Characteristics of Slant Path Loss according to Frequency and Elevation Angle by Clutters

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***Abstract*— In this paper, we analyzed the existing ITU-R slant path model and the extended WB model to predict additional loss due to clutter in the Korean urban environment, and introduced an developed empirical clutter loss prediction model based on measurement data. The measurement in the actual urban was carried out by carefully selecting among the candidate sites that can be measured in consideration of the slant path link among residential and commercial areas. Based on the clutter loss measurement results, the calculation results of the existing model were compared and analyzed. In general, the higher the frequency and the lower the angle of elevation, the higher the clutter loss. However, it was confirmed that the clutter loss value of the existing model is underestimated. In conclusion, the development of a highly advanced empirical model is required, and there is a need to improve the current model by considering the diversity of measurements and urban and suburban environments.**

***Keywords*— loss, clutter, empirical, deterministic, slant path**

I. Introduction

Above 10 GHz and mm-Wave bands have shorter wavelengths in the higher frequency bands, so terrestrial communication links in urban and suburban environments may be sensitive to communication quality due to obstructions such as buildings and street trees[1]-[2]. Therefore, research on clutter-based propagation characteristics is expected to be more important [3]-[5]. Let me introduce the existing basic transmission loss model. First, the ITU-R Study Group 3 (SG3) is currently developing a practical clutter loss model applicable to spectrum sharing between mobile and satellite service providers. The ITU-R model considered in this paper is an earth-space slant path model, even though it is limited to bands above 10GHz bands[6]-[7]. The ITU-R model has statistical properties that estimate the cumulative distribution of the calculated clutter loss values for each angle of elevation in the range of 0 to 90 degrees, locational variability due to shadow effects from building layout, and frequency effects. The second is the modified Walfisch-Bertoni model (EW-B), which extends the existing Walfisch-Bertoni model to the millimeter wave band[8]. This model adds the physical phenomena of rooftop path, slant path, and multipath among buildings to the existing W-B model. And, the COST 231 Walfisch-Ikegami (W-I) model was created based on the Walfisch-Bertoni model and is a physical propagation model that occurs in an urban environment using rooftop diffraction loss.

In this paper, the clutter loss measurement results were compared and analyzed with the existing slant path models. I would like to present the effect of suburban clutter characteristics according to frequency and elevation angle.

II. Geometric Clutter Loss

A. Geometric depiction by clutter effect

Clutter refers to obstacles such as buildings or vegetation on the ground. Clutter loss, which is depicted by subtracting the free space propagation loss in the total losses, is defined as additional loss in the slant path by obstacles around one or both ends of a radio link. Figure 1 shows the clutter-based multipath phenomenon and the beam tilt (elevation) angle (θ) in bore-sight direction. Here, the receiver (Rx) should be positioned inside the main vertical beam of the transmitter (Tx). The elevation angle of the slant path link depends on the height of the clutter (building) in front of the Rx and calculates from the geometric parameters. They include the transmit antenna height (h_{Tx}) and clutter height, and the two-dimensional (2D) horizontal distance between the Tx and the Rx antenna. The clutter-based multipath phenomena caused by diffracted and reflected waves from irregular rooftops of clutter. Transmitting waves pass through the clutter (red rectangular) or collide with other buildings (blue rectangular) in the background, as indicated by the black dotted lines in Fig.1.

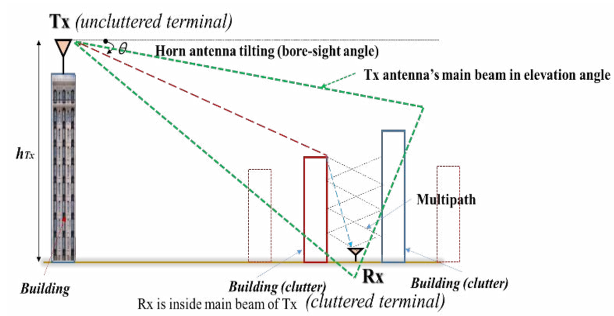

Fig. 1. A geometric depiction by the multipath clutter effect

III. Measurement

Measurement was performed in order to research the clutter (building only) effect for the 2.19 to 33.2 GHz frequency band in Cheong-ju city, which has suburban characteristics with residential and commercial buildings.

Fig. 2. Measurment area (environment) wtth residential and commercail buildings

Figure 2 shows the measurement area in a multi-clutter environment, including buildings and street trees. In addition to direct and diffraction signals, complex multipath signals (reflected and diffracted multipath signals by buildings, scattered signals by trees) may be transmitted or received by the receiving terminal (Rx).

A. Measurement equipment

Figures 3 and 4 show the configuration and actual fabrication of Tx and Rx, which are measurement equipment. The Tx antenna and power amplifier (PA) are attached to the inside or outside of the black box, and are connected to the 3-axis rotor to enable horizontal rotation and vertical tilting. The rotor is mounted on a tripod that can be adjusted up to 2m in height and installed on the roof of a building. The head of the Tx antenna faces the cluttered measurement area of a 3- to 5-story building.

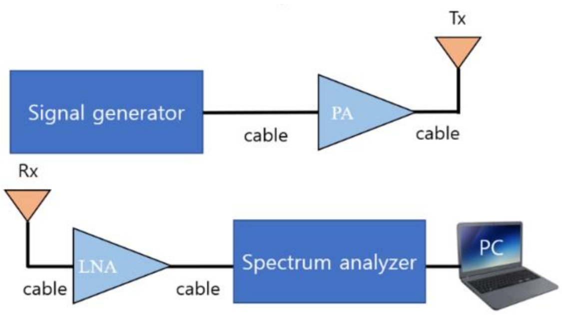

Fig. 3. Configuration of Tx and Rx as measurement equipment

The Tx consists of a signal generator (E8257D) placed next to a fixed tripod, a PA and a horn antenna with a typical gain of 13-18dBi. The Rx consists of a spectrum analyzer (N9030A), a wideband low-noise amplifier (LNA with a noise figure of typical 4 to 6 dB), a typical 1.8 to 3 dBi omnidirectional antenna (bi-conical or dipole type), and the Rx control and measurement data monitoring computer (notebook PC). In addition, a movable cart was separately manufactured to move along the measurement path, and a linear motion guide was assembled and installed for spatial average measurement. Each module is connected with a microwave cable and adapter (operating frequency of 0.01 to 40 GHz).

Fig. 4. Fabrication of the installed Tx (left) and Rx (Right)

B. Measurement campaign

Figure 5 shows four measurement paths (paths 1, 2, 3, and 4) as seen on a satellite map. A Tx point with a directional antenna transmits a continuous wave (CW) signal. Each measurement path includes parked cars, street trees, and various street structures on the road around the building. Measurement areas containing irregular height building clutter must be carefully selected. The 40 measuring points on each path must be located within the main beam on the horizontal and vertical plane of Tx antenna from which the signal is generated. This is because the antenna's main beam width differs depending on the wavelength in the 2.19 to 33.2 GHz frequency range, and the measurement point may deviate from the actual Tx beam width depending on the elevation angle (θ) range of 9 to 39 degrees in the tilt direction. The closer the Rx to the transmitting directional antenna, the larger is the down-tilting angle. The longer the distance, the smaller is the down-tilting angle.

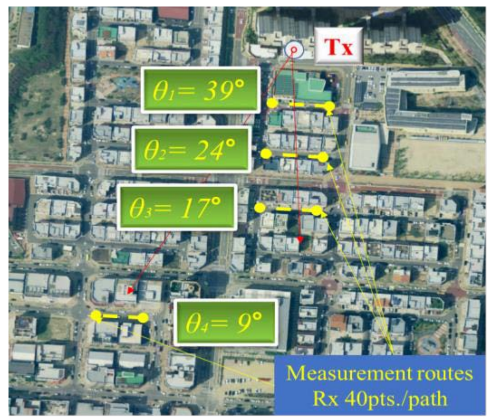

Fig. 5. Measurment area (environment) wtth residential and commercail buildings on a satellite map

The Tx is installed on the roof of a building away from each measurement area. The Rx height is the same 1.8m from the ground. During measurement, Rx is moved over 20 wavelength intervals for each measurement point (number of samples) in each measurement path. Measurement data for each measurement path were collected 36 times at each measurement point for local averaging in order to remove the fast fading effect. The signal-to-noise ratio (S/N) for collecting valid measurement data is defined as a delta from the maximum of the noise level of 15 dB or greater. The dynamic fundamental transmission loss range of the measurement is at least about 145 dB and higher. Table I provides a summary of the measurement campaign.

TABLE I. SUMMARY OF MEASUREMENT PARAMETERS

Parameter	Value
Environment	Suburban
Frequency	2.19, 4.99, 10.03, 33.2GHz
Transmit antenna height	73.6m
Receiving antenna height	1.8m
Elevation angle	9-39degrees
Clutter height	9-23m
Road width	12-22m
Separated distance in horizontoal	80-340m

IV. ANALYSIS AND EMPIRICAL MODEL

The clutter loss to each measurement point was obtained by subtracting the basic transmission loss depending on the Tx–Rx distance for the theoretical free space (or opened area) from one of the measuring data at individual frequencies.

The basic transmission loss at each frequency was calculated by applying the transmit power, the Tx and Rx system gains based on back to back calibration, the Tx and Rx antenna gains to received power by the Rx.

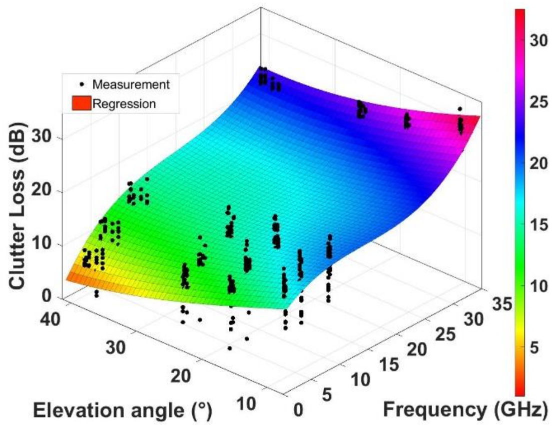

Fig. 6. Clutter loss characteristics according to frequency and elevation angle

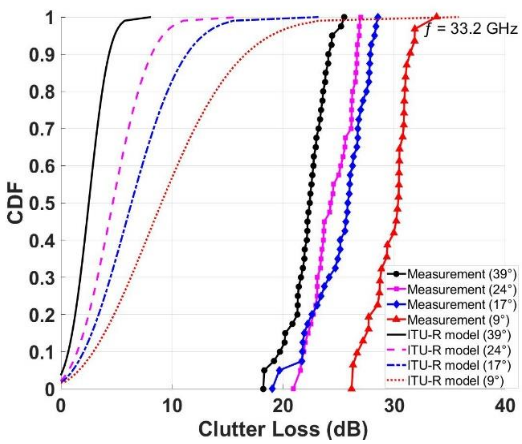

Fig. 7. CDF results of statistical clutter loss according to elevaiton angle at a frequency of 33.2GHz

Figure 6 shows the clutter loss and regression analysis results obtained from measured data as a function of frequency and elevation angle.

As example results at a frequency of 33.2GHz in Figure 7, the CDF trend of statistical clutter loss as a function of elevation angle based on earth-space paths (slant path) is shown. For measurement data, higher elevations tend to result in relatively less loss. However, existing ITU-R model underestimates the clutter-based excess loss values for selected suburban environment. We developed a slant path clutter loss model based on measurements applicable to the 2 to 33 GHz frequency range and 9 to 39 degree elevation range considering typical Korea's suburban environment. Figure 8 shows the results of comparing the existing model ('ITU-R model' and the modified 'EW-B model') with the developed and proposed model ('Proposed'). Considering these results, it is necessary to improve the existing propagation model by considering environmental characteristics according to various clutter types, such as frequency characteristics and clutter height characteristics.

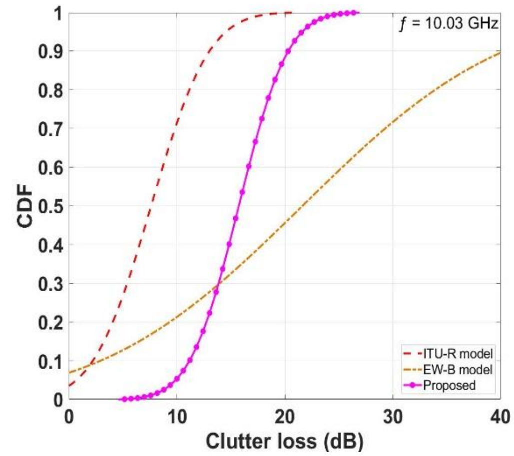

Fig. 8. Comparison between the existing model (ITU-R and modified EW-B model) and the proposed measurement-based model.

V. Conclusions

In this paper, the existing clutter loss models, the ITU-R and the modified W-B model, were analyzed and their limitations pointed out. The current models are a partial measurement-based or deterministic model using ray tracing simulation mechanism. Therefore, environmental features may not be accurately reflected. These limitations can be improved by taking into account the diversity of measurements and urban and suburban environments.

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