Coexistence of Korea's DVB-T2 and Japan's ITS using 700MHz frequency band

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***Abstract*—In this paper, we analyze the effects of interference between Korea's ultra-high definition TV broadcasting system and Japan's intelligent transport system using the 700 MHz frequency band when considering a practical deployment of both systems. We performed Minimum Coupling Loss (MCL) method to evaluate how much interference from the Korean UHDTV system is imposed on the Japan ITS system. We also employ the Advanced Propagation Model (APM) and ITU-R P. 452-15 model to calculate the propagation loss occurring in ducts. Our study can be applied to the deployment planning for each system with an interference impact acceptable to both parties.**

***Keyword*—DVB-T2, ITS, Interference, Ducting**

I. INTRODUCTION

Many countries converted their analog TV systems into digital TV (DTV). The South Korean government also allocated CH 14 through CH 51 (470-698 MHz) for DTV use [1] and recently determined to allocate additionally 30MHz (698-710 MHz and 753-771 MHz) for ultra-high definition TV (UHDTV) use [2]. Several broadcasters did test broadcasting with Digital Video Broadcasting-Terrestrial version 2 (DVB-T2) standard. But recently the Korean government picked the Advanced Television Systems Committee (ATSC) 3.0 standard for ultra-high-definition (UHD) television broadcasting set to launch next year [3].

In Japan, digital terrestrial TV broad-casting service is available at 460-710 MHz on the UHF band using the ISDB-T standard and a 9 MHz channel width in the 755.5-764.5 MHz radio frequency band will be used for Intelligent Transport System (ITS). It is the realization of safe driving support systems to reduce the number of traffic accidents. The 700 MHz frequency band is known for its good propagation characteristics in non-line-of-sight conditions such as behind buildings or large vehicles [4]. The 755.5-764.5 MHz frequency band partially overlaps with Korean UHDTV frequency band.

Although Korean UHDTV system and Japan ITS system are located with a sufficient separate distance, the potential interference would be produced. A few years ago, radio interference began to occur in the Trunked Radio Service (TRS) frequency band in the southern coastal area of Korea [5] and similar interference has also been observed in the mobile communication frequency band [6]. Monitoring such radio interference found that its main source was the ducting of radio signals produced in the coast of Japan.

The ducting of an 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 guides it to a farther distance than expected through an anomalously formed duct. These ducts can extend to hundreds or even thousands of miles. Once trapped, the ducted signal may cause interference to distant wireless systems [7]. As the height and duration of the duct layer are not constant, it is difficult to predict the effects of this type of interference. To allow better radio communication services, we need to be able to predict the effects of interference and study a method of coexistence between the two countries.

In this paper, we analyze the effects of interference between UHDTV services in Korea and ITS service in Japan at the 700 MHz frequency band. We focus particularly on an interference scenario of Korea's UHDTV to Japan's ITS, as this type of interference is more serious than the other interference scenario. Korean UHDTV is assumed in DVB-T2 system and the Minimum Coupling Loss (MCL) method is used for the interference analysis between fixed stations. We also employ the Advanced Propagation Model (APM) and ITU-R P. 452-15 model to calculate the propagation loss occurring in ducts. To protect against interference between Korean and Japanese radio signals, the required additional attenuation loss according to the UHDTV's antenna tilt degree is also calculated.

This paper is organized as follows. In section II, interference scenarios and the interference analysis method are described. In addition, the propagation model used are presented. The simulation parameters and results are presented in section III. Finally, some concluding remarks regarding our proposal are provided in section IV.

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II. Interference Scenario and Methodology

A. Interference scenario

Fig. 1 shows a scenario for interference analysis from Korea's DVB-T2 system to Japan's ITS system. We assumed that Korea's DVB-T2 site transmits signals using the 759-765 MHz frequency band and Japan ITS system has a 9 MHz channel bandwidth using 755.5-764.5 MHz frequency band. The distance between Korea and Japan ranges from about 240 to 300 km, we assumed the separate distance between two systems is 240 km.

Japan ITS systems are supposed to consist of two types of systems: vehicle-to-vehicle communication systems that support safe driving by inter-vehicular radio communications at intersections with poor visibility, and roadside-to-vehicle communication systems that support safe driving by sending information from roadside units of traffic infrastructure to vehicles through radio communications [4]. We considered only roadside-to-vehicle communication systems that vehicle transmit the signal to roadside units. We evaluated whether the received interference power at the antenna of Japan's ITS receiver satisfies the maximum allowable interference power.

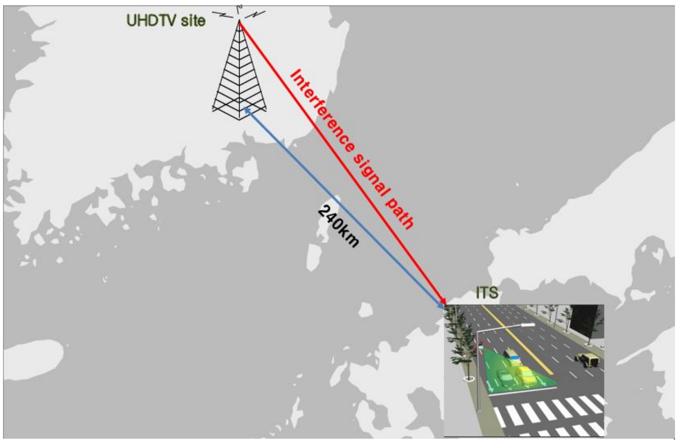

Fig. 1. Interference scenario between Korea's DVB-T2 and Japan's ITS

B. Methodology for an interference analysis

The possibility of frequency spectrum sharing depends on whether the received signal-to-interference plus noise ratio at the antenna of victim receiver satisfies the minimum signal-to-interference plus noise needed to process (vice just detect) a signal.

$$P_S - (P_N + P_I) \geq SINR_{\min} \quad (1)$$

where P_S is the received wanted signal power from vehicle's transmitting signal, P_N is the thermal noise power of the receiver and P_I is the received interfered signal power from Korean DVB-T2 transmitting signal.

The received interfered signal power from Korean DVB-T2 transmitting signal is expressed by [8]

$$P_I = P_t + G_t + G_r - PL(d) \quad (2)$$

where P_t is the transmit power of the interfering system in the reference bandwidth in dBm, G_t is the gain of the interferer antenna in the direction of the receiver in dBi, G_r is the gain of the victim receiver antenna in the direction of the interferer in dBi, $PL(d)$ is a basic transmission loss for separation distance d between the interferer and receiver in dB.

The receiver thermal noise power is given by

$$P_N = 10\log_{10}(kTB) + NF \quad (3)$$

where k is Boltzmann's constant (W/K/Hz), T is the ambient temperature (K), B is the channel bandwidth (Hz), and NF is the receiver noise figure (dB). For $k = 1.3804 \times 10^{-23}$, T=290 and NF=6dB, we have $P_N = -108\, dBm/MHz$.

In an interference-limited environment, equation (1) can be approximated as follow

$$P_N + P_I \approx P_I \quad (4)$$

The tolerable interference signal power can be determined using the following equation

$$P_{I,target} \leq P_S - SINR_{\min} \quad (5)$$

The required additional attenuation loss (L_a), in dB, of the interfering system on the victim system can be determined using the following equation [8]:

$$L_a = P_I - P_{I,target} \quad (6)$$

$P_{I,Target}$ is the tolerable, or target, interference power at the receiver.

C. Propagation model for path loss calculation

The basic transmission loss is the most important factor to predict the interference level and determine the additional required attenuation loss. For a calculation of this basic transmission loss occurring in a duct, we used ITU-R P.452-15 [9] and hybrid propagation model called an Advanced Propagation Model (APM).

ITU-R P.452-15 is a prediction method for the evaluation of interference between stations on the surface of the Earth at frequencies from about 0.1 GHz to 50 GHz, accounting for both clear-air and hydrometeor scattering interference mechanisms. The models within Recommendation ITU-R P.452 are designed to calculate propagation losses not exceeded for time percentages over the range $0.001 \leq p \leq 50\%$. This assumption does not imply the maximum loss will be at $p = 50\%$. The method includes a complementary set of propagation models which ensure that the predictions embrace all the significant interference propagation mechanisms that can arise. Methods for analyzing the radio-meteorological and topographical features of the path are provided so that predictions can be prepared for any practical interference path falling within the scope of the procedure up to a distance limit of 10000 km [9].

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 2.5km and for all elevation angles above 5°, APM uses a flat earth (FE) model region. For beyond the FE region, where the grazing angles of the 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 as determined by the maximum allowed 1024-point Fast-Fourier transform (FFT). For ranges beyond the RO region and heights above the PE region, an extended optics (XO) method is allowed, which can operate at the maximum PE altitude [10].

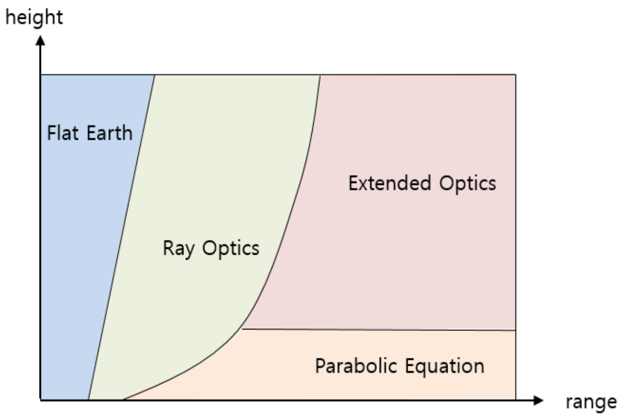

Fig. 2. Advanced Propagation Model(APM)

III. SIMULATION RESULTS

A. Simulation parameter

We considered a scenario of the interference between Korea's DVB-T2 and Japan's ITS, where DVB-T2 and ITS are deployed at the shores of Korea and Japan. We simulated only the interference effect from Korea's DVB-T2 station to Japan's ITS road station. Table I and II present the operational system parameters for the DVB-T2 and ITS systems used for simulation, respectively. We consider the DVB-T2's channel bandwidth to be 6 MHz and the transmitting power to be 5 kW. Hwang-Ryeong Mountain was chosen as Korean DVB-T2 site, which located near Japan. The vertical pattern of the DVB-T2 antenna [11] was shown in Fig. 3. We consider the channel bandwidth of ITS system to be 9 MHz and the vehicles transmitting power to be 200 mW. We also assumed 7m as the Road-side antenna height and 13dB minimum SNR as the protection ratio. Also we consider the Road-side noise figure is 6dB. A free space propagation model is used to calculate the path loss between ITS's vehicle and ITS's roadside.

An ITU-R P.452-15 propagation model and APM are used to calculate the path loss between Korea's DVB-T2 and Japan's ITS and Table III shows the path loss using the P.452-15 model. Table IV shows the modified refractivity index of Pohang provided by the WMO station. The values represent a surface-based duct and elevated ducts in June.

TABLE I
DVB-T2 SYSTEM PARAMETERS FOR SIMULATION

Parameter		Value
Center frequency		762MHz
Channel bandwidth		6MHz
Transmitting power		67dBm
Antenna gain		10dBi
Antenna height		450m
Distance		240km
Modified refractivity		WMO data
tilting		0°~9°
Location		35° 15′ 80″
		129° 08′ 22″
Antenna pattern	horizontal	omni
	vertical	ITU-R F. 1336

TABLE II
ITS SYSTEM PARAMETERS FOR SIMULATION

Parameter	Value
Center frequency	760MHz
Channel bandwidth	9MHz
Vehicles radiated power	20dBm
Road-side antenna height	7m
Road-side antenna gain	13dBi
Road-side noise figure	6dB
Minimum SNR	13dB
Vehicle antenna height	3m
Vehicle antenna gain	0dBi

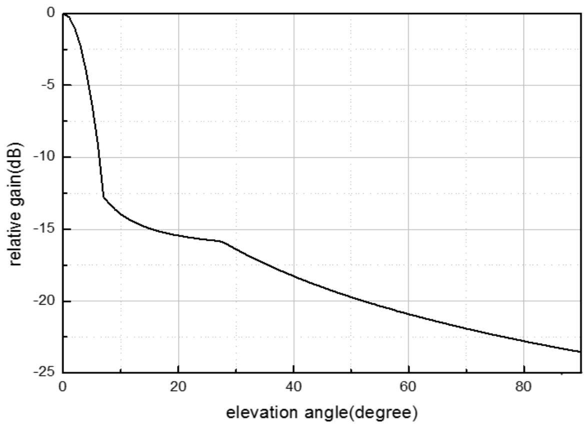

Fig. 3. DVB-T2's antenna vertical pattern

TABLE III
PATH LOSS USING ITU-R P.452-15

Time rate(%)	Path loss(dB)
1	144.2dB
10	172.8dB
50	179.6dB

TABLE IV
MODIFIED REFRACTIVITY-WMO DATA

Height(m)	Modified refractivity
0	337
16	339
47	343
72	334
1933	559
2055	551
3054	661

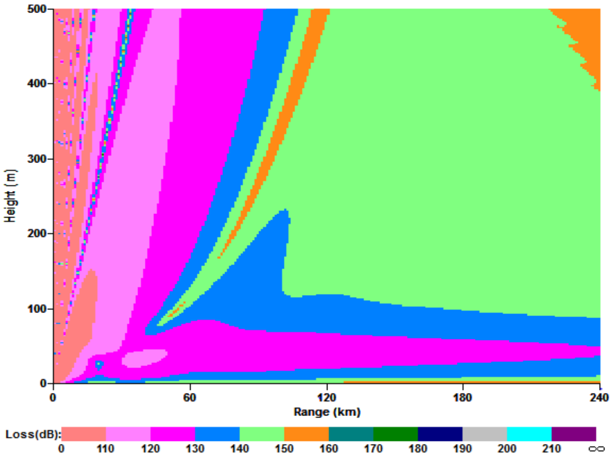

Fig. 4. Path loss between Korean DVB-T2 and Japan ITS using APM

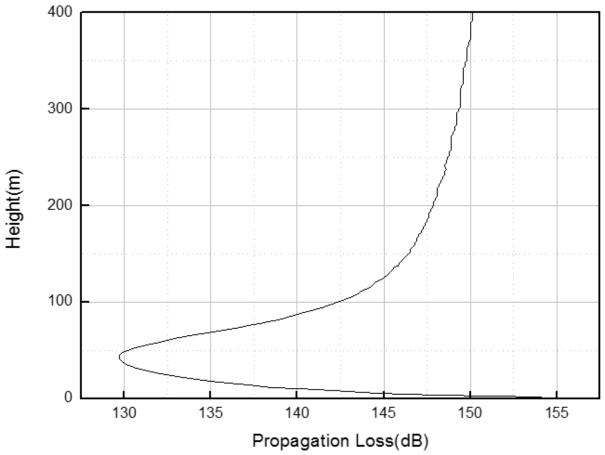

Fig. 5. Path loss versus receiving antenna height

B. *Simulation result*

The propagation loss using APM for variation of the distance between Korea's DVB-T2 and Japan's ITS is shown in Fig.4. 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.

Fig. 5 shows the propagation loss for variation of receiving antenna height when the distance between two countries is 240 km. The propagation loss appears to have an abnormal value near the receiving antenna height of 50m and the propagation loss below the height of 75m is smaller than the free space loss 137.5dB. 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.

Fig. 6 shows the received wanted signal strength and interfering signal strength ratio at the victim receiver, road-side antenna of ITS, for variation of the time rate and propagation model. Interfering signal strength is calculated using equation (2) and the parameters in Table I and Table II. After calculating the interference power level and the wanted signal strength at the victim receiver, we can determine whether the interference occurs. The received signal-to-interference plus noise ratio appears to be dependent on the separate distance between roadside unit and vehicle unit of ITS. The target signal-to-interference plus noise ratio of 13dB may be satisfied depending on the separate distance. For 10% time rate and 50% time rate of ITU-R P.452-15 model, it satisfied the target signal-to-interference plus noise ratio in all segments. However, for a 1% time rate of ITU-R P. 452-15 model and APM, the target signal-to-interference plus noise ratio appears to be satisfied at separate distance below 150 m.

The additional attenuation loss required for the receiving antenna height of ITS's roadside is shown in Fig. 7.

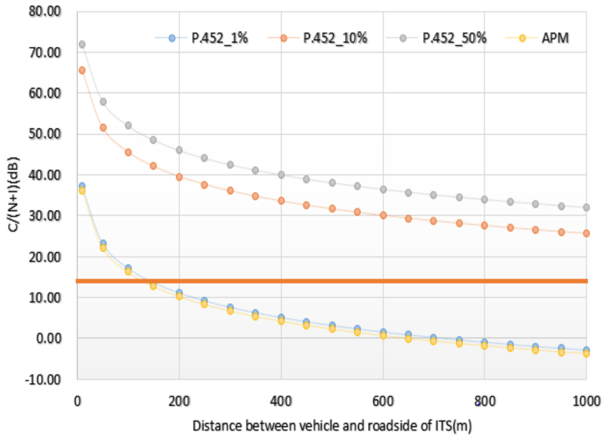

Fig. 6. Received signal-to- interference plus noise ratio according to the time rate at the roadside of ITS

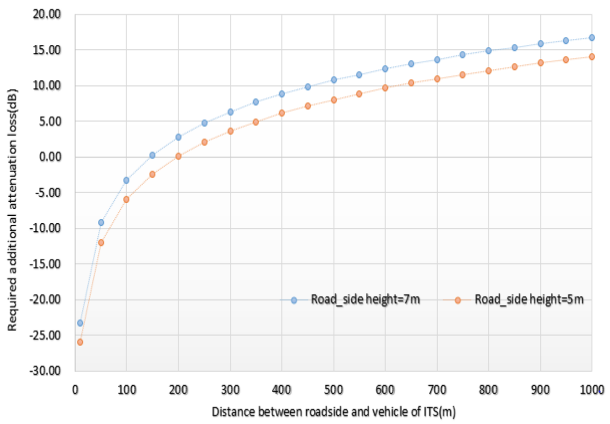

Fig. 7. Additional attenuation loss required for receiving antenna heights

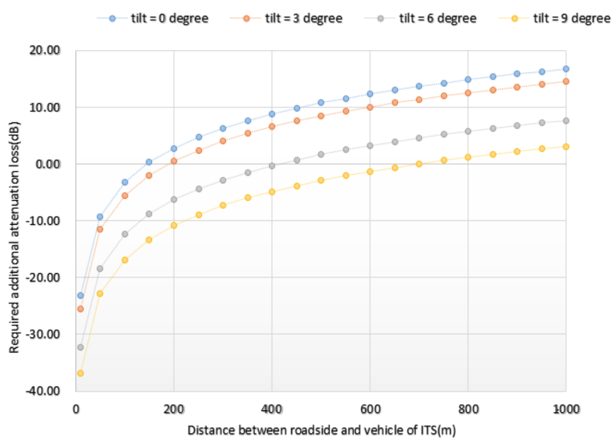

Fig. 8. Additional attenuation loss required for tilt degree of transmitting antenna

These are calculated using equation (6) and the parameters listed in Table I and Table II. When the heights of the receiving antenna of ITS's roadside is 5 m, an additional attenuation loss of above 8 dB is required to satisfy the target interference level with ITS's cell radius of 500m. As the separate distance between roadside and vehicle of ITS, cell radius, is extended, a required additional attenuation loss to satisfy the target interference level is increased. In addition, when the heights of the receiving antenna of ITS's roadside is 7 m, an additional attenuation loss of 11 dB is required. From the result, we confirm that the target interference level may be satisfied depending on the antenna height and ITS's cell radius.

Fig. 8 shows the additional attenuation loss required for variation of the tilting angle of a transmitting Korean DVB-T2 site antenna, which was simulated based on the vertical pattern of the DVB-T2 antenna in [9] and based on the APM. Also the required additional attenuation loss is compared when the tilting angle of the DVB-T2 site antenna is 0°, 3°, 6° and 9°. This result indicates that Korean DVB-T2 site system produces a higher interference on Japan's ITS system when the tilting angle of the transmitting antenna is 3° than when it is 9°.

The additional attenuation loss required, as shown in Fig. 7 and Fig. 8, can be used as a guideline for allowing the deployed Japan ITS system and Korean DVB-T2 to avoid an unacceptable amount of interference between systems.

IV. Conclusion

In this paper, we analyses the effect of interference between UHDTV services in Korea and ITS service in Japan at the 700 MHz frequency band when encountering a ducting phenomenon. The MCL method is used for an interference analysis, focusing on an interference scenario of Korea's UHDTV to Japan's ITS. The ITU-R P.452-15 model and APM were used to calculate the propagation loss in the ducts, and the modified refractivity indexes of a surface-based duct and an elevated duct as provided by a WMO station were applied. The propagation loss by ducting may be smaller than the free space loss.

The received signal-to-interference plus noise ratio and the required additional attenuation loss at Japan's ITS roadside occurring from Korea's DVB-T2 were simulated for antenna height and antenna's tilting angles. We confirmed that the strength of the received interfering signal depends on the antenna height, and that the target interference level may be satisfied by adjusting the antenna height. Also we confirmed that the received interfering signal strength depends on the transmitting antenna's tilting angles and that the target interference level may be satisfied by adjusting the tilting angle of antenna and Japan's ITS cell radius.

This paper can be used to evaluate the interference effects and find a spectrum-sharing method between Korean DVB-T2 and Japan ITS. It can also be useful for deployment planning by each system, resulting in an interference impact that is acceptable to both parties.

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