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Placement and Configuration of Antenna for Indoor Femtocell Application

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Reliable communication system such as fast internet access network is needed to support research activities in Computer System Laboratory and CNC Laboratory at IT Telkom. However, the signal from the nearest BTS microcell is not optimal forward the signal to the inside of the room. Therefore, it requires a special design to increase the average received power, minimize the blank spot areas, and increase SIR thus guaranteeing a good quality communication services. This paper will discuss the design of antenna configurations that will be compatible to femtocell applications on HSPA + technology in Computer System Laboratory and CNC Laboratory. An antenna configuration to 4 × 1 elements is studied in this paper. Additionally, the antenna placement of this configuration is changed three times. Performance with the antenna configurations will be simulated in RPS software and will be compared using 231 Cost Indoor and 3D Ray Tracing propagation models. Analysis results show that the most optimum configuration of Computer System Laboratory is the 4x1 elements at the second location for Cost 231 Indoor and the third location for 3D Ray Tracing model. While the most optimum configuration of CNC Laboratory is 4x1element at the second location for Cost 231 indoor and 3D Ray Tracing model.

Keywords: Coverage area, blank spot, SIR, the average of received power, femtocell, cost 231 indoor, 3D ray tracing.

1. INTRODUCTION

In the wireless communication system that greatly affects the quality of the received signal is the effect of multipath channel. Multipath can reduce power thus affecting the quality of the signal received at the receiver. To overcome this issue, the multiple antenna system is applied to make a better quality of the signal.

Besides that, the coverage area is also becoming a major problem in the communication system. The problem that arises is the presence of some parts that can not be reaching especially indoors due to the limited capability of the BTS. Good placement of the base stations is expected to reduce the blank spot area.

This paper will be focused on the design and placement of the antenna configuration suitable for femtocell applications. The expected results of this paper will provide solutions to improve performance and quality of the signal such as increase the average received power[2,6], minimize the blank spot area[3,7] and increase SIR[4,8] in a multiple antenna system on femtocell applications which using Cost 231 Indoor and 3D Ray Tracing model[1,5].

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2. PATH LOSS MODELING IN INDOOR SYSTEM

From the several alternative propagation models in RPS Software, the authors chose the indoor propagation model such as Cost 231 Indoor and 3D Ray Tracing to be research model. Using indoor propagation model, the result is more accurate than using outdoor propagation model. Indoor propagation model takes into account the loss caused by distance and the loss caused when the signal penetrating the materials in the room. The amount of this loss is influenced by the type of materials. While the outdoor propagation model only takes into account the loss caused by distance between the transmitter and receiver. Therefore, the authors chose Cost 231 Indoor and 3D Indoor Ray Tracing as indoor propagation models in this research.

A. COST 231 Keenan and Motley Model

In this model, all the walls that cut the direct beam between the transmitter and receiver as well as the properties of each wall material are calculated.
Path loss in this system is

$$L = Lo + 10.n\log d + \sum_{i=1}^{I} K_{f,i} . L_{f,i} + \sum_{j=1}^{J} K_{w,j} . L_{w,j}$$

B. 3D Ray Tracing Model

Ray tracing can accurately predict better the site with increased precision over other methods. One disadvantage is the static character of this approach can not solve the entire field distribution in a room.

3. SYSTEM DESIGN

The system to be designed in this paper is the placement and configuration of the antennas in an indoor femtocell HSPA+ technology.

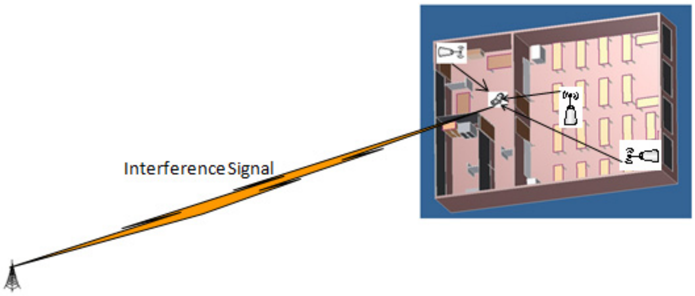

FIG. 1. SYSTEM DESIGN

From the Fig. 1, it shows that the position of the antenna will be changed three times. Additionally antenna configuration will also be changed three times that are 1x1, 2x1, and 4x1. From each combination of position and configuration of the antenna is then simulated using RPS (Radiowave Propagation Simulator). Before doing the simulations, the environment to be researched must be created an image using the integrated editor. Thus, database of the existing environment can be opened, or can be imported from DXF / DWG or tab-delimited ASCII. In this research, the initial mapping is done using CAD extension like .DWF formats which is converted to .DWG. But when exported to RPS software, it is occurred the unsynchronized in terms of the material type and the room size. So, it was decided that the initial mapping is only used as a visualization drawing. While the simulation environment uses a direct mapping in RPS. Increasing the accuracy, indoor mapping is done using the principle of Cartesian coordinates. Each object will be mapped in Cartesian coordinates, so the size and placement of the original objects. Furthermore, setting the antenna configurations (1x1, 2x1, and 4x1) and the transmitter position. While the receiver position is set in the matrix where the data is obtained. Finally, choosing the algorithm between Cost 231 Indoor and 3D Ray Tracing, and then the network simulation can be run for 36 times.

4 EXPERIMENTAL RESULTS

Reliable communication system such as fast internet access is required to support research activities, especially for the network laboratories. Based on discussion and interview with some respondents about the few network laboratories at IT Telkom, the obtained results that Computer System Laboratory and CNC Laboratory is the most laboratories requiring a reliable internet access. However, the signal from the nearest BTS microcell is not optimal forward the signal to the inside of the room. Therefore, the authors chose Computer System Laboratory and CNC Laboratory to be the location research.

A. Scenario I : Computer System Laboratory, Telkom Institute of Tecnology, Indonesia

Computer Systems Laboratory has a size of 15.4 x 14.5 m with a height of 3 m. Here is an overview of the laboratory computer.

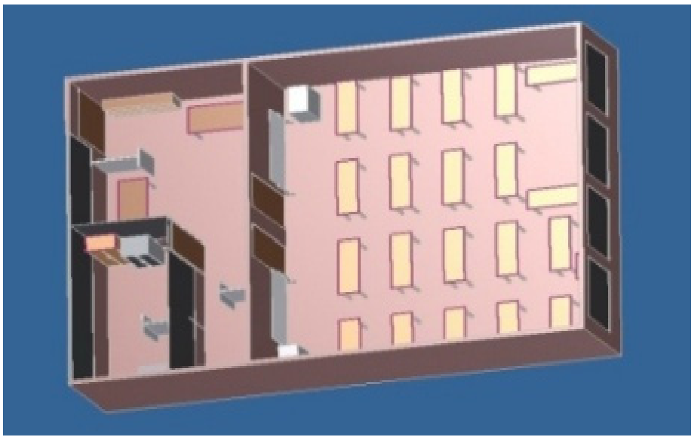

FIG. 2. COMPUTER SYSTEMS LABORATORY

1) Effect Cost 231 Indoor and 3D Ray Tracing Predictions to Coverage Area

Below are the simulation result graphs of coverage area on three transmitter locations with the predictions cost 231 Indoor on the left side and 3D Ray Tracing on the right side.

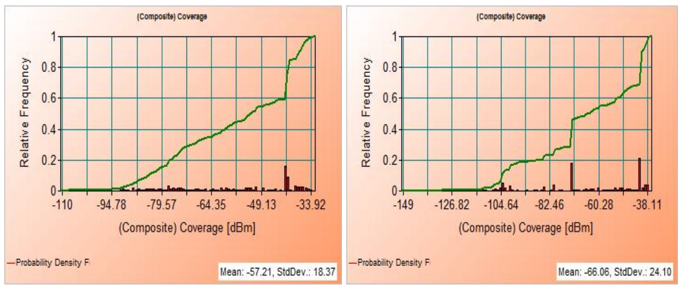

FIG 3. TRANSMITTER LOCATION

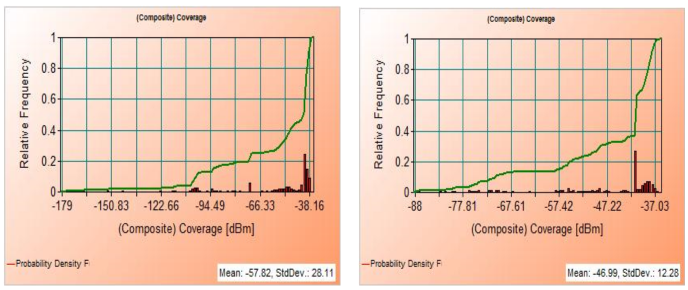

FIG 4. TRANSMITTER LOCATION

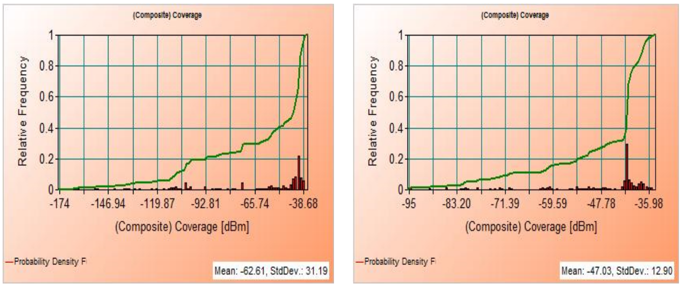

FIG 5. TRANSMITTER LOCATION

Here are statistical comparison results between Cost 231 Indoor and 3D Ray Tracing.

TABLE 1. STATISTICAL RESULT OF COST 231 INDOOR AND 3D RAY TRACING [1]

Configu-ration	Site	*Statistical Result*					
		Cost 231 Indoor			*3D Ray Tracing*		
		Mean Value [dB]	*Std. Dev. [dB]*	*Comp. Time [s]*	*Mean Value [dB]*	*Std. Dev. [dB]*	*Comp. Time [s]*
SISO 1x1	1	-66.06	24.10	0	-57.21	18.37	11
	2	-57.82	28.11	0	-46.99	12.28	9
	3	-62.61	31.19	0	-47.03	12.90	10
	Mean	-62.16	27.80	0	-50.41	14.52	10
MISO 2x1	1	-65.87	24.14	0	-57.95	18.37	17
	2	-57.58	28.13	0	-47.08	12.76	15
	3	-62.41	30.93	1	-46.82	12.50	16
	Mean	-61.95	27.73	0.33	-50.62	14.54	16
MISO 4x1	1	-65.29	23.69	0	-58.03	18.66	30
	2	-56.82	27.43	0	-46.63	12.26	25
	3	-62.15	30.79	1	-46.61	12.28	26
	Mean	-61.42	27.3	0.33	-50.42	14.40	27

According to Table 1, the predictions obtained by 3D Ray Tracing always provide the average received power and a standard deviation greater than Cost 231 Indoor predictions for SISO and MISO antenna configuration. However, the computational time of Cost 231 Indoor prediction is very fast compared to 3D Ray Tracing predictions. In addition, the greater elements configuration makes the computational time longer.

2) Effect of Antenna Configuration and Location Changes

The configuration and location of the antenna greatly affect the coverage area, the blank spot and SIR.

a) Scenario I : Effect of Antenna Configuration and Location Changes to Coverage Area

Below are the 2D simulation result figures of coverage area on three transmitter locations with SISO antenna configuration on the left side, MISO 2x1 in the middle, and MISO 4x1 on the right side.

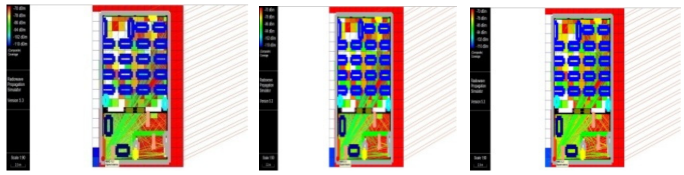

FIG 6. TRANSMITTER LOCATION

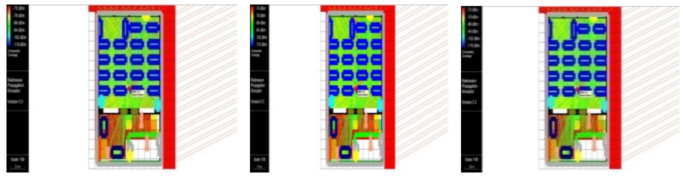

FIG 7. TRANSMITTER LOCATION

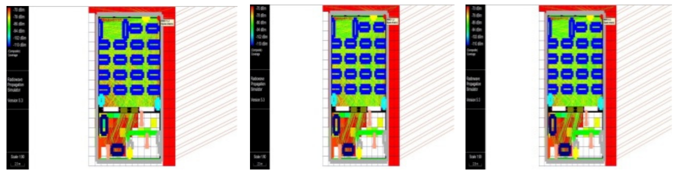

FIG 8. TRANSMITTER LOCATION

Beside the pictures above, the simulation results also show the average received power with location transmitter changes and antenna configuration changes as follows.

TABLE 2. AVERAGE RECEIVED POWER [2]

Path Loss Model	Antenna Configuration	Tx Location		
		1	2	3
Cost 231 Indoor	1 × 1	-66.06	-57.82	-62.61
	2 × 1	-65.87	-57.58	-62,41
	4 × 1	-65.29	-56.82	-62.15
3D Ray Tracing	1 × 1	-57.21	-46.99	-47.03
	2 × 1	-57.95	-47.08	-46.82
	4 × 1	-58.03	-46.63	-46.61

According to Table 2, can be concluded that the optimum antenna configuration with Cost 231 Indoor predicted is 4x1 configuration in second location with an average received power of -56.82 dBm. However, with the 3D Ray Tracing prediction that the optimum antenna configuration is 4×1 configuration in third location with an average received power of -46.61 dBm.

b) Scenario II: Effect of Antenna Configuration and Location Changes to Blank Spot

Blank spots value that occur can be determined based on the value of a signal strength received by the UE. Below are the tables of the percentage of blank spots that occur in any combination antenna configuration and antenna location.

TABLE 3. BLANK SPOT PERCENTANGE [3]

Path Loss Model	Antenna Configuration	Tx Location 1	Tx Location 2	Tx Location 3
Cost 231 Indoor	1 × 1	18.64%	13.36%	19.66%
	2 × 1	18.64%	13.36%	19.66%
	4 × 1	18.64%	12.93%	19.66%
3D Ray Tracing	1 × 1	1.08%	0	0
	2 × 1	1.57%	0.51%	0
	4 × 1	1.04%	0	0

Based on Table 3, the minimum percentage of blank spots by using Cost 231 Indoor model is occurred with 4x1 antenna configuration at the second transmitter location. While using a 3D Ray Tracing model, the minimum blank spots is occurred with 1x1 and 4x1 antenna configuration at the second transmitter location and 1x1, 2x1, and 4x1 antenna configuration at the third transmitter location.

c) Scenario III : Effect of Antenna Configuration and Location Changes to SIR

Below is the table of the relationship between the location of the Tx antenna and the antenna configuration to SIR level.

TABLE 4. SIR (SIGNAL INTERFERENCE RATIO) [4]

Path Loss Model	Antenna Configuration	Tx Location 1	Tx Location 2	Tx Location 3
Cost 231 Indoor	1 × 1	47.08	39.37	51
	2 × 1	41.72	42.17	38.68
	4 × 1	57.06	42.44	37.59
3D Ray Tracing	1 × 1	31.2	13.92	23.38
	2 × 1	32.14	34.54	31.38
	4 × 1	30.13	35.1	33.2

Based on Table 4 is obtained that all the configuration and placement of the antenna has SIR is above the threshold for Cost 231 Indoor and 3D Ray Tracing model.

B. Scenario II : CNC Laboratory, Telkom Institute of Teknologi , Indonesia

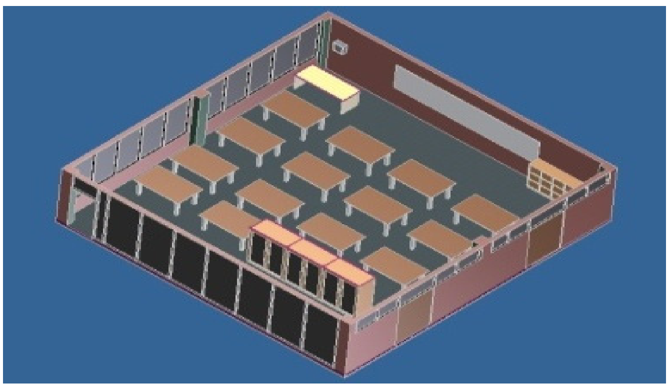

FIG. 9. CNC LABORATORY

1) Effect of Cost 231 Indoor dan 3D Ray Tracing Predictions to Coverage Area

Below are the simulation result graphs of coverage area on three transmitter locations with the predictions cost 231 Indoor on the left side and 3D Ray Tracing on the right side.

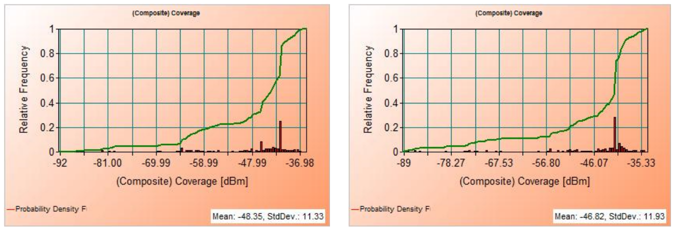

FIG 10. TRANSMITTER LOCATION

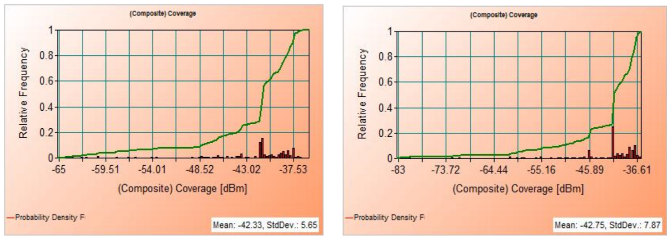

FIG 11. TRANSMITTER LOCATION

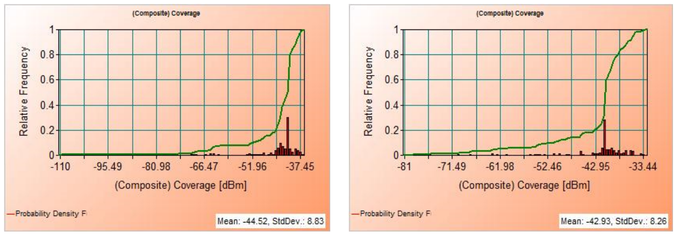

FIG 12. TRANSMITTER LOCATION

Here are statistical comparison results between Cost 231 Indoor and 3D Ray Tracing.

TABLE 5. STATISTICAL RESULT OF COST 231 INDOOR AND 3D RAY TRACING [5]

Configu-ration	Site	*Statistical Result*					
		Cost 231 Indoor			*3D Ray Tracing*		
		Mean Value [dB]	*Std. Dev. [dB]*	*Comp. Time [s]*	*Mean Value [dB]*	*Std. Dev. [dB]*	*Comp. Time [s]*
SISO 1x1	1	-48.35	11.33	0	-46.82	11.93	10
	2	-42.33	5.65	0	-42.75	7.87	10
	3	-44.52	8.83	0	-42.93	8.26	10
	Mean	-45.07	8.60	0	-44.17	9.35	10
MISO 2x1	1	-47.60	10.72	0	-47.60	10.72	18
	2	-42.09	5.61	0	-42.59	7.91	15
	3	-44.44	8.82	1	-42.86	8.19	16
	Mean	-44.71	8.38	0.33	-44.35	8.94	16.33
MISO 4x1	1	-47.41	10.67	0	-45.67	9.85	30
	2	-41.71	5.55	0	-42.26	7.98	27
	3	-44.25	8.84	1	-42.87	8.52	28
	Mean	-44.46	8.35	0.33	-43.60	8.78	28.33

Based on Table 5, the predictions obtained by 3D Ray Tracing always provide the average received power and a standard deviation greater than Cost 231 Indoor prediction. However, the computational time of Cost 231 Indoor prediction is very fast compared to the 3D Ray Tracing prediction. In addition, the greater elements configuration makes the computational time longer.

2) Antenna Configuration and Antenna Location Changes

a) Scenario I : Antenna Configuration and Antenna Location Changes to Coverage Area

Below are the 2D simulation result figure of coverage area with SISO antenna configuration on the left side, MISO 2x1 in the middle, and MISO 4x1 on the right side.

FIG 13. TRANSMITTER LOCATION

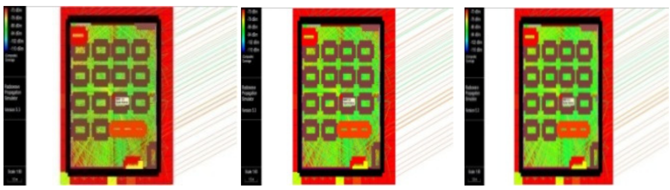

FIG 14 TRANSMITTER LOCATION

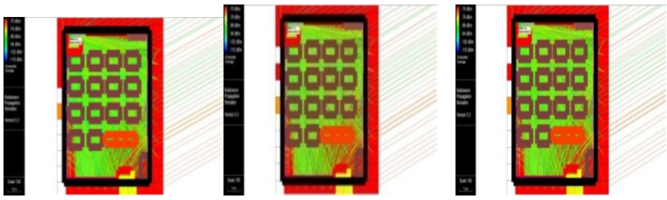

FIG 15. TRANSMITTER LOCATION

Below are the tables of the location relations Tx and antenna configurations on the average received power as follows.

TABLE 6. AVERAGE RECEIVED POWER [6]

Path Loss Model	Antenna Configuration	Tx Location		
		1	2	3
Cost 231 Indoor	1 × 1	-48.35	-42.33	-44.52
	2 × 1	-47.60	-42.09	-44.44
	4 × 1	-47.41	-41.71	-44.25
3D Ray Tracing	1 × 1	-46.82	-42.75	-42.93
	2 × 1	-47.60	-42.59	-42.86
	4 × 1	-45.67	-42.26	-42.87

From Table 6 using either the Cost 231 Indoor model or 3D Ray Tracing model found that the optimum antenna configuration is 4x1 configuration with the location of the transmitter at the second location.

b) Scenario II : Antenna Configuration and Antenna Location Changes to Blank Spot

Below are the tables of the percentage of blank spots that occur in any combination antenna configuration and antenna location.

TABLE 7. BLANK SPOT AREA PERCENTAGE [7]

Path Loss Model	Antenna Configuration	Tx Location		
		1	2	3
Cost 231 Indoor	1 × 1	0	0	0.69%
	2 × 1	0	0	0.69%
	4 × 1	0	0	0.69%
3D Ray Tracing	1 × 1	0	0	0
	2 × 1	0	0	0
	4 × 1	0	0	0

Based on Table 7, the minimum percentage of blank spots by using Cost 231 Indoor model occurs when the configuration is 1x1, 2x1, and 4x1 with transmitter site located at the first location and the second location. While using 3D Ray Tracing model, all combinations of configuration and location of the antenna gives the minimum blank spot.

c) Scenario III : Antenna Configuration and Antenna Location Changes to SIR

Below are the tables of the relationship between the location of the Tx and antenna configuration for SIR level as the following.

TABLE 8. SIR (SIGNAL INTERFERENCE RATIO) [8]

Path Loss Model	Antenna Configuration	Tx Location		
		1	2	3
Cost 231 Indoor	1 × 1	27.23	35.42	27.99
	2 × 1	12.16	8.36	10.07
	4 × 1	12.96	10.51	11.53
3D Ray Tracing	1 × 1	27.23	34.5	35.38
	2 × 1	8.3	5.71	5.6
	4 × 1	9.75	8.42	7.82

Based on Table 8 is obtained that all the configuration and placement of the antenna has a SIR that is above the threshold for Cost 231 Indoor model and 3D Ray Tracing model. So, all the configuration and placement of the antenna can be applied to meet the SIR.

5. CONCLUSIONS

Placement and configuration of the antenna greatly affects the coverage area. It is evident from the value of the received power varies according to location and antenna configuration at any given simulation time. MISO antenna configuration always gives a higher received power than SISO antenna. For example, the optimum antenna configuration on the computer systems laboratory is 4 × 1 element on the second location when using Cost 231 Indoor model. Meanwhile, if using a 3D Ray Tracing model, the optimum antenna configuration is 4 × 1 element on the third location. Moreover, the optimum antenna configuration on the CNC laboratory is 4 × 1 element on the second location using Cost 231 Indoor model as well as using 3D Ray Tracing model.

Based on these simulations can also be concluded that 3D Ray Tracing model always provide the average received power and standard deviation greater than Cost 231 Indoor prediction. However, the computational time Cost 231 Indoor prediction is very fast compared with the 3D Ray Tracing prediction.

ACKNOWLEDGMENTS

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Budi Prasetya, was born in 1975 in Purworejo, Central Java province, Indonesia. Completing his undergraduate studies in 2001 at the School of Technology Telkom. In that year also began as an assistant Lecture at the same school. In 2006 finished his studies at the Bandung Institute of Technology graduate and started to become a lecturer at the Institut Teknologi Telkom. Subjects who had been taught are: Communication Systems, Cellular Communication Systems, Electronic Communications, Antennas and Propagation, and Probability and Statistics. Since 2009 began to become members of the IEEE. In 2013 started Doctoral studies at the Institute of Technology Bandung. Research is being carried out are: Adaptive Modulation and Coding, OFDM (Orthogonal Frequency Division Multiplexing), MIMO (Multiple Input Multiple Output), IF and RF pocessing, Satellite Communications, and Designing Mobile Communications network.