# Application of S-UTD-CH Model into Multiple Diffraction Scenarios at 900 MHz

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**Abstract**— In this study, propagation prediction models based on ray tracing in coverage estimation for broadcasting systems are compared with respect to computation time and accuracy. Uniform Theory of Diffraction (UTD), Slope Diffraction (S-UTD) and Slope UTD with Convex Hull (S-UTD-CH) models are compared for computation time and propagation path loss. Moreover in this study, effects of transmitter height to relative path loss at the receiver are analyzed. 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 digital 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 to 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, Uniform Theory of Diffraction (UTD), 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 UTD 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, UTD, 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. UTD BASED MODELS

UTD based models have been used for a long time in terrestrial broadcasting. UTD model gives inaccurate results on predicting field strength in application of multiple diffractions. UTD model can be used 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, UTD model fails predicting the field strength at the receiver. To remove the failure of UTD 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 lose the accuracy due to more than 10 diffractions. To remove the failure of S-UTD model, S-UTD-CH model is proposed. In fact 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 is excluded according to Fresnel zone concept and then convex hull 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 of the obstacles having so little contributions are excluded from scenario, accuracy of predicted field is not compromised. Moreover, thank to less obstacle computation time reduced. Remarkably, even if only one obstacle is excluded, computation time reduce to one fifth [9].

## 3. COMPARISON OF UTD BASED MODELS

In the case of multiple diffraction scenario including less than 11 diffractions, S-UTD model is reference model with higher accuracy. To compare the model the scenario given in Fig. 1 is used. In this scenario, transmitting antenna height is selected as 25, 20, 15, 10 and 5 m respectively. Operational frequency assigned to 900 MHz. Average height of building 10 m and buildings' heights are randomly distributed between $10 \pm 4$ m. Distance between the buildings is 20 m and distances between the buildings are randomly distributed between $20 \pm 5$ m. Finally receiving antenna height is 1.5 m.

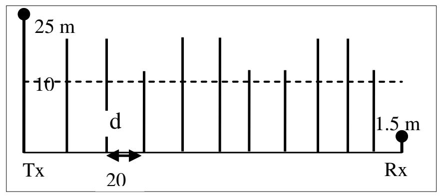


Figure 1: Scenario of comparison of UTD based models.

For given scenario, there made 20 simulations for UTD, S-UTD and S-UTD-CH models respectively. Firstly, transmitter antenna height is selected 25 m (highly elevated) and simulation results are given in Tables 1 and 2.

Table 1: Computation times for highly elevated receiver height (25 m).

| UTD (s) | S-UTD (s) | S-UTD-CH (s) |
|---|---|---|
| 1.143 | 223.252 | 0.011 |
| 0.418 | 73.240 | 0.017 |

As can be seen from the Table 1, leftmost column gives computation times for UTD, the second column is for S-UTD and the last column is for S-UTD-CH models, respectively. The first and second row gives the mean and standard deviations of simulations. Moreover, S-UTD model require the highest computation time. As the diffraction number increases, computation time increases, too. Because of excluding not effective buildings, 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 (only 0.254 dB difference); computation time of S-UTD-CH model is 0.011 s whereas computation time of S-UTD model is 223.256 s.

Table 2: Path loss for highly elevated receiver height (25 m).

| UTD vs S-UTD (dB) | S-UTD-CH vs S-UTD (dB) | ELECTED |
|---|---|---|
| 0.360 | 0.254 | 7.650 |
| 0.537 | 0.252 | 0.988 |

As illustrated in Table 2 leftmost column gives contribution of slope diffraction model to classical UTD model. The second column gives the difference of two slope diffraction models and the last column gives the number of elected buildings in S-UTD-CH model. Moreover, contribution of S-UTD model to UTD model is 0.360 dB resulting from adding of derivatives of incoming fields. Furthermore averagely 7.65 buildings 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 Tables 3 and 4.

As can be seen from the Table 3, leftmost column gives computation times for UTD, the second column is for S-UTD and the last column is for S-UTD-CH models, respectively. The first and second row gives the mean and standard deviations of simulations. Moreover, S-UTD model require the highest computation time. As the diffraction number increases, computation time increases, too. Because of excluding not effective buildings, 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 (only 0.366 dB

Table 3: Computation times for elevated receiver height (20 m).

| UTD (s) | S-UTD (s) | S-UTD-CH (s) |
|---|---|---|
| 1.539 | 309.089 | 0.024 |
| 0.587 | 111.851 | 0.049 |

Table 4: Path loss for elevated receiver height (20 m).

| UTD vs S-UTD (dB) | S-UTD-CH vs S-UTD (dB) | ELECTED |
|---|---|---|
| 0.267 | 0.366 | 7.050 |
| 0.470 | 0.249 | 0.999 |

difference); computation time of S-UTD-CH model is 0.024 s whereas computation time of S-UTD model is 309.089 s.

As illustrated in Table 4 leftmost column gives contribution of slope diffraction model to classical UTD model. The second column gives the difference of two slope diffraction models and the last column gives the number of elected buildings in S-UTD-CH model. Moreover, contribution of S-UTD model to UTD model is 0.276 dB resulting from adding of derivatives of incoming fields. Furthermore averagely 7.050 buildings 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 the Tables 5 and 6.

Table 5: Computation times for same receiver height (15 m).

| **UTD (s)** | **S-UTD (s)** | **S-UTD-CH (s)** |
|---|---|---|
| 1.462 | 319.442 | 0.695 |
| 0.582 | 122.972 | 1.192 |

Table 6: Path loss for elevated receiver height (15 m).

| UTD vs S-UTD (dB) | S-UTD-CH vs S-UTD (dB) | ELECTED |
|---|---|---|
| 0.626 | 0.153 | 4.950 |
| 0.904 | 0.205 | 0.999 |

As can be seen from the Table 5, S-UTD model require the highest computation time. As the diffraction number increases, computation time increases, too. Because of excluding not effective buildings, 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 (only 0.153 dB difference); computation time of S-UTD-CH model is 0.695 s whereas computation time of S-UTD model is 319.442 s.

As illustrated in Table 6, contribution of S-UTD model to UTD model is 0.626 dB resulting from adding of derivatives of incoming fields. Furthermore averagely 4.95 buildings 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 the Tables 7 and 8.

Table 7: Computation times for lower receiver height (10 m).

| UTD (s) | S-UTD (s) | S-UTD-CH (s) |
|---|---|---|
| 1.351 | 317.003 | 9.667 |
| 0.428 | 94.830 | 23.921 |

As can be seen from the Table 7, S-UTD model require the highest computation time. As the diffraction number increases, computation time increases, too. Because of excluding not effective buildings, 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 (only 0.119 dB difference); computation time of S-UTD-CH model is 9.667 s whereas computation time of S-UTD model is 317.003 s.

Table 8: Path loss for elevated receiver height (10 m).

| UTD vs S-UTD (dB) | S-UTD-CH vs S-UTD (dB) | ELECTED |
|---|---|---|
| 2.780 | 0.119 | 3.550 |
| 2.628 | 0.124 | 1.317 |

As illustrated in Table 8, contribution of S-UTD model to UTD model is 2.780 dB resulting from adding of derivatives of incoming fields. Furthermore averagely 3.55 buildings excluded from the scenario caused by not having contribution. Finally, transmitting antenna height is selected as 5 m (lower) with all the same parameters and results are given in the Tables 9 and 10.

Table 9: Computation times for lower receiver height (5 m).

| UTD (s) | S-UTD (s) | S-UTD-CH (s) |
|---|---|---|
| 0.935 | 231.956 | 10.713 |
| 0.346 | 83.781 | 23.938 |

As can be seen from the Table 9, S-UTD model require the highest computation time. As the diffraction number increases, computation time increases, too. Because of excluding not effective buildings, 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 (only 0.141 dB difference); computation time of S-UTD-CH model is 10.713 s whereas computation time of S-UTD model is 231.956 s.

Table 10: Path loss for elevated receiver height (5 m).

| UTD vs S-UTD (dB) | S-UTD-CH vs S-UTD (dB) | ELECTED |
|---|---|---|
| 1.933 | 0.141 | 3.6 |
| 1.503 | 0.151 | 1.353 |

As illustrated in Table 10, contribution of S-UTD model to UTD model is 1.933 dB resulting from adding of derivatives of incoming fields. Furthermore averagely 3.60 buildings excluded from the scenario caused by not having contribution.

## 4. CONCLUSIONS

In general, UTD 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. 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 model gives 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 close to each other. Therefore S-UTD model have the most contribution to UTD model resulted from adding derivatives of the incoming fields. In the cases of elevated and highly elevated transmitting antenna, direct fields are dominant and so contribution of derivative terms are very small and can be ignored. In these cases, UTD 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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