Comparison of Measurement and Prediction of ITU-R Recommendation P.1546

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***Abstract* – This paper compares measurement with prediction of ITU-R Recommendation P.1546. This recommendation mainly depends on propagation curves which are based on the measurement result. The basic field strength is derived from the curve corresponding to transmitting antenna height, frequency and required distance and then correction factor is added to this. There are two important correction values in this recommendation. First factor is the correction for receiving/mobile antenna height and second factor is the terrain clearance angle (TCA) correction. This paper specially focuses on first correction factor with regard to *R* which is representative of the height of the ground cover surrounding receiving/mobile antenna. We propose several considerations to enhance the prediction accuracy of ITU-R Recommendation P.1546.**

1. INTRODUCTION

In order to set up an efficient broadcasting network and to predict the exact field strength, we have to consider a lot of factors such as distance, obstruction, frequency, terrain profile and transmitting/receiving antenna height, etc. Because broadcasting service has to predict the field strength over expanded area, it is difficult to calculate the exact field strength. So we have to choose the most suitable propagation channel model in the broadcasting frequency band. Conventional propagation models are Hata, Okumura and ITU-R Recommendation P.1546. Among them, ITU-R Recommendation P.1546 is developed recently and this recommendation serves as a standard in areas of spectrum management and radio technology and is constantly under development. In this paper, we compare measurement with prediction of ITU-R Recommendation P.1546-2 over four cites of Korea. In section 2, The ITU-R Recommendation P.1546-2 is shortly introduced. In section 3, we illustrate measurement procedure and several statistical analysis methods. And then prediction results are compared with measurement results and the result of statistical analysis is presented. Finally, the conclusions are presented in section 4.

2. ITU-R RECOMMENDATION P.1546 -2

A. Overview

This is the recommendation of ITU for point-to-area prediction of field strength for the broadcasting, land mobile, maritime mobile and certain fixed services (e.g. those employing point-to-multipoint systems) in the frequency range 30MHz to 3000MHz and for the distance range 1km to 1,000km. The propagation curves represent field-strength values for 1kW effective radiated power (e.r.p) at nominal frequencies of 100, 600 and 2000 MHz, respectively, as function of various parameters which are frequency, transmitting antenna height, time variability and distance; these curves refer to are based on measurement data mainly relating to mean climatic conditions in temperate regions containing cold and warm sea. The field strength can be expressed as

$$E = E_{inf} + \left(E_{sup} - E_{inf}\right)\frac{\log\left[\frac{(d,f,h_1)}{(d_{inf},f_{inf},h_{inf})}\right]}{\log\left[\frac{(d_{sup},f_{sup},h_{sup})}{(d_{inf},f_{inf},h_{inf})}\right]} + C_1 + C_2 \;\; dB(\mu V/m) \quad (1)$$

where C_1, C_2 are corrections for receiving antenna height and terrain clearance angle, which are based on ITU-R Recommendation P.1546.

$$C_1 = \begin{cases} 6.03 - J(v) \quad dB & \text{for } h_2 \le R' \\ K_{h_2}\left(\log h_2 - \log R'\right) \quad dB & \text{for } h_2 > R' \end{cases} \tag{2}$$

$$C_2 = J(v') - J(v) \quad dB \tag{3}$$

B. Corrections

B-1. *Terrain clearance angle*

The terrain clearance angle correction improves the prediction accuracy by taking into account terrain near the receiving antenna. The terrain clearance angle θ_{tca} is given by:

$$\theta_{tca} = \theta - \theta_r \quad degrees \tag{4}$$

where θ is the elevation angle of the line from the receiving/mobile antenna which just clears all terrain obstructions in the direction of the transmitter/base antenna over a distance of up to 16 km but not going beyond the transmitting/base antenna. The reference angle θ_r, is given by:

$$\theta_r = \left(\frac{h_{1s} - h_{2s}}{1000d}\right) \quad degrees \tag{5}$$

where h_{1s} and h_{2s} are the height of transmitting/base and receiving antennas above sea level respectively. TCA correction is based on the height of Tx/Rx antenna and the terrain between them.

B-2. *Receiving/mobile antenna height*

The field strength values given by the curves are for a reference receiving/mobile antenna at height, *R*, representative of the height of the ground cover surrounding the receiving antenna, subject to a minimum height value of 10m. Examples of reference heights are 10 m for suburban areas, 20 m for urban areas and 30 m for dense urban areas. Where the receiving/mobile antenna is on land account should first be taken of the elevation angle of the arriving ray by calculating a modified representative clutter height R' (m), given by:

$$R' = \frac{1000dR - 15h_1}{1000d - 15} \ (m) \tag{6}$$

where h_1 and *R* (m) and distance *d* (km).

A correction depending on the ground cover should be applied if the receiving/mobile antenna height is different from the surrounding ground cover *R*. Figure 1 presents the relation *R* with R' [1]. Figure 2 illustrates correction for receiving antenna height for the nominal distances (*d=10km, 20km, 30km*). It shows that the change of *R* have a great effect on the field strength. If *R* is 30m, correction value can be about -23dB.

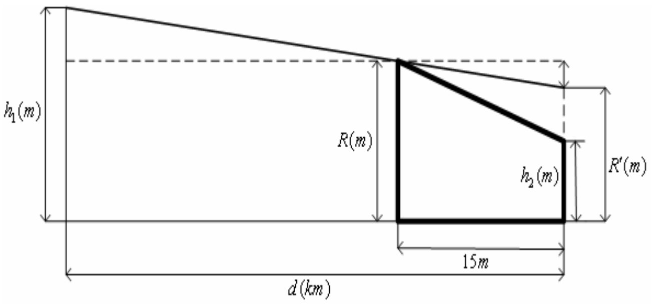

Figure 1. Definition of R'

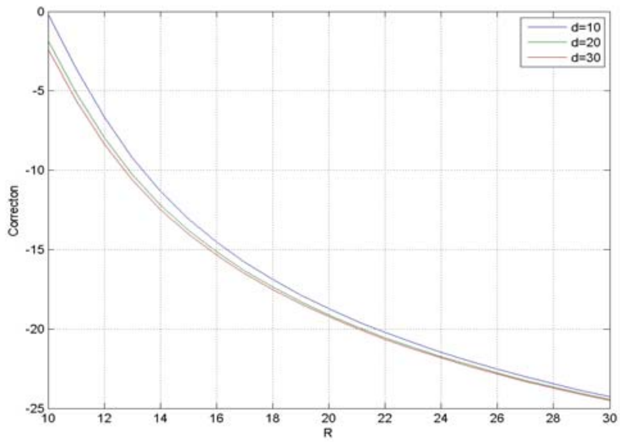

Figure 2. Correction versus *R*

3. MEASUREMENT PROCEDURE AND STATISTICAL ANALYSIS

Measurement was performed in four cities which are Pusan, Daegu, Daejeon, and Kwangju in Korea. The location of the transmitting and receiving antenna is measured with GPS system. The height of receiving antenna is 9m. Path profile is extracted using self-made GIS in Korea. Figure 3 is an example of Korean path profiles extracted using the GIS in other to predict the field strength whose resolution distance is 50m.

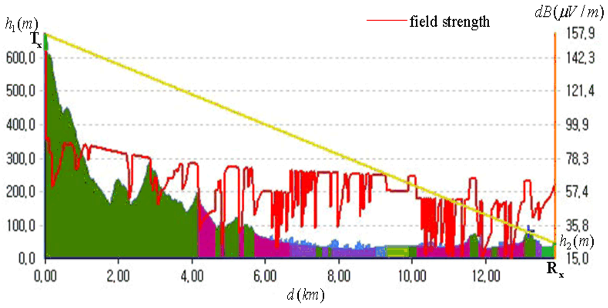

Figure 3. Path profile

In this paper, first order statistics (mean error, standard deviation), correlation coefficient and hit rate metrics [2] [3] have been used to evaluate the result.

A. First Order Statistics

The mean of the prediction error, e, positive max error, e_p, negative max error, e_n, and its standard deviation, σ_e, are first order statistics traditionally used for evaluating the accuracy of prediction models. Here, e is defined as the difference between the prediction curve, p_i, and measured values, m_i, on a logarithmic [dB] scale, i.e. assuming that the measured values are exactly correct.

B. Correlation Coefficient

The correlation coefficient provides a measure of the degree of linear relationship between two random variables and is calculated as

$$r_e = \frac{\sum_i^n (m_i - \overline{m})(p_i - \overline{p})}{\sqrt{\sum_i^n (m_i - \overline{m})^2 \sum_i^n (p_i - \overline{p})^2}} \qquad (7)$$

where $\overline{m}$ and $\overline{p}$ are the means of the measured and predicted values, respectively, and N_s is the number of samples. A correlation coefficient close to one indicates a strong linear relationship.

C. Hit Rate Metrics

To complement the first order statistics, *hit rate metrics* are introduced by Owadally, Montiel, and Saunders [3]. The hit rate is a measure of goodness when predicting the coverage by a single path loss threshold. In this paper, the location specific total hit rate (*THR*) is used as a direct indication of the quality of the prediction model. Given a path loss threshold, if both predicted and measured path loss is greater or less than the threshold, the prediction is regarded as correct irrespective to the deviation of the predicted from the measured value. For further details on the hit rate metrics, refer to [3]. To compare the different models using *THR*, we introduced in [2] the average total hit rate error (*AHRE*). The *AHRE* is the mean deviation from 100% *THR* and is expressed as

$$AHRE = \frac{1}{N_{L_T}} \sum_{min(N_{L_T})}^{max(N_{L_T})} 100\% - THR(L_T) \qquad (8)$$

where L_T is the path loss threshold and N_{LT} is the number of *THR* points. A small value of *AHRE* indicates a good fit between predicted and estimated. Figures 4-8 present the *THR* corresponding to the measurement. Prediction results are obtained by using ITU-R Recommendation P-1546 with R=20 or R=30.

The statistical analysis summary in the Table 1 shows how the difference in the application of different R affects the final prediction. Difference of mean error, standard deviation, maximum error, correlation coefficient and AHRE are about 4dB, 0.05dB, 13dB, 0.04 and 0.3%.

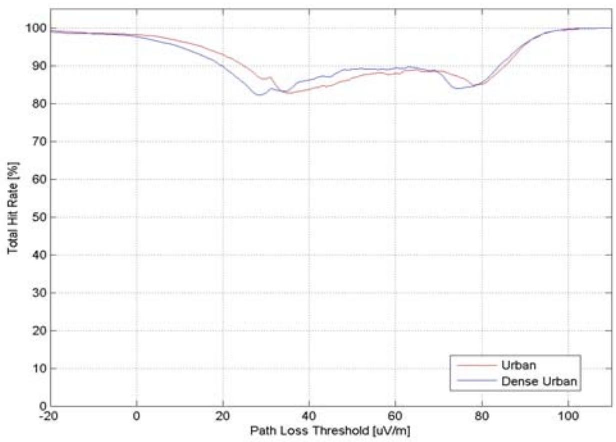

Figure 4. Total hit rate for total areas

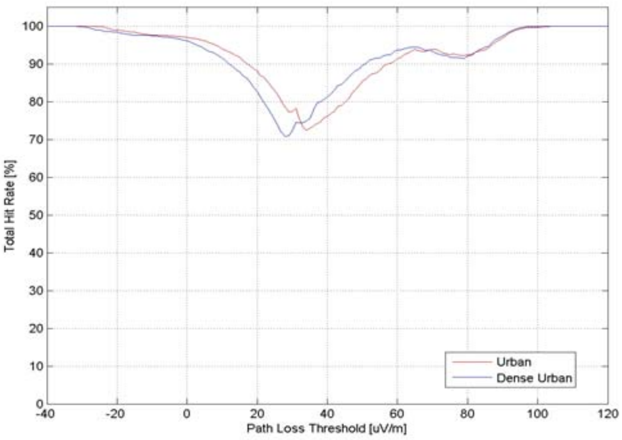

Figure 5. Total hit rate for Pusan

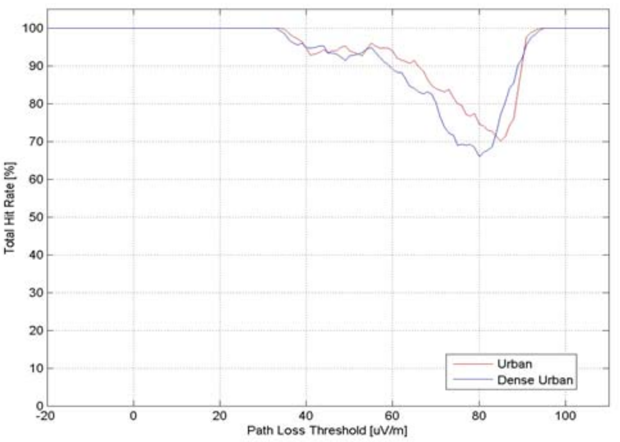

Figure 6. Total hit rate for Daegu

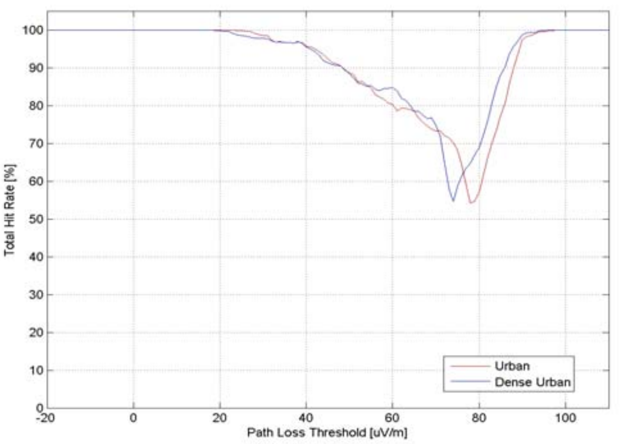

Figure 7. Total hit rate for Daejeon

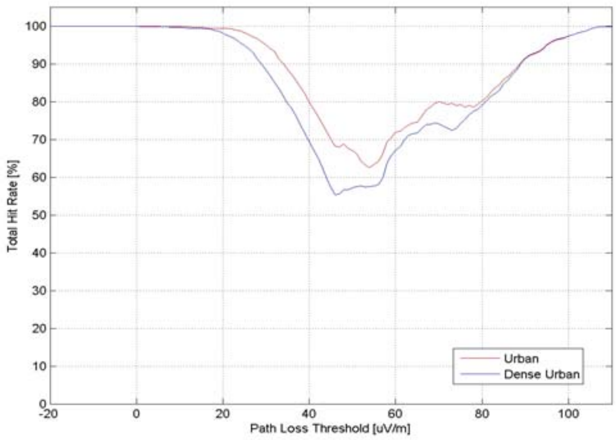

Figure 8. Total hit rate for Kwangju

Table 1. Statistical analysis summary

Measurement		N_s	e	σ_e	e_p	e_n	r_e	*AHRE*
Total	*R*=20	6453	-0.45	13.09	55.01	-34.02	0.824	7.59
	R=30	6453	4.47	13.04	21.17	-21.83	0.828	7.89
Pu san	*R*=20	3781	-0.11	14.77	55.01	-27.17	0.775	8.50
	R=30	3781	5.14	14.74	60.16	-21.83	0.774	8.68
Dae gu	*R*=20	466	-2.58	8.44	13.42	-22.25	0.835	5.26
	R=30	466	2.8	10.22	23.45	-34.02	0.765	6.36
Dae jeon	*R*=20	1440	0.45	8.34	16.75	-17.87	0.87	6.03
	R=30	1440	5.8	8.35	22.04	-12.43	0.869	5.75
Kwang Ju	*R*=20	769	-5.76	11.69	15.69	-31.82	0.648	8.13
	R=30	769	-0.3	11.62	21.17	-26.29	0.651	7.44

4. CONCULSION AND FUTURE WORK

This paper shows that ITU-R Recommendation P.1546 prediction can be changed as the surrounding ground cover *R* which is the site specific value. To predict exact the field strength using ITU-R Recommendation P.1546, the exact *R* value should be determined. To develop reliable prediction model, more consideration should be taken about the determination of correction with regard to *R*. The application of variable *R* in an urban environment can enhance the accuracy of the prediction. Though measurements are performed in same area and each antenna height is same, the application of *R* should be different. In conclusion, *R* value in LOS environment must be smaller than that in nLOS environment. To develop reliable correction model with regard to R, more analysis about the ground cover surrounding the receiving antenna should be achieved using the diffraction model and additionally a lot of measurement data may be obtained in different type of environment.

ACKNOWLEDGMENT

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