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Hindawi Publishing Corporation
International Journal of Antennas and Propagation
Volume 2013, Article ID 285304, 5 pages
http://dx.doi.org/10.1155/2013/285304

Application Article

Application of S-UTD-CH Model into Multiple Diffraction Scenarios

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Received 3 April 2013; Accepted 20 May 2013

Academic Editor: Stefano Selleri

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Propagation prediction models based on ray tracing in coverage estimation for digital broadcasting systems are compared. Geometrical Theory of Diffraction (GTD), Slope Uniform Theory of Diffraction (S-UTD), and Slope UTD with Convex Hull (S-UTD-CH) models are compared for computation time and propagation path loss. S-UTD-CH model is optimum model with respect to computation time and relative path loss.

1. Introduction

It is vital to calculate relative path loss of electromagnetic wave reaching to the receiver in multiple diffraction scenarios for more reliable radio broadcasting. A lot of electromagnetic wave propagation models based on ray tracing technique have been developed for a long time. Base station location is vital for efficiency of field strength on receiver and computational time. For reaching for all users, predicting the coverage field accurately and quickly is most significant. Radio propagation models run for calculating electromagnetic wave strength in radio planning tools predicting coverage and field strength on the receiver. In radio planning tools, Geometrical Theory of Diffraction (GTD), based on ray tracing technique, model is used due to less computation time [1]. In urban regions there are multiple diffractions, and due to that the height, of buildings are close to each other, buildings are in the transition region of the previous one. In that case GTD model fails to calculate the electric field strength at the receiver accurately. This model can be used in rural areas not having multiple diffractions with less computation time. To remove the continuity problem on the transition region, Slope Uniform Theory of Diffraction (S-UTD) model is proposed. This model based on adding of derivative of incoming fields [2, 3]. S-UTD model gives inaccurate prediction results and require great computation time in scenarios having diffraction larger than 10. According to accuracy of predicted field and computation time, Slope UTD with Convex Hull model is optimum model [4, 5]. In this study, GTD, S-UTD, and S-UTD-CH propagation models being used in broadcasting are compared with respect to accuracy and computation time. Moreover effects of transmitter height to relative path loss are discussed.

2. GTD Based Models

GTD based models have been used for a long time in terrestrial broadcasting. GTD model gives inaccurate results on predicting field strength in application of multiple diffractions. GTD model can be used in prediction in two cases. The first one is single diffraction case. The other one is that buildings are not in the transition zone of the previous buildings in multiple diffractions. Otherwise, GTD model fails to predict the field strength at the receiver. To remove the failure of GTD model in the transition zone, derivatives of the incoming fields are taken and added to total field. S-UTD model has large computation time and loses the accuracy due to more than 10 diffractions. To remove the failure of S-UTD model, S-UTD-CH model is proposed. In fact the proposed model is not new. It is only combination of two previously proposed models. This model is combination of Convex Hull [6] and S-UTD model. In this model firstly the obstacles not having contribution to total field are excluded according to

Table 1: Comparison results of highly elevated receiver height (25 m).

GTD (s)	S-UTD (s)	S-UTD-CH (s)	GTD versus S-UTD (dB)	S-UTD-CH versus S-UTD (dB)	Elected
0,562	83,585	0,047	0,071	0,05	6
0,749	154,722	0	0,017	0,002	7
0,499	114,302	0	0,54	0,054	7
0,905	145,471	0	0	0,074	8
1,108	209,135	0,015	0,175	0,02	7
1,294	215,375	0,047	0,208	0,131	6
0,639	170,79	0	0,173	0,038	7
1,17	197,138	0	0,238	0,239	8
1,544	296,761	0	0,034	0,015	7
0,89	148,7	0	0,014	0,446	9
0,874	141,353	0	0,001	0,473	9
0,609	86,814	0,047	0,014	0,027	6
0,78	180,571	0	0,603	0,143	8
0,889	129,871	0	0,025	1,63	9
1,357	189,447	0	0,01	0,541	9
0,499	85,426	0	0,03	0,006	7
1,388	215,001	0,015	0,019	0,564	7
0,499	75,957	0	0,044	0,134	7
1,279	236,498	0	0	0,049	8
0,421	75,442	0,032	0,135	0,041	6
0,898	157,618	0,010	0,118	0,234	7,400
0,347	60,877	0,018	0,173	0,379	1,046

Fresnel zone concept, and then Convex Hull is constructed via remaining obstacles [7]. Next, ray tracing algorithm runs for determining all ray paths ending at the receiver. Finally, S-UTD model runs for all ray paths [8]. In this model, because the obstacles having so little contributions are excluded from scenario, accuracy of predicted field is not compromised. Moreover, thanks to less obstacle computation time reduced. Remarkably, even if only one obstacle is excluded, computation time reduces to one-fifth [9]. Vogler's model [10] is numerical model and gives ultimate accuracy in field prediction to real scenarios. S-UTD-CH model is compared with this model in real geometry and gives accurate results [4].

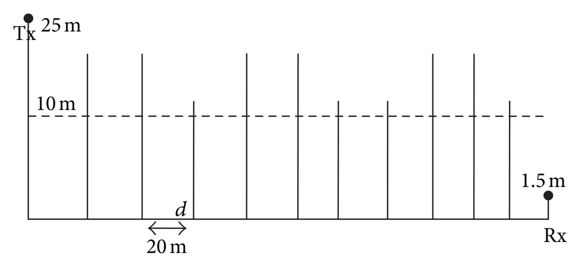

Figure 1: Scenario of comparison of GTD based models.

3. Comparison of GTD Based Models

In the case of multiple diffraction scenarios including less than 11 diffractions, S-UTD model is reference model with higher accuracy. To compare the model the scenario given in Figure 1 is used. In this scenario, transmitting antenna height is selected as 25, 20, 15, 10, and 5 m, respectively. Operational frequency, assigned to 2100 MHz. Average height of building 10 m and buildings' heights are randomly distributed between 10 ± 4 m. Distance between the buildings is 20 m, and distances between the buildings are randomly distributed between 20 ± 5 m. Finally receiving antenna height is 1,5 m.

For given scenario, are made 20 simulations, for GTD, S-UTD, and S-UTD-CH models, respectively. Firstly, transmitter antenna height is selected 25 m (highly elevated) and simulation results are given in Table 1.

As can be seen from Table 1, leftmost three columns give computation times for GTD, S-UTD, and S-UTD-CH models. Next column gives the contribution of S-UTD model to GTD model. This contribution is caused by adding derivatives of the incoming fields. Next column gives the difference between S-UTD and S-UTD-CH models. The rightmost column shows the elected building number. These buildings are elected because there is almost no contribution to total field at the receiver. 20 simulations are made for each model. Last two rows illustrate the mean and standard deviation. Moreover it is illustrated in Table 1 that S-UTD model requires the most computation time. As diffraction number increases, computation time increases. Because of excluding not effective building, computation time of S-UTD-CH model is very lower. In spite of that S-UTD and S-UTD-CH models give almost the same results (0,234 dB), computation time of S-UTD-CH model is 0,010 s whereas computation time of S-UTD model is 157,618 s. The contribution of S-UTD model to GTD model is 0,118 dB resulting from adding of derivatives of incoming fields. Furthermore averagely 7,4 buildings are excluded from the scenario caused by not having contribution.

Secondly, transmitting antenna height is selected as 20 m (elevated) with all the same parameters, and results are given in Table 2.

20 simulations are made for each model. Last two rows illustrate the mean and standard deviation. Moreover it is illustrated in Table 2 that S-UTD model again has the most

Table 2: Comparison results of elevated receiver height (20 m).

GTD (s)	S-UTD (s)	S-UTD-CH (s)	GTD versus S-UTD (dB)	S-UTD-CH versus S-UTD (dB)	Elected
1,357	262,051	0	0,038	0,585	9
1,358	213,581	0,015	0,001	0,029	7
0,577	156,048	0,016	0,061	0,33	7
1,872	346,228	0	0,003	0,424	7
0,982	177,561	0	0,022	0,821	9
0,499	143,942	0,016	0,097	0,185	7
0,78	172,506	0	0,059	0,011	7
0,983	184,596	0	0,002	0,22	8
1,529	259,507	0	0,129	1,355	9
0,826	199,728	0,016	0,072	0,07	7
1,217	212,598	0,234	0,066	0,037	5
0,531	118,982	0	0,043	0,056	7
0,702	122,336	0,046	0,863	0,173	6
2,356	391,578	0,015	0,034	0,182	7
0,577	97,938	0,046	0,033	0,181	6
0,452	68,531	0	1,848	0,278	7
0,484	80,777	0,047	0,125	0,14	6
0,437	79,576	0,016	0,109	0,036	7
1,077	266,933	0,016	1,03	0,044	7
0,78	199,182	0,046	5,376	0,014	6
0,969	187,709	0,026	0,501	0,259	7,050
0,518	86,713	0,052	1,239	0,332	1,050

computation time. Because of ignoring not effective building, computation time of S-UTD-CH model is very lower. In spite of that S-UTD and S-UTD-CH models give almost the same results (0,259 dB), computation time of S-UTD-CH model is 0,026 s whereas computation time of S-UTD model is 187,709 s. The contribution of S-UTD model to GTD model is 0,501 dB resulting from adding of derivatives of incoming fields. Furthermore averagely 7,05 buildings are excluded from the scenario caused by not having contribution.

Thirdly, transmitting antenna height is selected as 15 m (same) with all the same parameters, and results are given in Table 3.

20 simulations are made for each model. Last two rows illustrate the mean and standard deviation. Moreover it is illustrated in Table 3 that S-UTD model again has the most computation time. Because of ignoring not effective building, computation time of S-UTD-CH model is very lower. In spite of that S-UTD and S-UTD-CH models give almost the same results (0,119 dB), computation time of S-UTD-CH model is 0,363 s whereas computation time of S-UTD model is 235,013 s. The contribution of S-UTD model to GTD model is 0,576 dB resulting from adding of derivatives of incoming fields. Furthermore averagely 6,05 buildings are excluded from the scenario caused by not having contribution.

Fourthly, transmitting antenna height is selected as 10 m (lower) with all the same parameters, and results are given in Table 4.

20 simulations are made for each model. Last two rows illustrate the mean and standard deviation. Moreover it is illustrated in Table 4 that S-UTD model again has the most computation time. Because of ignoring not effective building, computation time of S-UTD-CH model is very lower. In spite of that S-UTD and S-UTD-CH model gives almost the same results (0,151 dB), computation time of S-UTD-CH model is 6,129 s whereas computation time of S-UTD model is 214,041 s. The contribution of S-UTD model to GTD model is 0,605 dB resulting from adding of derivatives of incoming fields. Furthermore averagely 5 buildings excluded from the scenario caused by not having contribution.

Finally, transmitting antenna height is selected as 5 m (highly lower) with all the same parameters and results are given in the Table 5.

There are made 20 simulations for each model. Last two rows illustrate the mean and standard deviation. Moreover it is illustrated in Table 5, S-UTD model again has the most computation time. Because of ignoring not effective building, computation time of S-UTD-CH model is very lower. In spite of that S-UTD and S-UTD-CH models give almost the same results (0,271 dB), computation time of S-UTD-CH model is 0,898 s whereas computation time of S-UTD model is 160,813 s. The contribution of S-UTD model to GTD model is 0,896 dB resulting from adding of derivatives of incoming fields. Furthermore averagely 4,65 buildings are excluded from the scenario caused by not having contribution.

4. Results and Discussions

In general, GTD model is the fastest model to predict the field strength in radio propagation. If the scenario includes less than 11 buildings, S-UTD model gives the ultimate accuracy.

Table 3: Comparison results of the same receiver height (15 m).

GTD (s)	S-UTD (s)	S-UTD-CH (s)	GTD versus S-UTD (dB)	S-UTD-CH versus S-UTD (dB)	Elected
1,404	289,35	0,016	0,127	0,185	7
0,811	186,062	0,266	0,081	0,028	5
0,749	92,43	0,016	0,103	0,241	7
0,39	77,938	0,032	1,992	0,23	6
1,342	303,422	0	0,248	0,171	7
0,562	82,712	0	1,887	0,015	7
2,012	443,511	0,016	0,089	0,015	7
1,185	277,152	0,031	2,239	0,166	6
1,061	297,291	0,046	0,174	0,315	6
1,342	276,153	0,046	0,037	0,28	6
1,295	259,195	0,25	0,386	0,077	5
0,686	133,319	0,062	0,074	0,119	6
1,077	216,841	0,25	0,638	0,114	5
1,887	379,598	0,031	0,597	0,039	6
1,077	240,101	0,031	1,397	0,193	6
0,998	142,85	5,881	0,31	0,072	3
2,808	514,164	0,015	0,009	0,043	8
0,5	119,527	0,219	0,017	0,005	5
0,733	188,871	0,046	0,731	0,011	6
1,014	179,776	0	0,385	0,07	7
1,147	235,013	0,363	0,576	0,119	6,050
0,574	118,359	1,302	0,714	0,097	1,099

Table 4: Comparison results of highly lower receiver height (10 m).

GTD (s)	S-UTD (s)	S-UTD-CH (s)	GTD versus S-UTD (dB)	S-UTD-CH versus S-UTD (dB)	Elected
0,327	103,85	0,094	0,081	0,236	5
0,749	191,086	0,702	1,208	0,015	4
1,638	313,063	0,047	1,019	0,091	6
1,186	288,227	0,203	1,53	0,166	5
0,671	126,018	0,187	0,052	0,005	5
0,546	158,465	0,016	0,026	0,285	6
1,17	324,17	0,187	0,065	0,27	5
1,529	347,539	0,202	1,075	0,451	5
1,279	322,766	5,21	0,886	0,173	3
0,468	76,441	0,031	1,517	0,019	6
0,468	66,862	0	0,127	0,112	8
1,731	342,017	113,553	0,613	0,001	1
0,531	86,409	0,156	1,832	0,29	5
0,858	182,646	0,156	0,225	0,073	5
0,904	198,215	0,827	0,148	0,15	4
0,312	50,326	0,609	0,021	0,268	4
0,733	153,443	0,202	0,884	0,068	5
1,623	367,429	0,031	0,054	0,078	6
1,201	233,659	0	0,173	0,255	7
1,248	348,179	0,171	0,556	0,006	5
0,959	214,041	6,129	0,605	0,151	5,000
0,459	109,416	25,311	0,595	0,125	1,451

Table 5: Comparison results of highly lowered receiver height (5 m).

GTD (s)	S-UTD (s)	S-UTD-CH (s)	GTD versus S-UTD (dB)	S-UTD-CH versus S-UTD (dB)	Elected
1,155	255,202	0,203	0,04	0,192	5
0,203	37,066	0,437	0,67	0,2	4
0,764	203,223	0,015	0,143	1,134	6
0,483	112,4612	0,531	0,429	0,081	4
0,359	82,852	0,015	0,612	0,041	6
0,795	194,705	0,172	0,107	0,166	5
1,529	351,314	0,156	2,207	0,144	5
0,764	181,227	0,546	0,353	0,001	4
0,437	91,666	0,436	1,687	0,007	4
0,873	235,999	0,093	0,082	0,457	5
0,624	145,643	0,093	0,202	0,396	5
0,671	165,486	0,514	0,332	0,321	4
0,952	225,905	4,196	1,455	0,007	3
0,608	138,045	0,016	0,037	0,071	6
0,639	176,079	0,452	2,954	0,003	4
0,265	46,77	0,093	0,471	0,079	5
0,327	75,879	0,094	0,591	0,158	5
0,499	104,318	9,75	3,515	0,077	2
0,89	258,072	0,031	0,314	0,589	6
0,561	134,348	0,125	1,715	0,12	5
0,670	160,813	0,898	0,896	0,212	4,650
0,317	79,980	2,272	1,021	0,271	1,040

Despite that S-UTD model gives accurate results, this model has large computation time. With decreasing eliminated building number, S-UTD and S-UTD-CH models give almost the same results. In the case of not eliminating buildings, these two models predict the relative path loss at the receiver similarly. As the difference between the building heights decreases, building heights are close to each other. Therefore S-UTD model has the most contribution to GTD model resulted from adding derivatives of the incoming fields. In the cases of elevated and highly elevated transmitting antennae, direct fields are dominant, and so contribution of derivative terms is very small and can be ignored. In these cases, GTD model can be used with higher accuracy and less computation time. As a conclusion, S-UTD-CH model is optimum model for accuracy of predicted field and relatively less computation time in multiple diffraction scenarios.

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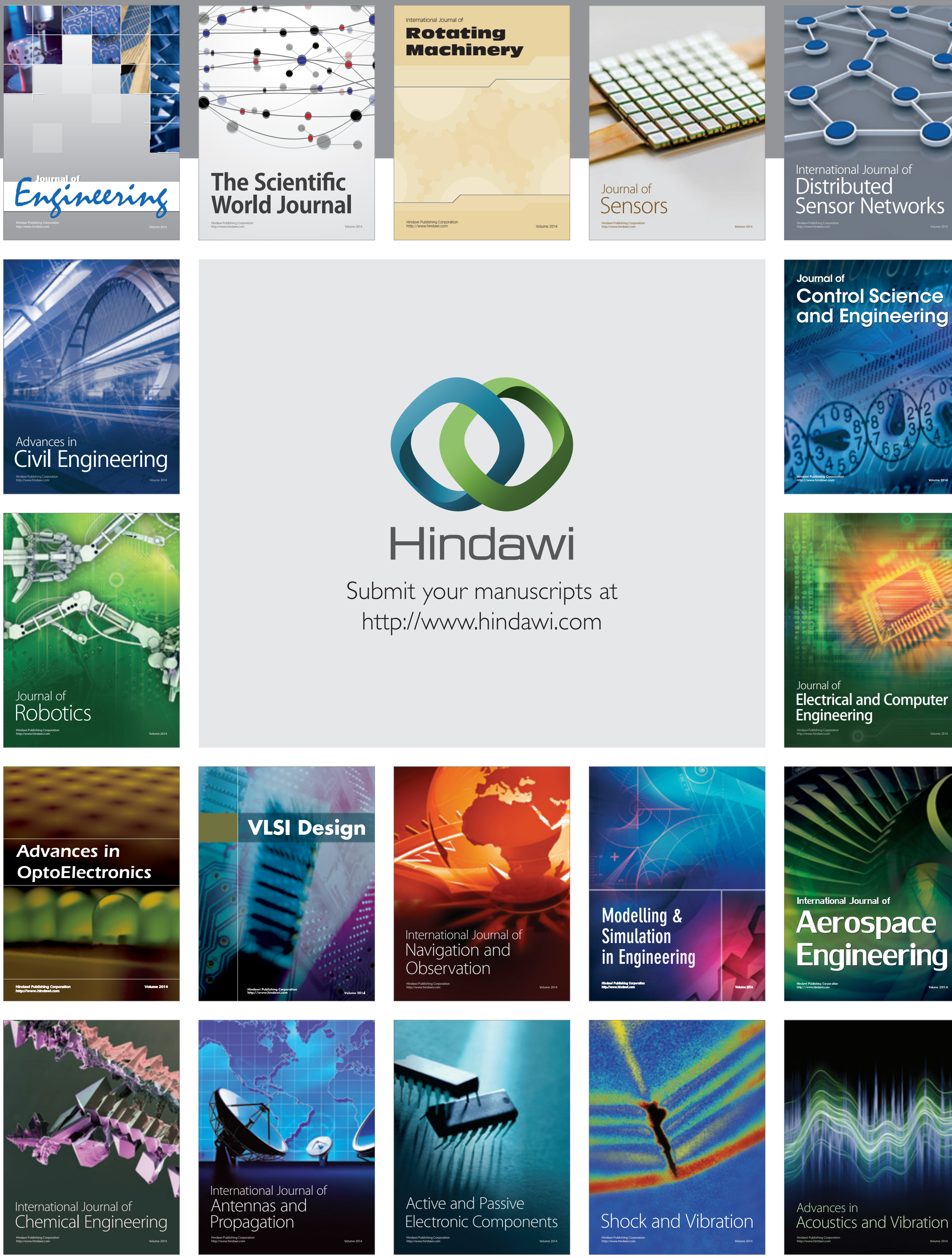
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