Radio Propagation Characteristics in the Large City

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Abstract—**This paper describes various radio propagation characteristics in the large city such as Seoul in Republic of Korea and talks on the closed form of a received interfering signal intensity to a victim system for the coexistence with two different systems. Actually, it is difficult to how to choose the optimum radio propagation model for predicting on the interference impact because of various environment conditions or system limits, even if the theoretic radio propagation models are known for various services. Specially, it is not known for the available median path loss model in order to calculate the interfering signal intensity to a victim system between the fixed communication link and mobile communication system for none line of site environment. Therefore, we measured the radio propagation characteristics in the large city and discussed with the adequate median path loss and shadowing characteristics in this paper**

***Keywords*— radio, propagation, path loss, measurement, FM**

I. INTRODUCTION

Long term evolution (LTE) to be enable operators to better and more cost effectively transport the rapidly growing volume of mobile data traffic has been developing. Also, the fixed microwave link system is required to transport the audio or video broadcasting data. FM broadcasting repeater is a sort of a microwave link system. In terms of the spectrum at 1.7GHz bands, LTE and FM broadcasting repeater's carrier frequency channels are in the adjacent bands each other in Korea. Therefore, we might predict the potential interference impacts in the coexistence cases. We should choose the radio propagation model in the various environments like urban, suburban, and open area.

Generally, the extended Hata model is used to none line of sight as well as line of sight. And, free space model, of which ITU-R P.525, is applied for line of sight between a transmitter and a receiver on the communication system [1]. Also, this median path loss model and shadowing with log-normal distribution can calculate the cell coverage corresponding to the sensitivity level of a receiver. It is very useful of predicting the channel characteristic without the complex measurement procedure. Currently, the choice of the median path loss model to calculate the link loss is so simple. For example, operators choose the extended Hata model for predicting the site coverage in the macro cell or TV broadcasters does the ITU-R P.1546 model with time varying and spatial rates [2]. However, this choice may be happened the large error and inaccuracy for the interfering link calculation between two different services in the large city (e.g. Fixed link and mobile communication link). Because one mobile communication system use the urban case of extend Hata model, in the other hands, other fixed microwave system may use the free space model or ITU-R P. 1546 model due to different environment conditions or system limits like antenna height.

In this paper, we try to solve this analysis problem of different two systems with different median path loss model. Therefore, we measured the radio propagation characteristics at the 1.7GHz bands and calculated the received signal strength in the adjacent channel to predict the impact on LTE system from FM broadcasting repeater interference in the large city.

Finally, we found to use the median path loss corresponding to various environments in the large city. Measurement results are good mapping with the simulation results with different path loss model, respectively.

II. SYSTEM PARAMETERS

Let me show the considered fixed services. They are a sort of FM broadcasting repeater system such as microwave link at 1.7GHz operation bands. But, FM broadcasting repeater is different from the microwave link in terms of the location of site, except for a fixed service. FM broadcasting repeater's transmitter is the top of building in the city, but, the microwave link's one is on the top of mountain.

In this paper, two fixed services operating at 1.7GHz bands in Korea are described. One is the fixed FM broadcasting repeater running by Far East Broadcasting Company (FEBC) system and the other is a system by Seoul Broadcasting Station (SBS) system. Fixed broadcasting repeater system consists of a kind of a studio-transmitter link (STL) system [3]-[5]. A STL sends a radio station's or television station's audio and video from the broadcast studio to a radio transmitter or television transmitter in another location. This is often necessary because the best locations for an antenna are on top of a mountain, where a much shorter tower is required, but where a studio is completely impractical. Even in flat regions, the center of the station's allowed coverage area may not be near the studio location or within a populated area where a transmitter would be frowned upon by the community, so the antenna must be placed several kilometres away. Depending on the locations that must be connected, a station may choose either a point to point (PTP) link on another special radio frequency, or a newer all-digital wired link via a dedicated T1 or E1 (or larger-capacity) line. Radio links can also be digital, or the older analogue type, or a hybrid of the two. Even on older all-analogue systems, multiple audio and data channels can be sent using subcarriers. Stations that employ an STL usually also have a transmitter-studio link (or TSL) to return telemetry information. Both the STL and TSL are considered broadcast auxiliary services (BAS).

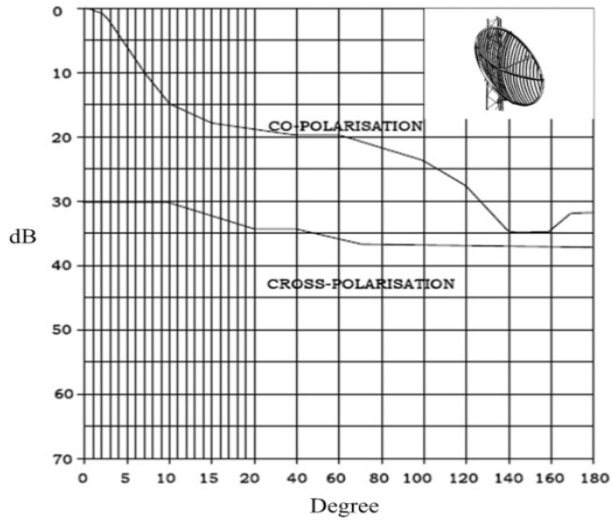

Figure 1. FM broadcasting repeater's antenna elevation pattern (e.g. Grid parabola)

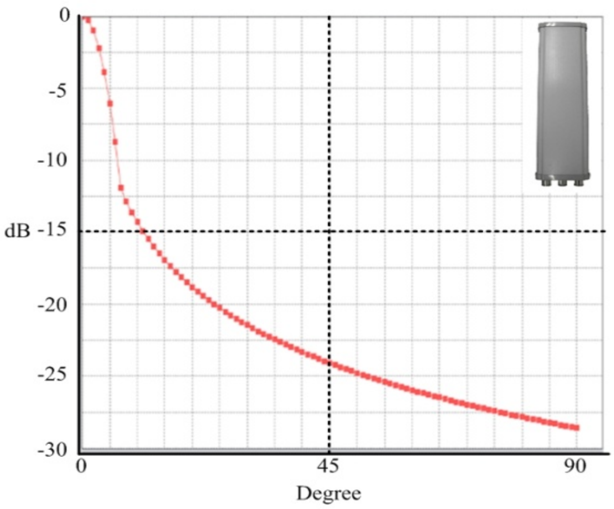

Figure 2. LTE base station's antenna elevation pattern (e.g. Linear)

FEBC's station consists of a kind of analogue STL system of TFT8300 [4]. It has a transmit power of 5.0Watts and the channel bandwidth of 230 kHz. Antenna type operating at 1.7GHz bands is the grid parabola and has the gain of 26dBi including 2dB feeder loss with 6.5degree elevation beamwidth shown in Figure 1. The antenna height of a transmit station is about 35m. The antenna height of a receiving station is about 625m in Gwanaksan Mt. SBS's station consists of a kind of digital STL system of SL9003Q [5]. It has a transmit power of 1.0Watts and the channel bandwidth of 230 kHz. Antenna type operating at 1.7GHz bands is the grid parabola and has the gain of 26dBi including 2dB feeder loss with 6.5degree elevation beamwidth shown in Figure 1. The antenna height of a transmit station is about 70m. The antenna height of a receiving station is about 625m in Gwanaksan Mt.

The LTE specification provides downlink peak rates of 100 Mbit/s, uplink peak rates of 50 Mbit/s and QoS provisions permitting a transfer latency of less than 5 ms in the radio access network. LTE has the ability to manage fast-moving mobiles and supports multi-cast and broadcast streams. LTE supports scalable carrier channel bandwidths, from 1.4 MHz to 20 MHz and supports both frequency division duplexing (FDD) [6]. In this paper, LTE is considered for supporting carrier channel bandwidths of 5MHz and is assumed that LTE is reverse link in FDD at adjacent channel of FM broadcasting repeater bands at 1.7GHz. Its antenna type operating at 1.7GHz bands is the linear x-pol antenna and has the gain of 15dBi including 3dB feeder loss with 7.0degree elevation beamwidth shown in Figure 2. The height of a receive antenna is about 10m. An antenna beam's down tilt angle is -3 degree.

III. Measurements

A. Measurement Paths

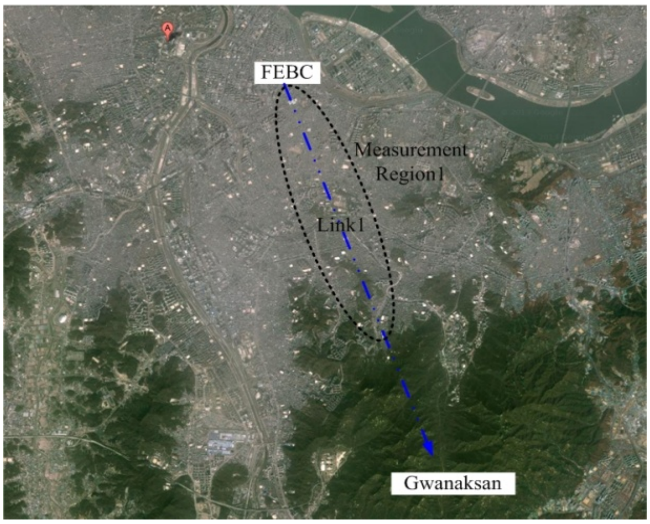

Figure 3. Measurement route (e.g. FEBC to Gwanaksan Mt.)

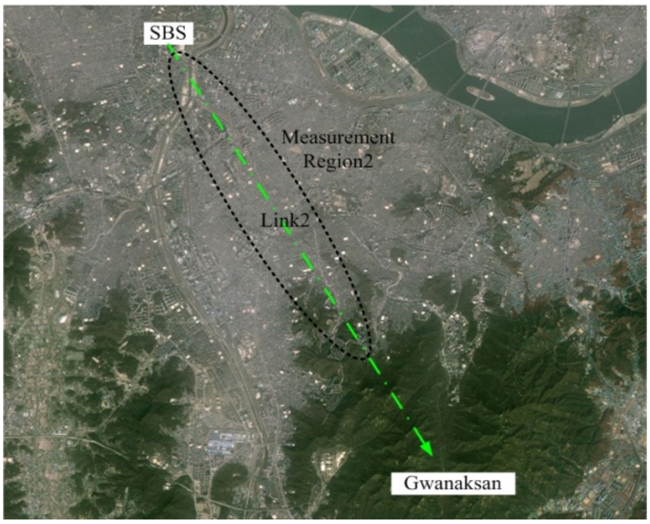

Figure 4. Measurement route (e.g. SBS to Gwanaksan Mt.)

Figure 3 and Figure 4 show each measurement path from the broadcasting station to the front of Gwanaksan Mt.

Link 1 in the Figure 3 means the measurement path from the FEBC broadcasting station to FEBC repeater in Gwanaksan Mt. Link1 distance between a broadcasting station and a receiving antenna of FEBC site on the Gwanaksan Mt. is about 10 km. Link 2 in the Figure 4 means the measurement path from the SBS broadcasting station to SBS repeater in Gwanaksan Mt. Link2 distance between a broadcasting station and a receiving antenna of SBS site on the Gwanaksan Mt. is about 12.4 km.

B. Measurement Environment

Figure 5 shows the measurement method in order to measure the radio propagation characteristic such as median path loss and shadowing. Measurement was performed on the road with a moving vehicular in the large city with huge or small buildings. Vehicular moves from a FM broadcasting station (Transmitter) to the front of Gwanaksan Mt. Here, the transmit antenna height of FM broadcasting station is H_1 and the receiving antenna height of FM broadcasting repeater on the top of Gwanaksan Mt. is H_2. The receiving antenna height of measurement vehicular is h_v. The antenna height H_1 of FEBC or SBS station is 35m or 70m, respectively. The antenna height H_2 of FM broadcasting repeater on the top of Gwanaksan Mt. is 625m. The antenna height h_v of a vehicular is 2.5m.

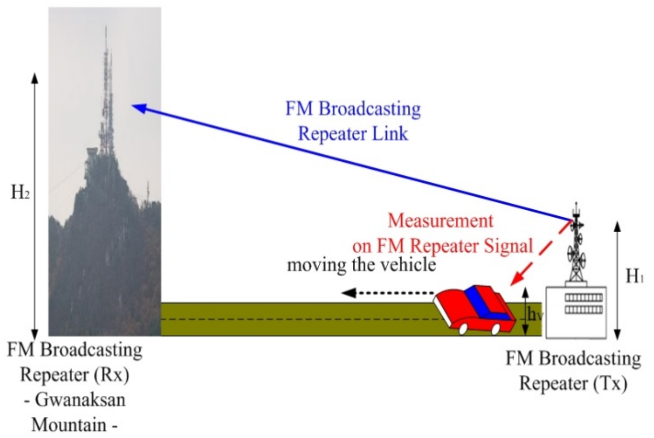

Figure 5. Measurement method

IV. Results & Analysis

A. Theoretic Median Path loss Models

For comparing the measurement results and theoretic analysis, we looked for candidate median path loss model. [1]

For line of sight in the large city, we used the free space model

$$PL_{FSL}(dB) = 32.44 + 10\log\left\{\left(\frac{H_1-h_v}{1000}\right)^2 + d^2\right\} + 20\log(f)$$

This model describes the theoretical minimum propagation path loss achievable in free space conditions. It is appropriate to use on paths were unobstructed direct line of sight propagation could be expected. They are example for point to point fixed service links such as FM broadcasting microwave link or links over short distance in open area, and so on.

For non-line of sight of urban, suburban, and rural communication link applications at 1.7GHz operation bands, we used the extended Hata model, which was developed and found by a European study committee (COST231). The basic formula for the median propagation loss in dB given by the extended Hata propagation loss model is as follows: The available range of parameters for which this model is considered, are valid to the operating frequency of less than 3GHz and the receive antenna height of 1 to 10m.

In case of urban environment,

$$PL_{Urban}(dB) = 46.3 + 33.9\log(f) - 13.82\log(\max\{30, H_1\}) + [44.9 - 6.55\log(\max\{30, H_1\})]\log(d) - a(h_v) - b(H_1)$$

In case of suburban environment,

$$PL_{Suburban}(dB) = PL_{Urban} - 2\{\log[(\min\{\max\{150, f\}, 2000\})/28]\}^2 - 5.4$$

In case of rural environment,

$$PL_{Rural}(dB) = PL_{Urban} - 4.78\{\log[\min\{\max\{150, f\}, 2000\}]\}^2 + 18.33\log[\min\{\max\{150, f\}, 2000\}] - 40.94$$

where,

$$a(h_v) = (1.1\log(f) - 0.7)\min\{10, h_v\} - (1.56\log(f) - 0.8) + \max\left\{0, 20\log\left(\frac{h_v}{10}\right)\right\}$$

$$b(H_1) = \min\left\{0, 20\log\left(\frac{H_1}{30}\right)\right\}$$

Long term fading calling for the shadowing has a different standard deviation according to a measurement environments: the standard deviation to both the separation distance range from 0.1km to 0.2km between a transmitter and a receiver and the below roof is 17dB. The standard deviation to the separation distance range from 0.2km to 0.6km is σ = 17-20(d-0.2) dB. And, the standard deviation to the separation distance range larger than 0.6km is 9dB [1].

B. Results Comparison

Figure 6 and Figure 7 show the received signal strength intensity to a meausrement vehicular with both omin direction antenna and its height of 2.5m. As shown in Figure 3 and Figure 4, each measurement path from the broadcasting station to the front of Gwanaksan Mt. is different. Of course, it is sure that RSSI has different value through vehicular moving path. Figure 6 and Figure 7 are median path loss including the shadowing from both measurement and analysis. The fluctation of a shadowing is about 6~10dB in the FEBC shown in Figure 6 to Gwanaksan path and 10~13dB in the SBS shown in Fiugre 7 to Gwanaksan path. This shadowing value is larger approximately 3~4dB than a standard deviatoin of shadowing given by COST231 [1]. Also, the median path loss of the measurement is good mapping with theoretic extended Hata model including the combined urban case and suburban case, except for the measurement point of the near location from FM broadcasting station as a transmitter. Results in Figure 6 and Figure 7 show that the median path loss model could use the urban case of extended Hata model by shorter than about 15km from a FM broadcasting station and could use suburban or open area case of extended Hata model from longer than 15km in case of the receiving antenna heigth of 2.5m in the large city in Korea at 1.7GHz bands.

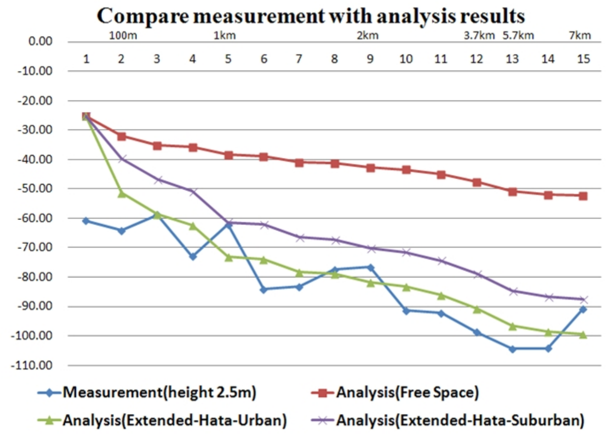

Figure 6. FEBC's RSSI in the large city

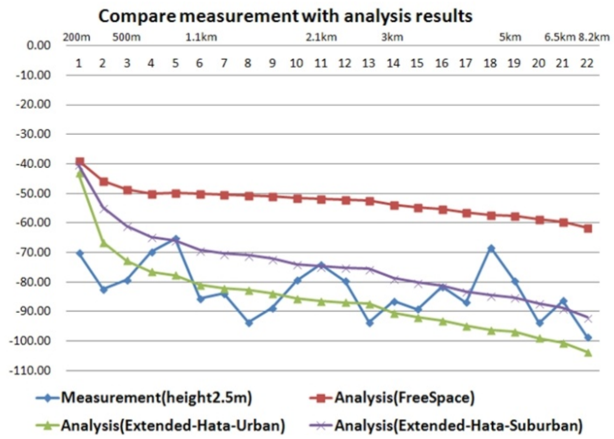

Figure 7. SBS's RSSI in the large city

C. Interference calculation

We found to apply for different median path loss model and realistic shadowing standard deviation in the large city in Korea according to the relative distance between a fixed FM broadcasting station and a mobile communication receiver such as LTE base station. In addition, for predicting on LTE interference impact in the adjacent channel, we used both the RSSI given to the measurement at FM broadcasting repeater's carrier frequency in shown in Figure 6 and Figure 7 and the correction value of the LTE antenna height of 10m instead of the vehicular antenna height of 2.5m. Finally, *RSSI* to LTE base station is derived as follow: Here, *RSSI* means totally received interfering signal strength intensity due to out of band emission of FM broadcasting repeater. FM broadcasting repeater's emission means FM broadcasting repeater's out of band interfering signal transmitting into LTE base station in related with the interfering link as shown in Figure 8. Figure 9 and Figure 10 show FEBC Station's emission and SBS's emission characteristics given to a realistic measurement.

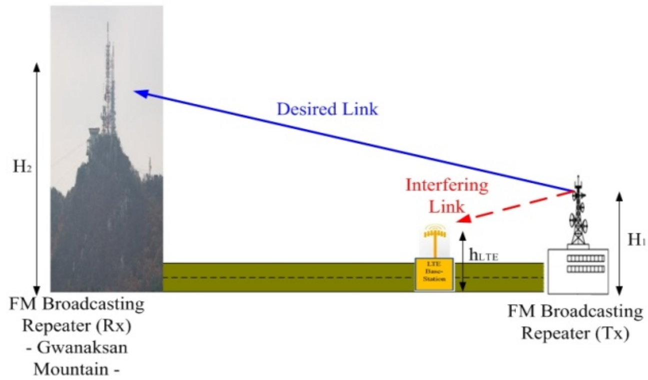

Figure 8. Desired and interfered link

$$RSSI\text{ (dBm)} = I_{\text{ooB},\Delta\text{F}} + G_{\text{Rx}}(H_1, h_{\text{LTE}}, \delta) + \text{a}(h_{\text{LTE}})$$

where, *RSSI* depicts totally received interfering signal strength intensity, $I_{\text{ooB},\Delta\text{F}}$ means a theoretic received interfering signal strength intensity to the LTE base station using out of band emission(ooB) characteristics in shown Figure 9 and Figure 10 to the separation frequency (ΔF) from offset frequency of FM station channel band edge with channel bandwidth of 5MHz derived from the measured FM station's signal intensity. $G_{\text{Rx}}(H_1, h_{\text{LTE}}, \delta)$ depicts the LTE antenna gain considering the direction elevation angle from main lobe to LTE base station. This antenna gain includes the antenna height (H_1) of FM broadcasting station, the antenna height h_{LTE} of LTE base station, and down tilt angle of LTE base station antenna. This down tilt angle is assumed as -3 degree. $\text{a}(h_{\text{LTE}})$ means the correction factor of the antenna height converting the vehicular antenna height of 2.5m to LTE base station antenna height of 10m.

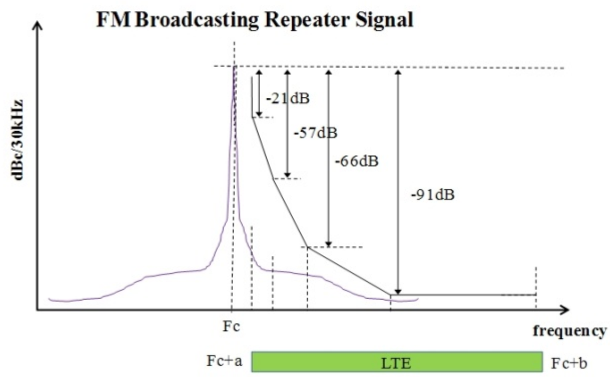

Figure 9. FEBC Station's Emission Characteristics

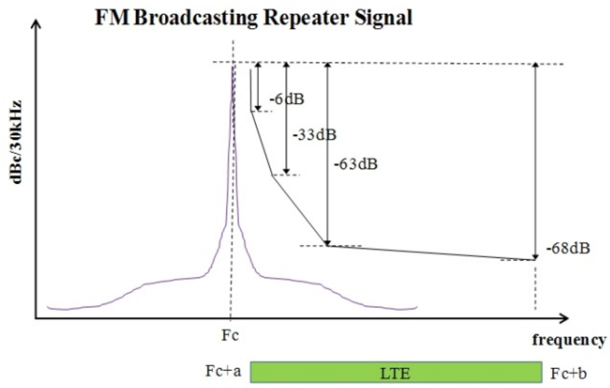

Figure 10. SBS Station's Emission Characteristics

For calculating the interference impact, a permissible interference level of -108dBm/5MHz to LTE base station should be satisfied. This value is derived from the protection ratio of LTE base station to prevent from FM broadcasting repeater's interference. This protection ratio (=I/N) depicts the interfering signal to the noise level of the victim system [7]-[8]. This value of I/N to LTE base station is -6dB. Finally, the separation distance of 2km from FM broadcasting station to LTE base station should be required in order to satisfy the permissible interfering level of -108dBm/5MHz to LTE base station.

V. Conclusions

This paper described the required median path loss characteristics and long term fading in the large city based on the measurement results. Also, we found that the median path loss of the measurement in the large city is good mapping with theoretic extended Hata model including combined the urban model with suburban model. In addition, for the protection of LTE base station from FM broadcasting repeater's interference, the separation distance from a fixed interferer to a victim receiver was given in none line of sites. For the coexistence between a fixed station such as FM broadcasting station and a mobile communication system like LTE, it is expected to use these results. Also, antenna correction factor is very important to predict the radio propagation with the accuracy and is applied to calculate the interference in the adjacent channel bands.

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