Compatibility Analysis for Frequency Allocation of Short Range Radars using 24GHz Frequency Band

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1. Introduction

A high number of equipments capable of operating in the frequency range 24.05 - 24.25GHz band are now available on the market [1,2,3]. In Korea, there was recently the frequency request for using this band. It covers three types of application operating at 24GHz as ITS (Intelligent Transport System), BSD (Blind Spot Detection), and Auto door sensor. BSD sensors continuously scan the blind spot area in the adjacent lanes of traffic from the side rear view mirror to one car length behind the rear bumper. The ITS is used to measure parameters such as the size of the car, its speed, etc. and fixed Roadside Unit will be considered only.

In this paper, we represent the effect of inter-band interference between ITS and BSD. First of all, interference scenario is defined and the related parameter is collected. And then the analysis is carried out by the single interferer case and aggregate interferer case. Also this result was compared with the result of interference test.

2. Compatibility Analysis Method between ITS and BSD

2.1 Scenario for Compatibility Analysis

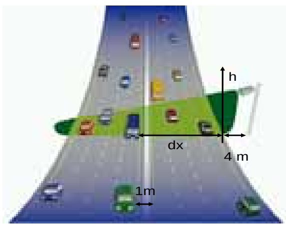

Figure 1: BDS - ITS scenario

Figure1 represent the scenario of interference analysis between BSD and ITS. As a first step approach, a single car/lorry in the middle of a one lane road (3m large) will be considered. The speed of the car will be 100 km/h. The car will go along a right line of +/-500 m in the vicinity of an ITS antenna located at 7 m height and 4 m from the road. The size of the center part of the road is assumed to be 1 m and the road main contains up to 8 lanes, each of them being 3 m large. Both BSD (left and right) are located on the side of the car at an equal distance of 1m from their respective side of the lane. The distance (dx) between the BSD antenna (i.e. on the right side of the car) and the beginning of the road, on the right of Figure 1, is 1 m for the first lane, 4 m for the second… and for the car located on the in the reverse direction of the road, the dx between the BSD (i.e. this time on the left side of the car) in the lane 5 is 14 m. Both interference from BDS on ITS and ITS on BDS will be considered.

2.2 Modelling ITS/BSD

Figure 2 provides an overview of the angles under which the BSD antenna for a car is seen from ITS. The ITS antenna is assumed to point toward the center of the road. And then α , pointing direction of the ITS compared to the vertical, is 53°. Where, Δh represents difference of antenna height between the car/lorry and the ITS Antenna and γ is angle under which the car is seen for $Y = 0m$ and $X = 4m$ (also elevation at this point). The car is assumed to move parallel to the Y axis.

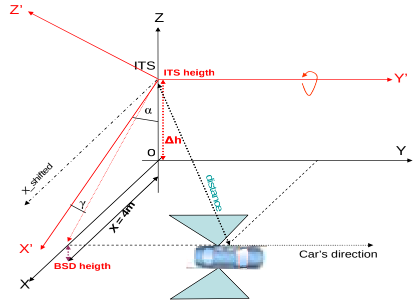

Figure 2: Geographical representation of the angles seen from the ITS Antenna

The coordinates in the reference $(ITS^{'}, Y^{'}, Z^{'})$ are calculated as assuming the translation of Δh in the Z direction and that followed by a rotation around $Y^{'}$ of the angle $\lambda = -(90 - \alpha)$. This gives as following

$$X' = X \cdot \sin\alpha - (Z - \Delta h) \cdot \cos\alpha = dist \cdot \cos(elev) \cdot \cos(az) \quad (1\text{-}1)$$

$$Y' = Y = dist \cdot \sin(elev) \cdot \sin(az) \quad (1\text{-}2)$$

$$Z' = X \cdot \cos\alpha + (Z - \Delta h) \cdot \sin\alpha = dist \cdot \sin(elev) \quad (1\text{-}3)$$

Where $elev$, az are respectively the elevation and the azimuth of the BSD in the ITS referential. (X′, Y′, Z’) is the new coordinates in the referential (ITS, X’, Y’, Z’). (X, Y, Z) is the coordinates in the referential (O, X, Y, Z).

3. Result of Compatibility Analysis between ITS and BSD

3.1 ITS victim

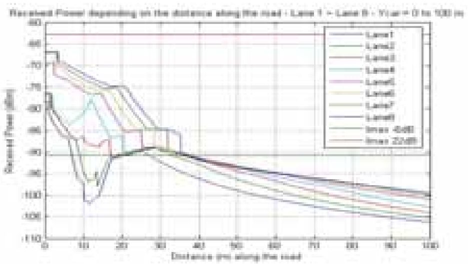

Figure 3: Simulated received power for vehicles located in lanes 1 to 8 driving from 0m to 100m along the road – ITS pointing 53° downward

Figure 3 represents the received power for vehicles located in lanes 1 to 8 driving along the road. The received power is calculated for distance ranging from 0 m to 100 m compared to the reference corresponding to the ITS mast. The BSD e.i.r.p is assumed to be 17dBm and 1 dB attenuation resulting from the bumper is considered. The power falling into the ITS bandwidth – taking into account the bandwidth ratio - is then, assumed to be around 13 dBm. It is quite difficult to find protection criterion for harmful interference threshold, therefore two values may be considered. I/N = 22 dB similarly to the value considered within CEPT for the UWB case [4]. I/N = -6 dB as given in ITU-R Recommendation M.1461-1 [5]. The value of -6dB is used in bands for which the Radiolocation Service has a Primary Allocation while the applications considered may not be considered as part of the radiolocation service. The noise may be calculated assuming Noise Factor is 3 dB and Mixer losses is 6 dB and Noise Floor is -82 dBm/200 MHz or -85dBm/100MHz. The sum of these parameters plus the I/N gives the protection criterion / I max. The occurrence of interference cases depend on the I/N value. In the case of I/N of 22dB the interference criterion is met in all cases while for the I/N of -6dB the number of interference cases is quite important. Interference may occur, in particular, for the I/N of -6dB when the BSD is located in the main lobe of the ITS (lanes 4 to 8). For the first lanes, at a speed of 20 m/s the probability of being in the interference area become quite low for lanes 1 to 4. Therefore, if the size of the road is only 4 lanes, the probability of interference will be quite limited. For the lanes 5 to 8, the BSD is located in the “operating area” of the ITS, while the ITS is also located in the “operating area” of the BSD.

Improvement in compatibility results may result from improvement of the BSD elevation antenna pattern in order to decrease the number of events where the interference situations may occur. In particular, an improvement for angles between 20° to 25° corresponding to lanes 4, would reduce the occurrence of interference in cases where the number of lanes is only 4. The use of lower e.i.r.p for the BSD (20 to 30 dB) lower but this may render the use of BSD non practicable. The decoupling the ITS and BSD antenna by proper location of the ITS antenna; a combination of these mitigations techniques.

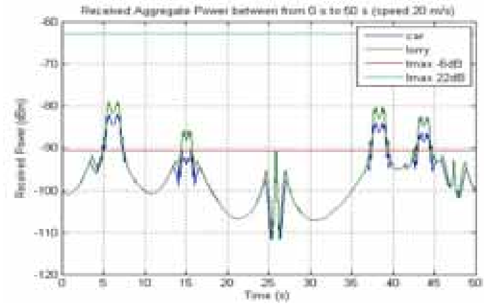

Figure 4: Simulated aggregate received power for vehicles located in lanes 1 to 8 driving along the road – ITS pointing 53° downward

Dynamic simulations were conducted considering 8 lanes and assuming that the cars are randomly distributed along the 8 lanes with a density of 330 car/km2. The overall surface being 1 km x 25 m, this gives 330 x 1 km x 24 m = 8 cars to be distributed. Therefore, 1 car is randomly allocated to each of the lanes. The speed is assumed to be 20 m/s, this implies that after 50s the distance covered by the car is: 20 m/s x 50 s = 1000 m (i.e. + or – 500 m from the ITS location). When, a car is located outside from the + or – 500 m area, a new car is added on the same line starting at the opposite distance. For the aggregate case, it is assumed that the BSD systems will not be transmitting at the same time. Considering a 30 % duty cycle, this will result in a decrease of 5dB for the e.i.r.p. The occurrence of interference cases depends on the I/N value. In the case of I/N of 22dB the interference criterion is met most of the time. However, for the I/N of -6dB the number of interference cases is quite important. Most of the interfering cases are resulting from lanes 5 to 8. In case where the number of lanes is only 4, an improvement in the elevation pattern of the BSD for angle 20° to 30° (reduction of 3-5dB) will reduce the occurrence of interference. An appropriate location of the ITS antenna may also mitigate part of the interference. This may need further studied in order to account for the possible BSD systems. Other mitigation techniques may also need to be considered through the use of different modulations within the ITS. The use sweeping frequencies would help to reduce the interference if the ITS bandwidth was smaller. An activation of the BSD linked with the speed of the vehicle (i.e. 10 km/h) will reduce the cases of interference resulting from the static cases (traffic jam situation). It is not expected to have areas where a high density of ITS antennas will be deployed in a given area therefore this case was not considered.

3.2 BSD victim

Figure 5 provides simulation results for the lanes 1 and 8 for an ITS pointing 53° downward**.** A 1 dB attenuation is assumed for the attenuation resulting from the bumper. The results are similar to those given in section 3.1 except that they have to be shifted by the differences. The maximum antenna gain is ITS (17 dBi) versus BSD (8dBi), and e.i.r.p in the victim bandwidth is +6dB. Therefore the curves given in Figure 3 will be shifted by 3dB down while the interference threshold should be shifted up by 3 dB. The occurrence of interference cases depends on the I/N value. In the case of I/N of 22dB the interference criterion is always met while for the I/N of -6dB the number of interference cases is quite important. In addition, a possible mitigation technique for BSD will be to implement filtering around their transmitting sweeping frequency. Assuming that the BSD “instantaneous” reception bandwidth is 1 MHz this will result in a mitigation factor of 20dB. Then, in all cases the interference criterion will be met.

Figure 6 represents the interference test result on the BSD from ITS. In this test, ITS mounted at 4m height and the MBR/MBM mounted on moving target car along lane 1 and 2.

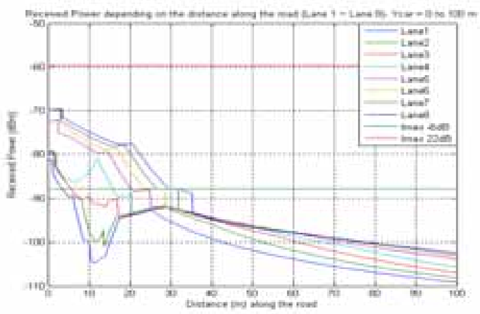

Figure 5: Simulated received power for vehicles located in lanes 1 to 8 driving from 0m to 100m along the road – ITS pointing 53° downward

The other MBR mounted on static tripod in lane_0, face to face versus ITS at 15m distance and 15deg azimuth shift, active Interface to PC for BSD alert evaluation and raw data record. We can confirm the static MBR operate normally under the ITS interference.

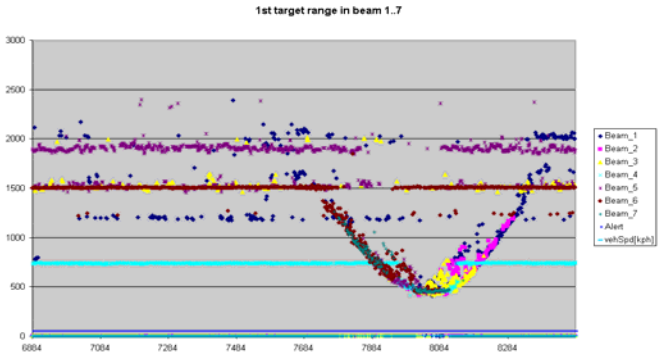

Figure 6: BSD interference test result for ITS

5. Conclusions

This paper discussed on the interference analysis between ITS and BSD. The simulation for single case and aggregate case is done. The occurrence of interference cases depends on the I/N value. Also the interference test was fulfilled but represented some part of that in here. The simulation result that the BSD is victim was compared with interference test result. In this interference test, the BSD is operated normally under the ITS interference. These results can provide technical support for frequency assignment and technical base for regulation.

Acknowledgments

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References

[1] ERC Recommendation 70-03: Short Range Devices(SRD)
[2] ETSI EN 300-440; ETSI EN 300 440-1: Electromagnetic compatibility and range devices; Radio equipment to be used in the 1GHz
[3] FCC PART 15-RADIO FREQUENCY DEVICES
[4] ECC Report 046: Immunity of 24GHz automotive SRRs operating on a non interference and non-protected basis form emissions of the primary Fixed Service operation in the 23GHz and 26GHz frequency bands
[5] Recommendation ITU-R M.1461-1: Procedures for determining the potential for interference between radars operating in the radiodetermination service and systems in other services