405437500	-53.887
60	2.405531250	-54.155
61	2.405625000	-54.815
62	2.405718750	-53.905
63	2.405812500	-54.613
64	2.405906250	-54.767
65	2.406000000	-54.765
66	2.406093750	-54.554
67	2.406187500	-54.470
68	2.406281250	-54.692
69	2.406375000	-54.402
70	2.406468750	-55.977
71	2.406562500	-55.142
72	2.406656250	-56.149
73	2.406750000	-54.763

Exhibit 2. Matlab Script for the function “load_data”

```
function [freq, mag] = load_data(file_name)

%
%   file_name is a string contain the data file name i.e. 'PRE1.dat'
%
num_points = 1600;
header_size = 33;
block_size1 = 26;
block_size2 = 47;
block_size3 = 24;
freq = zeros(num_points,1);
mag = zeros(num_points,1);
num_data_set = 33;

%----------------------------------------------------------
% open data file
fid = fopen(file_name);

% read past header
for m=1:header_size
   fgetl(fid);
end

%read first data block
tmp =fscanf(fid,'%i %f %f',[3,block_size1]);
%skip over header
for k=1:11
   fgetl(fid);
end
%load variable
for k=1:block_size1
   freq(k) = tmp(2,k);
   mag(k) = tmp(3,k);
end

for m=1:num_data_set
   %read data block
   tmp =fscanf(fid,'%i %f %f',[3,block_size2]);

   %skip over header
```

```
    for k=1:11
        fgetl(fid);
    end

    %load variable
    for k=1:block_size2
        freq((m-1)*block_size2+block_size1+k) = tmp(2,k);
        mag((m-1)*block_size2+block_size1+k) = tmp(3,k);
    end
end

%read last data block
tmp =fscanf(fid,'%i %f %f',[3,block_size3]);
%load variable
for k=1:block_size3
    freq(num_data_set*block_size2+block_size1+k) = tmp(2,k);
    mag(num_data_set*block_size2+block_size1+k) = tmp(3,k);
end

% close data file
fclose(fid);
```

Exhibit 3. Matlab Script for Plotting S21 vs. Distance Graphs at one Specific Transmitter Position, Angle and Receiver Height

```
%distances used for plotting
distance4 = [4,6,8,12];
logdistance4 = log10(distance4);
distance5 = [2,4,6,8,12];
logdistance5 = log10(distance5);
distance6 = [1,2,4,6,8,12];
logdistance6 = log10(distance6);
x4 = [logdistance4',ones(4,1)];
x5 = [logdistance5',ones(5,1)];
x6 = [logdistance6',ones(6,1)];

%Car = Neon Sedan
%Tx at Dashboard, Bumper Height, Angle = 0
```

```
%obtaining the variable
[fd3, s21neond3] = load_data('prod1.dat');
[fd4, s21neond4] = load_data('prod2.dat');
[fd5, s21neond5] = load_data('prod3.dat');
[fd6, s21neond6] = load_data('prod4.dat');

%calculate the mean
s21neond3_mean = mean(s21neond3);
s21neond4_mean = mean(s21neond4);
s21neond5_mean = mean(s21neond5);
s21neond6_mean = mean(s21neond6);

%calculate the standard deviation
s21neond3_std = std(s21neond3);
s21neond4_std = std(s21neond4);
s21neond5_std = std(s21neond5);
s21neond6_std = std(s21neond6);
s21neon_dash_bumper_0 = [s21neond3_mean, s21neond4_mean, s21neond5_mean,
s21neond6_mean];

%calculate the slope and intercept using linear regression
bneon_dash_bumper_0 = regress(s21neon_dash_bumper_0', x4);

%plotting the data
plot(logdistance4, s21neon_dash_bumper_0);
axis([0 1.1 -85 -40]);
hold on;

%plotting the regression line
plot(logdistance4, x4*bneon_dash_bumper_0, 'r');
legend('Data',sprintf('Linear Regression, Slope = %5.3f', bneon_dash_bumper_0(1,1)),
sprintf('Intercept = %5.3f', bneon_dash_bumper_0(2,1)));
xlabel('Log distance (m)');
ylabel('pathloss (dB)');
title('Pathloss vs logdistance with Tx on the Dashboard, Rx at Bumper Height, Angle = 0,
Car = Neon Sedan');
pause;
```

Exhibit 4. Matlab Script for Plotting S21 vs. Distance Graphs at one Specific Transmitter Position, and Receiver Height

```
%Part 2//////////////////////////////////////////////////////////////////////////////////////////////////
%avg pathloss vs distance with tx at dashboard, rx at bumper height
s21neon_dash_bumper = [zeros(1,2), s21neon_dash_bumper_0] + [zeros(1,2), s21neon_dash_bumper_225] + [zeros(1,1), s21neon_dash_bumper_45] + s21neon_dash_bumper_675 + s21neon_dash_bumper_90;
s21neon_dash_bumper = [s21neon_dash_bumper(1,1)./2, s21neon_dash_bumper(1,2)./3, s21neon_dash_bumper(1,3)./5, s21neon_dash_bumper(1,4)./5, s21neon_dash_bumper(1,5)./5, s21neon_dash_bumper(1,6)./5];
bneon_dash_bumper = regress(s21neon_dash_bumper', x6);
figure;
plot(logdistance6, s21neon_dash_bumper);
axis([0 1.1 -85 -40]); hold on;
plot(logdistance6, x6*bneon_dash_bumper, 'r');
legend('Data',sprintf('Linear Regression, Slope = %5.3f', bneon_dash_bumper(1,1)), sprintf('Intercept = %5.3f', bneon_dash_bumper(2,1)));
xlabel('Log distance (m)');
ylabel('pathloss (dB)');
title('Pathloss vs Log distance with Tx on the Dashboard, Rx at Bumper Height, Car = Neon Sedan');
pause;
```

Exhibit 5. Matlab Script for Scatter Plot for One Vehicle

```
%Part 3/////////////////////////////////////////////////////////////////////////////////////////////
%Slope verse Intercept
plot(bneon_dash_bumper(2,1), bneon_dash_bumper(1,1), 'bx');
hold on;
axis([-70 -40 -30 -5]); hold on;
plot(bneon_dash_Roof(2,1), bneon_dash_Roof(1,1), 'kx');
plot(bneon_Gearbox_bumper(2,1), bneon_Gearbox_bumper(1,1), 'b+');
plot(bneon_Gearbox_Roof(2,1), bneon_Gearbox_Roof(1,1), 'k+');
plot(bneon_Domelight_bumper(2,1), bneon_Domelight_bumper(1,1), 'b*');
plot(bneon_Domelight_Roof(2,1), bneon_Domelight_Roof(1,1), 'k*');
plot(bneon_Underdash_bumper(2,1), bneon_Underdash_bumper(1,1), 'b^');
plot(bneon_Underdash_Roof(2,1), bneon_Underdash_Roof(1,1), 'k^');
text(-58, -6, sprintf('x = Dashboard, + = Gearbox'));
text(-58, -7, sprintf('* = Domelight, ^ = Underdash'));
text(-58, -8, sprintf('blue -> rx at bumper, black -> rx at roof'));
xlabel('Intercept');
```

```
ylabel('Slope');
title('Slope vs Intercept of Pathloss vs Log Distance, Car = Neon Sedan');
pause;
close all;
```

Exhibit 6. Tables of Slopes and Intercepts in Pathloss vs. Distances Plots for Each Transmitter Position, Receiver Height, Angle, and Vehicle

RX at Bumper Height, Car = Neon

Angles (Degrees)	TX at Dashboard		TX at Gearbox		TX at Dome Light		TX at Under Dash	
	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept
0	-16.594	-58.879	-4.956	-69.621	0.449	-64.348	-16.594	-58.879
22.5	-21.950	-52.776	-15.199	-62.745	-12.431	-58.728	-8.732	-70.210
45	-13.701	-57.060	-5.336	-68.637	-22.369	-50.461	-20.526	-56.563
67.5	-13.527	-57.430	-5.851	-64.209	-4.338	-61.706	-18.814	-60.353
90	-28.994	-47.442	-11.695	-62.488	-9.157	-58.867	-13.060	-64.383

RX at Roof Height, Car = Neon

Angles (Degrees)	TX at Dashboard		TX at Gearbox		TX at Dome Light		TX at Under Dash	
	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept
0	-35.881	-34.702	-16.437	-54.389	0.713	-64.050	-26.563	-45.557
22.5	-32.130	-41.706	-15.926	-60.377	-15.475	-53.356	-18.783	-55.419
45	-31.145	-40.107	-16.573	-55.668	-19.877	-49.081	-21.288	-49.273
67.5	-24.688	-46.218	-21.317	-51.766	-11.615	-56.166	-22.626	-51.751
90	-27.792	-47.606	-21.842	-51.483	-21.569	-50.548	-24.042	-53.634

RX at Bumper Height, Car = Rav4

Angles (Degrees)	TX at Dashboard		TX at Gearbox		TX at Dome Light		TX at Under Dash	
	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept
0	-0.990	-68.146	-21.311	-51.190	-2.704	-64.135	-0.990	-68.146
22.5	-1.985	-67.054	-3.615	-66.869	-9.291	-59.774	-9.213	-63.789
45	-8.281	-60.690	-13.479	-55.881	-7.300	-61.183	-2.461	-62.897
67.5	-7.625	-61.822	-9.567	-57.516	-7.409	-58.962	-13.265	-51.893
90	-3.859	-65.332	-9.826	-55.828	-10.048	-59.922	-12.893	-56.634

RX at Roof Height, Car = Rav4

Angles (Degrees)	TX at Dashboard		TX at Gearbox		TX at Dome Light		TX at Under Dash	
	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept
0	-21.313	-46.647	-24.965	-39.252	-14.047	-55.903	-31.520	-43.680
22.5	-17.706	-51.650	-18.488	-48.788	-27.561	-43.882	-23.506	-45.292
45	-22.205	-42.318	-24.227	-45.094	-10.183	-56.890	-22.603	-45.581
67.5	-25.588	-44.033	-27.463	-40.518	-19.537	-49.756	-21.543	-49.497
90	-26.598	-43.095	-24.554	-43.285	-20.089	-51.833	-15.654	-55.376

RX at Bumper Height, Car = Sundance

Angles (Degrees)	TX at Dashboard		TX at Gearbox		TX at Dome Light		TX at Under Dash	
	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept
0	-1.215	-71.623	-9.129	-65.581	-16.535	-58.485	-1.215	-71.623
22.5	-12.547	-62.446	-10.242	-67.007	-5.158	-64.162	-12.379	-60.918
45	-14.025	-60.924	-8.379	-65.678	-12.951	-58.415	-9.809	-57.878
67.5	-6.806	-65.763	-12.176	-59.952	-12.664	-57.539	-9.980	-57.783
90	-10.822	-63.808	-12.137	-61.184	-14.856	-56.233	-21.018	-52.935

RX at Roof Height, Car = Sundance

Angles (Degrees)	TX at Dashboard		TX at Gearbox		TX at Dome Light		TX at Under Dash	
	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept
0	-5.520	-67.188	-23.959	-51.180	-14.073	-57.641	-27.294	-47.811
22.5	-10.595	-61.905	-16.178	-55.126	-9.840	-56.124	-26.765	-47.295
45	-25.757	-49.176	-18.733	-53.539	-9.762	-59.348	-24.631	-47.206
67.5	-19.964	-54.028	-17.870	-52.838	-16.846	-55.311	-23.432	-46.963
90	-18.750	-58.638	-19.634	-51.403	-15.117	-54.250	-16.342	-55.392

Exhibit 7. Table of Slopes and Intercepts in Pathloss vs. Distances Plots for Each Transmitter Position and Receiver Height (Neon)

RX Heights	TX at Dashboard		TX at Gearbox		TX at Dome Light		TX at Under Dash	
	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept
Bumper	-21.329	-52.659	-10.388	-63.983	-7.271	-60.666	-16.520	-61.546
Roof	-26.477	-45.384	-22.614	-51.175	-15.080	-53.272	-21.369	-52.197

Exhibit 8. Table of Slopes and Intercepts in Pathloss vs. Distances Plots for Each Transmitter Position and Receiver Height (Rav4)

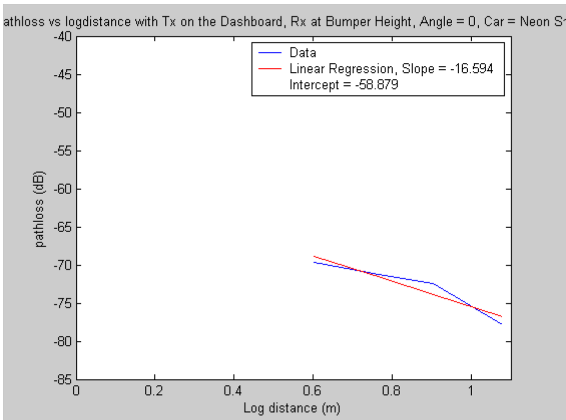
RX Heights	TX at Dashboard		TX at Gearbox		TX at Dome Light		TX at Under Dash	
	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept
Bumper	-5.619	-63.630	-12.584	-56.484	-7.058	-61.038	-15.229	-54.640
Roof	-25.497	-43.069	-24.741	-42.661	-19.246	-50.778	-19.176	-51.076

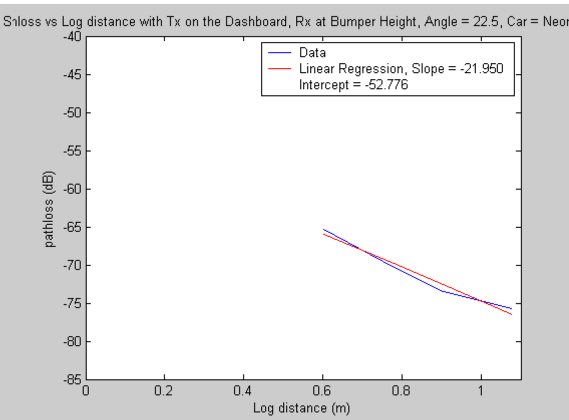
Exhibit 9. Table of Slopes and Intercepts in Pathloss vs. Distances Plots for Each Transmitter Position and Receiver Height (Sundance)

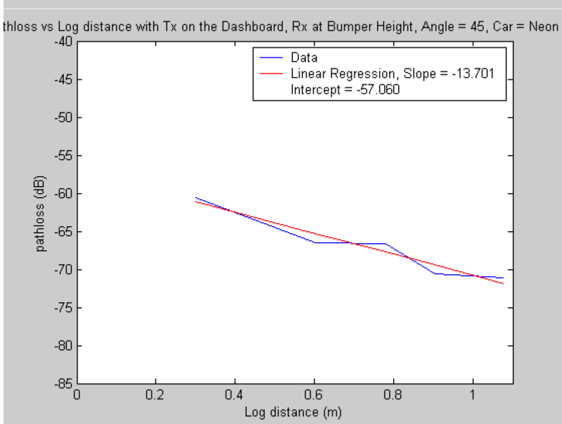
RX Heights	TX at Dashboard		TX at Gearbox		TX at Dome Light		TX at Under Dash	
	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept
Bumper	-8.858	-64.998	-13.945	-60.809	-13.147	-58.374	-16.194	-56.073
Roof	-18.855	-55.669	-19.810	-52.316	-14.620	-55.240	-21.873	-50.452

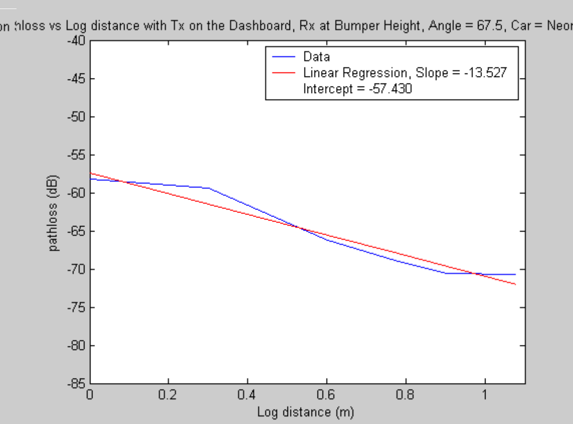
Exhibit 10. All Reduced Data Plots

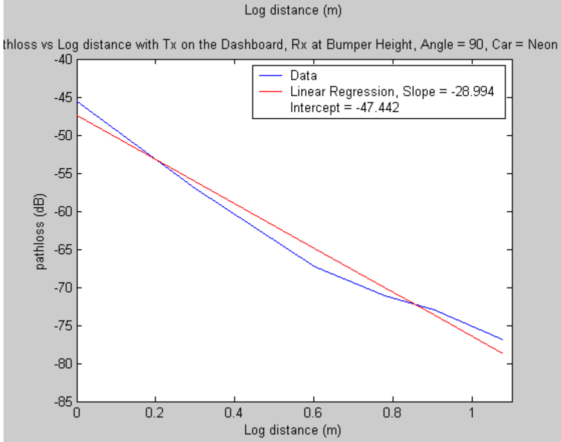
Neon

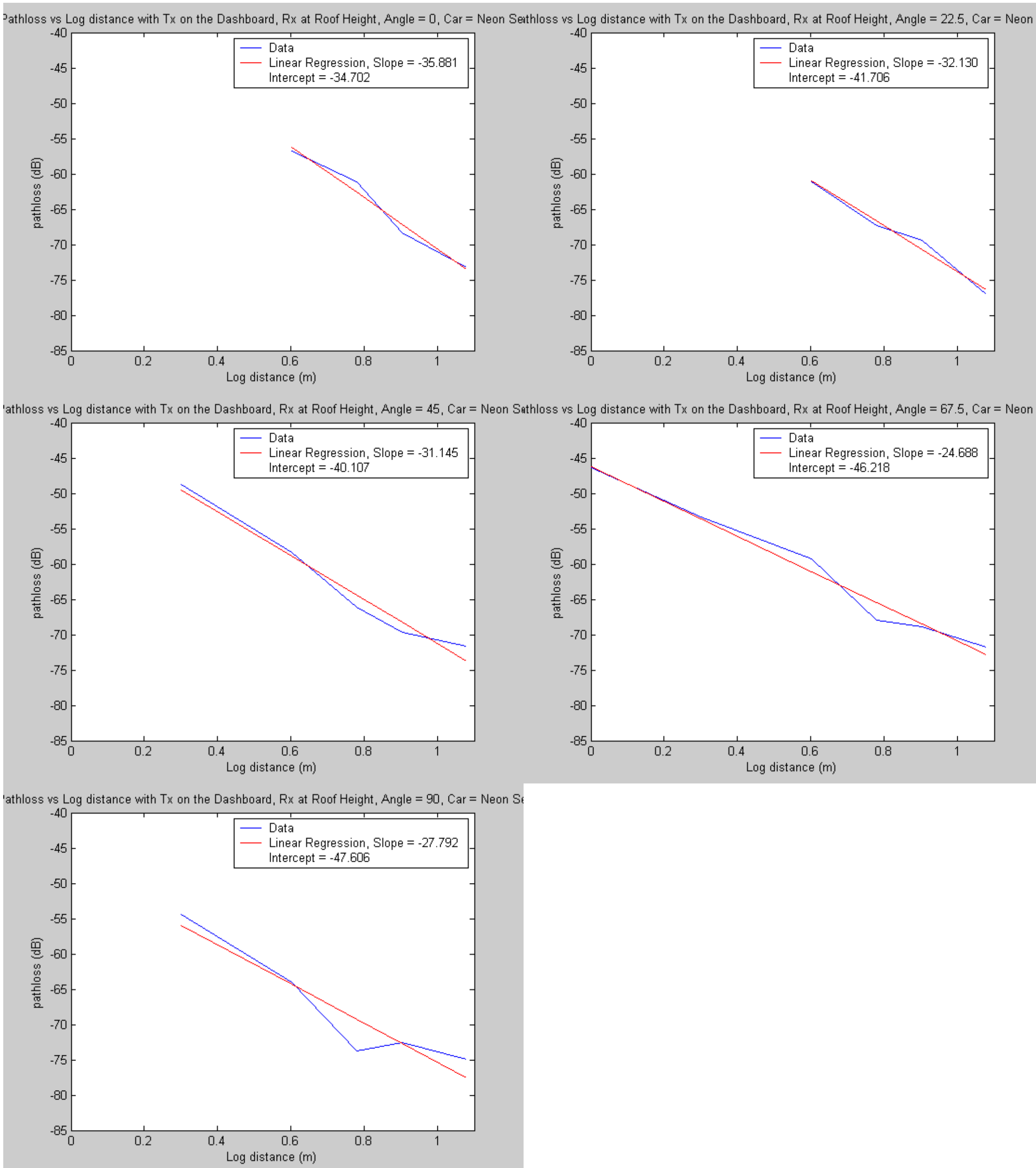


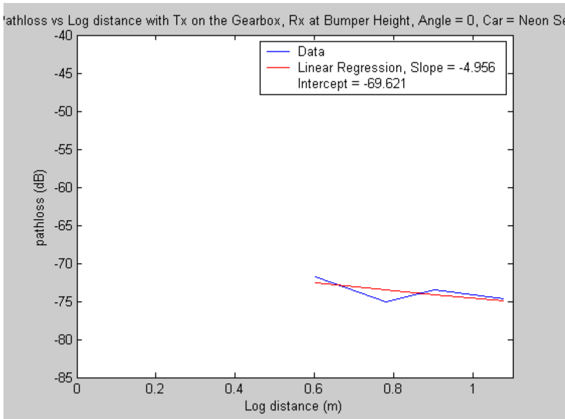


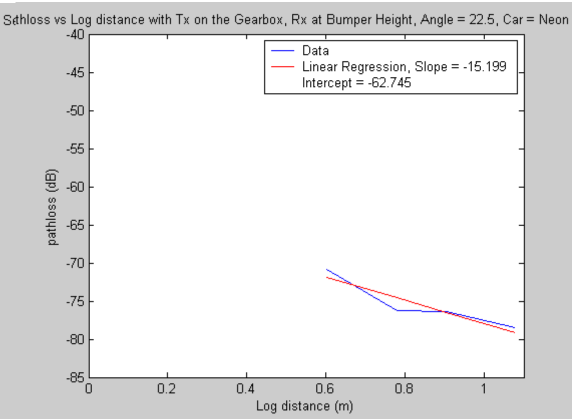


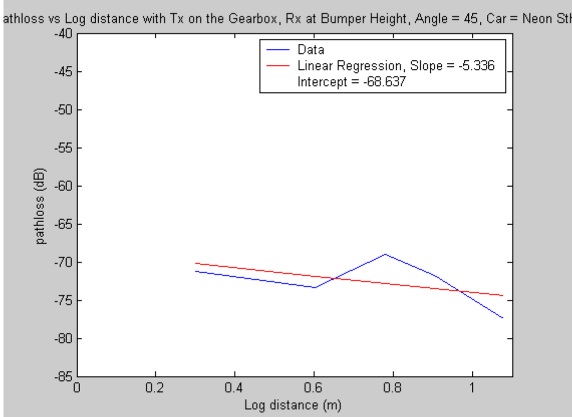


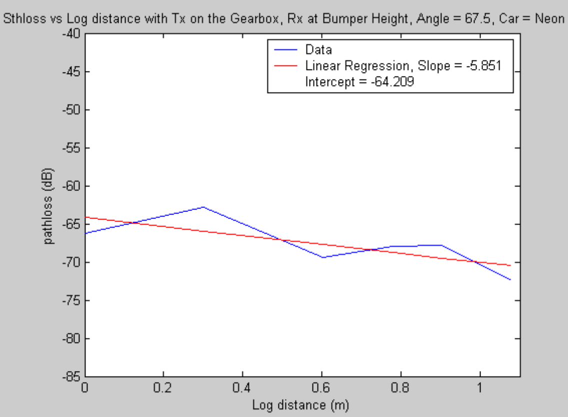


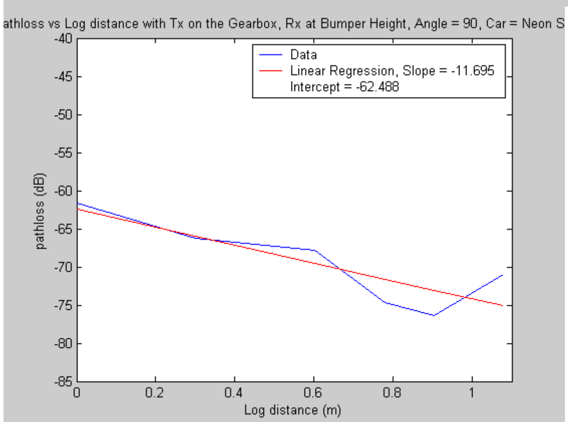

Pathloss vs Log distance with Tx on the Dashboard, Rx at Roof Height, Angle = 0, Car = Neon Se
Data
Linear Regression, Slope = -35.881
Intercept = -34.702
Pathloss vs Log distance with Tx on the Dashboard, Rx at Roof Height, Angle = 22.5, Car = Neon S
Data
Linear Regression, Slope = -32.130
Intercept = -41.706
Pathloss vs Log distance with Tx on the Dashboard, Rx at Roof Height, Angle = 45, Car = Neon Se
Data
Linear Regression, Slope = -31.145
Intercept = -40.107
Pathloss vs Log distance with Tx on the Dashboard, Rx at Roof Height, Angle = 67.5, Car = Neon S
Data
Linear Regression, Slope = -24.688
Intercept = -46.218
Pathloss vs Log distance with Tx on the Dashboard, Rx at Roof Height, Angle = 90, Car = Neon Se
Data
Linear Regression, Slope = -27.792
Intercept = -47.606
pathloss (dB)
Log distance (m)

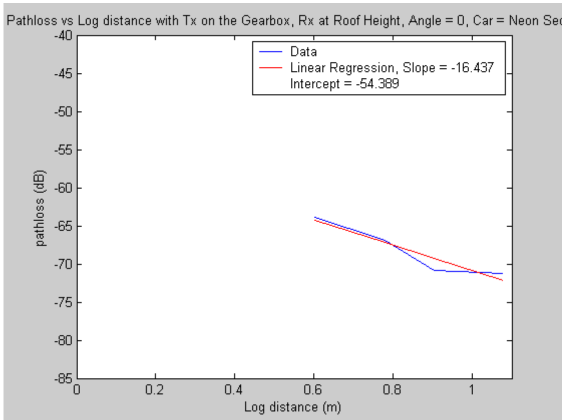

athloss vs Log distance with Tx on the Gearbox, Rx at Bumper Height, Angle = 0, Car = Neon S
Data
Linear Regression, Slope = -4.956
Intercept = -69.621
pathloss (dB)
Log distance (m)

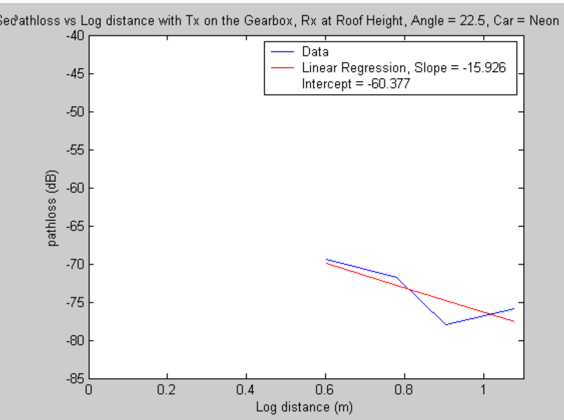

thloss vs Log distance with Tx on the Gearbox, Rx at Bumper Height, Angle = 22.5, Car = Neon S
Data
Linear Regression, Slope = -15.199
Intercept = -62.745
pathloss (dB)
Log distance (m)

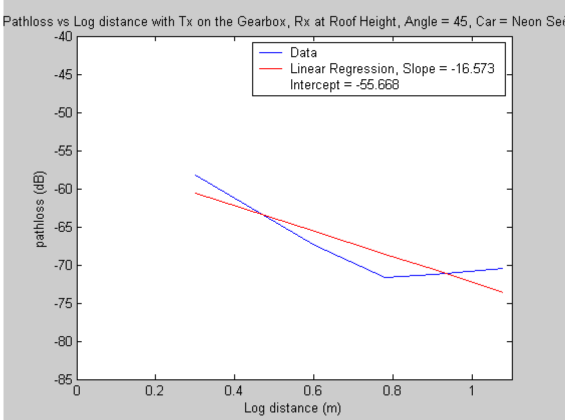

athloss vs Log distance with Tx on the Gearbox, Rx at Bumper Height, Angle = 45, Car = Neon S
Data
Linear Regression, Slope = -5.336
Intercept = -68.637
pathloss (dB)
Log distance (m)

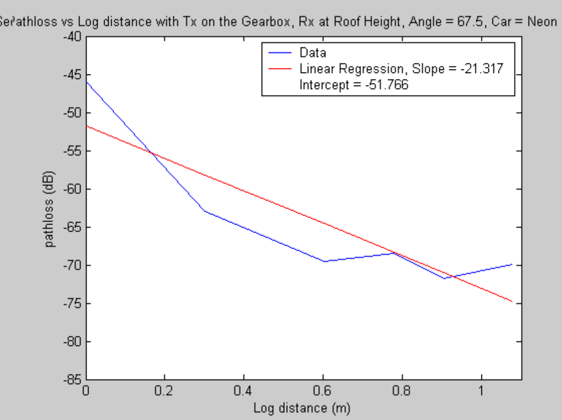

thloss vs Log distance with Tx on the Gearbox, Rx at Bumper Height, Angle = 67.5, Car = Neon S
Data
Linear Regression, Slope = -5.851
Intercept = -64.209
pathloss (dB)
Log distance (m)

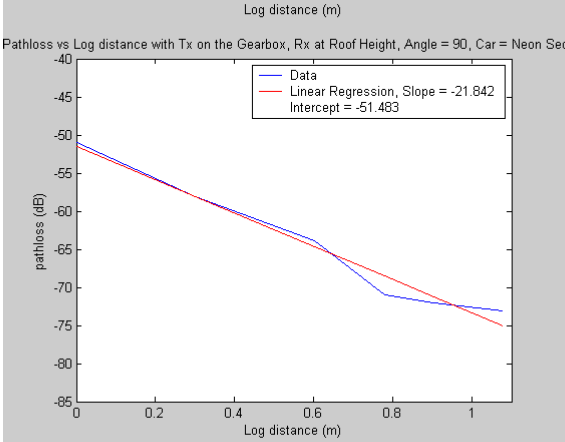

athloss vs Log distance with Tx on the Gearbox, Rx at Bumper Height, Angle = 90, Car = Neon S
Data
Linear Regression, Slope = -11.695
Intercept = -62.488
pathloss (dB)
Log distance (m)

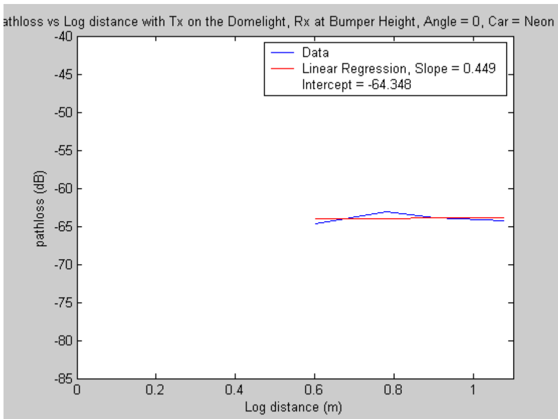

Pathloss vs Log distance with Tx on the Gearbox, Rx at Roof Height, Angle = 0, Car = Neon Se
Data
Linear Regression, Slope = -16.437
Intercept = -54.389
pathloss (dB)
Log distance (m)

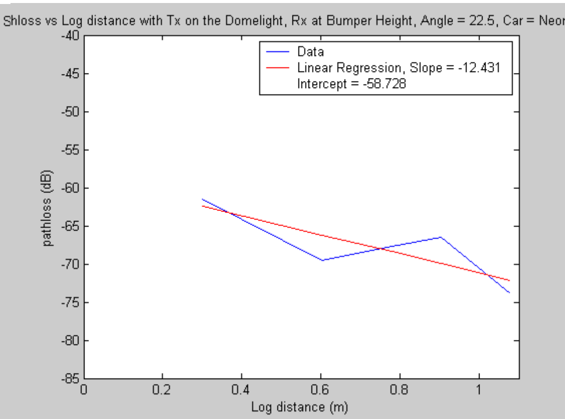

athloss vs Log distance with Tx on the Gearbox, Rx at Roof Height, Angle = 22.5, Car = Neon Se
Data
Linear Regression, Slope = -15.926
Intercept = -60.377
pathloss (dB)
Log distance (m)

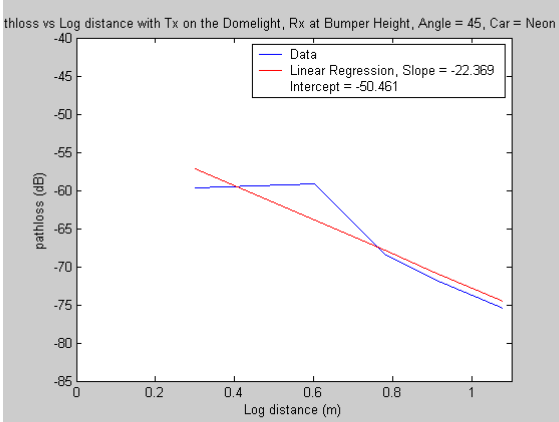

Pathloss vs Log distance with Tx on the Gearbox, Rx at Roof Height, Angle = 45, Car = Neon Se
Data
Linear Regression, Slope = -16.573
Intercept = -55.668
pathloss (dB)
Log distance (m)

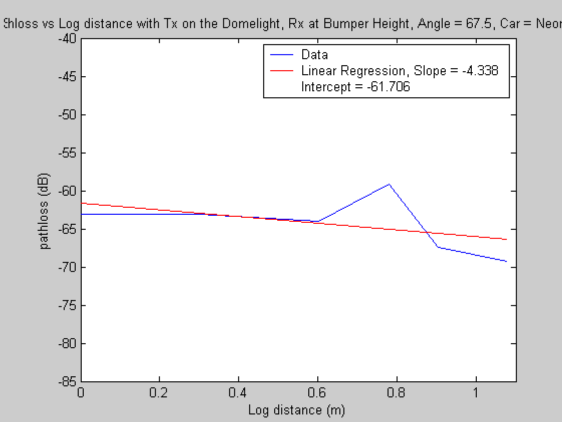

athloss vs Log distance with Tx on the Gearbox, Rx at Roof Height, Angle = 67.5, Car = Neon Se
Data
Linear Regression, Slope = -21.317
Intercept = -51.766
pathloss (dB)
Log distance (m)

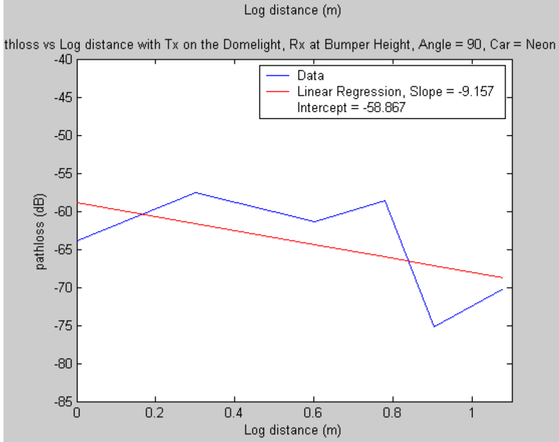

Pathloss vs Log distance with Tx on the Gearbox, Rx at Roof Height, Angle = 90, Car = Neon Se
Data
Linear Regression, Slope = -21.842
Intercept = -51.483
pathloss (dB)
Log distance (m)

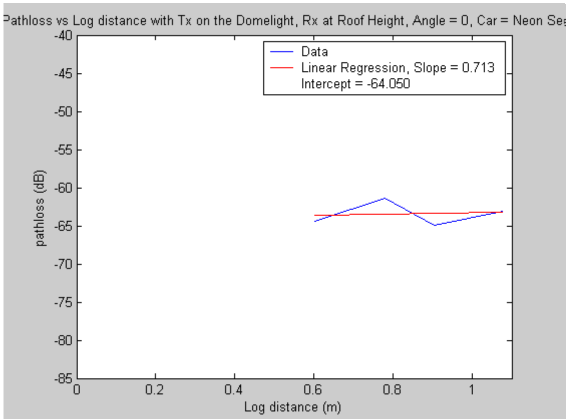

athloss vs Log distance with Tx on the Domelight, Rx at Bumper Height, Angle = 0, Car = Neon
Data
Linear Regression, Slope = 0.449
Intercept = -64.348
pathloss (dB)
Log distance (m)

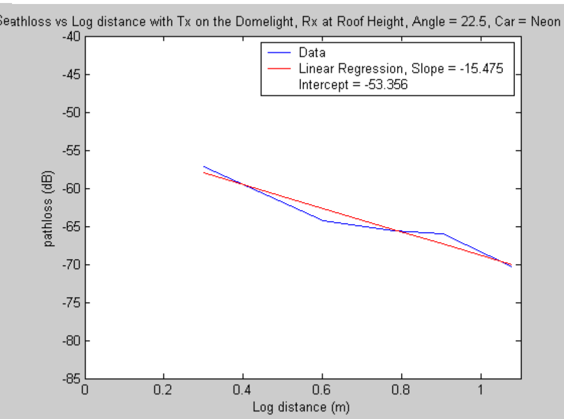

hloss vs Log distance with Tx on the Domelight, Rx at Bumper Height, Angle = 22.5, Car = Neon
Data
Linear Regression, Slope = -12.431
Intercept = -58.728
pathloss (dB)
Log distance (m)

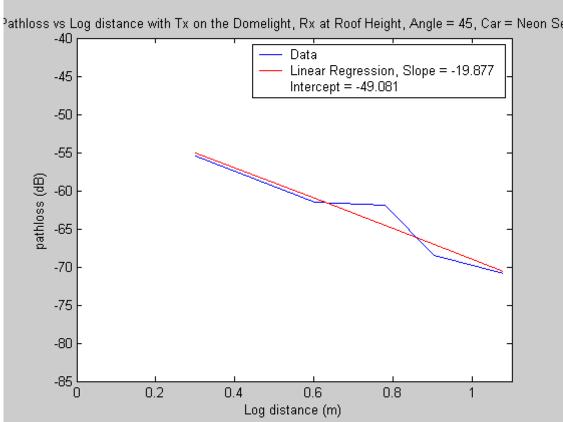

thloss vs Log distance with Tx on the Domelight, Rx at Bumper Height, Angle = 45, Car = Neon
Data
Linear Regression, Slope = -22.369
Intercept = -50.461
pathloss (dB)
Log distance (m)

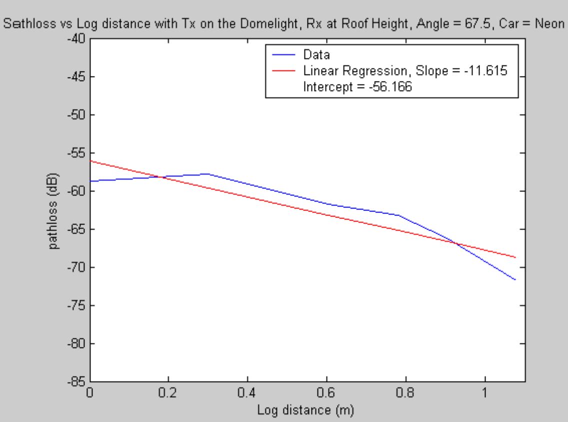

hloss vs Log distance with Tx on the Domelight, Rx at Bumper Height, Angle = 67.5, Car = Neon
Data
Linear Regression, Slope = -4.338
Intercept = -61.706
pathloss (dB)
Log distance (m)

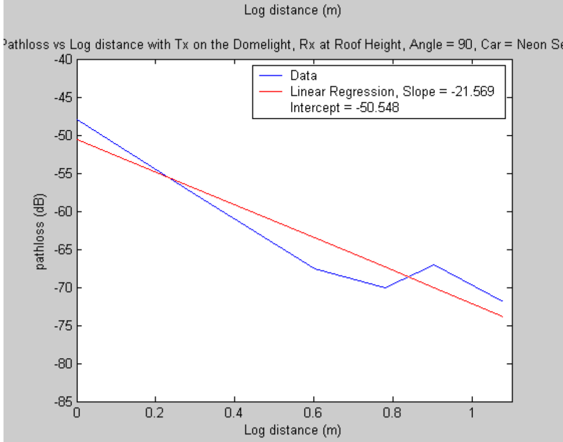

thloss vs Log distance with Tx on the Domelight, Rx at Bumper Height, Angle = 90, Car = Neon
Data
Linear Regression, Slope = -9.157
Intercept = -58.867
pathloss (dB)
Log distance (m)

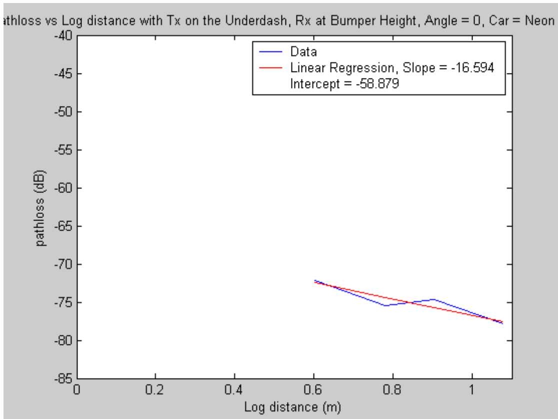

Pathloss vs Log distance with Tx on the Domelight, Rx at Roof Height, Angle = 0, Car = Neon Se
Data
Linear Regression, Slope = 0.713
Intercept = -64.050
pathloss (dB)
Log distance (m)

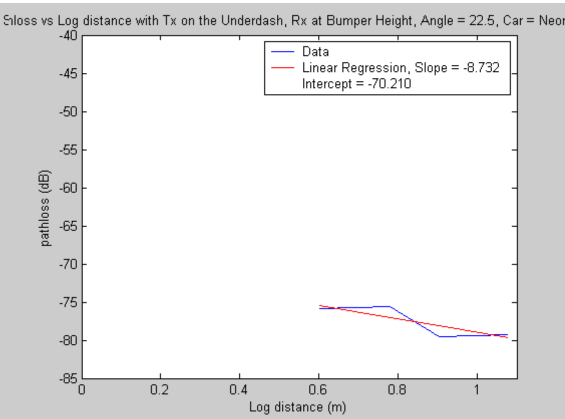

athloss vs Log distance with Tx on the Domelight, Rx at Roof Height, Angle = 22.5, Car = Neon S
Data
Linear Regression, Slope = -15.475
Intercept = -53.356
pathloss (dB)
Log distance (m)

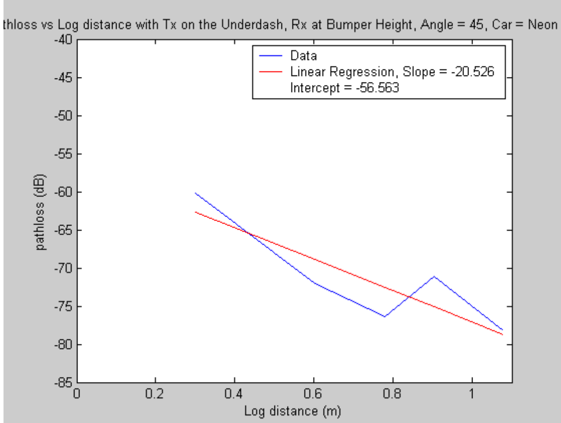

Pathloss vs Log distance with Tx on the Domelight, Rx at Roof Height, Angle = 45, Car = Neon Se
Data
Linear Regression, Slope = -19.877
Intercept = -49.081
pathloss (dB)
Log distance (m)

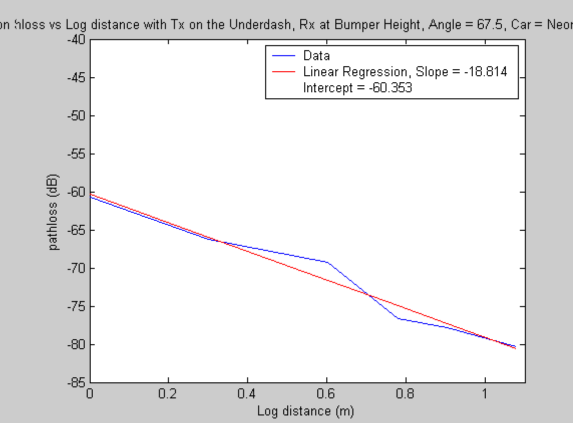

athloss vs Log distance with Tx on the Domelight, Rx at Roof Height, Angle = 67.5, Car = Neon S
Data
Linear Regression, Slope = -11.615
Intercept = -56.166
pathloss (dB)
Log distance (m)

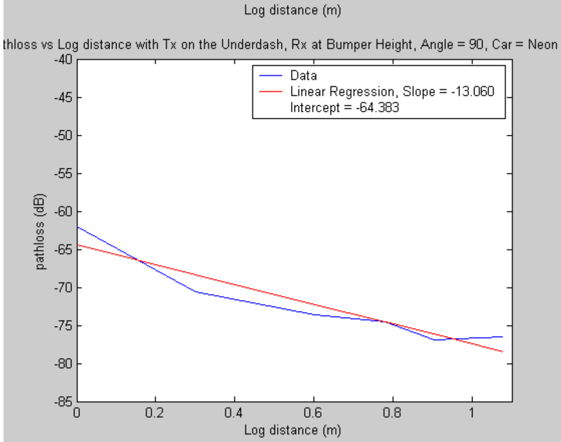

Pathloss vs Log distance with Tx on the Domelight, Rx at Roof Height, Angle = 90, Car = Neon Se
Data
Linear Regression, Slope = -21.569
Intercept = -50.548
pathloss (dB)
Log distance (m)

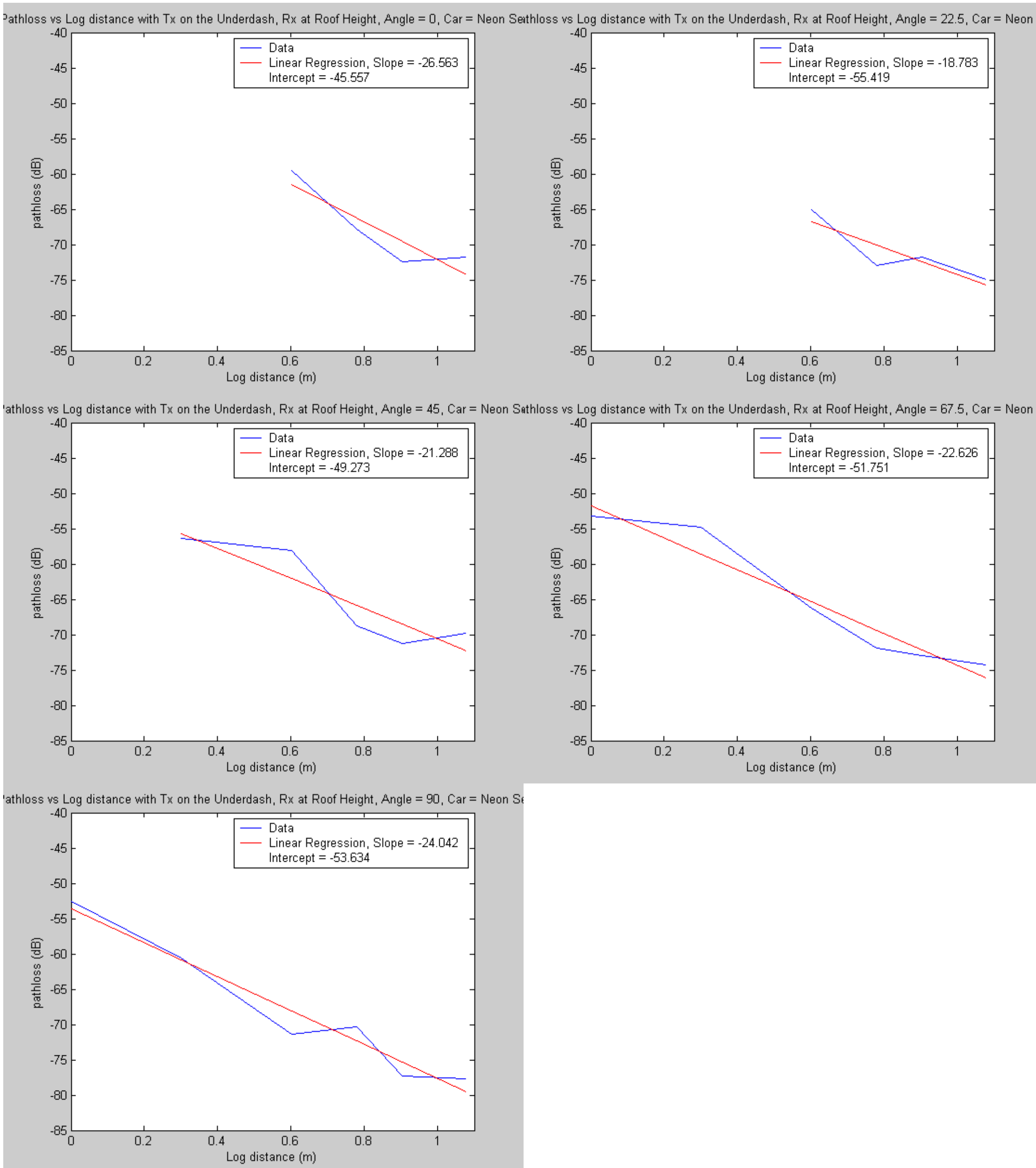

thloss vs Log distance with Tx on the Underdash, Rx at Bumper Height, Angle = 0, Car = Neon
Data
Linear Regression, Slope = -16.594
Intercept = -58.879
pathloss (dB)
Log distance (m)

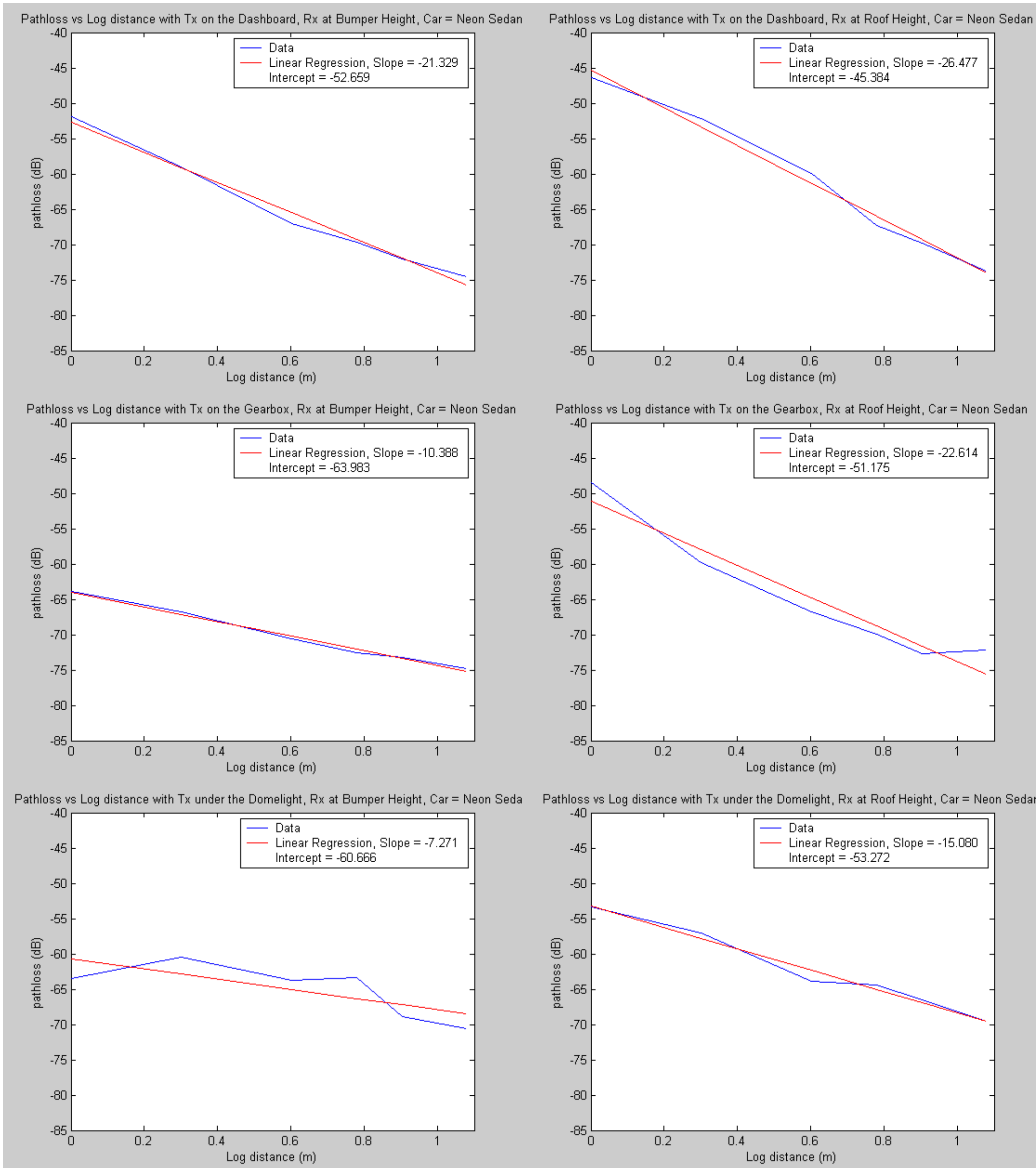

loss vs Log distance with Tx on the Underdash, Rx at Bumper Height, Angle = 22.5, Car = Neon
Data
Linear Regression, Slope = -8.732
Intercept = -70.210
pathloss (dB)
Log distance (m)


thloss vs Log distance with Tx on the Underdash, Rx at Bumper Height, Angle = 45, Car = Neon
Data
Linear Regression, Slope = -20.526
Intercept = -56.563
pathloss (dB)
Log distance (m)

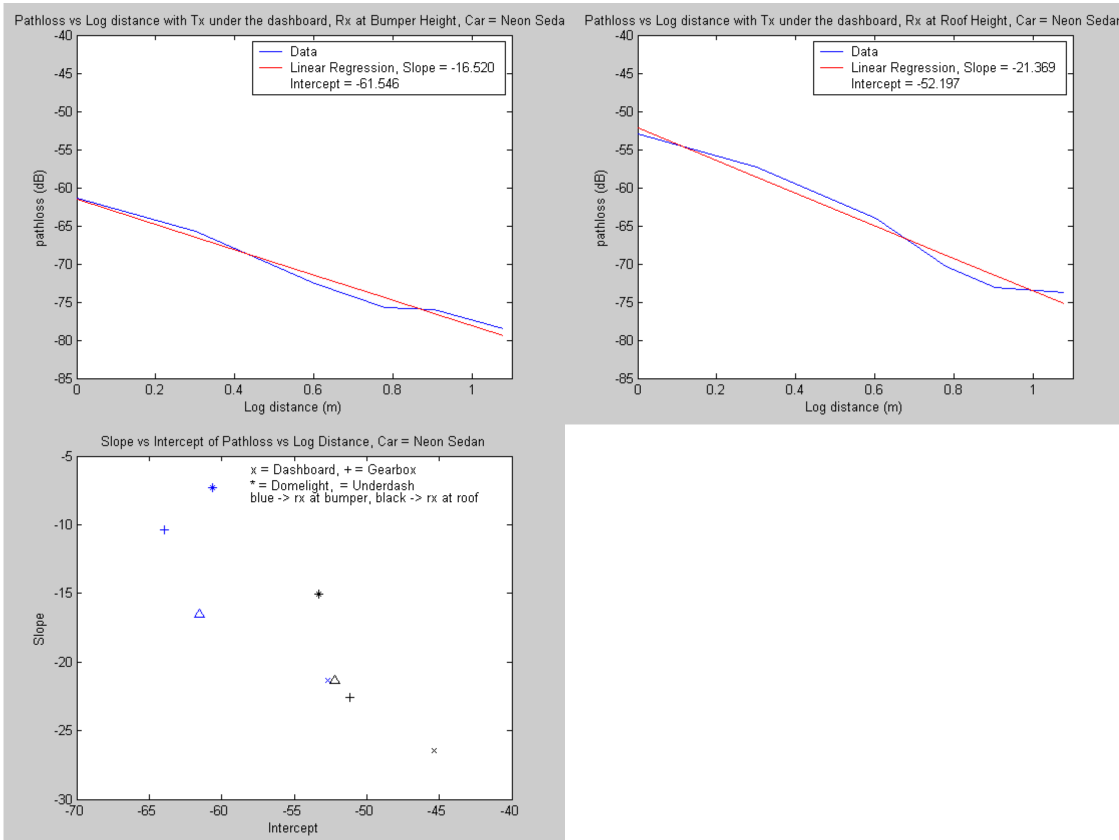

loss vs Log distance with Tx on the Underdash, Rx at Bumper Height, Angle = 67.5, Car = Neon
Data
Linear Regression, Slope = -18.814
Intercept = -60.353
pathloss (dB)
Log distance (m)


thloss vs Log distance with Tx on the Underdash, Rx at Bumper Height, Angle = 90, Car = Neon
Data
Linear Regression, Slope = -13.060
Intercept = -64.383
pathloss (dB)
Log distance (m)


athloss vs Log distance with Tx on the Underdash, Rx at Roof Height, Angle = 0, Car = Neon Se
Data
Linear Regression, Slope = -26.563
Intercept = -45.557
pathloss (dB)
Log distance (m)
thloss vs Log distance with Tx on the Underdash, Rx at Roof Height, Angle = 22.5, Car = Neon S
Data
Linear Regression, Slope = -18.783
Intercept = -55.419
pathloss (dB)
Log distance (m)
athloss vs Log distance with Tx on the Underdash, Rx at Roof Height, Angle = 45, Car = Neon Se
Data
Linear Regression, Slope = -21.288
Intercept = -49.273
pathloss (dB)
Log distance (m)
thloss vs Log distance with Tx on the Underdash, Rx at Roof Height, Angle = 67.5, Car = Neon S
Data
Linear Regression, Slope = -22.626
Intercept = -51.751
pathloss (dB)
Log distance (m)
athloss vs Log distance with Tx on the Underdash, Rx at Roof Height, Angle = 90, Car = Neon Se
Data
Linear Regression, Slope = -24.042
Intercept = -53.634
pathloss (dB)
Log distance (m)

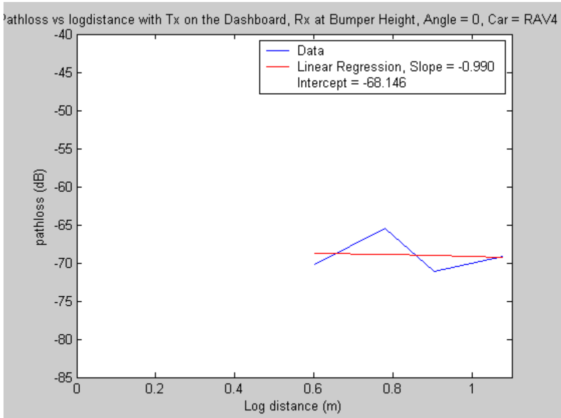


Pathloss vs Log distance with Tx on the Dashboard, Rx at Bumper Height, Car = Neon Sedan
Data
Linear Regression, Slope = -21.329
Intercept = -52.659
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Dashboard, Rx at Roof Height, Car = Neon Sedan
Data
Linear Regression, Slope = -26.477
Intercept = -45.384
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Gearbox, Rx at Bumper Height, Car = Neon Sedan
Data
Linear Regression, Slope = -10.388
Intercept = -63.983
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Gearbox, Rx at Roof Height, Car = Neon Sedan
Data
Linear Regression, Slope = -22.614
Intercept = -51.175
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx under the Domelight, Rx at Bumper Height, Car = Neon Seda
Data
Linear Regression, Slope = -7.271
Intercept = -60.666
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx under the Domelight, Rx at Roof Height, Car = Neon Sedan
Data
Linear Regression, Slope = -15.080
Intercept = -53.272
pathloss (dB)
Log distance (m)

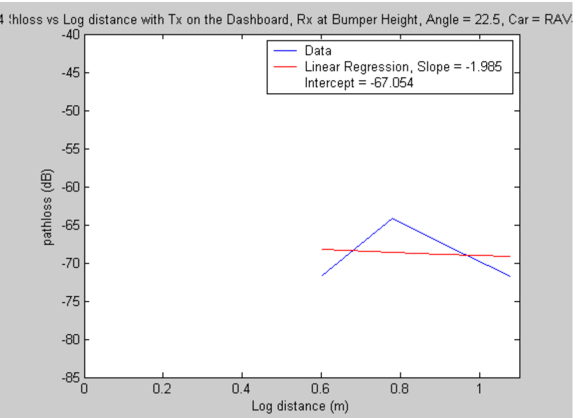


Pathloss vs Log distance with Tx under the dashboard, Rx at Bumper Height, Car = Neon Seda
Data
Linear Regression, Slope = -16.520
Intercept = -61.546
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx under the dashboard, Rx at Roof Height, Car = Neon Sedan
Data
Linear Regression, Slope = -21.369
Intercept = -52.197
pathloss (dB)
Log distance (m)
Slope vs Intercept of Pathloss vs Log Distance, Car = Neon Sedan
x = Dashboard, + = Gearbox
* = Domelight, = Underdash
blue -> rx at bumper, black -> rx at roof
Slope
Intercept

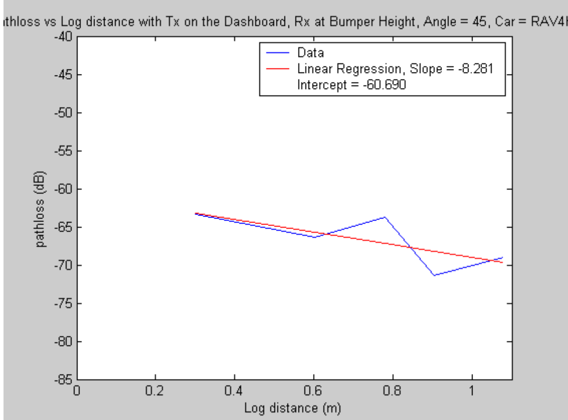
RAV4



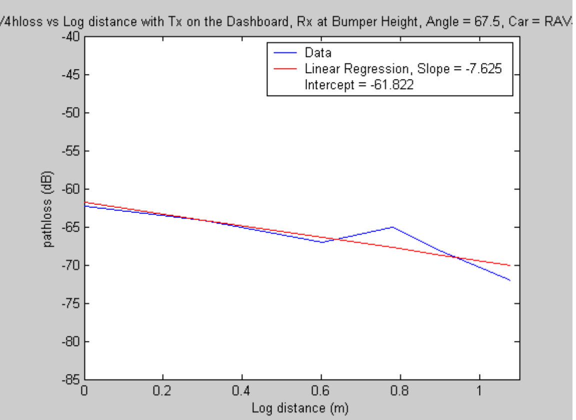
'athloss vs logdistance with Tx on the Dashboard, Rx at Bumper Height, Angle = 0, Car = RAV4
Data
Linear Regression, Slope = -0.990
Intercept = -68.146
pathloss (dB)
Log distance (m)



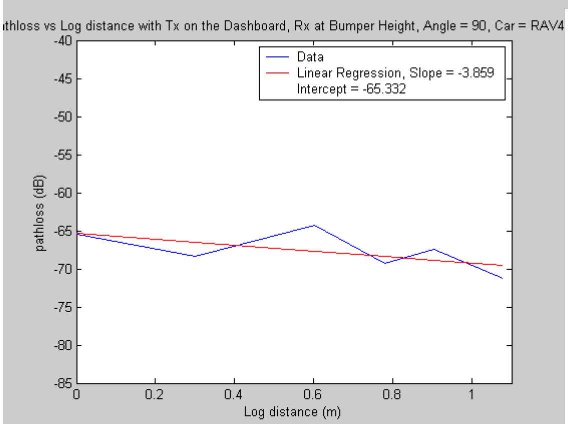
hloss vs Log distance with Tx on the Dashboard, Rx at Bumper Height, Angle = 22.5, Car = RAV
Data
Linear Regression, Slope = -1.985
Intercept = -67.054
pathloss (dB)
Log distance (m)



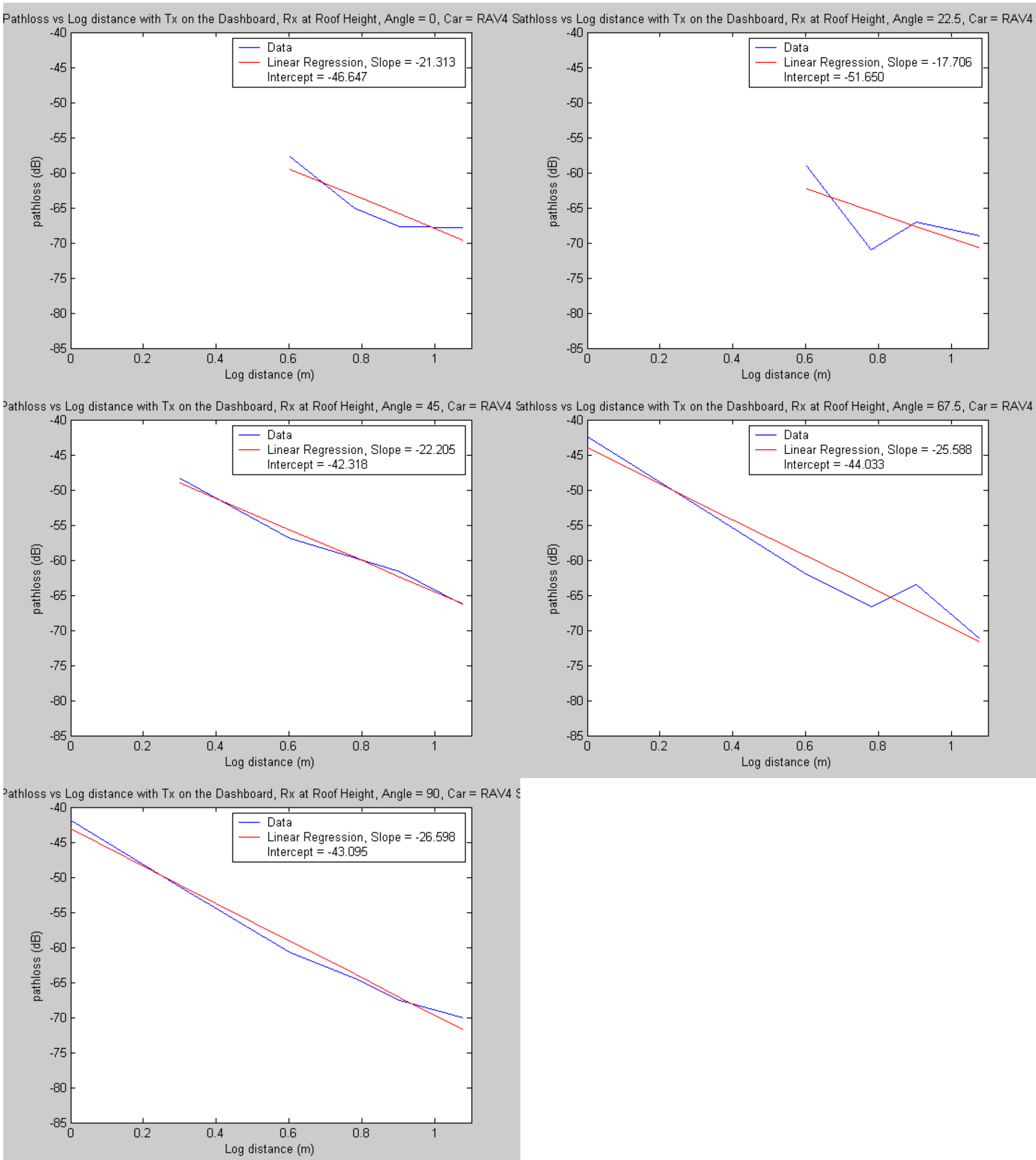
thloss vs Log distance with Tx on the Dashboard, Rx at Bumper Height, Angle = 45, Car = RAV4
Data
Linear Regression, Slope = -8.281
Intercept = -60.690
pathloss (dB)
Log distance (m)



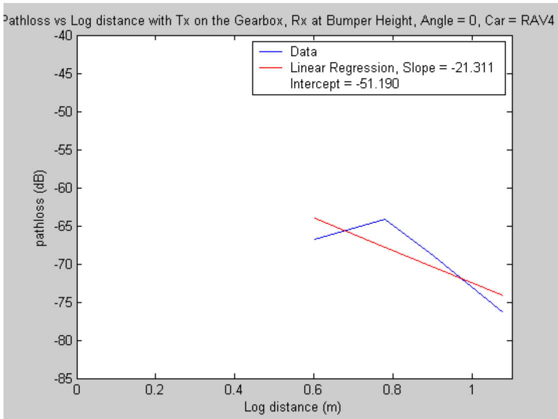
hloss vs Log distance with Tx on the Dashboard, Rx at Bumper Height, Angle = 67.5, Car = RAV
Data
Linear Regression, Slope = -7.625
Intercept = -61.822
pathloss (dB)
Log distance (m)

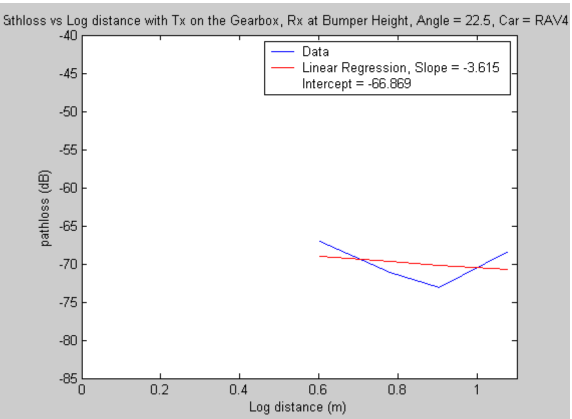


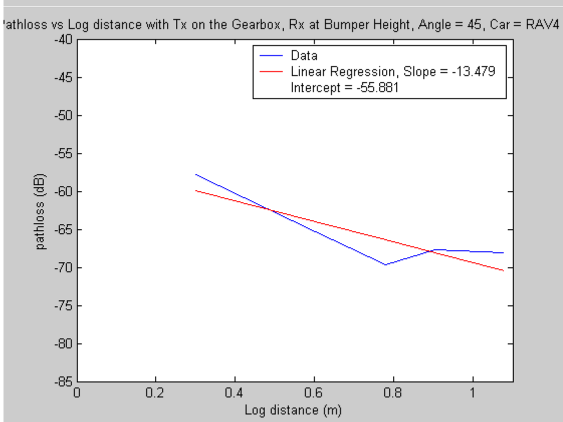
thloss vs Log distance with Tx on the Dashboard, Rx at Bumper Height, Angle = 90, Car = RAV4
Data
Linear Regression, Slope = -3.859
Intercept = -65.332
pathloss (dB)
Log distance (m)

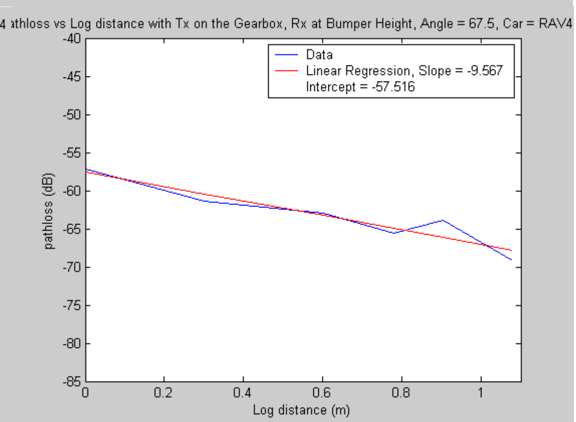


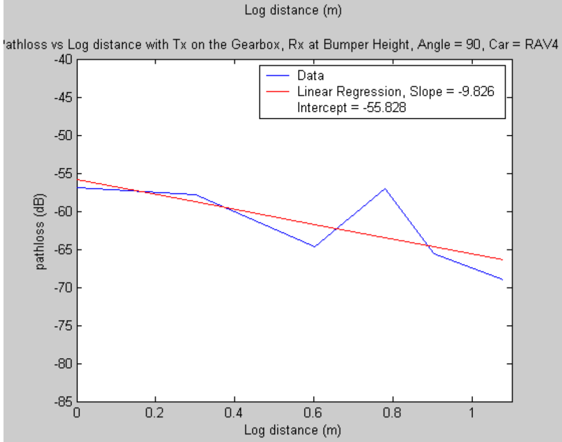
Pathloss vs Log distance with Tx on the Dashboard, Rx at Roof Height, Angle = 0, Car = RAV4
Data
Linear Regression, Slope = -21.313
Intercept = -46.647
pathloss (dB)
Log distance (m)
Sathloss vs Log distance with Tx on the Dashboard, Rx at Roof Height, Angle = 22.5, Car = RAV4
Data
Linear Regression, Slope = -17.706
Intercept = -51.650
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Dashboard, Rx at Roof Height, Angle = 45, Car = RAV4
Data
Linear Regression, Slope = -22.205
Intercept = -42.318
pathloss (dB)
Log distance (m)
Sathloss vs Log distance with Tx on the Dashboard, Rx at Roof Height, Angle = 67.5, Car = RAV4
Data
Linear Regression, Slope = -25.588
Intercept = -44.033
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Dashboard, Rx at Roof Height, Angle = 90, Car = RAV4
Data
Linear Regression, Slope = -26.598
Intercept = -43.095
pathloss (dB)
Log distance (m)

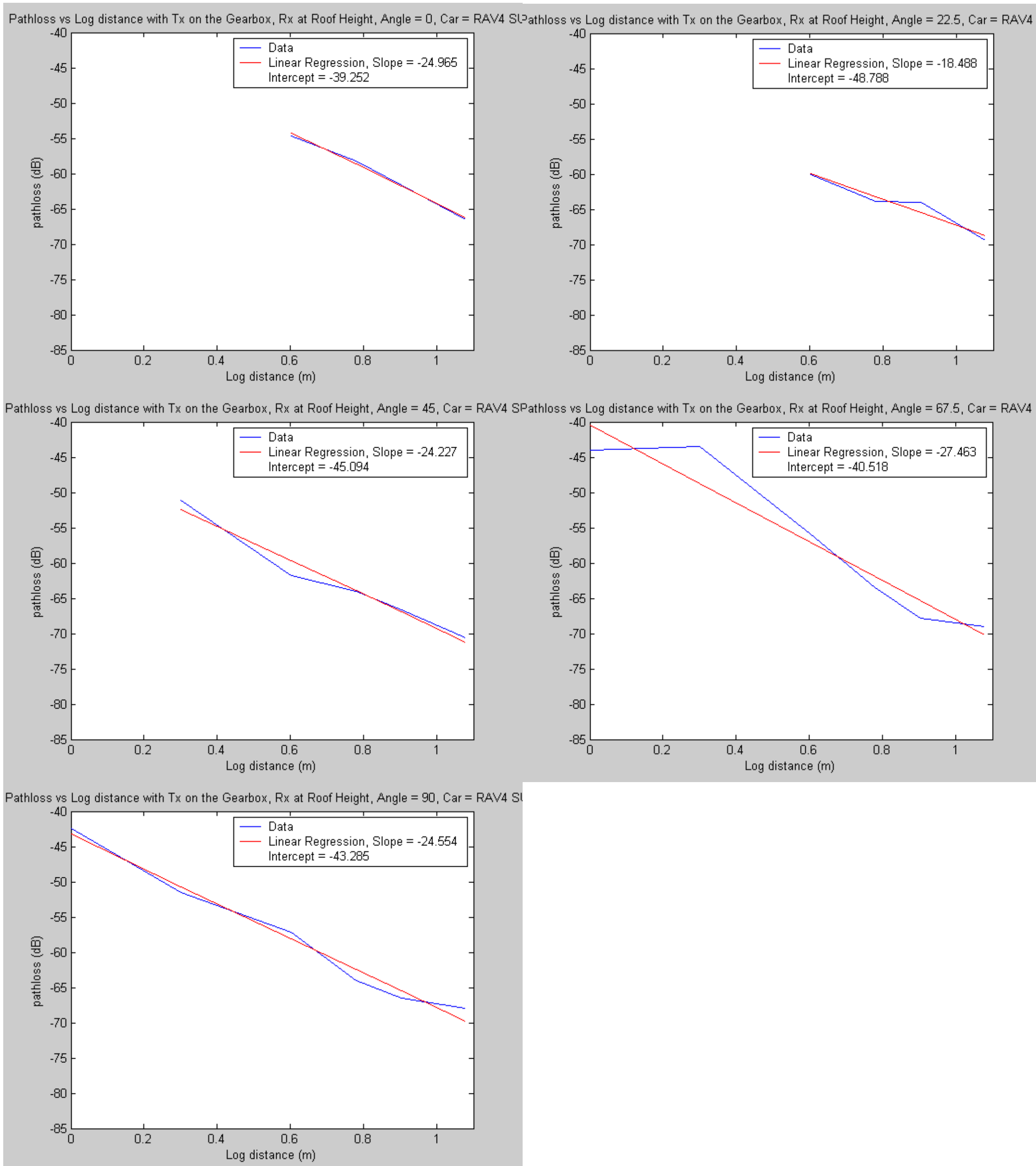

Pathloss vs Log distance with Tx on the Gearbox, Rx at Bumper Height, Angle = 0, Car = RAV4
Data
Linear Regression, Slope = -21.311
Intercept = -51.190
pathloss (dB)
Log distance (m)

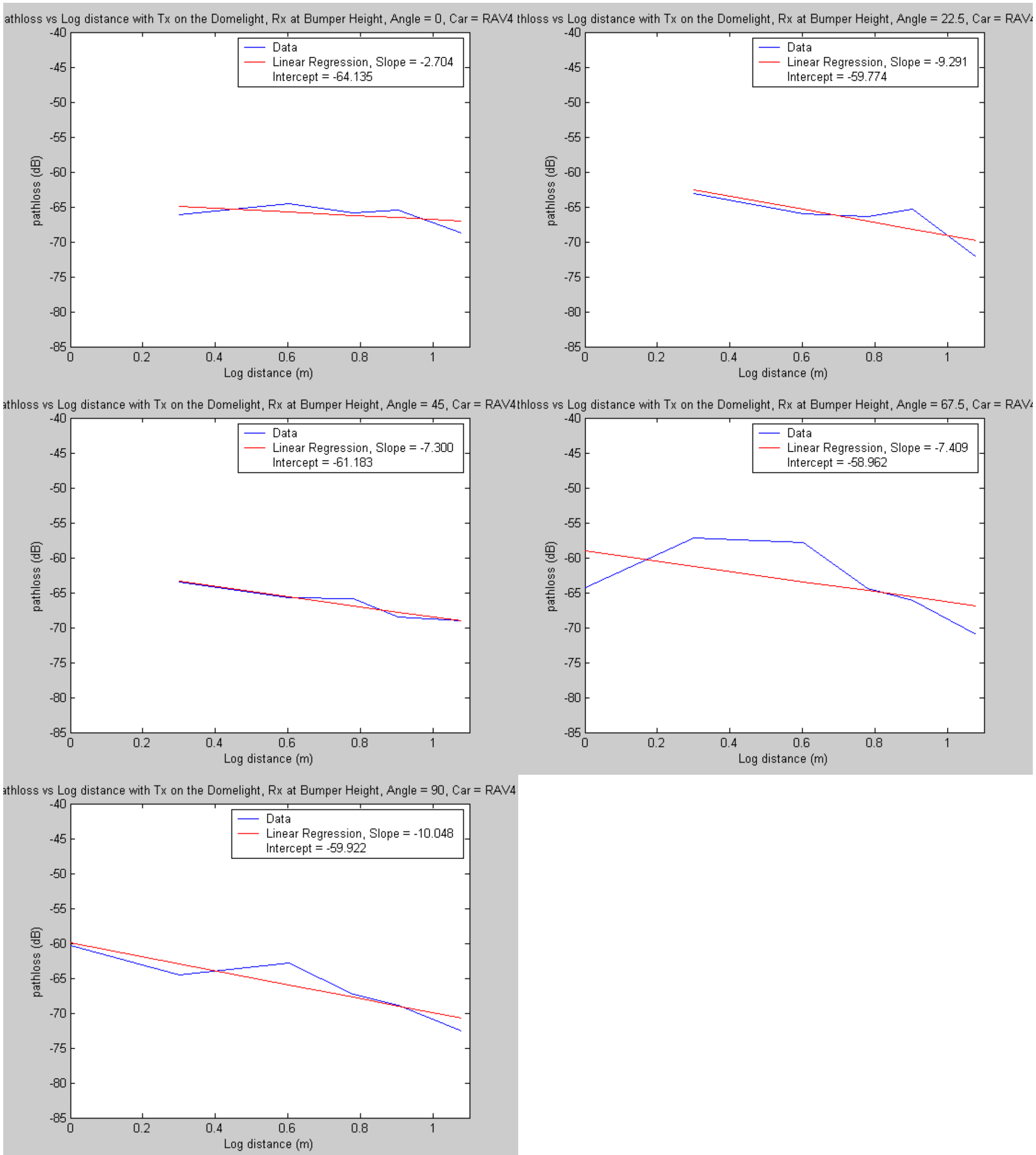

Pathloss vs Log distance with Tx on the Gearbox, Rx at Bumper Height, Angle = 22.5, Car = RAV4
Data
Linear Regression, Slope = -3.615
Intercept = -66.869
pathloss (dB)
Log distance (m)

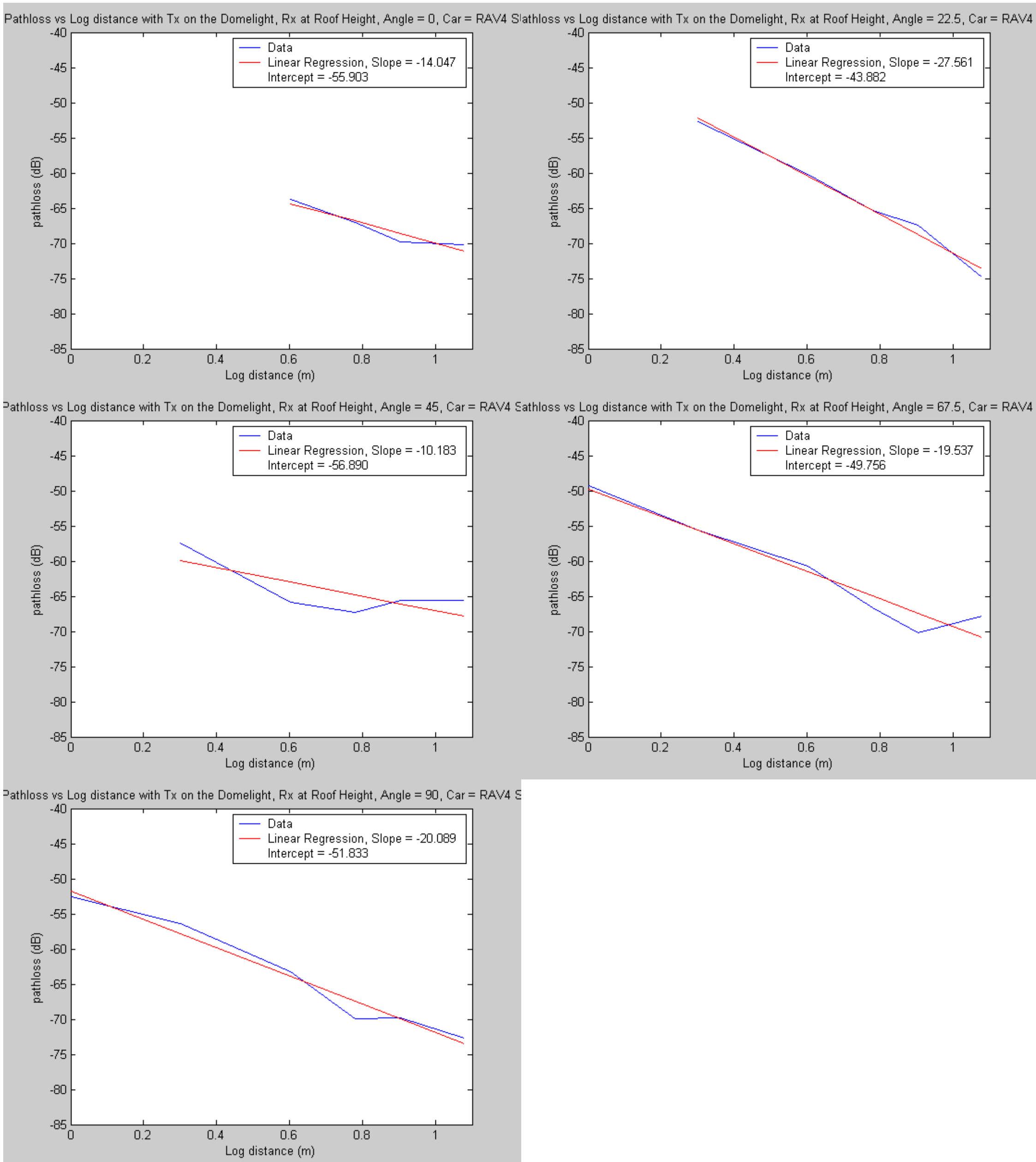

Pathloss vs Log distance with Tx on the Gearbox, Rx at Bumper Height, Angle = 45, Car = RAV4
Data
Linear Regression, Slope = -13.479
Intercept = -55.881
pathloss (dB)
Log distance (m)

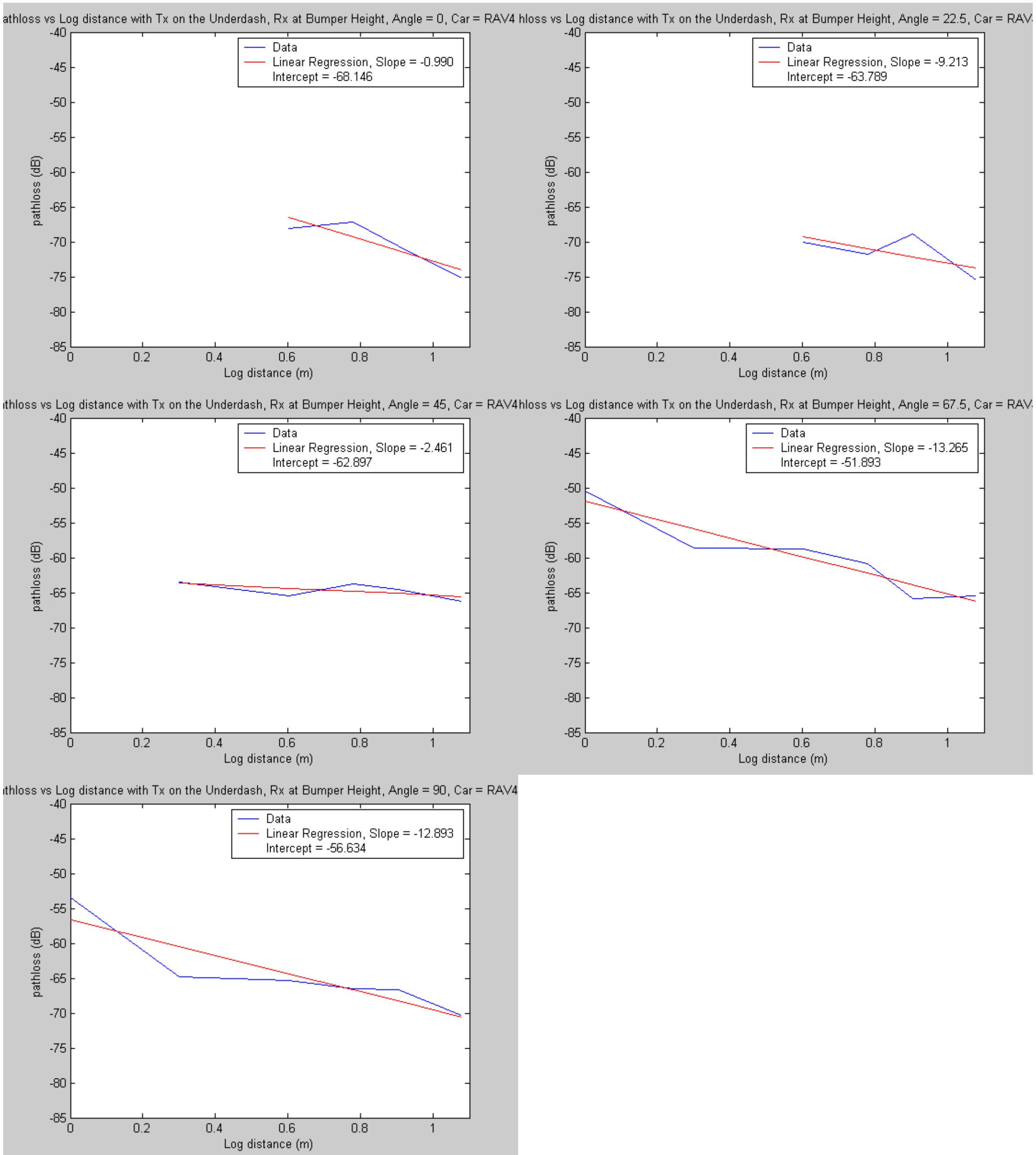

Pathloss vs Log distance with Tx on the Gearbox, Rx at Bumper Height, Angle = 67.5, Car = RAV4
Data
Linear Regression, Slope = -9.567
Intercept = -57.516
pathloss (dB)
Log distance (m)

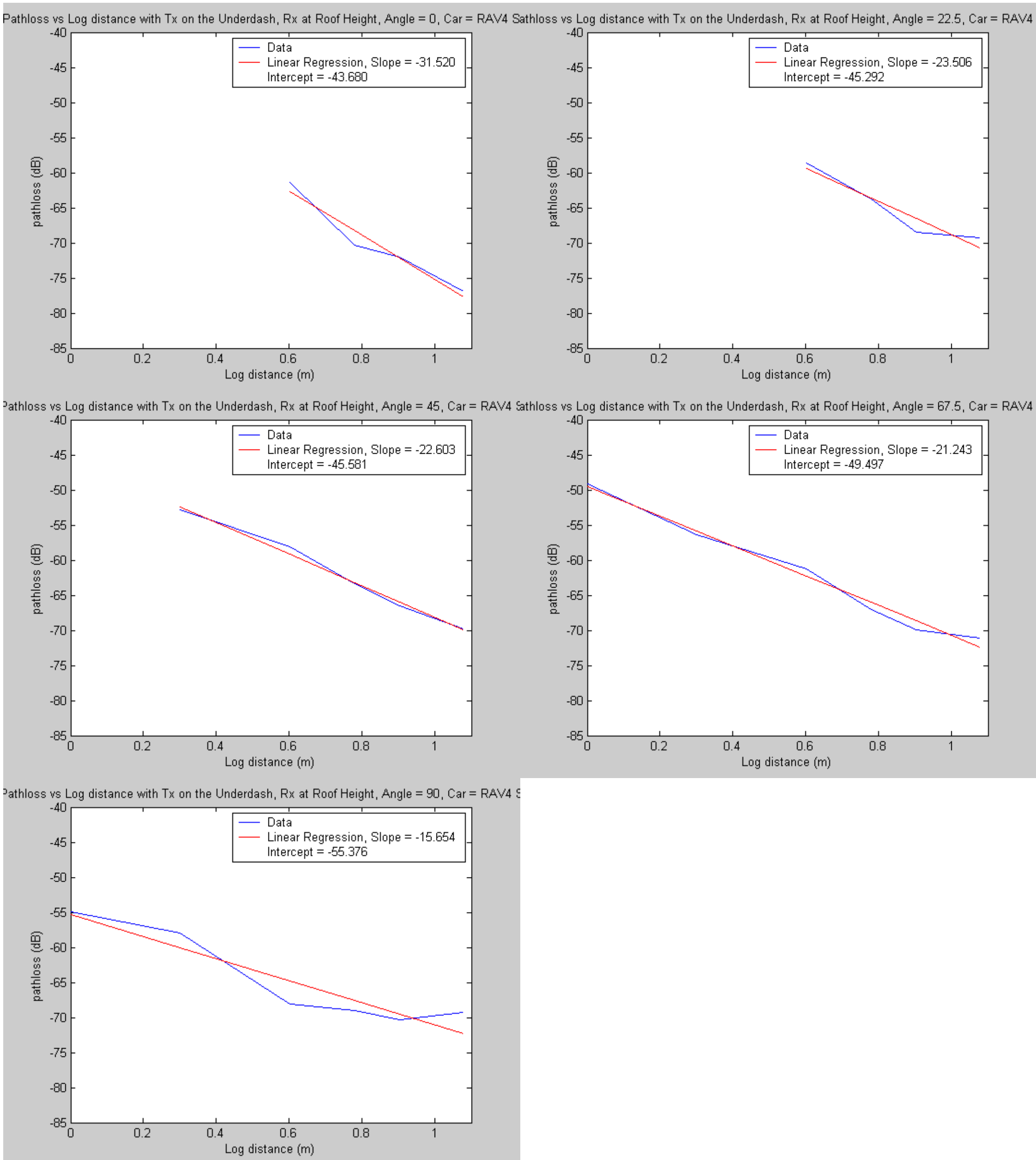

Pathloss vs Log distance with Tx on the Gearbox, Rx at Bumper Height, Angle = 90, Car = RAV4
Data
Linear Regression, Slope = -9.826
Intercept = -55.828
pathloss (dB)
Log distance (m)

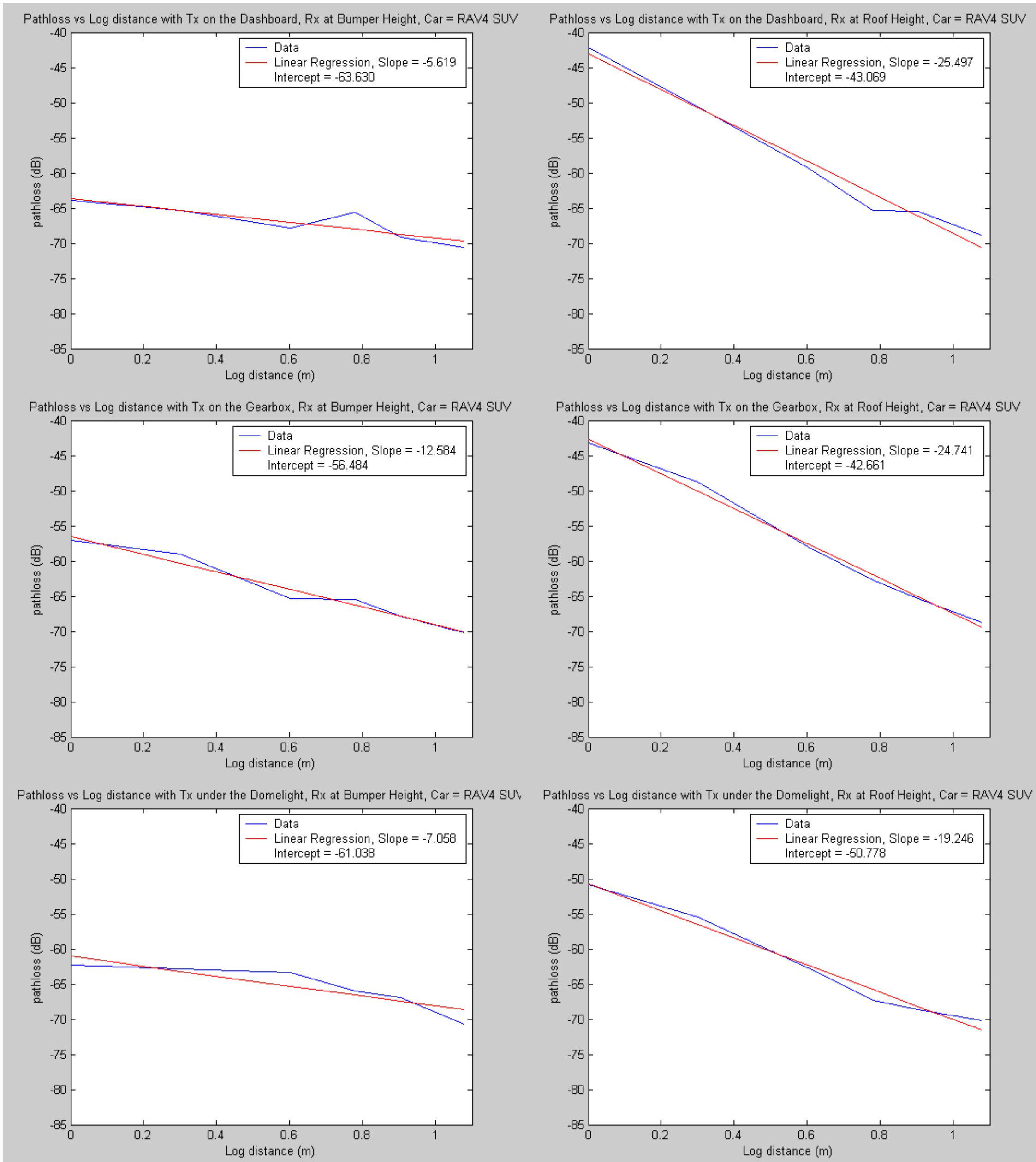

Pathloss vs Log distance with Tx on the Gearbox, Rx at Roof Height, Angle = 0, Car = RAV4 SU
Data
Linear Regression, Slope = -24.965
Intercept = -39.252
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Gearbox, Rx at Roof Height, Angle = 22.5, Car = RAV4 S
Data
Linear Regression, Slope = -18.488
Intercept = -48.788
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Gearbox, Rx at Roof Height, Angle = 45, Car = RAV4 SU
Data
Linear Regression, Slope = -24.227
Intercept = -45.094
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Gearbox, Rx at Roof Height, Angle = 67.5, Car = RAV4 S
Data
Linear Regression, Slope = -27.463
Intercept = -40.518
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Gearbox, Rx at Roof Height, Angle = 90, Car = RAV4 SU
Data
Linear Regression, Slope = -24.554
Intercept = -43.285
pathloss (dB)
Log distance (m)

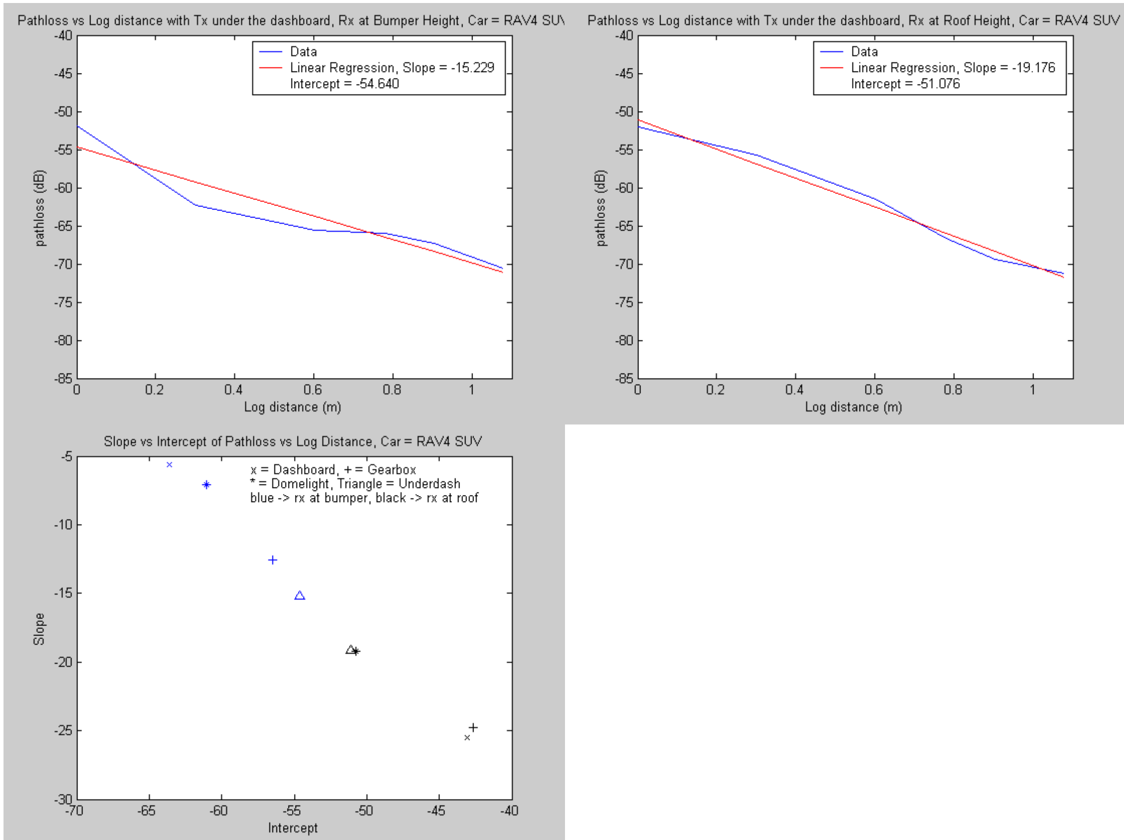

athloss vs Log distance with Tx on the Domelight, Rx at Bumper Height, Angle = 0, Car = RAV4
Data
Linear Regression, Slope = -2.704
Intercept = -64.135
thloss vs Log distance with Tx on the Domelight, Rx at Bumper Height, Angle = 22.5, Car = RAV
Data
Linear Regression, Slope = -9.291
Intercept = -59.774
athloss vs Log distance with Tx on the Domelight, Rx at Bumper Height, Angle = 45, Car = RAV4
Data
Linear Regression, Slope = -7.300
Intercept = -61.183
thloss vs Log distance with Tx on the Domelight, Rx at Bumper Height, Angle = 67.5, Car = RAV
Data
Linear Regression, Slope = -7.409
Intercept = -58.962
athloss vs Log distance with Tx on the Domelight, Rx at Bumper Height, Angle = 90, Car = RAV4
Data
Linear Regression, Slope = -10.048
Intercept = -59.922
pathloss (dB)
Log distance (m)


Pathloss vs Log distance with Tx on the Domelight, Rx at Roof Height, Angle = 0, Car = RAV4 S
Data
Linear Regression, Slope = -14.047
Intercept = -55.903
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Domelight, Rx at Roof Height, Angle = 22.5, Car = RAV4
Data
Linear Regression, Slope = -27.561
Intercept = -43.882
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Domelight, Rx at Roof Height, Angle = 45, Car = RAV4 S
Data
Linear Regression, Slope = -10.183
Intercept = -56.890
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Domelight, Rx at Roof Height, Angle = 67.5, Car = RAV4
Data
Linear Regression, Slope = -19.537
Intercept = -49.756
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Domelight, Rx at Roof Height, Angle = 90, Car = RAV4 S
Data
Linear Regression, Slope = -20.089
Intercept = -51.833
pathloss (dB)
Log distance (m)


athloss vs Log distance with Tx on the Underdash, Rx at Bumper Height, Angle = 0, Car = RAV4
Data
Linear Regression, Slope = -0.990
Intercept = -68.146
hloss vs Log distance with Tx on the Underdash, Rx at Bumper Height, Angle = 22.5, Car = RAV
Data
Linear Regression, Slope = -9.213
Intercept = -63.789
thloss vs Log distance with Tx on the Underdash, Rx at Bumper Height, Angle = 45, Car = RAV4
Data
Linear Regression, Slope = -2.461
Intercept = -62.897
hloss vs Log distance with Tx on the Underdash, Rx at Bumper Height, Angle = 67.5, Car = RAV
Data
Linear Regression, Slope = -13.265
Intercept = -51.893
thloss vs Log distance with Tx on the Underdash, Rx at Bumper Height, Angle = 90, Car = RAV4
Data
Linear Regression, Slope = -12.893
Intercept = -56.634
pathloss (dB)
Log distance (m)

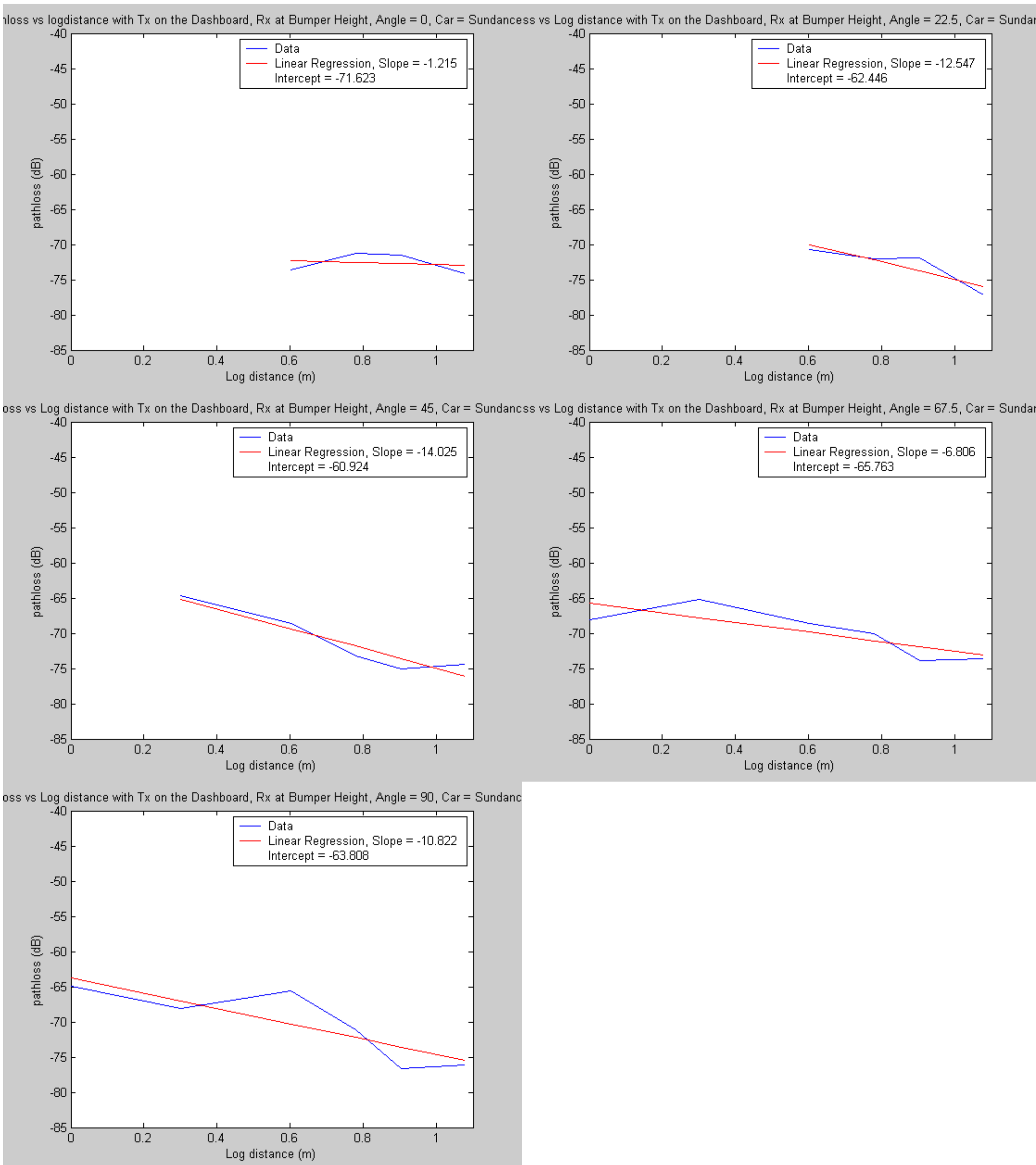

Pathloss vs Log distance with Tx on the Underdash, Rx at Roof Height, Angle = 0, Car = RAV4
Data
Linear Regression, Slope = -31.520
Intercept = -43.680
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Underdash, Rx at Roof Height, Angle = 22.5, Car = RAV4
Data
Linear Regression, Slope = -23.506
Intercept = -45.292
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Underdash, Rx at Roof Height, Angle = 45, Car = RAV4
Data
Linear Regression, Slope = -22.603
Intercept = -45.581
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Underdash, Rx at Roof Height, Angle = 67.5, Car = RAV4
Data
Linear Regression, Slope = -21.243
Intercept = -49.497
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Underdash, Rx at Roof Height, Angle = 90, Car = RAV4
Data
Linear Regression, Slope = -15.654
Intercept = -55.376
pathloss (dB)
Log distance (m)


Pathloss vs Log distance with Tx on the Dashboard, Rx at Bumper Height, Car = RAV4 SUV
Data
Linear Regression, Slope = -5.619
Intercept = -63.630
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Dashboard, Rx at Roof Height, Car = RAV4 SUV
Data
Linear Regression, Slope = -25.497
Intercept = -43.069
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Gearbox, Rx at Bumper Height, Car = RAV4 SUV
Data
Linear Regression, Slope = -12.584
Intercept = -56.484
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx on the Gearbox, Rx at Roof Height, Car = RAV4 SUV
Data
Linear Regression, Slope = -24.741
Intercept = -42.661
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx under the Domelight, Rx at Bumper Height, Car = RAV4 SUV
Data
Linear Regression, Slope = -7.058
Intercept = -61.038
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx under the Domelight, Rx at Roof Height, Car = RAV4 SUV
Data
Linear Regression, Slope = -19.246
Intercept = -50.778
pathloss (dB)
Log distance (m)

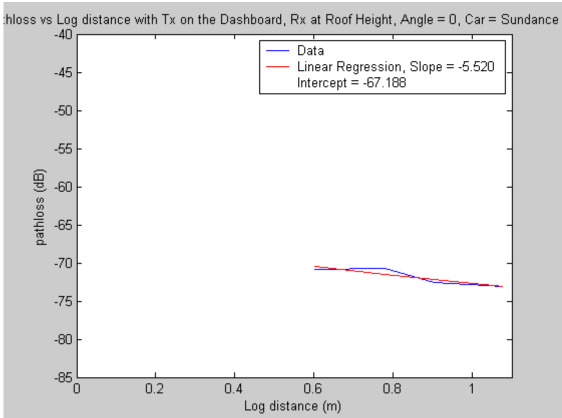


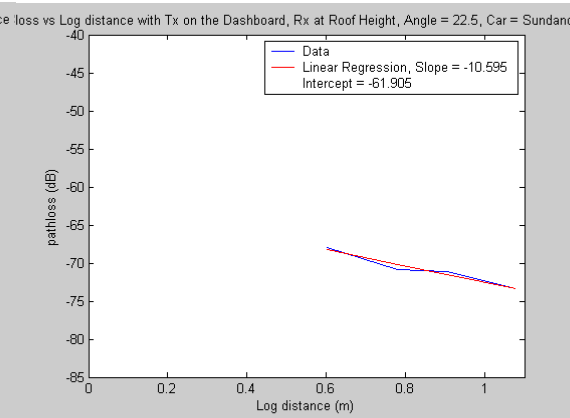
Pathloss vs Log distance with Tx under the dashboard, Rx at Bumper Height, Car = RAV4 SUV
Data
Linear Regression, Slope = -15.229
Intercept = -54.640
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx under the dashboard, Rx at Roof Height, Car = RAV4 SUV
Data
Linear Regression, Slope = -19.176
Intercept = -51.076
pathloss (dB)
Log distance (m)
Slope vs Intercept of Pathloss vs Log Distance, Car = RAV4 SUV
x = Dashboard, + = Gearbox
* = Domelight, Triangle = Underdash
blue -> rx at bumper, black -> rx at roof
Slope
Intercept

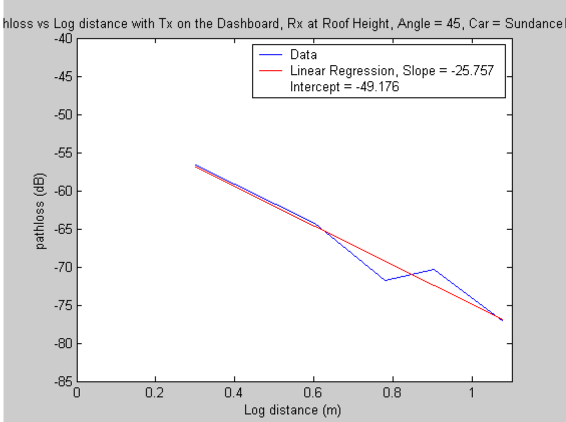
Sundance

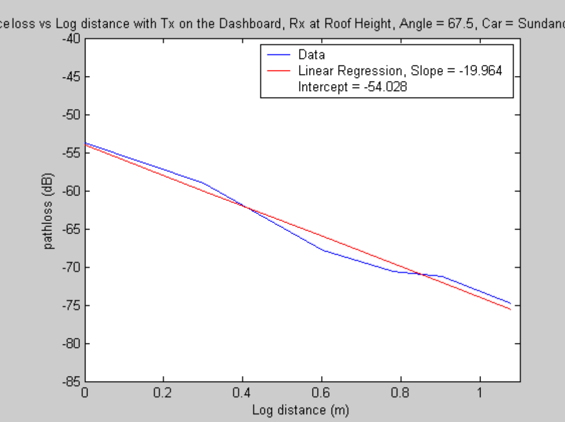


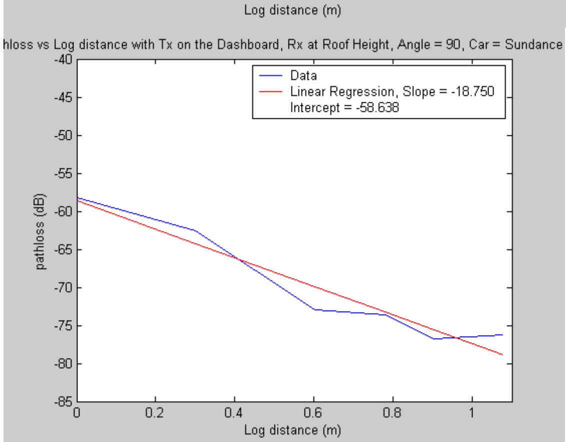
hloss vs logdistance with Tx on the Dashboard, Rx at Bumper Height, Angle = 0, Car = Sundance
Data
Linear Regression, Slope = -1.215
Intercept = -71.623
pathloss (dB)
Log distance (m)
ss vs Log distance with Tx on the Dashboard, Rx at Bumper Height, Angle = 22.5, Car = Sundan
Data
Linear Regression, Slope = -12.547
Intercept = -62.446
pathloss (dB)
Log distance (m)
oss vs Log distance with Tx on the Dashboard, Rx at Bumper Height, Angle = 45, Car = Sundance
Data
Linear Regression, Slope = -14.025
Intercept = -60.924
pathloss (dB)
Log distance (m)
ss vs Log distance with Tx on the Dashboard, Rx at Bumper Height, Angle = 67.5, Car = Sundan
Data
Linear Regression, Slope = -6.806
Intercept = -65.763
pathloss (dB)
Log distance (m)
oss vs Log distance with Tx on the Dashboard, Rx at Bumper Height, Angle = 90, Car = Sundanc
Data
Linear Regression, Slope = -10.822
Intercept = -63.808
pathloss (dB)
Log distance (m)

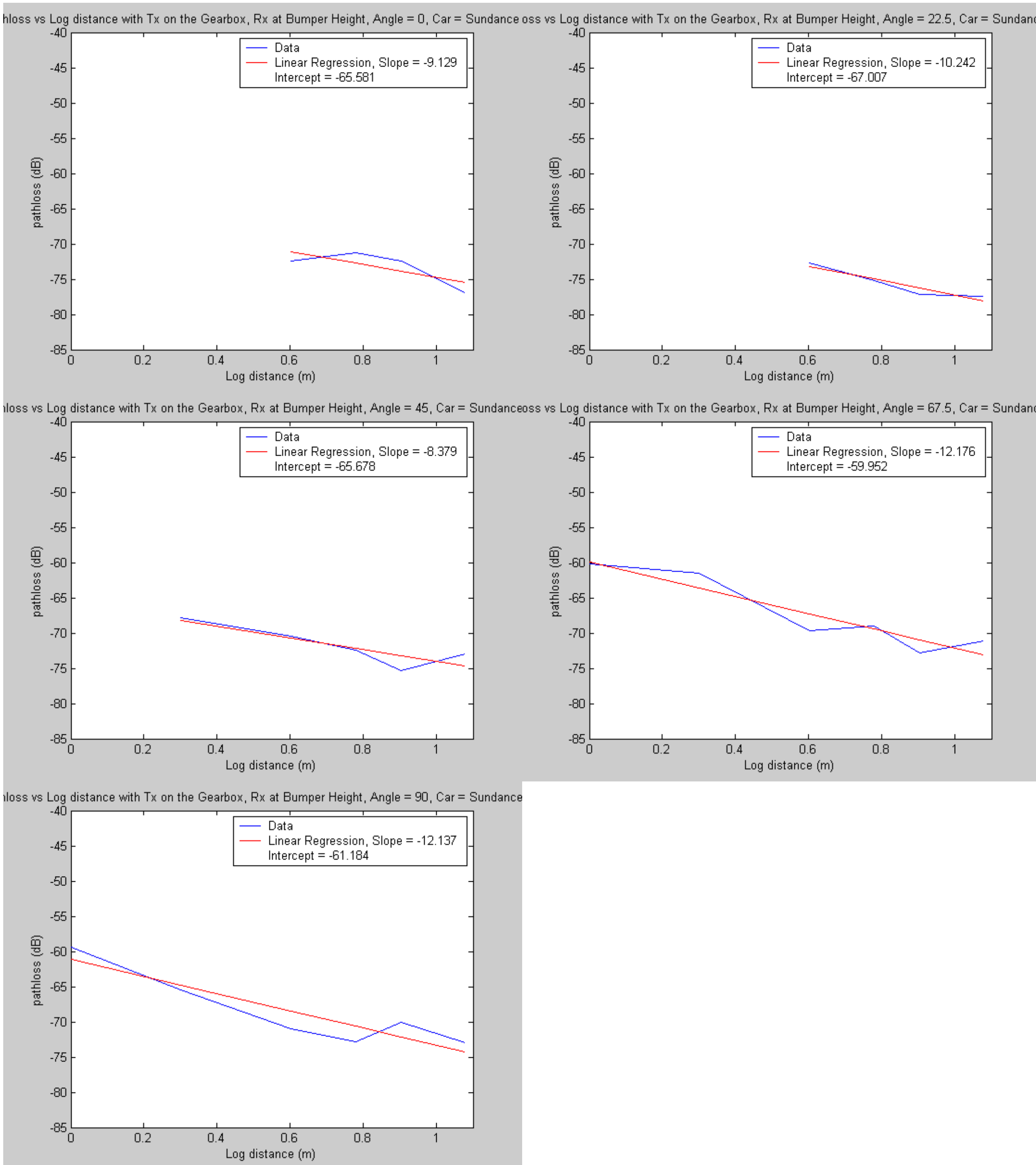

hloss vs Log distance with Tx on the Dashboard, Rx at Roof Height, Angle = 0, Car = Sundance
Data
Linear Regression, Slope = -5.520
Intercept = -67.188
pathloss (dB)
Log distance (m)

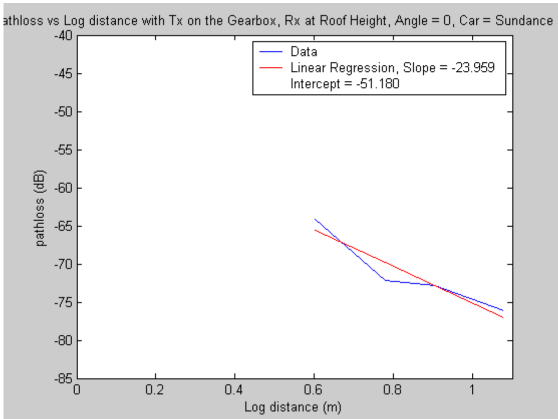

loss vs Log distance with Tx on the Dashboard, Rx at Roof Height, Angle = 22.5, Car = Sundance
Data
Linear Regression, Slope = -10.595
Intercept = -61.905
pathloss (dB)
Log distance (m)

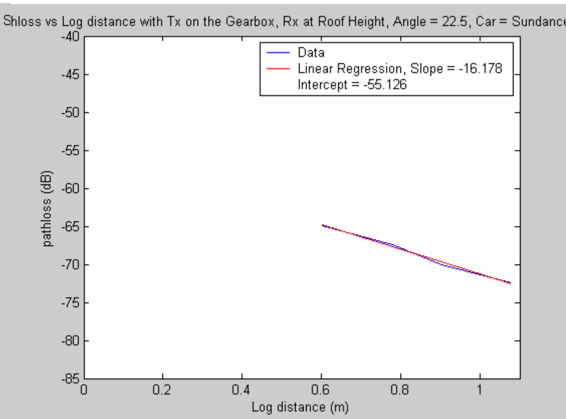

hloss vs Log distance with Tx on the Dashboard, Rx at Roof Height, Angle = 45, Car = Sundance
Data
Linear Regression, Slope = -25.757
Intercept = -49.176
pathloss (dB)
Log distance (m)

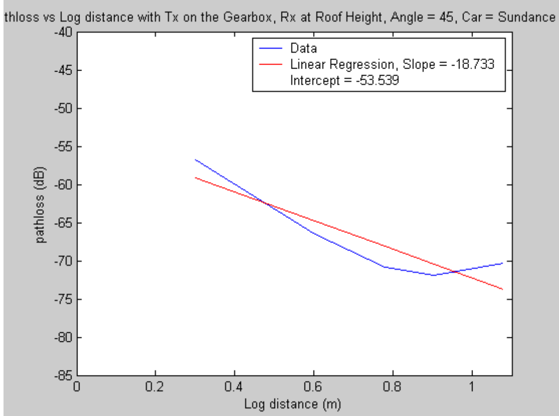

loss vs Log distance with Tx on the Dashboard, Rx at Roof Height, Angle = 67.5, Car = Sundance
Data
Linear Regression, Slope = -19.964
Intercept = -54.028
pathloss (dB)
Log distance (m)

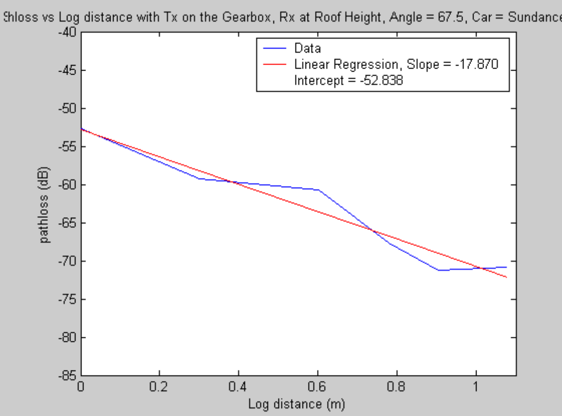

hloss vs Log distance with Tx on the Dashboard, Rx at Roof Height, Angle = 90, Car = Sundance
Data
Linear Regression, Slope = -18.750
Intercept = -58.638
pathloss (dB)
Log distance (m)

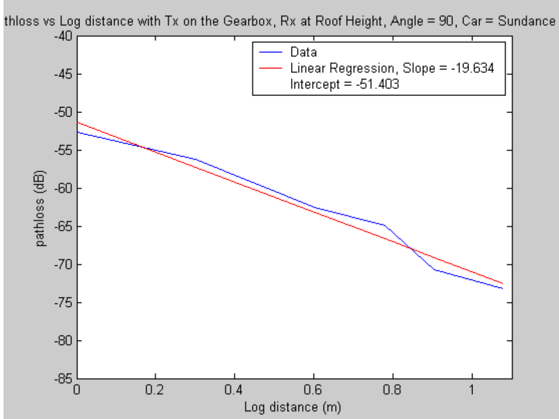

hloss vs Log distance with Tx on the Gearbox, Rx at Bumper Height, Angle = 0, Car = Sundance
Data
Linear Regression, Slope = -9.129
Intercept = -65.581
oss vs Log distance with Tx on the Gearbox, Rx at Bumper Height, Angle = 22.5, Car = Sundanc
Data
Linear Regression, Slope = -10.242
Intercept = -67.007
hloss vs Log distance with Tx on the Gearbox, Rx at Bumper Height, Angle = 45, Car = Sundance
Data
Linear Regression, Slope = -8.379
Intercept = -65.678
oss vs Log distance with Tx on the Gearbox, Rx at Bumper Height, Angle = 67.5, Car = Sundanc
Data
Linear Regression, Slope = -12.176
Intercept = -59.952
hloss vs Log distance with Tx on the Gearbox, Rx at Bumper Height, Angle = 90, Car = Sundance
Data
Linear Regression, Slope = -12.137
Intercept = -61.184
pathloss (dB)
Log distance (m)

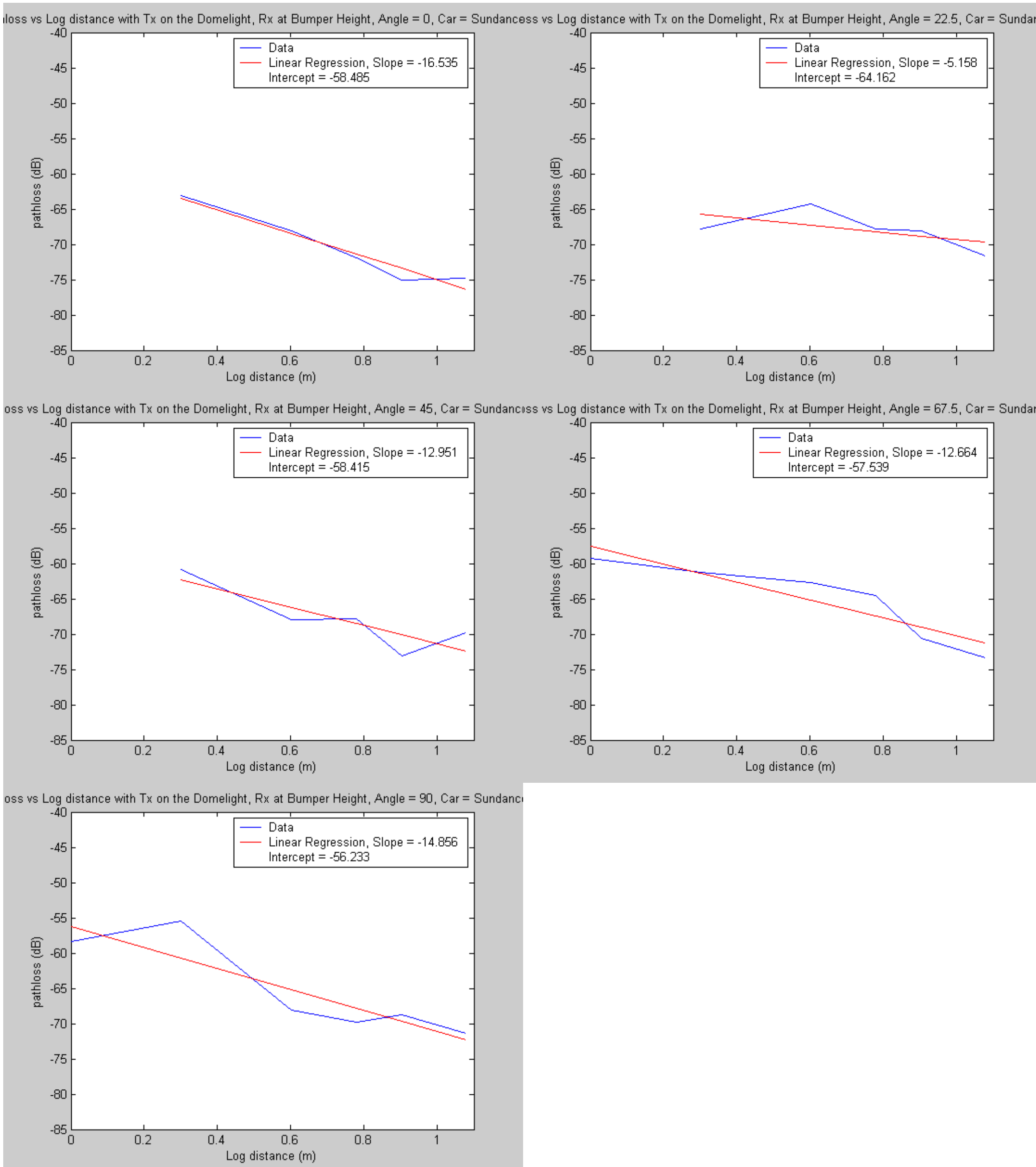

athloss vs Log distance with Tx on the Gearbox, Rx at Roof Height, Angle = 0, Car = Sundance S
Data
Linear Regression, Slope = -23.959
Intercept = -51.180
pathloss (dB)
Log distance (m)

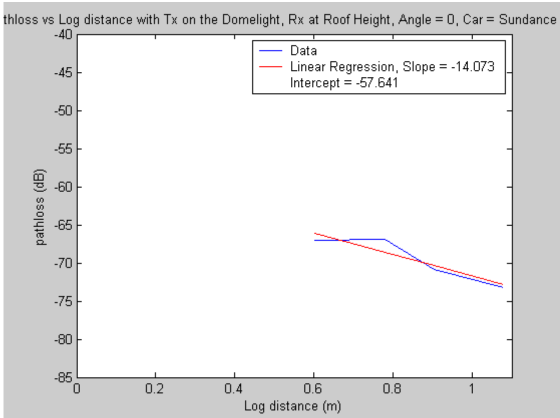

hloss vs Log distance with Tx on the Gearbox, Rx at Roof Height, Angle = 22.5, Car = Sundance
Data
Linear Regression, Slope = -16.178
Intercept = -55.126
pathloss (dB)
Log distance (m)

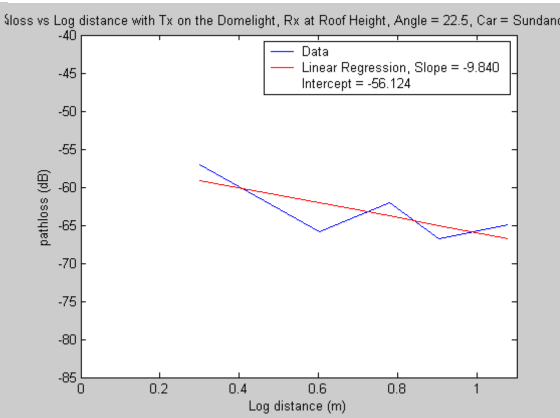

thloss vs Log distance with Tx on the Gearbox, Rx at Roof Height, Angle = 45, Car = Sundance S
Data
Linear Regression, Slope = -18.733
Intercept = -53.539
pathloss (dB)
Log distance (m)

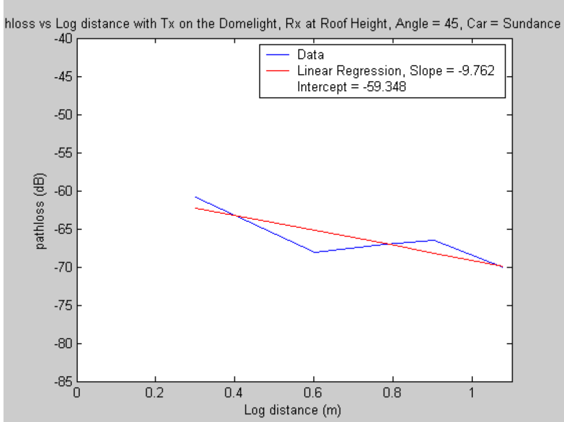

hloss vs Log distance with Tx on the Gearbox, Rx at Roof Height, Angle = 67.5, Car = Sundance
Data
Linear Regression, Slope = -17.870
Intercept = -52.838
pathloss (dB)
Log distance (m)

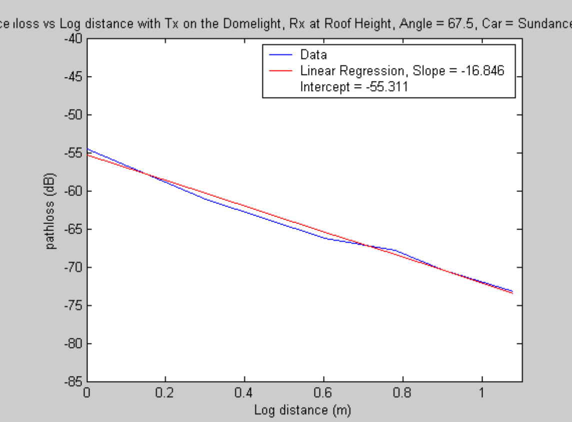

thloss vs Log distance with Tx on the Gearbox, Rx at Roof Height, Angle = 90, Car = Sundance S
Data
Linear Regression, Slope = -19.634
Intercept = -51.403
pathloss (dB)
Log distance (m)

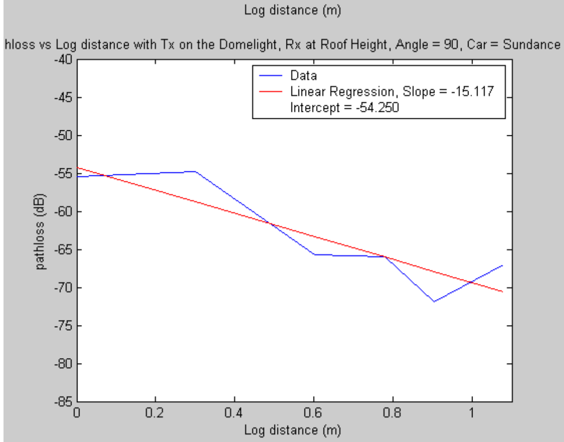

loss vs Log distance with Tx on the Domelight, Rx at Bumper Height, Angle = 0, Car = Sundance
Data
Linear Regression, Slope = -16.535
Intercept = -58.485
pathloss (dB)
Log distance (m)
ss vs Log distance with Tx on the Domelight, Rx at Bumper Height, Angle = 22.5, Car = Sundanc
Data
Linear Regression, Slope = -5.158
Intercept = -64.162
pathloss (dB)
Log distance (m)
oss vs Log distance with Tx on the Domelight, Rx at Bumper Height, Angle = 45, Car = Sundanc
Data
Linear Regression, Slope = -12.951
Intercept = -58.415
pathloss (dB)
Log distance (m)
ss vs Log distance with Tx on the Domelight, Rx at Bumper Height, Angle = 67.5, Car = Sundanc
Data
Linear Regression, Slope = -12.664
Intercept = -57.539
pathloss (dB)
Log distance (m)
oss vs Log distance with Tx on the Domelight, Rx at Bumper Height, Angle = 90, Car = Sundanc
Data
Linear Regression, Slope = -14.856
Intercept = -56.233
pathloss (dB)
Log distance (m)

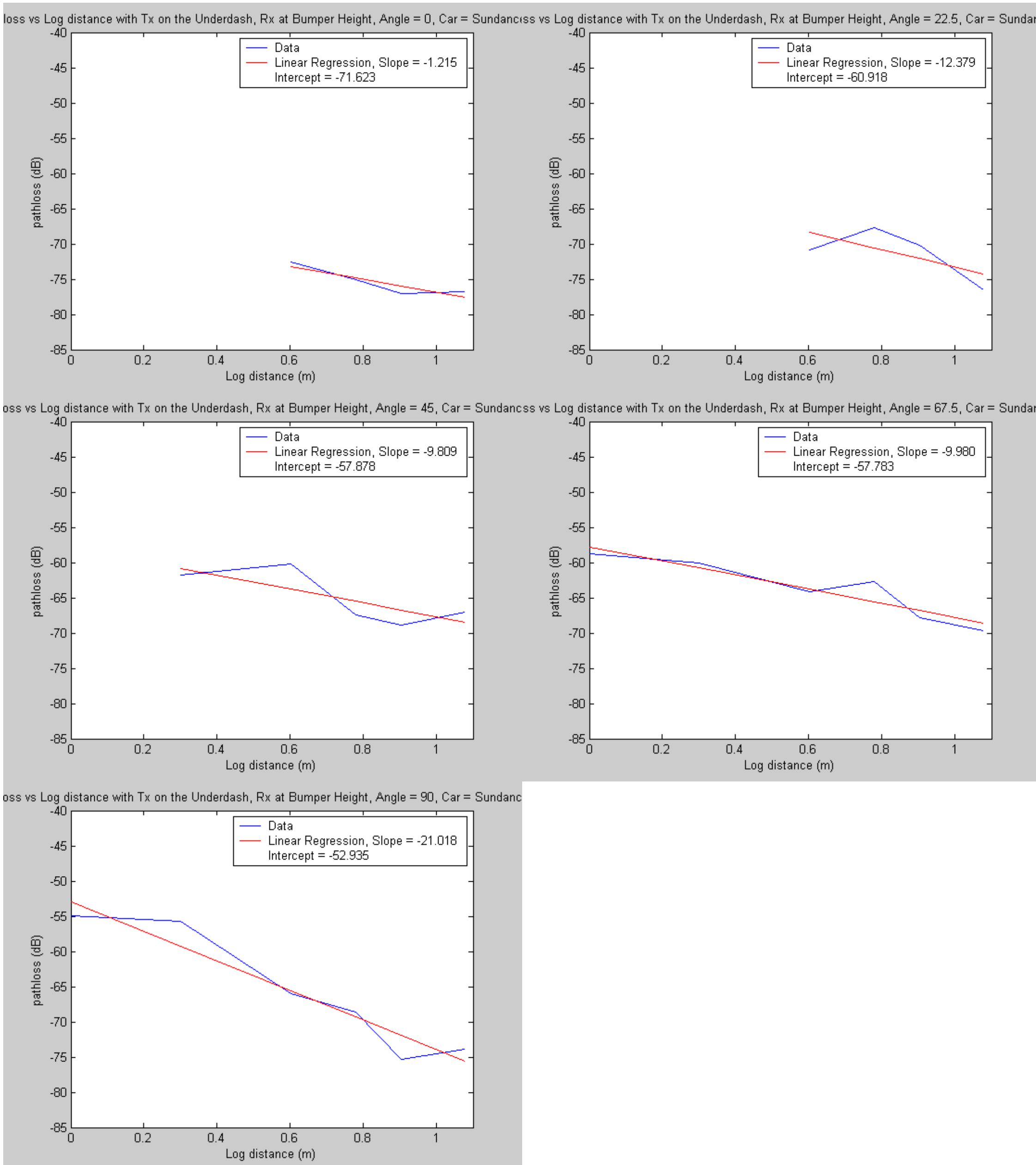

thloss vs Log distance with Tx on the Domelight, Rx at Roof Height, Angle = 0, Car = Sundance
Data
Linear Regression, Slope = -14.073
Intercept = -57.641
pathloss (dB)
Log distance (m)

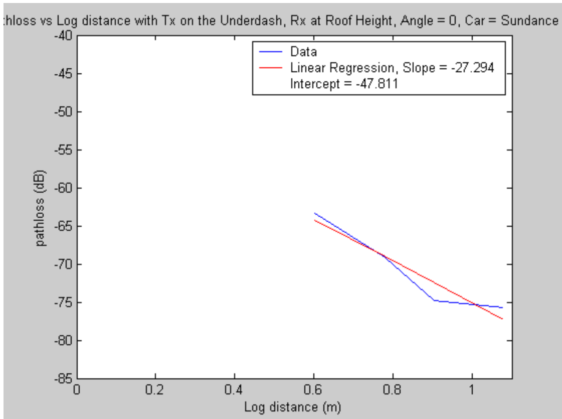

loss vs Log distance with Tx on the Domelight, Rx at Roof Height, Angle = 22.5, Car = Sundance
Data
Linear Regression, Slope = -9.840
Intercept = -56.124
pathloss (dB)
Log distance (m)

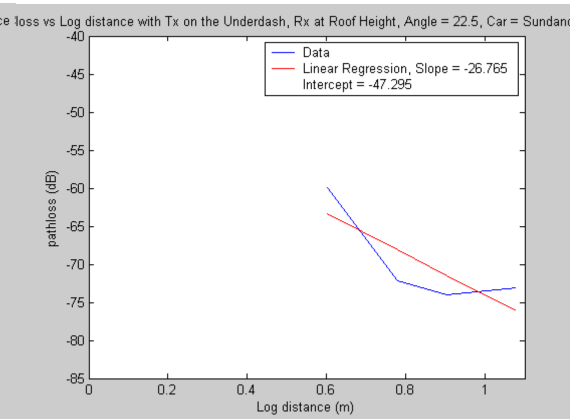

hloss vs Log distance with Tx on the Domelight, Rx at Roof Height, Angle = 45, Car = Sundance
Data
Linear Regression, Slope = -9.762
Intercept = -59.348
pathloss (dB)
Log distance (m)

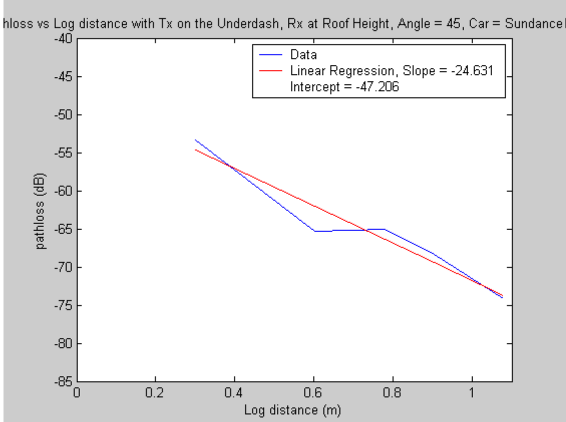

loss vs Log distance with Tx on the Domelight, Rx at Roof Height, Angle = 67.5, Car = Sundance
Data
Linear Regression, Slope = -16.846
Intercept = -55.311
pathloss (dB)
Log distance (m)

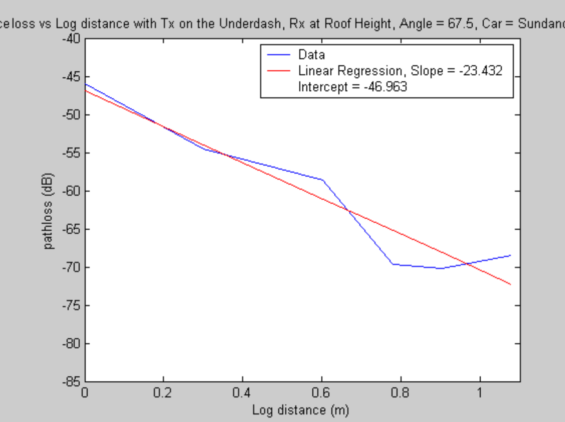

hloss vs Log distance with Tx on the Domelight, Rx at Roof Height, Angle = 90, Car = Sundance
Data
Linear Regression, Slope = -15.117
Intercept = -54.250
pathloss (dB)
Log distance (m)

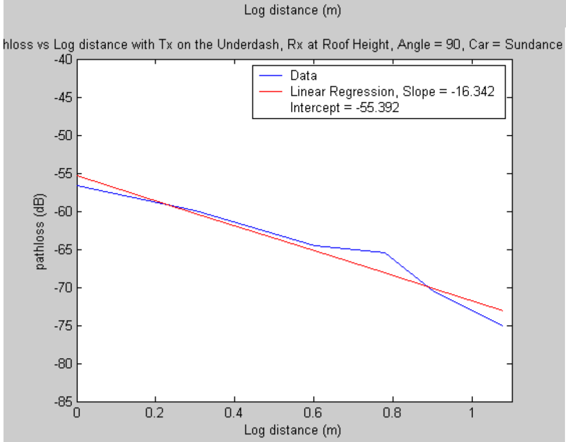

loss vs Log distance with Tx on the Underdash, Rx at Bumper Height, Angle = 0, Car = Sundanc
Data
Linear Regression, Slope = -1.215
Intercept = -71.623
pathloss (dB)
Log distance (m)
ss vs Log distance with Tx on the Underdash, Rx at Bumper Height, Angle = 22.5, Car = Sundan
Data
Linear Regression, Slope = -12.379
Intercept = -60.918
pathloss (dB)
Log distance (m)
oss vs Log distance with Tx on the Underdash, Rx at Bumper Height, Angle = 45, Car = Sundanc
Data
Linear Regression, Slope = -9.809
Intercept = -57.878
pathloss (dB)
Log distance (m)
ss vs Log distance with Tx on the Underdash, Rx at Bumper Height, Angle = 67.5, Car = Sundan
Data
Linear Regression, Slope = -9.980
Intercept = -57.783
pathloss (dB)
Log distance (m)
oss vs Log distance with Tx on the Underdash, Rx at Bumper Height, Angle = 90, Car = Sundanc
Data
Linear Regression, Slope = -21.018
Intercept = -52.935
pathloss (dB)
Log distance (m)

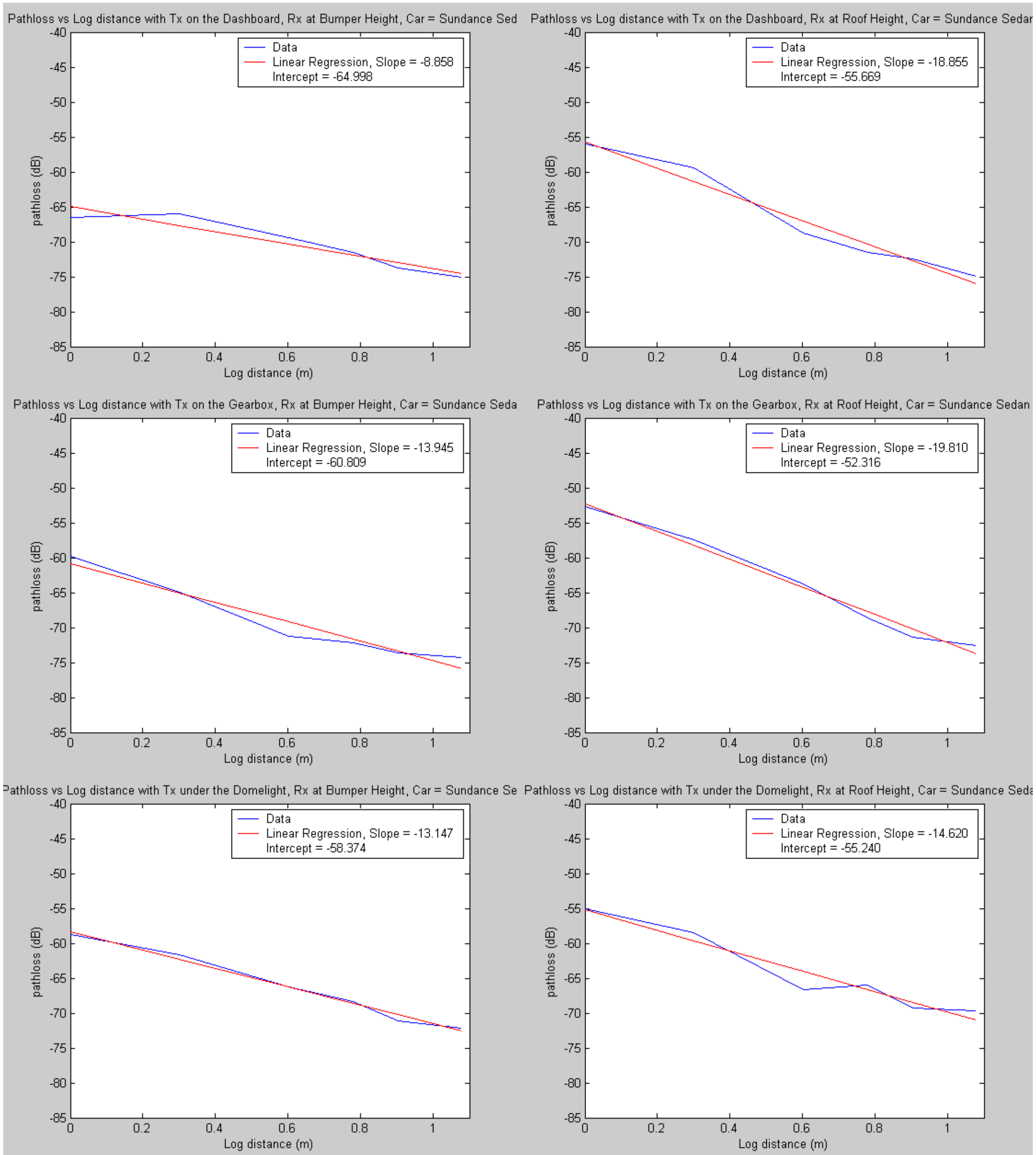

hloss vs Log distance with Tx on the Underdash, Rx at Roof Height, Angle = 0, Car = Sundance
Data
Linear Regression, Slope = -27.294
Intercept = -47.811
pathloss (dB)
Log distance (m)


loss vs Log distance with Tx on the Underdash, Rx at Roof Height, Angle = 22.5, Car = Sundance
Data
Linear Regression, Slope = -26.765
Intercept = -47.295
pathloss (dB)
Log distance (m)

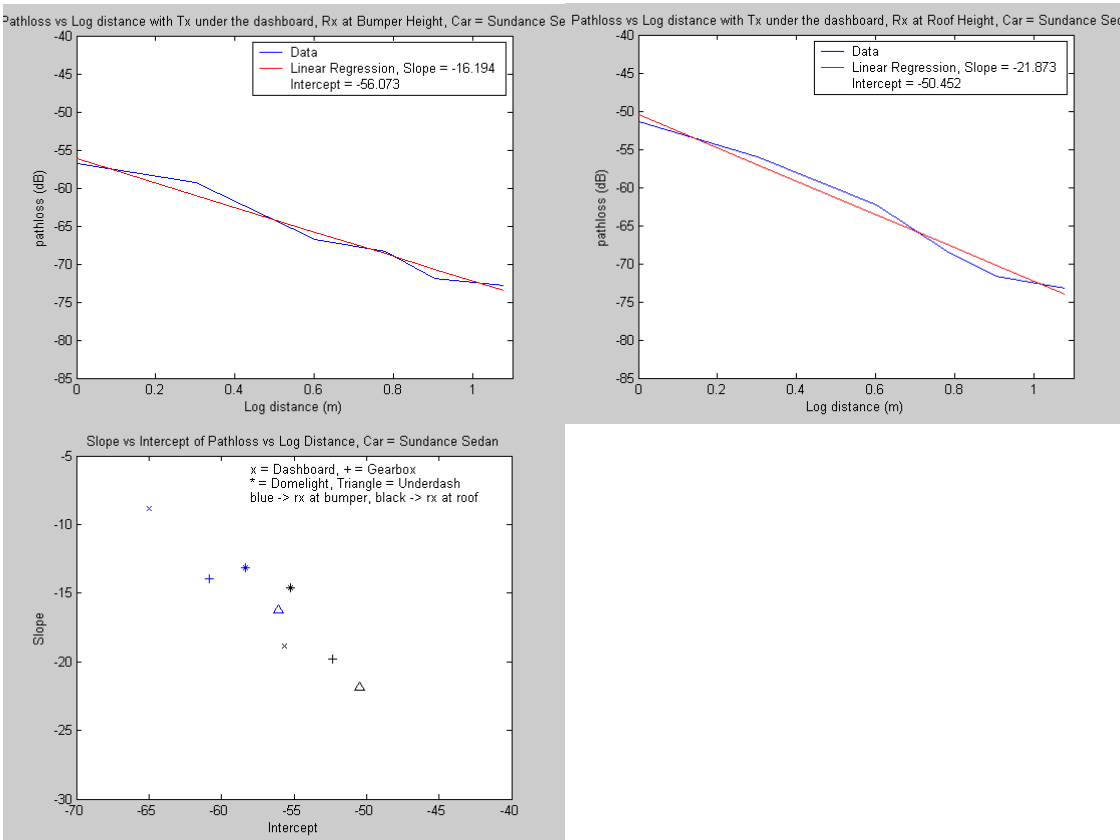

hloss vs Log distance with Tx on the Underdash, Rx at Roof Height, Angle = 45, Car = Sundance
Data
Linear Regression, Slope = -24.631
Intercept = -47.206
pathloss (dB)
Log distance (m)


loss vs Log distance with Tx on the Underdash, Rx at Roof Height, Angle = 67.5, Car = Sundance
Data
Linear Regression, Slope = -23.432
Intercept = -46.963
pathloss (dB)
Log distance (m)


hloss vs Log distance with Tx on the Underdash, Rx at Roof Height, Angle = 90, Car = Sundance
Data
Linear Regression, Slope = -16.342
Intercept = -55.392
pathloss (dB)
Log distance (m)



Pathloss vs Log distance with Tx on the Dashboard, Rx at Bumper Height, Car = Sundance Sed
Data
Linear Regression, Slope = -8.858
Intercept = -64.998
Pathloss vs Log distance with Tx on the Dashboard, Rx at Roof Height, Car = Sundance Sedar
Data
Linear Regression, Slope = -18.855
Intercept = -55.669
Pathloss vs Log distance with Tx on the Gearbox, Rx at Bumper Height, Car = Sundance Seda
Data
Linear Regression, Slope = -13.945
Intercept = -60.809
Pathloss vs Log distance with Tx on the Gearbox, Rx at Roof Height, Car = Sundance Sedan
Data
Linear Regression, Slope = -19.810
Intercept = -52.316
Pathloss vs Log distance with Tx under the Domelight, Rx at Bumper Height, Car = Sundance Se
Data
Linear Regression, Slope = -13.147
Intercept = -58.374
Pathloss vs Log distance with Tx under the Domelight, Rx at Roof Height, Car = Sundance Seda
Data
Linear Regression, Slope = -14.620
Intercept = -55.240
pathloss (dB)
Log distance (m)
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
0
0.2
0.4
0.6
0.8
1


Pathloss vs Log distance with Tx under the dashboard, Rx at Bumper Height, Car = Sundance Se
Data
Linear Regression, Slope = -16.194
Intercept = -56.073
pathloss (dB)
Log distance (m)
Pathloss vs Log distance with Tx under the dashboard, Rx at Roof Height, Car = Sundance Sed
Data
Linear Regression, Slope = -21.873
Intercept = -50.452
pathloss (dB)
Log distance (m)
Slope vs Intercept of Pathloss vs Log Distance, Car = Sundance Sedan
x = Dashboard, + = Gearbox
* = Domelight, Triangle = Underdash
blue -> rx at bumper, black -> rx at roof
Slope
Intercept