Coverage Mapping with UTD Model

ALP EREN AYDIN, ERAY ARIK, MEHMET BARIS TABAKCIOGLU
Electrical and Electronics Engineering Department
Bursa Technical University
Mimar Sinan Campus, Bursa
TURKEY
alp_eren_aydin92@outlook.com eray.arik@valeo.com mehmet.tabakcioglu@btu.edu.tr

Abstract: - Coverage prediction is vital for reliable digital communication and broadcasting systems. In order to increase QoS of these systems, the threshold field strength has to be provided and coverage map extracted before installation. In urban areas, direct fields are not allowed to reach the receiver point due to diffraction from high buildings. To calculate diffracted fields Uniform Theory of diffraction (UTD) model is proposed and this model is used to extract the coverage map. In this study, a scenario including 441 buildings is generated randomly and electric field is calculated at the top of all buildings. Finally, according to these electric fields coverage map is generated.

Key-Words: - Coverage mapping; UTD; diffraction; wave propagation; path loss.

1 Introduction

Coverage prediction is significant to install reliable and efficient wireless communication systems. Base stations have to be deployed after coverage prediction done. In order to calculate electric field, Geometrical Optic (GO) and Uniform theory of diffraction (UTD) model [1] is used. In order to increase the QoS of wireless communication systems, firstly coverage prediction is carried out. Geometrical optic model assumes that light propagates as a particle and explains reflection and refraction phenomena. However GO model cannot explain diffraction phenomena [2]. UTD model is introduced in order to solve problem of electric field behind an obstacle. UTD is a high frequency model and computes the electric field in a short time. In order to reduce base station number and increase QoS of broadcasting systems, coverage map have to be extracted. Coverage mapping can be made by means of some radio planning tools like FEKO [3] and ACCURA [4]. Ray-tracing is important to obtain more accurate coverage maps [5-7]. In this context, before deploying base station, coverage map has to be extract to provide the threshold electric field in everywhere. Base station is selected and then all the direct, diffracted and reflected fields are determined by using ray tracing program we have developed on top of all buildings in the environment. Next, field strength is calculated with geometrical optic and UTD model. According to calculated field strength color coverage map is generated. In the rest of paper, a brief information about UTD is given, then a coverage prediction simulation is carried out for a scenario and finally conclusion section is given.

2 UTD Model

Electric field behind an obstacle in UTD model can be found by the formula [8] given by,

$$E = [E_i D]A(s)e^{-jks} \tag{1}$$

where, E_i and D are incident field and amplitude diffraction coefficient, k stands for wave number, $A(s)$ symbolize spreading factor and finally s is travelling distance of electromagnetic wave. The amplitude diffraction coefficient [9] is expressed by,

$$D(\alpha) = -\frac{e^{-j\pi/4}}{2\sqrt{2\pi k}\cos(\alpha/2)}F[x] \tag{2}$$

where, α is diffraction angle as illustrated in Fig. 1. F[x] is transition function in [10] and it changes between 0 and 1.

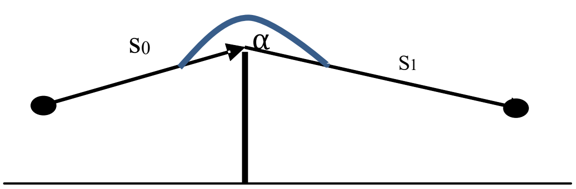


Fig.1. Diffraction Geometry

A(s) is spreading factor and can be calculated by,

$$A(s) = \sqrt{\frac{s_0}{s_1(s_1+s_0)}} \qquad (3)$$

where, s_0 and s_1 are the distance before and after the diffraction, respectively. Reflected field can be expressed by,

$$E = \left[\frac{E_i R_{s,h}}{s}\right] e^{-jks} \qquad (4)$$

where, E_i is incident field, s is total distance and $R_{s,h}$ reflection coefficient for soft and hard polarizations. Direct field can be calculated by

$$E = \left[\frac{E_i}{s}\right] e^{-jks} \qquad (5)$$

where, E_i is incident field and s is total distance.

3 Coverage Prediction

In order to calculate total electric field in a point, diffracted, reflected and direct fields have to be calculated via the formulas previously mentioned.

An extensive simulation is carried out with 1800 MHz operating frequency. A building matrix (21x21) is generated with height of buildings in z-direction. This matrix includes randomly distributed 441building's heights between 0 and 20 as shown in Table I. There is 50 m distance between two adjacent buildings.

Transmitter location is selected (0,0) point and the receiver location is changed one by one. Electric field in that point is 0 dB. In all situation total electric field strength is calculated and recorded in a cell in MATLAB environment. After all receiving points are tried; coverage map is generated according to recorded field strength values.

As a first simulation, transmitting and receiving point is selected (0,0) and (0,1000), respectively as depicted in Fig.2. All the obstacles between the receiver and transmitter are in x-direction. Y component of buildings are [50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950].

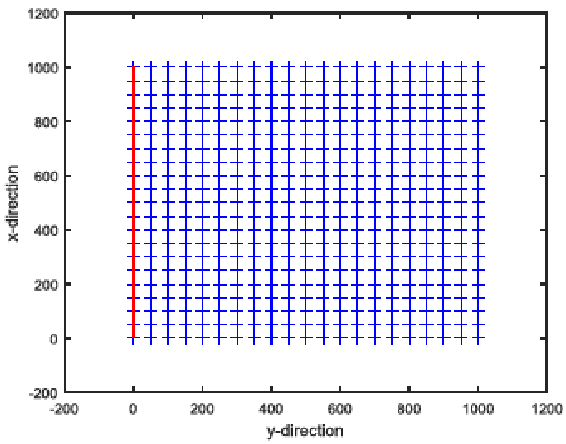


Fig. 2. Buildings are in x-direction

These buildings are shown in test scenario as in Fig.3.

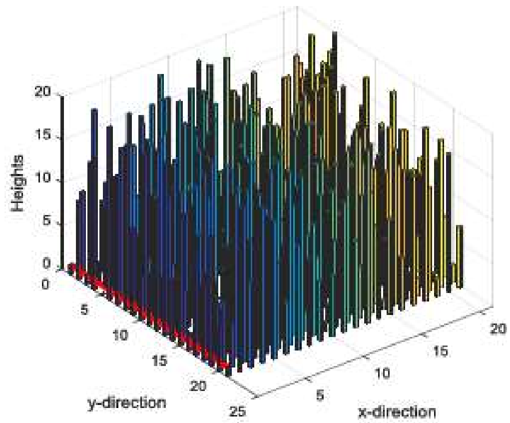


Fig. 3. Buildings in test scenario

As it is shown in Fig. 3, buildings in x-direction are shown with red line. All the rays emanate from the transmitter and reach to receiver are indicated in Fig. 4.

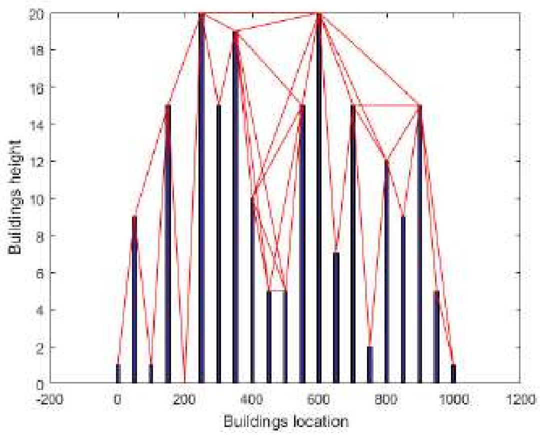


Fig. 4. Ray tracing

As shown in Fig. 4, all the ray paths contributing to total electric field at the receiving point are given.

As a second simulation, transmitting and receiving point is selected (0,0) and (1000,1000), respectively as depicted in Fig.5. All the obstacles between the receiver and transmitter are in diagonal. x and y component of buildings are [50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950].

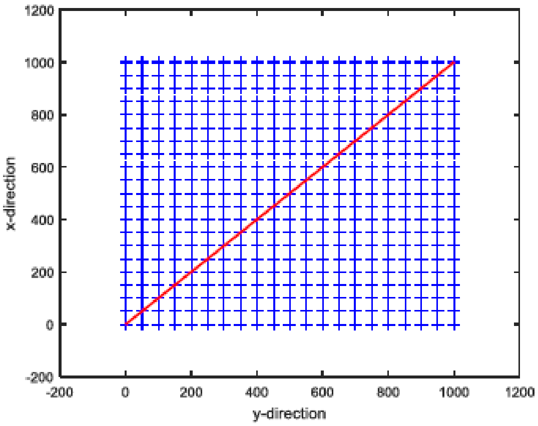


Fig. 5. Buildings are in xy-direction

As it is illustrated in Fig. 5, the buildings are deployed in xy-diagonal. These buildings are shown in test scenario as in Fig. 6.

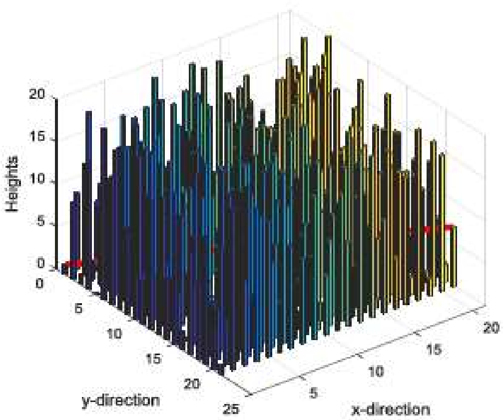


Fig. 6. Buildings in test scenario

As it is shown in Fig. 6, buildings in xy-direction are shown with red line. All the rays emanate from the transmitter and reach to receiver are indicated in Fig. 7.

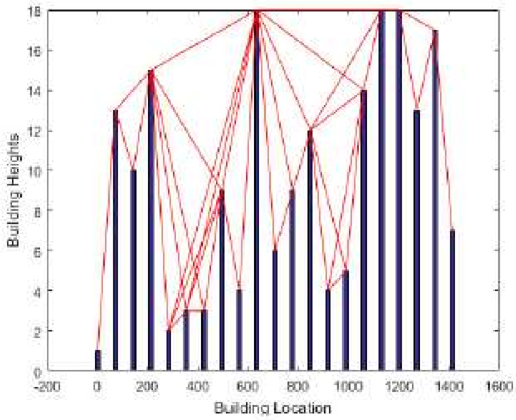
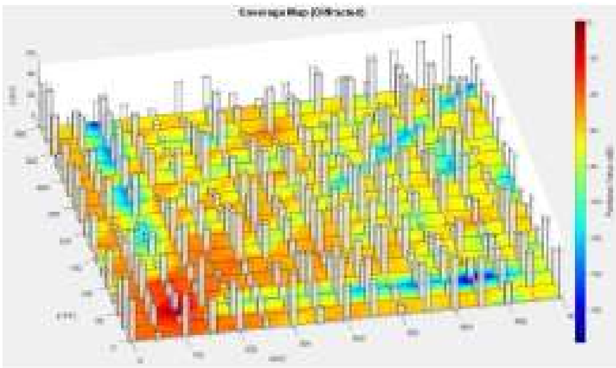


Fig. 7. Ray tracing

As shown in Fig. 7, all the ray paths contributing to total electric field at the receiving point are given.

Receiver position is changed one by one and electric fields are calculated all the positions. The electric fields in all receiving positions are given in Table II. As can be seen in Table II, as the transmitter is in (0,0) position, value of electric field is assumed to 1 and dB value of the electric field is zero. Moreover, it can be seen in Table II, as the receiving point is farther away, electric field is decreases. Furthermore, if there is multiple diffraction (x-direction, y-direction and diagonal), electric field is decreased greatly as it is shown in Table II.

After electric field is calculated in all cells, coverage map can be generated as in Fig. 7. If the field strength is high, it is drawn in red. On the contrary, if the field strength is low, it is drawn in blue.



4 Conclusion

Predicting of electric field is very important to install reliable and efficient broadcasting systems in radio planning tool. After predicting the field strength, base stations have to be deployed according to results. In multiple diffraction scenarios UTD and Geometrical optic models have to be used together. If the receiver is away from the transmitter, electric field decreases. As the receiving point move in x, y or diagonal, electric fields decreases greatly. As a conclusion, in order to increase QoS in broadcasting system or reducing base station number coverage mapping have to be made firstly.

Acknowledgement

This work is supported partially by TÜBİTAK (The Scientific and Technological Research Council of Turkey) under the grant no. 215E360.

References:

[1] R.G. Kouyoumjian and P.H. Pathak, "Uniform geometrical theory of diffraction for an edge in a perfectly conducting surface", Proceedings of IEEE, vol. 62, no: 11, pp.1448–1461, 1974.

[2] V.A. Borovikov and B.E. Kinber, "Geometrical Theory of Diffraction", Institution of Electrical Engineers, London, UK, 1994.

[3] https://www.feko.info

[4] http://www.wavecall.com

[5] E. Arik and M.B. Tabakcioglu, "Using of S-UTD-CH model in coverage mapping and comparison with FEKO software", 25th Signal Processing and Communications Applications Conference, pp. 1-4, 2017.

[6] M.B. Tabakcioglu, "A Top-down Approach to S-UTD-CH Model", ACES Journal, vol. 32, no:7, pp.586-592, 2017.

[7] M.B. Tabakcioglu, "S-UTD-CH model in multiple diffractions", International Journal of Electronics, vol. 103, no:5, pp. 765-774, 2017.

[8] R. J. Luebbers, "A General, Uniform Double Wedge Diffraction Coefficient", IEEE Transactions on Antennas and Propagation, vol. 39. no. 1, pp. 8–14, 1989.

[9] C. Tzaras, S. and R. Saunders, "An improved heuristic UTD solution for multiple- edge transition zone diffraction," IEEE Transactions on Antennas Propagatios, vol. 49, no. 12, 2001.

[10] D. A. McNamara, C. V. Pistorious, J. A. G. Malherbe, "Introduction to the Uniform Geometrical Theory of Diffraction", Boston. MA: Artech House, 1990.

TABLE I. HEIGHT OF BUILDING

1	9	1	15	0	20	15	19	10	5	5	15	20	7	15	2	12	9	15	5	1
9	13	2	9	13	17	6	8	18	14	5	15	6	5	0	7	9	6	6	5	19
18	8	10	11	10	5	20	3	18	0	6	15	13	3	19	11	5	12	19	18	10
9	6	1	15	2	7	8	18	0	17	6	5	10	15	4	4	20	12	6	20	18
3	0	14	18	2	0	12	12	10	0	14	19	18	2	7	5	11	12	6	16	16
16	7	1	14	20	3	2	19	10	17	17	3	5	1	12	16	10	0	20	10	6
3	13	12	15	3	7	3	17	7	5	0	16	10	11	18	15	14	3	11	20	12
16	20	18	4	0	9	0	9	19	5	8	9	17	17	9	7	19	15	15	19	10
16	9	17	8	15	20	10	9	4	6	2	7	6	7	17	11	10	16	2	13	7
7	12	18	4	14	18	4	6	10	18	10	5	11	12	8	0	14	10	8	1	7
4	4	17	8	1	7	16	3	19	6	6	4	16	1	19	3	6	14	2	10	15
19	15	15	8	5	10	4	17	13	17	16	9	6	14	20	16	17	14	12	15	10
18	1	20	2	11	8	2	15	12	16	11	17	12	19	18	10	16	9	17	6	20
5	1	15	17	19	6	16	11	9	17	19	1	14	4	8	5	17	20	13	14	19
14	11	7	13	7	8	7	9	10	19	4	7	12	10	5	12	18	1	9	1	11
11	16	4	12	9	18	13	7	7	5	20	6	3	7	15	14	14	0	7	18	6
12	6	2	8	17	20	18	1	7	4	6	20	11	15	17	3	18	2	15	15	15
2	9	10	11	18	14	16	11	20	1	11	5	10	14	4	12	6	18	2	2	20
3	3	3	1	9	14	17	16	14	9	14	20	10	6	16	4	4	9	13	12	2
2	5	15	8	17	19	8	1	11	15	6	10	4	19	10	11	4	2	1	17	16
4	18	14	13	20	0	8	10	12	1	13	1	11	14	10	12	4	13	7	2	7

TABLE II. ELECTRIC FIELDS IN ALL POSITIONS

0,0	-17,0	-33,9	-37,5	-57,2	-60,6	-75,2	-63,8	-83,5	-63,3	-69,9	-82,5	-60,0	-93,1	-97,4	-114,2	-100,7	-105,6	-85,8	-111,2	-91,4
-17,0	-18,6	-20,5	-22,0	-23,1	-24,1	-24,8	-25,5	-26,1	-26,6	-27,0	-27,4	-27,8	-28,1	-28,5	-28,8	-29,0	-29,3	-29,5	-29,8	-30,0
-17,5	-20,5	-34,4	-22,6	-20,3	-24,3	-22,6	-25,6	-33,7	-26,6	-39,7	-27,5	-24,3	-28,2	-25,0	-28,8	-41,2	-29,3	-36,2	-29,8	-27,7
-33,9	-22,0	-22,6	-33,7	-24,0	-24,6	-32,9	-25,8	-26,3	-35,4	-27,2	-27,6	-48,5	-28,2	-28,5	-36,9	-29,1	-29,4	-36,5	-29,8	-30,0
-28,1	-23,1	-27,5	-24,0	-53,2	-25,1	-34,3	-26,1	-30,7	-26,9	-23,8	-27,7	-32,8	-28,3	-25,8	-28,9	-47,3	-29,4	-26,8	-29,9	-41,2
-37,5	-24,1	-24,3	-24,7	-25,1	-52,9	-25,9	-26,3	-26,7	-27,1	-34,5	-27,8	-28,1	-28,4	-28,7	-39,1	-29,2	-29,5	-29,7	-29,9	-52,8
-56,6	-24,8	-21,3	-40,6	-22,6	-25,9	-36,2	-26,6	-23,6	-44,5	-36,9	-28,0	-51,8	-28,5	-38,6	-33,8	-26,2	-29,5	-45,9	-30,0	-26,7
-40,7	-25,5	-25,6	-25,8	-26,1	-26,3	-26,6	-46,8	-27,3	-27,6	-27,9	-28,1	-28,4	-28,7	-46,3	-29,2	-29,4	-29,6	-29,8	-30,1	-30,3
-38,6	-26,1	-23,1	-26,3	-38,9	-26,7	-39,3	-27,3	-65,9	-27,8	-25,8	-28,3	-46,1	-28,8	-35,1	-29,3	-39,0	-29,7	-26,7	-30,1	-44,3
-50,4	-26,6	-26,6	-35,0	-26,9	-27,1	-28,2	-27,6	-27,8	-59,1	-28,3	-28,5	-24,3	-29,0	-29,2	-36,3	-29,6	-29,8	-44,3	-30,2	-30,4
-48,9	-27,0	-24,7	-27,2	-23,4	-66,8	-36,2	-27,9	-38,9	-28,3	-78,8	-28,7	-25,8	-29,1	-39,2	-43,9	-38,0	-29,9	-41,9	-30,3	-53,0
-41,3	-27,4	-27,5	-27,6	-27,7	-27,8	-28,0	-28,1	-28,3	-28,5	-28,7	-73,4	-29,1	-29,3	-29,5	-29,7	-29,9	-30,1	-30,2	-30,4	-30,6
-56,2	-27,8	-33,7	-39,4	-37,4	-28,1	-54,4	-28,4	-22,8	-39,1	-33,0	-29,1	-36,5	-29,5	-38,6	-24,4	-22,8	-30,2	-43,0	-30,5	-43,1
-68,1	-28,1	-28,2	-28,2	-28,3	-28,4	-28,5	-28,7	-28,8	-29,0	-29,1	-29,3	-29,5	-83,2	-29,8	-30,0	-30,1	-30,3	-30,5	-30,6	-30,8
-77,5	-28,5	-41,2	-28,5	-40,7	-28,7	-26,0	-76,3	-25,7	-29,2	-37,8	-29,5	-26,9	-29,8	-81,4	-30,1	-39,9	-30,4	-26,8	-30,7	-35,6
-83,9	-28,8	-28,8	-36,8	-28,9	-27,5	-24,4	-29,2	-29,3	-48,5	-22,0	-29,7	-49,8	-30,0	-30,1	-67,7	-30,4	-30,5	-39,3	-30,8	-35,8
-57,8	-29,0	-38,2	-29,1	-41,1	-29,2	-27,1	-29,4	-82,7	-29,6	-41,9	-29,9	-49,1	-30,1	-26,4	-30,4	-63,0	-30,7	-28,5	-30,9	-24,8
-84,5	-29,3	-29,3	-29,4	-29,4	-29,5	-29,5	-29,6	-29,7	-29,8	-29,9	-30,1	-30,2	-30,3	-30,4	-30,5	-30,7	-59,9	-30,9	-31,1	-31,2
-86,0	-29,5	-39,7	-54,4	-40,8	-29,7	-47,1	-29,8	-38,2	-61,0	-40,2	-30,2	-36,2	-30,5	-28,1	-47,3	-39,2	-30,9	-72,6	-31,2	-39,9
-58,5	-29,8	-29,8	-29,8	-29,9	-29,9	-30,0	-30,1	-30,1	-30,2	-30,3	-30,4	-30,5	-30,6	-30,7	-30,8	-30,9	-31,1	-31,2	-84,7	-31,4
-65,1	-30,0	-26,7	-30,0	-38,7	-57,2	-36,3	-30,3	-35,9	-30,4	-51,8	-30,6	-52,6	-30,8	-27,7	-45,8	-52,5	-31,2	-35,9	-31,4	-106,6