A study on the coexistence analysis of intelligent transport systems in 60GHz bands

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Abstract. As information provided by intelligent transport systems is expanded from simple traffic information to high-resolution maps for autonomous driving and various infotainment services, the need for additional frequency allocation is increasing. Therefore, in Europe, the 63-64GHz band is allocated in addition to the existing 5.9GHz. However, the 60GHz band is used for unlicensed services and the wireless multi-gigabit service is already utilized in the frequency band. For the safe utilization of the frequency band, coexistence analysis between the intelligent transport systems and the wireless multi-gigabit service is required. In this paper, the coexistence between the two services in the 60GHz band is analyzed assuming the case that the same millimeter wave frequency as Europe is allocated for intelligent transport systems in various countries. First, the international specifications and characteristics of the wireless multi-gigabit service and intelligent transport systems are investigated. Furthermore, protection distances between the two services in various application scenarios are analyzed based on the minimum coupling loss. The results show that a careful consideration of frequency allocation for ITS is required for the safe coexistence. The coexistence analysis presented in this paper is expected to be used as a guideline in millimeter wave frequency allocation for ITS.

Keywords: Coexistence, intelligent transport systems, wireless multi-gigabit service, protection distance, 60GHz, millimeter wave

1 Introduction

Intelligent transport system (ITS) is an advanced application which provides innovative traffic management services and enables users to be better informed. ITS services can ensure the safety of pedestrians and vehicles and increased the efficiency of traffic and logistics. As the first phase of the ITS application for enhancing safety, a driver support system based on vehicle-to-everything (V2X) communication that delivers a message in an emergency situation has been proposed. And as the 2nd phase, ITS aims for automatic driving through the monitoring of the environment and driving vehicles. In order to safely implement an automatic driving system, low-delay transmission of a very highly resolved and dynamic map is required. Also, it is necessary to transmit various traffic information collected through the sensors attached to the vehicle. [1].

In addition, a vehicle that was considered only as a mean of transportation has evolved into a cultural living space as ITS technology advances. Thus, the information provided by the ITS includes not only traffic information, but also human friendly infotainment services. As a result, data traffic for the ITS applications is expected to increase significantly.
Currently, ITS frequency band has been allocated in 5GHz frequency band in many countries as shown in Table 1. In EU and Korea, frequency between 5855 to 5925 MHz is allocated for ITS. In US, additional 5MHz between 5850 to 5855MHz is reserved in addition to 5855-5925 MHz band for ITS. In Japan, 5770-5850 is allocated. Also, 5725-5875MHz is allocated in Australia [2]-[4].

Table 1. ITS frequency allocation

Country	Its frequency [MHz]
EU	5855-5925
US	5850-5925
Korea	5855-5925
Japan	5770-5850
Australia	5725-5875

However, additional allocation of ITS frequency is required to accommodate all of these extensional applications. The millimeter wave (30GHz-300GHz) is attracting attention as a major frequency for ITS service because of many advantages such as high data rates through wideband, strong interference and excellent security. In addition, it is possible to miniaturize and lighten the devices due to the short wavelength.
The candidates of millimeter wave frequency to be used for ITS is being discussed in many organizations such as World Radiocommunication conference (WRC)-15 in radiocommunications sector of international telecommunication union (ITU-R), European conference of postal and telecommunications administrations (CEPT), Federal communications commission (FCC) and Fifth Generation Mobile Communications Promotion Forum (5GMF) [5]-[8]. These organizations require the ITS frequency to meet the certain conditions such as more than 1GHz bandwidth, internationally used band, avoiding unnecessary interference. Millimeter wave frequency bands such as 31.8-33.4GHz, 40.5-42.5GHz, 47.0-50.2GHz, 66-71GHz and etc. are considered as the possible candidates.
In Europe, 63-64GHz frequency band is preemptively allocated for the ITS service [9]. However, the 60GHz band is used for unlicensed services and the wireless multi-gigabit service (WiGig) is already utilized in the frequency band. Therefore, coexistence analysis between the ITS and WiGig is necessity for the stable and safe operations of the two services. In this paper, coexistence of ITS is analyzed assuming the case that the same millimeter wave frequency as Europe is allocated to ITS frequency in various countries. First, we investigate the application specifications and characteristics of the ITS and WiGig. And then we analyze the coexistence in the 60GHz band by calculating

the protection distance between ITS and WiGig according to the application scenarios and the interference criterions.
The paper is organized as follows. The international technical regulations and specifications for ITS and WiGig in 60GHz are investigated in section 2. In section 3, the protection distances based on minimum coupling loss are calculated. Finally, discussions and conclusions are shown in section 4.

2 Regulations and Specifications

2.1 Specifications for WiGig

WiGig is a wireless multi-gigabit communication technology operating over the unlicensed 60GHz frequency band, which is standardized through IEEE 802.11ad. It enables high performance wireless data, display and audio applications that supplement the capabilities of previous wireless Local area network devices. WiGig has six channels in 60GHz band as shown in Table 2 [10], thus the 3rd channel (61.56-63.72GHz) and the 4th channel (63.72-65.88GHz) of the WiGig are overlapped with the ITS frequency band which is allocated in 63-64GHz in EU.

Table 2. WiGig Channel frequency

Channel number	Center Frequency [GHz]	Minimum Frequency [GHz]	Maximum Frequency [GHz]
1	58.32	57.24	59.4
2	60.48	59.4	61.56
3	62.64	61.56	63.72
4	64.8	63.72	65.88
5	66.96	65.88	68.04
6	69.12	68.04	70.2

For the coexistence analysis with ITS, the specification of WiGig is investigated as shown in Table 3. The noise factor is 10dB and the sensitivity of WiGig is set as -78dBm [11].

Table 3. WGig Characteristics

WiGig Parameters	Characteristics
Frequency [GHz]	57.24-70.2
Channel bandwidth [GHz]	2.16
Noise factor [dB]	10
Sensitivity [dBm]	-78

2.2 Regulations in 60GHz

Considering the case where 63-64GHz band frequency will be allocated to ITS service in other countries, the allowed powers of unlicensed services in 60GHz is investigated. As shown in Table 3, considering the environments for WiGig excluding peer to peer fixed services (P2P FS), EU has an equivalent isotropic radiated power (EIRP) of 40dBm for indoor and 25dB for indoor and outdoor services. In US and Canada, the allowed EIRP is identical to that applied to the indoor/outdoor of EU, while the EIRP in Korea is 27dBm for the service except P2P FS [12]-[17].

Table 4. Allowed Power in 60GHz band

Country	Frequency [GHz]	Maximum TX power [dBm]	Maximum EIRP[dBm]	Antenna Gain [dBi]	Comment
EU	57-64	-	25	-	Indoor/ outdoor
		-	40		Indoor
		10	55	45 (min.30)	P2P
US	57-71	-	40 average, 42 peak	-	-
		-	82 average, 85 peak	≥51	P2P
		-	82-2x(51-Ag)	<51	
Canada	57-64	Allowed powers and antenna gains are same as US			
Australia	59.3-62.9	10	51.7 peak	-	P2P
Japan	57-66	10	57	-	P2P
Korea	57-64	10	27	17	-
			57	47	P2P

2.3 Specifications of ITS in 63-64GHz

The specification of ITS in 63-64GHz band is shown in Table 5. The EIRP of ITS is 40dBm and the antenna gains has difference values for road side unit (RSU) and in-vehicle unit (IVS). Also, the antenna gain of ITS IVU depends on the communication environments of vehicle-to-vehicle (V2V) or vehicle-to-pedestrian (V2P). The sensitivities of ITS is set as -86dBm [18].

Table 5. ITS Characteristics in 63-64 GHz band

WiGig Parameters	Characteristics
Frequency [GHz]	63-64
EIRP [dBm]	40
RSU antenna gain [dBi]	23
IVU antenna gain [dBi]	21(V2V), 14(V2P)
Side lobe attenuation [dB]	20
Bandwidth [MHz]	120
Noise factor [dB]	8
Sensitivity [dBm]	-86

3 Coexistence Analysis

3.1 Description of Scenarios

For the coexistence analysis, scenarios that reflect various application environments of ITS and WiGig are established as shown in Fig. 1. As an antenna used for the ITS service has a narrow beam width, the WiGig devices generally operate outside the area of the main lobe of the ITS antenna. Thus, the interference effect is reduced by the side lobe attenuation of the ITS antenna (Scenario 1). However, in the specific case when a WiGig operates in the vehicle, the WiGig receiver can be interfered by the main bean of the ITS RSU (scenario 2). In addition, the cases when the ITU RSU is the victim and interfered by the WiGig transmitter in the general case (scenario 3) and that in the vehicle (scenario 4) are investigated. Finally, the case when the ITS IVU is the victim and interfered by the WiGig in the vehicle is considered (scenario 5).

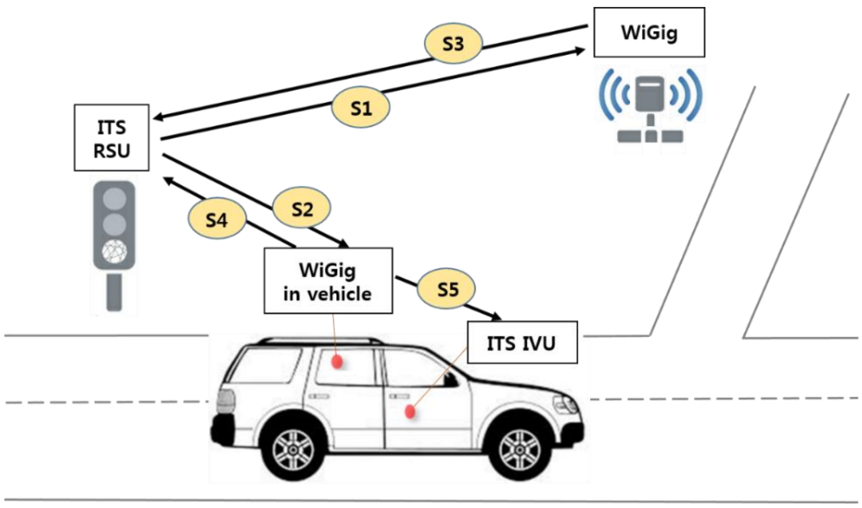

Fig. 1. Scenarios for Analysis

The interferers and victims according to the scenarios are listed in Table 6.

Table 6. Interferers and victims according to the Scenarios

Scenarios	Interferer	Victim
S1	ITU RSU	WiGig
S2	ITU RSU	WiGig in Vehicle
S3	WiGig	ITU RSU
S4	WiGig in Vehicle	ITU RSU
S5	WiGig in Vehicle	ITU IVU

3.2 MCL applying interference criterions

The protection distance between WiGig and ITS is calculated by deriving the minimum coupling loss (MCL), which is the minimum path loss required to avoid interference.

When applying I/N criterion, the MCL is calculated by the following equation.

$$MCL_{I/N} = P_{int} - L_{sidelobe} - N_{vic} + I/N \tag{1}$$

where

- P_{int} is the radiated interference power density inside the victim receiver [dBm/MHz]
- $L_{sidelobe}$ is the side lobe attenuation compared to the main beam of the antenna [dB]
- N_{vic} is the noise power density at the victim receiver [dBm/MHz]
- I/N is the allowed interference to the noise ratio at the victim receiver

The MCL applying C/I criterion is obtained by the following equation.

$$MCL_{C/I} = P_{int} - L_{sidelobe} - ST_{vic} + C/I \tag{2}$$

where

- ST_{vic} is the victim receiver sensitivity considering the antenna gain [dBm/MHz]
- C/I is the allowed carrier to the interference ratio at the victim receiver

3.3 Path Loss model

For the coexistence analysis in 60GHz band, a path loss model combining the gas absorption model and the free path model is applied as eq. (3) [17].

$$PL = 32.4 + 20\log(f) + 20\log(d) + abst(f) \times d \tag{3}$$

where

- f is the applying frequency [MHz]
- d is protection distance between the two systems [km]
- $abst(f)$ is the gas absorption attenuation per distance at the applied frequency [dB/km]

The gaseous absorption attenuation $abst(f)$ is about 10 dB/km at 63GHz, and 7dB/km at 64GHz [19].

3.4 Protection distance between WiGig and ITS

The protection distances between the WiGig and ITS according to the scenarios are obtained by applying the MCL values obtained from eq. (1) and (2) to the path loss model provided in eq. (3)
The interference criterions are identically applied for both WiGig and ITS services. The interference to the noise ratio (I/N) and the carrier to the interference ratio (C/I) are set as shown in Table 7.

Table 7. Interference criterions for WiGig and ITS

Interference criterions	Values
I/N [dB]	-10
C/I [dB]	6

Applying the I/N criterion base on the background noise level of -174dBm/Hz, the protection distances are analysis as show in Table 8. For the analysis, the window barrier loss is set as 15dB and the frequency is set as 64GHz. Comparing the protection distances by country in the equivalent scenario, large protection distance are derives in order of US/Canada, Korea and Europe for outdoor use depending on the magnitude of the transmitted power.

Table 8. Protection distances (I/N=-10dB at 64GHz)

Scenarios	US/Canada	US(outdoor)	Korea
S1	202	41	51
S2	1382	500	587
S3	121	24	30
S4	1031	324	388
S5	906	269	324

In the cases of scenario 1 and 3 where the interference effects are attenuated by the side lobe of the ITS antenna, the protection distances are derived less than other scenarios. However, in scenarios 2, 4 and 5 where WiGig is used in vehicle, the interferences greatly increase, thus, the protection distances between WiGig and ITS reach several hundred meters or more. In particular, in scenario 2, the WiGig in vehicle is directly affected by the interference from the ITS RSU with a high transmit antenna gain, and thus the longest protection distance is derived. On the other hand, in the case of scenario 3 where the WiGig outside the vehicle is the interferer, the protection distance is the lowest.

Applying the C/I criterion, the protection distances are analysis as show in Table 9. In this case, there is a slight difference in the calculated protection distance compared to applying the interference criterion of N/I, however, a generally similar tendency is derived. The longest protection distance is derived in the scenario 2, and the protection distance is the lowest in the case of scenario 3.

Table 9. Protection distances (C/I=6dB at 64GHz)

Scenarios	US/Canada	US(outdoor)	Korea
S1	269	57	71
S2	1616	634	736
S3	79	15	19
S4	790	222	269
S5	684	183	222

3.5 Discussion

The millimeter wave frequency is considered to be strong against interference because the attenuation is large due to gas absorption and the antenna beam is narrow. However, careful considerations about the allowed powers and application environments are necessary for the safe coexistence between the WiGig and ITS according to the coexistence analysis. Under the current regulations, it is concluded that coexistence is possible if the certain protection distance is guaranteed between WiGig and ITS in the environment where WiGig does not exist in the vehicle. However, in case of using WiGig device in a vehicle, there is a possibility of interference even considering the characteristics of such millimeter wave.

As ITS services are directly connected with the safety of vehicles and human life, it is important to secure safety be minimizing such interference. Therefore, it is necessary to limit the application environment of WiGig so that interference with ITS does not occur. However, this method can be a severe constraint on the utilization of WiGig service. The most obvious way to avoid interference is to secure a separate ITS dedicated frequency. If the frequency of the licensed band, not the unlicensed band shared with various services, is utilized in ITS service, there is no need to consider unnecessary interference effects.

An alternative to using the current 60 GHz unlicensed band is to adjust the ITS frequency band that currently spans two channels of WiGig to be within one channel of the WiGig. The ITS frequency band which is allocated in 63-64GHz in EU is overlapped with the 3rd channel (61.56-63.72GHz) and the 4th channel (63.72-65.88GHz) of the WiGig. If the ITS frequency is adjusted to the 62-63 GHz or 64-65 GHz band, it will be within only the one channel of WiGig. Therefore, it is possible to more effectively utilize the frequency while reducing the interference by adding a minimum constraint to the use channel of WiGig.

4 Conclusions

In this paper, we analyzed the coexistence between WiGig and ITS in 60GHz band. The regulations and specifications of various countries in 60GHz are investigated and the protection distances between the WiGig and ITS are derived based on the MCL calculations. As a result of the analysis, when the WiGig is used outside a vehicle, the influence of interference was relatively low, so the protection distance was derives to be within a few tens of meters. On the other hands, when the WiGig is used inside a vehicle, the protection distance increase significantly by more than several hundred meters. The result shows that a careful consideration of frequency allocation for ITS is required for the safe coexistence. The coexistence analysis presented in this paper is expected to be used as a guideline in millimeter wave frequency allocation for ITS.

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