RESEACH

MEASUREMENTS OF RADIOWAVE SIGNAL STRENGHT AND PATH LOSS PROPAGATION USING EGLI MODEL

By:

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TITLE:

Measurement Of Radiowave Signal Strength And Path Loss Propagation Using Egli Model.

ABSTRACT:

The research is done to measure the radio frequency (RF) signal strength in the field and interpreting the results as radio signal coverage. Measurements are collected at random locations at the La Trobe University, Bundoora Campus. These collected measurements will be used and compare to the calculated strength signal by using Egli Model.

To achieve it, the coordinates (Easting and Northing) of each location recorded using a hand held GPS receiver. The signal strength that transmitted from transceiver to base station at each location will be measured using Field Strength Analyser.

As a final result after being analysed, it gives radiowave signal coverage and also path loss propagation in the area.

1. INTRODUCTION

In radio communication network, the measurement of radio frequency (RF) field strength is an important aspect in design, operation, and maintenance. We can measure the electric field strength by measure it in V/m, mV/m or µV/m units depending on its strength. Beside these units, we also can measure it by receive signal level (RSL) in dBm unit to express radio signal coverage and in this research, this unit being used in measurements.

The aim of the research is to measure the radiowave signal strength and validate the Egli's path loss propagation model for La Trobe University, Bundoora Campus environment. This field work measurement give a researcher a real practice on radiowave signal strength analysis.

A number of radio frequency field strength measurements taken for a Base Station (BS) and Mobile Station (MS) roaming in the campus. The measurements from the Field Strength Analyser that recorded will be compared to calculated values of Receive Signal Level using Egli model. For information, Egli model is used in estimating radio frequency coverage over short distance (a few kilometres).

When measuring the signal strength, as a general guide, the voice quality should be noted as an indication of the receive radio signal power at the various locations.

2. METHOD

The general idea is the Mobile Station (MS) transmit the radio frequency (RF) signals using hand-held transceiver (also refer to walkie talkie) at random location in the campus ground. This signal then will be received by the scanner antenna at the rooftop of Beth Glessen Building that connected to Field Strength Analyser to show the receive signal level in dBm.

The collected data will be in the form of pairs of variables, a receive signal level (RSL) in dBm and a set of site coordinates in Australian Map Grid (AMG) Easting and Northing.

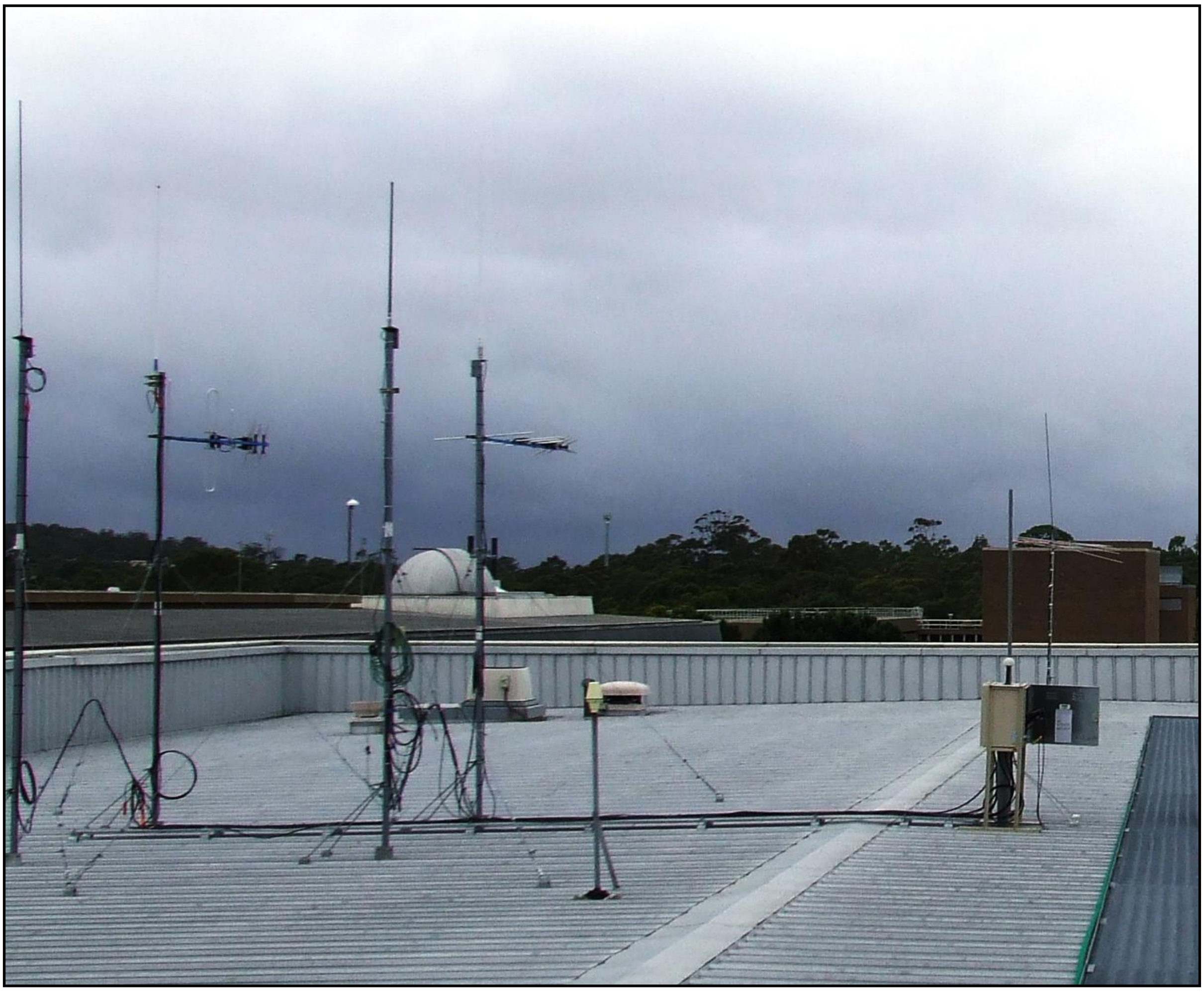


Figure 1: Antennas on the Rooftop of BG Building as a Base Station – One of these antennas is the scanner antenna that connected to Field Strength Analyser

2.1. Antennas.
Figure 1 shows several of antennas mounted on the rooftop of Beth Gleeson Building. The antenna that be used is the UHF Citizen Band (CB) and the scanner (25 - 1300 MHz).

The former connected to the UHF CB transceiver for communication with the mobiles and the latter will be connected to a Field Strength Analyser meter.

2.2. Equipment.
The equipments used are listed below.
i. Protek 3290 RF Field Strength Analyser Figure 2 (one unit)
ii. Uniden UH-012 5W transceiver Figure 3 (one unit, used as a Base Station)
iii. Uniden UH036SX 0.5W hand-held transceivers Figure 4
iv. Magellan eXplorist 100 GPS receiver Figure 5

Figure 2: Protek 3290 Field Strength Analyser

Figure 3: Uniden UH-012 5W transceiver (two-way radio)

Figure 4: Uniden UH036SX-0.5W hand-held transceivers (walkie-talkie) and also as a Mobile Station (MS)

Figure 5: Magellan eXplorist 100 GPS Receiver

2.3. System Setup.

i. Connect Protek RF Field Strength Analyser to the scanner antenna on BG rooftop.

ii. Connect Uniden UH-012 (BS) to CB antenna on BG rooftop.

iii. Equipments with hand held transceiver or walkie talkie as Mobile Station (MS) and GPS.

2.4. System parameters.

The following system parameters are used in the calculation and analysis of the systems performance.

i. Calculation RF frequency: 477 MHz

ii. Base station output power: 5 Watts

iii. BS feeder loss: 2dB

iv. Antenna gain for both Protek and MS (0dBd)

v. Protek and BS antenna height: 16 m

vi. Protek feeder loss: 2dB

vii. MS antenna height: 1.5 m (Pedestrian)

viii. MS RF feeder loss (negligible)

ix. Rooftop antennas coordinate: Zone 55, 327761 E, and 5823131 N

x. Antenna gain for MS (0dBd)

2.5. Procedure.

The procedure for taking the field measurements are listed below.

i. Head to four direction from BG building, within the campus area as attached
- Head to North and record the measurement
- Head to South and record the measurement
- Head to East and record the measurement
- Head to West and record the measurement

The channel being used is channel 20 (476.900 MHz).

For each direction obtain about ten readings.

i. Switch on the GPS receiver and wait for a while to track satellites
ii. Choose a location at random, listen of the allocated channel, when the channel is free, and make a call to BS to take a measurement,
iii. Upon request from BS operator, press and hold the transmit button for about five seconds, (silence, no speaking in the microphone)
iv. The group record Easting and Northing coordinates and receive signal power in dBm, as given by BS operator, and then move on to the next location
v. The above steps repeat for other direction
vi. Finally, all results will be aggregated into a single result sheet

3. RESULTS

The result is an aggregate of all measurements obtained from various direction and location. The results then tabulated in three columns, Easting, Northing, and RSL in dBm. The coordinates of the rooftop antennas is a reference. To obtain the distance from each measurement location to the reference point by using the distance equation below:

Distance, $d_i = \sqrt{(Er - Ei)^2 + (Nr - Ni)^2}$ --- distance equation

Where *di* is the distance from the i^{th} measurement location to the reference point, and *Er* and Nr are the coordinates of the reference point and *Ei* and Ni are the coordinates of the i^{th} measurement point. Using Equation 3.1, a new table is generated containing the receive signal power in dBm against distance in ascending order. The table is then plotted x distance and y receive signal level.

By using Egli's model, then calculated the path loss and calculate the receive signal level as seen by Field Strength Analyser due to transmission from the walkie-talkie. The results are compared with that obtained by measurements.

3.1: Result from the measurement

Easting	Northing	RSL (dBm)	Path Length (m)
327746	5823152	-66	23
327777	5823158	-66	40
327696	5823141	-77	54
327792	5823094	-77	55
327683	5823142	-85	67
327806	5823174	-76	73
327712	5823199	-72	79

327785	5823206	-89	85
327684	5823185	-81	86
327730	5823213	-80	86
327700	5823226	-75	109
327703	5823228	-80	109
327738	5823013	-83	117
327617	5823159	-73	135
327882	5823165	-87	138
327757	5822985	-83	144
327699	5823265	-68	145
327732	5823282	-98	154
327892	5823194	-91	157
327903	5823178	-86	162
327916	5823157	-86	169
327892	5823017	-87	182
327889	5823012	-95	182
327560	5823129	-85	189
327708	5823339	-79	214
327746	5822915	-85	214
327540	5823080	-81	215
327673	5823339	-79	223
327511	5823082	-87	243
327548	5822963	-83	261
327849	5822879	-78	269
328022	5823182	-92	278
327910	5822900	-85	280
327717	5823413	-90	286
328038	5823208	-89	300
327980	5822889	-86	333
327697	5823466	-95	341
327465	5822936	-87	343
327674	5823501	-84	379
328080	5822910	-94	397
327336	5822873	-95	486
328255	5822977	-95	528
328279	5823280	-98	551
328337	5823012	-90	600
328369	5823176	-93	622
327261	5822683	-91	661
327127	5822536	-86	859

Table 1: Receive Signal Level (dBm) from the measurement for various location in the campus

The figure 6 below shows the graph of Receive Signal Level (RSL) in dBm over a distance from the Base Station in the campus. As we can see, the RSL decreasing from -66dBm to -94dBm when the distance increasing starting from 23m to 520m but after this point, the RSL increasing from -94dBm to -86dBm. This is because after this point, it is less obstruction and have line of sight.

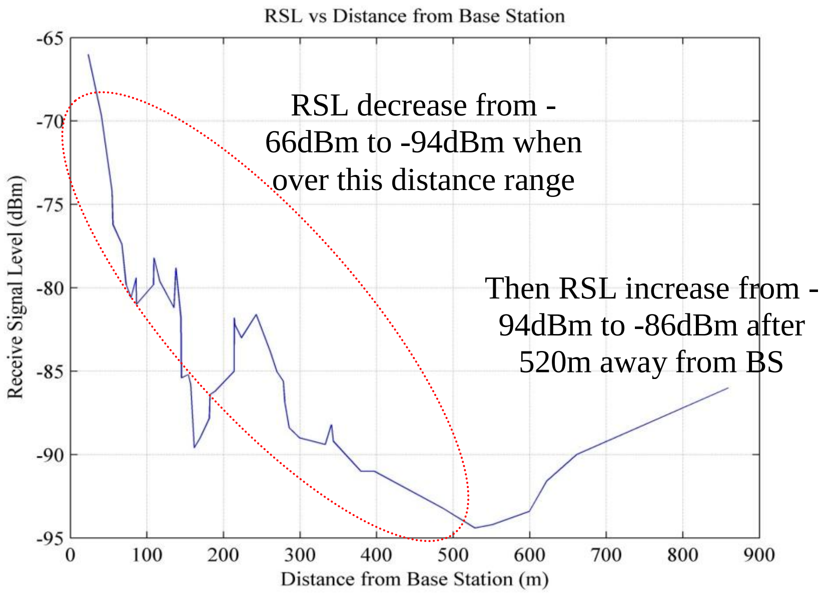


Figure 6: Receive Signal Level (dBm) over distance from Base Station (m)

3.2 Result from calculation using Egli Model

The formula for path loss using Egli Model is

$$L_{50} = G_b G_m \left(\frac{h_b h_m}{d^2} \right)^2 \beta \quad \text{Where } \beta \text{ is} \quad \beta = \left(\frac{40}{f_{MHz}} \right)^2$$

In this case, the gain for Mobile Station, Gm and gain for Base Station, Gm is zero in decimal unit. So, the path loss in this case can be simplified by:

L_{path} = $40\log_{10}(d) - 20\log_{10}(h_b) - 20\log_{10}(h_m) - 10\log_{10}(\beta)$ and,
RSL = $Pt - L_{path} - L_{feeder}$ + Gain, where Gain is zero, thus
RSL = 10log(500mW) - L_{path} – 2dB

The values of h_b, h_m, β and L_{feeder} are 16m, 1.5m, 0.007032 and 2dB respectively.

After got the path loss, L_{path}, then the RSL formula is used to determine RSL for the distance from 20m to 900m. Here are the graphs for path loss in dB and Receive Signal Level, RSL in dBm for Egli Model.

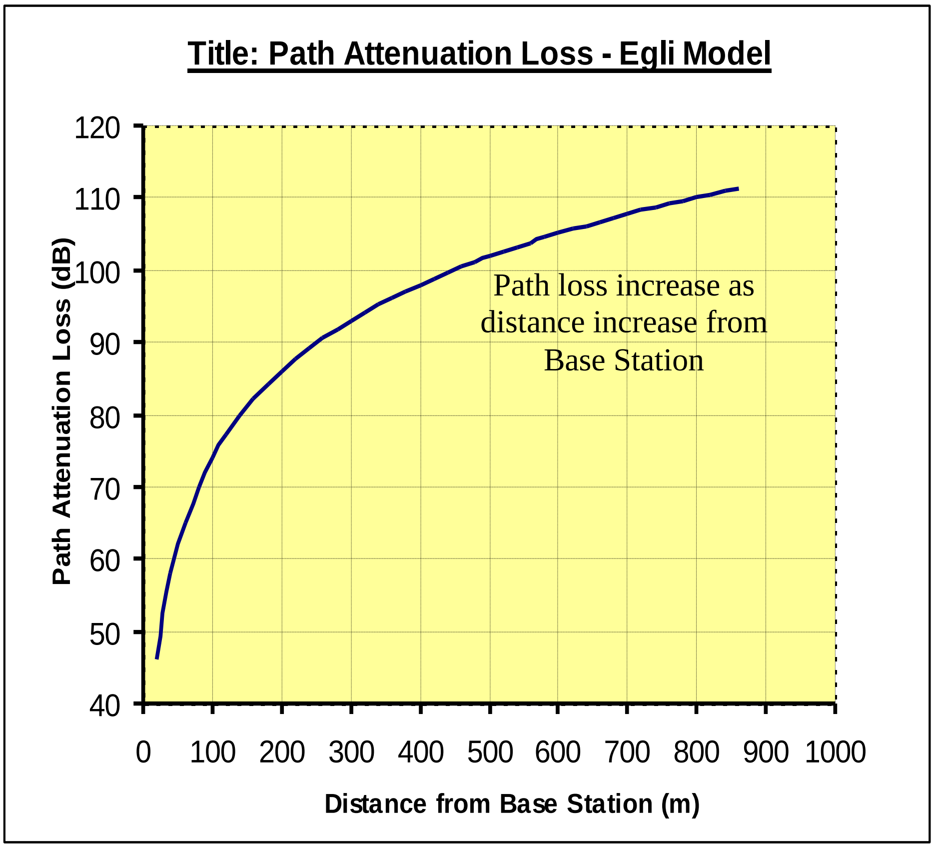


Figure 7: Path Loss (dB) over distance from Base Station (m)

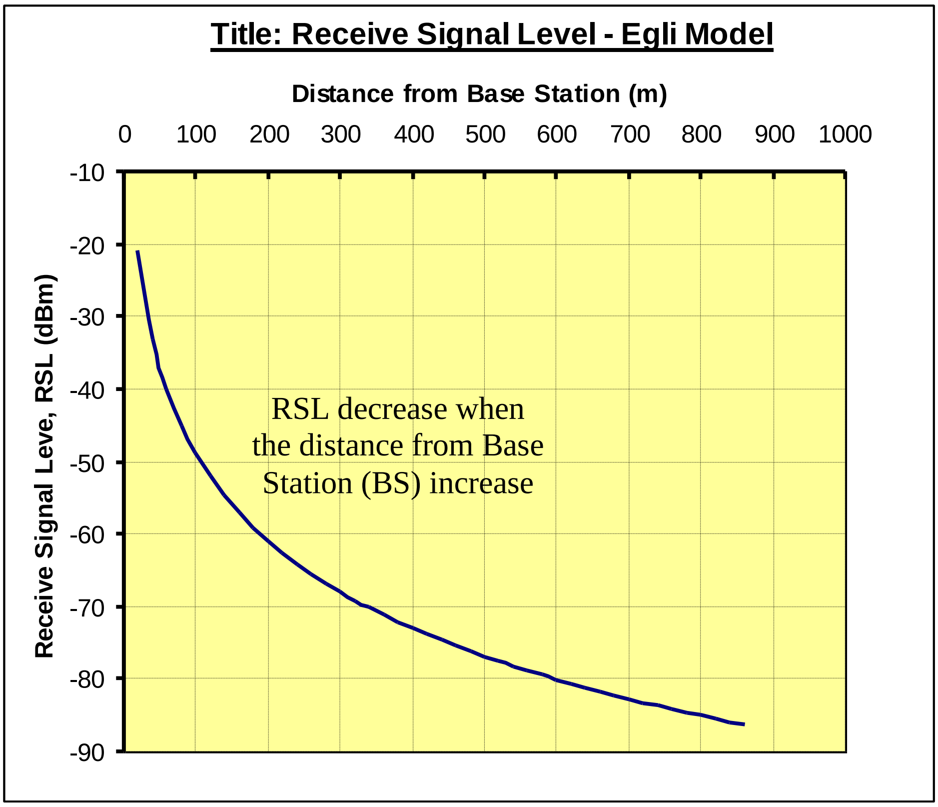


Figure 8: Receive Signal Level (dBm) over distance from Base Station (m)

The figure 7 in previous page shows the path loss increase as distance increase from Base Station (BS). This will affect the Receive Signal Level by decreasing it as predict from the RSL equation. Theoretically, RSL will decrease from -21dBm to -86dBm for the distance range from 20m to 860m from the Base Station as we can see in figure 8.

3.3 Comparison Result – Calculated Value Using Egli Model and Measured Value

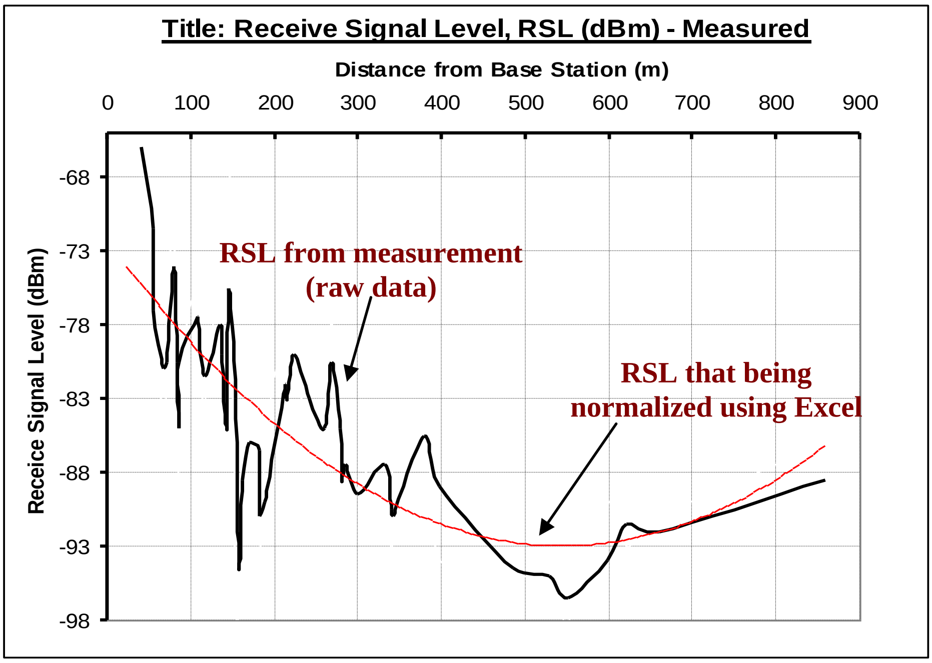


Figure 9: RSL from Measurement and Normalized RSL

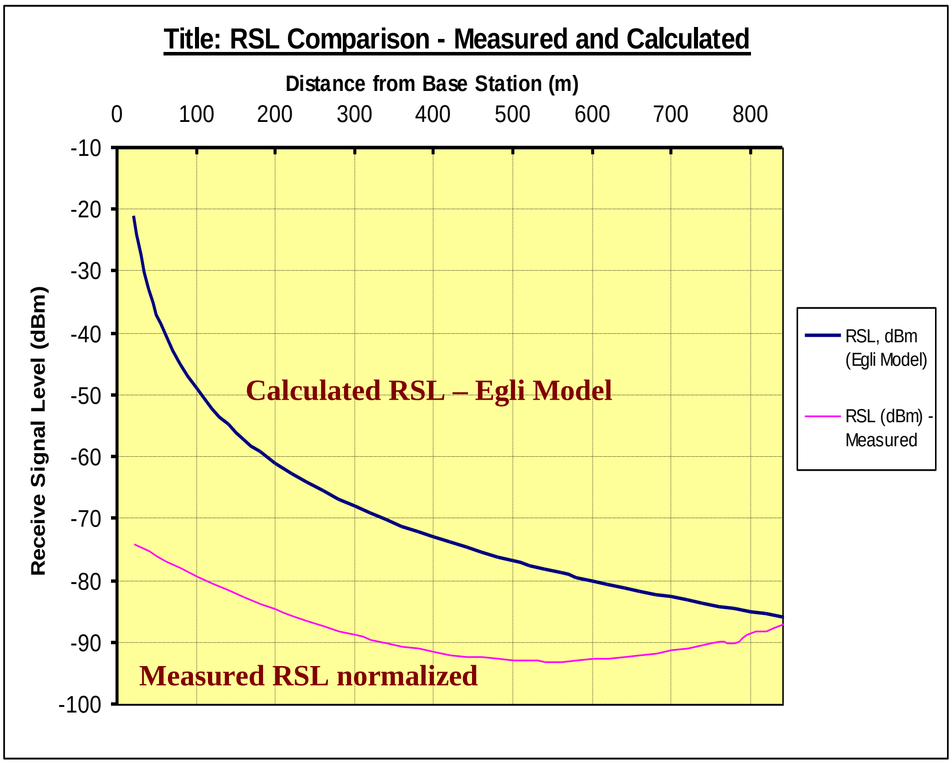


Figure 10: Comparison of RSL for Measured and Calculated Value

As shown in figure 10, the measured RSL value is less than calculated value using Egli Model. This is because in measurement in the campus, there are a lot of obstructions such as trees, buildings and also with the effect of terrain, uneven surface and various type of ground surface (car park area, pond, typical ground etc). But with Egli Model, it assume that there is a flat surface and without any obstruction such buildings and trees. That is why our measurements of RSL are lower than calculated Egli Model.

Another interesting point is the measured RSL in average increase after 520m from Base Station. This occurs because of the obstruction after this distance is less and then if we go further we can see an antenna (get line of sight) and the level of ground is higher as we go away from Base Station, thus will give a better signal coverage.

4. CONCLUSION

Here we can conclude some points on radiowave propagation path loss:

i. The path loss increase as the distance increase from the base station and this will result the Receive Signal Level (RSL) will decrease as distance increase.

ii. In the measured RSL value is lower compare to RSL calculated with Egli Model due to the obstruction of trees and building (resulting the signal diffracted and being absorbed), and also the effect of uneven terrain.

iii. In the measurement, after some distance (nearly 520m from base station) the RSL increase because at this point, there are less obstruction and we can see line of sight.

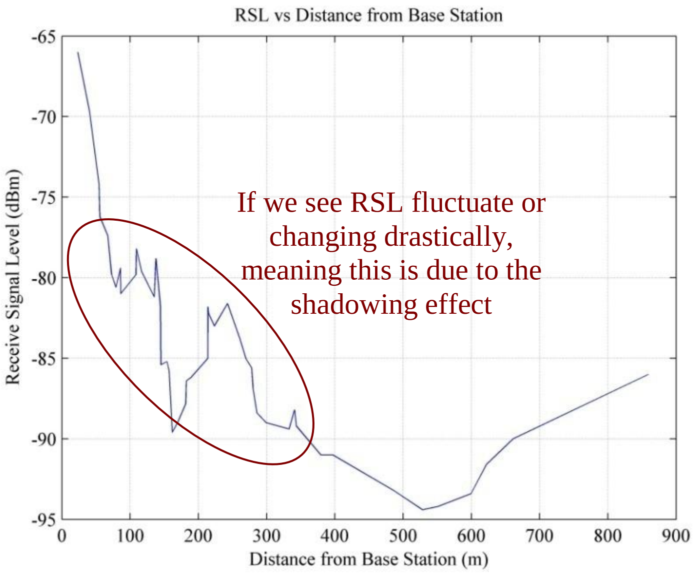
5. DISCUSSION

Egli Model being chosen because we can use it to estimate the radio frequency coverage over short distance (a few kilometres). In this laboratory exercise, the distance is below than 900 meter.

The channel is narrow band because the range of the frequency is between 25 kHz. In this case, it used channel 20 that occupy 476.900 MHz and other channel are more or less 25 kHz of this channel.

(Note: In wideband, the frequency range is 100 kHz)

To identify the effect of shadowing by looking to the RSL graph measurement (refer to the graph of RSL versus distance), when we can see the RSL fluctuated / changing drastically, so we know that it is due to the shadowing effect.



In case of when the Mobile Station (MS) can't achieve line of sight (LOS), Mobile Station (MS) is too close to the Base Station (BS) building and antenna at the rooftop of the building as we can see in the figure below.

Then it will cause a shadowing. This shadowing will be affect;

- Our Receive Signal Level will decrease
- Introduces additional fluctuation in signal
- Changing the signal phase
- Signal will scattered

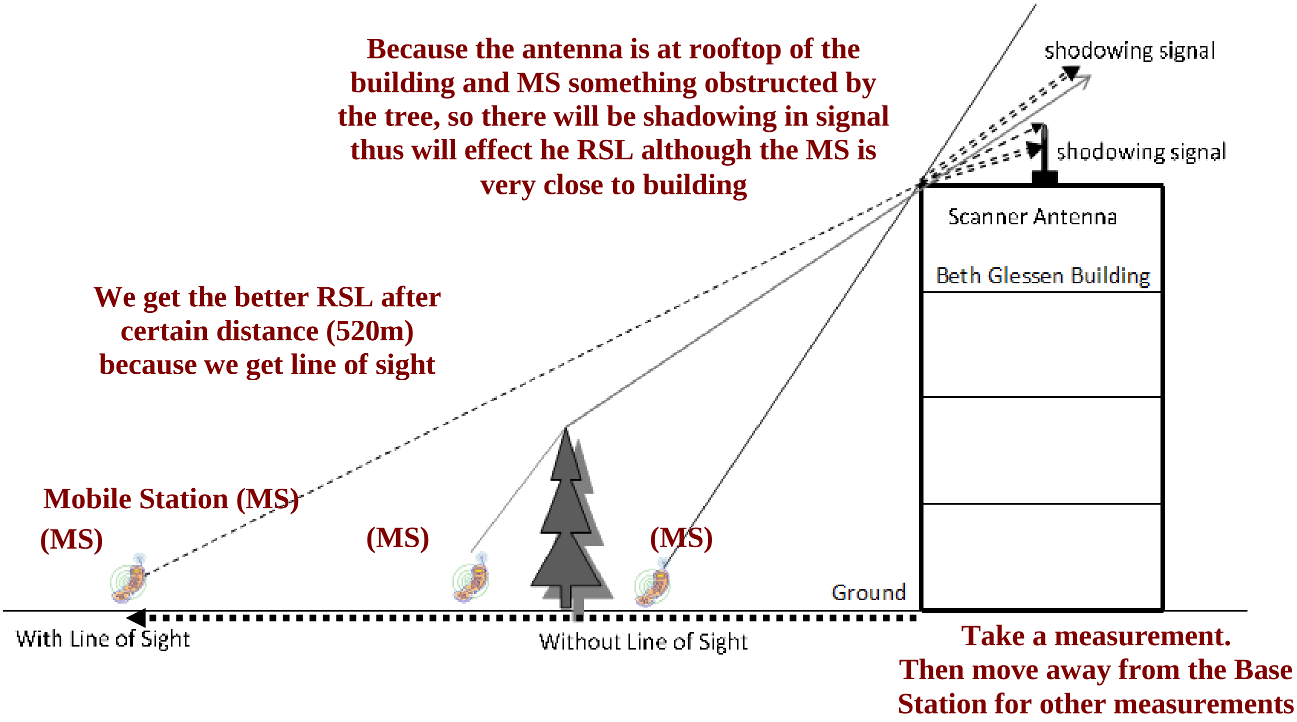
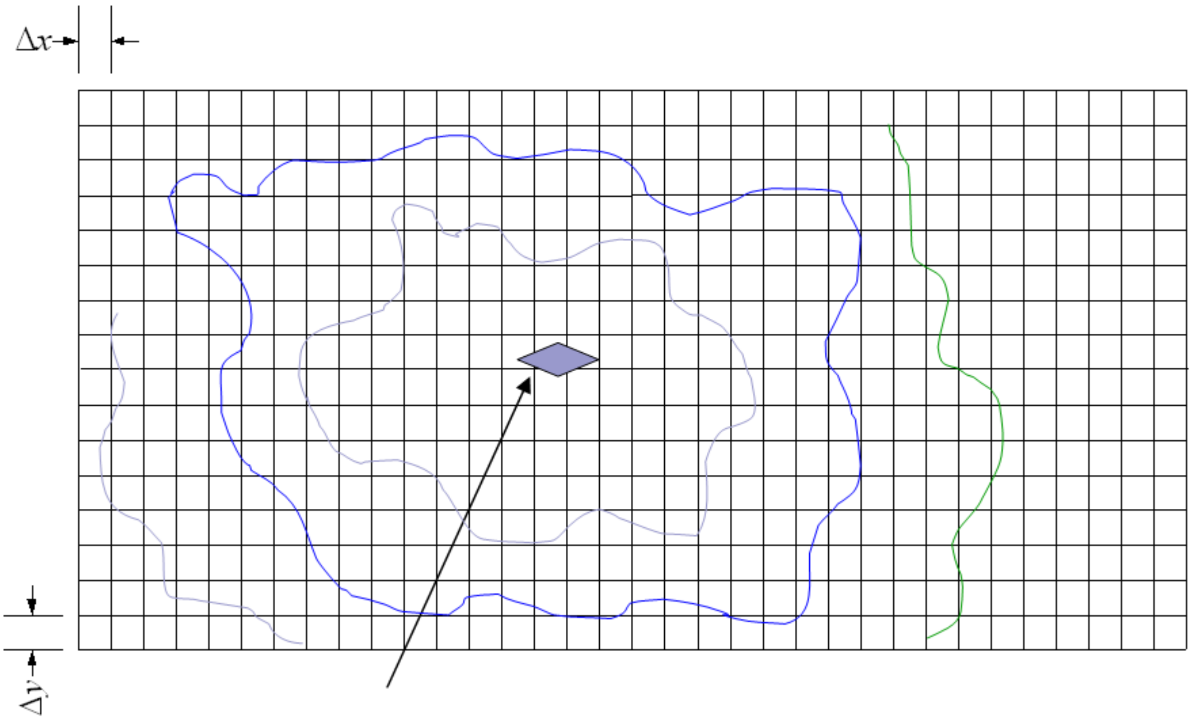
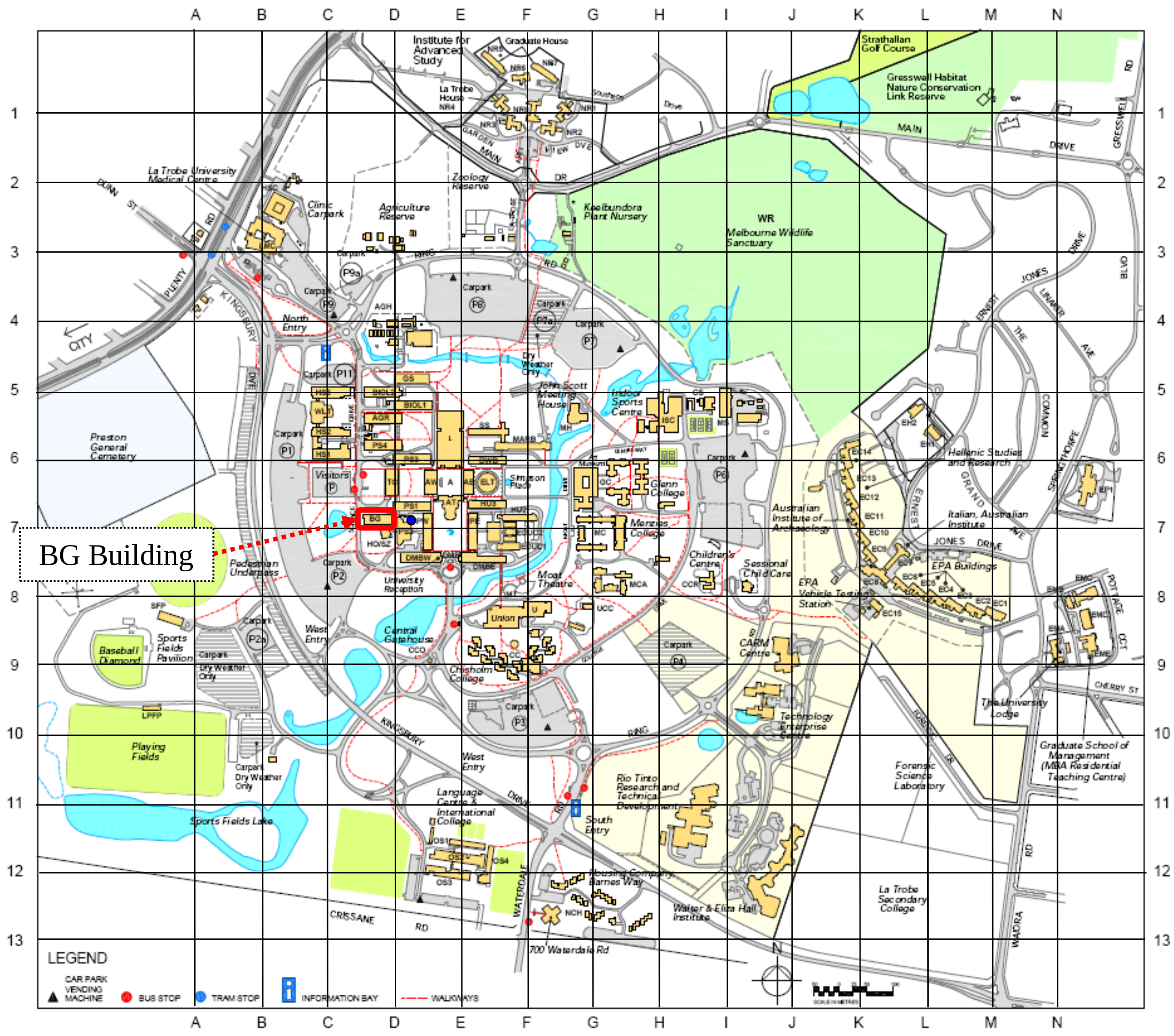


Figure above showing the shadowing effect

Appendices



A base station (Beth Glessen Building)



Example of Calculation using Egli Model

Calculation for Receive Signal Level (RSL)

RSL $= Pt - L_{path} - L_{feeder} + Gain$, where Gain is zero and L_{feeder} is 2dB thus
RSL $= Pt - L_{path} - 2dB$ where Pt is Power Transmitted
RSL $= 10\log(500mW) - L_{path} - 2dB$ so, we have to find Path Loss, L_{path}

$L_{path} = 40\log_{10}(d) - 20\log_{10}(h_b) - 20\log_{10}(h_m) - 10\log_{10}(\beta)$ and,
The values of h_b, h_m, β and L_{feeder} are 16m, 1.5m, 0.007032 and 2dB respectively. So the path loss is depending on distance, d from mobile station to base station.

If distance is ***40 meter***, then L_{path} is

$$L_{path} = 40\log_{10}(d) - 20\log_{10}(h_b) - 20\log_{10}(h_m) - 10\log_{10}(\beta)$$
$$= 40\log_{10}(40) - 20\log_{10}(16) - 20\log_{10}(1.5) - 10\log_{10}(0.007032)$$
$$= 64.08 - 24.08 - 3.52 - (-21.53)\ dB$$
$$= 58dB$$

So, Receive Signal Level (RSL) is

$$RSL = 10\log(500mW) - 58dB - 2dB$$
$$= 27dBm - 58dB - 2dB$$
$$= -33dBm$$

Table of Path Loss and Receive Signal Level depending on distance as follow

Path Length (m)	Path Loss, dB (Egli Model)	RSL, dBm (Egli Model) Calculated	Path Length (m)	Path Loss, dB (Egli Model)	RSL, dBm (Egli Model) Calculated
23	48.54	-24	157	81.77	-57
40	58.14	-33	162	82.26	-57
54	63.33	-38	169	83.07	-58
55	63.68	-39	182	84.29	-59
67	67.04	-42	182	84.37	-59
73	68.37	-43	189	84.98	-60
79	69.87	-45	214	87.14	-62
85	71.10	-46	214	87.14	-62
86	71.26	-46	215	87.20	-62
86	71.33	-46	223	87.88	-63
109	75.37	-50	243	89.32	-64
109	75.45	-50	261	90.57	-66
117	76.58	-52	269	91.13	-66
135	79.19	-54	278	91.69	-67
138	79.49	-55	280	91.81	-67
144	80.29	-55	286	92.17	-67
145	80.37	-55	300	92.99	-68
154	81.42	-56	333	94.83	-70