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Analysis of Radio Interference through Ducting for 2.5 GHz WiMAX Service

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Abstract

Radio interference has been occurring in mobile communication services on the southern seashore in Korea. Monitoring the radio interference signal revealed that the main reason for the radio interference was a radio ducting signal coming from the seaside of Japan. In this paper, we have analyzed the effect of interference on WiMAX service using a 2.5 GHz frequency band between Korea and Japan. We focus on the interference scenario from base station to base station and we use the Minimum Coupling Loss (MCL) method for interference analysis and the Advanced Propagation Model (APM) for calculating the propagation loss in ducts. The propagation model is also compared with experimental measurement data. We confirm that the interfering signal strength depends on the antenna height and this result can be applied to deployment planning for each system with an interference impact acceptable to both parties.

Key words: WiMAX, Ducting, Interference Analysis, Minimum Coupling Loss (MCL), Advanced Propagation Model (APM).

Ⅰ. Introduction

Interference problems occur among the wireless communication systems because several radio systems must share a limited frequency band. Therefore, accurate prediction of the potential interference effects between wireless communication systems is necessary for more efficient use of the limited frequency resources. Radio interference problems also exist between neighboring countries.

A few years ago, radio interference began to occur in the Trunked Radio Service (TRS) frequency band in the south coastal area of Korea [1]. Similar interference has also been observed in the mobile communication frequency band [2]. Monitoring the radio interference revealed that the main reasons for radio interference is radio signal ducting from the seaside of Japan.

Ducting of a RF signal is caused by an atmospheric anomaly known as temperature inversion. A layer of ice cold or very hot air traps the RF signal and propagates for as long as the duct exists. These ducts can extend for hundreds or even thousands of miles. Once trapped, the ducted signal could cause interference in quite distant wireless systems [3].

In recent years, UQ Communication of Japan has started a WiMAX service using 2,595～2,625 MHz frequency band. In Korea, a new operator is initiating procedures to start a WiMAX service using the 2,575～2,615 MHz frequency band. To allow better radio communication service, we need to be able to predict interference effects between two countries.

In this paper, we have analyzed the effect of interference between WiMAX services of two countries using the 2.5 GHz frequency band. We analyzed the interference by focusing in particular on the interference scenario for base station to base station transmission because this type of interference is more serious than any other interference scenarios. The Minimum Coupling Loss (MCL) method is used for the interference analysis between base stations. We also employ the Advanced Propagation Model (APM) for calculating the propagation loss in ducts.

This paper is organized as follows. In section Ⅱ, interference scenarios and a mechanism of interference occurrence are described. In section Ⅲ, the method of interference analysis and the used propagation model are presented. The propagation model is also compared with experimental measurement data. Simulation parameters and simulation results are presented in Section Ⅳ. Finally, the conclusions are discussed in Section Ⅴ.

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Table 1. Scenarios for interference analysis between WiMAX systems.

Scenario		Interferer	Victim
Synchronous case	Case 1	WiMAX BS	WiMAX MS
	Case 2	WiMAX MS	WiMAX BS
Asynchronous case	Case 3	WiMAX BS	WiMAX BS
	Case 4	WiMAX BS	WiMAX MS
	Case 5	WiMAX MS	WiMAX BS
	Case 6	WiMAX MS	WiMAX MS

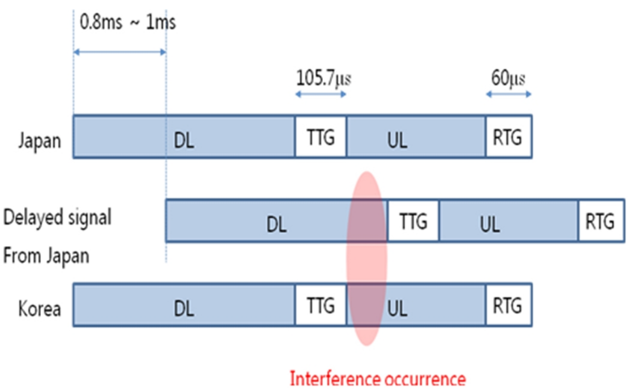

Fig. 1. A mechanism for interference.

Ⅱ. Interference Scenarios

The interference analysis between the mobile WiMAX TDD systems can be carried out according to different interference scenarios. Six interference scenarios are possible, as shown in Table 1. The base station to base station interference would produce more serious interference than base station to mobile station or mobile station to mobile station interference. No interference problem seems to occur between WiMAX systems if the system timing of the base stations between two countries is synchronous. However, we have to consider a mechanism of interference as shown in Fig. 1. The distance between Korea and Japan is about 240~300 km. Therefore, the transmitted signals from Japan's WiMAX base station arrive at Korea with a time delay of 0.8~1 ms. The delayed signals from Japan arrive at WiMAX base stations located in Korea and this can induce interference. The extent of interference depends on the level of the received interference signal.

Ⅲ. Interference Analysis Method between WiMAX services

3-1 Basic Equation for Interference Analysis

The interference level at the receiver is a function of the gains and losses that the interference signal will incur between the interferer transmitter and the victim receiver and is expressed by [4]

$$P_I = P_t + G_t + G_r - L_b(d) - FDR(\Delta f) \quad (1)$$

where P_I is an interference power level in dBm, P_t is an interferer transmitter power in dBm, G_t is a gain of interferer antenna in direction of receiver in dBi, G_r is a gain of victim receiver antenna in direction of interferer in dBi, $L_b(d)$ is a basic transmission loss for a separation distance d between interferer and receiver in dB, $FDR(\Delta f)$ is a measure of the rejection produced by the receiver selectivity curve on an unwanted transmitter emission spectrum in dB.

After calculating the interference power level at the victim receiver using equation (1), the received interference power level is compared with the tolerable, or target, interference power at the receiver. We then determine whether the interference occurs.

The tolerable, or target, interference power at the receiver may be written in the logarithmic domain is [5]

$$P_{I,Target} = P_N + 10\log_{10}(10^{\frac{D}{10}} - 1) \quad (2)$$

where D is the acceptable degradation in receiver sensitivity, or desensitization, in units of dB, and the receiver thermal noise power is given by

$$P_N = 10\log_{10}(kT) + 10\log_{10}(10^6) + NF \quad (3)$$

where k is Boltzmann's constant (W/K/Hz), T is the ambient temperature (K), and NF is the receiver noise figure (dB). For $k = 1.3804\times10^{-23}$, $T = 290$ and $NF = 5$, we have $P_N = -109$ dBm/MHz. For a 1 dB desensitization, we have $P_{I,Target} = -115$ dBm/MHz.

3-2 Advanced Propagation Model

APM is much faster than split-step parabolic equation (PE) method, yet it requires far less memory and can be used in wider applications. APM considers four regions shown in Fig. 2. At ranges less than 2.5 km and for all elevation angles above 5°, APM uses a flat earth (FE) model region. For the region beyond the FE region where the grazing angles of reflected rays from the transmitter are above a small limiting value, the ray optics (RO) model is used. The PE model is used for ranges beyond the RO region, but only for altitudes below a maximum PE altitude determined by the maximum the 1024-point Fast-Fourier transform (FFT) allowed.

For ranges beyond the RO region and heights above the PE region, an extended optics (XO) method allowed. For ranges beyond the RO region and heights above the

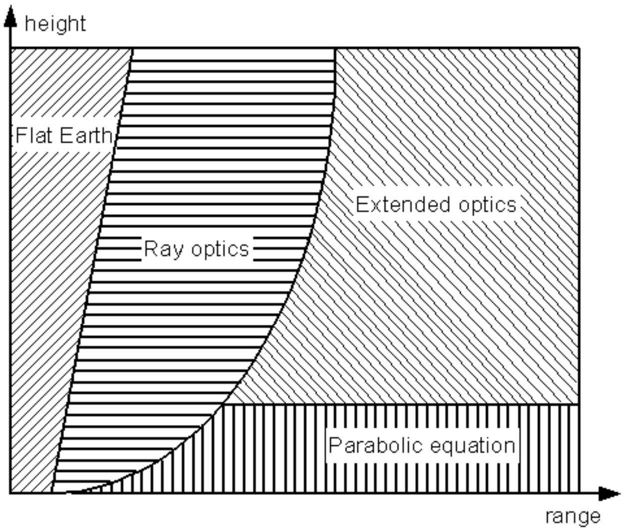

Fig. 2. APM region.

PE region, an extended optics (XO) method can operate at the maximum PE altitude. This uses ray-optics methods to propagate the signal to higher altitudes [6].

In the flat earth region, a simple two-ray model is used, assuming the rays propagate in straight lines that ignores refractive and earth-curvature effects.

A limiting grazing angle ψ_0 for reflected rays determining the RO region is computed as

$$\psi_0 = 0.04443 / f^{\frac{1}{3}} \tag{4}$$

where ψ_0 is in radians and f is frequency in MHz. The RO method consists of tracing a series of direct and reflected rays through selected points. The direct and reflected rays through a given point are characterized by their elevation angles at the transmitter.

Propagation loss L in dB is computed as

$$L = 20\log f + 20\log x - 10\log F^2 - 27.56 \tag{5}$$

where log is base 10, f is frequency in MHz and x is range in meters. F is the propagation factor defined as the ratio of the field strength to the free-space field strength [7].

In the PE region, the split-step PE model proposed by Dockery [8] is used. The propagation factor F is computed from the PE solution at the top of the PE region and is used to initialize an RO model in the XO region.

3-3 Field Measurement and Comparison

The measurement for interference between Korea and Japan was fulfilled. The transmitter was located in Kyushu, Japan. The receiver was located in the Kumlyn-

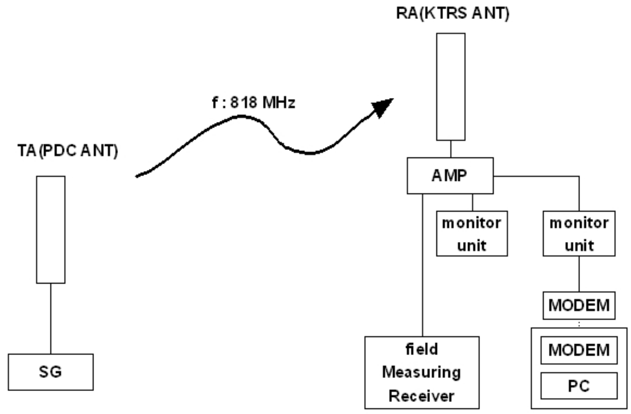

Fig. 3. Measurement system.

Table 2. The Spec. of Tx and Rx.

	Transmitter	Receiver
East longitude	130°23'37"	129°12'53"
North latitude	33°35'16"	35°14'19"
Height	80 m	298 m
Frequency	818 MHz	
Power	36 dBm	29.7 dB
Cable loss	2.4 dB	15.5 dB
Ant. gain	17 dB_i	10 dB_i
EIRP/gain	50.6 dBm	24.2 dB

mountain area in Pusan, Korea [9]. The measurement system is shown in Fig. 3. Each specification is listed in Table 2. The measurements were recorded from the middle of March to the late November. The noise level was about 15 $dBuV$ and maximum received voltage was about 70 $dBuV$ in March, June, and July due to ducting and in November, except for a day, the received voltage was about 15 $dBuV$. These measurements confirmed that no radio ducting occurred in November.

Fig. 4 shows comparison of the measurement values with the simulation values for June. We used the approximate input parameters to compare real measurements for interference between Korea and Japan. Frequency and antenna height were set as shown in Table 2. Neither Pusan nor Kyushu are World Meteorological Organization (WMO) stations so modified refractivity input came from Pohang and Fukuoka, which were adjacent to the measurement site. It is impossible to compare the measurement results on a day-to-day basis; however, it is possible to make a rough prediction of the daily propagation loss in the duct. The result indicates that the simulation value is consistent with a 7 % time rate of measurement.

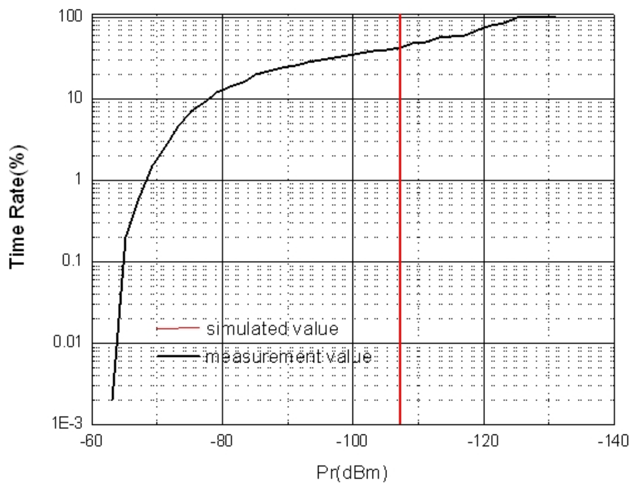

Fig. 4. Comparison of measurement value and simulation value.

Ⅳ. Simulation Results

4-1 Simulation Scenario and Parameters

Fig. 5 describes a simulation scenario caused by the other country's WiMAX base station. We consider this interference scenario to reflect a base station to base station interference where WiMAX networks are deployed on the shores of Korea and Japan. We have only simulated the interference effect from Japan's WiMAX base station to Korea's WiMAX base station. Table 3 presents the simulation parameters for interference analysis. We consider that the receiver bandwidth is 10 MHz and noise figure is 5 dB. We also assumed a 1 dB desensitization as a protection ratio. Table 4 shows the modified refractivity index of Pohang and Fukuoka provided by the WMO station. The value represents a surface-based duct and the elevated ducts in June.

4-2 Simulation Results

The propagation loss for variation of the distance between Korea and Japan is shown in Fig. 6. The propagation loss using APM is compared with the result using the free space model. This is the simulated value

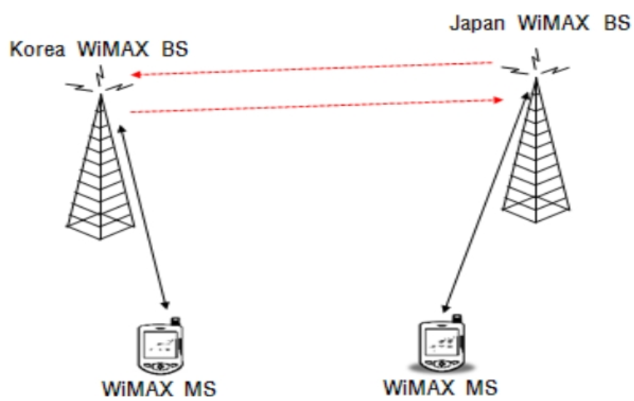

Fig. 5. Simulation scenario.

Table 3. Parameter value of WiMAX system.

Parameter	Value
Operating frequency	2,600 MHz
Channel bandwidth	10 MHz
Transmitting power	43 dBm
Transmitter antenna height	30 m
Receiver antenna height	30 m
Transmitter antenna gain	15 dBi
Receiver antenna gain	15 dBi
Base station noise figure	5 dB
Cable loss	3 dB
Desensitization	1 dB
Distance	240 km
Modified refractivity	WMO data
Desensitization	1 dB

Table 4. Modified refractivity - WMO data.

Pohang		Fukuoka	
Height(m)	Modified refractivity	Height(m)	Modified refractivity
0	337	0	349
16	339	3	349
47	343	49	354
72	334	71	345
1,933	559	1,283	491
2,055	551	1,389	487
3,054	661	2,389	596

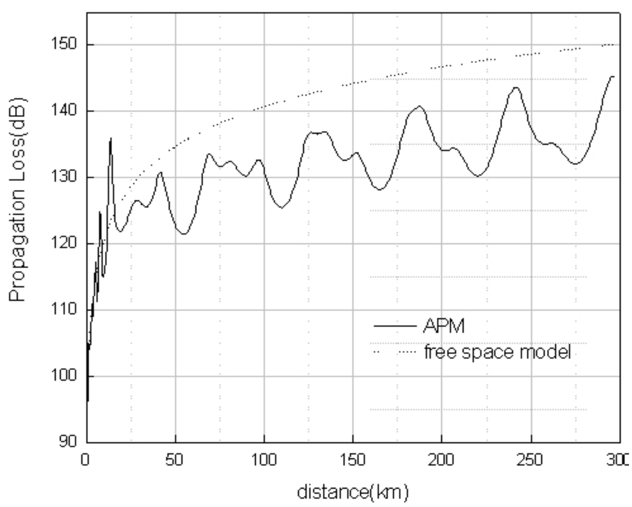

Fig. 6. Path loss versus distance between two countries.

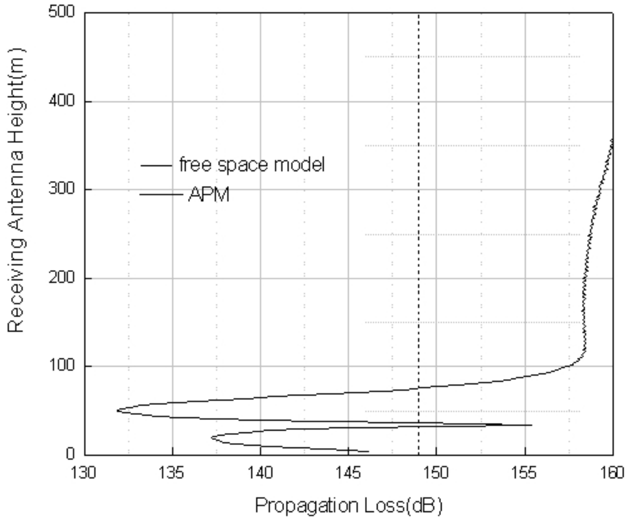

Fig. 7. Path loss versus receiving antenna height.

when the transmitting and receiving antenna height is 30 m. The propagation loss appears to increase as the distance is increased and the propagation loss by ducting may be smaller than the free space loss.

The propagation loss for variation of receiving antenna height is shown in Fig. 7.

In this simulation, the transmitting antenna height is 30 m and the distance between two countries is 240 km. The propagation loss appears to have an abnormal value near the receiving antenna height of 50 m and the propagation loss below the height of 75 m is smaller than the free space loss.

The propagation loss for variation of transmitting antenna height and receiving antenna height is shown in Fig. 8. In this case, the distance between two countries is also 240 km. The propagation loss appears to have values lower than 150 dB when the transmitting antenna height is less than 80 m and the receiving antenna height is less than 75 m. This result indicates that the propagation loss depends on the antenna height and the propagation loss also appears to vary according to the ducting layer height.

The received interfering signal strength at the victim receiver is shown in Fig. 9. This is calculated using equation (1) and the parameters in Table 3. The loss due to antenna tilt at each of the transmitters and receivers is considered to be 3 dB. After calculating the interference power level at the victim receiver, we can determine whether the interference occurs. The tolerable, or target, interference power at the receiver is then −105 dBm/10 MHz as determined using equation (2).

When the heights of the transmitting antenna and receiving antenna are 30 m, the received interfering signal strength from WiMAX base station of Japan is about

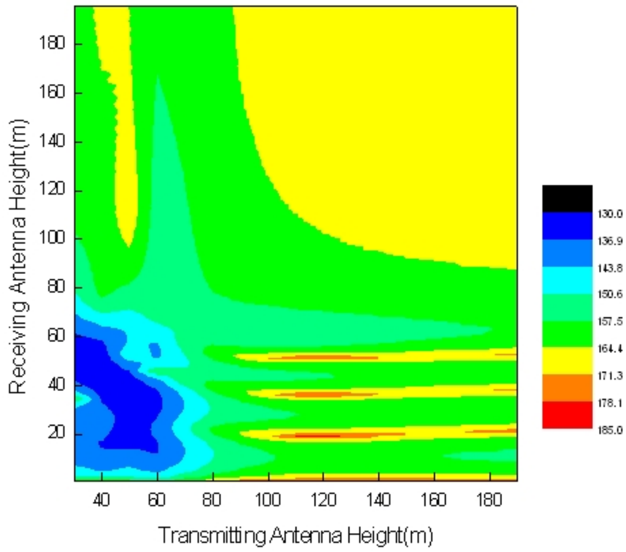

Fig. 8. Path loss for transmitting antenna height and receiving antenna height.

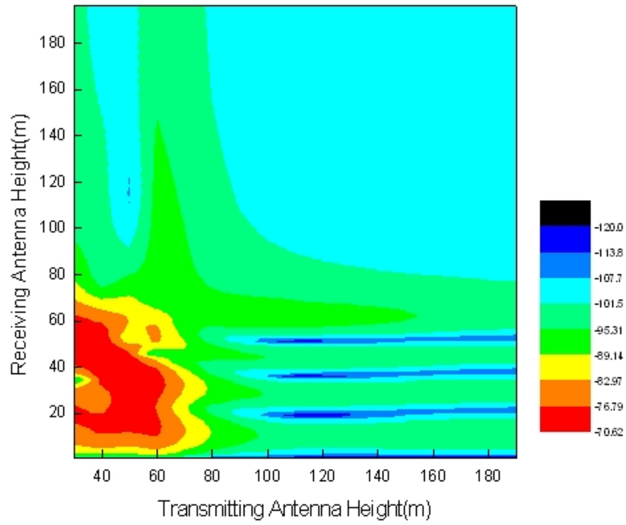

Fig. 9. Received interference signal strength for transmitting antenna height and receiving antenna height.

−81.7 dBm/10 MHz. This signal strength does not agree with the target interference level. The target interference level appears to be satisfied at antenna heights above 100m.

Therefore, the received interfering signal strength appears to depend on the antenna height. It may be satisfied with a target interference level that depends on the antenna height.

Ⅴ. Conclusion

This paper analyzes the effect of interference for 2.5 GHz WiMAX services between Japan and Korea by ducting. The MCL method is used for the interference analysis focusing on a base station to base station interference scenario. The APM model is also used to calculate the propagation loss in ducts and the modified refractivity index of the surface-based duct and the elevated ducts provided by WMO station are applied. The predicted propagation loss calculated by using the APM is compared with measurement results. The received interfering signal strength at Korea's WiMAX base station from Japan's WiMAX base station is simulated. We confirm that the received interfering signal strength depends on the antenna height and that the target interference level may be satisfied by adjusting antenna heights.

This paper can be used to evaluate the interference effect for frequency assignment of WiMAX systems between Korea and Japan. It can also be useful for deployment planning by each system to result in an interference impact that is acceptable to both parties.

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