Taste of Research
Gough Yumu LUI
Engineer's Log Book

Week 8

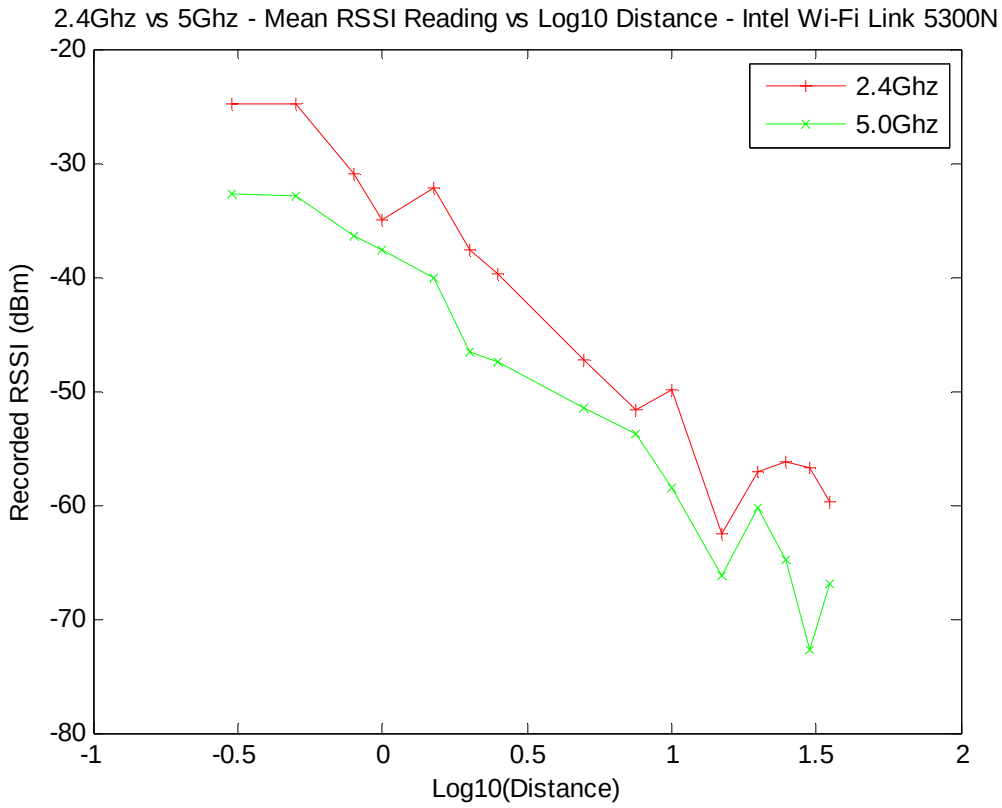
- Sunday 16th January 2011

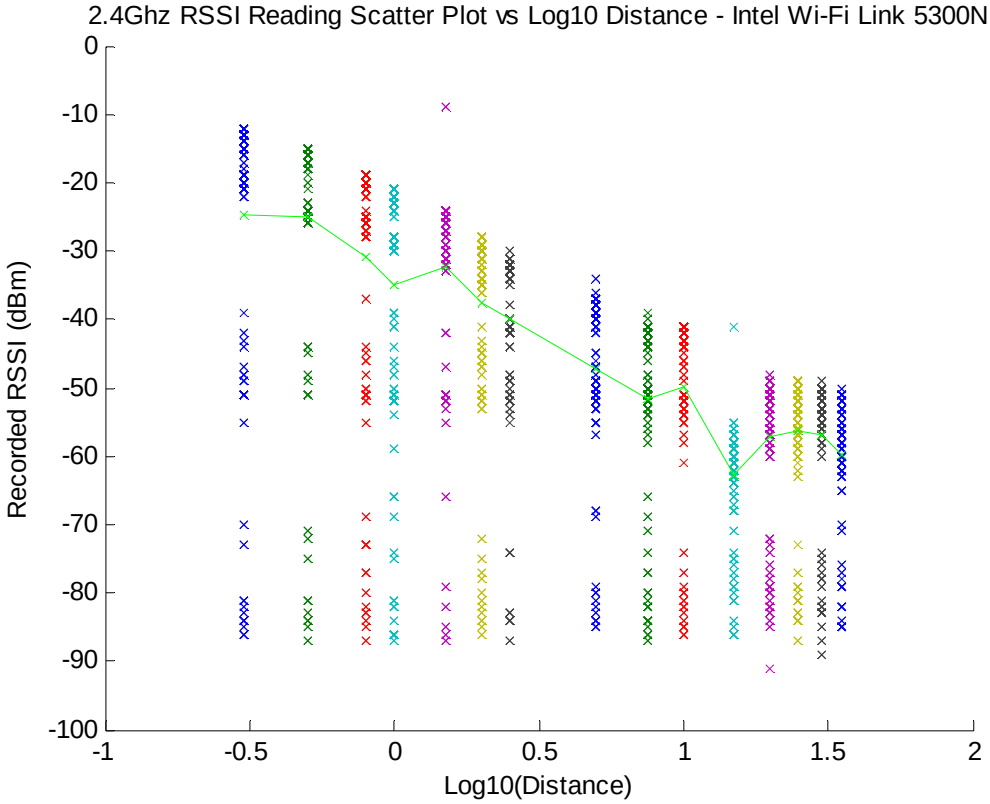
It's a Sunday … so what am I doing … doing research on a Sunday?

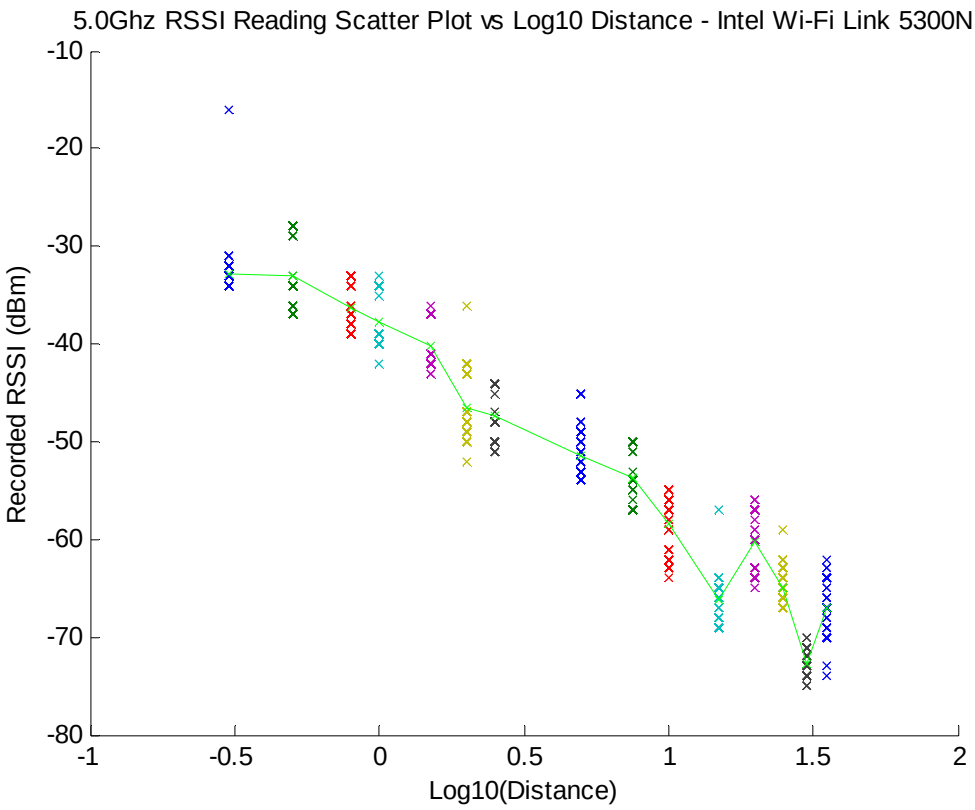
Well, in the interests of saving time, I decided to do some data analysis. First, the disappointing news – the data for the MSI Wind U100 is all useless. It has the same issue as the HP Elitebook – very erratic sample numbers for the early positions. I don't think I can trust any of the data, so while I still have it stored away, I don't intend to use it. Instead, the data will probably need to be manually collected. The same method, however, worked before on that same laptop. And the same method worked now, on my BenQ laptop. The problem doesn't seem to be related to my code – so I can't quite say what it is.

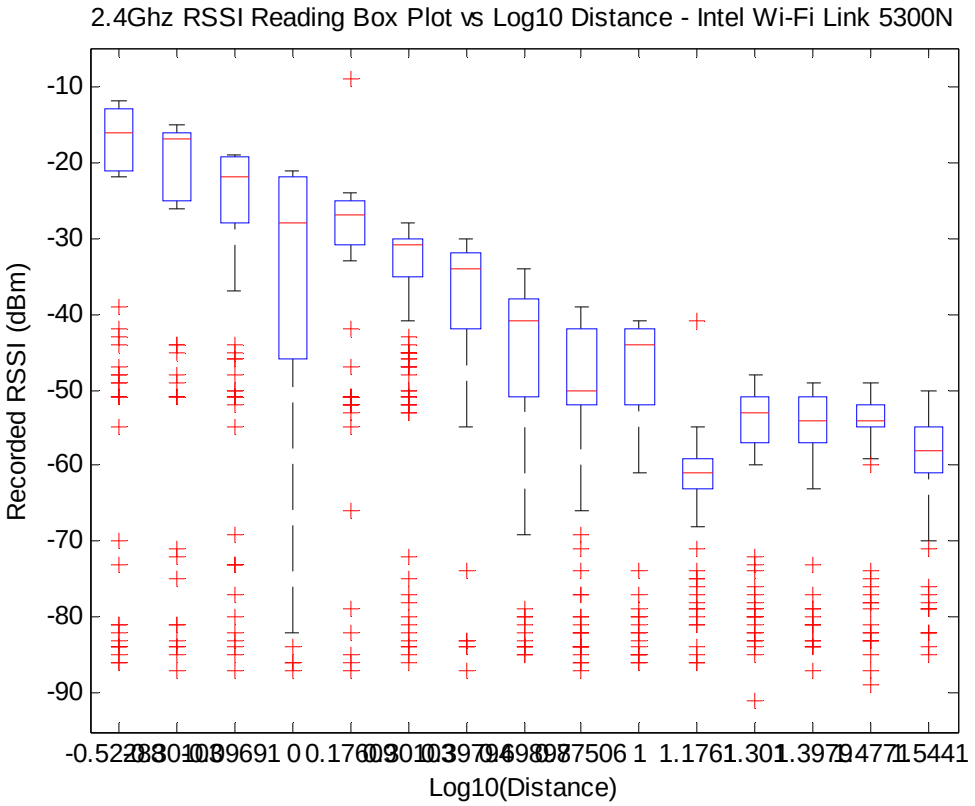
Here are the outdoor results for the HP Elitebook with the Intel 5300N card, with the experiment performed manually. The 2.4Ghz and 5Ghz sample numbers are equal and very even throughout the test as I was very careful to try and keep good timing. The resulting lines are much more pleasing, looking as if they were meant to be straight lines. The scatter plots do tell a different story with the 2.4Ghz – it has lots of spurious data, and at one point – the variance jumped to very large numbers. Overall, this is the sort of thing I was expecting from outdoor tests.

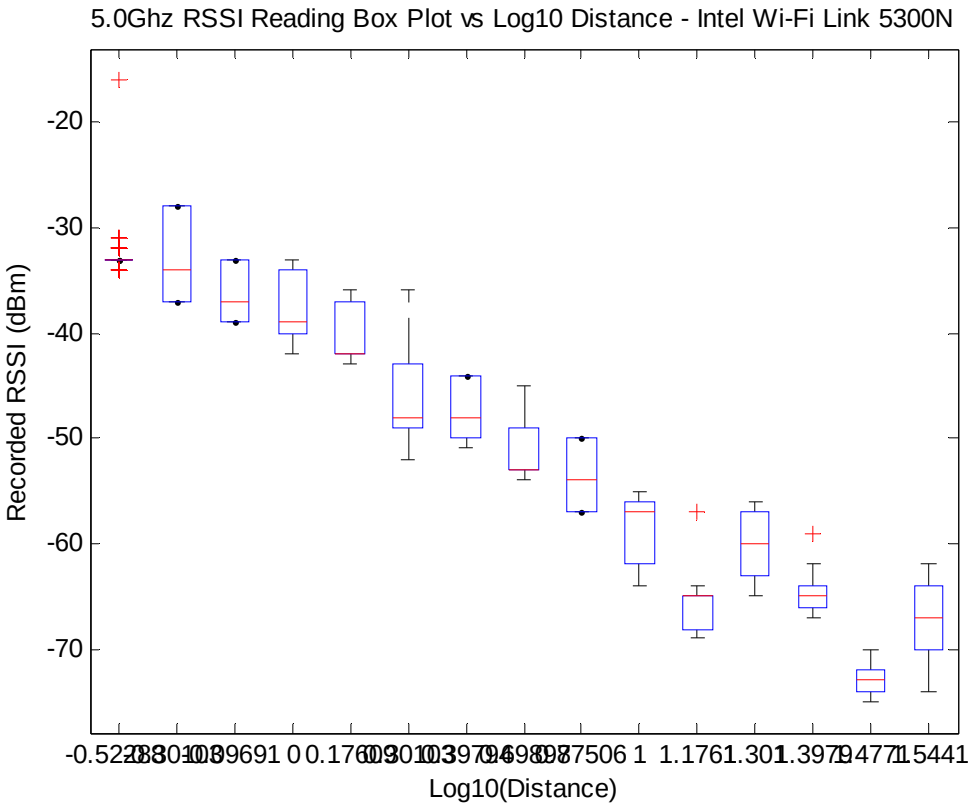
Distance	**2.4Ghz**	**5Ghz**
0.3m	293	293
0.5m	295	295
0.8m	291	291
1m	297	297
1.5m	290	290
2m	290	290
2.5m	290	290
5m	288	288
7.5m	289	289
10m	288	288
15m	289	289
20m	289	289
25m	291	291
30m	291	291
35m	293	293


2.4Ghz vs 5Ghz - Mean RSSI Reading vs Log10 Distance - Intel Wi-Fi Link 5300N
2.4Ghz
5.0Ghz
Recorded RSSI (dBm)
Log10(Distance)
-20
-30
-40
-50
-60
-70
-80
-1
-0.5
0
0.5
1
1.5
2


2.4Ghz RSSI Reading Scatter Plot vs Log10 Distance - Intel Wi-Fi Link 5300N
Recorded RSSI (dBm)
Log10(Distance)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-1
-0.5
0
0.5
1
1.5
2

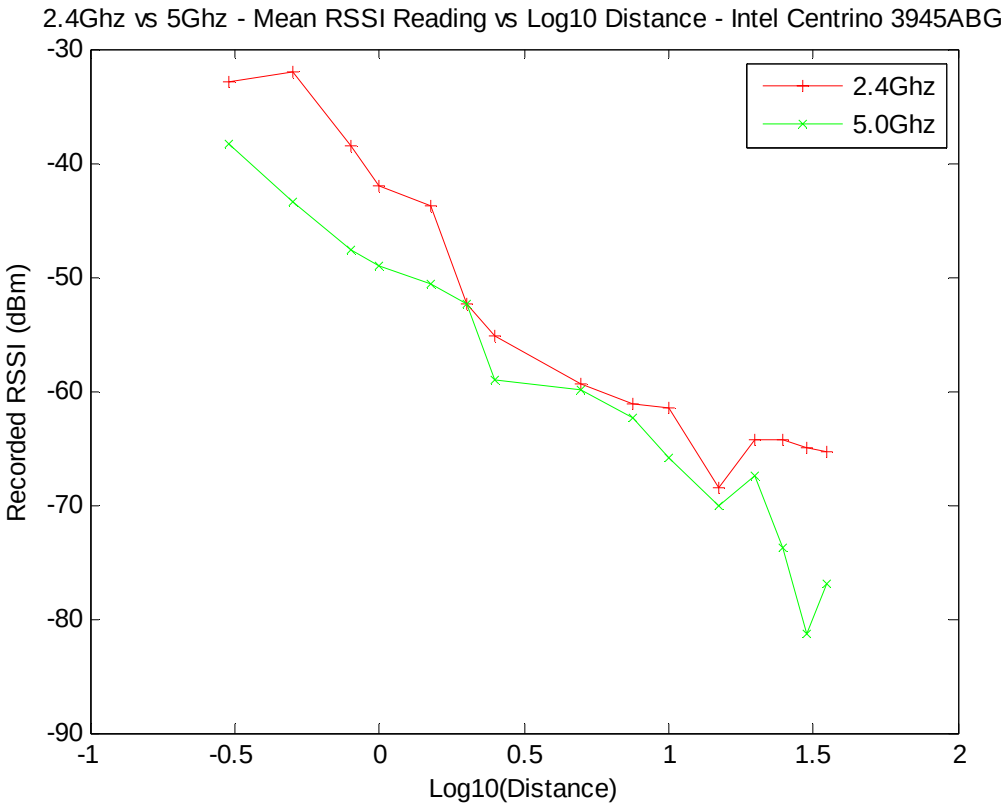

5.0Ghz RSSI Reading Scatter Plot vs Log10 Distance - Intel Wi-Fi Link 5300N
Recorded RSSI (dBm)
-10
-20
-30
-40
-50
-60
-70
-80
-1
-0.5
0
0.5
1
1.5
2
Log10(Distance)

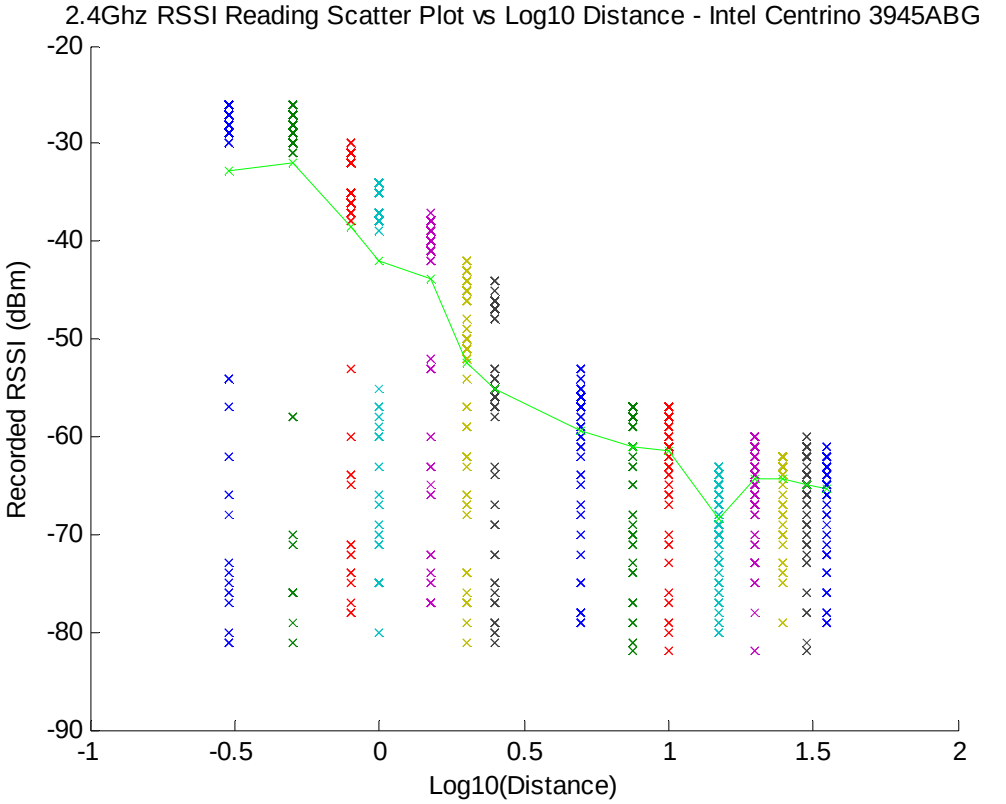

2.4Ghz RSSI Reading Box Plot vs Log10 Distance - Intel Wi-Fi Link 5300N
Recorded RSSI (dBm)
-10
-20
-30
-40
-50
-60
-70
-80
-90
Log10(Distance)

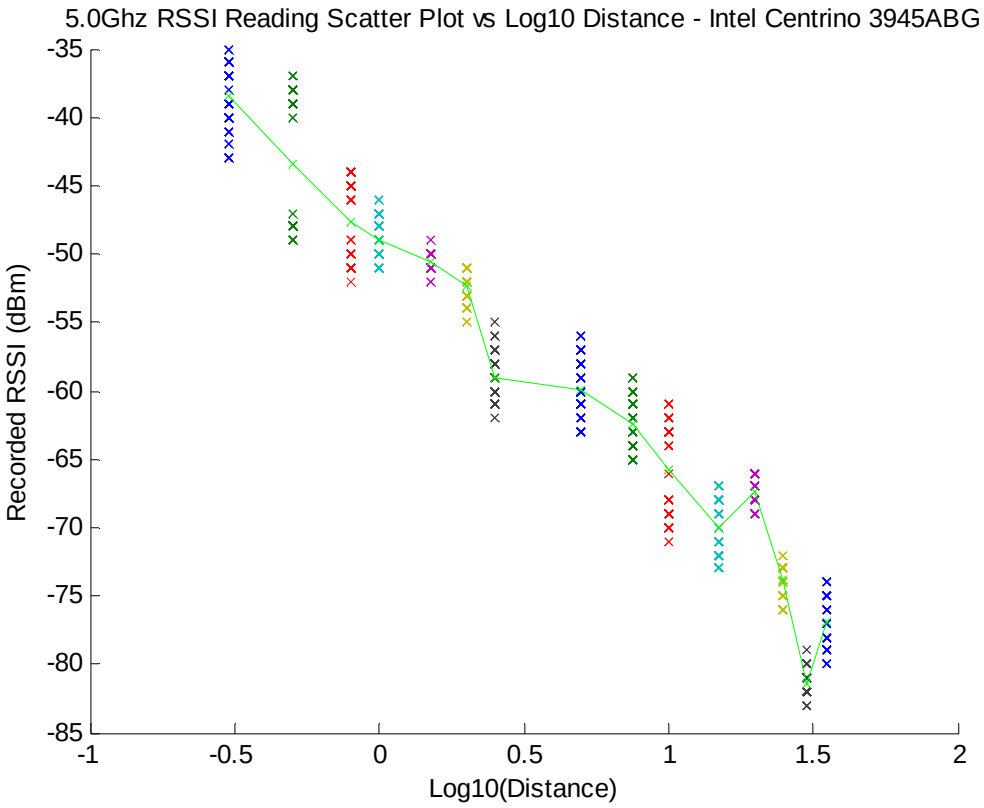


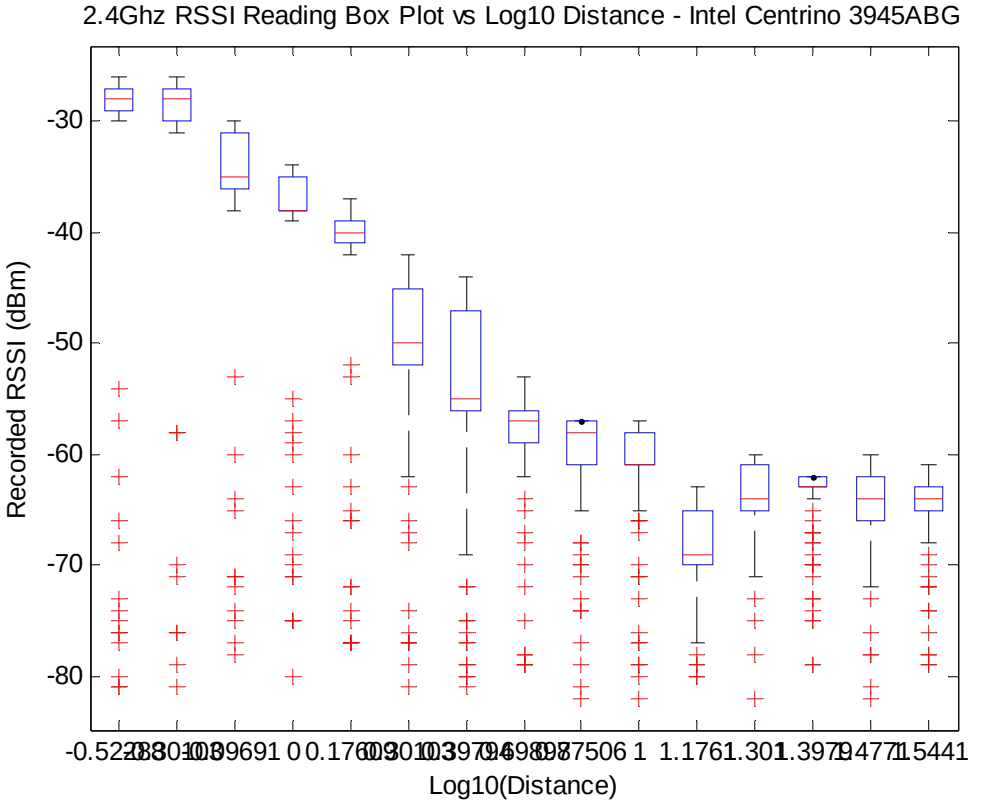
The other card that was tested was the Intel Centrino 3945ABG. This test was done with the GPS and shows the sample number decrease issue – but it remains relatively well controlled and stable. The GPS time system makes things a lot easier for me compared to doing things manually. These curves are also reminiscent of straight lines, but they do have a few strange dips as expected from real life experimental data.

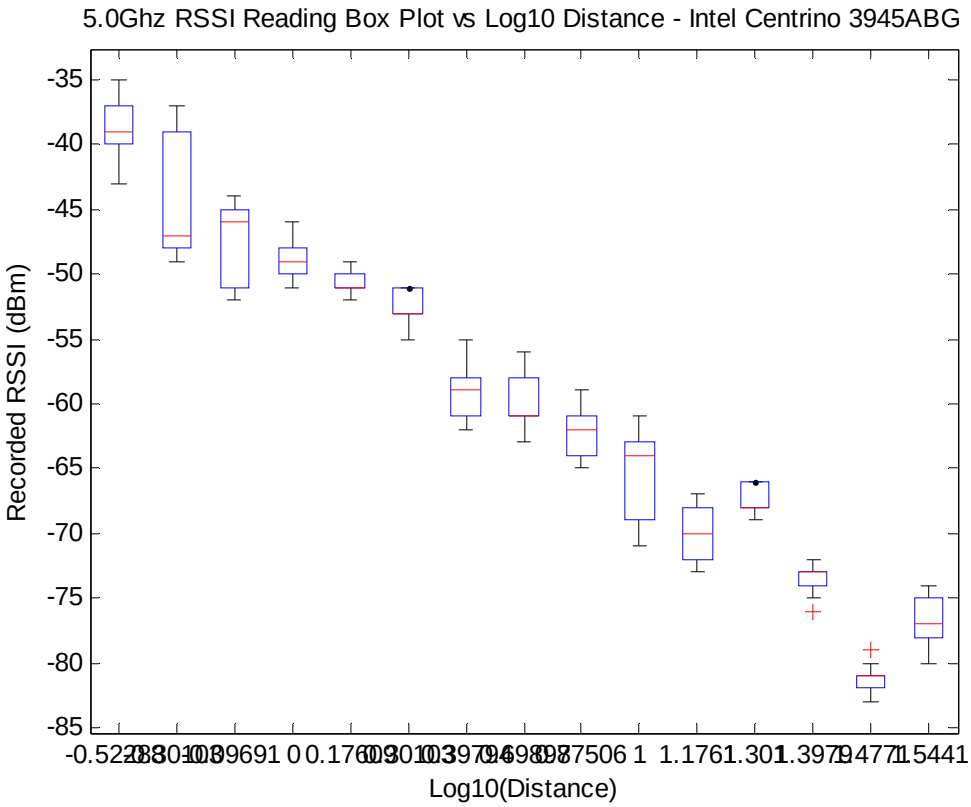
Distance	**2.4Ghz**	**5Ghz**
0.3m	223	223
0.5m	223	223
0.8m	223	223
1m	222	221
1.5m	218	218
2m	218	217
2.5m	216	216
5m	214	214
7.5m	220	219
10m	224	223
15m	221	221
20m	218	219
25m	213	216
30m	211	215
35m	215	214


2.4Ghz vs 5Ghz - Mean RSSI Reading vs Log10 Distance - Intel Centrino 3945ABG
2.4Ghz
5.0Ghz
Recorded RSSI (dBm)
Log10(Distance)
-30
-40
-50
-60
-70
-80
-90
-1
-0.5
0
0.5
1
1.5
2


2.4Ghz RSSI Reading Scatter Plot vs Log10 Distance - Intel Centrino 3945ABG
Recorded RSSI (dBm)
Log10(Distance)
-20
-30
-40
-50
-60
-70
-80
-90
-1
-0.5
0
0.5
1
1.5
2

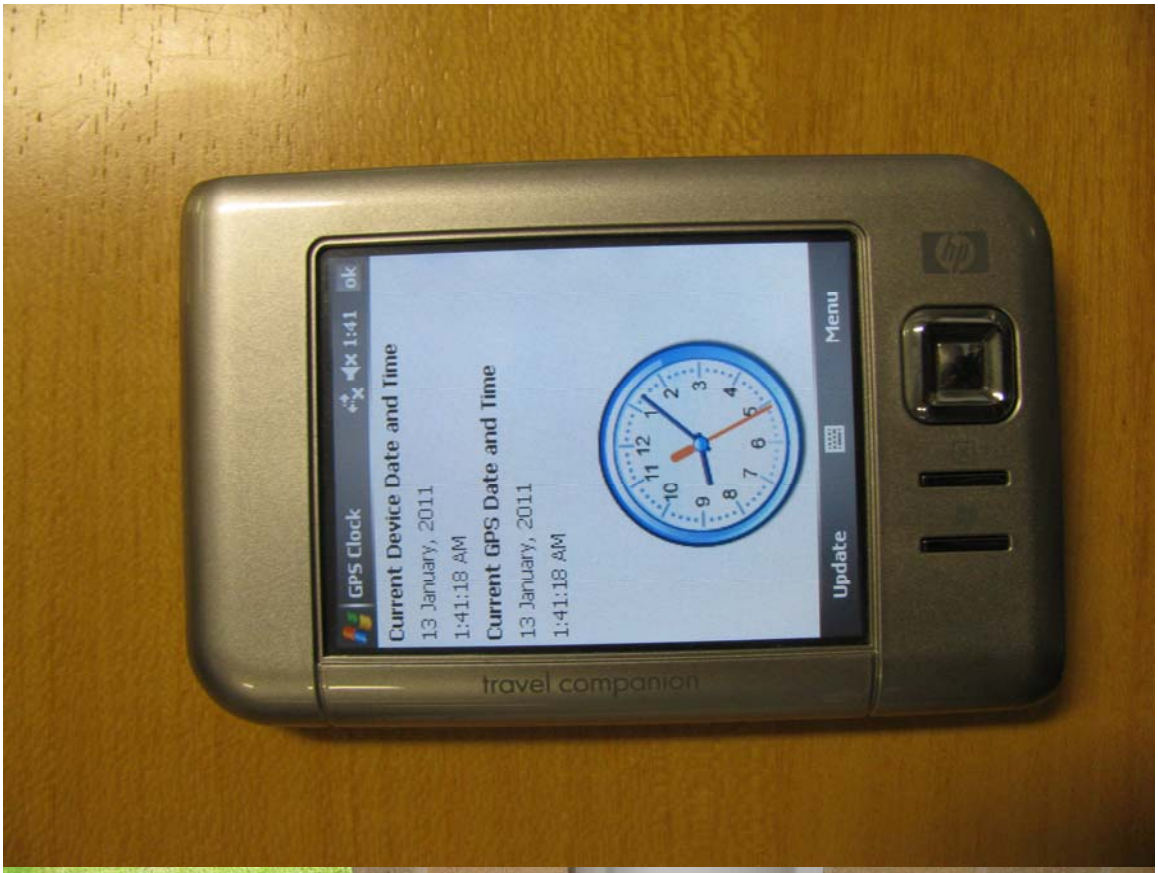

5.0Ghz RSSI Reading Scatter Plot vs Log10 Distance - Intel Centrino 3945ABG
Recorded RSSI (dBm)
-35
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
-1
-0.5
0
0.5
1
1.5
2
Log10(Distance)


2.4Ghz RSSI Reading Box Plot vs Log10 Distance - Intel Centrino 3945ABG
Recorded RSSI (dBm)
-30
-40
-50
-60
-70
-80
Log10(Distance)

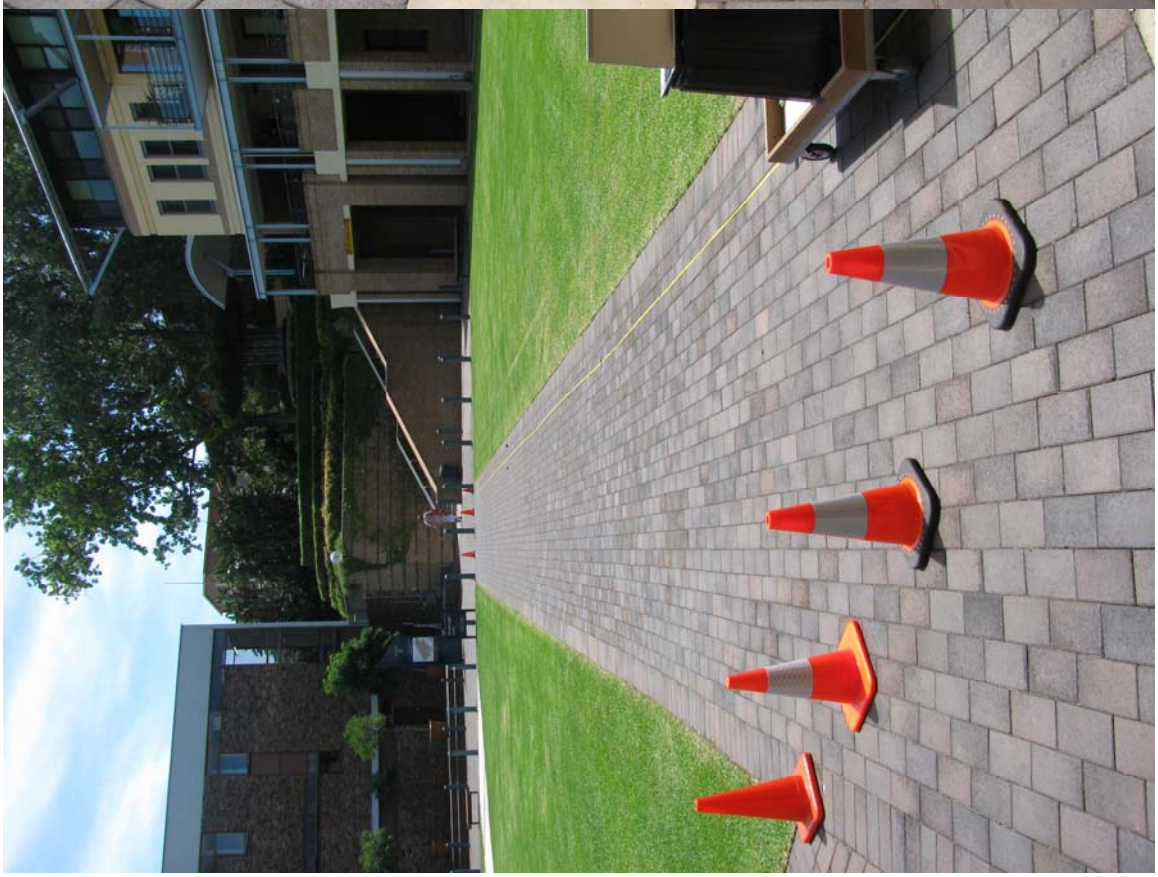


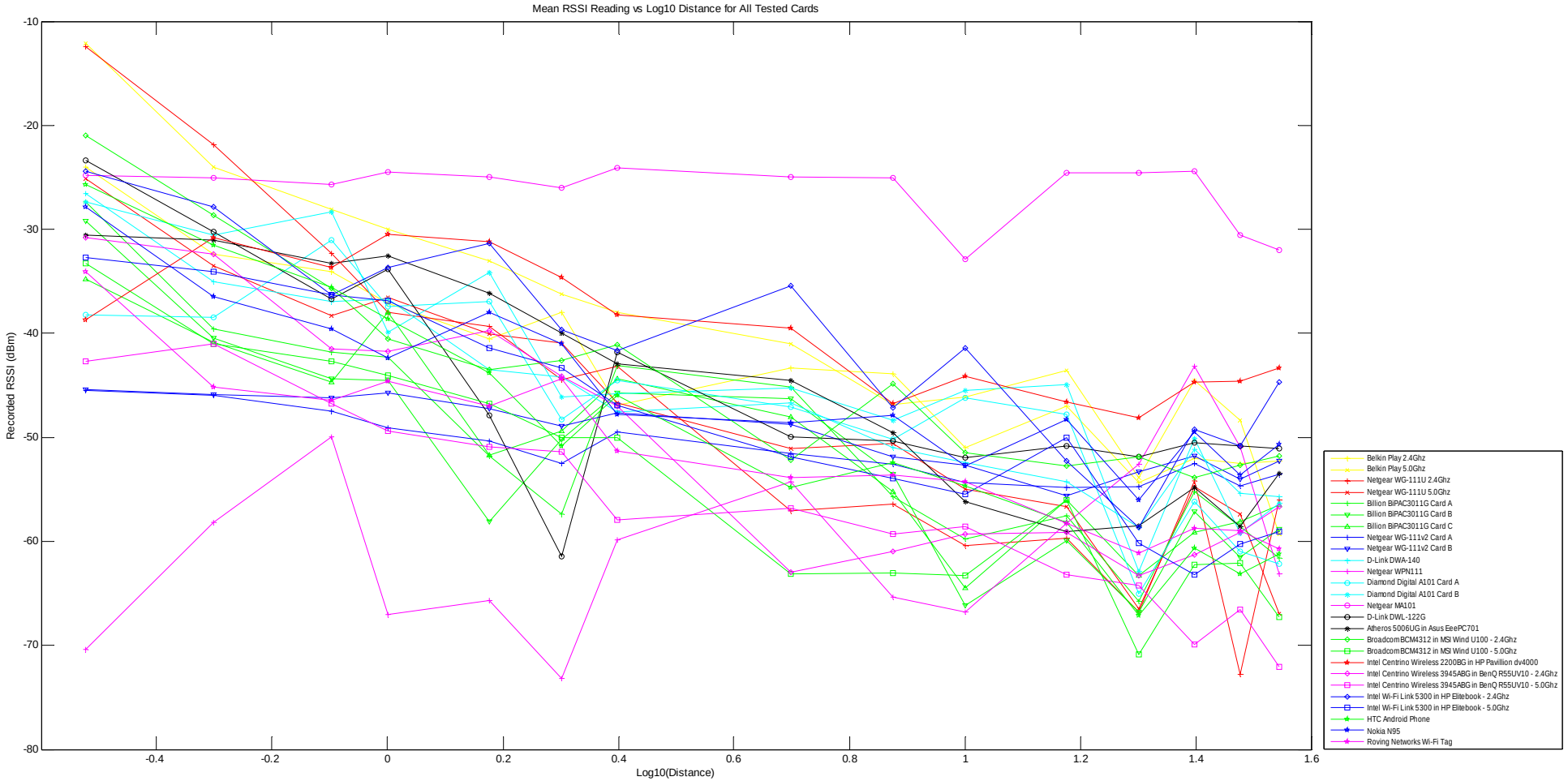
Earlier last week, I was reminded by Binghao and Thomas that I should take some pictures of my test setup for reference. So I did. And here are some of them just for documentation purposes. I think I may also take some pictures of the devices themselves to add to the report.

And I said I would update the plotall.m – here's the new plotallindoor.m which has all the final indoor test means plotted for all tested devices/cards. It's really messy thanks to all the cards that are in there, but it pretty much summarizes it all.


GPS Clock
1:41
ok
Current Device Date and Time
13 January, 2011
1:41:18 AM
Current GPS Date and Time
13 January, 2011
1:41:18 AM
Update
Menu
travel companion


BELKIN
INTIMIDATOR




Mean RSSI Reading vs Log10 Distance for All Tested Cards
Recorded RSSI (dBm)
Log10(Distance)
-10
-20
-30
-40
-50
-60
-70
-80
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Belkin Play 2.4Ghz
Belkin Play 5.0Ghz
Netgear WG-111U 2.4Ghz
Netgear WG-111U 5.0Ghz
Billion BiPAC3011G Card A
Billion BiPAC3011G Card B
Billion BiPAC3011G Card C
Netgear WG-111v2 Card A
Netgear WG-111v2 Card B
D-Link DWA-140
Netgear WPN111
Diamond Digital A101 Card A
Diamond Digital A101 Card B
Netgear MA101
D-Link DWL-122G
Atheros 5006UG in Asus EeePC701
Broadcom BCM4312 in MSI Wind U100 - 2.4Ghz
Broadcom BCM4312 in MSI Wind U100 - 5.0Ghz
Intel Centrino Wireless 2200BG in HP Pavillion dv4000
Intel Centrino Wireless 3945ABG in BenQ R55UV10 - 2.4Ghz
Intel Centrino Wireless 3945ABG in BenQ R55UV10 - 5.0Ghz
Intel Wi-Fi Link 5300 in HP Elitebook - 2.4Ghz
Intel Wi-Fi Link 5300 in HP Elitebook - 5.0Ghz
HTC Android Phone
Nokia N95
Roving Networks Wi-Fi Tag

- Monday 17th January 2011

Outdoor testing continued today. The weather, although predicted to be unfavourable, remained clear for the day. Unfortunately, today was cursed in a way. The battery in the PDA only managed to get 60% charged, and the eeePC 701 that I charged at home only decided that it had 30%, and so it was not able to be completely tested today.

Data was recorded for the BCM4312 in MSI Wind U100 manually, and for the Intel Centrino 2200BG and Belkin Play cards using the GPS method.

The Motormate inverter that we were using earlier had developed issues. While connecting it, I felt my hand tingle as if there was some sort of insulation problems. Worse still, the connector on it became loose and refused to hold onto the power adaptor very well. A replacement inverter had to be sought – and interestingly enough, it was borrowed from a fellow staff member who had some testing to do on Wednesday and required the inverter and a battery which we were using. We resolved to return the inverter and use the small batteries instead.

- Tuesday 18th January 2011

Outdoor testing continued again. This time, I've taken on the challenge to try and test five devices in a day. And I succeeded. But it drove me crazy and kept me at uni until 6pm. I resolved never to do so much at the same time.

We tested the Atheros 5006UG in the eeePC 701 in manual mode, and Netgear WG-111U, D-Link DWA-140, D-Link DWL-122G and Billion BiPAC3011G.

The hot sun, beating down on the laptops was making them behave a bit slower than usual, and inSSIDer had a habit of "freezing" and not being able to save the GPX file. This frustrated me a lot. However, GPS runs were just fine.

There was still no reply from any of the contacted manufacturers about signal strength readings. Thomas did send me a paper about device calibration for handheld phones which involve somewhat complex test procedures in an anechoic chamber. Unfortunately, we don't have the ability to do that, and I'm not sure how much of it is applicable to us.

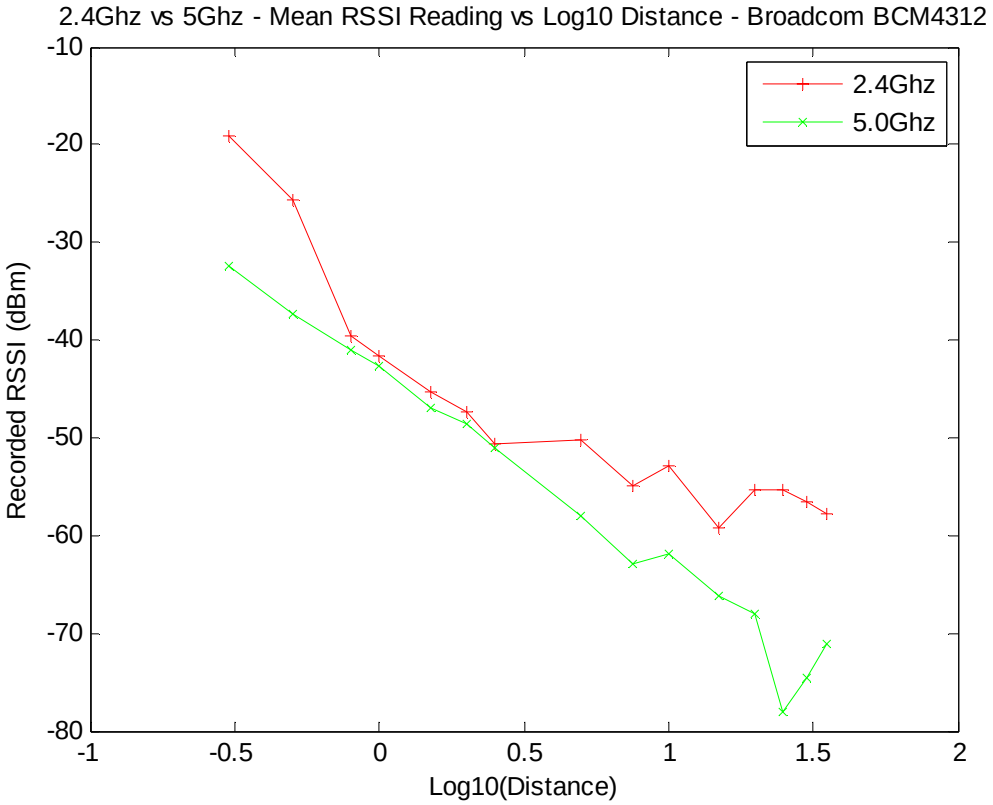
I did talk to Binghao about data analysis (which will be a big job, which I will save for later). I asked him about using the means and worrying about standard deviations or whether to use the mode (most popular value). My reasoning is that the mode will be the number you observe most, which should be pretty much the mean, discounting the effect of any spuriae which may not be filterable using sensible algorithms and will yield nice numbers (without many decimal points etc). He stated that there was a preference to use the means, although some other teams have used max readings instead – which, from our data, may not be a sensible idea.

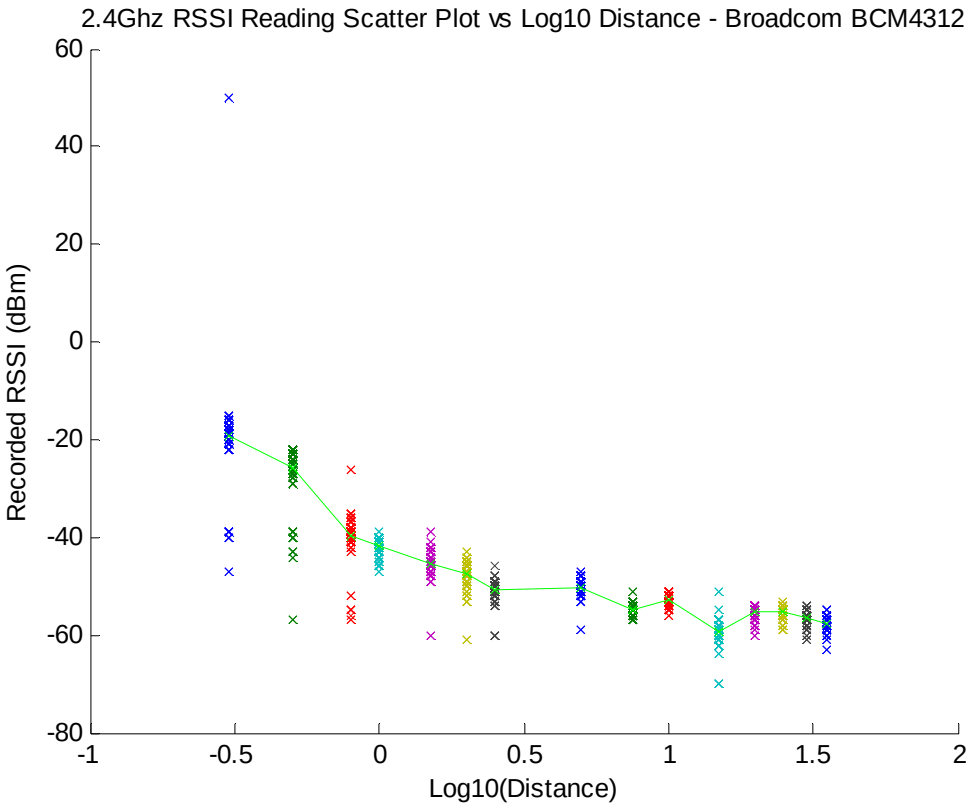
- Wednesday 19th January 2011

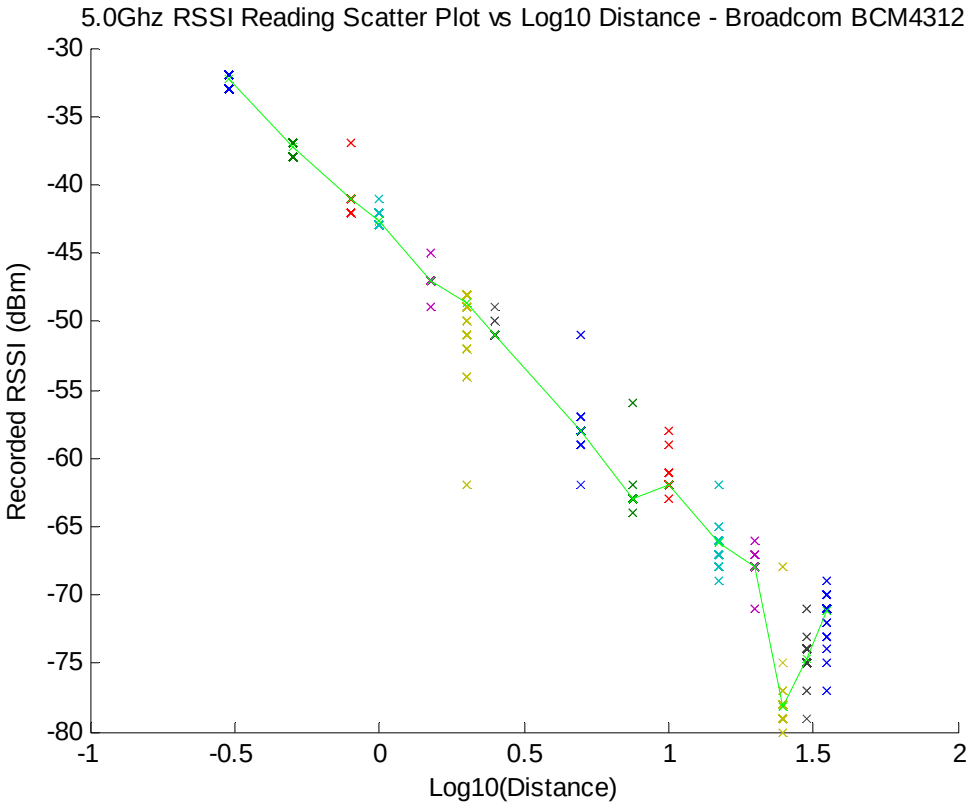
After some thought, it was decided to take Wednesday off for data analysis. We have collected a lot of data and I hadn't any time or resources to analyse it as I was going. So today, staying home and analyzing the data, we can verify the quality of the data and the other staff member can conduct their testing without my interference.

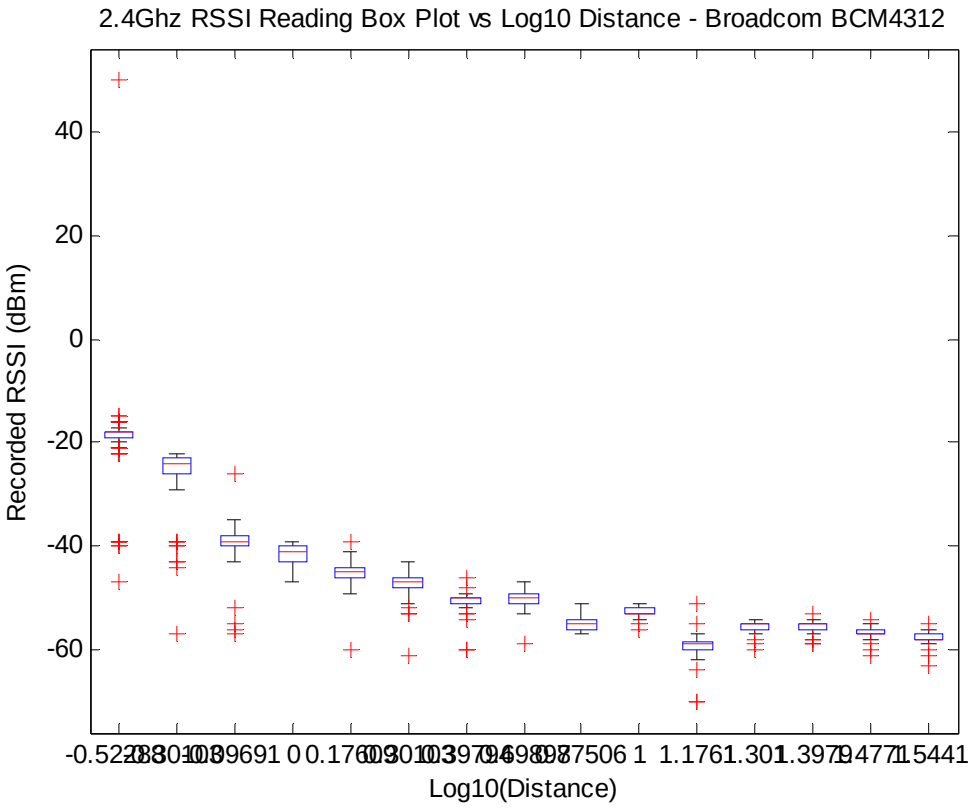
Results for testing Broadcom BCM4312 in MSI Wind U100 (test conducted in manual mode). You will notice that the sample numbers jump up and down quite a bit – part of this has to dow tih the laptop freezing a bit as the test commences and or finishes, the other has to do with the timing variation of me going to the laptop and clicking on the start/stop button. Overall, the 5Ghz line is lovely and straight for the most part, the 2.4Ghz is not too bad, but there was noise. The card, for 2.4Ghz, reported two points at 50dBm (yes, that's 50dBm not -50dBm – and it's not a flaw in my program as I found those samples in the GPX file) which was very unusual.

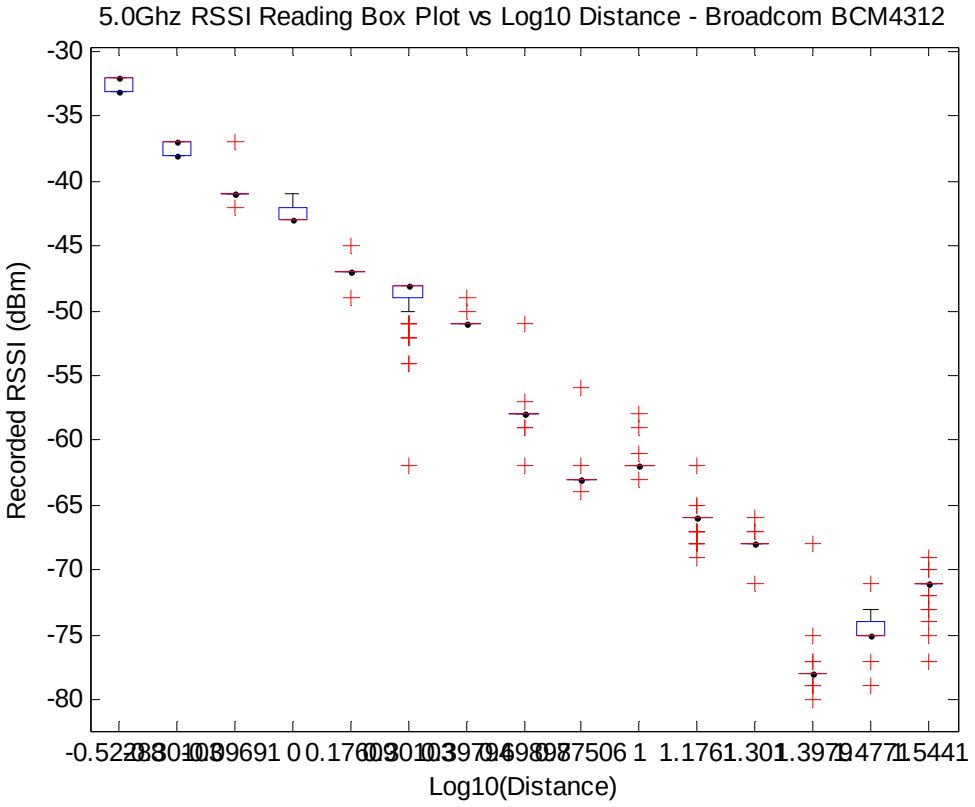
Distance	2.4Ghz	5Ghz
0.3m	265	265
0.5m	280	280
0.8m	268	272
1m	270	272
1.5m	262	268
2m	313	315
2.5m	265	265
5m	260	264
7.5m	261	265
10m	261	263
15m	304	312
20m	253	265
25m	255	265
30m	263	271
35m	270	274




2.4Ghz RSSI Reading Scatter Plot vs Log10 Distance - Broadcom BCM4312
Recorded RSSI (dBm)
60
40
20
0
-20
-40
-60
-80
-1
-0.5
0
0.5
1
1.5
2
Log10(Distance)

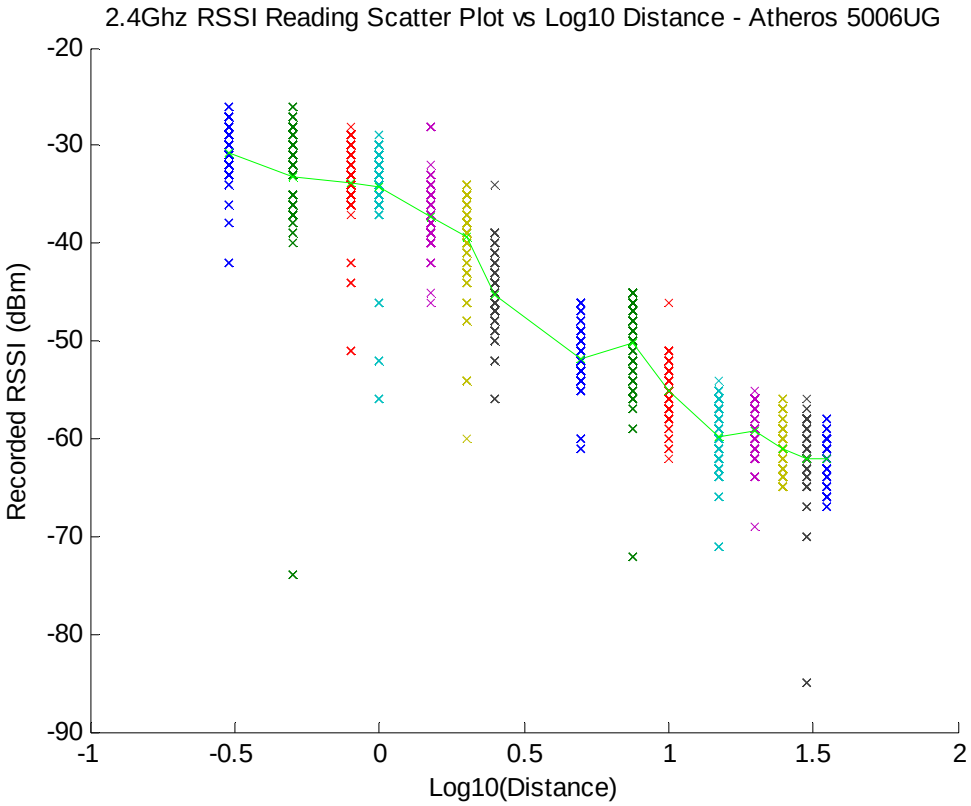

5.0Ghz RSSI Reading Scatter Plot vs Log10 Distance - Broadcom BCM4312
Recorded RSSI (dBm)
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-80
-1
-0.5
0
0.5
1
1.5
2
Log10(Distance)

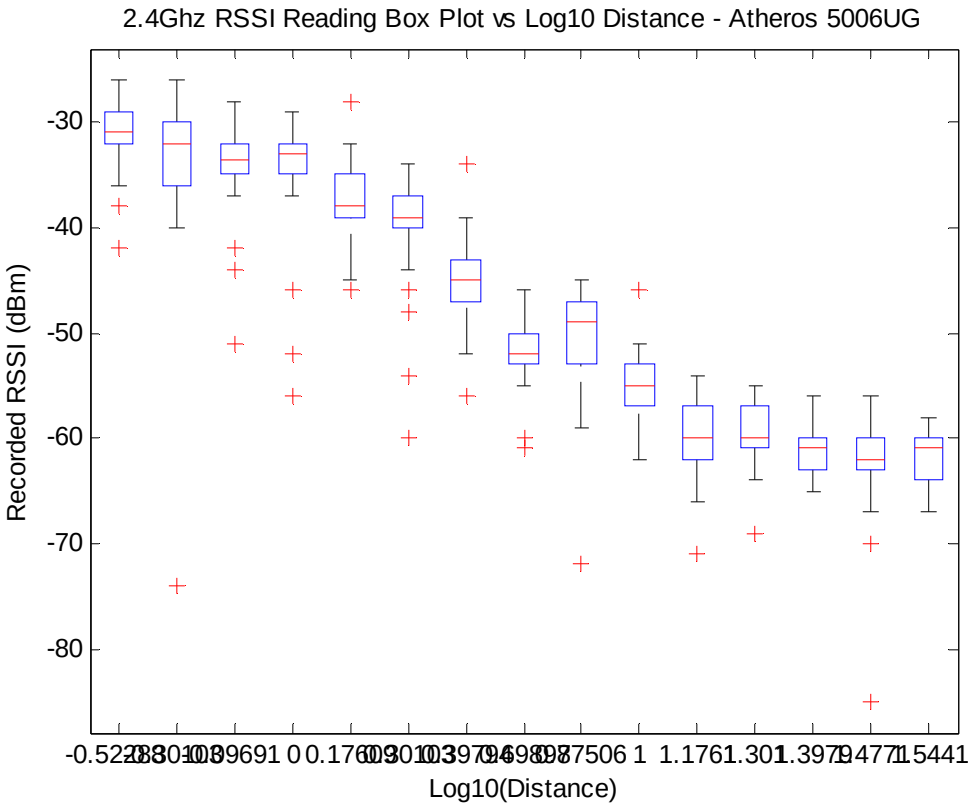

2.4Ghz RSSI Reading Box Plot vs Log10 Distance - Broadcom BCM4312
Recorded RSSI (dBm)
40
20
0
-20
-40
-60
-0.52
0
0.1761
1.1761
1.3010
1.3979
1.9477
2.1544
Log10(Distance)


5.0Ghz RSSI Reading Box Plot vs Log10 Distance - Broadcom BCM4312
Recorded RSSI (dBm)
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-80
-0.52
0
0.1761
1.1761
1.3010
1.3979
1.9477
2.1544
Log10(Distance)

Next up is test results from the Atheros 5006UG in the Asus EeePC701 tested in the manual mode. Again, the sample numbers vary wildly, and as the laptop is relatively underpowered, it falls quite drastically. Almost at every second point, I had to restart inSSIDer because it would lock up so hard that there was no way to recover from it without force quitting it. The signal output is pretty much reminiscent of a straight line, which is nice, with a reasonable amount of noise.

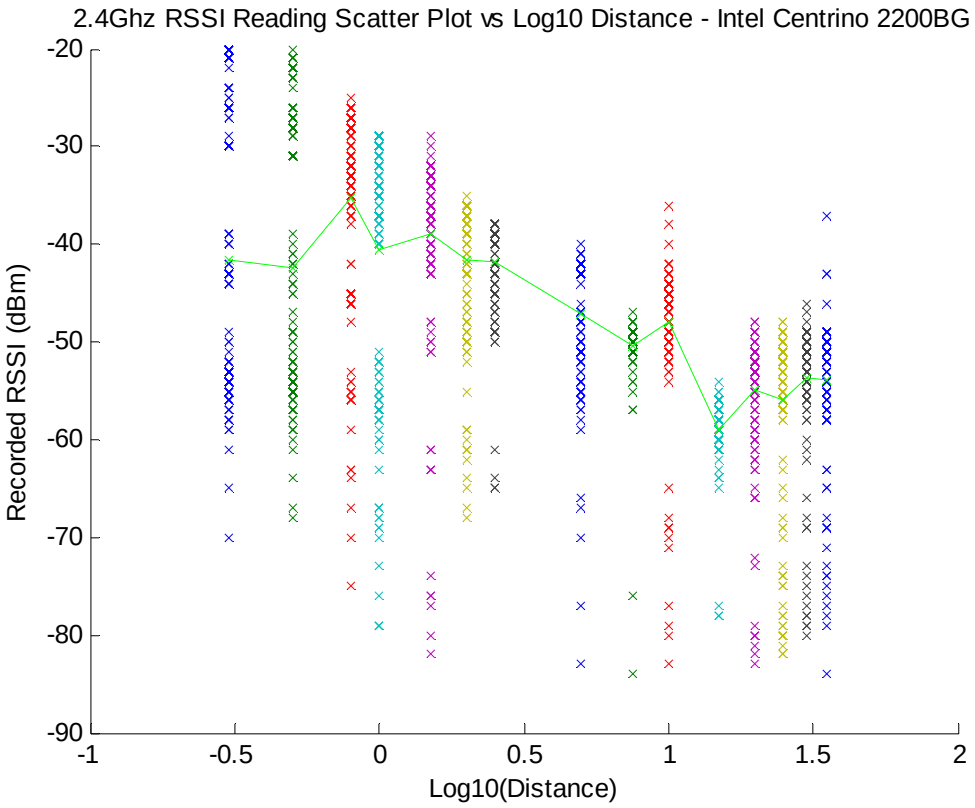
Distance	**2.4Ghz**
0.3m	225
0.5m	202
0.8m	178
1m	217
1.5m	188
2m	213
2.5m	190
5m	215
7.5m	222
10m	165
15m	202
20m	176
25m	205
30m	203
35m	202

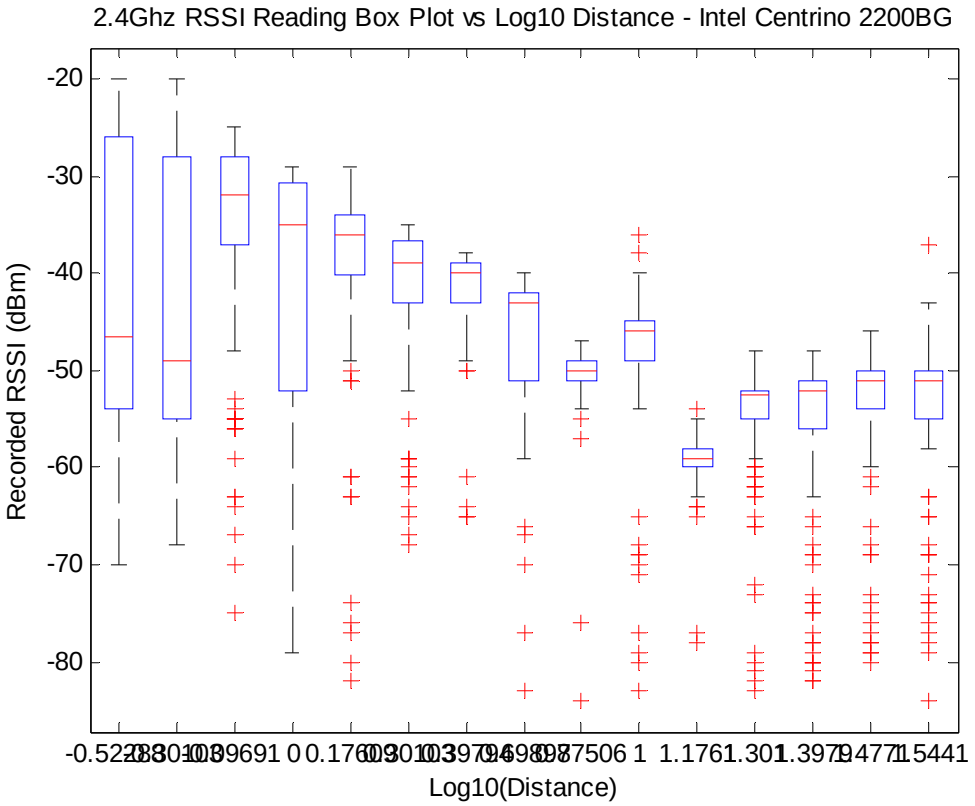




We now move onto the results from the Intel Centrino 2200BG card performed by GPS. Another underpowered laptop, we did not manage to get 200 samples in any case whatsoever, but all numbers are above 174. Again, this card has massive amounts of variation in strong signals, the trend is somewhat distorted.

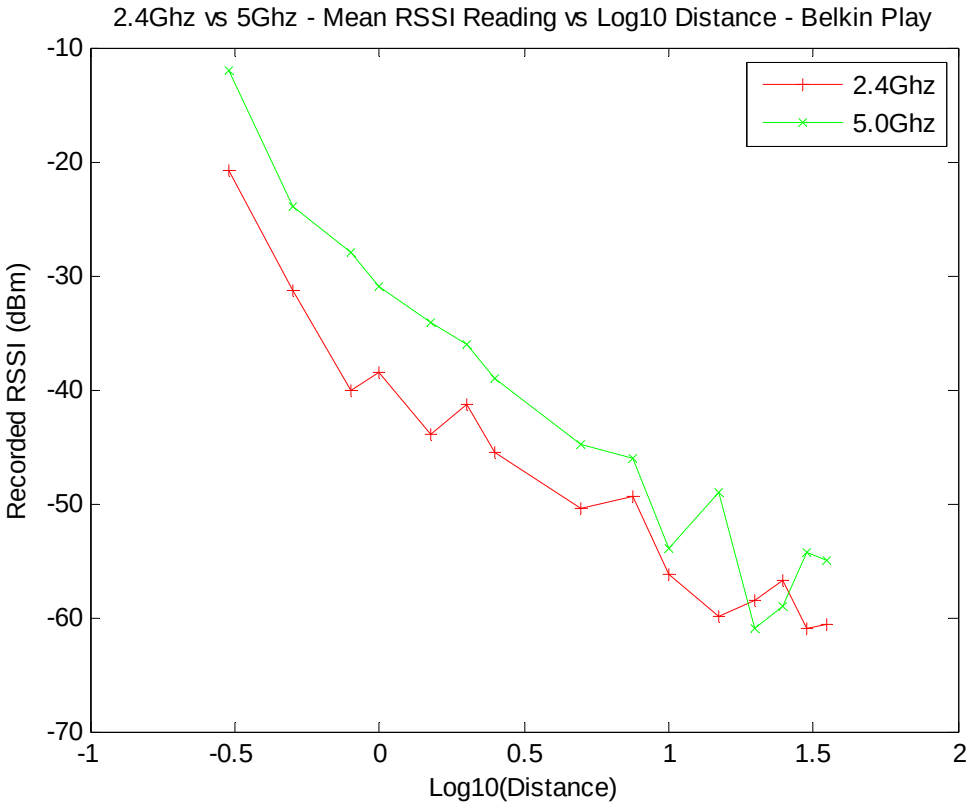
Distance	**2.4Ghz**
0.3m	194
0.5m	189
0.8m	187
1m	181
1.5m	177
2m	177
2.5m	175
5m	168
7.5m	189
10m	187
15m	182
20m	178
25m	175
30m	176
35m	174

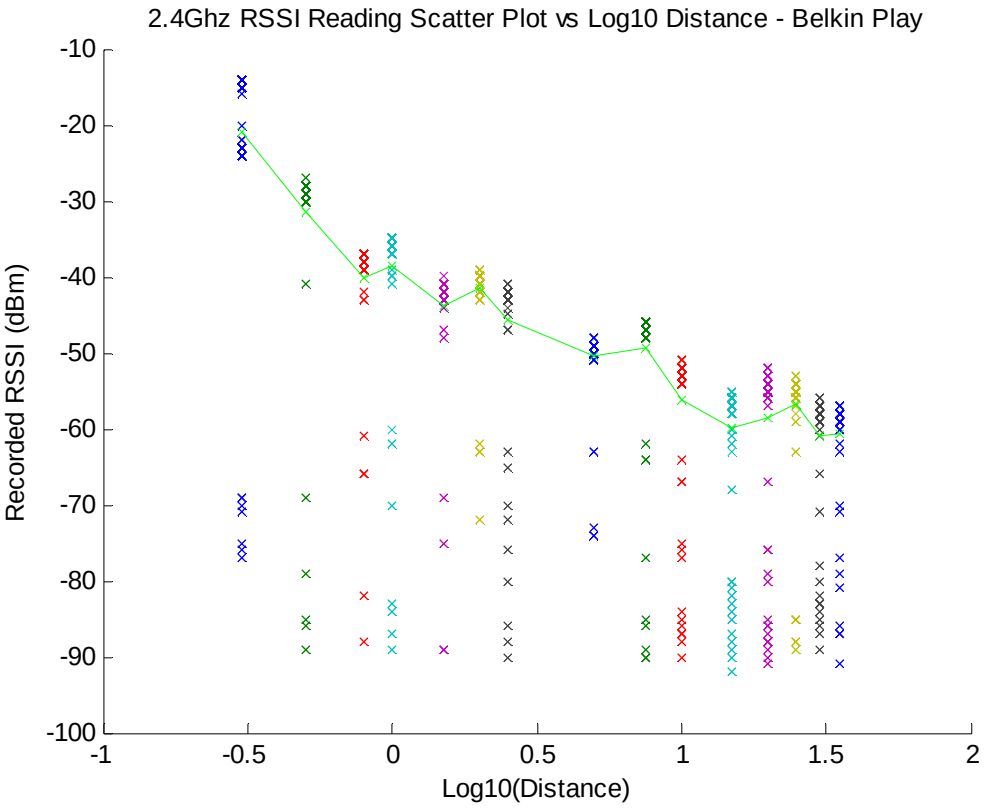

2.4Ghz RSSI Reading Scatter Plot vs Log10 Distance - Intel Centrino 2200BG
Recorded RSSI (dBm)
-20
-30
-40
-50
-60
-70
-80
-90
-1
-0.5
0
0.5
1
1.5
2
Log10(Distance)

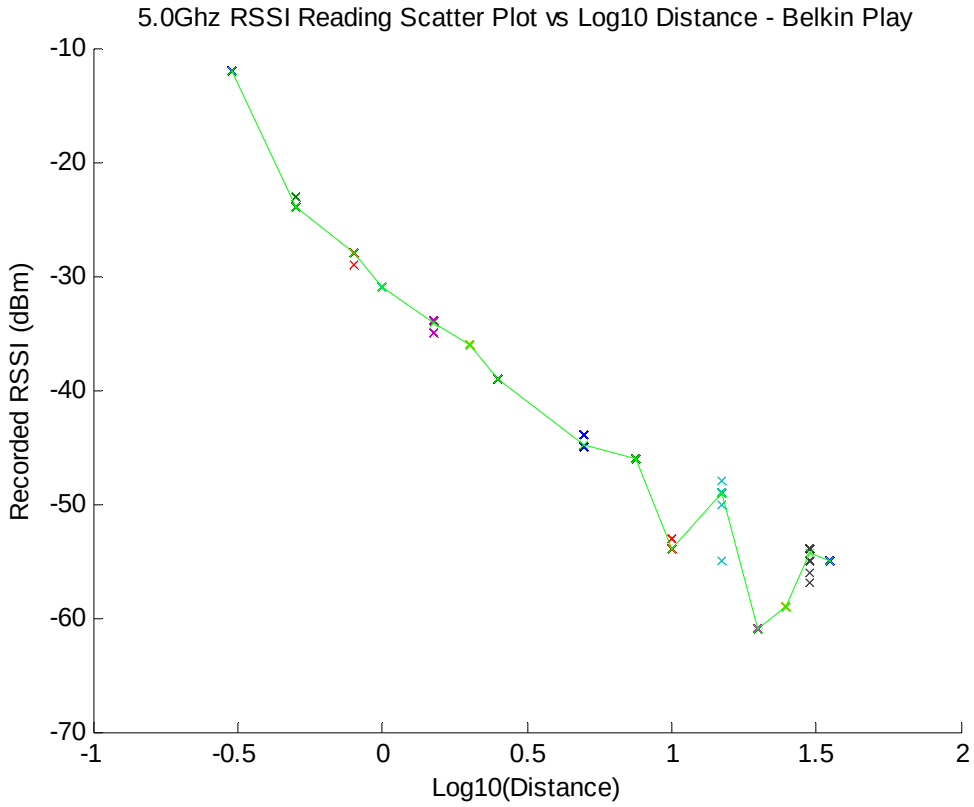

2.4Ghz RSSI Reading Box Plot vs Log10 Distance - Intel Centrino 2200BG
Recorded RSSI (dBm)
-20
-30
-40
-50
-60
-70
-80
1
1.1761
1.301
1.3979
1.4771
1.5441
Log10(Distance)

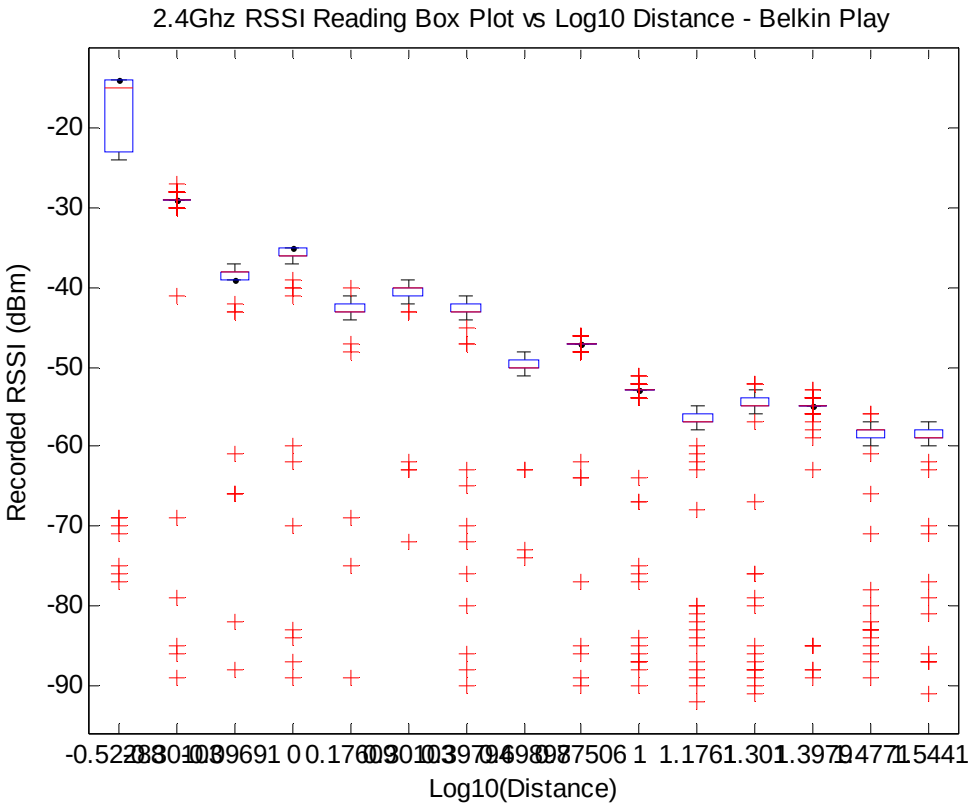
Here are the results from the Belkin Play done in GPS. All samples are above 200, which is healthy, and the unusual characteristic of this card where 5Ghz appears stronger than 2.4Ghz is again reflected in the results. The standard noise we get from this card is still here, but the 5Ghz is almost unbelievably clean.

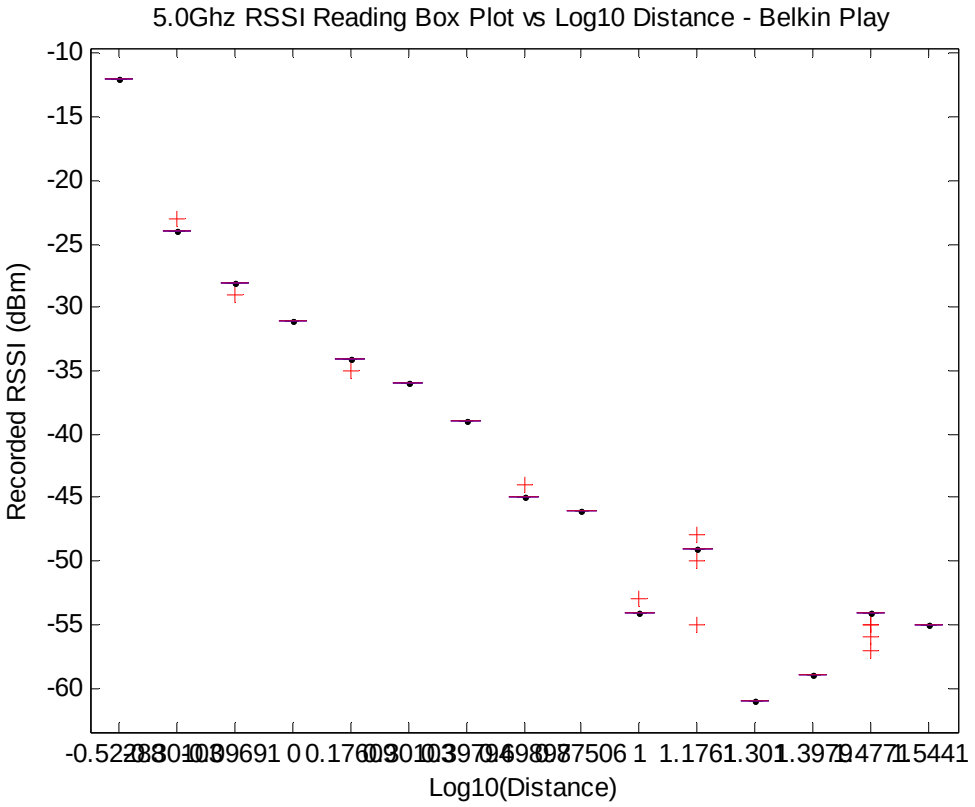
Distance	2.4Ghz	5Ghz
0.3m	221	221
0.5m	220	220
0.8m	218	218
1m	216	216
1.5m	215	215
2m	211	211
2.5m	212	212
5m	211	209
7.5m	224	224
10m	224	224
15m	221	221
20m	218	220
25m	217	217
30m	215	215
35m	212	214




2.4Ghz RSSI Reading Scatter Plot vs Log10 Distance - Belkin Play
Recorded RSSI (dBm)
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-1
-0.5
0
0.5
1
1.5
2
Log10(Distance)

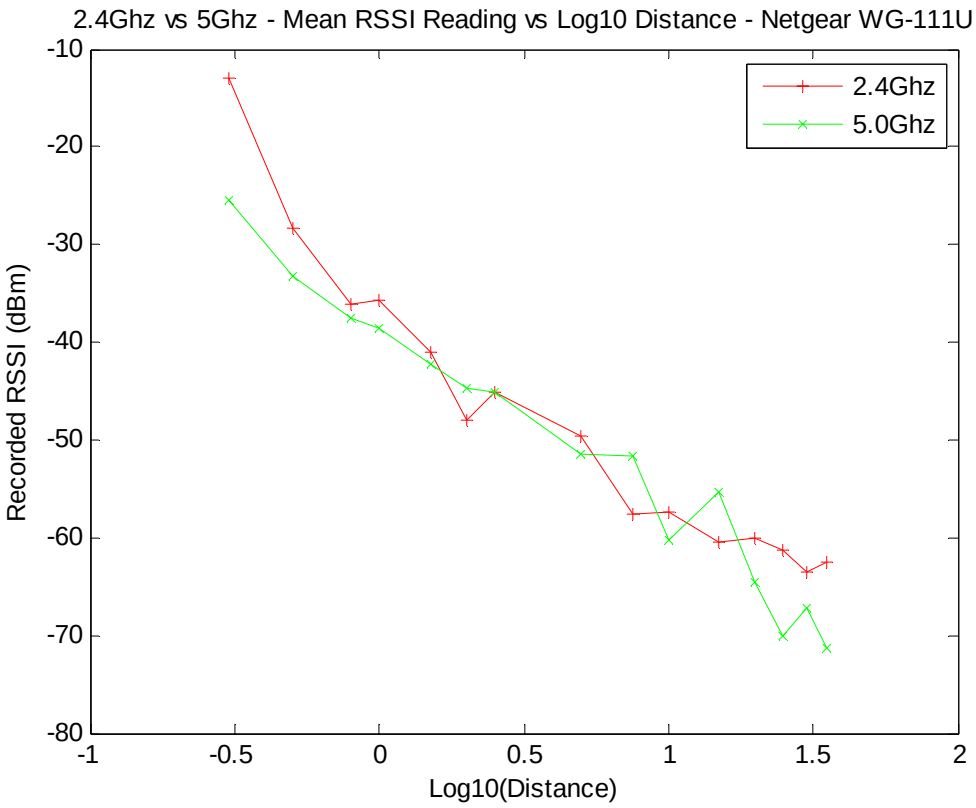

5.0Ghz RSSI Reading Scatter Plot vs Log10 Distance - Belkin Play
Recorded RSSI (dBm)
-10
-20
-30
-40
-50
-60
-70
-1
-0.5
0
0.5
1
1.5
2
Log10(Distance)

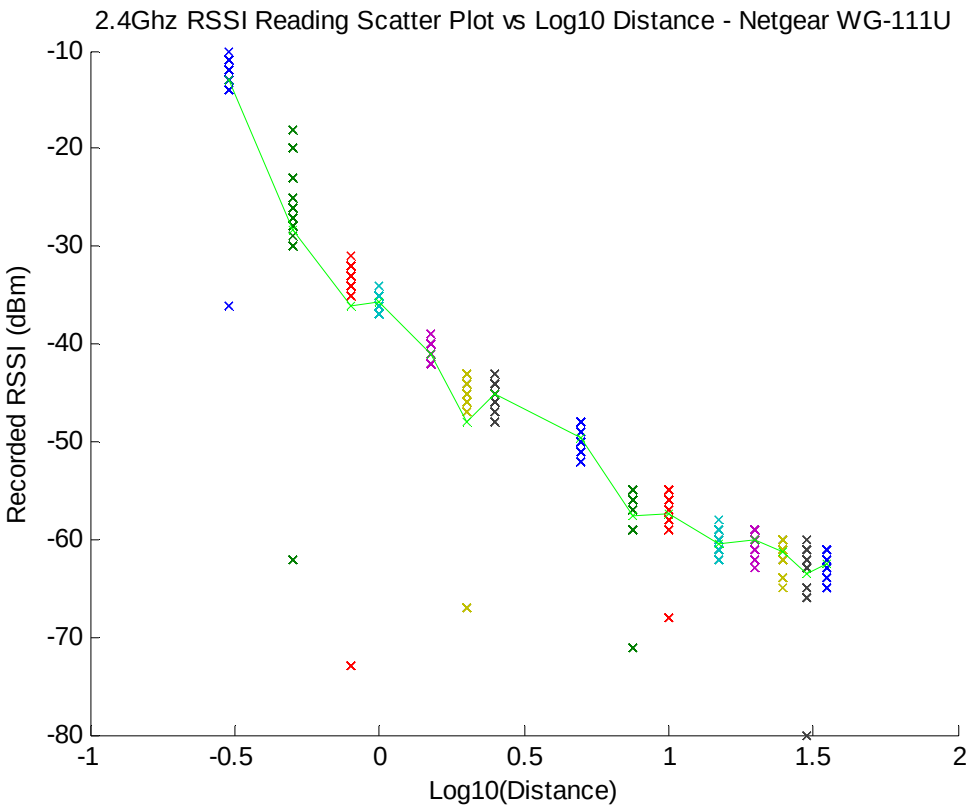

2.4Ghz RSSI Reading Box Plot vs Log10 Distance - Belkin Play
Recorded RSSI (dBm)
-20
-30
-40
-50
-60
-70
-80
-90
-0.52
0
0.17609
0.30103
0.39794
0.49897
0.87506
1
1.1761
1.301
1.3979
1.4771
1.5441
Log10(Distance)

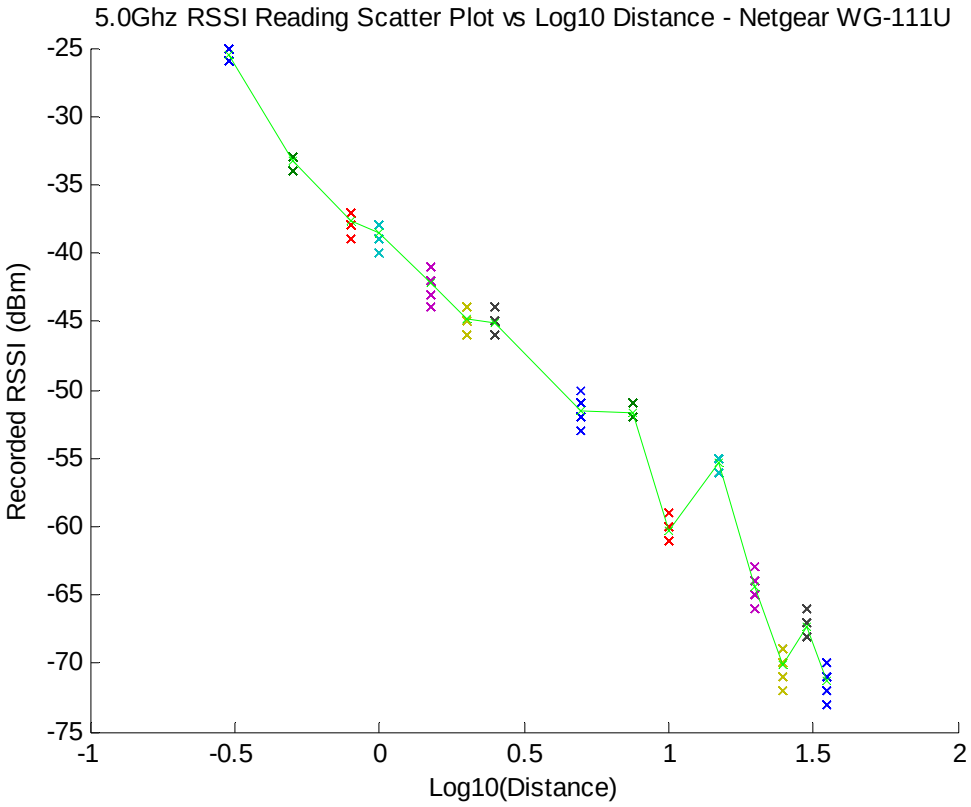

5.0Ghz RSSI Reading Box Plot vs Log10 Distance - Belkin Play
Recorded RSSI (dBm)
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-0.52
0
0.17609
0.30103
0.39794
0.49897
0.87506
1
1.1761
1.301
1.3979
1.4771
1.5441
Log10(Distance)

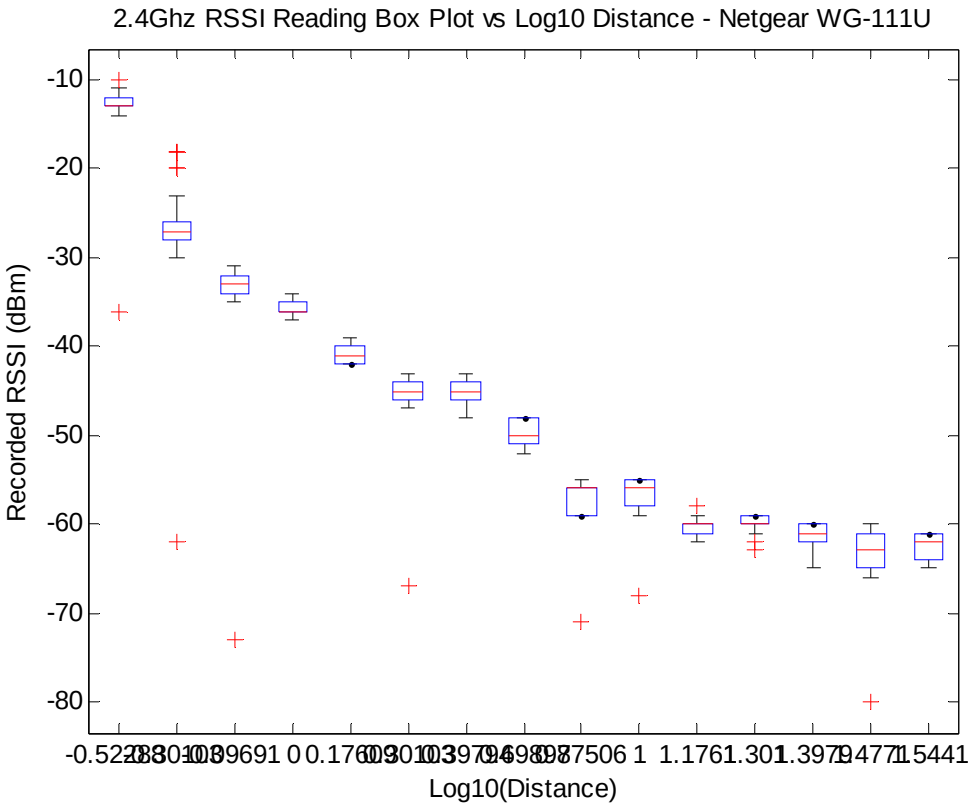
Now, the Netgear WG111U also done by GPS doesn't fare as well. The numbers for both 5 and 2.4Ghz are the same since there's some sort of "caching" going on as I discussed earlier. The numbers do fall to 188 samples though. Both lines are reminiscent of straight lines, and it appears unusually clean. The 2.4Ghz line actually seems to reflect a exponential decay instead.

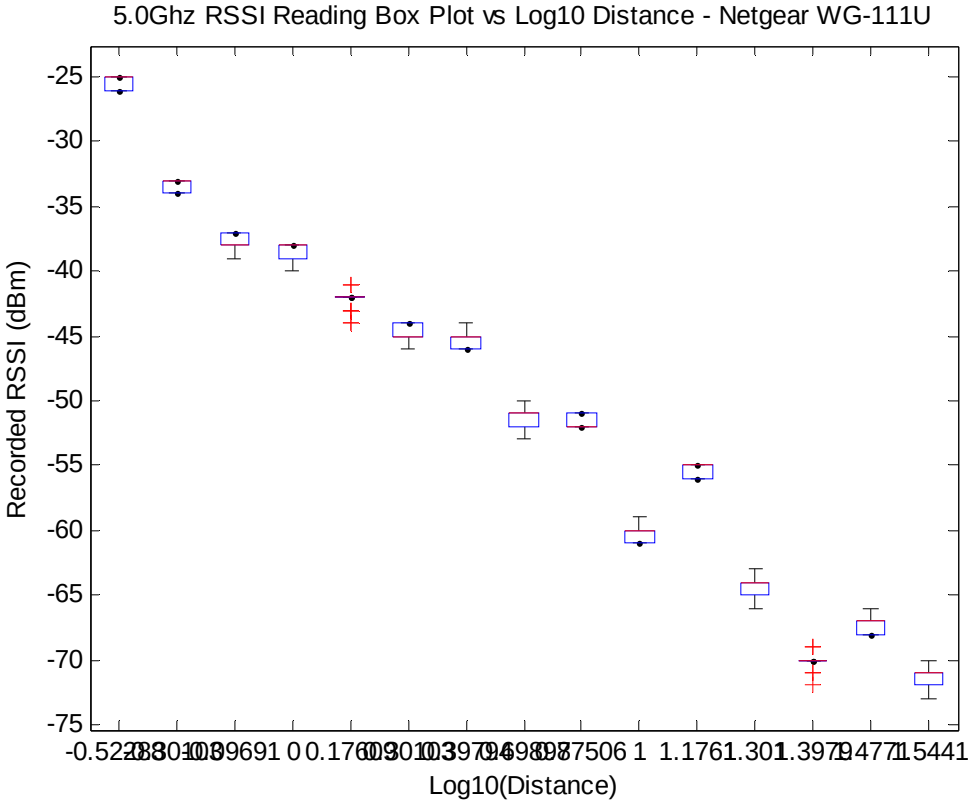
Distance	**2.4Ghz**	**5Ghz**
0.3m	206	206
0.5m	205	205
0.8m	202	202
1m	197	197
1.5m	195	195
2m	194	194
2.5m	189	189
5m	184	184
7.5m	207	207
10m	205	205
15m	203	203
20m	199	199
25m	194	194
30m	191	191
35m	188	188




2.4Ghz RSSI Reading Scatter Plot vs Log10 Distance - Netgear WG-111U
Recorded RSSI (dBm)
-10
-20
-30
-40
-50
-60
-70
-80
-1
-0.5
0
0.5
1
1.5
2
Log10(Distance)

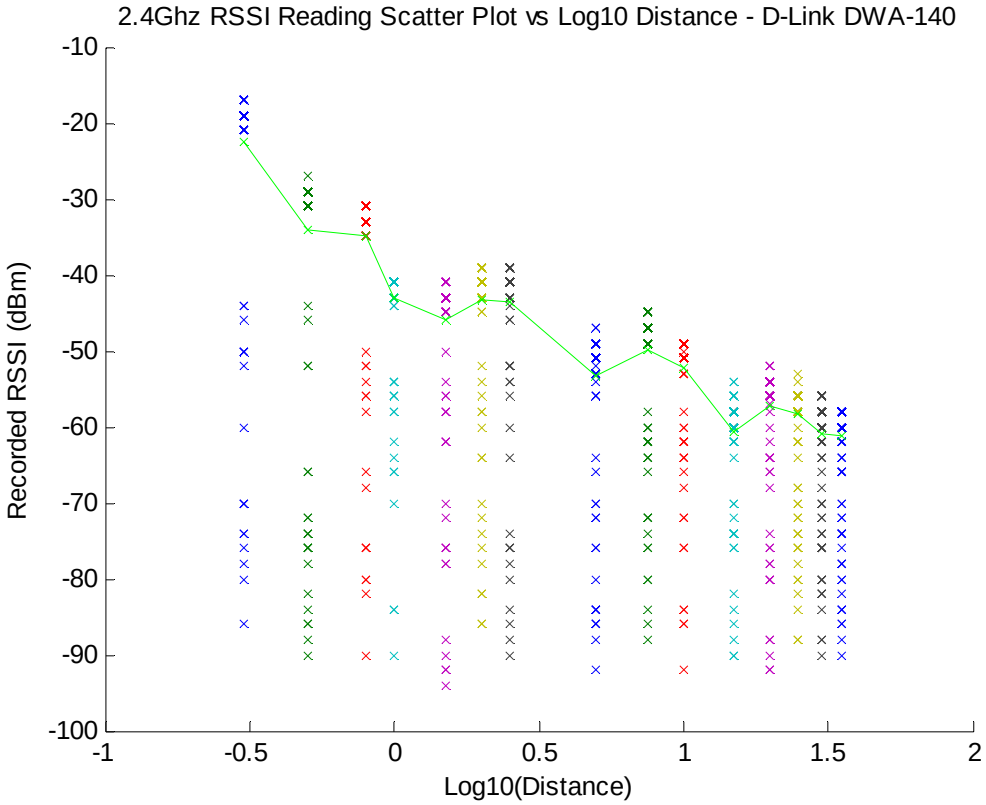

5.0Ghz RSSI Reading Scatter Plot vs Log10 Distance - Netgear WG-111U
Recorded RSSI (dBm)
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-1
-0.5
0
0.5
1
1.5
2
Log10(Distance)

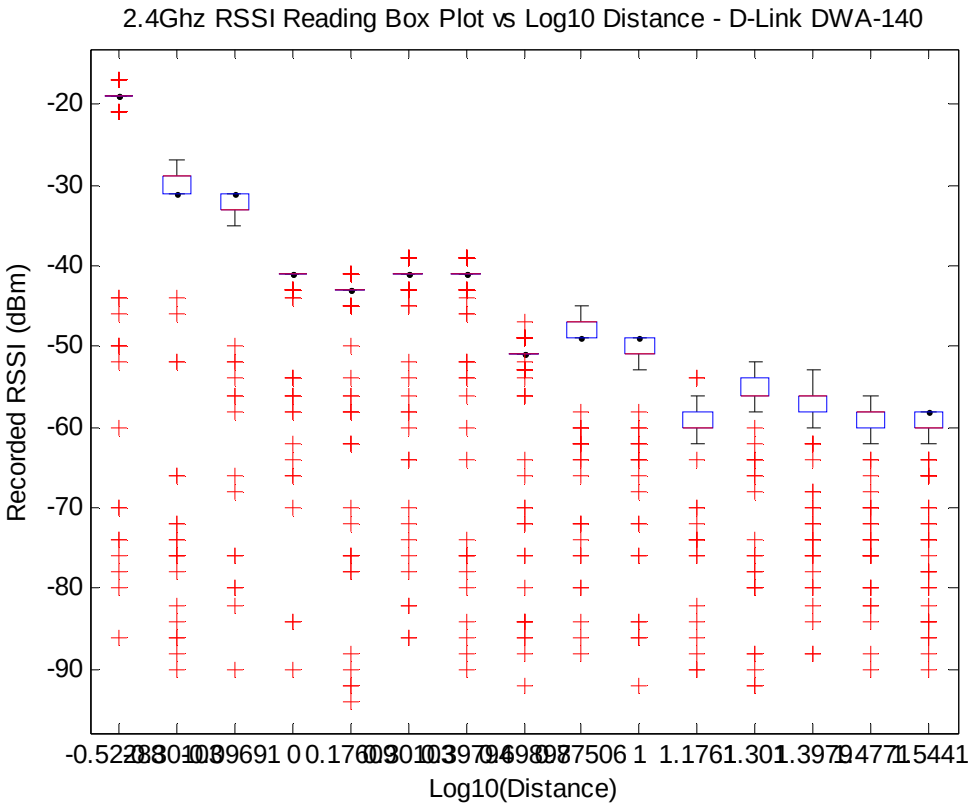

2.4Ghz RSSI Reading Box Plot vs Log10 Distance - Netgear WG-111U
Recorded RSSI (dBm)
-10
-20
-30
-40
-50
-60
-70
-80
Log10(Distance)


5.0Ghz RSSI Reading Box Plot vs Log10 Distance - Netgear WG-111U
Recorded RSSI (dBm)
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
Log10(Distance)

Now we come to the single band D-Link DWA-140 Wireless N card. Number of samples are healthy, with a large amount of noise as usual. Trend is quite bumpy.

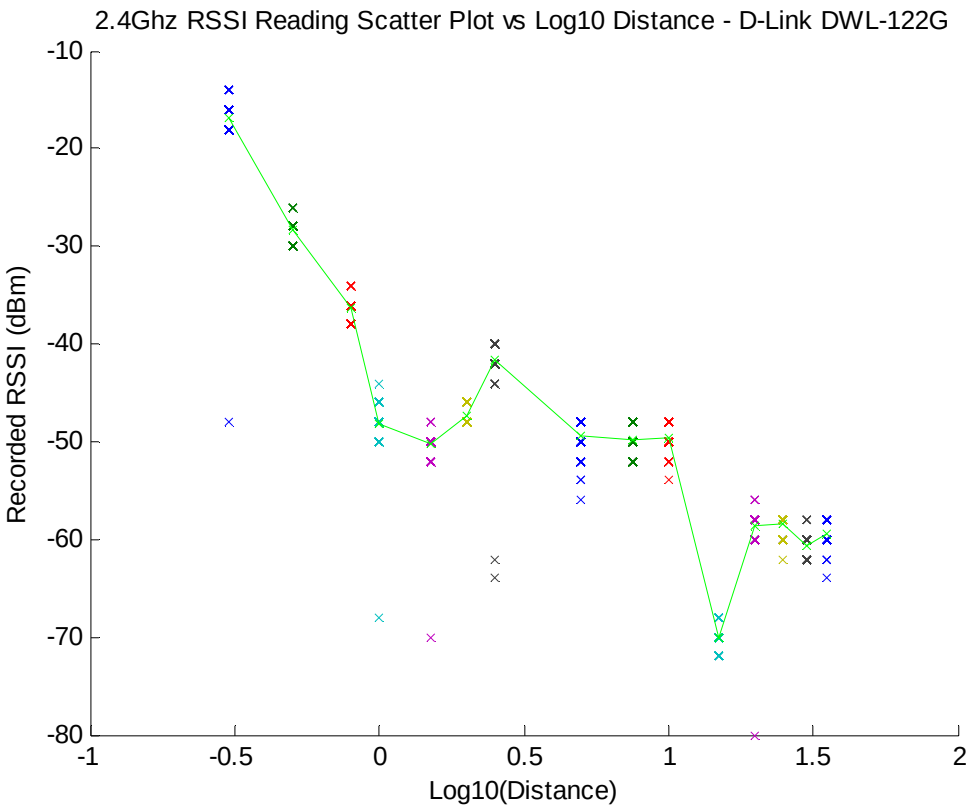
Distance	2.4Ghz
0.3m	218
0.5m	216
0.8m	217
1m	215
1.5m	212
2m	214
2.5m	209
5m	208
7.5m	219
10m	220
15m	218
20m	222
25m	228
30m	231
35m	254

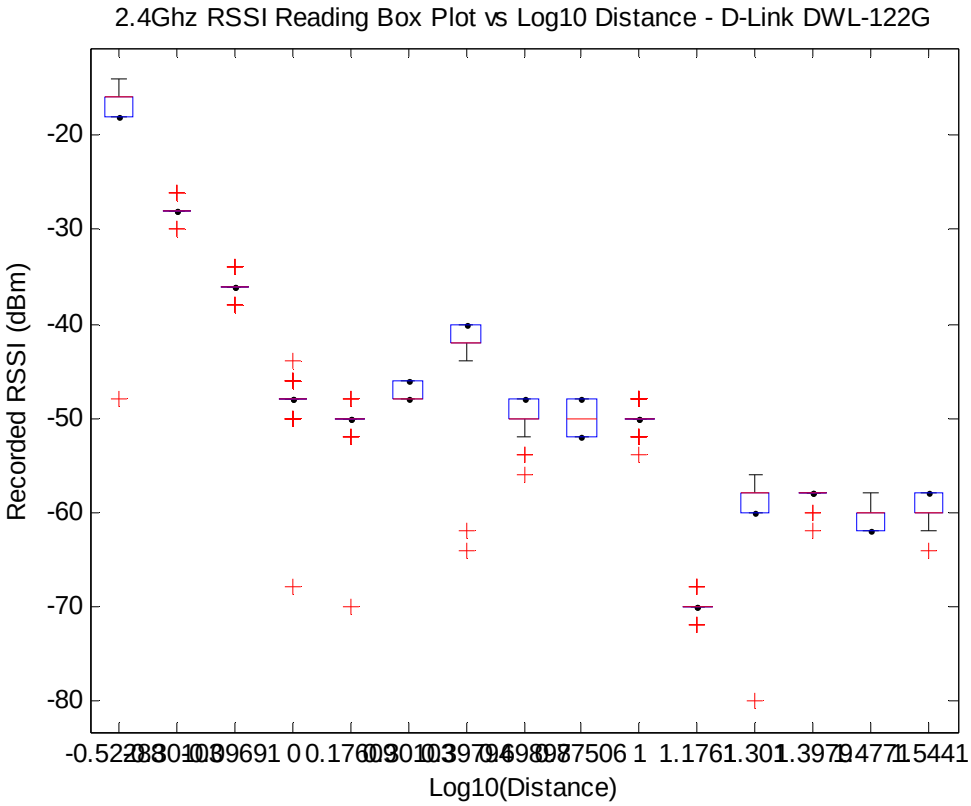




The D-Link DWL-122G also has sample numbers which are healthy and a trend which is bumpy – this time, more bumpy than before, but there is less noise.

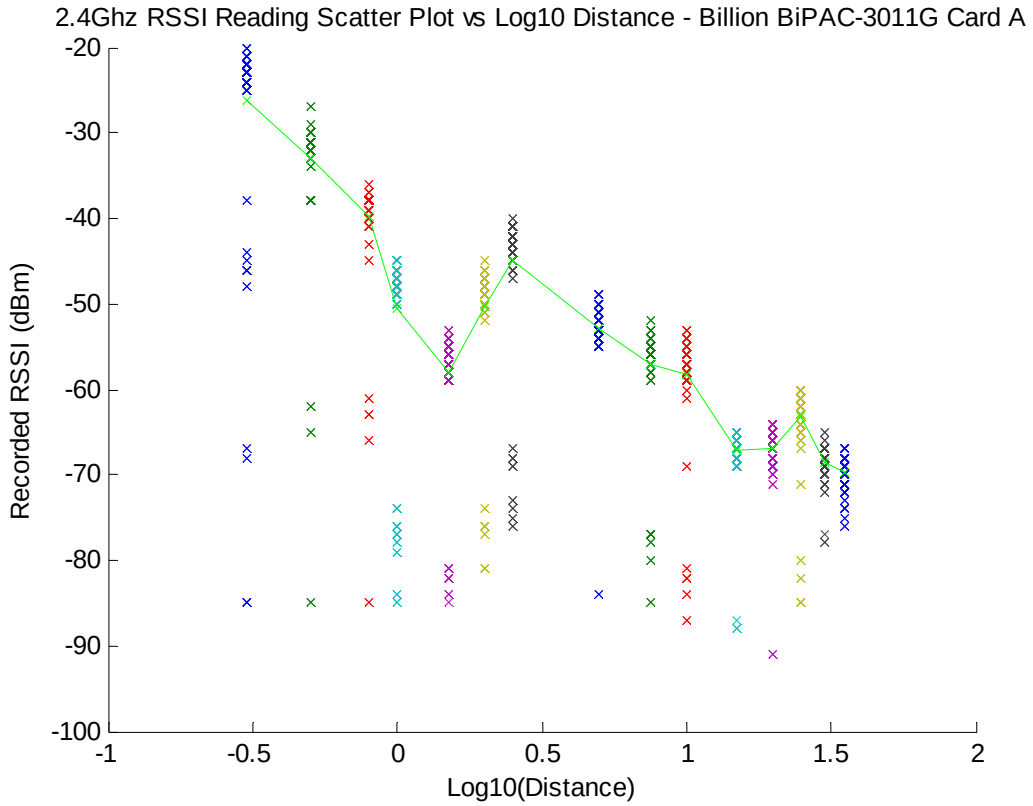
Distance	**2.4Ghz**
0.3m	228
0.5m	224
0.8m	224
1m	226
1.5m	222
2m	224
2.5m	225
5m	219
7.5m	226
10m	229
15m	223
20m	220
25m	227
30m	225
35m	221

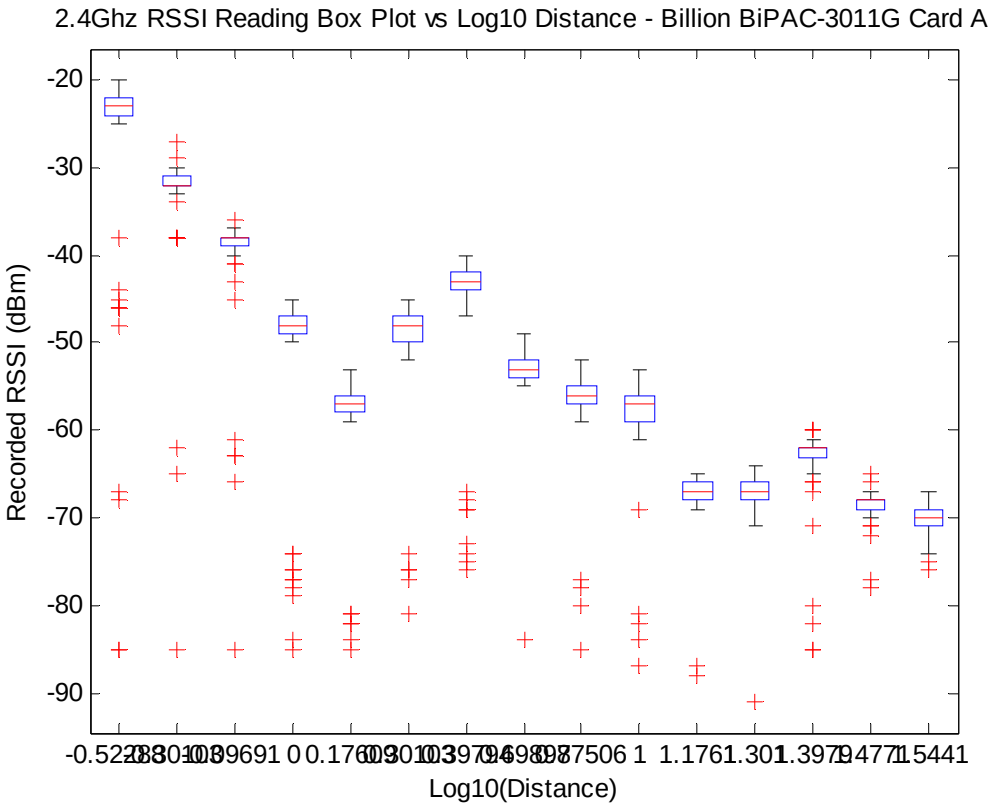

2.4Ghz RSSI Reading Scatter Plot vs Log10 Distance - D-Link DWL-122G
Recorded RSSI (dBm)
-10
-20
-30
-40
-50
-60
-70
-80
-1
-0.5
0
0.5
1
1.5
2
Log10(Distance)


2.4Ghz RSSI Reading Box Plot vs Log10 Distance - D-Link DWL-122G
Recorded RSSI (dBm)
-20
-30
-40
-50
-60
-70
-80
Log10(Distance)

Finally, we come to the Billion BiPAC-3011G Card A, also with healthy sample numbers – and a bumpy trend. If you notice where the bumps in the trend are – they correlate quite well with the bumps in the trend in the card above.

Distance	2.4Ghz
0.3m	224
0.5m	222
0.8m	219
1m	216
1.5m	215
2m	217
2.5m	212
5m	211
7.5m	223
10m	223
15m	217
20m	221
25m	217
30m	216
35m	212





The progress so far for outdoor testing:

Number	Card	Status
1	Belkin Play	Tested
2	Netgear WG111U	Tested
3	Billion BiPAC 3011G –A	Tested
4	Billion BiPAC 3011G –B	Low Priority
5	Billion BiPAC 3011G –C	Low Priority
6	Netgear WPN111	Waiting
7	Netgear WG111v2 – A	Waiting
8	Netgear WG111v2 – B	Low Priority
9	D-Link DWA-140	Tested
10	D-Link DWL-122G	Tested
11	Netgear MA101	Low Priority
12	Diamond Digital A101 –A	Waiting
13	Diamond Digital A101 –B	Low Priority
14	Broadcomm BCM4312	Tested
15	Intel Centrino 3945ABG	Tested
16	Intel Centrino 2500BG	Tested
17	Atheros 5006UG	Tested
18	Android Mobile Phone	Special
19	Roving Networks Wireless Tag	Special
20	Intel Wifi Link 5300	Tested
21	Nokia N95	Special

For further analysis for the paper – here are some hypothesis that I hope to be able to use the data to analyse:

- Multiple cards of the same make do not differ significantly.
- Cards with multiple antennas have less signal variations (difficult).
- Cards from the same manufacturer are much more alike than others.
- Significant differences between different manufacturers.
- Less variance on 5Ghz than 2.4Ghz.
- Some cards have less variance than others.
- Some cards are not useful for fingerprinting.

Once all the data is collected, I will produce a plot-all for outdoor. Furthermore, I will have to tabulate means, modes, standard deviations for each point as well.

- Thursday 20th January 2011

Today, I tested the Billion BiPAC 3011G Card B and C, and also the Netgear WG111v2 Card A and B.

- Friday 21st January 2011

Today, I tested the Netgear WPN111, Netgear MA101, and also the Diamond Digital A101 Card A and B. This completes all the testing for my gear. Analysis will be pending. Three special devices will be tested on Monday.