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# Propagation Path-Loss Model for TV White Space of Korea

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***Abstract***

*With the recent development of the 4th Industrial Revolution, efforts have been made to carry out communication in a smart factory, farm, etc. at low cost and reliably. Methods for utilizing empty frequencies using TVWS(TV White Space) have been studied which can be used locally within 30 km. However, there have not been many studies on Path-Loss model considering Korean environment. In this paper, the Path-Loss model is divided into LOS (Line Of Sight) and NLOS (None LOS). In case of LOS model, we checked the difference between Free space model, Friis model, 2-ray model and Hata model with measured data. In the case of NLOS model, we checked the difference between Lee Model, ITU-R526-3 Model with measured data. In order to overcome the difference in Korean environment, we derived a model that can be applied in LOS and NLOS and prove its usefulness through performance evaluation through simulation.*

***Keywords:*** *TVWS, White Space, Propagation, Path-Loss Model*

## 1. Introduction

The video stream is transmitted from the transmitting station located at a high place, and can be decoded and watched on a TV if the signal strength is maintained. There is a TV broadcasting station in each area so that the TV can be watched in all areas. If the same frequency is broadcasted from neighboring broadcasting stations, the same frequency acts as noise in the TV, so it cannot perform video decoding properly. In order to prevent this, the signals of the same frequency should be arranged so as not to be used in adjacent areas. Therefore, unused frequency bands occur in each region, which is called TV white Space (TVWS). Discussions on the use of idle TVWS continued, and in 2016, it was decided by the frequency reviewer to make the frequency available to the public [1]. It is expected that the DTV band 470 ~ 698 MHz TVWS will be used for smart farm, smart factory, remote meter reading and remote monitoring.

In order to conduct long distance communication in the suburbs, an analysis of the communication environment has to be carried out, and even the propagation path loss model, which has been proven, may show different characteristics when applied in a specific area [2]. Therefore, in order to use DTV TVWS in Korean environment, we have to study propagation path loss model that fits Korean terrain. In this paper, the approach is divided into LOS (Line Of Sight) and NLOS (None Line Of Sight) environments. First, in Chapter

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2, Free Space, Friis, 2-ray, and Hata models will be applied to compare with the actual measurements and will check the difference, and the optimal model for Korean environment will be presented. In Chapter 3, Lee, ITU-R 526-3 model will be applied in the NLOS environment to check the difference compared with the actual measured values, and the optimal model for the Korean environment will be proposed. In Chapter 4, the simulations will be presented using the proposed model to show that they are similar to the actual measurements and we will conclude in Chapter 5.

## 2. Line of Sight Models

Free Space, Friis, 2-ray, and Hata models will be applied to compare with the actual measurements and their mathematical formula were as follows.

### 2.1 Free Space Model

In the free space model, the power received by the antenna is defined as $P_r$ [3].

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} \tag{1}$$

$P_t$ : transmitter antenna, λ : wavelength, $L$ : system loss factor
$G_t$ : power gain of transmitter antenna, $G_r$ : power gain of receiver antenna,
$d$ : distance between transmit and receive antennas

### 2.2 Friis Model

When a radio wave is transmitted in free space, it is modeled based on the power of the radio wave. The meaning of the abbreviations are the same as in 2.1 [3].

$$P_r = \left(\frac{\lambda}{\pi d}\right)^2 \times G_t \times G_r \times P_t \tag{2}$$

### 2.3 2-ray Model

The 2-ray ground reflection model considers the ground reflected wave component in addition to the direct wave and is well applied for mobile wireless communication systems at a distance of at least several kilometers. In particular, it has characteristics suitable for estimating electric field strength of large-scale signals.

$$P_r = \left(\frac{h_t^2 h_r^2}{d^4}\right) \times G_t \times G_r \times P_t \tag{3}$$

$$PL(dB) = 40 \log d - (10 \log G_t + 10 \log G_r + 20 \log h_t + 10 \log h_r) \tag{4}$$

When ht and $h_r$ are the height of transmitter and receiver, the power received by the antenna is defined as $P_r$ of equation (3). Considering the antenna gain, the path loss (*PL*) in the 2-ray model is expressed as equation (4) [4].

### 2.4 Hata Model

The Hata model provided the urban area propagation path loss standardization model based on the empirical formulation of the graphic path loss data provided by Okumura, and has the advantage of being applicable in other environments .

$$L_{path} = 69.55 + 26.16\,log\,f_c - 13.82 log h_b - (44.9 - 6.55\,log\,h_b)\,log\,d + a(h_m) \tag{5}$$

Path loss $L_{path}$ is defined as equation (5) where $h_b$ and $h_m$ are the heights of the transmitter and receiver, respectively, and $f$ is the frequency [5].

### 2.5 Proposed Model

The proposed model is based on the 2-ray ground reflection model. The reason is that the 2-ray model is well applied to the mobile wireless communication system at the distance of at least several km considering the reflection component of the ground as well as the direct wave. But this model may have gap compared with measurement data depending on the measurement position.

$$PL[dB] = 40(log\,d\,[km]) - \{10\,log(G_t) + log(G_r) + 20\,log(h_t + 20\,log\,h_r)\} + a(k) \tag{6}$$

To compensate for this, the criteria used to classify LOS areas are divided into sub-centers, urban centers, and metropolitan areas, and various transmission loss factors are added to fit the characteristics of each zone like Hata model. $\alpha(k)$ has 22.17 *dB*, 37.32 *dB* and 55.58 *dB* for sub-center, downtown and metropolis, respectively [6] .

## 3. None Line of Sight Models

The NLOS propagation model was proposed by analyzing the measured values of the TVWS region and diffraction models such as Lee model and ITU-R 526.3 model.

### 3.1 Lee Model

Diffraction loss is divided into single diffraction and multiple diffraction depending on the number of obstacles. In single diffraction, there is an obstacle between the transceivers, so that radio waves are not directly transmitted, but are diffracted and transmitted.

$$v = -h_p\sqrt{\frac{2}{\lambda}\left(\frac{1}{r_1} + \frac{1}{r_2}\right)} \tag{7}$$

$$\begin{aligned}
&G_d(dB) = 0 && v \le -1\\
&G_d(dB) = 20\,log(0.5 - 0.62v) && -1 \le v \le 0\\
&G_d(dB) = 20\,log(0.5e^{-0.95v}) && 0 \le v \le 1\\
&G_d(dB) = 20\,log\left(0.4 - \sqrt{0.1184 - (0.38 - 0.1v)^2}\right) && 1 \le v \le 2.4\\
&G_d(dB) = 20\,log(0.025/v) && 2.4 \le v
\end{aligned}$$

When the height of the mountain is $h_p$ and the distances from the top to the transmitter and receiver are $r_1$ and $r_2$ [7][8] , respectively, the loss factor $v$ is calculated and then the attenuation coefficient $G_d(dB)$ is calculated according to the range [4].

### 3.2 ITU-R 526-3 Model

Where $h$ is the height of the obstacle above the imaginary line connecting the transmitting and receiving antennas, $d_1$ is the distance from the transmitting antenna to the obstacle, and $d_2$ is the distance from the obstacle to the receiving antenna, the diffraction loss is expressed as equation (8) [9].

$$= h\sqrt{\frac{2}{\lambda}\left(\frac{1}{d_1}+\frac{1}{d_2}\right)} \quad (8)$$

The diffraction loss *J (v)* caused by a single edge obstacle is summarized as equation (9).

$$J(v) = 6.9 + log(\sqrt{(v-0.1)^2+1} + v - 0.1) \quad (9)$$

In the case of two edges, the diffraction loss can be expressed as the loss $L_1$ occurring at each edge and the loss $L_2$ between the edges. $L_c$ corresponds to the correction term. *a* is the distance from the transmitter to the first edge, *b* is between the first and second edges, and *c* is the distance between the second edge and the receiver.

$$L = L_1 + L_2 + L_c \qquad L_C = 10\,log[\frac{(a+b)(b+c)}{b(a+b+c)}] \quad (10)$$

### 3.3 Proposed Model

The diffraction model is proposed by changing the distance factor in Lee model. In order to reflect the characteristics that the location of the domestic transmitting antenna has a considerably high altitude unlike the existing models, a line connecting the transmitting antenna and the receiving antenna in a straight line with each other is set to $d_1$ and $d_2$. And h corresponding to the height of the obstacle is set in the vertical direction at the boundary of $d_1$ and $d_2$. That is, in the proposed method, the equation of the propagation prediction model is applied to the Lee model as it is, but the method of extracting the distance and antenna factors, which are input elements, is applied differently.

The distance $d_1$ between the transmitting point and the obstacle, the distance $d_2$ between the obstacle and the receiving point, and the height *h* of the obstacle are as follows [6].

$$\begin{aligned} h &= \sqrt{(a_4-a_2)^2+(b_4-b_2)^2} \\ d_1 &= \sqrt{(a_4-a_1)^2+(b_4-b_1)^2} \\ d_2 &= \sqrt{(a_4-a_3)^2+(b_4-b_3)^2} \end{aligned} \quad (11)$$

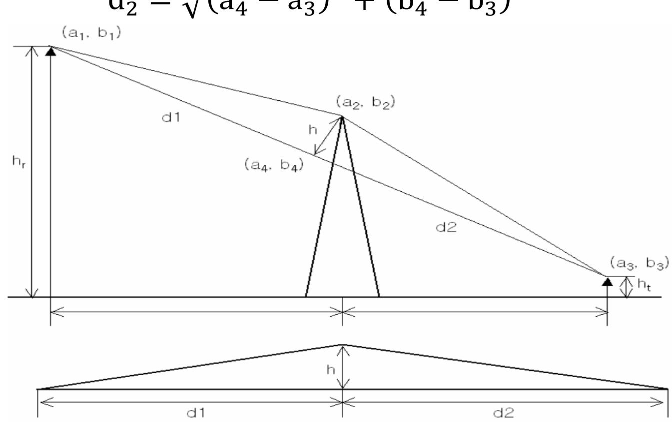


**Figure 1. Distance factor and height between changed transmission point and receiving point obstacle**

## 4. Simulation of Proposed Model

In order to prove the performance of the model proposed in section 3, the existing model and the proposed model were compared and analyzed with the LOS and NLOS. Measured data was taken from KBS's terrestrial DTV data [10].

### 4.1 Line of Sight Models

Figure 2 shows the comparison of the measured data and the LOS model of the DTV band in the Seoul metropolitan area. The free space and friis models rose linearly and slowly, while the 2 Ray and Hata models showed significant differences from the measured data, although their values varied. The proposed model was most similar to the measured value. The standard deviations of the measured data were 12.31, 23.16, 35.66, 20.71, and 4.51 for free space, 2-ray, Hata, and proposed models, respectively.

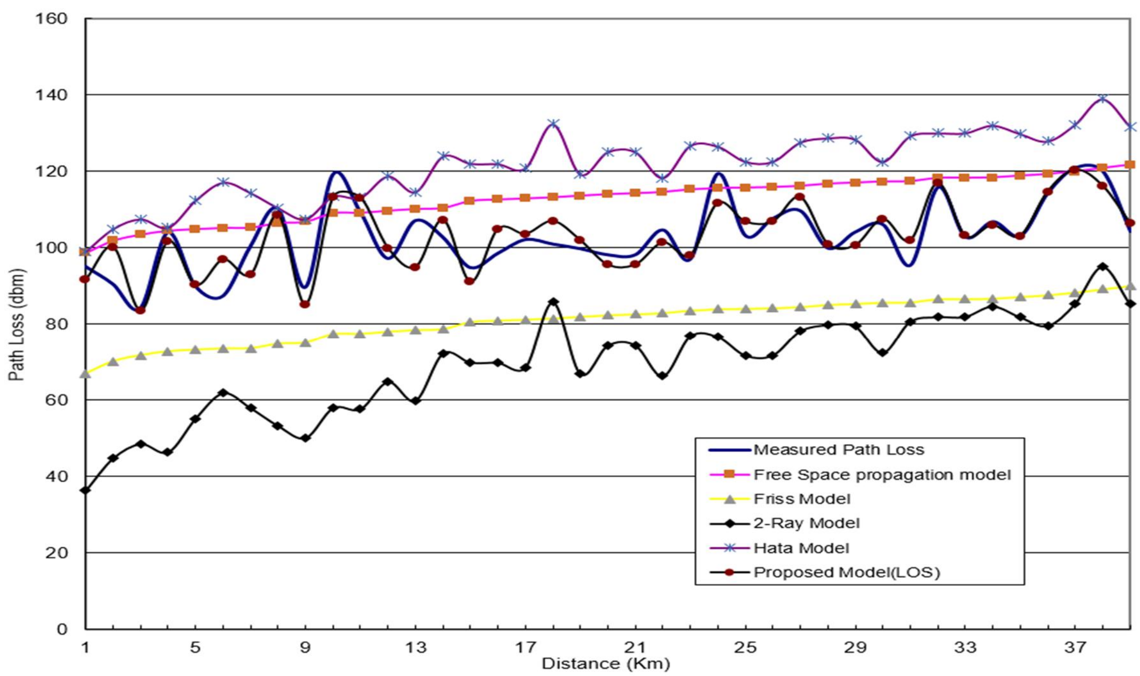


**Figure 2. Path-loss model and measurement value under LOS condition**

### 4.2 None Line of Sight Models

Figure 3 compares the measured data of the Korean metropolitan area's DTV band and the NLOS model. Lee, ITU-R 526-3, and the proposed model showed similar patterns with the measured data, but the proposed model was the most similar to the measured data. The standard deviations from the measured data were Lee, ITU-R 526-3, and the proposed models were 9.79, 9.34, and 7.92, respectively.

## 5. Conclusion

In this paper, we compared the actual results with the existing radio model using the results of DTV Field Test of Korea Broadcasting Corporation. It is confirmed that the existing radio wave prediction model has a limitation in applying to domestic TVWS band channel. And we proposed channel model of DTV TVWS band based on actual measurement data. This channel model is divided into LOS and Non-LOS areas. The LOS area was divided into for sub-center, downtown and metropolis in consideration of the surrounding environment characteristics. Non-LOS area was divided into single diffraction loss and multiple diffraction loss area.

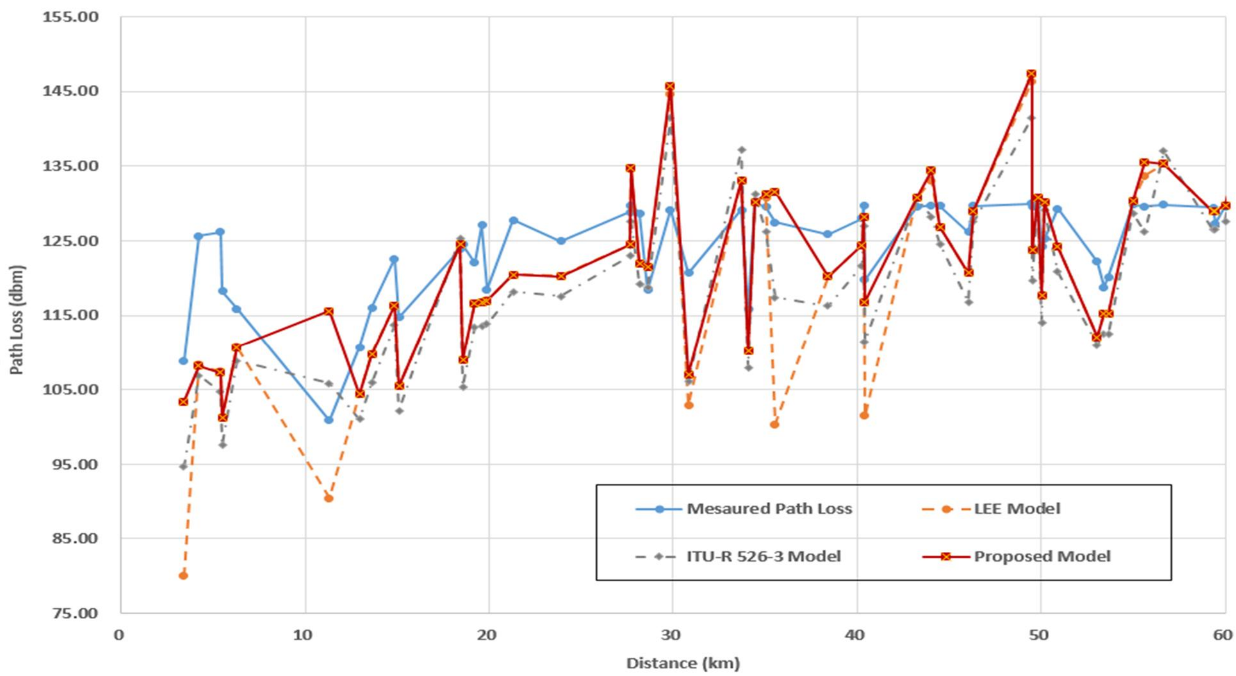


**Figure 3. Path-loss model and measurement value under NLOS condition**

By comparing the standard deviation, we verified that the proposed channel model of the DTV TVWS band is superior to the existing models. In addition, the proposed model can be used to predict the received field strength and provide directions for improving the reception performance.

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