Analysis of Radio Interference through Ducting for 2.5 GHz WiMAX Service

Ho-Kyung Son\(^1\) · Jong-Ho Kim\(^1\) · Che-Young Kim\(^2\)

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).

\(^1\)Radio Technology Research Department, Electronics and Telecommunications Research Institute, Daejon, Korea.
\(^2\)School of Electrical Engineering and Computer Science, Kyungpook National University, Daegu, Korea.

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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.
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]

\[ P_I = P_r + G_t + G_r - L_b(d) - FDR(\Delta f) \]  

(1)

where \( P_I \) is an interference power level in dBm, \( P_r \) 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]

\[ P_{I,\text{Target}} = P_N + 10\log_{10}(10^{10} - 1) \]  

(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

\[ P_N = 10\log_{10}(kT) + 10\log_{10}(10^6) + NF \]  

(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 \( P_{I,\text{Target}} = -115 \) 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 ROI region and heights above the
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 $\psi_0$ for reflected rays determining the RO region is computed as

$$\psi_0 = 0.04443 / f^3$$

where $\psi_0$ 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

$$L = 20 \log f + 20 \log x - 10 \log F^2 - 27.56$$

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-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.
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

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**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.**

| Height(m) | Modified refractivity | Height(m) | Modified refractivity |
|-----------|-----------------------|-----------|-----------------------|
| Pohang    | Fukuoka               |           |                       |
| 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                   |

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![Fig. 4. Comparison of measurement value and simulation value.](image)

![Fig. 5. Simulation scenario.](image)

![Fig. 6. Path loss versus distance between two countries.](image)
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 $-81.7$ 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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Ho-Kyung Son received her B.S and M.S degrees in Electrical Engineering from Kyungpook National University, Daegu, in 1997 and 1999. In 2000, she joined the Electronic and Telecommunications Research Institute (ETRI) where she is a senior member of the engineering staff of the Radio Technology Department. She has been involved in the research of spectrum engineering since 2003, and is currently working toward her Ph.D. Degree in the same university. Her research interests include radio resource management, interference analysis between wireless communications, and radio propagation.

Jong-Ho Kim received the B.S., M.S. and Ph.D. degree in Electronic Engineering from Chungnam National University, Daejeon, Korea, in 1986, 1988 and 2006 respectively. Since 1989, he has been working for Electronics and Telecommunications Research Institute (ETRI) where he is a principal member of engineering staff of the Radio Technology Department. His main interests are radio propagation and spectrum engineering.
Che-Young Kim completed his Ph.D. degree in electrical engineering at Korea Advanced Institute of Science and Technology, Seoul in 1990, and received his Bachelor degree in Electronics Engineering at Kyung-pook National University, Daegu in 1976. During 1979~1992, he was an instructor, assistant professor, and associate professor at Kyung-pook National University. Since 1993, he has been a professor at the same university. He was a visiting scholar at Syracuse University from 1985 to 1986 and became a research scientist at Massachusetts Institute of Technology in USA from 1991 to 1993. He is now serving as one of editors in the Progress in Electromagnetics Research (PIER) and Journal of Electromagnetic Waves and Applications (JEMWA) since 2006. He was awarded the Paper of Year entitled "A propagation model of microcell and picocell in urban environments," listed on Journal of SK Telecommunications Review in June 1996. His technical interests include the basic electromagnetic theory and measurements, wave propagation, metamaterials, and wireless energy transmission. His current research involves the RF filters using the metamaterial technology.