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Authors

Amer Aijaz, Volkswagen AG

Dieter Seeberger, Daimler Chrysler AG

Soeren Hess, COMeSafety Frequency Consultant

General Secretary

Rudolf Mietzner

Softlab GmbH

Zamdorfer Straße 120

81677 München / Germany

Phone +49 89 / 9936 1216

E-mail Rudolf.Mietzner@softlab.de

Project Coordinator

Dr. Timo Kosch, BMW Forschung und Technik GmbH

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Executive Summary

ITS technologies for road safety and traffic efficiency based on IVC and R2V have strong needs for a protected spectrum to provide the necessary service quality. An early spectrum allocation will give the industry regulatory certainty and support the development of ITS in Europe.

Reflecting different needs for radio resources and quality of service the various IVC and R2V based applications are divided into three categories, namely: *Critical Road Safety ITS Applications, Safety and Traffic Efficiency ITS Applications and Non-Safety Related ITS Applications*. A frequency band with clear sharing conditions and priority rules must be used for *Critical Road Safety ITS Applications* and *Safety and Traffic Efficiency ITS Applications*, in order to ensure the necessary quality of service.

The spectrum allocation process starts at ETSI, where the spectrum requirements are first specified in a so-called System Reference Document (SRDoc). ETSI's Technical Group 37 (TG 37) has already prepared a SRDoc requesting spectrum for ITS applications in the 5 GHz spectrum. This SRDoc is released as a two part ETSI Technical Report, ETSI TR 102 492-1 and ETSI TR 102 492-2. The SRDoc was the first milestone achieved on the road to spectrum allocation. It was forwarded to the CEPT and is under consideration in the Frequency Management Working Group (WG FM).

In a first step WG FM had decided to perform a full compatibility study, which took place in WG SE 24 and is available as draft ECC Report 101 "Compatibility Studies in the Band 5,855-5,925 MHz between Intelligent Transport Systems (ITS) and other Systems" After public consultation until 15 Dec. 2006 the final report will be provided to the WG FM for their January meeting 2007.

In the progress of the WG FM considerations additional justification of the bandwidth requirements was requested from ETSI and provided to the last FM meeting. WG SE (SE 41) was requested to evaluate the justification of the requested frequency bandwidth in particular whether an efficient spectrum usage would be given by the ITS system.

The Radio Spectrum Committee (RSC) of the EC mandated the CEPT to study harmonised radio spectrum use for safety critical applications of ITS in the European Union. The Committee underlines the political importance of Road Safety and ITS as a flagship in the i2010 policy.

1 Introduction

Human fatalities involved in traffic accidents are a tragic reality of the modern world. The automobile industry and the various EU initiatives are investing a lot of money and efforts to reduce these fatalities. As research work focussed on mitigating the impact of accidents matures, emphasis is now shifting towards avoidance of accidents.

Intelligent sensors play an important role in the research activities on road safety, allowing vehicles to detect a safety hazard and to react to it timely. In most cases, sensors detect hazards when the vehicle itself is already affected. However, through immediate forwarding of hazard warning information to other vehicles via direct vehicle-to-vehicle communication, here referred to as Inter-Vehicle Communication (IVC), other vehicles could avoid running into the hazardous situation. The same wireless communication interface could be used to provide the vehicle with traffic control and road safety information from roadside infrastructure (e.g. traffic lights, traffic signs etc.). We refer to such a communication as Road-to-Vehicle (R2V) communication.

Both IVC and R2V communications are the basis for Intelligent Transportation Services (ITS) providing a huge potential for avoidance of accidents and thereby saving many lives every day.

A common requirement of ITS applications is that they use standardised wireless technologies, protocols and messages in order to ensure interoperability among vehicular and infrastructural ITS systems manufactured by different vendors.

The most popularly deployed and accepted technology offering the throughput required by the whole range of ITS applications is the IEEE 802.11 WLAN standard. The popularity of this standard provides vehicle manufacturer with the economies-of-scale essential for a fast market introduction.

To benefit from advantages of the IEEE 802.11 standard, which was originally designed for stationary nodes, a derivative standard named as IEEE 802.11p is being developed for communication among fast moving nodes and highly dynamic changing networking topologies.

Wireless communication among vehicles, as well as between vehicles and the roadside infrastructure, offers a great potential to avoid life threatening traffic accidents. Standardisation activities for such wireless communication are already underway. The reliability of wireless communication depends on the transmission characteristics of the selected frequency, instantaneous availability of the frequency channel and its protection from interference with other wireless communication systems.

In order to allow for reliable communication of safety-relevant messages among traffic nodes, COMeSafety project, in collabora-

tion with related EU research projects, is pursuing a frequency allocation request with the responsible authorities. This document describes the current status of frequency allocation process supported by the COMeSafety project.

2 Position on need for spectrum allocation

The highly dynamic nature of network topology formed by vehicles on the road means that vehicles could not depend on a constant wireless link state for too long. The performance of the link depends on the channel model describing chosen frequency's behaviour within the communication environment. The underlying communication technology must ensure fast link establishment and cope with temporary link losses, so that the IVC and R2V based ITS applications could have enough time to exchange information. As mentioned previously, IEEE 802.11p has already started work on adapting the IEEE 802.11 standard for R2V and IVC based ITS applications, using the channel model of spectrum allocated for this purpose in the US. Considering the global success of the IEEE 802.11 standard, the derived IEEE 802.11p version has the potential of becoming a single global standard for IVC and R2V communication. In order to help IEEE 802.11p standardisation in considering technical issues that may be specific to the European spectrum allocation for IVC and R2V based ITS services, it is important that an early regulation including spectrum designation is reached in Europe.

3 Position on channel allocation for different ITS application classes

Not all IVC and R2V applications have similar needs for radio resources. In order to ensure efficient allocation of scarce radio resources, it is important to group various IVC and R2V based applications in different categories based on their need for radio resources.

The first such category is the *Critical Road Safety ITS Applications*. These are mainly IVC based ITS applications (though R2V applications may also be possible) characterized by strict time constraints where one vehicle must warn another vehicle of a sudden safety hazard instantaneously. Such applications have strict requirements on communication reliability, tolerable transmission latency, minimum throughput and medium access delays.

Examples of such applications are lane-changing collision warning, emergency brake warning etc. Such applications could help save lives in situations where it is humanly not possible to react fast to a life-threatening situation.

Second category is the *Safety and Traffic Efficiency ITS Applications*. These are mainly R2V communication based ITS applications (although IVC based applications are also possible). The nature of the safety messages communicated by these applications is informa-

tional. Though such messages may not require a vehicle's instantaneous reaction, yet they may warn the driver of traffic situations that must not be ignored. With respect to the *Critical Road Safety ITS Applications*, these applications may be less time-critical and may benefit from central resource management by roadside units, more link stability due to roadside unit's static nature and better antennas.

All other applications, which do not have any impact on driving safety, can be categorized as *Non-Safety Related ITS Applications.* These could be either IVC or R2V communication based ITS applications. Messages communicated by these applications may be purely informational for the driver and shall not require any need of the vehicle's safety systems to react to them. No harm could come to the driver if he ignores or does not receive these messages. Such applications shall not require any special treatment, except that they must work with sufficient effectiveness in a highly dynamic vehicular ad-hoc network.

Due to the huge potential of *Critical Road Safety ITS Applications* and *Safety and Traffic Efficiency ITS Applications* in saving lives by avoiding accidents on the road, these two categories of R2V and IVC based ITS applications should be provided with a spectrum fulfilling their communication requirements.

4 Envisaged frequency channels

Depending on their unique requirements, *Critical Road Safety ITS Applications* and *Safety and Traffic Efficiency ITS Applications* require a higher quality of service than just best effort, such as:

- Instant access to frequency channel
- High signal to noise ratio and low channel interference
- Reliable communication in order to ensure that the safety messages are received by vehicles with high probability

Such quality of service could not be provided to *Critical Road Safety ITS Applications* and *Safety and Traffic Efficiency ITS Applications*, if they are forced to coexist in frequency bands with other wireless communication devices of lesser importance with respect to importance of saving human lives. Within a WLAN band, messages sent by *Critical Road Safety ITS Applications* and *Safety and Traffic Efficiency ITS Applications* could be delayed, corrupted or even disrupted by radio signals of other wireless communication devices using the same frequency as the vehicles.

Hence, a frequency band with clear sharing conditions and priority rules must be used for *Critical Road Safety ITS Applications* and *Safety and Traffic Efficiency ITS Applications*, in order to ensure the necessary quality of service.

COMeSafety [Deliverable 5] titled *Frequency Requirements* makes a strong case for allocating frequency in the 5.9 GHz range for IVC and R2V based ITS services and provides arguments which back

the spectrum allocation proposed in ETSI's System Reference Document. Figure 1 shows the requested spectrum for different types of applications.

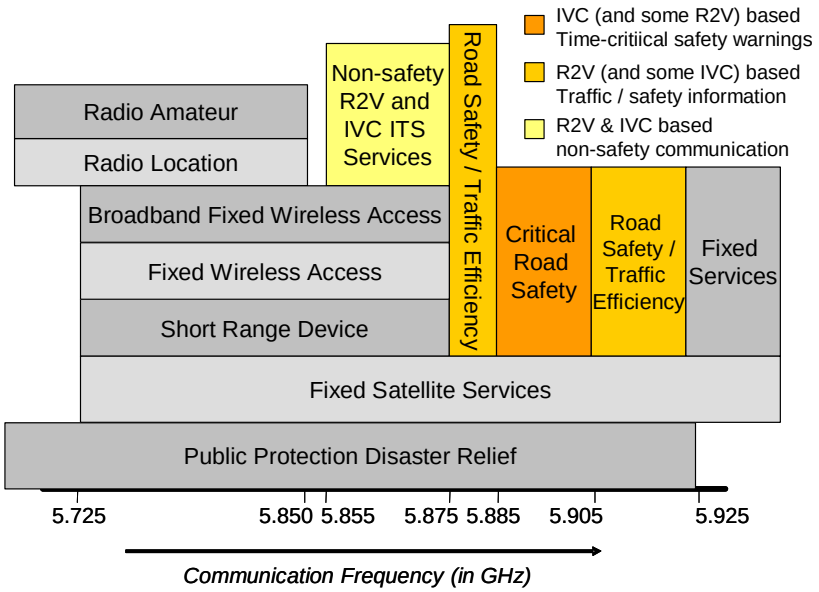

Figure 1: COMeSafety-preferred spectrum allocation requested from ETSI

4.1 System Reference Document

In general, the spectrum allocation process starts at ETSI, where the spectrum requirements are first specified in a so-called System Reference Document (SRDoc). The ETSI group relevant to ITS matters is the Technical Group 37 (TG 37).

TG 37 has already prepared a SRDoc requesting spectrum for ITS applications in the 5 GHz spectrum. This SRDoc is released as a two part ETSI Technical Report, ETSI TR 102 492-1 and ETSI TR 102 492-2. The preferred spectrum is depicted in Figure 1. It fits into the existing European frequency allocation with mobile as a primary service in this range.

In the first part of the SRDoc [SRDoc 5p1] a bandwidth of 20 MHz is requested for "critical road safety" applications, mainly based on IVC, but R2V communications is not excluded.

Critical road safety applications require fast and highly reliable communications, even with the very dynamically changing network topology of IVC. Therefore the channel access and the transmission reliability should not suffer from interference with other communication systems and applications. Clear sharing conditions with primary use rights should provide the necessary fast channel access and link quality.

R2V communications is less vulnerable because with fixed roadside

units the network topology changes are less than with IVC. Furthermore in comparison to vehicles, roadside units allow a higher position of the antenna and provide the possibility of sophisticated antenna concepts with fewer constraints on the antenna size. The consequence is a higher grade of line-of-sight communications and the exclusion of interferer through the antenna beam shape.

Although the requirements for R2V communications are less stringent than for IVC, there is a need to share the spectrum for critical safety applications in order to receive all low latency information on the same channels.

The requested bandwidth of 20 MHz is split into 2 channels of 10 MHz each. One channel serves as a control and application channel and one only as an application channel. For compatibility reasons, the 10 MHz suggested here as a shareable application/control channel, should use the same frequency allocated for it in the US by the FCC, i.e. 5,885-5,895 MHz. The second application-only 10 MHz channel should be adjacent to the control channel at 5,875-5,885 MHz or 5,895-5,905 MHz in order to allow simplified engineering.

The second part of the SRDoc describes the requirement for additional spectrum of 30 MHz envisaged for road *Safety and Traffic Efficiency ITS Applications* [SRDoc 5p2]. As explained in the previous section, these applications are usually based on R2V communication, although IVC is excluded. In comparison to part 1 the applications of part 2 are less time critical, which allows some time for negotiation and channel switching before the transmission of messages. With roadside units there is a possibility of a centralised channel access management channel load distribution.

The introduction of safety system based on IVC is a challenge, because at the beginning there will be a low penetration of equipped vehicles and the possibilities of data exchange between vehicles will be poor. In order to speed up the system introduction it is considered to complete the list of ITS applications by non-safety applications. Examples for this kind of applications are the Internet access at hotspots to download extended travel information or entertainment data like music etc. For this type of R2V applications the WLAN spectrum from 5,470-5,725 MHz is available. Due to the Dynamic Frequency Procedure (DFS), which is required in that band to protect military radar systems, IVC is not permitted. This led to the additional request of 20 MHz of spectrum for *Non-Safety Related ITS Applications in the* SRDoc part 2. Examples of non-safety IVC applications are the exchange of data between different vehicles travelling together or chat between the passengers etc.

The SRDoc was the first milestone achieved on the road to spectrum allocation. It was forwarded to the CEPT and is under consideration in the Frequency Management Working Group (WG FM).

5 Outcome of compatibility studies

5.1 Preliminary results of the compatibility studies

As background for an ITS frequency allocation, CEPT had decided to perform a full compatibility study. Consequently, all sharing possibilities for ITS with all other services existing in the requested frequency range were studied with both ITS as 'interferer' and as 'victim'. The latter is necessary to determine whether some kind of protection of ITS is feasible. The compatibility study took place within the SE WG (SE 24) We were represented in the work and provided additional information requested by the study group. With the results of the compatibility studies the FM WG will consider the spectrum request and take decisions on the frequency allocation for ITS in Europe.

The general conclusions of the compatibility study adopted by the WG SE are as follows:

- In the frequency band between 5,875 MHz and 5,905 MHz, ITS will not suffer from excessive interference from other systems and services.
- In the frequency band between 5,855 and 5,925 MHz, ITS is compatible with all services providing the unwanted emissions below 5,850 MHz are lower than -55 dBm/MHz and unwanted emissions falling above 5,925 MHz lower than -65 dBm/MHz.

This means that the 30 MHz within the frequency band 5,875-5,905 MHz may be provided as a 'protected band' for ITS applications as interference is not caused to or from ITS within this band. Within the bands 5,855-5,875 MHz and 5,905-5,925 MHz ITS equipment will have to meet the required unwanted emission levels in order to use these bands.

The following table shows the compatibility status of ITS services with respect to each existing service in the requested spectrum:

Services and applications	**ITS as interferer**	**ITS as victim**
Radio Amateur (Below 5,850 MHz)	Compatibility is achieved	Compatibility achieved.
FSS (Above 5,725 MHz)	Compatibility is achieved.	Compatibility achieved in most cases taking into account the limited number of earth station and real terrain models
Radiolocation (below 5,850 MHz)	Compatibility assumed with ITS unwanted power of	Between 5,855 and 5,875 MHz ITS may suffer from interfer-

	-55dBm/MHz below 5,850 MHz.	ence.
FS **(above 5,925 MHz)**	Co-frequency: No study needed since few equipment are existing [1] Nearby band: ITS unwanted power below -65dBm/MHz above 5,925 MHz (frequency separation[1] or filtering).	ITS within the band 5,905 – 5,925 MHz may suffer from FS links. In the case of 90 MHz channel spacing, the required frequency separation[1] may be larger (up to 45 MHz). There will be a need to refine the characteristics of the FS to define the exact frequency separation[1]).
SRD **(5,725-5,875 MHz)**	Compatibility is assumed if ITS systems are operating above 5,875 MHz. Mitigation techniques are required in the frequency range 5,855-5,875 MHz.	Mitigation techniques are needed in the frequency range 5,855-5,875 MHz. LBT may avoid interference to ITS.
FWA **(5,725-5,875 MHz)**	Compatibility is achieved if ITS systems are operating above 5,875 MHz. Mitigation techniques are required in the frequency range 5,855-5,875 MHz.	Mitigation techniques are needed in the frequency range 5,855-5,875 MHz. LBT may avoid interference to ITS.

The complete compatibility study is available as draft ECC Report 101 "Compatibility Studies in the Band 5,855-5,925 MHz between ITS and other Systems" and was subject to public consultation until 15 Dec. 2006.

5.2 Protection of ITS spectrum allocation from interfering with new services

The project team SE 24 investigated the compatibility between ITS and existing services. But currently two other services/systems have requested spectrum within the frequency range – the Broadband Fixed Wireless Access (BFWA) within the band 5,725-5,875 MHz and the Public Protection Disaster Relief (PPDR) on a tuning range basis within the frequency range 4,990-5925 MHz. The CEPT has therefore decided to look at all 3 services/systems together and also

[1] offset between the edge of the FS band and the higher frequency used by ITS systems

to consider the aggregate interference from all 3 services to other services in the band. This will take place in the project team SE 41 where the already developed compatibility studies for ITS and BFWA will be used as the basis. The final output of the SE 41 will depend on similar studies for the PPDR systems. PPDR should be limited to disaster relief and not daily ongoing communication with fire brigades etc.

It is important that critical road safety and traffic efficiency applications do not suffer from interference with other services coming up in the future.

As the principle of ‘first come - first served’ is normally true in the case of spectrum allocation, once an ECC or EC Decision regarding IVC and R2V based ITS services is achieved, other applications requesting permission to share this spectrum with ITS applications will have to prove that ITS services will not be adversely affected, through new compatibility studies.

Thus the use of ITS applications in Europe will be based on the interference potential described in the compatibility studies (interference to and from the ITS equipment).

6 Current Status and Future Steps

6.1 Evaluation of the preliminary results from compatibility study

Figure 2 depicts the current status of this compatibility study. The result of the very comprehensive compatibility study is positive in the sense that the 30 MHz requested within the frequency band 5,875-5,905 MHz may be provided as a 'protected band' for ITS applications. In this band ITS is fully compatible if considering the limitations of unwanted emissions below 5,850 MHz and above 5,925 MHz without any further restrictions.

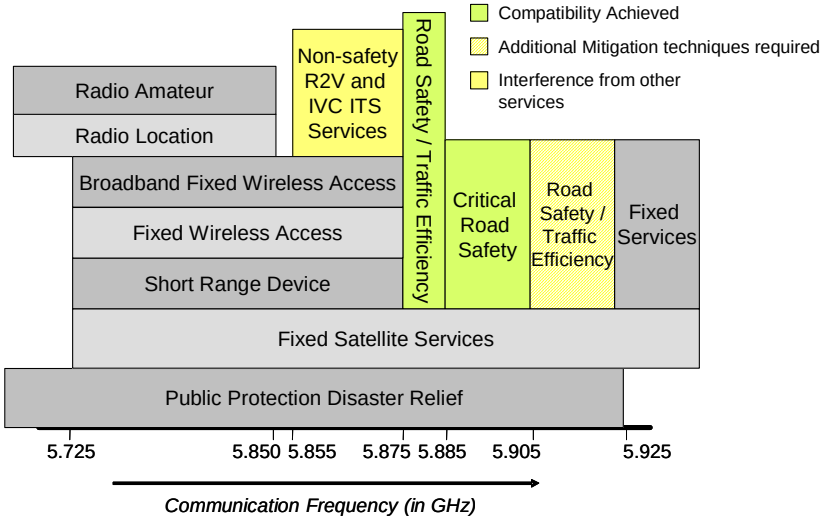

Figure 2: Preliminary outcome of the compatibility study by CEPT

However, not all the bands required in the ETSI system reference document have this advantage.

Within the band 5,855-5,875 MHz, ITS equipment may suffer from interference with radiolocation systems. Beside the required general limitation on the unwanted emission levels, ITS systems will have to implement a mitigation technique to share the spectrum with FWA and SRD.

Within the band 5,905-5,925 MHz, ITS equipment may suffer from interference with Fixed Services and has also to meet the required general limitation on the unwanted emission level.

The requested limitations of unwanted emissions below 5,850 MHz and above 5,925 MHz are hard constrains for the ITS equipment. Even for the 30 MHz in the middle of the requested bandwidth the limitations will not be achieved with the standard IEEE 802.11p chipsets. Potential solutions might include power reduction or additional filtering. While power reduction has an impact on the communication range, external filters might bring up an important cost

factor. Using the spectrum closer to the boundaries of the ITS spectrum the constraints are even worse and possibly a part of the spectrum might serve only as guard band.

In a first feedback manufacturers of communication equipment see not an unsolvable problem in the additional requirements, but at least it will be an expensive solution.

Further discussions on the impact of the result of the compatibility study concerning the usability of the requested ITS spectrum has to take place in the different project teams, forums and initiatives. In the general standardisation process, ETSI TG 37 will have to consider the limitations determined during the compatibility studies and to develop a concept how the available spectrum should be used for the different applications.

6.2 Further processing of compatibility study within CEPT

The draft ECC Report 101 on compatibility for ITS at 5 GHz was under public consultation until 15 December 2006. Afterwards SE 24 will consider all the received comments and it is planned that SE 24 will present the final report to the SE WG for approval in their January meeting 2007.

The project team SE 41 is proceeding their studies on compatibility of the 3 services/systems in the 5 GHz band: BFWA, ITS and PPDR. The Compatibility between BFWA and ITS is already investigated by the SE 24 by considering FWA. There is a frequency co-usage in the range from 5,855-5,875 MHz and for compatibility between the two services a mitigation technology like LBT (Listen before Talk) is required.

For the investigation of the potential aggregate impact from the three new applications on other systems/services following scenarios have been identified:

- 5,725-5,855 MHz: potential combined effect from BFWA and PPDR,
- 5,855-5,875 MHz: potential combined effect from BFWA, ITS and PPDR,
- 5,875-5,925 MHz: potential combined effect from ITS and PPDR.

Further details on those scenarios will have to take into account the outcome from the studies on their mutual interference and coexistence.

Interference between PPDR and ITS is probable, but not yet finally clarified. It is important to consider, that the use of PPDR will be limited to disaster situations and will then be used only at the disaster location. PPDR will not be used for disaster prevention.

6.3 Frequency allocation issues

The WG FM will now consider the frequency allocation issues for ITS and the other 'applications' for the band. The WG FM will consider proposals for the bandwidth to be designated to ITS in Europe and in this context they requested SE 41 to evaluate the justification for the requested frequency bandwidth and whether an efficient spectrum usage would be given by the ITS system.

There already exists a frequency assignment for ITS systems in the band from 63 GHz to 64 GHz. At present the technical parameters for this band are not approved. Recently a system reference document [SRDoc 63] with the required parameters was presented to WG FM.

Considering both frequency ranges for ITS the WG FM asked SRD/MG to determine the most appropriate frequency band for each application. In the view of the ITS industry both technologies in the 5.9 GHz and the 63 GHz frequency bands are not necessarily providing the same service offerings and applications but with the benefits and advantages of each of the bands regarding propagation and bandwidths the two technologies will supplement each other to meet the short and long term road safety requirements in Europe.

The Radio Spectrum Committee (RSC) of the EC mandated the CEPT to study harmonised radio spectrum use for safety critical applications of ITS in the European Union [EC Mandate]. The Committee underlines the political importance of Road Safety and ITS as a flagship in the i2010 policy.

In detail the CEPT is asked to

1. verify the spectrum requirements for safety critical applications in the context of ITS and Co-operative Systems;

2. define the level of protection requested and available in the various frequency bands under consideration;

3. determine the frequency range to focus upon for the safety critical applications, and justify this selection; study the possible use of additional frequency ranges in the future and the opportunity costs of making those bands available;

4. undertake required technical compatibility studies and consider the results of any measurement results, if available, between the safety critical applications and potentially affected radio services for the frequency ranges under consideration, based on expected interference scenarios;

5. consider optimal channel plans for the identified bands, whilst avoiding undue discrimination towards any specific technology;

6. propose a work plan for further future activities on the safety critical applications, if necessary.

In response to the mandate an interim report should be provided until 30 May 2007 and the final report until 28 November 2007. WG FM requested WG SRD/MG to provide the draft interim report

for the next FM meeting in January 2007. COMeSafety is actively supporting this work.

The natural follow on from such a report is an EC Decision on ITS to provide legally binding harmonised bands for ITS in the European Union.

The following timescales are envisaged for activities on ITS spectrum allocation during 2007:

Activity	**Timescale**
SE WG activities to finalise the compatibility studies	March 2007
FM WG Allocation issues and draft ECC Decision Interim Report for the EC Mandate	May 2007
ECC Decision decided by ECC	October 2007
Final Report for the EC Mandate	November 2007
EC Decision in the Radio Spectrum Committee	December 2007

References

[SRDoc 5p1] ETSI TR 102 492-1 V1.1.1 (2005-06)
Electromagnetic compatibility and Radio spectrum Matters (ERM) Intelligent Transport Systems (ITS)
Part1: Technical characteristics for pan-European harmonized communications equipment operating in the 5 GHz frequency range and intended for critical road-safety applications;
System Reference Document
ETSI, Sophia Antipolis, France
http://www.etsi.org

[SRDoc 5p2] ETSI TR 102 492-2 V1.1.1 (2006-06)
Electromagnetic compatibility and Radio spectrum Matters (ERM) Intelligent Transport Systems (ITS)
Part2: Technical characteristics for pan-European harmonized communications equipment operating in the 5 GHz frequency range intended for road safety and traffic management applications;
System Reference Document
ETSI, Sophia Antipolis, France
http://www.etsi.org

[SRDoc 63] ETSI TR 102 400-V1.2.1 (2006-07)
Electromagnetic compatibility and Radio spectrum Matters (ERM)
Short Range Devices (SRD)
Intelligent Transport Systems (ITS)
Road Traffic and Transport Telematics (RTTT)
Technical characteristics communications equipment in the frequency range from 63 GHz to 64 GHz
System Reference Document
ETSI, Sophia Antipolis, France
http://www.etsi.org

[ECCreport101] Draft ECC Report 101
Compatibility Studies in the Band 5855– 5925 MHz between Intelligent Transport Systems (ITS) and other Systems
Lübeck, September 2006
www.ero.dk/consultation

[EC Mandate] Mandate to CEPT to study harmonised radio spectrum use for safety critical applications of Intelligent Transport Systems in the European Union
European Commission, DG INFSO/B4
Brussels, 5 July 2006

[Deliverable 5] COMeSafety Deliverable 05: “Frequency Requirement” (Draft ver1.0) (2006-08)
http://www.comesafety.org

Annex 1 Acronyms

BFWA	Broadband Fixed Wireless Access
CEPT	Conférence Européenne des Administrations des Postes et des Télécommunications
DFS	Dynamic Frequency Procedure
DG INFSO	Directorate General Information Society and Media (EC)
EC	European Commission
ECC	Electronic Communications Committee
ERM	Electromagnetic compatibility and Radio spectrum Matters
ETSI	European Telecommunications Standards Institute
ETSI TR	ETSI Technical Report
FCC	Federal Communications Commission (USA)
FM WG	*see: WG FM*
FS	Fixed Service
FSS	Fixed Satellite Service (Earth-to-Space)
FWA	Fixed Wireless Access
IEEE	Institute of Electrical and Electronics Engineers
ITS	Intelligent Transport Systems
IVC	Inter-Vehicle Communication
LBT	Listen before Talk
PPDR	Public Protection Disaster Relief
R2V	Roadside-to-Vehicle (Communication)
RSC	Radio Spectrum Committee
RTTT	Road Traffic and Transport Telematics
SE WG	*see: WG SE*
SRD	Short Range Device
SRD/MG	Short Range Device Maintenance Group
SRDoc	System Reference Document
TG	Technical Group (ETSI)
WG FM	Working Group Frequency Management (CEPT-ECC)
WG SE	Working Group Spectrum Engineering (CEPT-ECC)
WLAN	Wireless Local Area Network