A Method to Reduce Correction Error for Electromagnetic Wave Propagation Model

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Abstract: Electromagnetic wave propagation model needs to be corrected before it is used to predict wireless signal coverage. Control of the correction error will directly affect the accuracy of coverage prediction. A method to reduce the correction error is introduced in this paper. In this way, we carry out the test along concentric circles, which is unusual in such tests; and take an appropriate means for data process, so that we can reduce correction errors.

Introduction

Electromagnetic wave propagation in real space is very complicated and much more complex in the mobile communication system, which is mainly displayed in three aspects:

(1)The openness of wireless channel. When electromagnetic wave transmits in open space, the wireless channels are easily affected by all kinds of interference signals.

(2)The complexity and diversity of propagation environment. The mobile communication system works both in big cities with high buildings and small villages in mountains.

(3)The random mobility of users. Users might call anywhere, such as in rooms, in a high-speed train or car.

Above three aspects have a great influence on the propagation of electromagnetic wave in a mobile communication system, therefore it is hard to accurately predict the path loss of wireless channel in the system. Generally, wireless propagation models are built to predict the path loss, so as to estimate the field strength of received signals.

Propagation models commonly used in mobile communication network planning are mostly empirical models, which are mathematical model summarized from a large number of measured data, for example, Okumura-Hata's model, COST231-Hata model, COST231-Walfisch-Ikegami model and SPM model, etc.

Empirical models have the advantages of convenient use and simple calculation. However, due to different propagation characteristics are in different areas, if empirical models are mechanically copied in all areas, a great error will generate between calculation results and actual values. Especially in China, because of the vast area of the country and various types of geography in different places, if you want to apply a model in different regions, some parameters must be modified, which means that a model correction is needed.

Nevertheless, we have to notice that there will be errors in correction of propagation model. There are mainly two sources causing errors: errors from test data for correction and error from correction algorithm.

Errors from test data are mainly composed of three aspects: GPS errors, digital map errors, and CW (Continuous Wave) test equipment errors. GPS errors depend on the measuring accuracy of GPS equipment; digital map Errors depend on the resolution of digital maps; CW test equipment errors, on one hand, result from the test device itself, on the other hand, from improper operation.

Correction algorithm errors are determined by core algorithm, mainly depending on correlation processing method of individual variables in the model and test data.

The method introduced in this paper will effectively reduce errors of propagation model correction by improvement of data collection and processing.

We will describe the method through the example of Okumura-Hata's model correction.

Okumura-Hata's Model

Okumura-Hata's model is one of the most widely used models for signal prediction in urban areas. This model is applicable for frequencies in the range 150MHz to 1500MHz and distances of 1km to 100km.It can be used for the height of base station antenna ranging from 30m to 200m,and the height of receiver antenna ranging from 1m to 10m.The standard formula for median path loss in urban areas is given by

$$L(urban)(dB)=69.55+26.16\log f-13.82\log h_{te}-a(h_{re})+(44.9-6.55\log h_{te})\log d. \quad (1)$$

Where f is frequency in MHz, h_{te} is effective transmitter antenna height in meters, h_{re} is effective receiver antenna height in meters, d is the T-R separation distance in km, and $a(h_{re})$ is the correction factor for effective receiver antenna height. For a small and medium sized city, the receiver antenna correction factor is given by

$$a(h_{re})=(1.1\log f-0.7)\, h_{re}-(1.56\log f-0.8)dB. \quad (2)$$

and for a large city, it is given by

$$a(h_{re})=8.29(\log 1.54h_{re})^2-1.1dB \quad \text{for } f\leq 300MHZ. \quad (3)$$

$$a(h_{re})=3.2(\log 11.75h_{re})^2-4.97dB \quad \text{for } f > 300MHZ. \quad (4)$$

To obtain the path loss in a suburban area, the standard formula in Eq.1 is modified as

$$L(suburban)(dB)=L(urban)-2[\log(f/28)]^2-5.4. \quad (5)$$

And for path loss in open rural areas, the formula is modified as

$$L(rural)(dB)=L(urban)-4.78(\log f)^2+18.33\log f-40.94. \quad (6)$$

Model Correction Process

Overview. In order to correct the model, we will replace the constants in Eq.1 with variables. In the cause of our test, the transmitting frequency, antenna height of transmitters and receivers are all fixed, we focus on measuring path loss changes with distance, so we just need to introduce two correction factors k1 and k2. See the following equation

$$L(urban)=69.55+26.16\log f-13.82\log h_{te}-a(h_{re})+(44.9-6.55\log h_{te}+k1)\log d+k2. \quad (7)$$

We can calculate the correction factors of k1 and k2 by Eq.7 after we get path loss from test.

Due to fast fading, less test data will lead to greater error of correction result. According to the well-know lee's theorem, when intrinsic length is 40 wavelength and the sampling points is 30 ~ 50, fast fading will be effectively eliminated and slow fading will be kept. In this way, we can find out slow fading trend of signal in local environment to reach the goal of the model correction.

Test Site and Route Choice. We choose the urban area of Tianjin as test area. The transmission site is located in a building near Hebei road in the center of Tianjin. Transmitting antenna is 34 meters high with 2dBi gain .Transmitter output power is 5 w and transmission frequency is 876.03 MHz.

Concentric circle is usually avoided in choosing test route, to prevent the complexity of data processing increased by data redundancy at same distance. However, we take the way of the concentric circles for testing. The test vehicle runs in ways similar to concentric circles from near to far around the transmission site, so that we can test throughout various terrain environment around the transmission site, and make the sampling density increase greatly. While in data processing, an unusual way is taken. The test route is shown in figure 1.

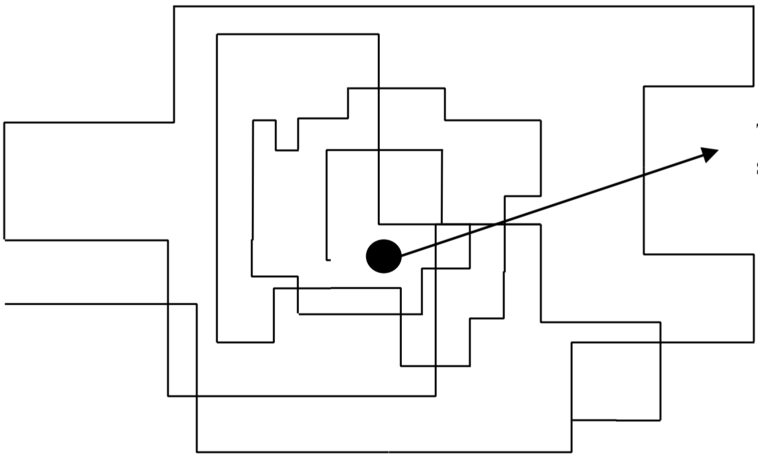


Figure 1. Test route map

According to lee's theorem, we set sampling density as 50 points per 40λ at least. When f=876MHz(λ=0.342m)and the amount of receiver sampling points is 60 per second, we can get the vehicle speed of 16.4 m/s, that is 59 km/h. In the actual course of testing, because of heavy traffic, the real speed is around 30km/h, so the sampling density is above 50 points per 40λ.Furthermore, the concentric circle route makes the sampling density far greater than 50/40λ. In this way, the effects of fast fading is decreased to an extremely low level.

Data Processing: The main purpose of data processing is to filter the unreasonable data, complete geographical average and correct data deviation.

Commonly used data processing method is to divide test route into many parts, each part is several meters long (typically 1-15 meters).The field strength of the center of every part is the average of test data of the part.

Since we adopt the way of concentric circles when we decide the test route, the above method of data processing is not applicable. Our data processing method is as follows:

Step one: All the test area is divided into many grids, the grid unit is 0.5 seconds (because of the sampling frequency of the test device is in seconds, the grid should be in seconds here so that the amount of sampling points in each grid is almost the same). In each grid the data including 5% of the maximum and 5% of the minimum will be removed, and the average of the remaining 90% of data is regarded as the test value of the lower left corner in the grid. The distance from that point to the transmission site is also calculated. As shown in Fig.2.

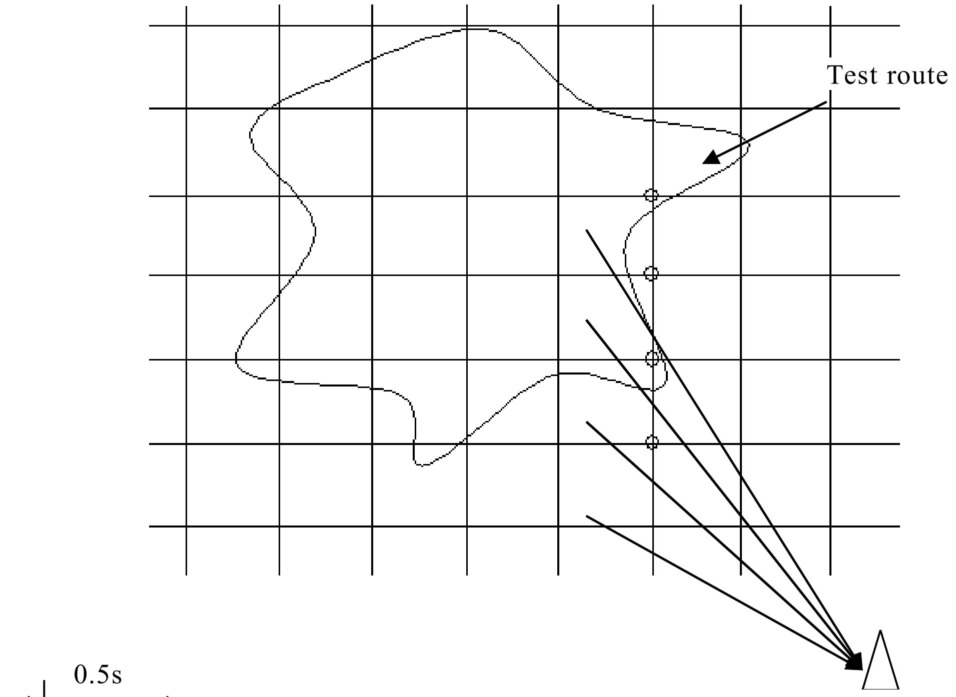


Figure 2. Data processing process

Step 2: On the basis of the above data processing results, in every 3 meters of distance, data including 5% of the maximum and 5% of the minimum will be removed, and the average of the remaining 90% of data is regarded as the field strength at that distance. As shown in Fig.3.

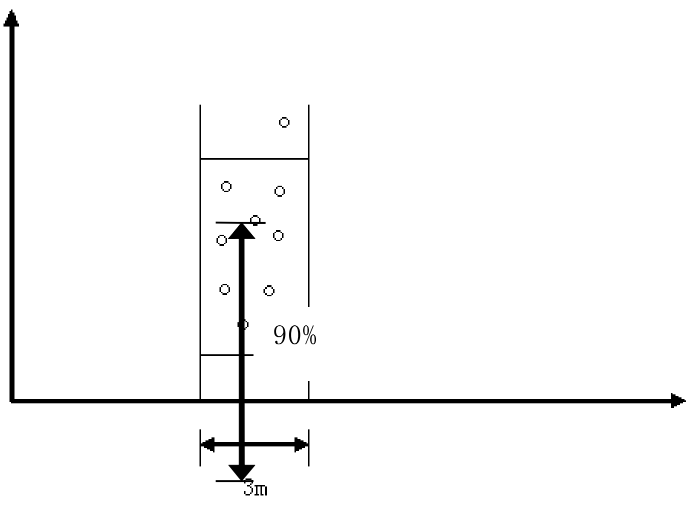


Figure 3. Data processing process 2

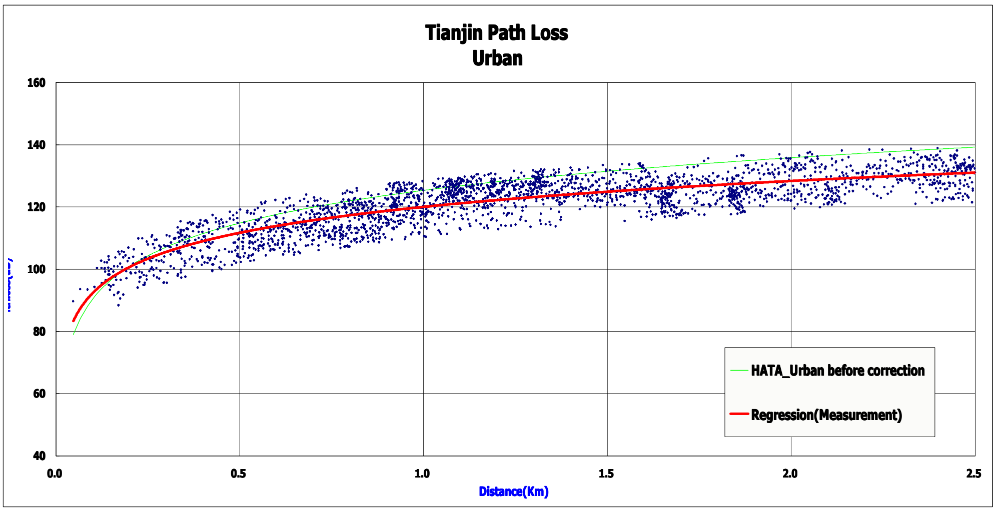
Step 3: By iterative processing of k1 and k2 to minimize the mean square deviation and the standard deviation of predicted value and test data, we will get the corrected value of k1 and k2.

The Results and Analysis

Through the test, data processing and iterative calculation, finally we get the corrected value k1=-6.236 and k2=-5.942. When the value is put into Eq.7, we will get

$$L(urban)(dB)= 63.61+26.16\log f-13.82\log h_{te}-a(h_{re})+(38.7-6.55\log h_{te})\log d. \quad (8)$$

The average path loss after correction is about 5.9 dB lower than that before correction. As shown in figure 4.



Note1: Thin line stands for prediction of path loss before model correction
Note2: Thick line stands for prediction of path loss after model correction
Note3: dots stand for test value of path loss

Figure 4. Comparison of predictions of path loss before and after model correction

Summary

The method we introduced is a way to reduce the correction error for electromagnetic wave propagation model. In this method, concentric circles test route is chosen to obtain large amounts of test data and make the test route through various terrain around the transmission site, and a complex and appreciate means of data processing is adopted so as to achieve the goal of reducing error. This method is proven to be very effective and feasible by practical application.

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