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Electromagnetic Waves Propagating Around Buildings

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1. Introduction

It is a matter of great concern that places where no electromagnetic waves are reached are seen even nowadays when various types of wireless equipment are available anywhere without any concern. That is to say, the fact that places where no electromagnetic waves are reached are found is a problem bringing about unpleasantness to the users, and concurrently is a problem to be solved for those engaged in communication business. Here arises a skepticism why places where no electromagnetic waves are reached are in existence. The matter believed to be the greatest cause of the above is attenuation and interference generated by encounter of the electromagnetic waves with their obstacles. For example, almost all of the base stations (base exchanges) of cellular phones are established outdoors. To accomplish indoor-use of cellular phones, the electromagnetic waves should be aligned so that it will enter the spot deep enough from the entrance in the inside of the buildings by overcoming the obstructing walls. However the electromagnetic waves are liable to be attenuated when they go through the walls, and the waves reflected by the walls interferes with the ones that are going to reach the walls. As a result, the electromagnetic waves are made weak in the vicinity of the buildings or inside of them. This is believed to consequently be linked with creation of difficulty in achieving wireless communications.

It remains to be seen in what a manner the number of the places where no electromagnetic waves are reached is being reduced. As a matter of the fact however, none of easy method to solve this problem is available, and the number of such places has to be reduced one by one every day by repeating such strenuous operations as allowing the places where no electromagnetic waves are reached to be identified and by permitting the waves to be reached on such places with the change of the spots where base stations are settled together with adjustment of the output. Such strenuous trials are put to action by the hands of various researchers with a view to eliminating the troublesomeness of the work. At this stage, let the research that has been made to now be reviewed. With the operations to identify the places where none of electromagnetic waves are reached, two methods, i.e. the one to measure the waves and the other one in accordance with simulation are available. Despite the above, it might be next to impossible to recognize the field strength of the electromagnetic waves in the whole area where wireless communication is utilized. Therefore proposals for a simulation method that can adjust the settling position of the base

station or output have been made by many researchers with respect to several methods such as the one to estimate attenuation loss of the electromagnetic on a propagation route utilizing the building height in the communication area obtained by residence maps and its distribution (Kita et al., 2007; Kitao & Ichitsubo, 2008; Xia, 1997) together with the state of the roads (Ikegami et al., 1984; Walfisch & Bertoni, 1988) or the one to estimate the propagation route in accordance with the Ray Tracing method (Lim et al., 2008). However with these methods, difficulties are pointed out in purport that they just enables the attenuation amount of the electric field strength outdoors to be estimated roughly along the propagation route, and real values of the electric field strength are greatly different from the estimated values. In addition the electric field strength distribution in the inside of the building cannot be estimated. Studies to enhance the estimation accuracy by solving these problems are also under way. Landron and Lim (Landron et al., 1996; Lim, 2008) release reports stating to the effect that consideration of the outside wall shape of the building enhances estimation accuracy. In the meanwhile, proposal is by Axiotis (Axiotis & Theologou, 2003) with an estimation method of the electric field strength extended into the inside of the building. However no observation is made to ascertain how electromagnetic waves propagating into the inside of the building are changed according to the shape of the outside wall and structure of it. Such being the case, we, the authors of this paper, have made research to explain how the electromagnetic waves propagating not only in the vicinity of the building but also through the inside are changed (Matsunaga et al., 2009; Matsuoka et al., 2008a; Matsuoka et al., 2008b). Special importance is attached to the detection by measurement, and studies are being made to comprehend whether estimation by means of simulation will make it possible to obtain the electric field strength distribution explaining to what extent the detection will be close enough to the measurement (Matsunaga et al., 1988; Matsunaga et al., 1996).

In this chapter, details are described with the method to measure the change to explain in what a manner the electromagnetic waves propagating in the vicinity of the building will change according to the difference in wall shape or the building or structure of it. In addition comparison is shown between the results from the measurement and the result obtained by the simulation in accordance with the FVTD, a kind of time domain difference method. Furthermore it is shown that as a result of such studies, 2 types of epoch-making effective discoveries as shown below are claimed. The first thing is that with many of the conventional methods, on the supposition of the building being dealt with just as a concrete square pillar the whole of which was filled with concrete to the extent of its pivotal point. However it is understood that great difference in the electric field strength is in existence between the building supposed to be comprised of the wall and inside space and that of the electromagnetic waves propagating in the vicinity of the building and through the inside of it. The second thing is that it is also understood that the amount of the reflection is greater with the concrete wall having round convexities on the outside wall and the amount of the invasion is smaller than with the reinforced-concrete wall.

However it is regrettable to state that the authors of this paper themselves are never free from defects in the research. That is to say, although it is understood that conduction simulation in consideration of the shape of the wall or structure of it makes it possible to estimate accurately the electric field distribution in the vicinity of it or inside of it, the authors are not aggressive enough to grapple with the problem of the simulation for improvement so as to allow the electromagnetic waves to reach the place where no

electromagnetic waves generated in the vicinity of a specific building are reached. Nothing has been obtained with the result explaining that it is possible to shut the electromagnetic waves intruding from the outside or to allow the electromagnetic waves propagating through the room to be made homogeneous on supposition of, e.g., a tile as convexities on the wall surface by adequately adjusting the size of the tile, raw material, attaching position, etc. this might be called a future assignment.

2. A way of measurement

In this section, a way of measurement of the electromagnetic waves propagating in the vicinity of the building and inside of it is described. It is explained what kind of influence will be exercised on the electromagnetic waves propagating around the building by the shape or structure of the wall of the building. Details of the way of measurement are provided with: (1) Explanation of measurement methods. (2) Composition of the measurement systems such as measurement units and equipment. (3) Measurement procedure.

2.1 A method of measurement

Around a scaled-down model building which is settled in a radio-frequency anechoic chamber, a virtual 2-dimensional space is furnished, and measurement of the electromagnetic waves is made in the inside of the space. With the role of the measurement at this stage, it is necessary to use a measurement method from which the influence exercised by the factors except for the shape of the building or structure of it is removed as far as possible deducing from the fact that the shape of the wall of the building or change of the structure of it is the influence to be exercised on the electromagnetic waves propagating around the building. For such a reason, measurement is made in a virtual 2-dimensional space composed in a radio-frequency anechoic chamber.

First of all, let it be understood that measurement is made by using a scaled-down model regarding it as the building utilized for the experiment, because it is difficult to settle a real building in the radio-frequency anechoic chamber owing to its size. At this stage, a scaled-down model is a model building taken up based on the idea that the size of the building is made smaller by shortening the wavelength of the wave source used for the measurement, keeping constant the ratio of the size of the real building complying with the wavelength of the electromagnetic waves used for general mobile wireless devices such as mobile telephones, in-room wireless LAN, RFID, etc. Incidentally in this chapter, the scaled-down model building used for measurement shall be called a building model in this chapter since now on.

Secondly the virtual 2-dimensional space that has been referred to before is a space obtained by actually composing the 2-dimensional space used, for example, in the 2-dimensional simulation in the radio-frequency anechoic chamber. As illustrated in Figure 1, the said virtual 2-dimensional space is made real by putting the building model having conductor plates wide enough to be equivalent to the electric wall between the upper and the lower sides as seen above. Thus making measurement in the 2-dimensional space makes it possible to remove the influence exercised by the change of the building in a height direction, and it becomes possible to consider the influence of shape or structure change exclusively in a lateral direction. When the electromagnetic waves propagating in the vicinity of a building that is exceedingly great in comparison with the wavelength is

measured or in case in-room propagation on a spot where a base station is located in the building is measure, it is easy to comprehend what shape of structure of the wall in the inside or outside of the building will exercise influence on the electromagnetic waves propagating around the wall so long as measurement is made in a 2-dimensional space rather than in a 3-dimensional space.

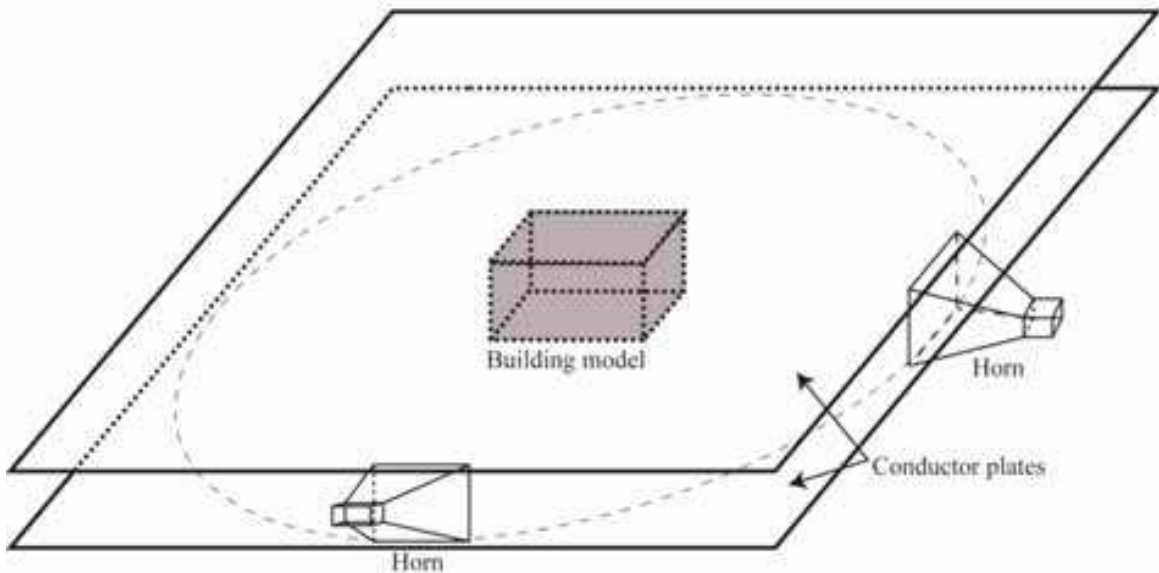


Fig. 1. A measurement unit comprised of a virtual two dimensional measurement space

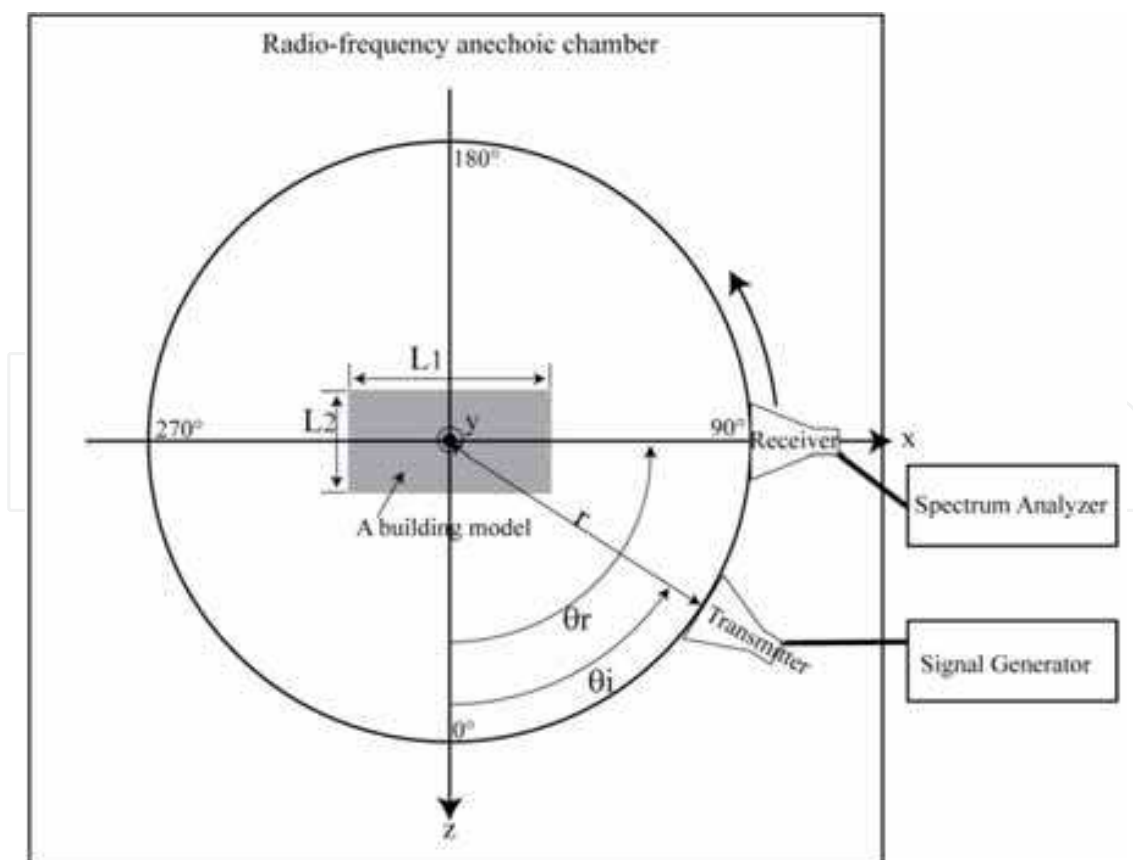


Fig. 2. A schematic diagram of the measurement system



Fig. 3. A photograph of measurement system inside our radio-frequency anechoic chamber

2.2 Composition of measurement systems

Description is hereunder made with the measurement system such as the building model or measurement units composed in the radio-frequency anechoic chamber. Illustrated in Figure 2 is a schematic diagram of the measurement system. In the left side of the figure, a top view of the measurement unit composed in the radio-frequency anechoic chamber is provided, and furthermore how the said unit is linked with the measurement equipment settled outside the radio-frequency anechoic chamber is shown. Illustrated in Figure 3 is a photograph in the radio-frequency anechoic chamber. It is noticed that virtual 2-dimensional space is composed in the center of the photograph. The building model is as a matter of reality settled in the inside of the space although no trace of the model is to be seen in the photograph. Now that, explanation is hereby made with measurement unit composed in the virtual 2-dimensional space by using Figure 2. First of all, coordinate axis is established as seen in Figure 2. And the building model whose configurational dimension is $L_1 \times L_2$ is placed at its center. Around the building model, both transmitting and receiving antennae placed on a circle whose radius is r is settled. Thereafter an incident wave is provided from the transmitting antenna fixed at an angle, and the electric field strength distribution around the building model is measured rotating the receiving antenna around the building. A horn antenna was utilized as the transmitting/receiving antenna, and the source wave is provided by the transmitting antenna using a signal generator. Meanwhile measurements of the electric field strength are made by means of a spectrum analyzer connected to the receiving antenna. In this connection, the settlement angles of the transmitting and receiving antennae are defined as θ_i and θ_r as the angles from the z axis.

2.3 Measurement procedure

At the final stage, actual measurement procedure is described. First a single piece of the building model is placed on a pivotal point of the measurement unit. Secondly the transmitting antenna is fixed on an angle θ_i on the circle whose radius is r from the pivotal point. Thirdly the receiving antenna, which is settled on the circle whose radius is r from the pivotal point, is placed on a lateral side of the transmitting antenna close enough to the right side. Thus the angle θ_i on that position and the electric field strength are measured. Fourthly the receiving antenna is moved by $\Delta\theta$ in a counterclockwise direction, and the electric field strength is measured. Thereafter measurement is continuously made as far as the receiving antenna comes immediately to the side of the left of the transmitting antenna in accordance with the fourth procedure.

3. Measurement results

In this section, the results are shown with the electric field strength distribution in the vicinity of the building model having various types of shapes of the wall and structure of it obtained in accordance with the measurement methods referred to above. In advance of exhibiting the measurement results, description of the building model used before the measurement is at first made, and secondly description is again made with the measurement conditions regarding the size of the building model and detailed dimensions of the shapes or structure of the wall together with the positions of the transmitting/receiving antennae are made. Thereafter with the measurement results of the electric field strength distribution brought about by using the building model are shown, observing the individual factors in comparison with them.

3.1 Individual types of the building models

First of all description is made with the building models used for the measurement. There are 4 types illustrated in Figure 4, and each of them is: (a) A square pillar model where the building is regarded as a concrete square pillar. (b) A building model with flat walls where the building is dealt with as the one comprised of a flat wall and inside space. (c) A building model with reinforced-concrete walls where the building is dealt with as being comprised from a flat wall and inside space. (d) A building model with walls having round convexities that are dealt with as being comprised of a wall having periodic convexities on the outside of it and inside space. In this connection, details of the part of the round convexities of the wall model having round convexities are defined as illustrated in Figure 5.

3.2 Measurement conditions

At the next stage, measurement conditions are described. In Table 1, the measurement systems and detailed dimensions of the building model defined in Figures 2 and 4 are concisely listed. First with respect to the measurement systems, the electric field strength distribution around the building model was measured allowing an electromagnetic wave with frequency $f = 9.35$ GHz to be radiated from the transmitting antenna fixed on a position whose angle $\theta_i = 0^\circ$ on a circle whose radius $r = 1000$ mm, rotating the receiving antenna by individually $\Delta\theta = 1^\circ$. Furthermore, detailed dimensions of the individual portions of the building model in Figure 4 are described. The description is made on the assumption that the configurational dimensions of the building model are as $L_1 = 700$ mm and $L_2 = 350$ mm throughout the whole models. Meanwhile with a model having a wall, description is

likewise made on the assumption that its wall thickness is $T = 45$ mm. The reinforced-concrete wall model was composed by inserting metal bars with a diameter $w = 2$ mm into the concrete wall in a series at an interval $p = 10$ mm. Both the tips of these bars are connected with the conductor plates used for composing a 2-dimensional space.

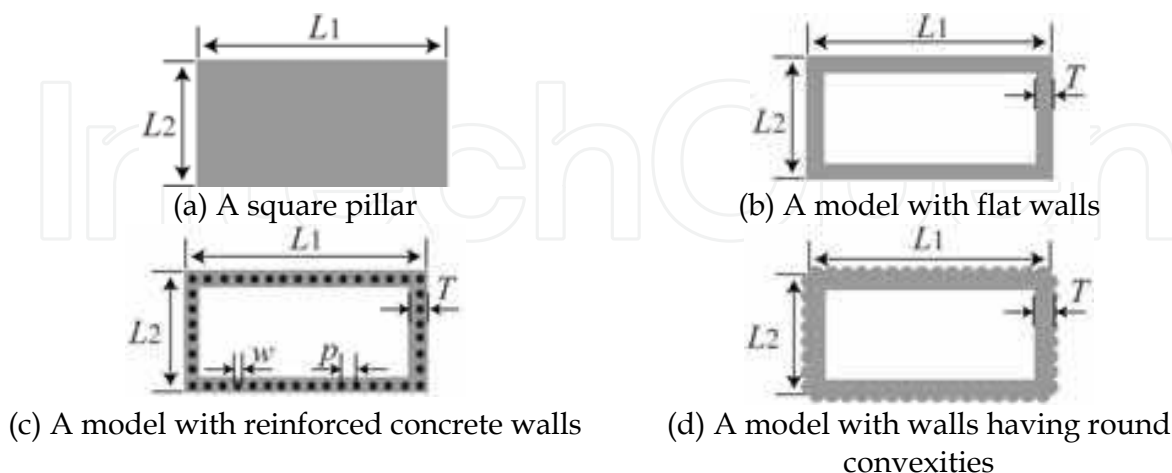


Fig. 4. The plane figures of building models

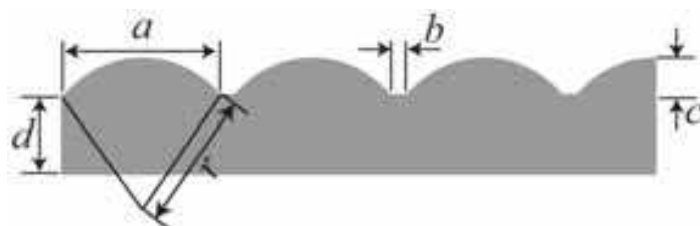


Fig. 5. Detailed figure of the round convexities in Figure 4(d)

| f | r | θ_i | $\Delta\theta$ | L_1 | L_2 | T | w | p |
|----------------------------------|-------------------------------|------------|----------------|------------------------------|------------------------------|----------------------------|---------------------------|----------------------------|
| 9.35 GHz ($\lambda=32.0$ mm) | 1000 mm (31.25λ) | 0° | 1° | 700 mm (21.88λ) | 350 mm (10.94λ) | 45 mm (1.41λ) | 2 mm (0.06λ) | 10 mm (0.31λ) |

Table 1. Detailed measurements of the measurement system and building models in Figures 2 and 4

With respect to the wall model having round convexities, measurement is made by using 2 types of building models, that is to say, in case of the model whose round convexities are slightly greater and in case of the model whose round convexities are slightly smaller than the wavelength of the source wave. Listed in Table 2 are the detailed dimensions of the portion of the round convexities of the 2 types of building model in accordance with the definition in Figure 5.

| | r | a | b | c | d |
|-------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|
| Big | 60.0 mm (1.88λ) | 77.5 mm (2.42λ) | 10.0 mm (0.31λ) | 14.2 mm (0.44λ) | 36.4 mm (1.14λ) |
| Small | 30.0 mm (0.94λ) | 38.7 mm (1.21λ) | 5.0 mm (0.16λ) | 7.1 mm (0.22λ) | 40.1 mm (1.25λ) |

Table 2. Detailed measurements of the round convexities defined in Figure 5

3.3 Comparison among the measurement results obtained by using the individual building models

By comparing the experimented value obtained in response to the allusion referred to above with the measurement by using the individual building models, it is observed what influence the difference of the wall structure will exercise on the electric field distribution propagating in the vicinity of the building. First, illustrated in Figure 6 are the measurement values of the electric field distribution around the square pillar and the ones of the flat wall model comprised of the wall closer to the structure of the real building and the inside space simultaneously shown. Comparison of the 2 types of the measurement values reveals that great difference is noted in the electromagnetic waves in the rear side of the building whose receiving angle ranges close enough from 50 degrees to 220 degrees owing to the existence of the inside space. That is to say, it is understood that the penetrating wave directed rearward exhibits increase ranging from 20 dB to 30 dB exclusively with respect to the flat wall model in the inside of which space is in existence. It can be understood from the result that with the electromagnetic waves propagating in a direction of the other side of the building viewed from the transmitting point, almost all of them have been successful enough to reach there by penetrating the building. Contrarily, it can safely be said that just a slight amount of the waves have been successful in reaching there by diffraction. It is therefore suggested, it can be said, that whether the building should be a square pillar model or a building model with flat walls is a very important point in heightening the simulation value.

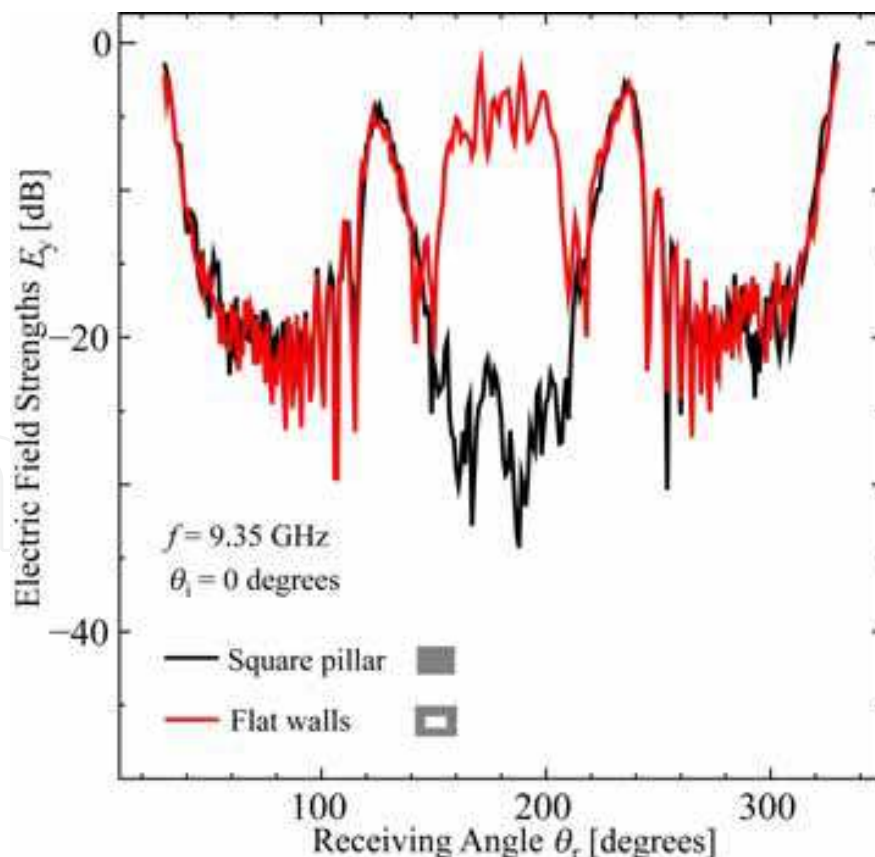


Fig. 6. A comparison of measurement results of electric field strength around the square pillar model and around the flat wall model comprised of the wall and inside space

Illustrated in Figure 7 are the measurement values of the electromagnetic waves around the reinforced-concrete wall model obtained by allowing the building to come closer to the real building and the ones around the flat wall model having no metal skeletons in it simultaneously shown. Comparison of these measurement values reveals that the electric field whose receiving angle ranges from 150 degrees to 220 degrees strength in the rear side of the building is decreased less than approximately 10dB. In addition in the vicinity of 90 degrees and 270 degrees as well, it is understood that the electric field strength is rather than decreased when metal skeletons are available. From the fact that such change cannot be witnessed in the result in Figure 6, it can safely be affirmed that existence of the metal skeletons in the inside of the concrete wall results in not only the penetration of the electromagnetic wave in a rear side of the building but also the propagation of the electric wave in a lateral side of the building is decreased.

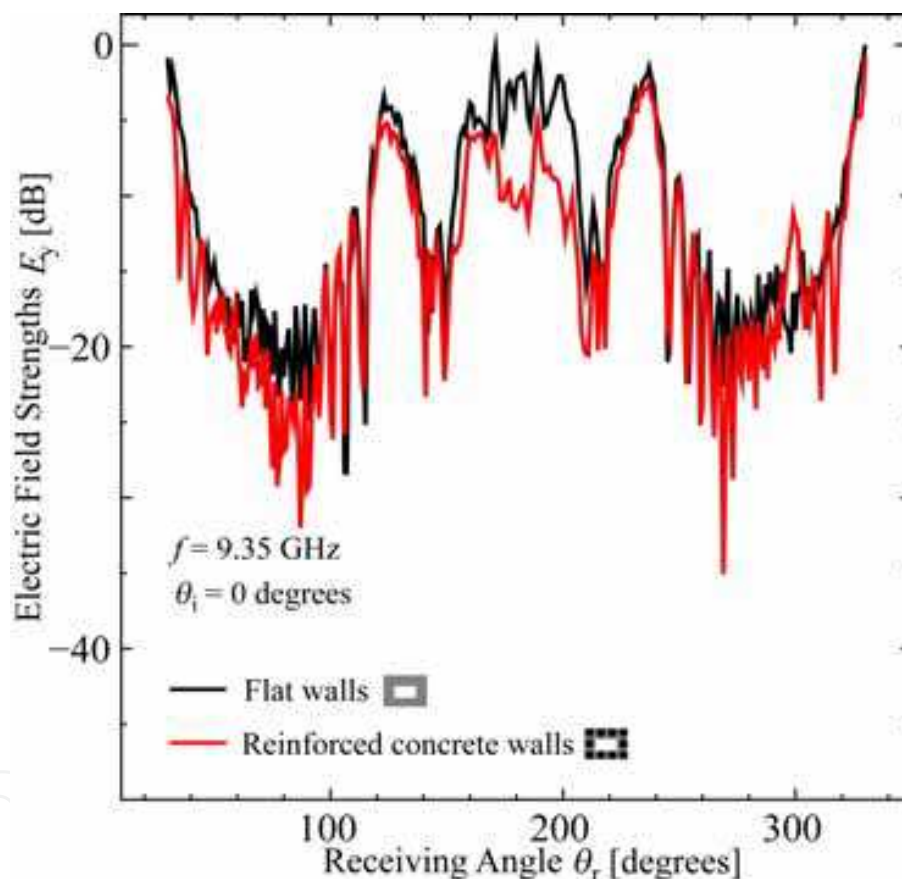


Fig. 7. A comparison of measurement results of electric field strength around the flat wall model and around the reinforced-concrete wall model

Illustrated in Figure 8 are distributions of the electric field strength around a building model with walls where round convexities are periodically in existence on the outside wall and around the building model with flat walls are simultaneously shown. By comparing these two types of measurement values, it is explained that existence of round convexities on the outside wall decreases the penetrated wave approximately 10 dB to 20dB in a rear direction of the building in the vicinities ranging from 150 degrees to 220 degrees. The matter to which attention should be arrested is that despite the fact that the two results are almost the same in the right and left square portions in the rear side of the building in the vicinities

ranging from 110 degrees to 140 degrees and from 220 degrees to 250 degrees, in the closer vicinities ranging to the incidence side than these angles the electric field strength in case the round convexities are in existence is higher than in case they are not in existence. That is to say, it is imagined that although reflection in an incident side is increased and penetration in the rear side is decreased, the diffraction in a rear side is not so changed.

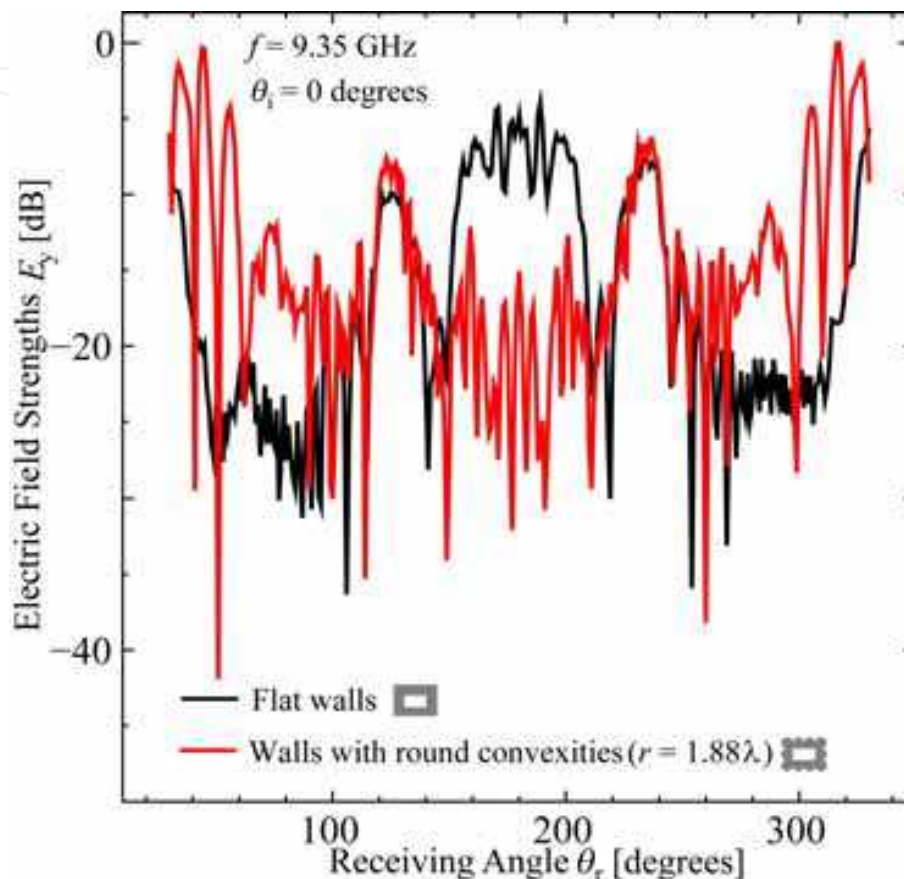


Fig. 8. A comparison of measurement results of electric field strength around the flat wall model and around the building model with walls where round convexities are periodically in existence on the outside wall

Illustrated in Figure 9 are the measurement results simultaneously shown with the electric field strength distributions in case the radius of the round convexity is slightly greater than the wavelength and in case the radius is slightly smaller than the length in relation to a building model with walls having round convexities. Comparison of these two measurement results reveals that penetrating wave is increased with the model whose radius of the round convexities is smaller, and the reflection wave is decreased. However from the fact that considerable change is noted with the electric field strength on the square portion in the diagonally rear side of the building as is known from the result in Figure 8, it is imagined that almost none of influence by diffraction is to be seen.

At the final stage, the whole of the results illustrated in Figure 6 through Figure 8 are shown simultaneously in Figure 10. By so doing, it is explained that the electromagnetic waves propagating in the vicinity of the building are subject to change depending upon the thickness of the wall of the building, presence or absence of metal skeletons, and shape of the surface of the outside wall. Especially the fact that existence of the round convexities on

the outside wall encourages the reflection waves propagating from the lateral side in a direction of the incident side to be increased rather than the fact that reinforcement bar is in existence in the inside of the wall. This evidently brings about decrease of the penetrating waves in the rear side of the building. Accordingly for adjustment of the electric field strength distribution in the inside and outside of the building with which construction is already finalized, it is suggested that it is effective to paste convexities e.g. tiles onto the wall of the building after finalization of the construction.

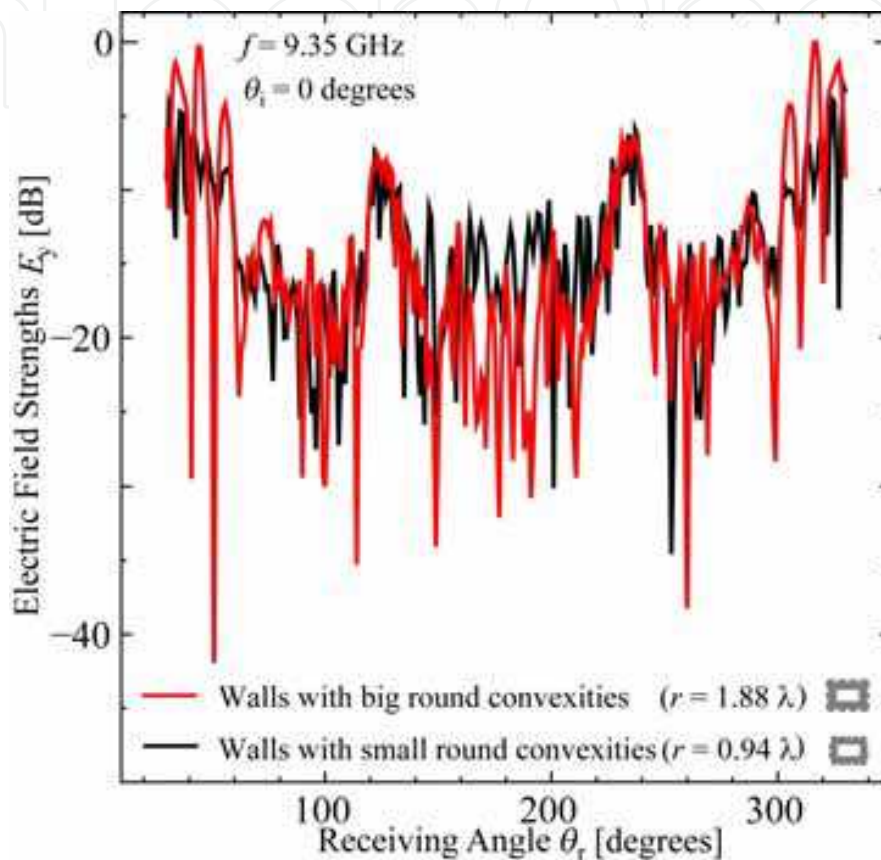


Fig. 9. A comparison of measurement results of electric fields around two building models which have different sizes of round convexities each other on their walls

4. Application of the measurement results to simulation

Making use of the measurement utilizing a building model, observation has been made to now in consideration of the influence of the shape of the wall or structure of the building that exercises influence on the electromagnetic waves propagating around the wall. From now on, investigation is made to determine whether these observation results should be applied to the simulation or not. Incidentally as a way to conduct the simulation, Finite Volume Time Domain method (hereinafter FVTD) method was taken up. The said method is a method similar to FDTD method widely applied to various types of electromagnetic field analysis, by which Maxwell's equation is discretized based on volume integral. For this reason several features are pointed out: The lag equivalent to half an amount of space difference quantity is produced when FDTD method is utilized, whereas the fact that the electric field and magnetic field are placed in the same position when the FVTD method is

dealt with. With the electromagnetic field analysis having a boundary that is hard to be dealt with on an orthogonal coordinate as seen for example in a complicated surface area boundary, the FVTD method is preferable because the method very widely simplified rather than the FDTD method. Thus analysis time is also shortened. This is the reason why the FVTD method is adopted in this paper as a simulation method by which comparison of measurement values is made. Meanwhile with the FVTD method, readers are advised to refer to the details offered by Uchida et al., (Uchida et al., 1996a; Uchida et al., 1996b) and Yee and Chen (Yee & Chen, 1994).

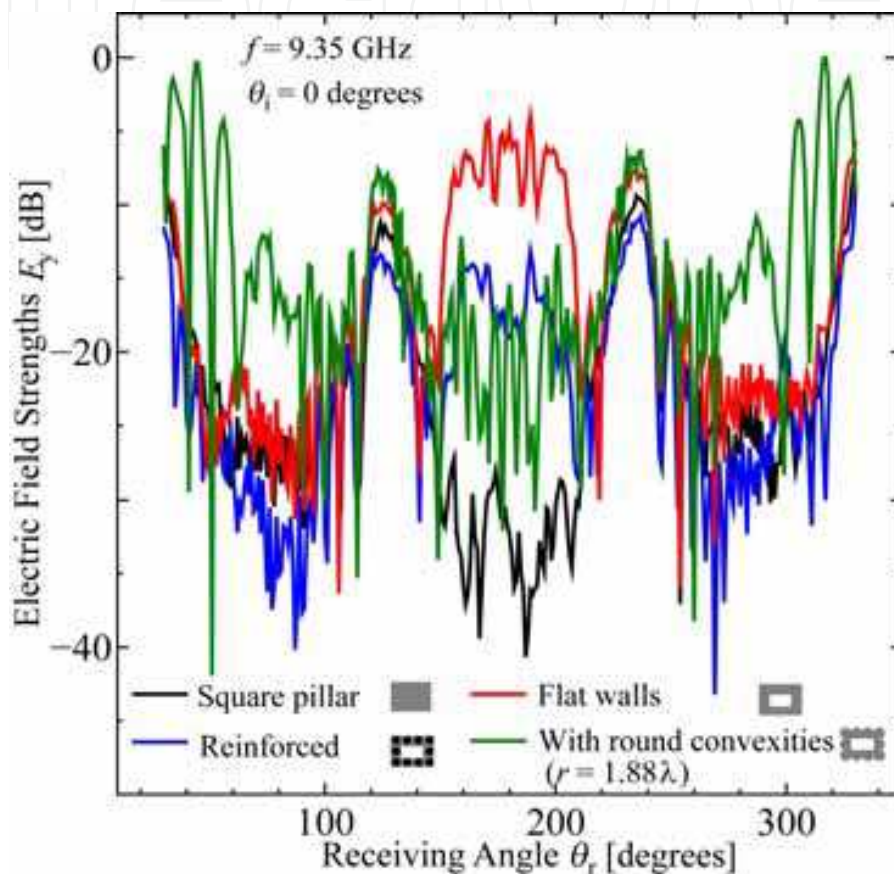


Fig. 10. The whole of the results illustrated in Figure 6 through Figure 8 are shown simultaneously

In this connection, an analytical model in accordance with FVTD method is described. Illustrated in Figure 11 is an analytical compositional diagram to make FVTD analysis with respect to the 2-dimensional virtual space portion on the measurement system referred to in Figure 2. First the analytical space is divided into $N \times N$ cells, and PML adsorption layer having 20 cells is located on the outer side of the analytical model with a view to suppressing the reflection from the surrounding boundary of the analytical mode. At this stage, the analysis is made by dividing the time difference quantity into 64 per cycle.

4.1 Comparison between the measurement result and analytical result in accordance with FVTD method

First of all, the following are determined in the simulation using FVTD method by comparing the measurement result with the simulation result to which the FVTD method is

applied. (1) Electrical constant of the concrete. (2) Partitioning number N . With the dielectric constant of the concrete, the value calculated in accordance with the dielectric constant calculation method (Matsuoka et al., 2009) based on the measurement is, first of all, applied to FVTD method, and furthermore fine adjustment is made by comparing it with the measurement results. On that occasion, almost none of adjustment is required with the specific relative permittivity, and slight adjustment was just necessary with the conductivity. As a result, the dielectric constant of the concrete is obtained as specific relative permittivity $\epsilon_r = 6.0$ and conductivity $\sigma = 0.1$ S/m. With regard to the partition cell number, it is likewise decided by comparing the measurement result with the simulation result that $N = 4460$. Illustrated in Figure 12, the results obtained by conducting the simulation in accordance with FVTD method using the dielectric constant and partition cell number determined as above together with the measurement value are simultaneously shown. From these results, it is explained that the electric field strength distribution changes in a complicated manner depending on the places around the building, but the simulation value exhibits its manner of the change faithfully almost to the measurement value. From the above, it is construed that the simulation close enough for the actual situation has been possible with the use of the measurement value.

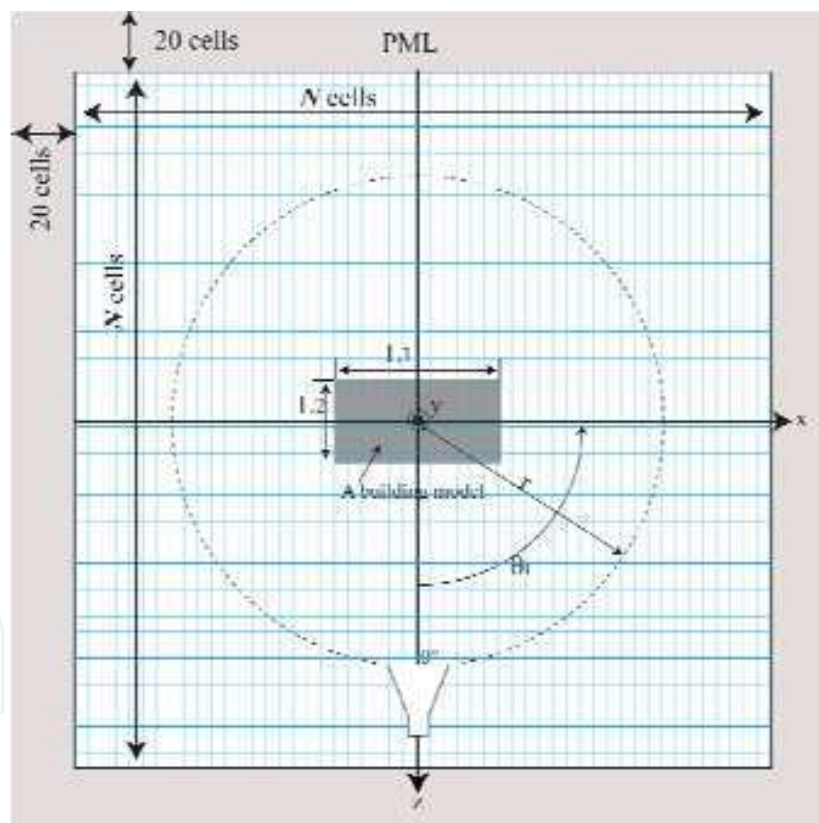


Fig. 11. A plane figure of the analytical compositional diagram for FVTD analysis

4.2 Field strength distribution simulation in the analytical model

As the final trial, the result obtained by conducting simulation with the electric field strength distribution of the whole of the analytical space utilizing FVTD is shown. Illustrated in Figure 13 are the results obtained by simulating the electric field strength distribution, using FVTD method. It is evident from Figure 11 that in what place of the

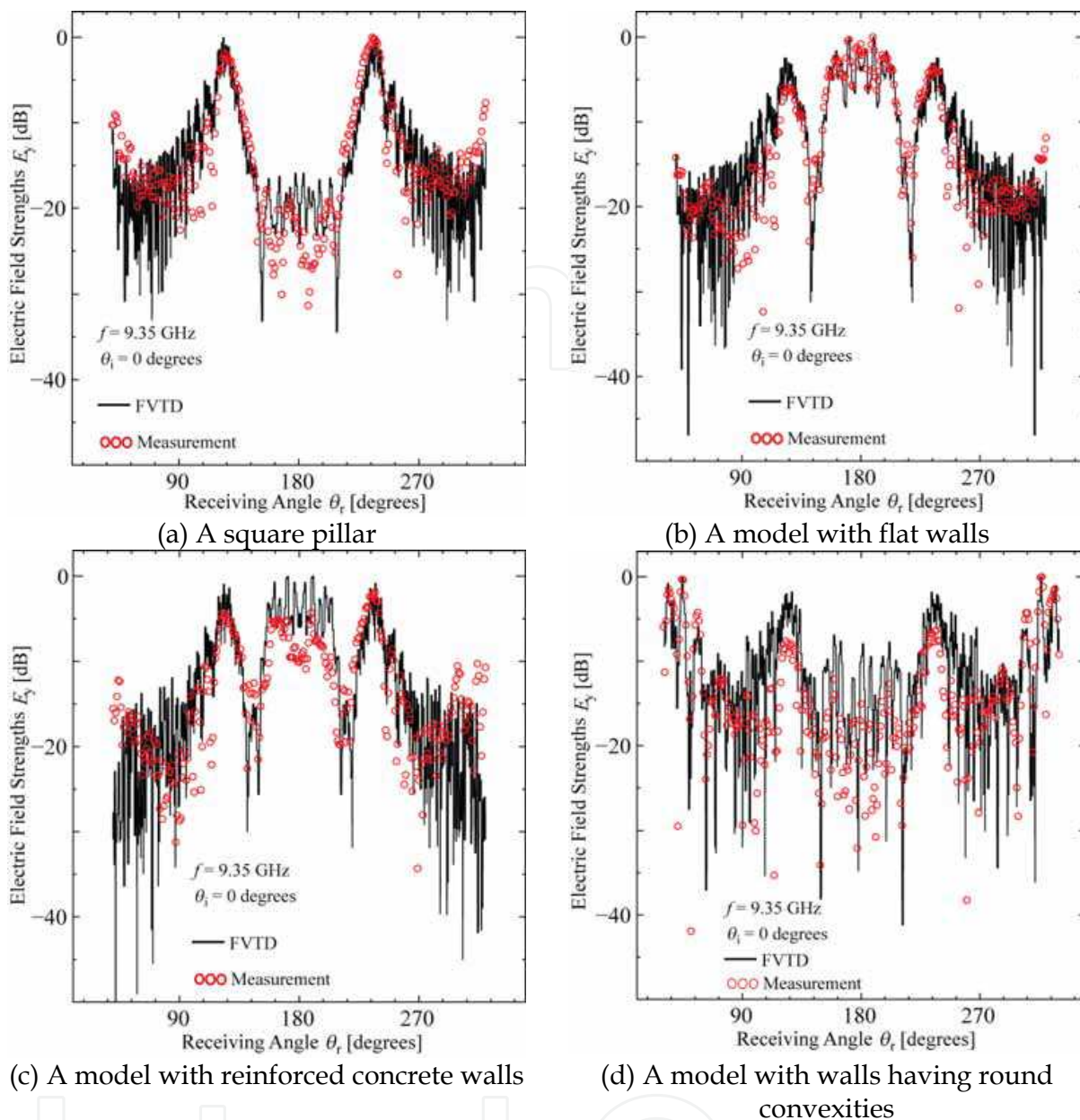


Fig. 12. Comparisons of the electric fields around buildings obtained by measurements and the FVTD method

analysis space the building model is and where the source wave is. Thus readers are advised to observe the individual simulation results by making comparison with the said figure. By so doing, it can be recognized again that the electric field strength distribution around the building is widely subject to change. First it is explained that the square pillar model is widely different from the other models in the electric field strength distribution. It is likewise explained that to faithfully simulate the electric field strength distribution, it is necessary for the building to be actually approached to some extent. Secondly none of great difference can be seen with either of the model devoid of reinforcement bar in the wall and the one in possession of such reinforcement bar. From this it can safely be said that in the simulation, it is not so much necessary to keep in mind the presence and absence of the reinforcement bar. Finally it is made known that existence of round convexities on the

outside wall brings about great change to the electric field strength distribution in the inside and outside of the building. From this it can safely be affirmed that with the shape of the wall surface, conducting simulation considering as profoundly as possible encourages the electric field strength distribution close enough to reality to be obtained very easily.

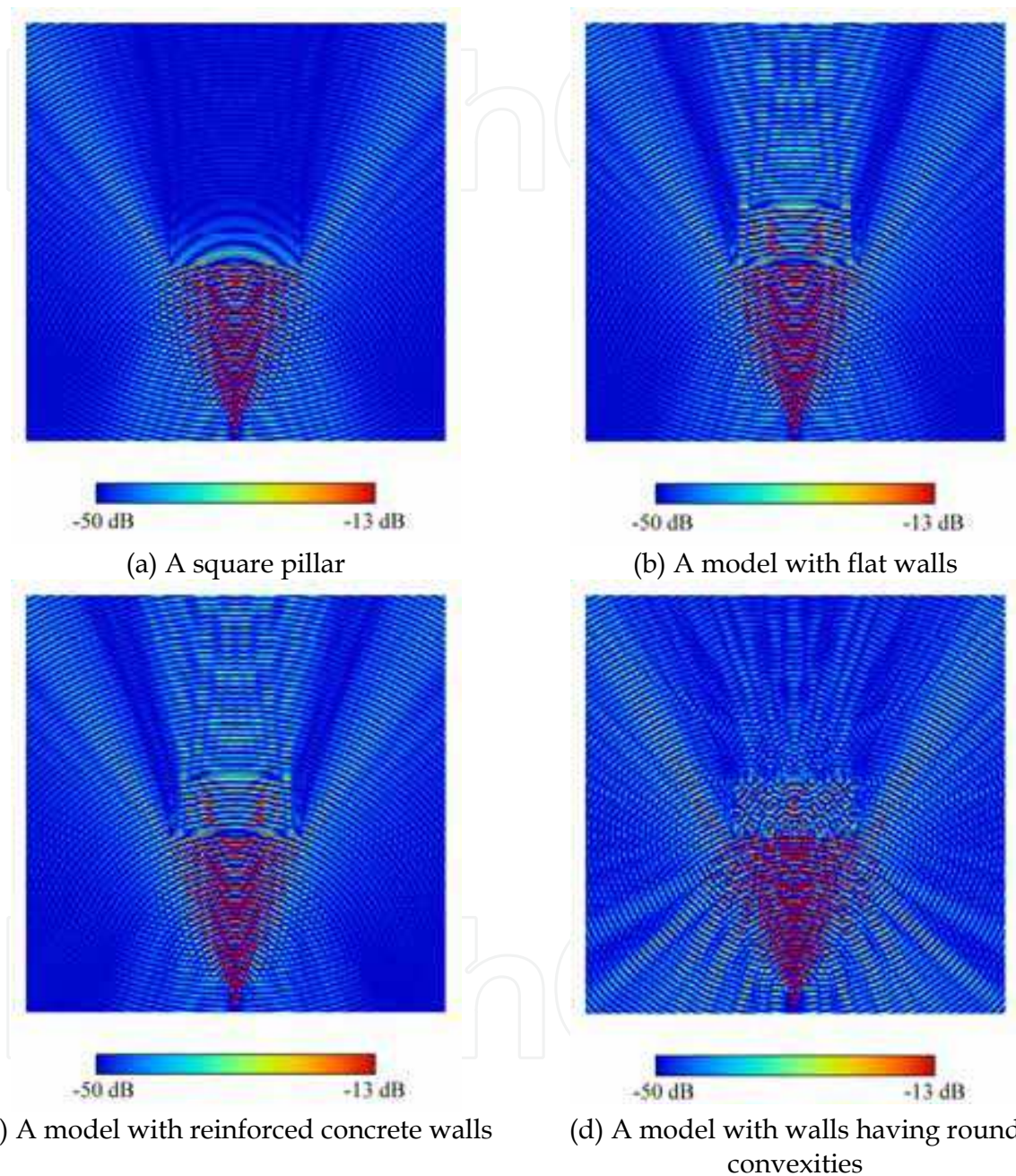


Fig. 13. Distribution of electric field strength obtained by the FVTD method

5. Concluding remarks

The electromagnetic waves propagating in the vicinity of the building or through the inside of it are influenced by the shape of the wall of the building or structure of it, and therefore the propagation becomes a complicated one. This brings about a portion where sufficient

electric field strength can be obtained and a portion where such a factor cannot be obtained. This is a matter of seriousness with wireless communication. To solve this problem, it is necessary to be acquainted with first of all the electric field strength distribution in the vicinity of the building. Electromagnetic wave propagation simulation is quite an effective measure to be very easily acquainted with such electric field strength distribution in the vicinity of the building, but simulation results different from the actual value are liable to be obtained depending on the occasion in a manner how the structure or shape of the wall of the building should be considered. Keeping such a situation in mind, the electric field strength distribution around the building was measured using a scaled-down model of the building having shapes of various walls or structure of them. As a results, it is explained that: (1) It is advisable to deal with the building as the one comprised of a wall and inside structure rather than the one as a square pillar model filled with concrete to the extent of the inside. (2) It is unnecessary to consider the structure of the wall inside so much as with the case of the reinforced concrete, but it is understood that the surface shape such as of tiles is preferable to consider. Meanwhile by investigating the dielectric constants of the concrete or cell sizes based on the comparison between the measurement and the simulation results, it is shown that simulation close enough to actual measurement becomes possible.

Despite the above, no improvement has been attempted with the simulation to allow the electromagnetic waves to reach any place, taking account of the fact that there are not a few places where no electromagnetic waves are reached. Such being the case, a project is under way to develop new methods in future to decrease the regions where none of sufficient electric field strength is obtained due to change in the wall shape, taking up the examples actually full of problematic points. With the effectiveness of the method, recognition is to be made as a matter of course in accordance with the measurement method introduced in this chapter. When such research advances, possibilities are wide spread before us, availing ourselves of the technology with accomplishment of successful monitoring in a detailed manner, explaining what objects are in existence in what a place in what a situation in the building. This is connected to development of information communicating technology by which peoples' life is steered into a direction of a more abundant and wealthier state.

6. Acknowledgments

Part of this research has been conducted with a grant provided by the Ministry of Internal Affairs and Communications of Japan's Strategic Information and Communications R&D Promotion Programme (SCOPE) (082309008) and the Ministry of Education, Culture, Sports, Science and Technology of Japan's Grant-in-Aid for Young Scientists (A) (21686035), for which the authors including myself feel deeply grateful.

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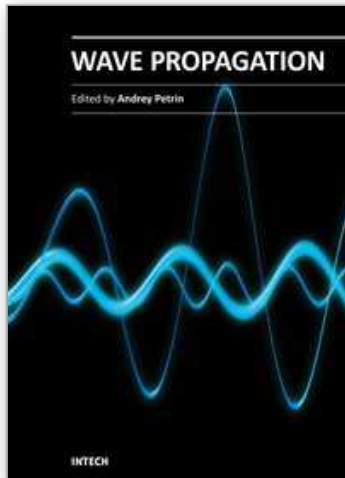
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Wave Propagation

Edited by Dr. Andrey Petrin

ISBN 978-953-307-275-3

Hard cover, 570 pages

Publisher InTech

Published online 16, March, 2011

Published in print edition March, 2011

The book collects original and innovative research studies of the experienced and actively working scientists in the field of wave propagation which produced new methods in this area of research and obtained new and important results. Every chapter of this book is the result of the authors achieved in the particular field of research. The themes of the studies vary from investigation on modern applications such as metamaterials, photonic crystals and nanofocusing of light to the traditional engineering applications of electrodynamics such as antennas, waveguides and radar investigations.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Mayumi Matsunaga and Toshiaki Matsunaga (2011). Electromagnetic Waves Propagating Around Buildings, Wave Propagation, Dr. Andrey Petrin (Ed.), ISBN: 978-953-307-275-3, InTech, Available from:
<http://www.intechopen.com/books/wave-propagation/electromagnetic-waves-propagating-around-buildings>

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