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OPTIMIZATION MODEL OF WAVE PROPAGATION IN COMPLEX ENVIRONMENTS

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ABSTRACT

The accurate prediction for wave propagation field is very important in wireless communication, which can improve the quality in the wireless communication. However, the field prediction in complex environments is a not easy problem. In order to improve the accuracy of field prediction, many methods are presented. The optimization of the semi-experimental model is one method for improving field predictions. The semi-experiment wave prediction model is established by using a great deal experiment data. For the optimization of propagation model, the parameters in the model are determined according the practical propagation path.The optimization of propagation model in complex environment is not satisfactory now. In this paper, an improved optimation method is presented for wave propagation model in the complex environments. The main idea in the method is to divide the propagation path into multiple sections and each section has the similar propagation characteristics. In the optimization, in order to regularize the experimental data an interpolation method is used to the experimental data, which can improve the prediction accuracy. The simulation is performed and the simulation results show that the presented method can reduce the prediction error significantly

KEYWORDS: Optimization, Wave propagation, Wireless Communication, Hata model.

I. INTRODUCTION

As results of rapid growth in wireless communications, there are more demands for proper network coverage prediction. A good field coverage prediction requires a deep understanding of the limitations caused by environmental condition to the wave propagation. Methods for predicting wave propagation coverage is being developed for decades. These methods predict the path propagation loss at a given point. The propagation models can be classified in to three models: empirical model, stochastic model and deterministic model. Empirical models are those models that based on the observationsand measurements alone.These models are mainly used to predict the path loss.Empirical models can be described by equations derived from a statistical analysis of a large number of measurements. The models are doing not require verydetailed information about the environment. The input parameters for the empirical models are usually qualitativeand not very specific; one of the main drawbacks of empirical models is that they cannot be used for differentenvironments without modification. The okumura model, hata model andcost 231-hata mode are popular empirical models. For the application of the empirical models, some model parameters should be determined for differentenvironments, which are usually done with some optimization techniques.The several empiricalmodelsis used to model a suburbanarea and compared with the experimental data. The results show that measurement data are more close to the Hata model[2].For the urban coverage, a path loss model is developed with regression fitting method, by which the prediction error can reduced. The model use linear model and have the limitation for the more complexes propagation path and environments. The Bertoni-Walfisch model is first model which takesinto consideration the effect of buildings on radiopropagation channel in path-loss modeling [4]. Themodel assumes that propagation takes place over rows ofbuildings having equal heights and equal spacing arrangedin a perfect grid.Bertoni-Walfisch model has 5 parameters, which is optimized with mearement data. Another empirical model is Davidson model, which is a derivative of the Hata model. The optimization for Davidson model shows that the path loss exponent depends the propagation environments [5].The effect of land cover is studied and the optimization method improves the standard deviation of theerror from 9.6 to 6.3 dB [6].However, the land cover data are required as input parameters, which haveeffects to the accuracy of prediction.

Considering the prediction accuracy and the optimization method simplicity, an improved prediction method for complex environment is presented in this paper. Generally speaking, a simplelinear model can't adapt to the complexes propagation environments. In order to adapt to the complex propagation path, the propagation path is divided to multiple less complex sections. In each section, a linear prediction model is used. Because the experimental data may not be regular in space distribution, the interpolation method is used to the experimental data before optimization. By this method, the prediction accuracy can be improvedsignificantly. Next section, an algorithm is presented and the simulation is performed to the different propagation paths.

II. OPTIMIZATION METHOD

A possible method of predicting the path loss is by using of amathematical model

$$PL = A\cdot\log(x) + B\cdot\log(f) + C \qquad 1)$$

Where PL is propagation loss, A is related to path loss exponent, x is propagation path length, B describes the frequency dependence and C can be viewed as lossat reference position. For the fixed frequency, the formula can be reduced to [1]

$$PL = A\cdot\log(x) + C \qquad 2)$$

For the complex propagation path, it is difficult to predict the path loss with a simple propagation model. In order to deal with the problem, we can divide the propagation path into multiple sections that can be described with simple linear model. Assume the propagation path is divided into n sections; the model in section k can be expressed as

$$PL(k) = a_k + b_k\cdot\log(x_k) \qquad 3)$$

Where the a_k , b_k is the model parameters in the section k that is optimized using the experiment data in the section k. For the optimization of model parameters, the experimental data may be not regularly or not enough, which can affect the model accuracy. In order to improve the model accuracy, an interpolation is used to the experimental data. By the interpolation method. The model accuracy can be improved. The formula 4) is used to optimize the model parameters in section k, in which $y_{k,i}$ is the interpolated experimental data in the section k.

$$P(a_k,b_k) = \sum_{i=1}^{N_k}\left|y_{k,i} - E(x_{k,i},a_k,b_k)\right|^2 = \min \qquad 4)$$

By leased square method, the equations for the parameters can be written as

$$\sum_{i=1}^{N_k}\left((y_{k,i} - E(x_{k,i},a_k,b_k))\frac{\partial E}{\partial a}\right) = \sum_{i=1}^{N_k}\left(y_{k,i} - a_k - b_k\cdot\log(x_{k,i})\right) = 0$$

$$\sum_{i=1}^{N_k}\left((y_{k,i} - E(x_{k,i},a_k,b_k))\frac{\partial E}{\partial b}\right) = \sum_{i=1}^{N_k}\left(y_{k,i} - a_k - b_k\cdot\log(x_{k,i})\right)\cdot x_{k,i} = 0 \qquad 5)$$

Solving the equations 5),it is obtained

$$a_k = \frac{\sum_{i=1}^{N_k}(\log(x_{k,i}))^2\sum_{i=1}^{N_k}y_{k,i} - \sum_{i=1}^{N_k}\log(x_{k,i})\cdot\sum_{i=1}^{N_k}y_{k,i}\cdot\log(x_{k,i})}{n\sum_{i=1}^{N_k}(\log(x_{k,i}))^2 - \left(\sum_{i=1}^{N_k}\log(x_{k,i})\right)^2}$$

$$b_k = \frac{\sum_{i=1}^{N_k}y_{k,i}\cdot\log(x_{k,i}) - \sum_{i=1}^{N_k}\log(x_{k,i})\cdot\sum_{i=1}^{N_k}y_{k,i}}{n\sum_{i=1}^{N_k}(\log(x_{k,i}))^2 - \left(\sum_{i=1}^{N_k}\log(x_{k,i})\right)^2} \qquad 6)$$

In order to optimize and validate the effectiveness of the proposed model, rootmean square error (RMSE) was calculated between the results of the path loss data of the optimized modeland the measured path loss data. The rootmean square error (RMSE) is defined by the expression

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}[p_m(i) - p_r(i)]^2}{N}} \qquad 7)$$

Where p_m is measured path loss, p_r predicted path loss by the optimized model. In the nest section, the simulation results are given to validate the model.

III. THE SIMULATION AND DISCUSSION

After completing the model optimization process, thefield test data was used to validate the optimized modelsobtained using the tuned model parameters in order toascertain the level of accuracy and improvement. Firstly, an artificial propagation loss data is generated for the validation purpose. The path loss data are generated using free space propagation loss plus the random loss that simulate the complex environments as shown in formula 8).

$$L = 32 + 20\cdot\log(d) + 20\cdot\log(f) + \sigma\cdot randn \quad dB \qquad 8)$$

Where the randn is random variable with normal distribution and the σ is variance in dB. In the following, several cases are considered to validate the presented optimization model.

1. Free space with diffraction

In this case, wave is propagated in free space with an obstacle. For the diffraction loss, an additional loss is added to the formula 8). As reference, a wave propagation loss in free space is given in Fig.1, where the generated path loss is compared with the optimized model. For the simple propagation path, a simple model can give a good prediction for the path loss. Considering the diffraction loss, the path loss 20dB is added after 50 km and the path loss is predicted using a simple optimized Hata model in whole propagation path.The comparison between the predicted and simulated path loss data are shown in Fig.2 .it can be seen that there is a large error in the predicted results.In order to improve the prediction error, the whole propagation path is divided into 10 sections and the Hata model is optimized in each section. The path loss with the improved optimization model is given in Fig.3. It can be seen that the prediction accuracy is improved significantly.

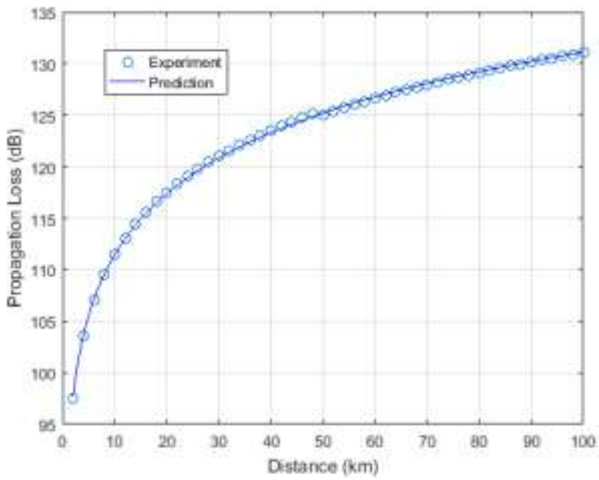

Fig .1 Path loss comparisons between experiment and predicted results in free space

The prediction model is a simple model in whole path.

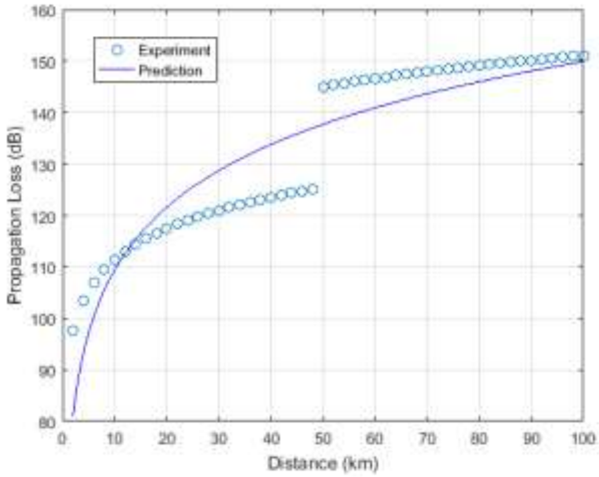

Fig.2 Path loss comparison between experiment and predicted results

The path consists of free space and one obstacle with diffraction loss 20 dB.

The prediction model is an optimized Hata model in whole path.

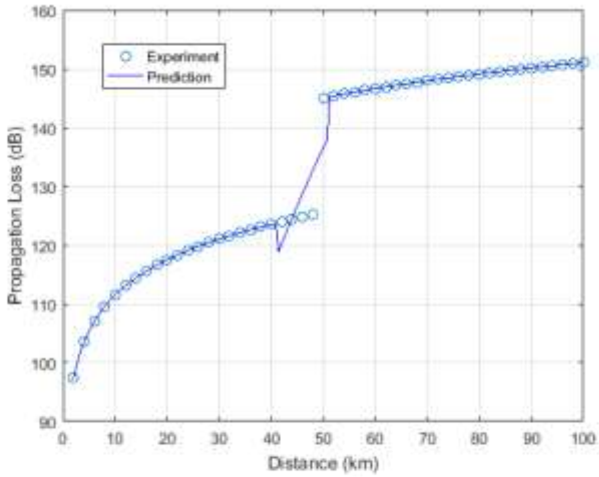

Fig .3 Path loss comparisons between experiment and predicted results

The path consists of free space and one obstacle with diffraction loss 20 dB.

Propagation path is divided into 10 sections and each section use an optimized Hata model.

2. Complex environment with obstacle diffraction

For the complex propagation environments, a random variable is added to the free space path loss. Different variance can describe the different complex environment. A random variable with variance 2 dB is added to free space path loss. The propagation path loss with variance 2 dB and the predicted path loss are shown in the Fig.4. The one simple model is used in prediction and the predicted RMSE is 6.3 dB.As a comparison, the 10 sections model is used to predict the path loss that is shown in Fig.5. The RMSE is 2.28 dB for the multiple sections prediction model. Next, the complex path includes an obstacle, in which a diffraction loss 20 dB is added to t path loss. Results between a simple prediction model and the generated simulation data are given in Fig.6. It can be seen that the prediction model gives the RMSE 15.47 dB, which mean the simple model gives too much prediction error that is not acceptable. For the multiple sections model, the compared results are shown in Fig.7, which gives the RMSE 5.4 dB and has a big improvement in prediction accuracy.

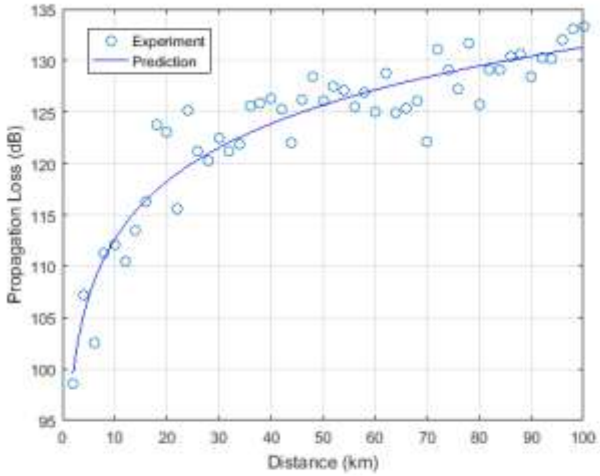

Fig.4 Results comparision between optimized model and path loss data

The path loss data are generated with variance 2dB. The predicted RMSE is 6.30 dB and the optimization model is for whole path .

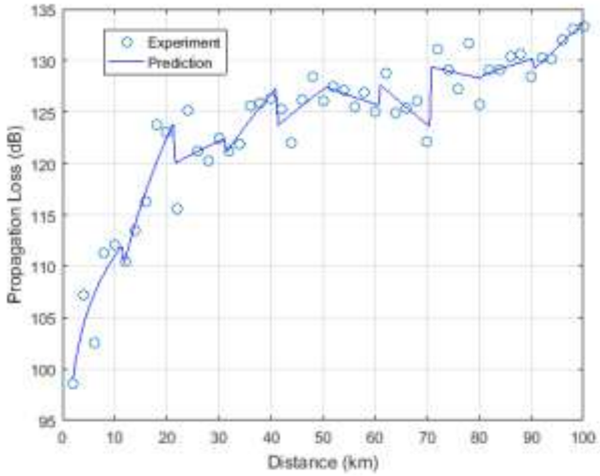

Fig.5 Results comparision between optimized model and path loss data

The path loss data are generated with variance 2dB. The predicted RMSE is 2.28 dB and the optimization model is divided into 10 sections .

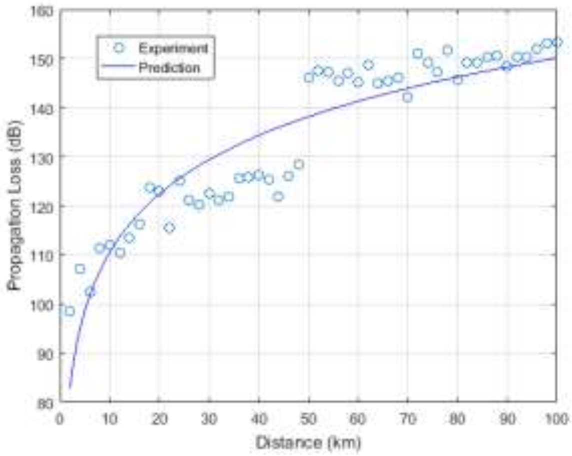

Fig.6 Results comparision between optimized model and path loss data with diffraction loss 20 dB

The path loss data are generated with variance 2dB. The predicted RMSE is 15.47 dB and the optimization model is for whole path.

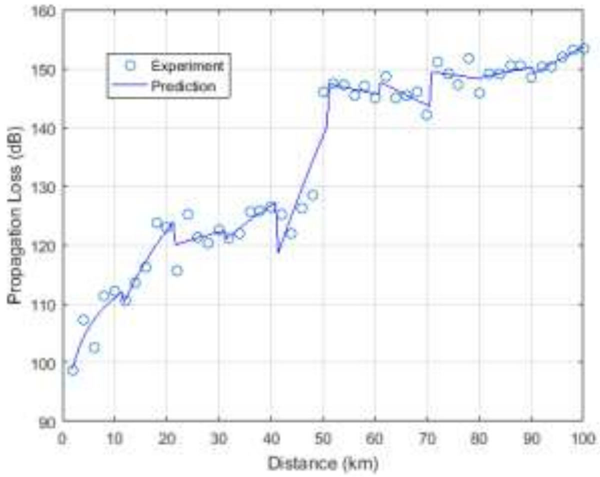

Fig.7 Results comparision between optimized model and path loss data with diffraction loss 20 dB

The path loss data are generated with variance 2dB. The predicted RMSE is 5.4 dB with the path dividing into 10 sections.

3. Practical example

In order to validate the presented model in the paper, the measurement data in reference 3 is taken to compare the prediction of path loss. The path loss data in table 1 for BTS01 line 1 is used in the comparison. The comparison between the measured data and path loss with one simple model is show in Fig.8. The RMSE for the simple model is 4.34 dB. Byusing 3 sections prediction model without interpolation, the predicted result is shown in Fig.9, with interpolation, the predicted result is shown in Fig.10. The predicted RMSE is 1.87 dB without interpolation and 1.65 dB with interpolation.

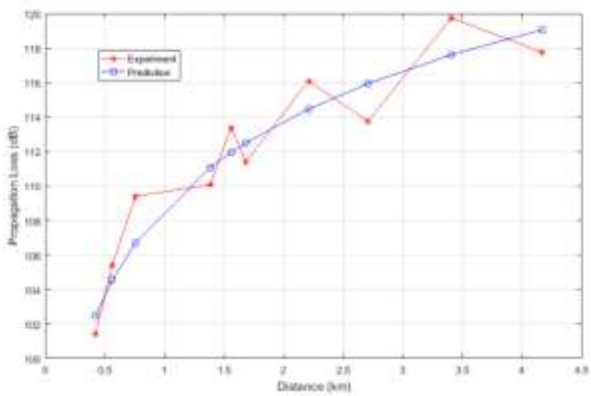

Fig.8 Resultscomparison between optimized model using only one whole path and experimental data from the reference [3]

The predicted RMSE is4.34 dB.

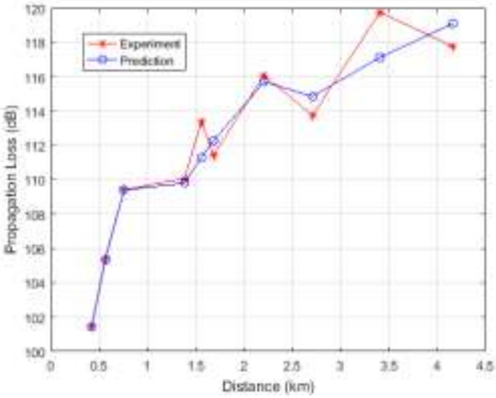

Fig.9 Results comparison between optimized model in which the path is divided into 3 sections and experimental data from the reference [3]

The experimental data are divided into 3 groups for model optimization, the group 1 and 3 have 3 data points and the group 2 has 4 data points. The predicted RMSE is 1.87 dB.

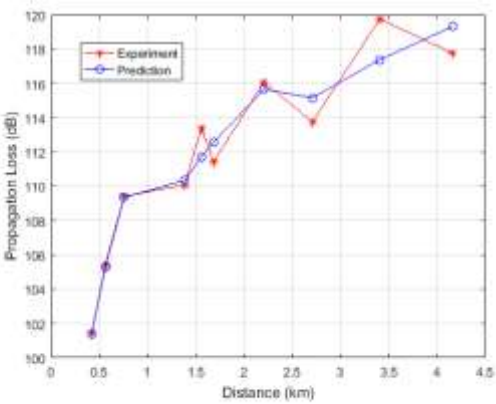

Fig.10 Results comparison between optimized model in which the path is divided into 3 sections and experimental data from the reference [3].

The interpolation method is used before optimization and the predicted RMSE is 1.65 dB. The interpolation points in each section are 5.

From the above results it can be seen that the optimization method has an advantage which is simple and the terrain data independent. For conventional optimization method, the predicted RMSE is generally very large in complexes environments. Here a different optimization method is presented, in which the propagation path is divided into multiple sections, each section have a simple environment and can be described with a simple propagation model. The simulation proves that the presented method can improve the prediction accuracy. In order to improve prediction accuracy, an interpolation method is given to preprocessing the experimental data.Because the empirical data is not regularized, the interpolation for the experimental data can give a regularized data for the model optimization, which can improve the model accuracy. From Fig.9 and Fig.10, it can be seen that by interpolation the RMSE can be improved.

IV. CONCLUSION

The optimized path loss model is developed to predict accurately the path loss in complexes propagation path. This path loss model is very useful forpredicting various complexes environments, which can help the interference analysis, frequency assignments and cell parameters in which areall fundamental elements for the network planning processes in mobile radio systems. The main contributions in this paper are that by dividing the path into multiple sections and each section use a simple model to describe the path loss. Another contribution is that using the interpolation method to improve the model prediction accuracy, in which experimental data is regularized before the model parameters being optimized. The validation is performed by using the generated path loss which models the complexes propagation path. Finally the experimental data from reference [3] is used to validate the presented optimization method.

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