Position Paper
Frequency Bands for V2X

CAR 2 CAR Communication Consortium

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Partners of the C2C-CC

Content

1 Introduction

1.1 Abstract

This position paper treats frequency bands for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, collectively known as V2X communication. It will highlight the current challenges with the allocated 5.9 GHz band and the reasoning why the automotive industry is supporting investigations on using a lower carrier frequency for new approaches to achieve V2X such as the 3.4-3.8 GHz.

1.2 Introduction

In 2008, the ECC[1] issued a recommendation (ECC/REC/(08)01) and a decision (ECC/DEC/(08)01) regarding intelligent transport systems (ITS) in the 5.9GHz band, see Figure 1. The very same year the European Union designated a 30 MHz frequency band (5 875-5 905 MHz) for ITS through Commission Decision 2008/671/EC.

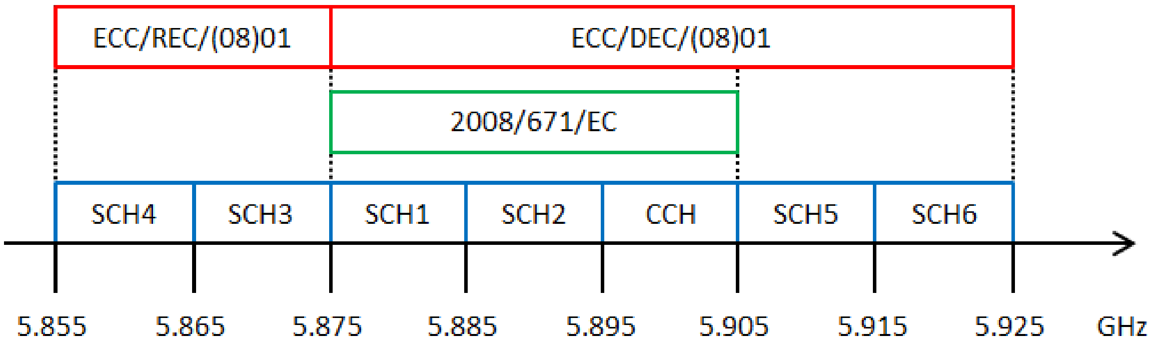

Figure 1. Overview of frequency band at 5.9 GHz.

Standardization took off in 2008 with the creation of Technical Committee on Intelligent Transport Systems (TC ITS) within ETSI[2] with the goal to develop a set of protocols facilitating an interoperable V2X system between vehicles and between vehicles and smart infrastructure in support of traffic safety applications. In 2014, standardization was more or less finalized and the work with deployment issues started. C2C-CC[3] has announced deployment to commence in Europe 2019[4]. The plan is to use the wireless technology ITS-G5 (a.k.a. IEEE 802.11p) for establishing communication between vehicles from different OEMs for initial deployment in the 5.9 GHz frequency band. More information about V2X deployment using ITS-G5 in Europe can be found in [1].

Lately, also V2X initiatives have been taken by the cellular industry. In the next release of cellular specifications from 3GPP planned for July 2017 (Release 14), there will be two modes of V2V operation (*i*) *cellular-assisted V2V (called Mode 3)* and (*ii*) *pure ad hoc V2V (called Mode 4)*. The V2V communication in Release 14 is not targeting operation on the frequency bands,

[1] Electronic Communications Committee (ECC) is one out of three business units of European Conference of Postal and Telecommunications Administrations (CEPT), www.cept.org/ecc

[2] European Telecommunications Standards Institute, www.etsi.org, officially recognized by EU as a European Standards Organization

[3] CAR2CAR Communication Consortium, www.car-2-car.org, non-profit organization collecting OEMs, suppliers, research institutes and universities in Europe, working towards deployment of ITS-G5 at 5.9 GHz

[4] C2C-CC press information, https://www.car-2-car.org/index.php?id=214

which operators have under license, but rather use license-exempt bands such as the 5.9 GHz. To operate in *Mode 3* vehicles need to be in coverage of a base station, that divides the resources among vehicles (using the frequency channel under license by the operator) and then the V2V communication takes place on a license-exempt band (e.g., 5.9 GHz). It should be noted that only vehicles under management of the same operator can enjoy this V2V communication. Mode 4, which on the paper looks like a replacement of ITS-G5, is still benighted and the final details are not sorted out yet. Mode 3 and Mode 4 will hereafter be collectively called LTE-V2X.

ITS-G5 and LTE-V2X cannot co-exist on the same frequency channel due to different approaches on how to access the communication channel (i.e., medium access control, MAC). This would otherwise imply that the 5.9 GHz frequency band would need to be divided between the two technologies ITS-G5 and LTE-V2X, i.e., separate frequency channels for each of the technologies with guard bands [7]. This split would lead to that none of the technologies can carry all traffic safety applications because the frequency band will not be enough for one technology if divided. In summary, sharing the frequency band would lead to a great confusion on the application side and among the OEMs (which technology should carry a certain application on what frequency channel?). The whole idea with using ITS-G5 and have a set of road traffic safety applications attached to different channels within the 5.9 GHz band will diminish and an increase in safety will not occur.

2 The 5.9 GHZ Band

Several hundreds of millions of EUR have been spent on V2X research, trials and standardization, by OEMs, suppliers, road operators as well as by EC and national authorities in general, using the wireless technology ITS-G5 (a.k.a. IEEE 802.11p). Much research efforts have been devoted to issues related to the high carrier frequency at 5.9 GHz and the signal propagation. The high carrier frequency is challenging because the higher carrier frequency the more optical behaviour of the signal. The wavelength at 5.9 GHz is approx. 5 cm and objects larger than the wavelength will affect the signal when it is travelling between sender and receiver. Radio waves having a wavelength smaller than 9 cm have difficulties in penetrating into buildings and through rugged terrain [2]. Best performance is achieved when there is line-of-sight between the antennas of the sender and receiver, respectively. When the line-of-sight component is blocked, the receiving antenna needs to rely upon strong multipath components (replicas of the signal bounced off from objects in the environment) to receive packets successfully.

From an OEM perspective, the antenna installation to achieve maximum performance of the V2X system at 5.9 GHz is crucial. For large vehicles such as trucks, the antenna cannot be placed on the roof of the cabin because the majority of trucks have some kind of trailer or bodywork that is higher than the cabin itself. This implies that putting the antenna on the cabin is not providing good radio coverage behind the truck because the line-of-sight component will always be blocked backwards (however, good coverage in front of the truck). Therefore, two antennas are needed in trucks and those need to be placed in the wing mirrors or on the side of the truck itself to achieve acceptable performance backwards and around the truck.

For antenna installations in cars, curved roofs of today’s passenger cars induce problems. The shark fin, placed at the end of the roof, is not an ideal placement for a 5.9 GHz antenna due to the curvature of the roof. The shark fin contains antennas for, e.g., cellular connectivity and broadcast radio. The reception of signals in these kind of systems is different compared to V2X since the car is receiving signals from a fixed base station above as opposed to in the V2X case from other moving objects where the antennas are at approx. the same height. An ideal placement in a passenger car would be in the middle of the roof, which is from a practical point of view not possible.

In summary, the antenna installation at 5.9 GHz is crucial and this is not depending on the selected wireless technology itself but merely the natural characteristics of wave propagation at 5.9 GHz and the small wavelength. In other words, regardless of technology (ITS-G5 or LTE-V2X) the problems with antenna installations and performance remain due to the high carrier frequency. Further, the distance between the receiver (i.e., radio) and the antenna within a vehicle shall be kept as small as possible because signals at 5.9 GHz exhibit higher attenuation compared to lower carrier frequency signals when propogating in an antenna cable.

Due to the propagation conditions at 5.9 GHz mainly the closest neighbors are reached, which is exactly the intention with safety related applications (100-300 meters in urban environment). This leads to a significantly higher spatial capacity and a natural reuse of frequencies. Much lower carrier frequency such as the 700 MHz band designated for V2V communication in Japan leads to signals travelling much further than needed creating unnecessary interference.

3 The 3.4-3.8, 3.4-4.2 GHZ Band

As pointed out in the section about the 5.9 GHz band, a frequency band with a lower carrier frequency for V2X would be beneficial. The sweet spot for mobile communication is between 300 MHz to 3.5 GHz [2] when one or both communicating parties is moving and the line-of-sight component might be missing (it should be noted that for, e.g., fixed communication links on roof tops a high carrier frequency is of course possible). Too low carrier frequency results in large antennas, which is also impractical from an automotive perspective.

The 3.4-3.8 GHz band would not imply the same difficulties with antenna installations for vehicles at large. However, investigations and new research and development need to be carried out also for this frequency band for vehicles to find a suitable placement maximizing performance. Further, communication at a carrier frequency between 3.4-3.8 GHz does not have harmonics in the 5.9 GHz band, which is an advantage.

In summary, the 3.4-3.8 GHz band is a good compromise between high and low carrier frequencies with regards to propagation characteristics and antenna size.

4 FUNCTIONAL SAFETY ASPECTS

Connected and automated vehicles put the functional safety analysis of cooperative applications in a new perspective. Up until now, OEMs have been working on hazard analysis on the in-vehicle electrical systems using mainly ISO 26262. However, this standard is only addressing the internal architecture and does not include external sources of information coming from other vehicles or backend systems (e.g., clouds), here the more generic ISO 61508 comes into play. Initial hazard analysis of new cooperative and automated applications point to that it cannot rely upon a cellular connection to function properly (this is mainly due to that there is an operator in between that need to guarantee packet delivery).

ITS-G5 might be included in a hazard analysis because it deals with communication directly between vehicles but certain applications such as platooning might require a redundant communication channel to solve the hazard analysis. This redundant communication channel could be LTE-V2X using another frequency band, e.g., 3.4-3.8 GHz. If ITS-G5 and LTE-V2X would both operate at 5.9 GHz, the redundancy would diminish because signals from the two systems would undergo the same channel impairments, i.e., both technologies would fail at the same time. But separating the two V2X technologies on two different carrier frequencies (e.g., 5.9 GHz and 3.4-3.8 GHz) would add true redundancy and the overall system would be, e.g., more robust towards jamming. Therefore, instead of having two different technologies on the same frequency band, the automotive industry supports investigations on having LTE-V2X on a lower carrier frequency band such as the 3.4-3.8 GHz. Besides redundancy, functional safety assessment also has to analyse for example the communication delay. ITS-G5 achieves an end-to-end latency from MAC-layer device1 over the air to MAC-layer device2 of below 2 ms, in all circumstances this latency does not exceed 10 ms.

5 Conclusions

ITS-G5 and LTE-V2V cannot co-exist on the same frequency channel because there are major differences between the wireless systems. In practice, this implies that the 5.9 GHz band would need to be divided between the two technologies with a major confusion regarding when, where, and how to operate different V2X applications as an outcome. Further, if both technologies are operating at 5.9 GHz, they will most likely fail at the same time due to co-channel and adjacent channel impairments, which are not technology specific. Installation of 5.9 GHz antennas is crucial, especially, for trucks due to the high carrier frequency.

LTE-V2V in the 3.4-3.8 GHz band and ITS-G5 in the 5.9 GHz can be redundant technologies for serving connected automated vehicles. V2X applications in need of redundancy can run applications on two different technologies on well separated frequency channels. Further, using two different technologies on different frequency bands will provide extra robustness to the overall V2X system (compare how line-of-sight sensors such as radar and camera provide robustness for different applications).

Deployment of ITS-G5 infrastructure at 5.9 GHz has already started in several cities and in-between cities in Europe. The European C-ITS corridor project [3, 4, 5] has created a corridor of smart infrastructure using ITS-G5 from Rotterdam via Frankfurt to Vienna, and the city Kassel [6] has created a smart city environment. These are just a few examples of deployment initiatives.

In summary, the automotive industry supports investigations regarding using LTE-V2X as well as the upcoming 5G new radio at a carrier frequency between 3.4-3.8 GHz given the rationales provided in this position paper.

6 Appendix 1 – References

6.1 Applicable documents

[1] K. Sjöberg, P. Andres, T. Buburuzan, and A. Brakemeier, “C-ITS Deployment in Europe – Current Status and Outlook,” submitted for publication in IEEE Vehicular Technology Magazine, available online: https://arxiv.org/abs/1609.03876

[2] K. Sjöberg, P. Andres, T. Buburuzan, and A. Brakemeier, “C-ITS Deployment in Europe – Current Status and Outlook,” submitted for publication in IEEE Vehicular Technology Magazine, available online: https://arxiv.org/abs/1609.03876

[3] C-ITS Corridor Germany, http://www.c-its-korridor.de/

[4] C-ITS Corridor Austria, http://eco-at.info/

[5] C-ITS Corridor The Netherlands, https://itscorridor.mett.nl/

[6] Kassel City, www.stadt-kassel.de/aktuelles/meldungen/23148/

[7] ECC Report 172 der WG SE, CEPT Report 55, ECC/DEC/(14)02.

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