

Asyed O. SHAROUN*
Esam E. ARTIMEI**

PROPAGATION PREDICTION FOR INDOOR WIRELESS LOCAL AREA NETWORK APPLICATION

The application of wireless local area network (WLAN) is increasing in offices, it becomes important to study signal propagation indoor environment. In this Paper, the Site Ware Technologies' site specific propagation prediction tool is a Three-dimensional (3-D) ray tracing code employing modified shoot and bounce Ray (SBR) method known as the Vertical Plane Launch (VPL) is used to predict indoor propagation effects in a cultural Center. The simulation experiment is carried out to select the best location for installing a transmitter in a large center with many rooms and corridors. Receivers should available in all of the rooms. To understand how electromagnetic waves reach the receiver, visualization software was used based on Matlab. This type of simulation will save money by selecting the minimum power of a single transmitter and choosing the least number of transmitters in large buildings.

KEYWORDS: indoor WLAN, ray tracing by using (VPL)

1. INTRODUCTION

The past decade has witnessed a phenomenal growth in wireless communication Indoor wireless communication such as personal communication (PCs) and wireless local area networks (LAN) are exploding rapidly. The need for an efficient way to evaluate and tracing radio propagation in buildings is increasing. It is also critical to find method for provide coverage, consequently, we that the ray-tracing technique has been the methods to predict radio propagation in indoor environments.

2. BUILDING DATABASE

The building database is comprised of a single American Standard Code for Information Interchange (ASCII) file which contains six columns of integer and floating point numbers that represent the building. The first column is a unique building identity number that must be different from the building number before

* Zawia University, Libya.

** The Center of Technology, Libya.

and after. The second and third columns are the X and Y coordinates are entered as a relative position from some arbitrary fixed reference position of the database coordinate system. The fourth column is the Z coordinates which representing the height of the top of the building above the reference plane and the fifth column is ΔZ which representing the vertical distance that the corner of the building extends downward from Z, are assigned to each (X; Y) point, while the final column in the database is representing the relative dielectric constants [10]. The recommended dielectric constant is 6 because it provides the least error compared to value [11]. Figure 1 shows the map of culture center, while; Figure 2 shows a sample of database of a building.

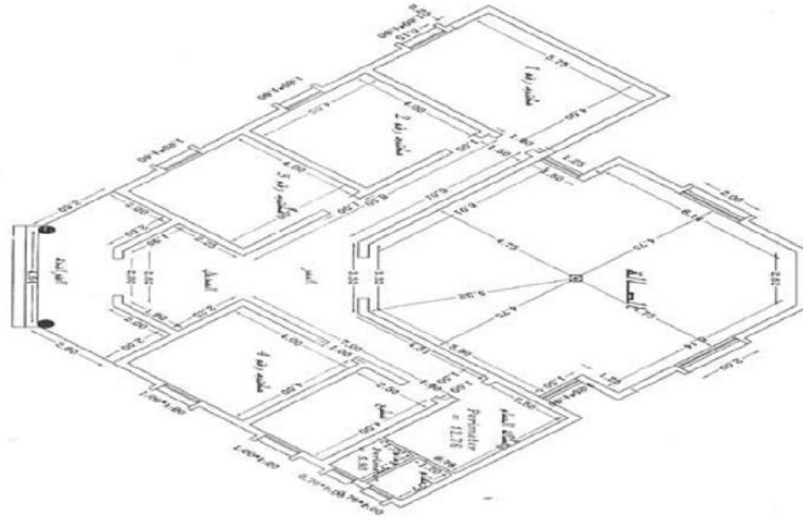


Fig. 1. Map of culture center

Number of building	x	y	z	xy	Prediction loss
1	1.0000	1.0000	1.0000	1.0000	0.0000
2	1.1000	1.1000	1.1000	1.1000	0.0000
3	1.2000	1.2000	1.2000	1.2000	0.0000
4	1.3000	1.3000	1.3000	1.3000	0.0000
5	1.4000	1.4000	1.4000	1.4000	0.0000
6	1.5000	1.5000	1.5000	1.5000	0.0000
7	1.6000	1.6000	1.6000	1.6000	0.0000
8	1.7000	1.7000	1.7000	1.7000	0.0000
9	1.8000	1.8000	1.8000	1.8000	0.0000
10	1.9000	1.9000	1.9000	1.9000	0.0000
11	2.0000	2.0000	2.0000	2.0000	0.0000
12	2.1000	2.1000	2.1000	2.1000	0.0000
13	2.2000	2.2000	2.2000	2.2000	0.0000
14	2.3000	2.3000	2.3000	2.3000	0.0000
15	2.4000	2.4000	2.4000	2.4000	0.0000
16	2.5000	2.5000	2.5000	2.5000	0.0000
17	2.6000	2.6000	2.6000	2.6000	0.0000
18	2.7000	2.7000	2.7000	2.7000	0.0000
19	2.8000	2.8000	2.8000	2.8000	0.0000
20	2.9000	2.9000	2.9000	2.9000	0.0000
21	3.0000	3.0000	3.0000	3.0000	0.0000
22	3.1000	3.1000	3.1000	3.1000	0.0000
23	3.2000	3.2000	3.2000	3.2000	0.0000
24	3.3000	3.3000	3.3000	3.3000	0.0000
25	3.4000	3.4000	3.4000	3.4000	0.0000
26	3.5000	3.5000	3.5000	3.5000	0.0000
27	3.6000	3.6000	3.6000	3.6000	0.0000
28	3.7000	3.7000	3.7000	3.7000	0.0000
29	3.8000	3.8000	3.8000	3.8000	0.0000
30	3.9000	3.9000	3.9000	3.9000	0.0000
31	4.0000	4.0000	4.0000	4.0000	0.0000
32	4.1000	4.1000	4.1000	4.1000	0.0000
33	4.2000	4.2000	4.2000	4.2000	0.0000
34	4.3000	4.3000	4.3000	4.3000	0.0000
35	4.4000	4.4000	4.4000	4.4000	0.0000
36	4.5000	4.5000	4.5000	4.5000	0.0000
37	4.6000	4.6000	4.6000	4.6000	0.0000
38	4.7000	4.7000	4.7000	4.7000	0.0000
39	4.8000	4.8000	4.8000	4.8000	0.0000
40	4.9000	4.9000	4.9000	4.9000	0.0000
41	5.0000	5.0000	5.0000	5.0000	0.0000
42	5.1000	5.1000	5.1000	5.1000	0.0000
43	5.2000	5.2000	5.2000	5.2000	0.0000
44	5.3000	5.3000	5.3000	5.3000	0.0000
45	5.4000	5.4000	5.4000	5.4000	0.0000
46	5.5000	5.5000	5.5000	5.5000	0.0000
47	5.6000	5.6000	5.6000	5.6000	0.0000
48	5.7000	5.7000	5.7000	5.7000	0.0000
49	5.8000	5.8000	5.8000	5.8000	0.0000
50	5.9000	5.9000	5.9000	5.9000	0.0000

Fig. 2. Database building collation

3. RECEIVER DATABASE

The receiver file is also in multi-column format, with each line containing the coordinates of a single receiver point. The first column represents the receiver number and the following three columns represent the location of the receiver in x, y and z coordinates, with respect to the building database coordinate system. The z value of the receiver point is the height of the ground at the point and not absolute height of the receiver. The height of the receiver above the ground, which is specified by the user, is added to the z value to get the height of the receiver. Samples of the receiver database for simulation and map of receiver will be shown in Figure 3.

Number of receiver	x	y	z
1	1000	1000	1000
2	2000	2000	2000
3	3000	3000	3000
4	4000	4000	4000
5	5000	5000	5000
6	6000	6000	6000
7	7000	7000	7000
8	8000	8000	8000
9	9000	9000	9000
10	1000	1000	1000
11	2000	2000	2000
12	3000	3000	3000
13	4000	4000	4000
14	5000	5000	5000
15	6000	6000	6000
16	7000	7000	7000
17	8000	8000	8000
18	9000	9000	9000
19	1000	1000	1000
20	2000	2000	2000
21	3000	3000	3000
22	4000	4000	4000
23	5000	5000	5000
24	6000	6000	6000
25	7000	7000	7000
26	8000	8000	8000
27	9000	9000	9000
28	1000	1000	1000
29	2000	2000	2000
30	3000	3000	3000
31	4000	4000	4000
32	5000	5000	5000
33	6000	6000	6000
34	7000	7000	7000
35	8000	8000	8000
36	9000	9000	9000
37	1000	1000	1000
38	2000	2000	2000
39	3000	3000	3000
40	4000	4000	4000
41	5000	5000	5000
42	6000	6000	6000
43	7000	7000	7000
44	8000	8000	8000
45	9000	9000	9000
46	1000	1000	1000
47	2000	2000	2000
48	3000	3000	3000
49	4000	4000	4000
50	5000	5000	5000

Fig. 3. Database of receivers

4. BUILDING INTERIOR DATABASE FORMAT

When the floor plan of building is not known but propagation into the interior of a building is desired it is possible to assume some average characteristics of the building. The loss associated with this general description of the building is due mostly to the penetration through the exterior face and the interior walls of the building. The first number represents the building and must be an integer number. The number should correspond with the same building number as the one being described in the building database file. The next three numbers represent the average height of each floor, the height of the first (or ground floor), the average width of the rooms. The following three numbers represent the type of interior wall, type of floor and the type of exterior walls and must be integers. Currently, the numbers that represent the wall and floor types are used directly to determine the penetration loss. In words a wall or floor with a number 8 means that there is -8dB of loss associated with propagation through this material. Finally the last number represents the number of elevator shaft in the building if it is found. Figure 4 shows interior building database.

Number of receiver	Average height of floor and average width of rooms	Type of wall due to penetration loss	Number of elevator
1	3	4	8
2	3	4	10
3	3	4	10
4	3	4	10
5	3	4	10
6	3	4	10
7	3	4	10
8	3	4	10
9	3	4	10
10	3	4	10
11	3	4	10
12	3	4	10
13	3	4	10

Fig. 4. Interior building database

5. POWER AND DELAY SPREAD OUTPUT

The power and delay spread output file contains the predicted path loss for receivers, a section that contains the different components that add together to get the total power received, rms delay spread and mean excess delay. The results for each receiver are listed in a multicolumn format on a single line with brief heading describing the program execution parameters. Below the headers, the first column represents receiver numbers while second to fourth columns list the x, y, and z coordinates for those receivers. The fifth column is the predicted path loss value in dB. The column after in between vertical line (|) separators is breakdown of the total power received into its separate components. The first two columns indicate the value in watts and number of LOS rays, the second two columns show value in watt and number of reflected rays that arrived at receiver. The third and fourth two columns indicate value in watt and number of rays that undergo 1 and 2 vertical edge diffraction beside on top of reflection. The final two columns of data represent the rms delay spread and the mean excess delay in seconds. Figure 5 is an example of power and delay spread output.

Header

```

-----
*****
*** INPUT FILED
*** Scenario: C:\1.m
*** Receiver: C:\3.m
*** Terrain: none
*** Source Position: C:\add1.m
*** Propagation Model: ray
-----
*** INPUT PARAMETERS
*** Number of Receivers: 4
*** Number of Transmitters: 2
*** Prediction Frequency: 2400 MHz
*** Receiver Width: 1.00
*** Single Ray Model: Yes
*** Transmitter Location: 7.5, 7.5, 0=2.7
*** Height of Transmitter: 0.3
*** Height of Receiver: 0.3
-----
1 10 2 2 12 -95.121000e+000 0 2.64e-010 14.82e-011 3.000e+000 0 14.74e-009 2.60e-008
2 20 2 2 12 -83.201000e+000 0 2.77e-009 3.000e+000 0 0.000e+000 0 1.232e-012 3.07e-008
3 30 2 2 12 -84.491000e+000 0 2.51e-009 3.441e-011 1.000e+000 0 1.739e-009 1.14e-008
4 7 0 2 1 2 -80.541000e+000 0 2.71e-009 5.171e-011 1.000e+000 0 1.329e-009 1.20e-008
5 110 3 0 1 2 -87.691000e+000 0 1.60e-009 2.200e-011 1.000e+000 0 1.452e-009 1.60e-008
6 110 2 0 1 2 -82.001000e+000 0 3.12e-009 1.000e+000 0 0.000e+000 0 1.230e-012 3.12e-008
7 130 3 0 1 2 -85.771000e+000 0 2.40e-010 1.232e-009 3.610e-011 1 1.325e-009 3.11e-008
8 145 0 0 1 2 -86.671000e+000 0 1.24e-010 2.000e-012 3.000e+000 0 1.212e-009 3.11e-008
9 145 0 0 1 2 -80.701000e+000 0 2.22e-011 3.122e-012 2.000e+000 0 1.427e-009 3.53e-008
10 11 0 2 1 2 -84.261000e+000 0 1.000e+000 0 0.000e+000 0 0.000e+000 0 1.207e-012 1.71e-008
11 11 0 2 1 2 -55.081000e+000 0 1.000e+000 0 0.000e+000 0 0.000e+000 0 1.332e-012 1.88e-008

```

Fig. 5. Power and delay spread output

6. IMPULSE RESPONSE OUTPUT

In this result, the header is same with the one used for the power and delay spread. Below the header is the individual path information according to the receiver. The first line is the receiver number and the x, y, and z coordinates of the receiver. Listed below the receiver are the individual rays contributed at the receiver. The columns represent the angle at which the ray left the transmitter and path length of the ray in meters, the propagation time in seconds and the predicted path loss in dB. The fifth and final column is numerical representation of the type or class of ray. Example of impulse response output is displayed in Figure 6 set of low-level file input output (I/O) functions that are based on the I/O function of the American National Standards Institute (ANSI) Standard C Library.

```

out2 - Notepad
File Edit Format View Help
Wed Nov 12 08:42:08 2008
*****
#*** INPUT FILES
#*** Buildings: C:\1.txt
#*** Exciters: C:\1.txt
#*** Terrain: none
#*** Indoor Features: C:\bid1.txt
#*** Preprocessed Data: none
*****
#*** INPUT PARAMETERS
#*** Incremental angle: 1.000
#*** Number of Reflections: 6
#*** Number of Diffractions: 3
#*** Prediction Frequency: 2400 MHz
#*** Resonant Width Used: 1.00
#*** Single Ray Model Was Used
#*** Transmitter Located at: x=7.3 y=6.0 w=2.7
#*** Height of Transmitter: 0.3
#*** Height of Receiver: 0.3
*****

1 10 25 12
3.63 0.49 0.256972 7.61 2.54e-008 -95.79 1
3.67 0.47 0.253709 7.62 2.54e-008 -104.19 1001
6.25 0.49 0.095605 21.00 7.80e-008 -114.72 1000
3.21 0.70 0.167439 10.80 3.60e-008 -115.50 1000

2 38 30 12
3.62 0.60 0.036606 5.60 1.07e-008 -85.50 1

3 70 38 12
4.49 1.34 0.750505 29.6 9.04e-009 -85.50 1
4.47 1.33 0.719691 29.9 9.06e-009 -92.51 1
  
```

Fig. 6. Impulse response output

Fading and Multipath Effects

Fading is the result of multipath propagation. The signal arrives at the receiver as a result of reflection and diffraction plus the direct path if it exists.

Figures 8 represented ray tracing path with LOS when there is no object between receivers and transmitter. Also shown the effect of obstructions, the position of reflection and diffraction where they occur.

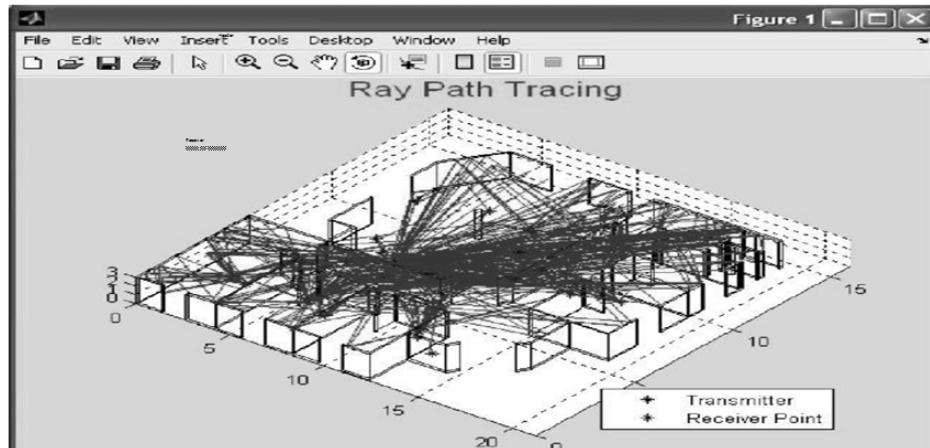


Fig. 7. Ray paths visualization for receivers (1) to (25) in 3D

Comparison between Results by changing the location of the transmitter

The received power depending on the location of the transmitter which is varied in three directions. From the mentioned figure, we can make the following observations. The received power in case of the transmitter is moving in the z direction The received power in case of the transmitter is moving in the Y direction.

7. RAY PATH INFORMATION OUTPUT

The ray path information is stored in separate file for each receiver in every simulation. These outputs generate details of each ray path that arrive at a particular receiving point. Each group of information starts with a # sign heading representing a single ray path. The heading with a # sign shows the total path length and total path loss associated with the ray. Information below the heading is a list of x, y, and z coordinates for all ray segments that combine together to form a complete path from source to receiving point. The number of ray paths arrives at a particular receiving point depends on the simulation output.

8. CONCLUSIONS

The objectives of the project have been achieved. The visualization of the radio wave propagation with 3 dimensional introduces effect of reflection, diffraction, delay spread and multi path fading helps in designing indoor wireless network planning and give image for ray path behaviors.

For the design of WLAN we must take into consideration the following points:

1. The transmitter should be located inside the building.
2. Simulation of electromagnetic propagation in the indoor environment is a convenient tool to use in selecting the best location for installing the transmitter and selecting its power.
3. It is observed that the power reaching the receivers is minimum when doors are closed, hence in testing by simulation or in real experiment doors should be closed to give a more reliable reception.
4. It is preferable to select a location that has less corridors so that there are less reflections.
5. Receiver should not be placed in contact with walls.
6. This type of simulation will save money by selecting the minimum power of a single transmitter and choosing the least number of transmitters in large buildings.

REFERENCES

- [1] Martyn Millick, *Mobile and Wireless Design Essentials*, 2003.
- [2] Robert K. Crane, *Propagation Handbook for Wireless Communication System Design*, 2003.
- [3] Michel D. Yacoub, *Foundations of Mobile Radio Engineering*, 1993.
- [4] Stanislav Zvezonvec, Pavel Pechac, Martin Klepal, *Wireless LAN networks design site survey or propagation modeling*.
- [5] <http://www.tapr.org/ve3jfdcc97.html>
- [6] <http://www.fas.org/man/dod-101/navy/docs/es310/propagat/Propagat.htm>
- [7] <http://www.ycars.org/EFRA/Module%20C/EMInteract.htm>
- [8] http://www.tpub.com/content/neets/14182/css/14182_72.htm
- [9] Theodore S. Rappaport, *wireless communications*, second edition.
- [10] George Liang, *User's Manual for Site Specific*.
- [11] Liang G. and Bertoni, H.L. "A new approach to 3-D ray tracing for propagation prediction in cities". *IEEE Transactions on antenna and Propagation* 1998.46(6):853-863.
- [12] <http://www.airmagnet.com/products/laptop.htm>
- [13] G.E Athanasiadou, A.R Nis and J.P.McGeehan, "A new 3D indoor ray-tracing propagation model with particular reference to the prediction of power and delay spread" Centre for Communications Research.