PREDICTION OF BEST COVERAGE AREA FOR OUTDOOR WIRELESS PROPAGATION AT 2.4 GHZ USING WALFISCH-IKEGAMI SIMULATION MODEL

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To my beloved wife and family

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ABSTRACT

Propagation prediction and measurement is one of the foremost processes that must be taken into consideration prior to any deployment of wireless networks. This will certainly eliminate issues such as weak received signals or even not in coverage areas. In front battle area where tactical communications normally consist of deployed wireless network, prediction capability is crucial to the success of operation since networks planners have limited time and access to the battle area. The continuous advent in the field of satellite mapping makes available more precise information about terrain that finally produces more accurate propagation prediction. The outdoor propagation and measurement was done at Universiti Teknologi Malaysia Skudai Campus Residential Blocks of S08, S37-S40. The WCC wireless network carrier frequency is at 2.4 GHz. Measurement was done using AirMagnet Survey Solutions while Radiowave Prediction Software (RPS) is used as outdoor propagation prediction software using COST 231 Walfisch-Ikegami Outdoor Model. Signal strength was measures around these blocks and compared with predicted received signal level using RPS.

ABSTRAK

Ramalan perambatan dan pengukuran adalah aspek penting perlu diambilkira sebelum rangkaian tanpa wayar dibangunkan. Ini akan mengurangkan isu-isu seperti penerimaan isyarat lemah ataupun luar kawasan litupan. Dalam suasana medan perang, perhubungan taktikal yang biasanya terdiri rangkaian tanpa wayar, ramalan perambatan adalah penting untuk kejayaan operasi disebabkan limitasi masa dan maklumat kawasan medan perang. Pembangunan pesat dalam pemetaan menggunakan satelit membolehkan maklumat kawasan medan perang diperolehi dan ramalan perambatan diperolehi dengan lebih tepat. Ramalan kawasan terbuka dan pengukuran kawasan telah dilakukan di Blok Kediaman pelajar UTM Skudai iaitu Blok S08 and Blok S37 hingga S40. Frekuensi pembawa adalah 2.4 GHz dengan Patch Antenna sebagai Antenna pemancar. Pengukuran kekuatan isyarat dilaksanakan menggunakan AirMagnet manakala perisian Radiowave Prediction Software (RPS) dan Model COST 231- Walfisch-Ikegami Outdoor digunakan. Ramalan perambatan dan pengukuran isyarat dibandingkan.

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LIST OF ABBREVIATION

RL	-	Return Loss
dB	-	Decibel
GHz	-	Giga Hertz
MHz	-	Mega Hertz
WLAN	-	Wireless Local Area Network
LOS	-	Line Of Sight
Km	-	kilometer
COST	-	European Cooperation in the Field of Scientific and Technical Research
ITU	-	International Telecommunication Union
RPS	-	Radiowave Propagation Simulator
GUI	-	Graphical user interface

LIST OF SYMBOLS

D	-	Distance
h	-	Height
$\emptyset$	-	Angle
α	-	Angle
	-	Ohm
f	-	Frequency
L_o	-	Loss in free space
L_{rts}	-	Loss in diffraction
L_{ms}	-	Loss in Multiplan
L_T	-	Total loss
Δh_m	-	Difference in height
K_a	-	Attenuation
K_f	-	Attenuation
L_t	-	Path loss

CHAPTER 1

INTRODUCTION

1.1 Background

Modern warfare requires extensive exchange of information and uses real-time application such as telephony, video conferencing, video broadcasting and data application. This translates to the requirement for high bandwidth connectivity. A general scenario, where units tasked to conduct a military operation in a forward area, a tactical headquarters will be deployed as a rear support for the units. The composition of this headquarters will consist of all elements such as signals, engineering, field hospital and other required elements. This headquarters will occupy an area within a radius of 5-10 km and away from its permanent headquarters at a distance to able support and remain in safe distance from the battle area. A typical communication link setup is as shown in Fig. 1.1.

1.2 Problem Statement

The communication within the headquarters various elements thus will be affected by various factors such as terrain, vegetation, trees and foliage. This poses a great challenge to telecommunication engineers in ensuring good tactical communication within elements in deployed headquarters be established and sustained throughout the military operation. Due to inaccessibility and security reason, a precise simulation is needed prior to deployment of communication devices to ensure proper location of the devices in ensuring good coverage of wireless access within the headquarters.

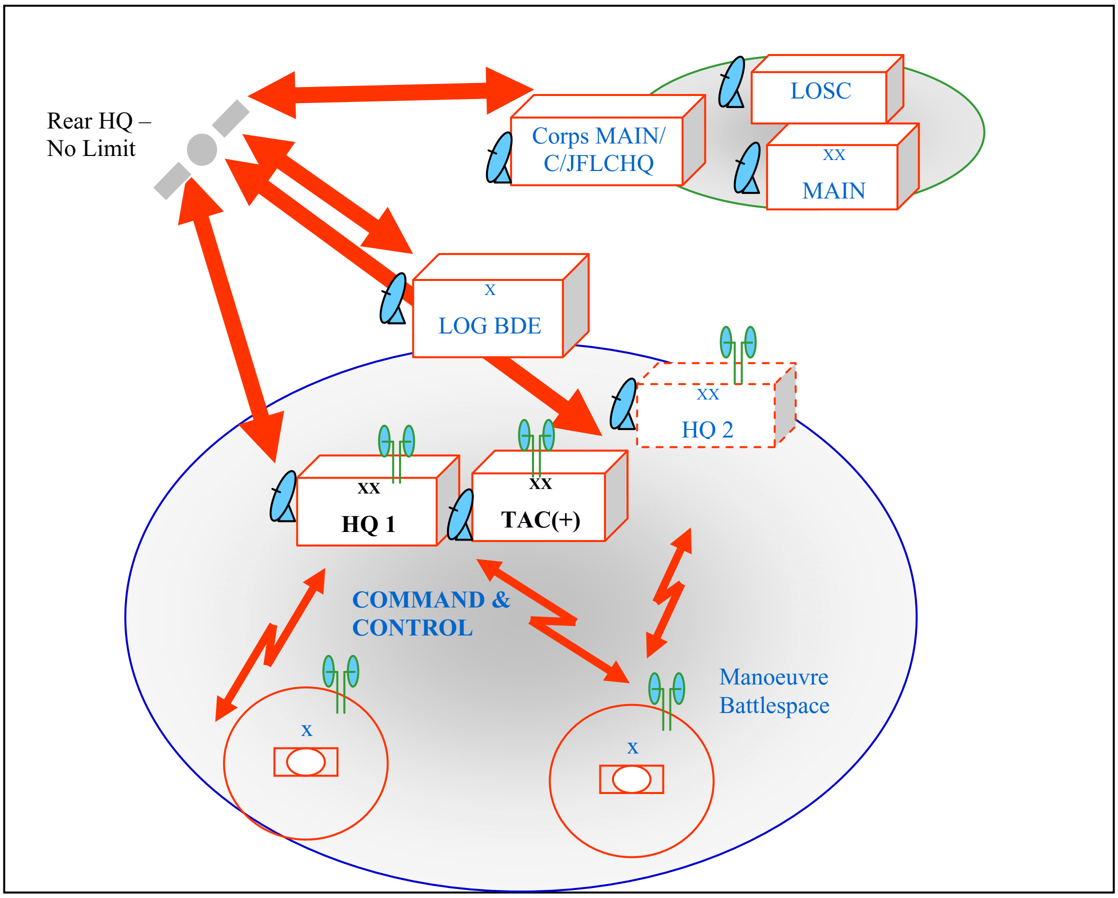


Figure 1.1 Typical Communication Link Setup

1.3 Objective and Project Overview

This project objective is to be able to predict signal strength and to conduct actual measurement on the same area so that a comparison can be made. The project overview is to design a simulation method to effectively predict maximum received signal based on specific location for tactical communication using wireless propagation. For software simulation, Radiowave Propagation Simulator is used to determine received signal strength with satellite obtained real background image and prior surveyed environment build up within the location.

1.4 Scope of Project

Area to conduct measurement and simulation is identified and location image was obtained via satellite image. The same satellite obtained background image precisely pinpoint measurement location and used in signal strength measurement using AirMagnet. The background image also used in Radiowave Propagation Simulator (RPS) in simulating the received signal. The simulated signal strength was compared with measured signal strength. Effect of diffraction, terrain and vegetation on radio propagation was studied.

1.5 Outlines

Chapter one presents an introduction on problem statement, the objective and project overview. A general description on wireless network, theories of radio propagation mechanism, theories on outdoor radio propagation model based on Longley-Rice Models, Okumura Model, Hata Model, Walfisch-Ikegami Model (COST 231 Outdoor- WI) are given in Chapter 2. Chapter 3 presents Radiowave Propagation Simulator software introduction, developing and simulating a model. The AirMagnet Solution Survey consists of hardware and software and the method of measuring signal was presented in this chapter. Results are presented and analysed in Chapter 4. The last chapter concludes the thesis and recommendations for future work.

CHAPTER 2

WIRELESS PROPAGATION CHANNEL

2.1 Introduction to Wireless Network

In today's world, where there is an increasing demand for speedier network connectivity and mobility, the need for improvement in wireless technology will definitely be in great demand. Currently, new technologies and innovation in wireless network are rapidly replacing copper cable and fibre optic or other traditional method used for network access. Through the invention and continuous improvement in Wireless Local Area Network (WLAN), the wireless network is now being used extensively in homes, buildings and offices, eliminating the need for expensive infrastructure such as fibre optic cabling and subsequent expensive maintenance cost.

2.2 Introduction to Radio Propagation

In tropical countries like Malaysia, transmission path between receivers and transmitter suffers from dense tropical jungles consists of thick foliage or hilly terrain in suburban areas to dense build up of buildings in urban areas. Radio propagation traverse mostly through reflection, diffraction and scattering in a free space. This causes the waves travelling at different path and reaches receivers at different times. Thus this phenomenon can severely cause erratic received signal strength. Thus it is paramount important to effectively able to model radio propagation path in design a wireless network. Propagation models designed to predict the average received signal strength at a given distance from the transmitter. These readings in turn can be combined to give the coverage area of a transmitter[2].

2.3 Basic Propagation Mechanism

2.3.1 Reflection

Electromagnetic waves when travelling from a transmitter to a receiver, when hit an obstacle, a part of the incoming electromagnetic wave front will be reflected and another part will be transmitted. Depending on the obstacle material properties, for example if it is a perfect dielectric, part of energy will be transmitted into the second medium and part of the energy will be reflected back into the first medium. In essence there will be no loss of energy in absorption [2].

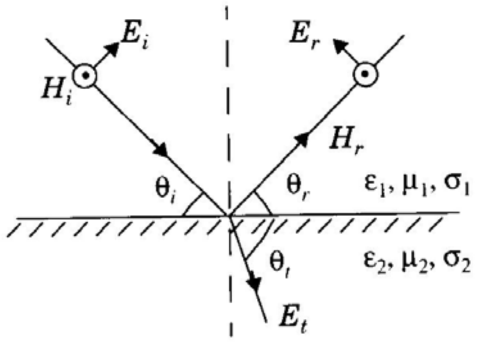


Figure 2.1 E-field in the plane of incidence[2]

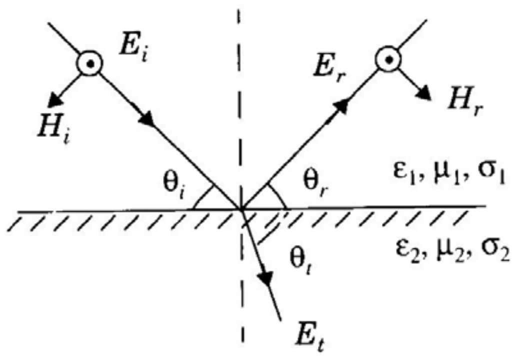


Figure 2.2 E-field normal to the plane of incidence[2]

2.3.1.1 Reflection from Dielectrics

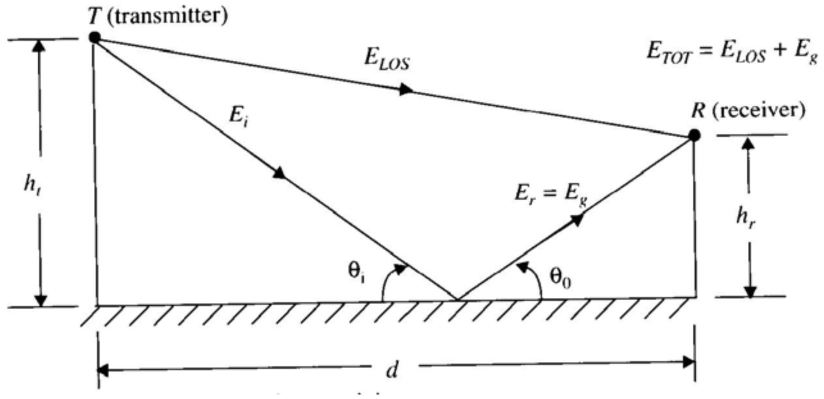


Fig 2.1 and 2.2 shows part of the energy is refracted into second media at an angle θ_t. The nature of reflection depends on direction of E-field polarization. The plane of incidence is defined as the plane containing the incident, reflected and transmitted wave. In Fig 2.1 the E-field polarisation is parallel with plane of incidence and in Fig 2.2 the E-field polarisation is perpendicular to the plane of incidence.

2.3.1.2 Ground Reflection (Two-Ray) Model

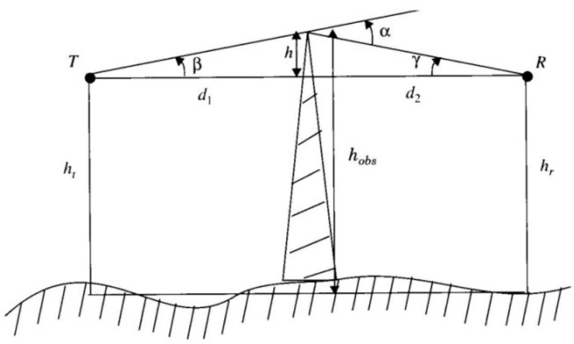


Figure 2.3 Two-ray ground reflection model[2]

This model provides a good prediction over received signal strength over distances of several kilometres since both direct path and ground reflected propagation path is taken into consideration. The total received E-field, E_{TOT} is a result of the direct line-of-sight component, E_{LOS} and the ground reflected component, E_g.

2.3.2 Diffraction

Electromagnetic waves are diffracted at edges. The ability of radio signals received beyond obstruction such as building depends on this phenomenon of diffraction. Simplified, a diffraction edge can be interpreted as an outgoing point of electromagnetic waves or, in other words, it can be treated as a new transmitting source. This allows in situation when receiver located within obstruction but yet able to produce enough signal strength to allow communication. The field strength of a diffracted wave in the shadowed region is the vector sum of the electric field components of all the secondary wavelets in the space around the obstacle[2].

2.3.2.1 Fresnel Zone Geometry[2]

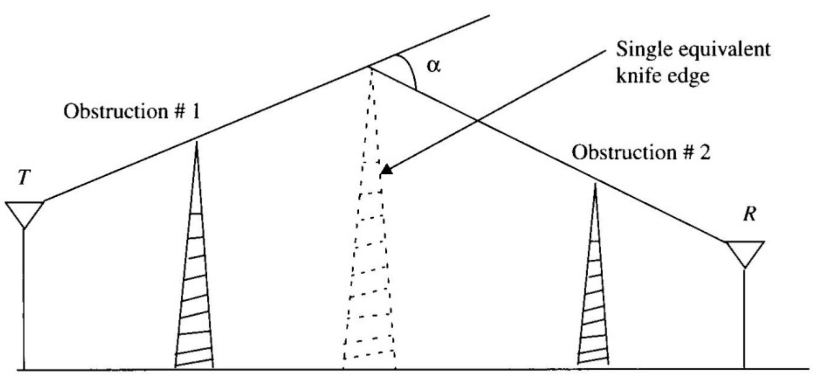


Figure 2.4 Knife-edge diffraction geometry

Wave propagating from the transmitter to the receiver via the top of the screen travels a longer distance than if a direct line-of-sight path existed. Fresnel

Zone explained the diffraction loss as a function of the path difference around an obstruction. Fresnel Zone is the successive regions where secondary waves have a path length from the transmitter to the receiver which are greater than the total path length of a line-of-sight. This means, in wireless communication, only certain amount of transmitted energy received by receiver by the effect of diffraction at around an obstacle.

2.3.2.2 Knife-end Diffraction Model

It is important that signal strength loss due diffraction of radio waves over obstruction such as terrain, vegetation and buildings were able to be estimated. Using Fresnel Zone, in single object shadowing such as by buildings, the diffraction loss can be estimated using classical Fresnel solution for the field behind a knife edge.

2.3.2.3 Multiple Knife-end Diffraction

In this project, propagation path is subjected to more than one obstruction especially in urban areas where multiple buildings are located. There are many methods available in estimating the diffraction losses. Bullington suggested that the series obstacles be replaced by a single equivalent obstacle so that the path loss can be obtained[2]. The method provides good estimates on received signal strength.

2.3.2.4 Scattering

This phenomena provides additional received signal at receiver since when radio wave hit rough surface, the radio wave will spread out in all direction and will act as a secondary source of energy[2]. This also provides the sufficient signal for areas which does not received signal via reflection or diffraction. Flat surfaces that have much larger dimension than a wavelength may be modelled as reflective surfaces. The roughness of such surfaces often induces propagation effects different from the specular reflection as described in 2.3.1. Surface roughness is defined by Rayleigh Criterion which defined a critical height (h_c) of surface protuberances for a given angle of incidence θ_i, given by

For rough surfaces, the flat surface reflection coefficient need to be multiplied by a scattering loss factor, ρ_S, to account for diminished reflected field.

2.4 Outdoor Propagation Models

A few outdoor propagation models were studied in order to understand the parameter taken in predicting the signal strength within the coverage area. In this project, the important parameters that were intended to study are the terrain, vegetation and building's effect on radio propagation. In doing so, some of the propagation models studied had incorporated these parameters into making of models.

2.4.1 Longley-Rice Model

This model is applicable for frequency range from 40 MHz to 100 GHz for point-to-point communication over different kind of terrain. The path geometry of the terrain profile and refractivity of the troposphere is used in predicting the median transmission loss, while the two-ray model is used for prediction of signal strength within the radio horizon. Diffraction losses over isolated obstacles are estimated using Fresnel-Kirchhoff knife-edge model. Forward scatter theory is used to make troposcatter predictions over long distances, and far field diffraction losses in double horizon paths are predicted using a modified Van der Pol-Bremmer method. This models were able to models in two modes, the first mode when terrain path profile were available, this prediction called the point-to-point mode, the second mode is when that terrain path were not available, the models uses technique to estimate the path-specific parameters and this prediction is called an area mode. The short comings of this models it that its inability to consider effects of buildings and vegetation[2].

2.4.2 Okumura Model

This model is used for frequencies from 150 MHz to 1920 MHz, distances of 1 km to 100 km and for base antenna height from 30 m to 1000 m. This model was developed by extensive measurement and provides curves of Median attenuation relative to free space $,(A_{mu})$, in a urban area over quasi-smooth terrain. To use Okumura model, free space path loss need to be determined, then from the Okumura curve, the A_{mu} value will be ascertained.

The model can be expressed as[2]:

$$L_{50}(dB) = L_F + A_{mu}(f,d) - G(h_{te}) - G(h_{re}) - G_{AREA}$$

Where L_{50} is the 50th percentile (i.e., median) value of propagation path loss, L_F is the free space propagation loss, A_{mu} is the median attenuation relative to free space, $G(h_{te})$ is the base station antenna height gain factor, $G(h_{re})$ is the Mobile antenna height gain factor and G_{AREA} is the gain due to type of environment. Base station antenna height gain factor as follows:

$$G(h_{te}) = 20\log(\frac{h_{te}}{200}) \qquad 1000\ m > h_{te} > 30\ m$$

$$G(h_{te}) = 10\log\left(\frac{h_{re}}{3}\right) \qquad h_{re} \leq 3\ m$$

$$G(h_{re}) = 20\log\left(\frac{h_{re}}{3}\right) \quad 10\ m > h_{re} > 3\ m$$

2.4.3 Hata Model

This model is the empirical formulation of the graphical path loss provided by Okumura, the useful frequency range is from 150 MHz to 1500 MHz. The standard formula for median path loss in urban areas is given by[2]:

$$L_{50}(urban)(dB) = 69.55 + 26.16\log f_c - 13.82\log h_{te} - a(h_{re}) +$$

$$(44.9 - 6.55\log h_{te})\log d$$

Where f_c is the frequency (in MHz) from 150 MHz to 1500 MHz, h_{te} is the effective transmitter (base station) antenna height (in meters) from 30 m to 200 m, h_{re} is the effective receiver (mobile) antenna height (in meters) ranging 1m to 10 m, d is the T-R separation distance (in km) and $a(h_{re})$ is the correction factor for effective mobile antenna height.

2.4.4 Walfisch-Ikegami Model (COST 231 Outdoor- WI)

European Cooperation in the Field of Scientific and Technical Research (COST), an open and flexible framework for research and development cooperation between universities, industry, and research institutions. The COST 231 Walfisch-Ikegami model is now part of Recommendation 567-4 of the ITU. One additional main concern of COST 231 was the precise definition of a common framework for comparing the performance of the proposed models. Prediction models are devised for a specific environment category in a given frequency band. They exploit some topographical information about the investigated site. Using the terminology proposed by COST 231, topographical information considered together is referred to as geographical information in the sequel.

The following model classes have been identified in COST 231: empirical, semi-deterministic, and deterministic. Empirical models consist of diagrams or equations for path loss calculation which are obtained from statistical analysis of a large number of measurements. Two approaches are used to establish deterministic models. First, a path loss equation is provided which has been derived based on a conceptually idealized or abstracted environment, retaining some basic features of the physical one in order to make a theoretical treatment possible. Second, geographical information about the investigated site supplied by means of digital maps is exploited to predict the dominant propagation paths and their loss.

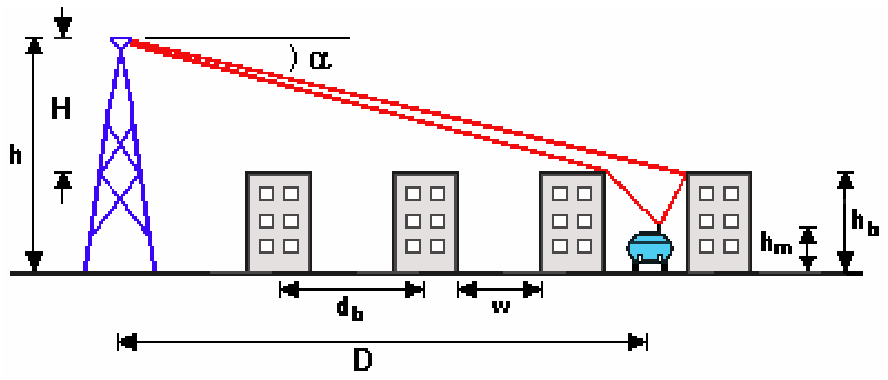


Figure 2.5 Walfisch-Ikegami model (seen along the street)[4].

Semi-empirical models result from an empirical modification of deterministic models to improve the agreement with measurements[5]. The Walfisch-Ikegami model is mainly based on the studies made by Bertoni-Walfisch and Ikegami for propagation in urban environments, adding some empirical corrections due factors as height of antennas, street orientation and used frequency[4]. Fig. 3 and Fig. 4 show the parameters through which the model is defined.

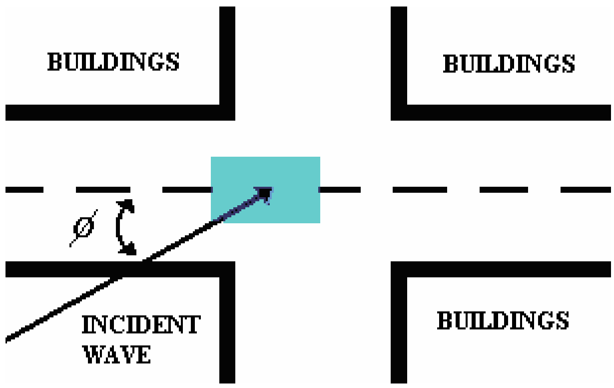


Figure 2.6 Definition of street orientation angle φ[4].

Walfisch-Ikegami model possess owns three basic components [4]:

- Loss in the free space (L_o);

- Loss by diffraction to the level of the streets and by scattering (L_{rts});
- Loss due the Multiplans (L_{ms}).

The total attenuation (L_T) is given by:

$$L_T = L_o + L_{rts} + L_{msd}$$

$$L_T = L_o \qquad \text{for} \qquad L_{rts} + L_{msd} \leq 0$$

The average transmission losses L_0, L_{rts} and L_{ms}.

$$L_o = 32.4 + 20 \log D + 20 \log f,$$

$$L_{rts} = -16.9 + 10 \log W + 10 \log f + 20 \log \Delta h_m + L_{ori}$$

$$L_{ms} = L_{bsh} + K_a + K_d \log D + K_f \log f - 9 \log d_b$$

Being D the distance between transmitter and receiver, in kilometers; h the height of the transmitter antenna and Δh_m is the difference between the height of the buildings (h) and the height of the mobile station (h_m), in meters. The model takes in consideration the following parameters for the calculation of the loss: the buildings height (h_p), in meters, the distance between buildings (d_b), in meters and the width of the street (w), in meters. L_s is the correction factor due to orientation of the street in function of the incidence angle φ given for:

$$-10 + 0.354\emptyset \; for \; 0° \leq \emptyset < 35°$$

$$2.5 + 0.075\,(\emptyset - 35°) for \; 35° \leq \emptyset < 55°$$

$$4.0 - 0.114\,(\emptyset - 55^{\circ})\,for\ 55 \leq \emptyset < 90^{\circ}$$

Using, $\Delta \mathrm{h} = \mathrm{h} - \mathrm{h_p}$

The other terms of the equation can be defined by:

$$L_{bsh} = -18\log(1 + \Delta h)\ for\ h > h_p$$

$$L_{bsh} = 0\ for\ h \leq h_p$$

$$K_a = 54\ for\ h > h_p$$

$$K_a = 54 - 0.8\Delta h_b\ for\ D \geq 0.5\ Km\ and\ h \leq h_p$$

$$K_a = 54 - 0.8\Delta h_b \frac{D}{0.5}\ for\ D < 0.5\ Km\ and\ h < h_p$$

The terms K_d and K_f in the equation above are related with the attenuation due the diffraction on the multiples semi plan considered in the model as function of the distance and the operation frequency, respectively, and are defined by:

$$K_d = 18\ for\ h > h_p$$

$$K_d = 18 - 15\frac{\Delta h}{h_p}\ for\ h \leq h_p$$

$$K_f = -4 + 0.7\left(\frac{f}{925} - 1\right) \textit{ medium sized cities and suburban centers}$$

$$K_f = -4 + 1.5\left(\frac{f}{925} - 1\right) \textit{ for metropolitan centers}$$

Observation:

- The height of the radio station base and the mobile station is restricted to the following limits: $4m < h < 50$

  $1m < h_m < 3m$

- The orientation of the road with respect to the Tx-Rx line is not considered in the proposed model, because the orientation of the road cannot be determined for all environments. Taking in consideration factors like heights of antennas, orientation and widths of streets, the used frequency, gain and irradiation power of antennas and adjusting the terms K_a, K_d and K_f for the environments studied, the model of Walfisch-Ikegami is given by:

$$P_{teor} = 96.49 + 38\log d + 20\log(h_p - h_m) - 9\log d_b$$

- The model takes into account two key parameters for the loss calculation: the height of the buildings (h_p), in meters, and the distance between the buildings (d_b), in meters. These parameters can vary for each urban environment. Consequently, these parameters must be generalized so that the Walfisch-Ikegami model can be used in different urban areas.

Nagendra Sah and Tilak Thakur[5] conducted a study on Impact of Clutters on Quality of Service in Mobile Communication Using Walfisch-lkegami Propagation Model and deducted the model can be modified with the inclusion of Indian subcontinent condition s such as Attenuation Due to Trees /Vegetation, Loss Due to Rain Clutter, Loss Due to Snowfall and Scattering from Cloud. This conditions was incorporated into their model called Modified Walfisch-lkegami Propagation Model. In this project, matter of interest is the effect of vegetation and terrain. The additional path loss due to blockade by dense, dry, in-leaf trees found in temperate climate can be calculated from the following expression.

$$L_t = 1.33(f_c)^{0.284}\left(h_f\right)^{0.588}\ dB, for\ 14 \leq\ h_f\ \leq 400$$

$$L_t = 0.45(f_c)^{0.284}\ h_f\ dB\ for\ 0 \leq\ h_f \leq 14$$

Where, L_t= loss in dB, f_c = frequency in GHz, and h_f= tree height in meters.

The difference in path loss for trees with and without leaves has been found to be about 3 to 5 dB. For a frequency of 900 MHz, the above equations, are reduced to

$$\mathrm{L_t} = 1.291(\mathrm{h_f})^{0.588}\ \mathrm{dB\ for}\ 14 \leq \mathrm{h_f} \leq 400$$

$$= 0.437\ \mathrm{h_f}\ \mathrm{dB,\ for}\ 0\ \leq\ \mathrm{h_f} \leq 14$$

CHAPTER 3

PROPAGATION PREDICTION AND EXPERIMENTAL SETUP

3.1 Radiowave Propagation Simulator 5.4[1]

The software is ray based and developed mainly for outdoor and indoor propagation in micro and pico cells. The frequency range is given from 0.3 to 300 GHz, with slow degradation below 300 MHz Besides two deterministic models two empirical models are implemented. Ray launching can be implemented in 2.5D or 3D. Reflection, diffraction and penetration are accounted for. The complex impulse response are calculated and saved. Dynamic impulse response can be generated. The angles of departure and arrival are calculated. The antenna radiation function can be

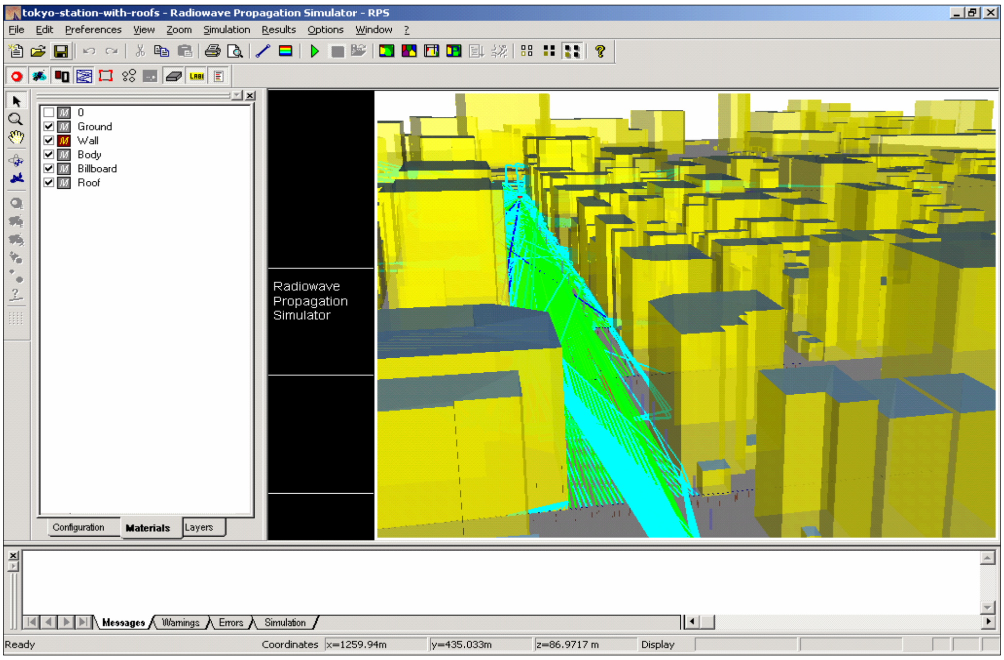


Figure 3.1 RPS Environment Window Snapshot

interpolated from given tables for vertical and horizontal antenna plane antenna diagram. Radiowave Propagation Simulator (RPS) [1] is a simulation suite that gives radio coverage/performance planning for a variety of radio systems. It helps a better visualization of how radio frequency propagates in a any environment. An example of RPS environment window is as shown in Figure 3.1.

There are many outstanding features of the RPS available within the RPS software suites. The RPS also has the state-of-the-art graphical user interface (GUI) with extensive analysis and presentation functions. It is also have a very fast and accurate 3-D ray tracing as well as empirical propagation algorithms. The ray tracing capabilities is highly parallelized ray tracing engine with sophisticated load balancing and hybrid prediction mode for unprecedented simulation performance. The RPS has open system architecture due to various data import/export interfaces for network configuration environment, and network performance data. Apart from built in propagation for various empirical method, the RPS also allows Propagation/post-processing plug-in technology for user-defined algorithms.

(a) Steps Creating A Project

Although there are few ways to build an environment in RPS, in this project an environment is built based on actual build up as seen in GoogleEarth^{TM}. The maps obtained through GoogleEarth^{TM} were used as background image and environment such as buildings, vegetation and other supported environment was later built on top of it. The background image used for this project is UTM Skudai Campus Student Residential Block S08 as the first image. This image is chosen to simulate a 2-storey building on a flat terrain, while the second image consisting of 4 blocks of 3 storey buildings named as Blocks S37, S38, S38 and S40 will be simulated with effect of vegetation and terrain. Figure 3.2 and Figure 3.3 shows both images that were captured from GoogleEarth^{TM}.

Figure 3.2 Satellite Image of Block S08

Figure 3.3 Block S37, S38, S39, S40

(b) Inserting Background Image

For this project a background image is inserted. This function is initiated by clicking the icon (tooltip Insert Image) as shown in Figure 3.4. Then the origin (i.e. the insertion position for the lower left corner of the image) and the total dimension in x-direction specified in [m]. Figure 3.4 and Figure 3.5 shows the insertion of the image and final appearance of the image in the environment window.

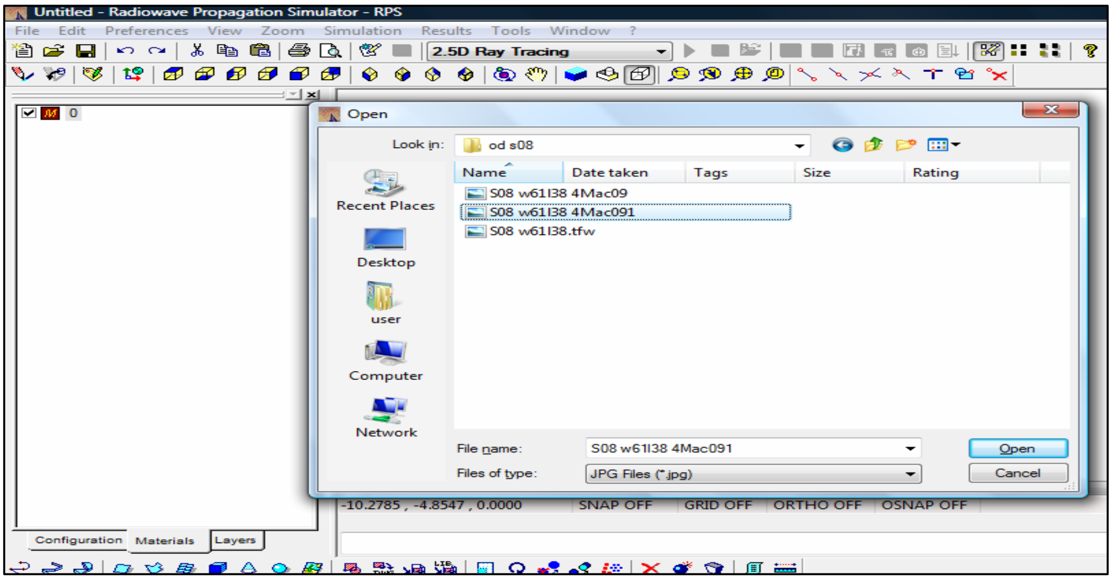


Figure 3.4 Inserting background Image File

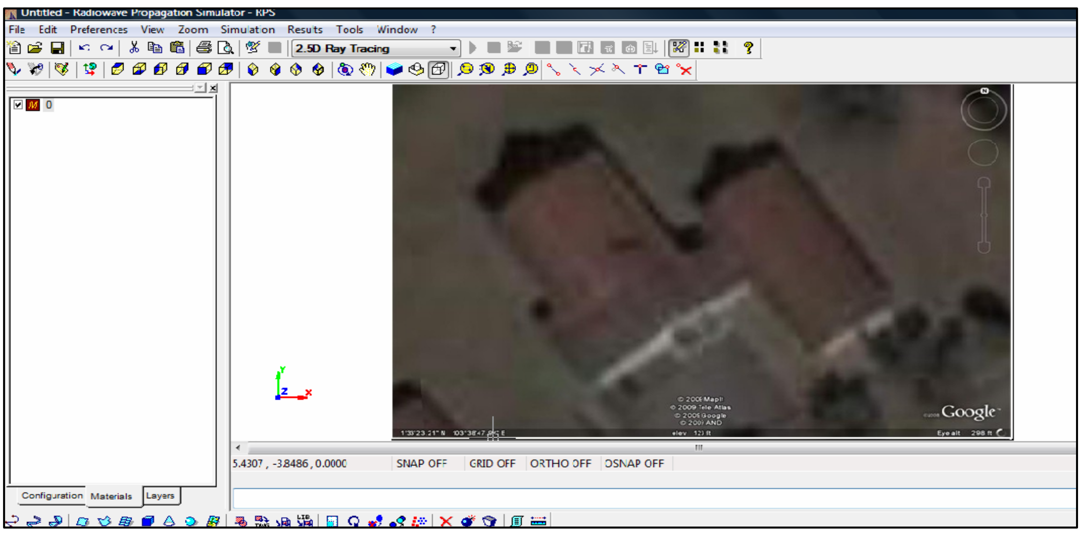


Figure 3.5 Background Image

(c) Creating Material Layer

All available material layers are listed in the Materials tab of the tree window. There is always a layer “0” which is mandatory. All other layers follow below it. For this project, up to five material layer was created, the first named Map where back ground image was then inserted. The ground material layer was created and ground was drawn to the map. This is followed by creating walls, roofs, trees material and drawn into the environment. Figure 3.5 shows the background image with all the required Material Layer such as Map, Ground, Wall, Roof and Trees.

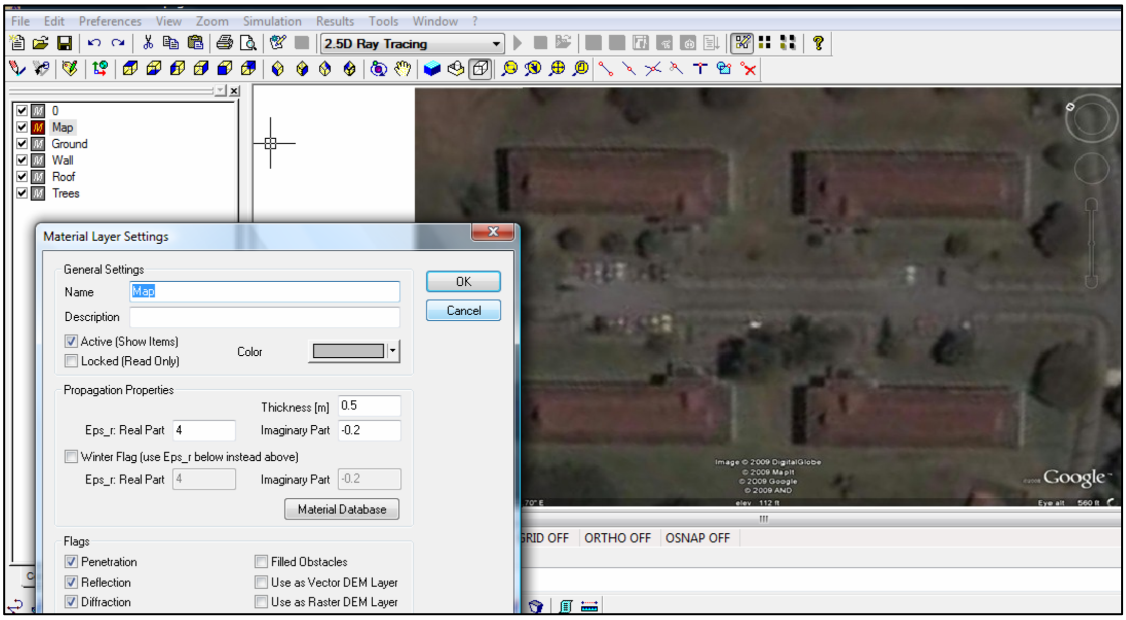


Figure 3.6 Creating Material Layer

(d) Selecting Material Database

Each of the created Material layer differs mainly in the selection of material database where different material affect RF propagation. Figure 3.6 shows material layer setting with all material database available in the RPS.

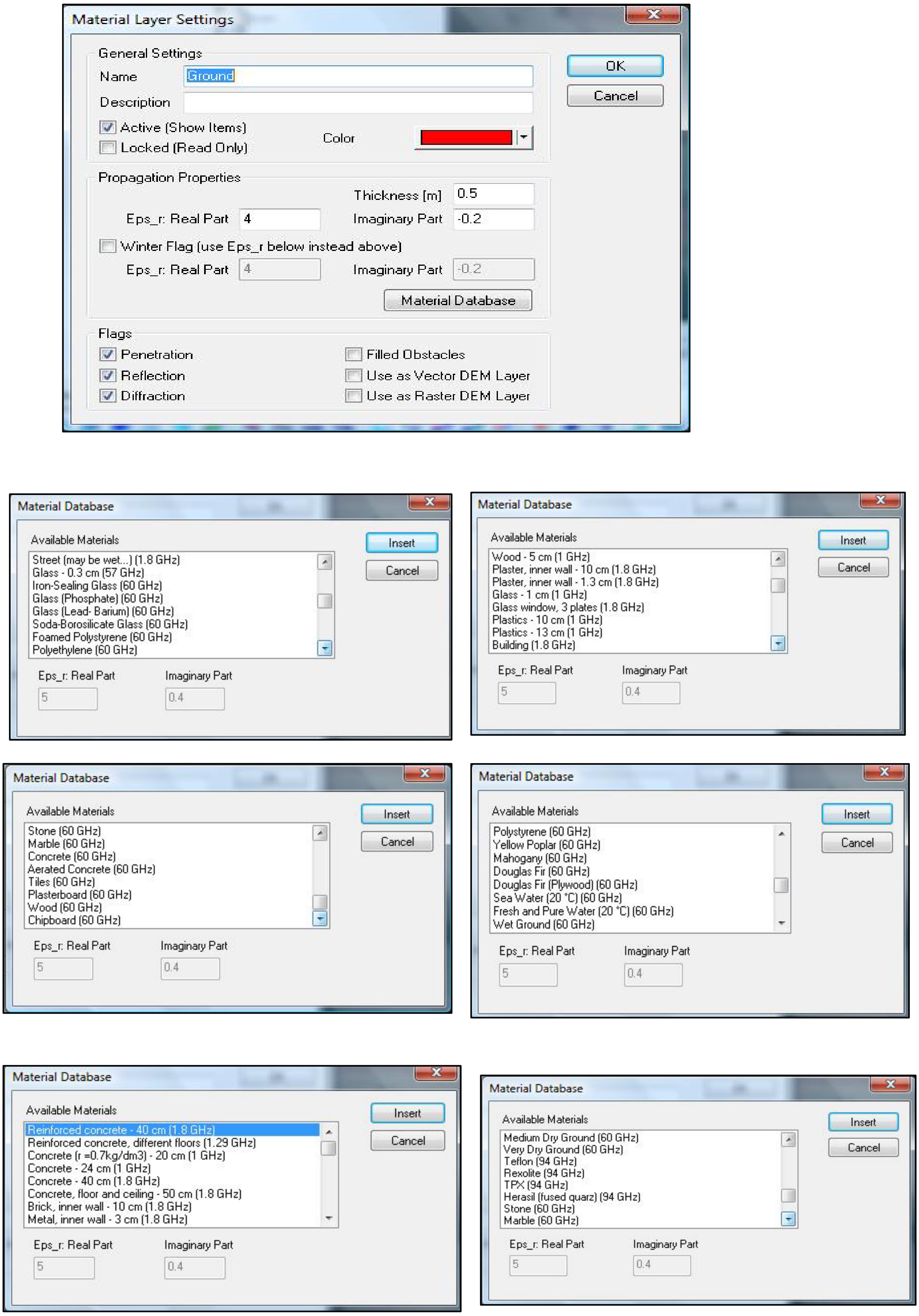


Figure 3.7 Material Layer Setting With Material Database

(e) Building Environment

For drawing buildings, first the ground layer is selected and drawn. Next the wall layer is selected with required height and drawn on top of the ground image earlier. Lastly roof layer was chosen and drawn on top of wall drawn earlier. Figure 3.7 shows the final building with roof (green in colour) as seen in Environment Editor.

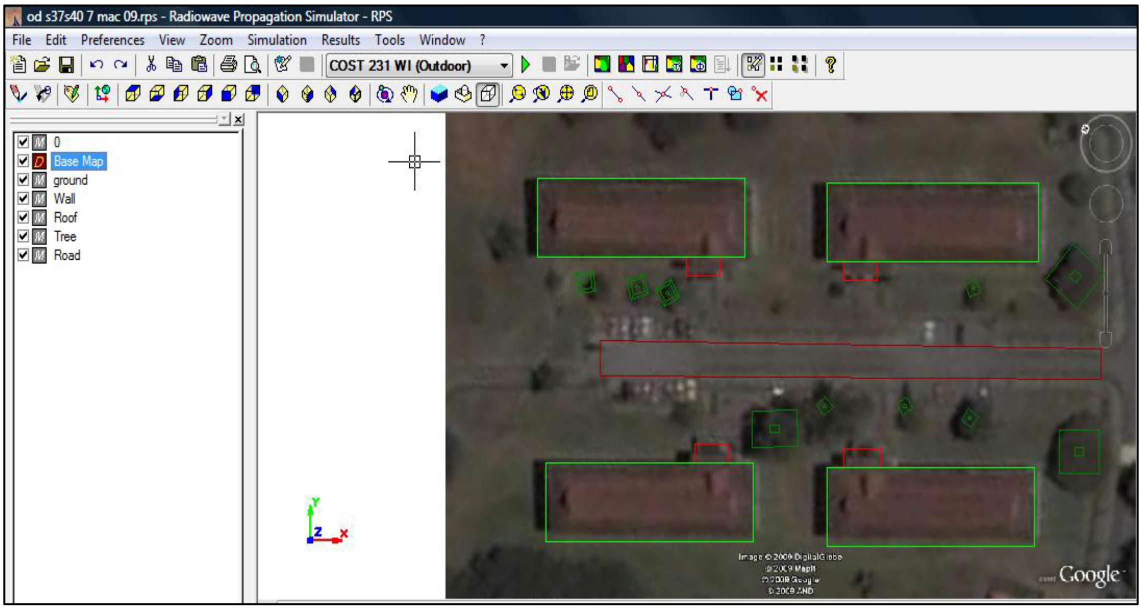


Figure 3.8 Final Build Up in Environment Editor

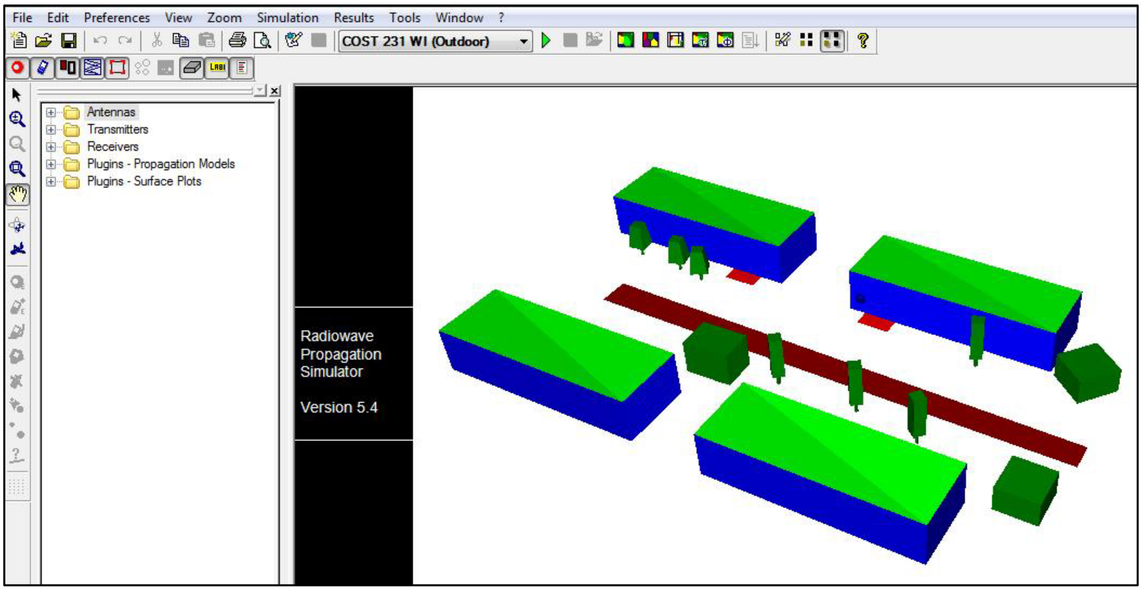


Figure 3.9 Final Build Up in 3D View

(f) Setting Up Network Device

In RPS, transmitters need to be placed together with their locations and radio system configuration. Receivers, on the other hand need to be placed where received signal need to be measured. Each transmitter will be assigned an antenna. A new transmitter can be placed at a given position in the 2D view. To use this function, the Transmitter Editing Mode must be entered by clicking the icon (tooltip Edit Transmitters) in the paint toolbar. Then to set the transmitter, click the right mouse button at a position in a surface plot where a transmitter shall be added. Figure 3.8 shows General and Hardware window in Transmitter Settings.

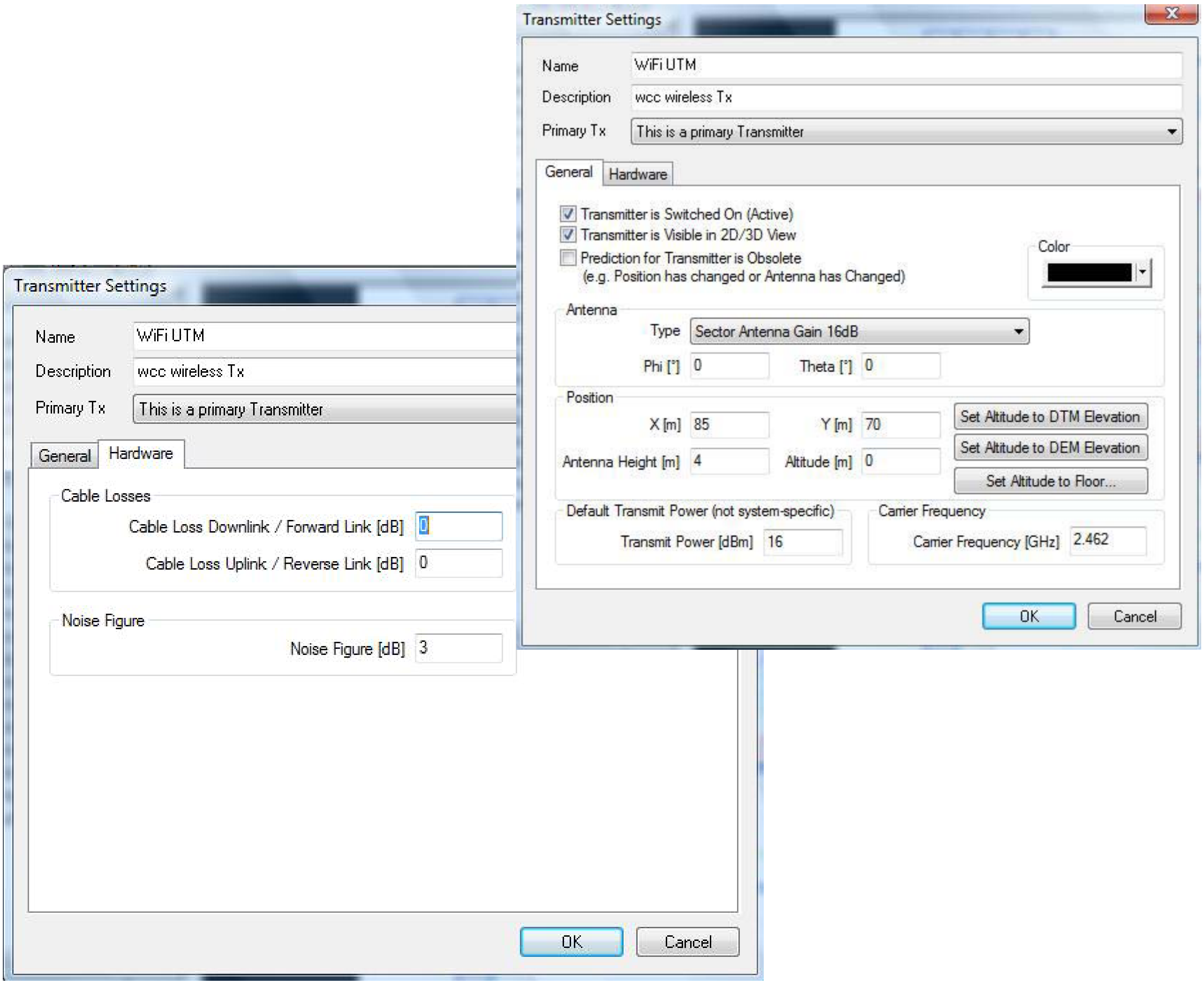


Figure 3.10 Adding Transmitters

(f) Setting Up Receivers

Receivers can be placed in the 2D view by using different Receiver Editing Modes. These functions can be activated by clicking the icons (tooltip Edit Receivers), (tooltip Line of Receivers) and (tooltip Field of Receivers) in the paint toolbar. In this project, identical receivers were created and placed at different location to see the effect of buildings, terrain and trees on RF propagation. Figure 3.9 shows receivers location in 3D view.

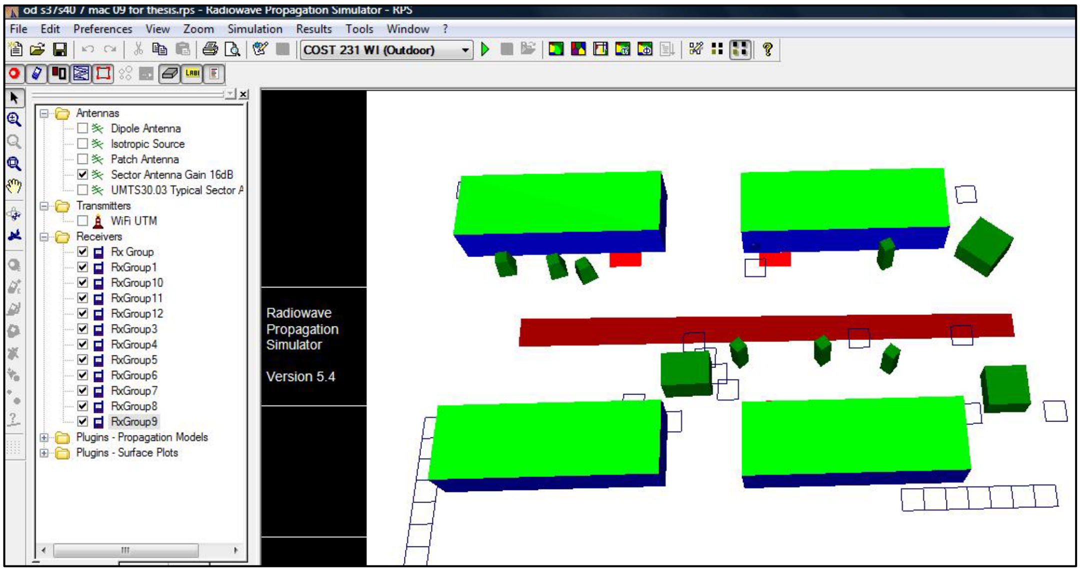


Figure 3.11 Receivers Location in 3D View

(g) Simulation

In running the simulation, we must first select one of propagation algorithm, which is in this project, COST 231 WI (OUTDOOR) is selected. The simulation is started by choosing Simulation -> Run menu entry. The results can be viewed in Result menu and selecting either Coverage, Delay Spread, Signal to Interference or Best Server. Figure 3.10 shows Coverage in 3D view, Figure 3.11 shows Best Serving Transmitter, Figure 3.12 shows Signal to Interference Ratio, Figure 3.13 shows Delay Spread in 2D view.

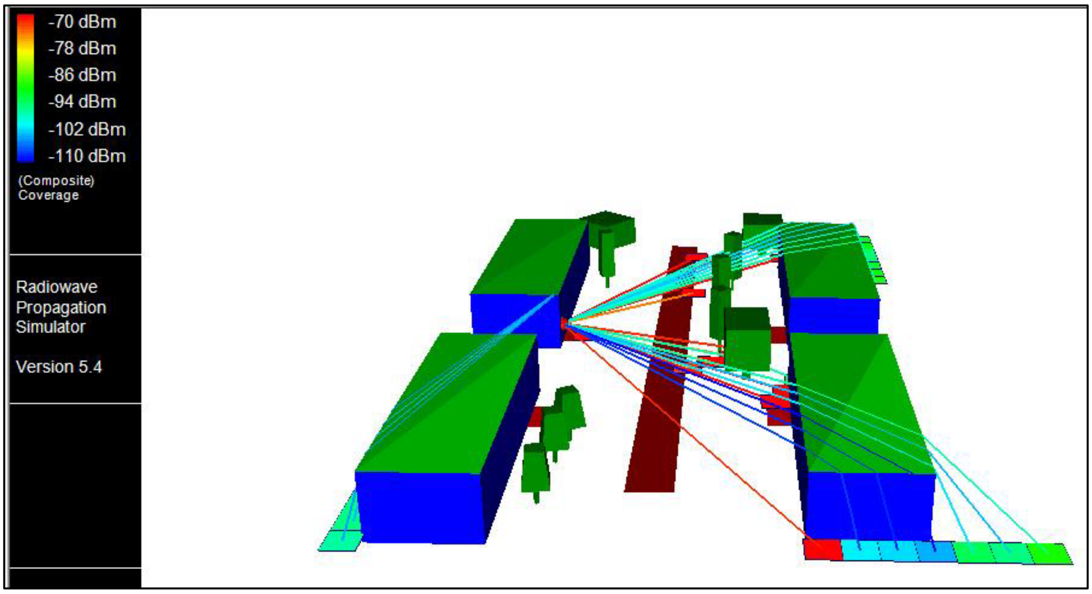


Figure 3.12 Coverage

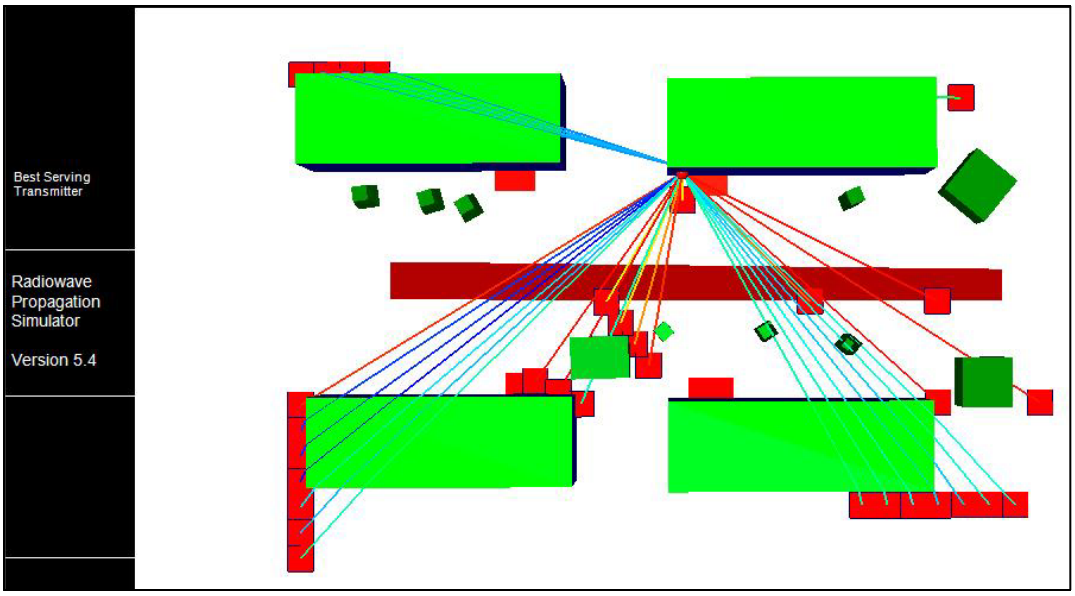


Figure 3.13 Best Serving Transmitter

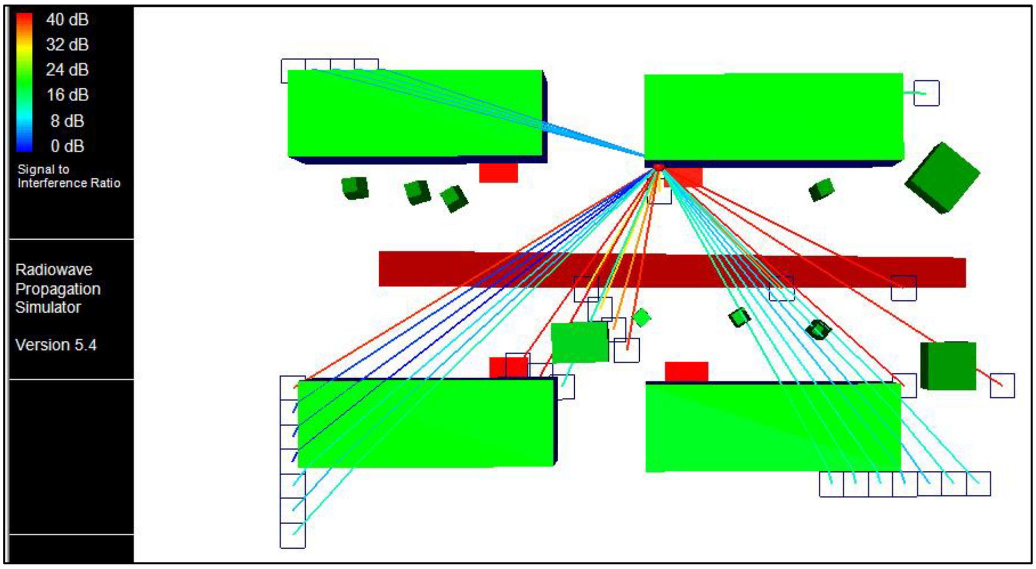


Figure 3.14 Signal to Interference Ratio

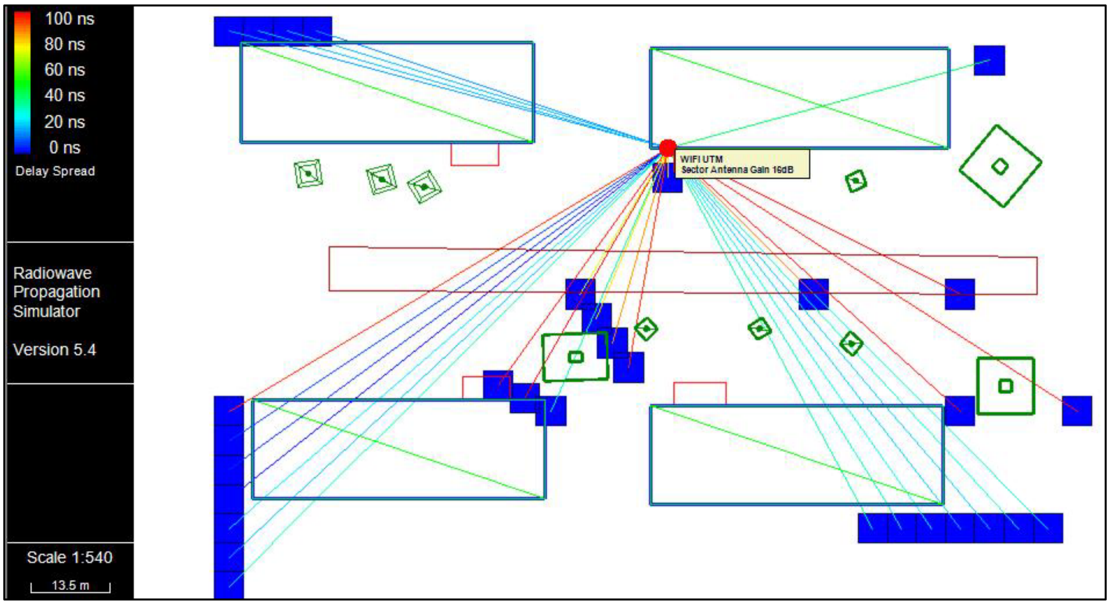


Figure 3.15 Delay Spread in 2D view

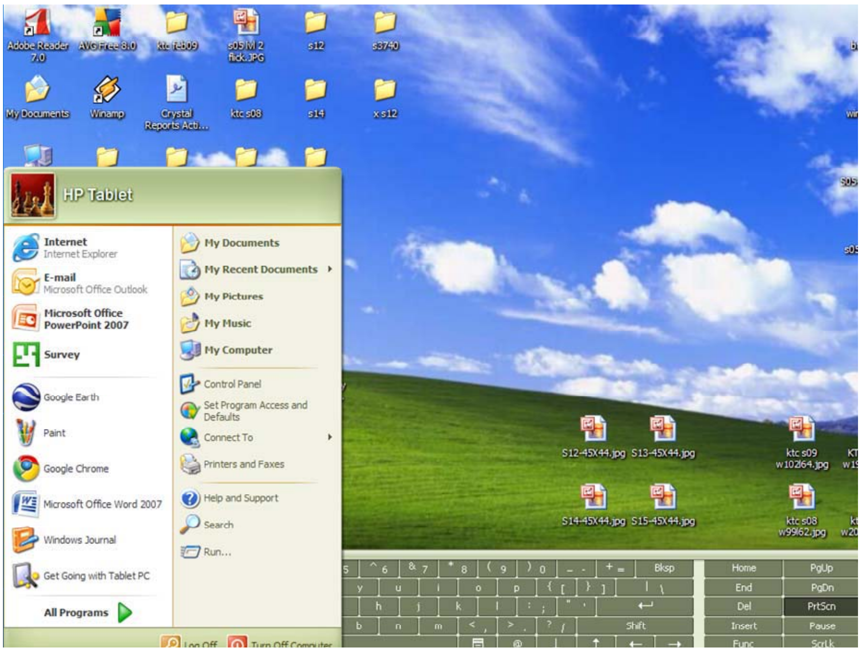
3.2 AirMagnet Survey Solutions

The AirMagnet solution used to capture signal strength from wireless AP's using Wireless PC Card and AirMagnet Survey Software installed in a tablet PC. The solutions provide a good view about relationship between AP's, surrounding environment and client. Figure 3.14 shows the Airmagnet Wireless Card and Laptop used in this project. The Airmagnet supports 802.11 a/b/g/n. The Airmagnet also enable us to conduct a pre deployment modelling and also performance of the current WLAN setup.

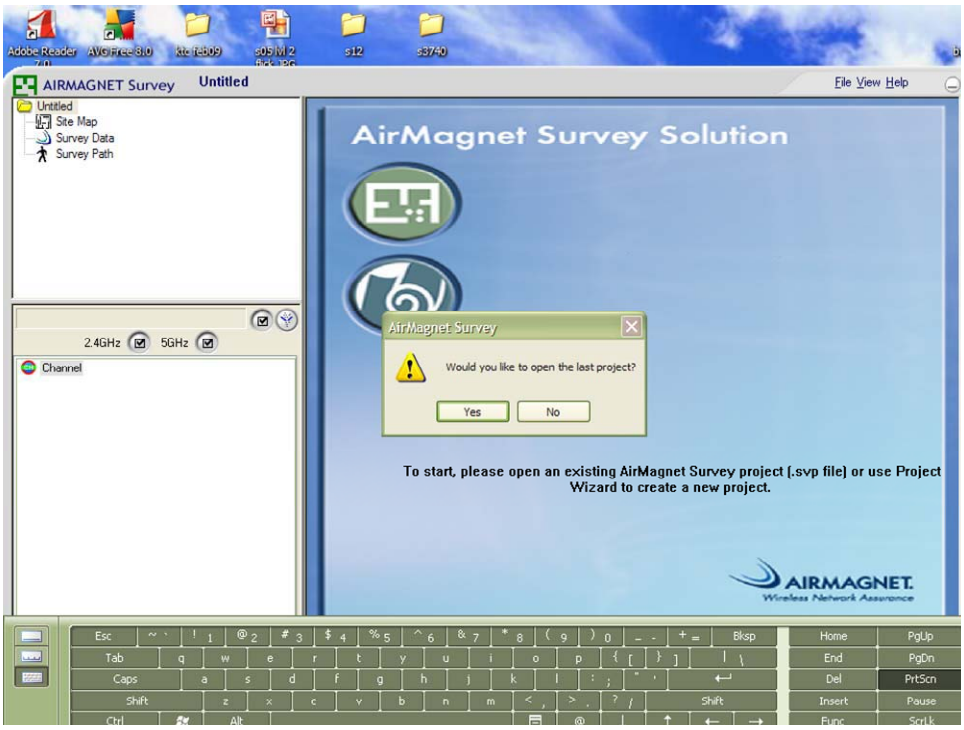
Figure 3.16 AirMagnet Wireless Card and Laptop

(a) Measurement Setup

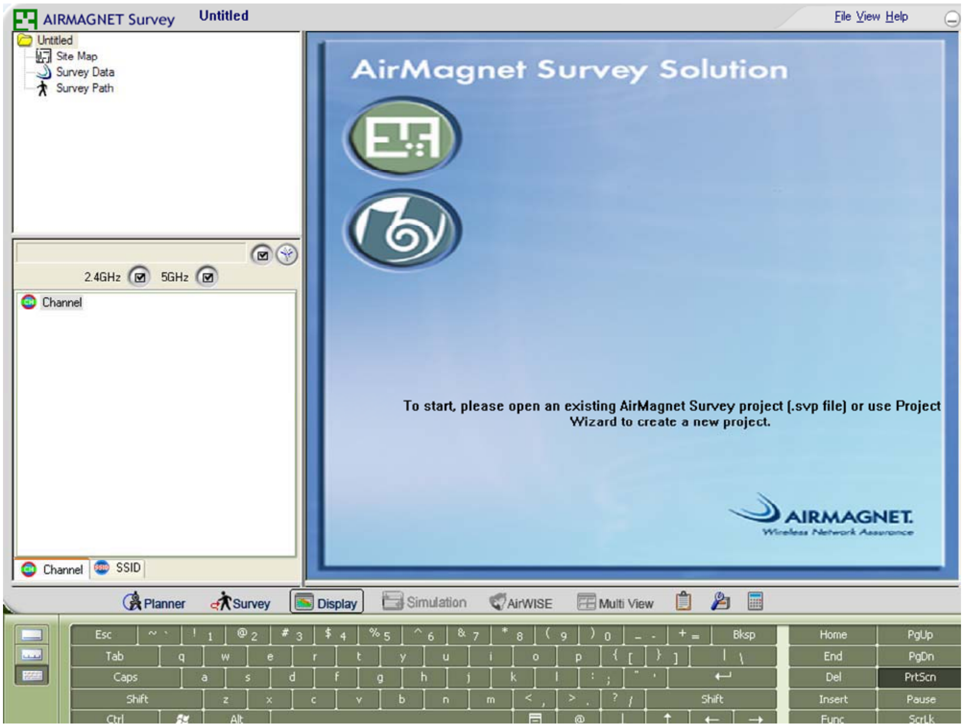
The measurement part were focussed on two Residential Block at UTM Campus Skudai. The Blocks are the single block of S08 and 4 blocks consist of S37, S38, S38 and S40. The S08 was chosen to enable propagation effect study on double storey buildings build on flat. The block also being serviced by single transmitter located on the same block. While blocks S37, S38, S38 and S40 was chosen to enable a study on effect of terrain and vegetation on propagation. It is also observed that a single transmitter located on block S37 and provides internet access to remaining 3 blocks. Figures 3.15 to 3.25 shows a laptop (HP Tablet PC) being setup prior to measurement. The tablet PC was then brought to areas need to measured and the location was marked in the survey map in AirMagnet software.



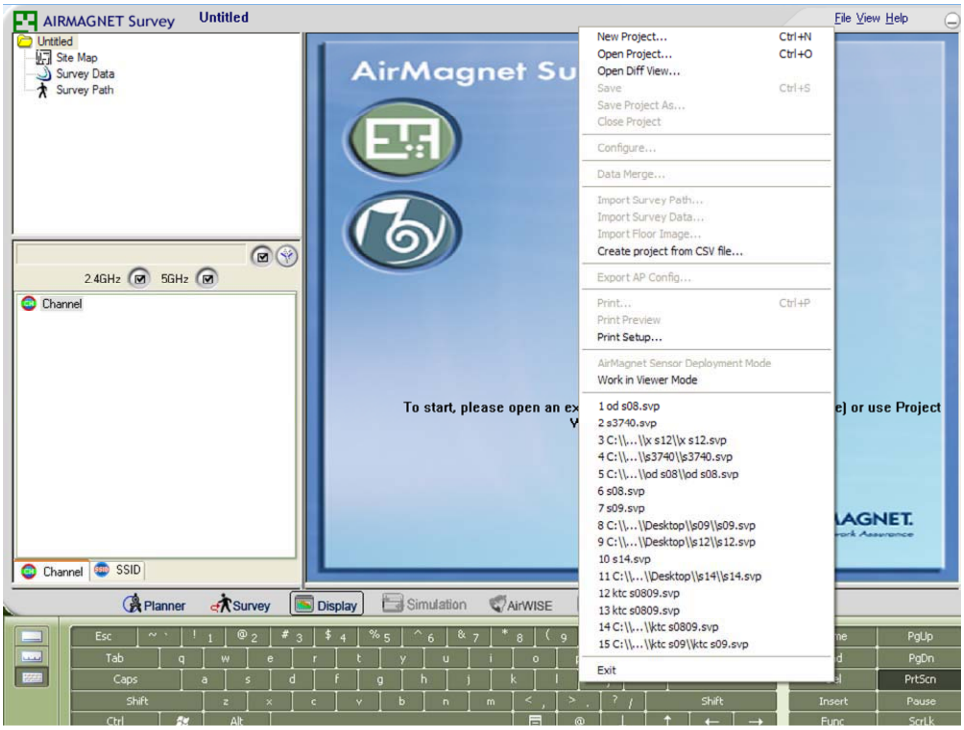
Figures 3.17 Selecting AirMagnet Survey Software



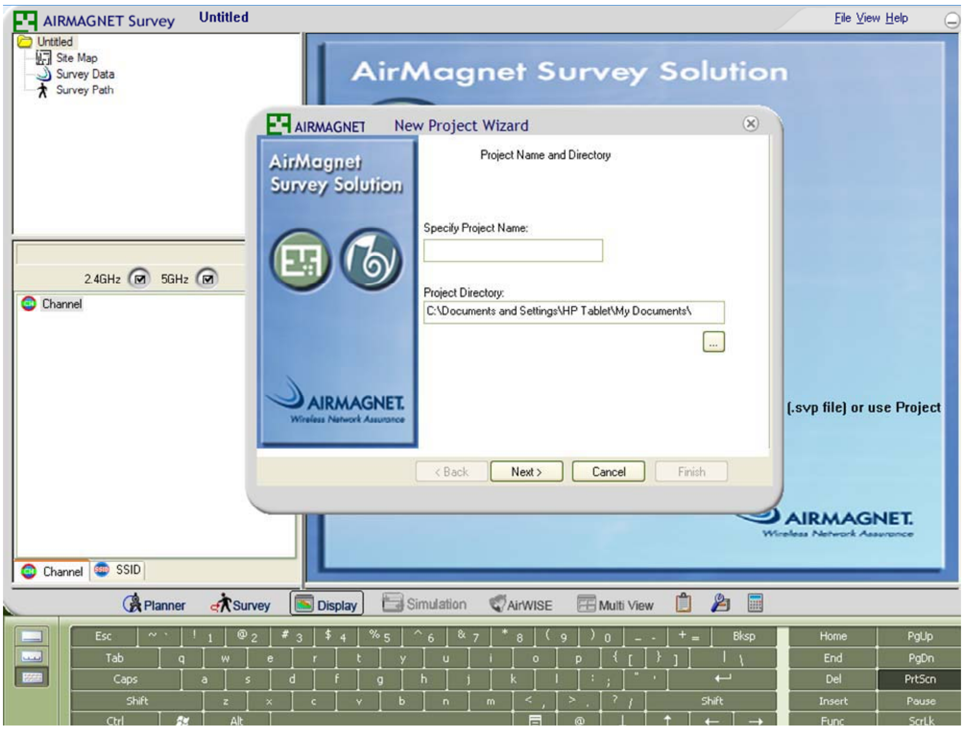
Figures 3.18 Initial Window in AirMagnet Survey Solution



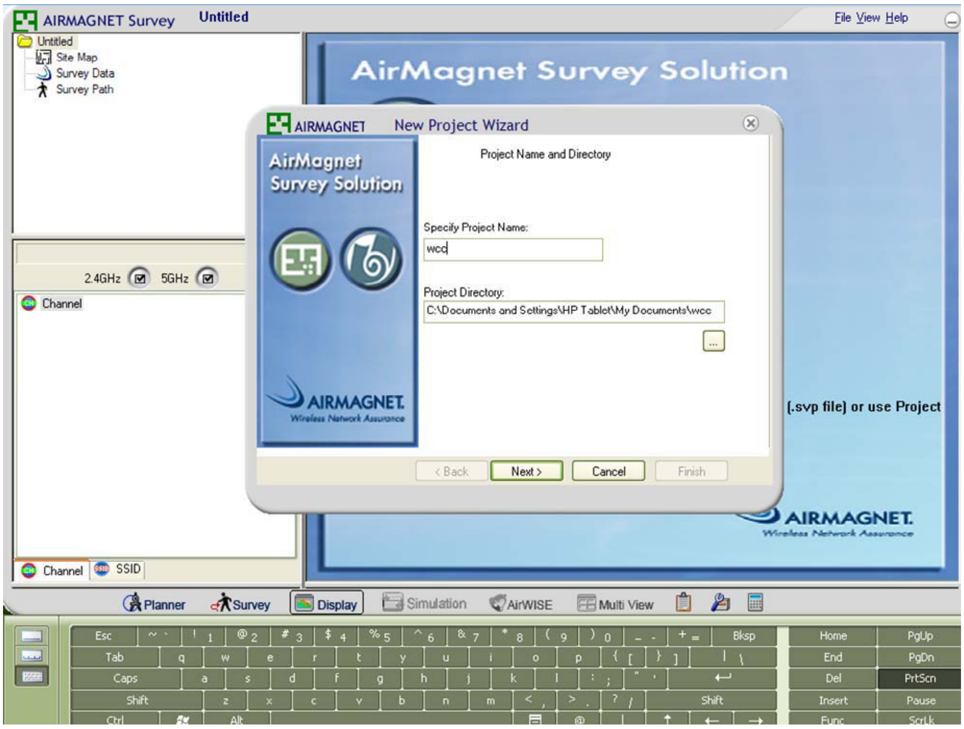
Figures 3.19 Creating New Project



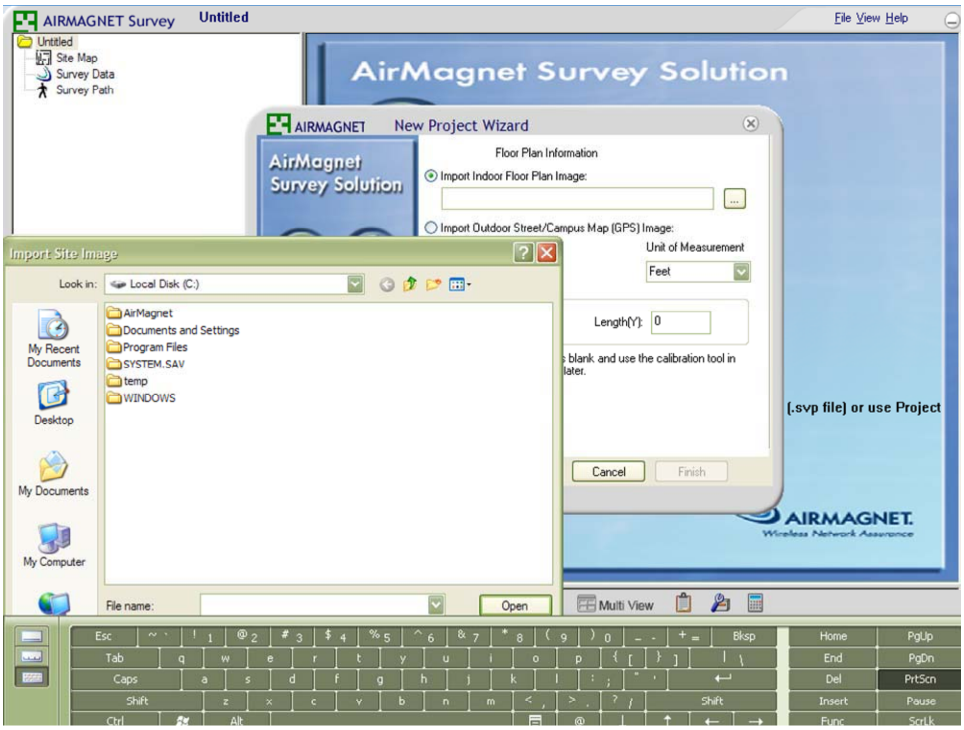
Figures 3.20 Drop Down File Menu



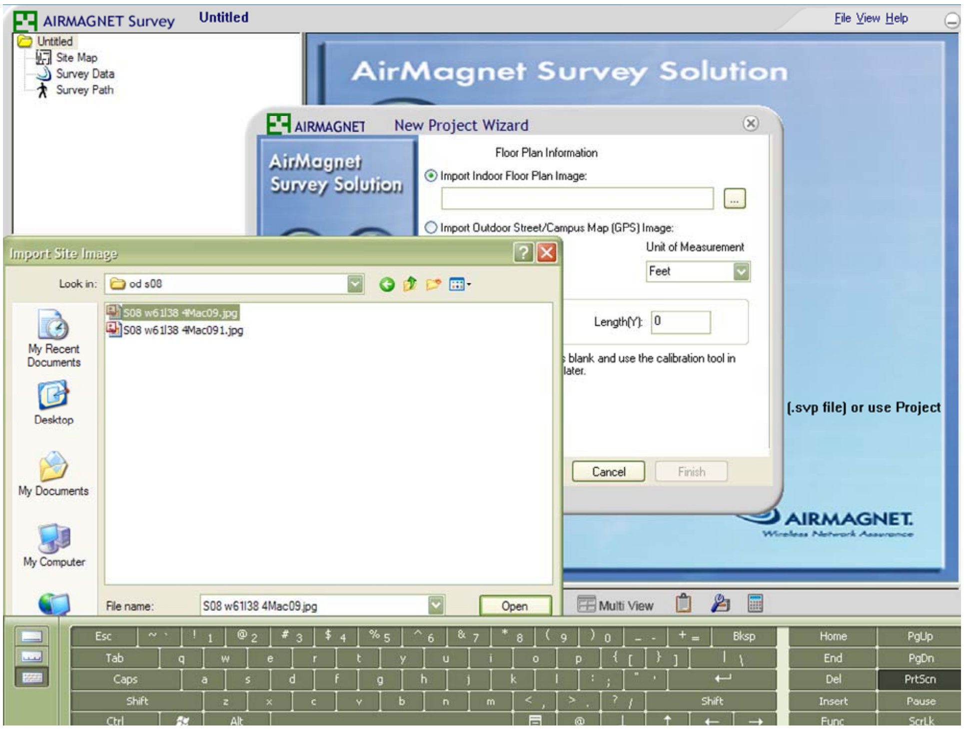
Figures 3.21 New Project Window



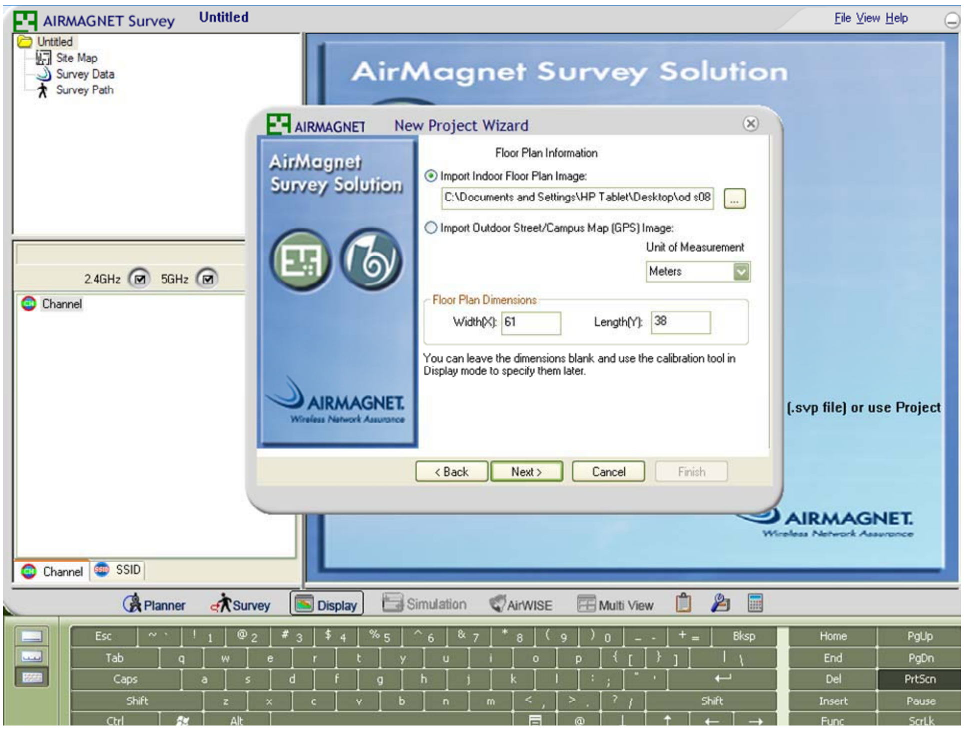
Figures 3.22 Naming A New Project



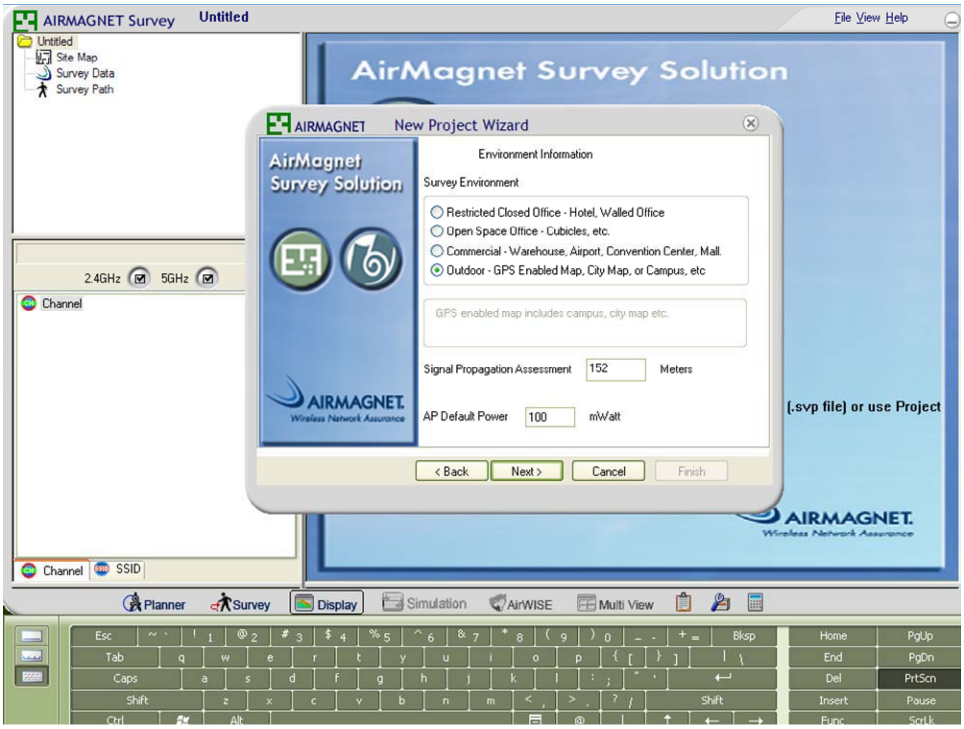
Figures 3.23 Inserting A Background Image



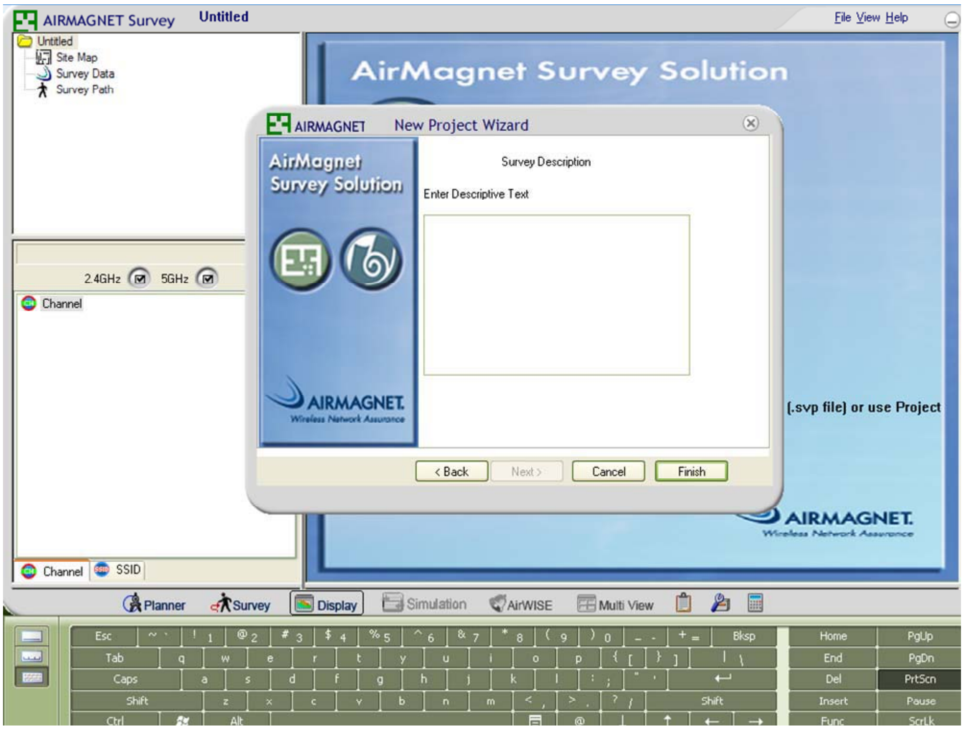
Figures 3.24 Selecting Pre-prepared Image From Google Earth™



Figures 3.25 Specify Image Dimension



Figures 3.26 Specifying Outdoor Survey



Figures 3.27 Starting The Survey

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This project is divided into two, the first part is the measurement part where predetermined area within UTM residential campus is selected. For the measurement part, AirMagnet Survey Solution software, Wireless PC Card is used as measurement tool while Wireless AP and Patch antenna is part of wireless devices used in existing UTM-WCC wireless network. The second part is the simulation part. For this part, by using background image obtained in Google Earth on predetermined area, an environment such as buildings, trees with surveyed information such as buildings height or material and trees height and size is built into the background image[1]. Together this information, a simulation is done. Both result were then compared and discussed.

The measurement and simulation was done taken at two locations, within single Block S08 and within clusters of Block S37, S38, S39 and S40.

4.2 Measurement Result At Block S08

The measurement was taken at many points within the Block S08. Each point taken was captured with parameters such as signal level in dBm, noise level in dBm and Signal to Noise ratio. Each point taken was marked with red dot on the base map and blue line resembles the path taken for measurement.

Figure 4.1 Picture of Block S08

Figure 4.2 Satellite Image of Block S08

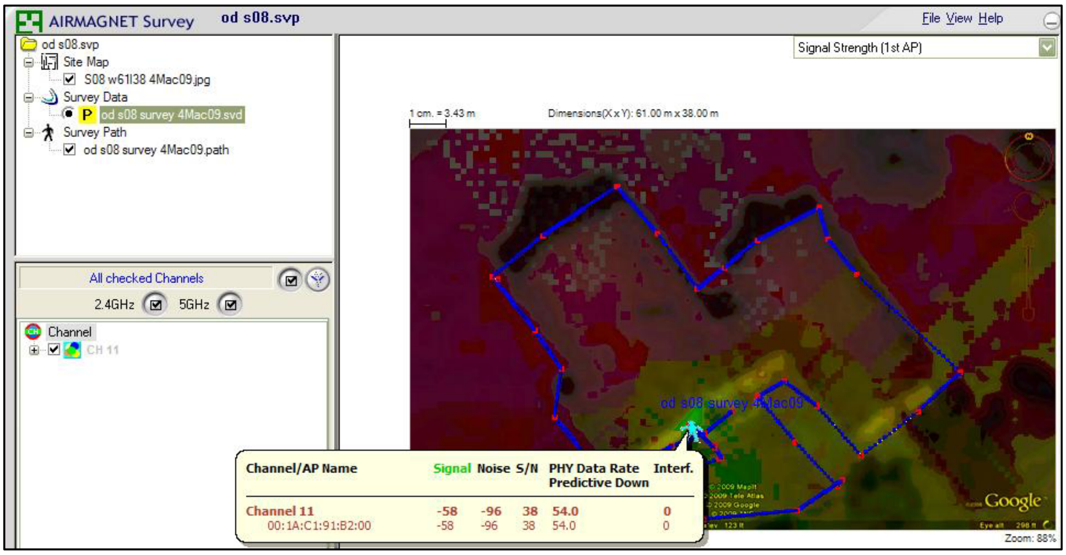


Figure 4.3(a) 1st Measurement Point

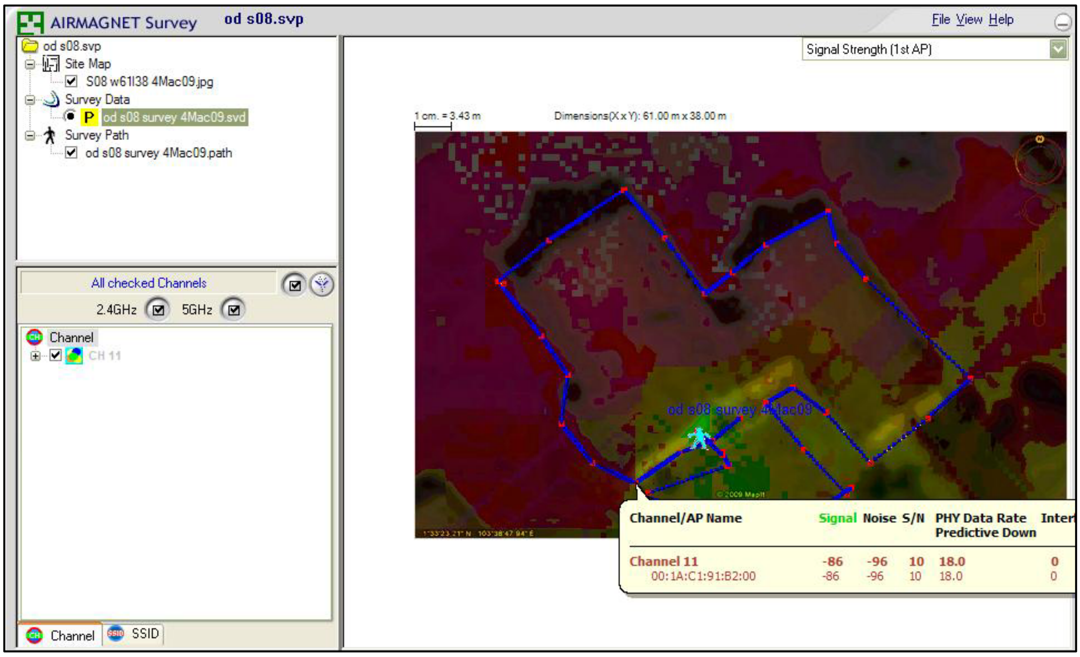


Figure 4.3(b) 2st Measurement Point

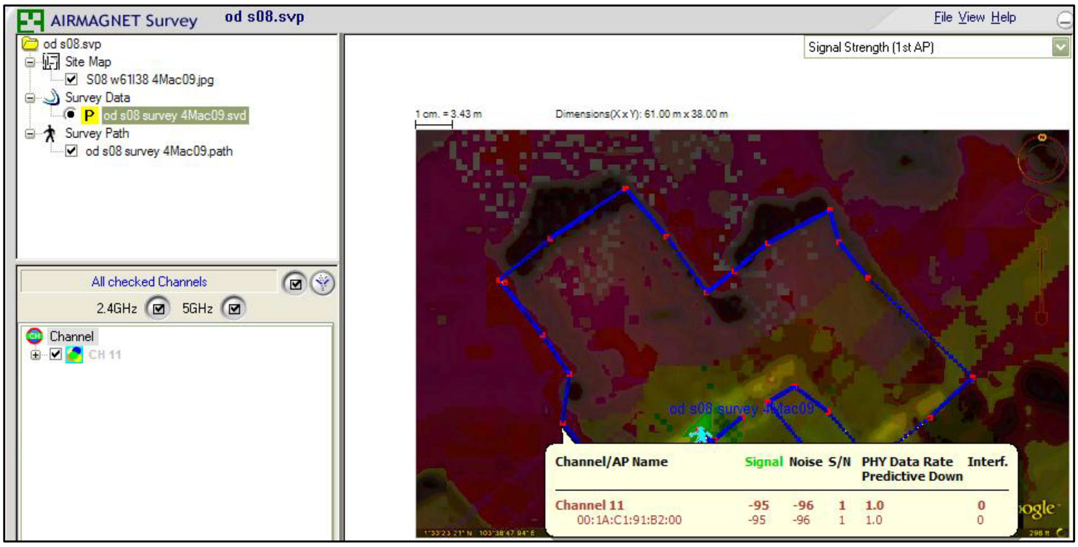


Figure 4.3(c) 3rd Measurement Point

Figure 4.3(d) 4th Measurement Point

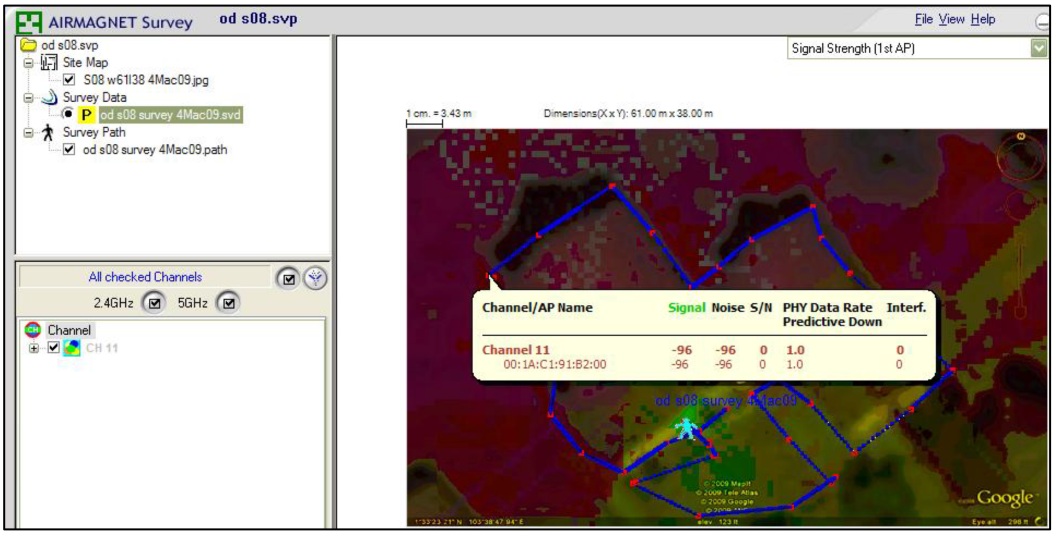


Figure 4.3(e) 5th Measurement Point

Figure 4.3(f) 6th Measurement Point

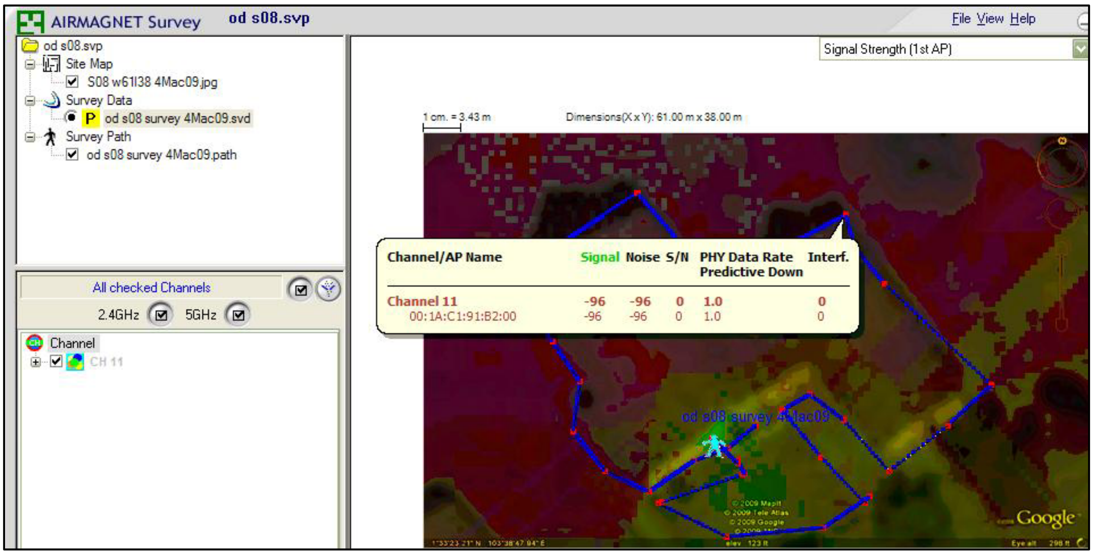


Figure 4.3(g) 7th Measurement Point

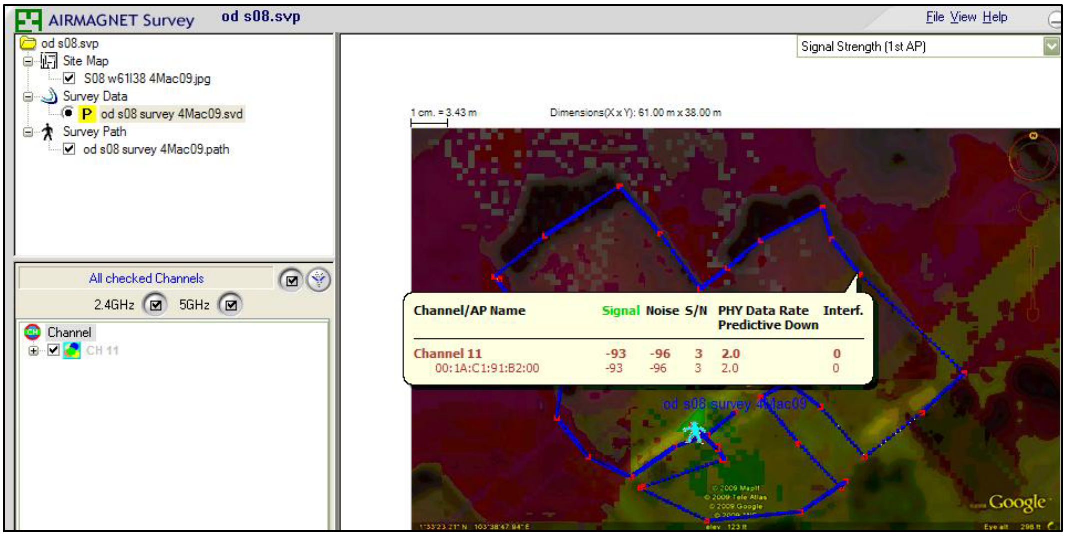


Figure 4.3(h) 8th Measurement Point

Figure 4.3(i) 9th Measurement Point

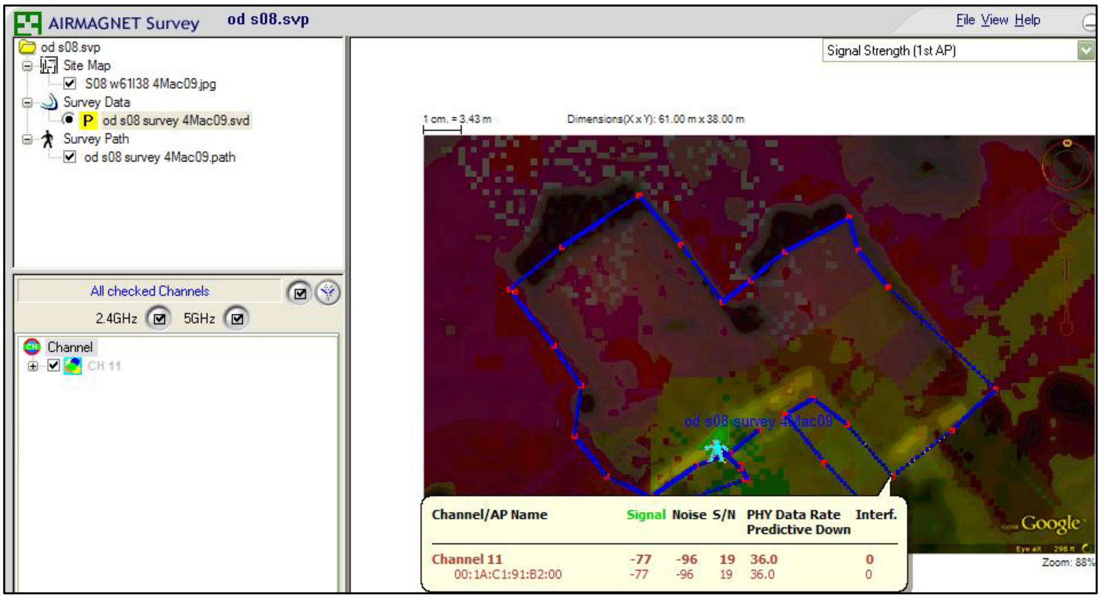


Figure 4.3(j) 10th Measurement Point

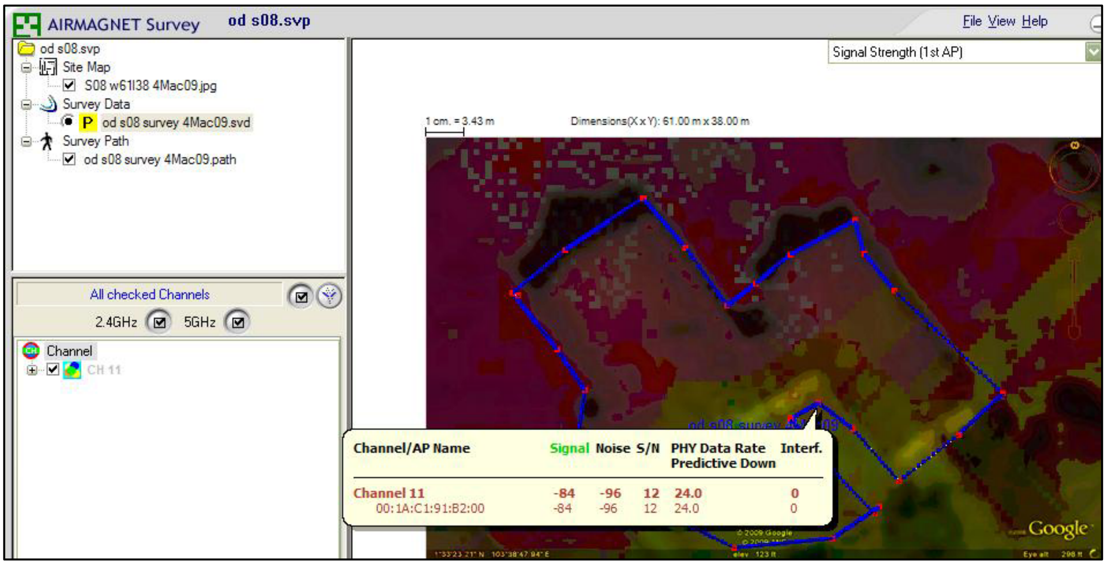


Figure 4.3(k) 11th Measurement Point

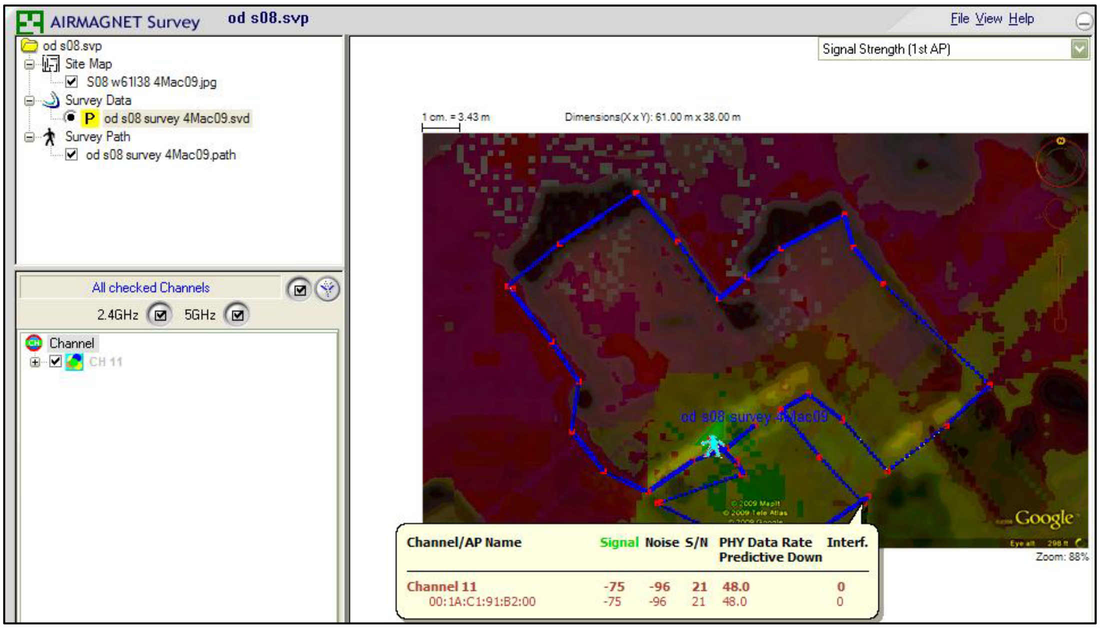


Figure 4.3(l) 12th Measurement Point

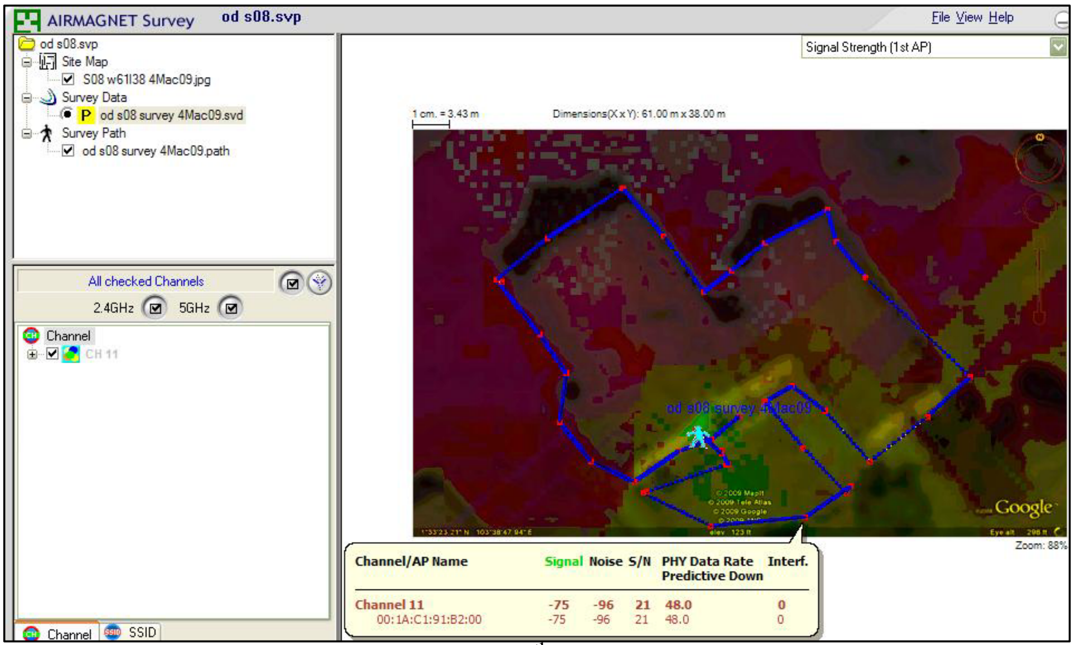


Figure 4.3(m) 13th Measurement Point

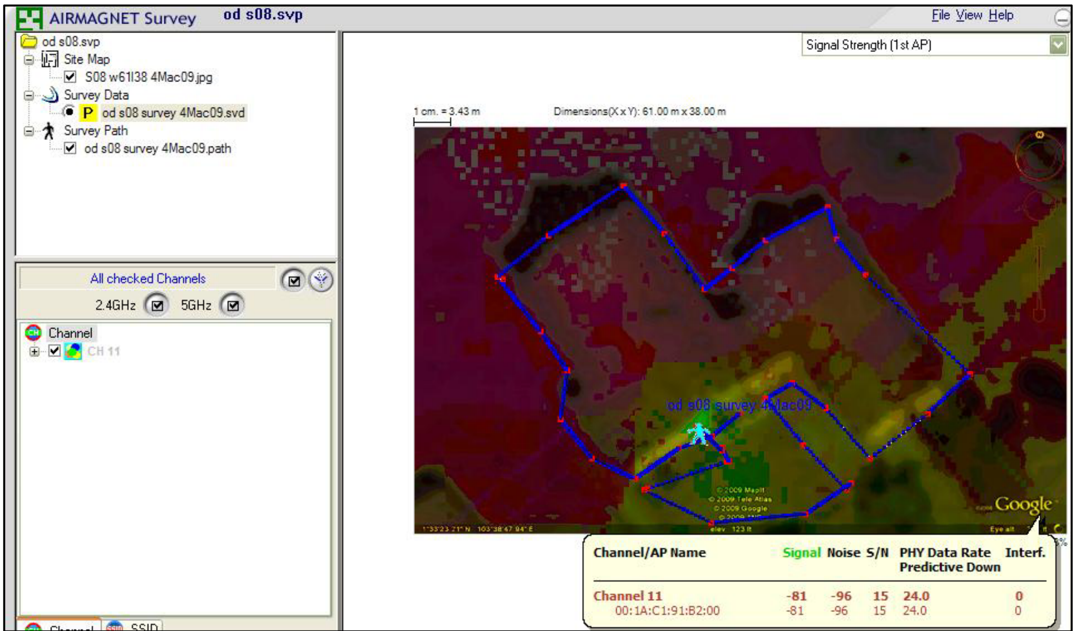
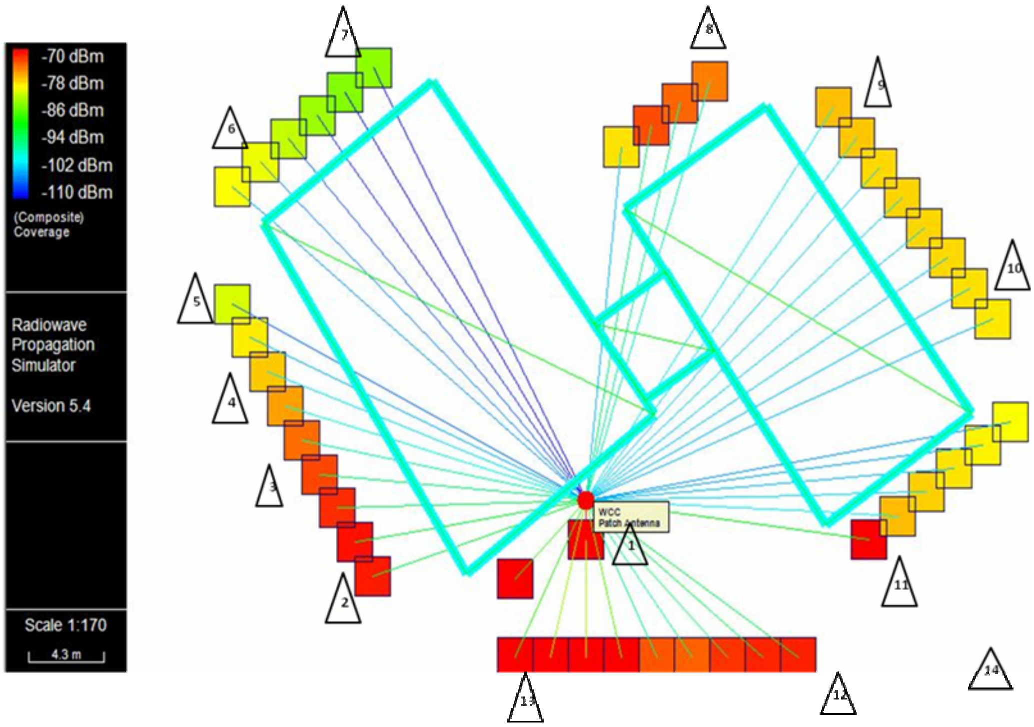


Figure 4.3(n) 14th Measurement Point

4.3 Simulation Result For Block S08

Using background image and site survey information such as build environment at site and vegetation, an environment is built into the RPS and simulated under COST 231-Walfisch-Ikegami (Outdoor). Various points where receivers were placed labeled as numbered triangle as in Figure 4.17.

Figure 4.4 Simulation In 2D View



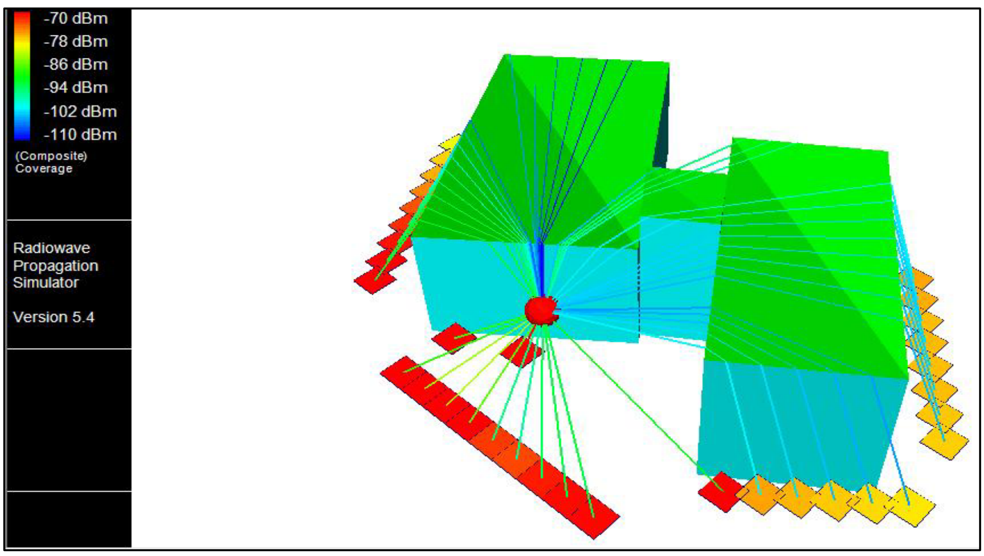


Figure 4.5 Simulation In 3D View

4.4 Comparison Between Simulated And Measured Received Signal

From the measurement and simulation result, a table is tabulated to list the measured received signal strength and simulated received signal strength at same point in the environment. The difference between the two values is also calculated.

Table 4.1 Received Signal Comparison

POINT	SIMULATED(sim) VALUE (dBm)	MEASURED(mea) VALUE (dBm)	DIFFERENCE (sim-mea) (dBm)
1	-52.73	-58	5.27
2	-70.03	-75	5
3	-71.77	-86	14.23
4	-76.91	-96	19.09
5	-80.53	-96	15.47
6	-79	-100	21
7	-83.39	-100	16.61
8	-73.96	-100	26.04
9	-76.56	-96	19.44
10	-78.16	-96	17.84
11	-68.84	-93	24.16
12	-70.27	-93	22.73
13	-67.13	-91	23.87
14	NA	-77	NA

4.5 Measurement Result At Blocks S37, S38, S39, S40

The measurement was taken at many points within the Blocks. This location differs from Block S08 mainly for the presence of trees and terrain condition which is shown in Figure 4.20, Figure 4.21, Figure 4.22 and Figure 4.23. Each point taken was captured with parameters such as signal level in dBm, noise level in dBm and Signal to Noise ratio. Each point taken was marked with red dot on the background image and blue line resembles the path taken for measurement.

Figure 4.6 Picture of Block S38

Figure 4.7 Picture of Block S39

Figure 4.8 Picture of Block S37

Figure 4.9 Picture of Block S40

Figure 4.10 Background Image of The Blocks

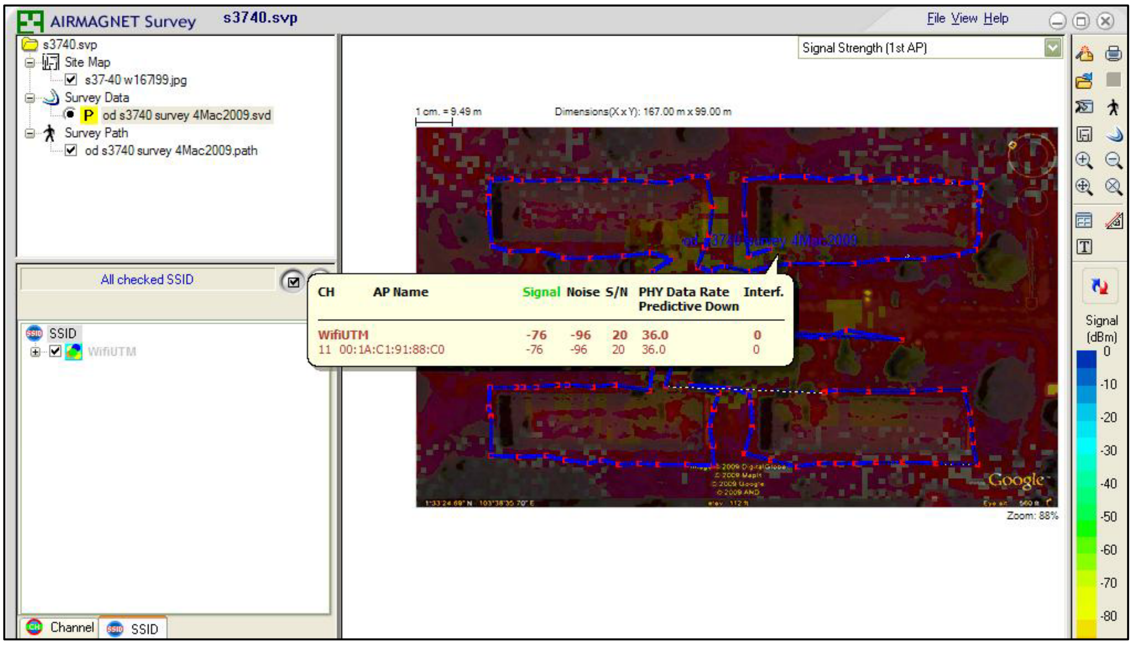


Figure 4.11(a) 1st Measurement Point

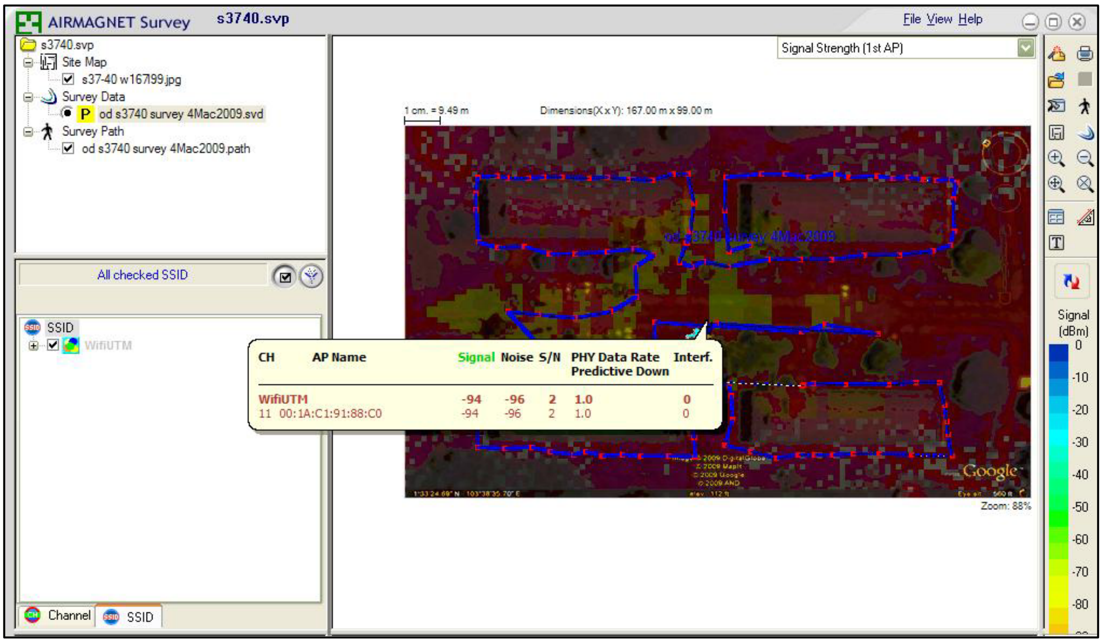


Figure 4.11(b) 2nd Measurement Point

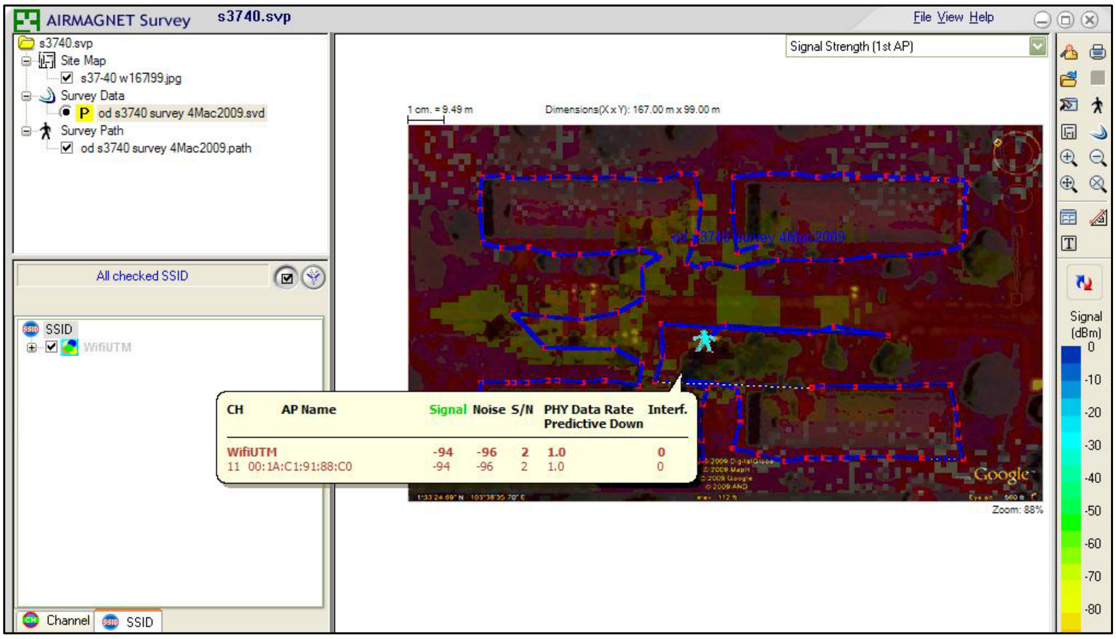


Figure 4.11(c) 3rd Measurement Point

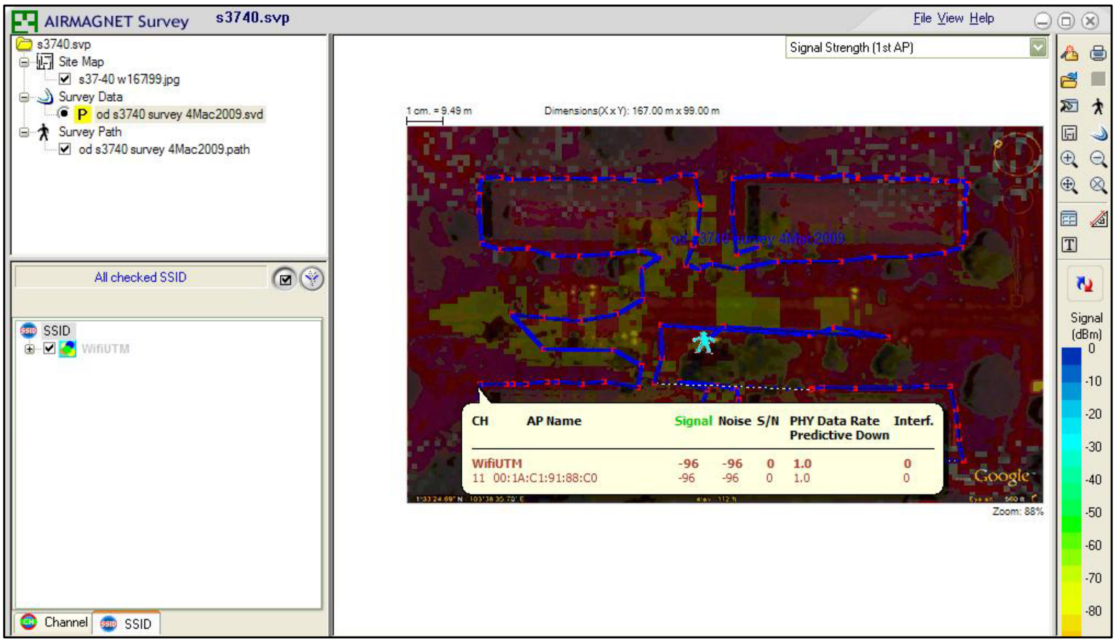


Figure 4.11(d) 4th Measurement Point

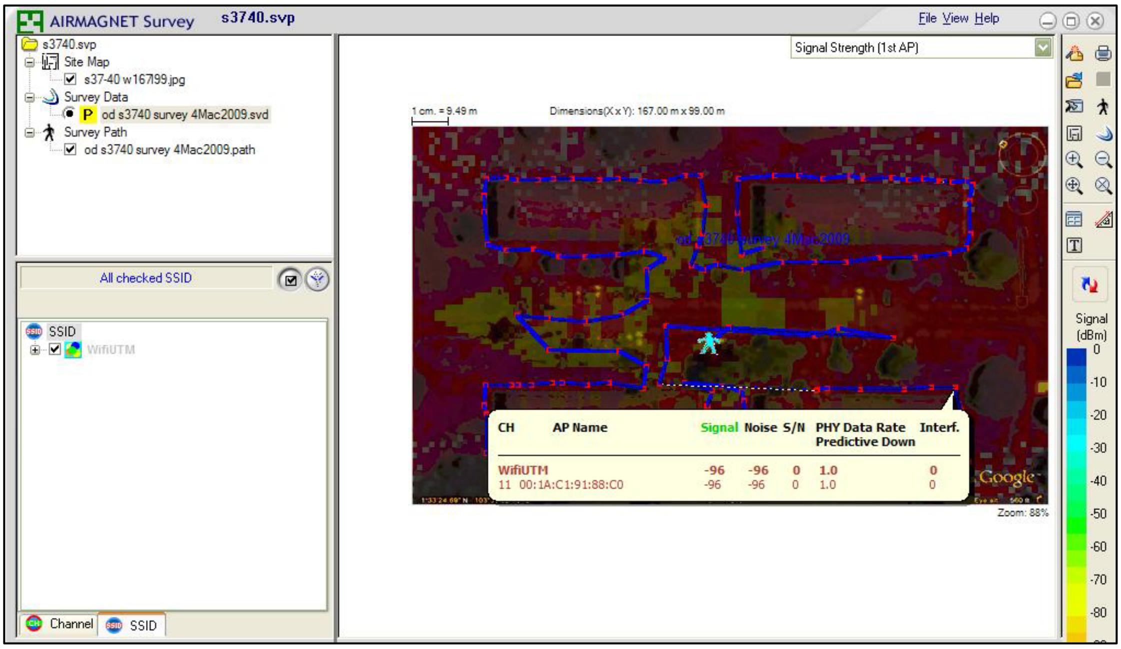


Figure 4.11(e) 5th Measurement Point

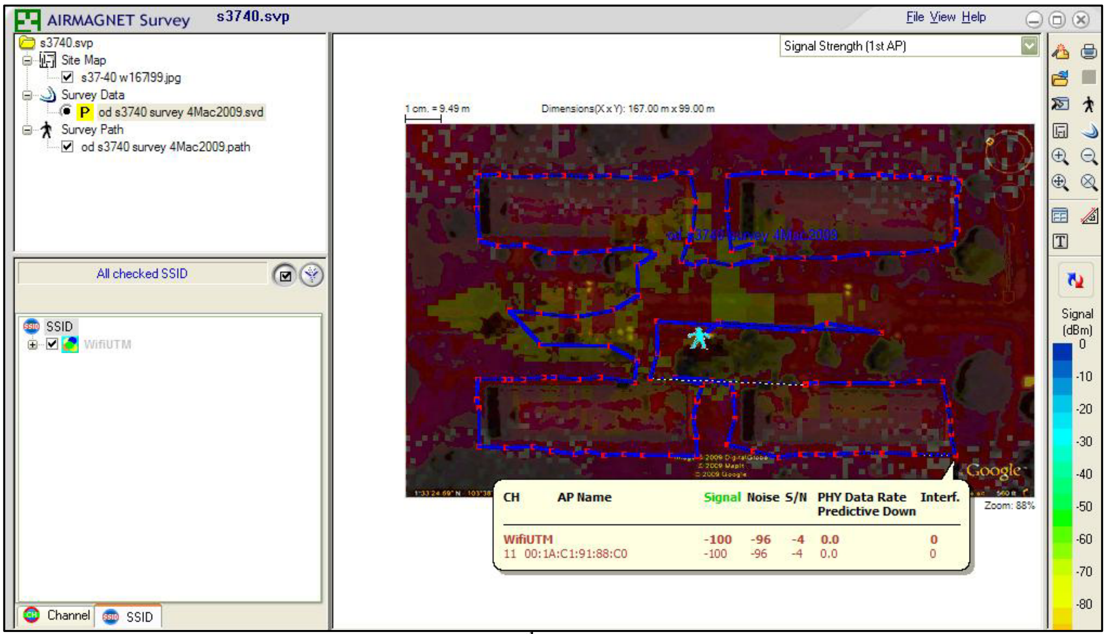


Figure 4.11(f) 6th Measurement Point

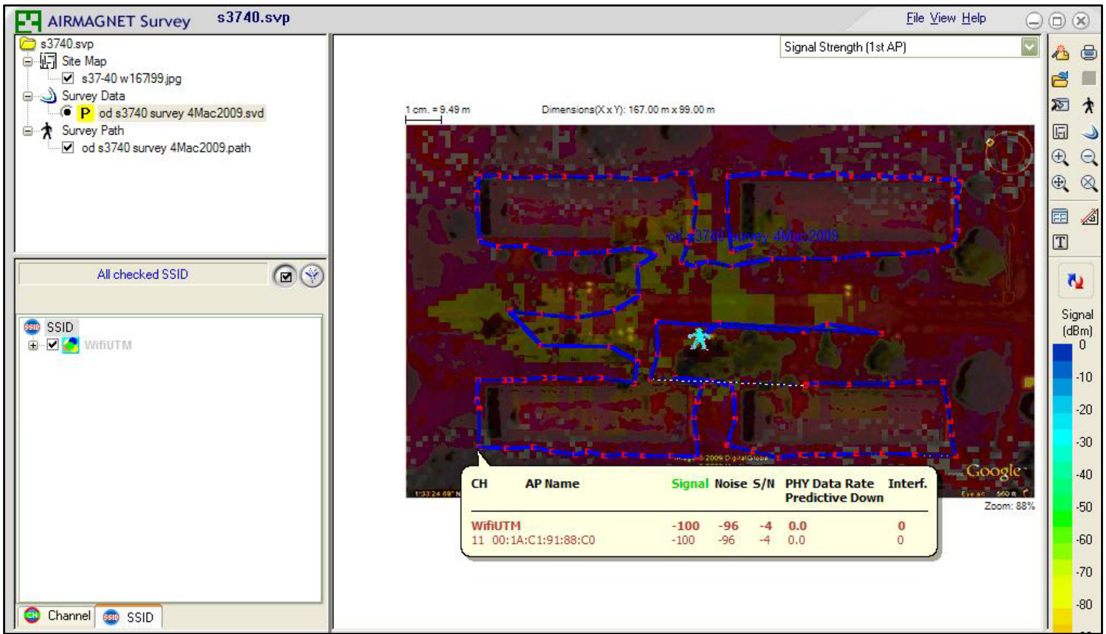


Figure 4.11(g) 7th Measurement Point

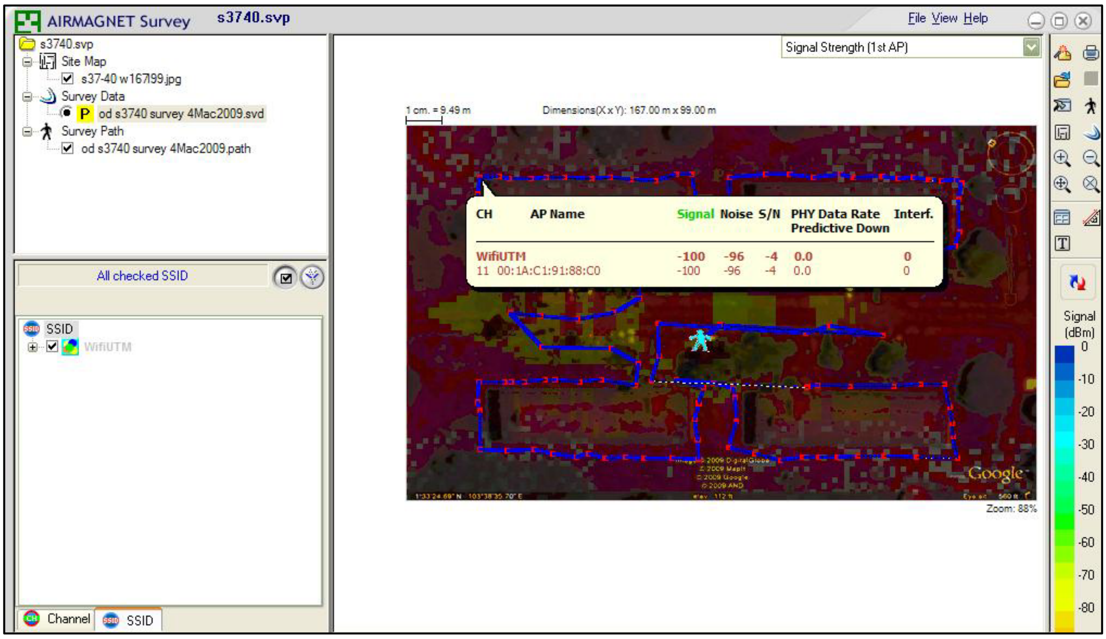


Figure 4.11(h) 8th Measurement Point

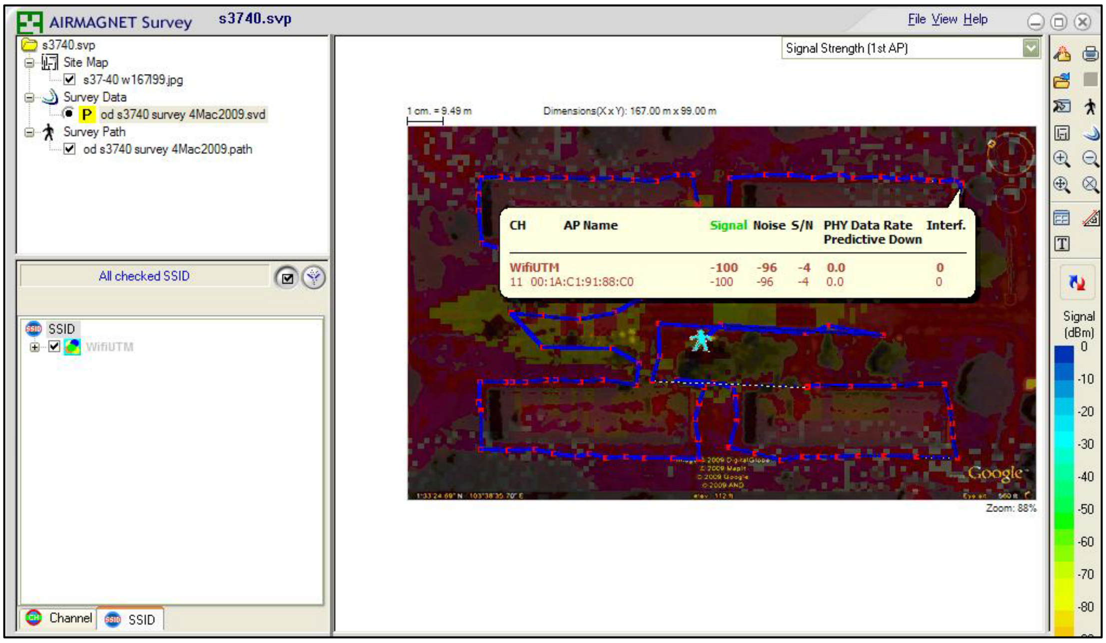


Figure 4.11(i) 9th Measurement Point

Figure 4.11(j) 10th Measurement Point

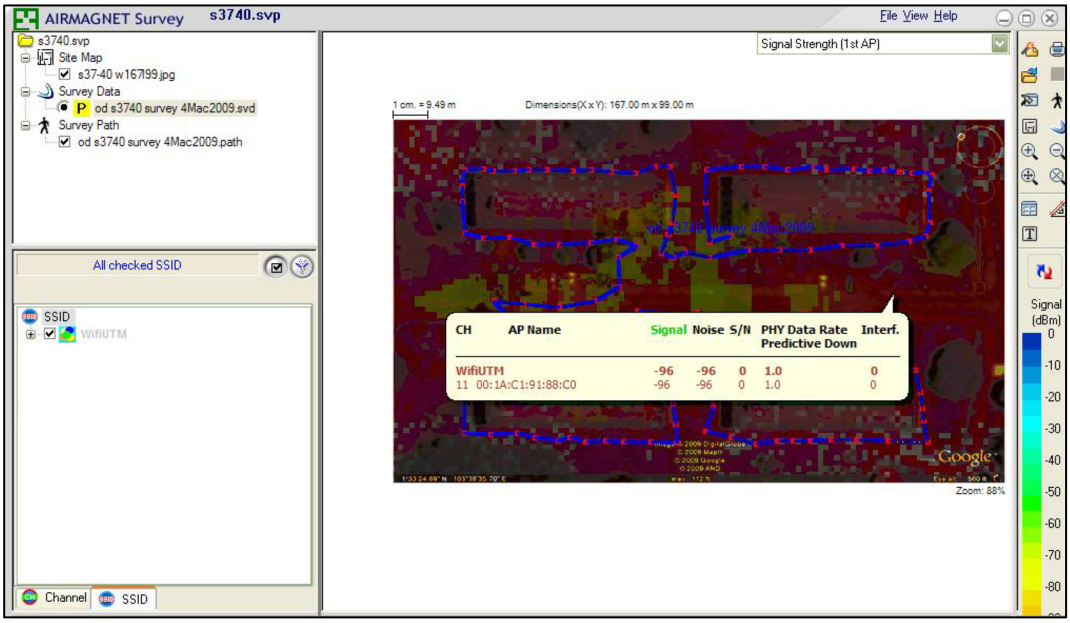


Figure 4.11 (k) 11th Measurement Point

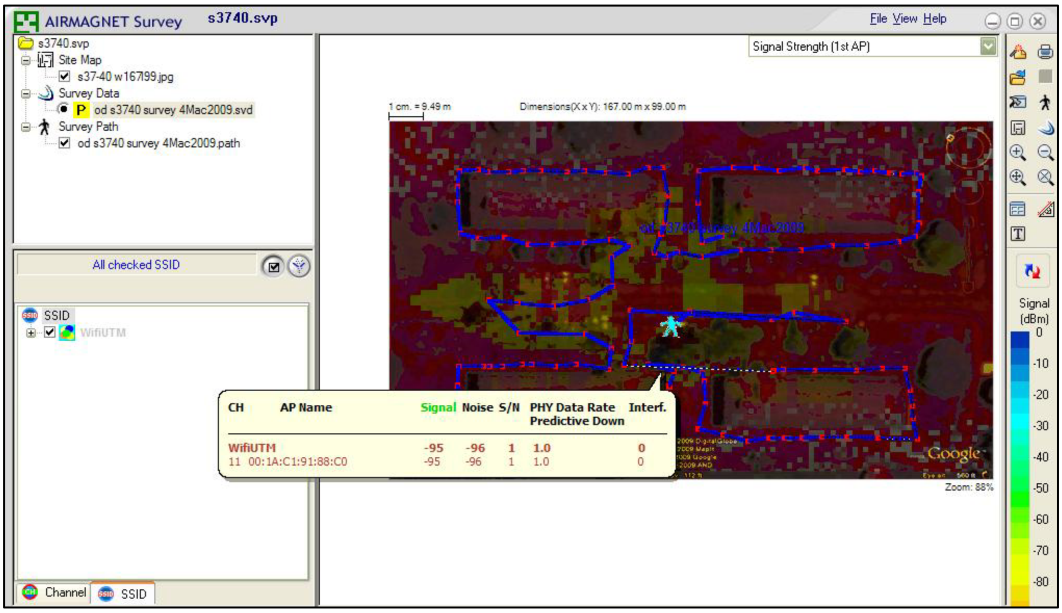


Figure 4.11(l) 12th Measurement Point

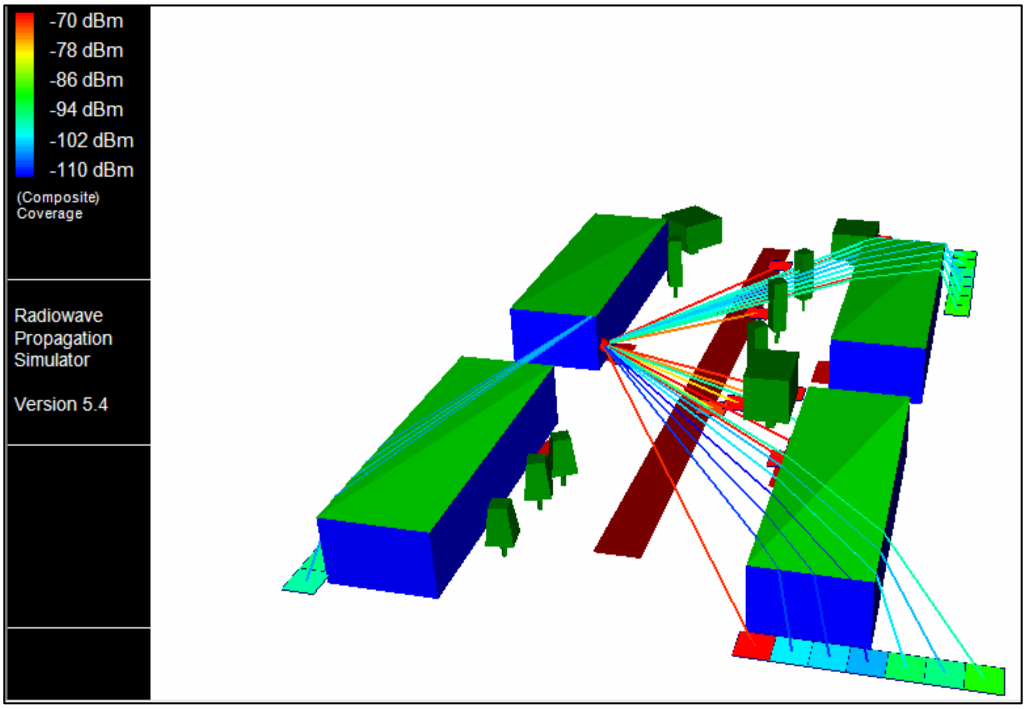


Figure 4.12 Simulation In 3D View

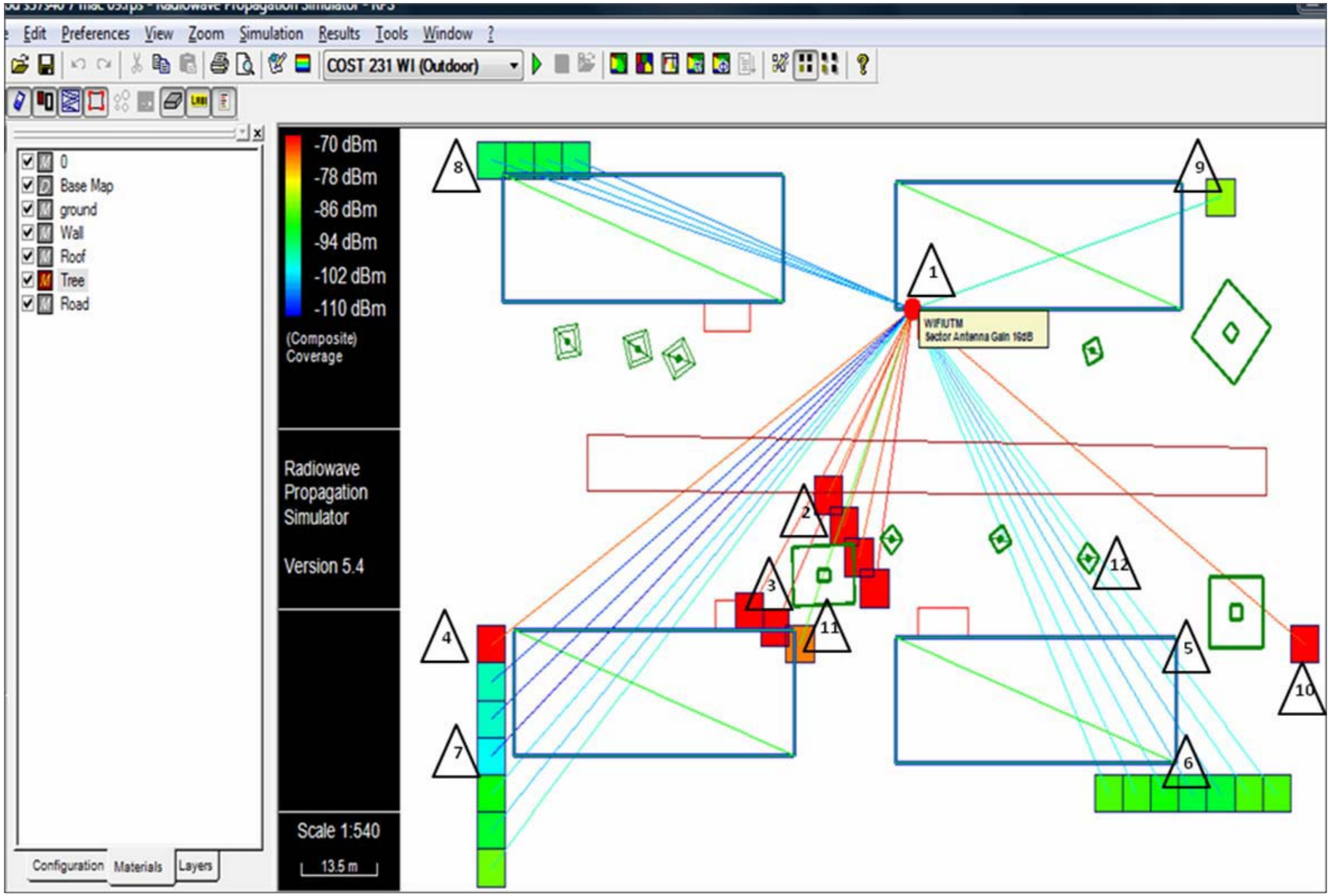


Figure 4.13 Simulation In 2D View

4.6 Comparison Between Simulated And Measured Received Signal

From the measurement and simulation result, a table is tabulated to list the measured received signal strength and simulated received signal strength at same point in the environment. The difference between the two values is also calculated.

Table 4.2 Received Signal Comparison

POINT	SIMULATED(sim) VALUE (dBm)	MEASURED(mea) VALUE (dBm)	DIFFERENCE (sim-mea) (dBm)
1	-70.01	-76	5.99
2	-73.63	-94	20.37
3	-78.37	-94	15.63
4	-80.96	-96	13.04
5	-81.79	-96	14.21
6	-91.52	-100	8.48
7	-89.30	-100	10.7
8	-85.25	-100	14.75
9	-79.14	-100	20.86
10	-81.88	-100	18.12
11	-89.04	-95	5.96
12	-77.13	-96	18.87

4.7 DISCUSSION

From the Table 4.1, for Block **S08** Measurement and Simulation result, it is found that in general, all the readings showed received signal strength in simulation is higher than in measurement. At point 1 and 2, both reading agree each other. Point 1 is just beneath the patch antenna which may explain the similarities by both measurement and simulation while point 2 is about 5 m in distance from antenna and is line of sight to antenna. Other reading showed that the difference from simulation and measurement varies from 14 dB to 26 dB.

S08 is a building where radio propagation were supposed be affected by diffraction by the buildings itself. The lower signal strength received in measurement may result from cable loss which was not accounted in simulation or degradation in transmitted power. Since the antenna type is of patch antenna type but designed by UTM-WCC, some of the properties is not available in RPS built-in antenna database. Higher measurement reading may also result from building design, S08 roof is actually slanted roof compared to type flat type roof which was simulated. The diffraction is greater at sharp edge roof which resulted from multiple obstructions as explained in Section 2.3.2.2.

From Table 4.2, for Block S37, S38, S39 and S40 which is generally a 3-storey building, effect of terrain to radio propagation were to observed since two buildings on higher ground and the other two on lower ground. Effect vegetation was also to be observed since many trees of different height present in the vicinity of the blocks. In general, simulated signal strength showed higher values than measured signal. The terrain effect were seen since Point 4, 5, 6 and 7 which was located at lower area received the lowest signal compared higher terrain located points. The effects of dense vegetation were observed at point 2 and 3 in Figure 4.13 where signal received behind the tree is weaker by 5 dB. In simulation as shown in Figure

4.13, terrain effect was not incorporated into the study due to short of time duration although there is a method to incorporate terrain information in RPS. This may resulted the higher simulation value in received signal.

CHAPTER 5

CONCLUSION

5.1 Conclusion

From the project carried out, it can be concluded a Radio Propagation Model that able to visualize the COST 231 Walfisch-Ikegami (Outdoor) outdoor propagation model can be achieved. This model enables radio propagation characteristic to be simulated in the required terrain and vegetation condition. The effect of terrain and vegetation to radio propagation was able to be observed in results both in simulation and measurement.

Deployment of communication devices into unknown terrain conditions now can be launched successfully. This is due the capability to predict wireless coverage via simulation. The proper location of communication devices can be planned earlier such that any failure of communications due to weak signal strength can be prevented.

The use of freely available satellite based mapping helps simulation done with minimal information of build up environment. Any additional information such as precise physical information will able a accurate prediction to be done.

5.2 Future Work

Recommendations for future work are as follows:

i. Improve the propagation model by incorporating wireless network devices parameters as provided by original equipment manufacturer.

ii. Effect of different type vegetation in Malaysia shall be studied to determine and set up a Malaysian vegetation database which can be incorporated into RPS.

REFERENCES

[1] Dr. J. Deibner, J. Hubner, D. Hunold, Dr. J. Voigt (2009). *RPS Radiowave Propagation Simulator*, RPS-v5.4. Retrieved on 2 Feb 2009 from fttp://www.actix.com

[2] Theodore S. Rappaport (2002). *Wireless Communications Principles And Practice* (2^{nd} ed) N.J, Prentice Hall.

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