ECC REPORT 101

Electronic Communications Committee (ECC)
within the European Conference of Postal and Telecommunications Administrations (CEPT)

COMPATIBILITY STUDIES IN THE BAND 5855– 5925 MHz BETWEEN INTELLIGENT TRANSPORT SYSTEMS (ITS) AND OTHER SYSTEMS

Bern, February 2007

EXECUTIVE SUMMARY

In response to a request from ETSI for the designation of spectrum for Intelligent Transport Systems (ITS) around 5.8 GHz, the compatibility studies were conducted between these systems and the existing users.

It was decided to conduct compatibility studies between ITS in general and the following services/systems:

1) Fixed Satellite (E-s) Service,
2) Radiolocation service
3) Non-Specific Short-Range Devices (SRD) introduced in accordance with the Recommendation 70-03,
4) Fixed Wireless Access (FWA) devices
5) Fixed service (above 5925 MHz)
6) Radio amateur (below 5850 MHz)
7) RTTT below 5815 MHz

The report has been completed for the compatibility studies in the band 5855-5925 MHz and the following table shows the conditions under which sharing would be feasible:

Services and applications	Section of this report	ITS as interferer	ITS as victim
Radio Amateur	3.1	Compatibility is achieved.	Compatibility is achieved.
FSS	3.2	Compatibility is achieved.	Compatibility achieved in most cases taking into account the limited number of earth stations and real terrain shielding.
Radiolocation	3.3	Compatibility assumed with ITS unwanted power of -55dBm/MHz, below 5850 MHz.	Between 5855-5875 MHz ITS may suffer from interference.
SRD	3.4	Compatibility is assumed if ITS are operating above 5875 MHz. Mitigation techniques are required in the frequency range 5855 – 5875 MHz.	Mitigation techniques are needed in the frequency range 5855-5875 MHz. LBT may help avoiding interference to ITS.
FWA	3.5	Compatibility is achieved if ITS are operating above 5875 MHz. Mitigation techniques are required in the frequency range 5855 – 5875 MHz.	Mitigation techniques are needed in the frequency range 5855-5875 MHz. LBT may help avoiding interference to ITS.
RTTT	3.6	Compatibility is achieved if ITS are operating with unwanted power less than -65dBm/MHz below 5815 MHz	Interference depend to the antenna beams alignment and is limited to the RTTT communication zone.
FS	3.7 and Annex 2	Co-frequency: no study needed since few systems exist [1]. Adjacent band: ITS unwanted power less than -65dBm/MHz, above 5925 MHz (frequency separation[1] or filtering required).	ITS within the band 5905-5925 MHz may suffer from interference.

Conclusions of compatibility studies

Between 5875 MHz and 5905 MHz ITS will not suffer from excessive interference resulting from other systems/services.

Between 5855 MHz and 5925 MHz, ITS are compatible with all services providing:

- their unwanted emissions power below 5850 MHz is less than -55dBm/MHz;
- their unwanted emissions power below 5815 MHz is less than -65dBm/MHz or alternatively, a mitigation technique would be to switch off ITS while within the RTTT communications zone;
- the unwanted emissions power above 5925 MHz is less than -65dBm/MHz;
- mitigation techniques are implemented by ITS in the frequency range 5855-5875 MHz to ensure compatibility with FWA and SRD equipments.

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LIST OF ABBREVIATIONS

Abbreviation	**Explanation**
ACEA	Association des constructeurs Européens d'Automobiles
AF	Activity Factor
CEPT	European Conference of Postal and Telecommunications
DFS	Dynamic Frequency Selection
DVS	Digital Video Sender
ECC	European Electronic Communications
e.i.r.p.	Equivalent isotropically radiated power
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
FS	Fixed Service
FSS	Fixed Satellite Service
FWA	Fixed Wireless Access
GSO	Geo Stationary Orbit
ITU	International Telecommunication Union
ITS	Intelligent Transport System
IVC	Inter-Vehicle-Communication
LBT	Listen Before Talk
MCL	Minimum Coupling Loss
OBU	On-Board Unit
OoB	Out Of Band emissions
P-MP	Point-to-Multipoint
P-P	Point-to-Point
PSD	Power Spectral Density
RL	Radiolocation Service
RSU	Road Side Units
RTTT	Road Transport and Traffic Telematics
R2V	Roadside-to-Vehicle Communications
SRD	Short Range Devices
TPC	Transmitter Power Control
V2R	Vehicle-to-Roadside Communications
WAS/RLANs	Wireless Access Systems including Radio Local Area Networks

Compatibility studies in the band 5855– 5925 MHz between Intelligent Transport Systems (ITS) and other systems

1 INTRODUCTION

This report is intended to analyse the compatibility between Intelligent Transport Systems (ITS)within the frequency band 5855-5925 MHz, in accordance with ETSI TR 102 492 [2, 3], and other services.

Following initial recommendation from WG FM to consider the control channel as 1 x 10 MHz channel (5885 – 5895 MHz) and the second 1 x 10 MHz channel in the upper part of the ISM band (5865 – 5875 MHz) and additional requests as well as clarifications from WG SE the study concentrated on following issues:

- Impact of ITS in the band 5865 – 5875 MHz on the other services;
- Sharing between two 10 MHz ITS channels and other systems in the band 5875 – 5925 MHz.

2 DESCRIPTION OF ITS

2.1 Overview

Inter-Vehicles Communication (IVC) systems have been a topic in research since the second half of the eighties. Although many technical key challenges were solved in a number of research activities, IVC systems have not been implemented in vehicles so far. Reasons for this are the absence of an appropriate frequency band which grants effective protection for road safety applications and the lack of suitable commercially available (and cheap) radio hardware.

Europe was pioneering the use of radiocommunications with the RTTT DSRC system at 5.8 GHz. The WLAN (IEEE 802.11) technology, now available as a mass product, fulfils technical as well as business requirements. Therefore, radiocommunications systems in the 5 GHz range can today offer communications with a high data rate, ranges up to 1 000 m, low weather-dependence, and global compatibility and interoperability.

The connectivity required by the applications can be summarized as:

1) Inter-Vehicles (IVC) (this includes multi-hop routing involving several vehicles):
    - Linear (e.g. for convoys of vehicles);
    - Vehicle cluster covering several lanes (e.g. for lane management, overtaking assist).
2) Vehicle to roadside (uplink) V2R and roadside to vehicle R2V (downlink):
    - One vehicle to beacon;
    - Beacon to one vehicle;
    - Beacon to many vehicles (broadcast, short range and long range);
    - Beacon to selected vehicles.
3) Cluster of vehicles communication, including to roadside beacon.

A certain penetration of equipped cars is required to realize the advantage of the system for traffic safety and safety applications.

Non-safety applications would rely on data exchange between vehicles and fixed stations. Hotspot access at refuelling stations could give the possibility to get information about restaurants, sightseeing points, or traffic data along the anticipated route.

For market roll-out, it is important that the use of the communications system is available both for official (i.e. safety, public information and road management) and for commercial purposes, so that viable business cases can be established.

The standards for operation must be such that an evolutionary roll-out is possible, with backward-compatibility so as not adversely to affect early entrants.

Lists of applications for Inter-Vehicles and Vehicle-Roadside Communication have been investigated by various projects and groups, and the number of applications is very high (see Table A.1.2.1.1 in the SRDoc 102 492-1 [2]).

Hereafter are presented some typical applications involving ITS devices:

- Work zone (road works) warning. Special cones in work zones can be equipped as communicating beacons to warn upcoming traffic about lane closures or speed limits (green cars have ITS).

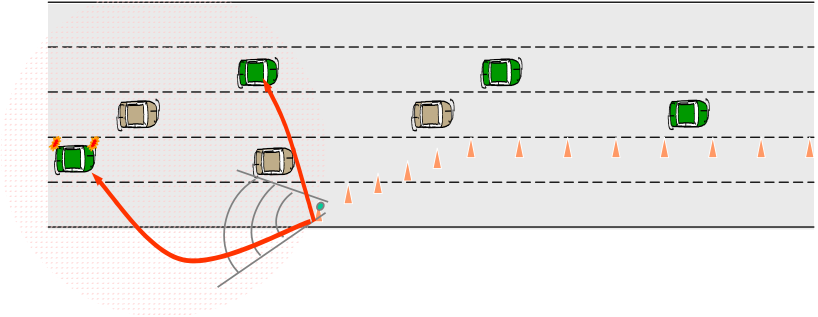


Figure 1: Work zone warning

- Hazard warning with car-to-car communication. Vehicles switching on their warning lights send out a warning message to the following traffic to avoid rear-end collisions.

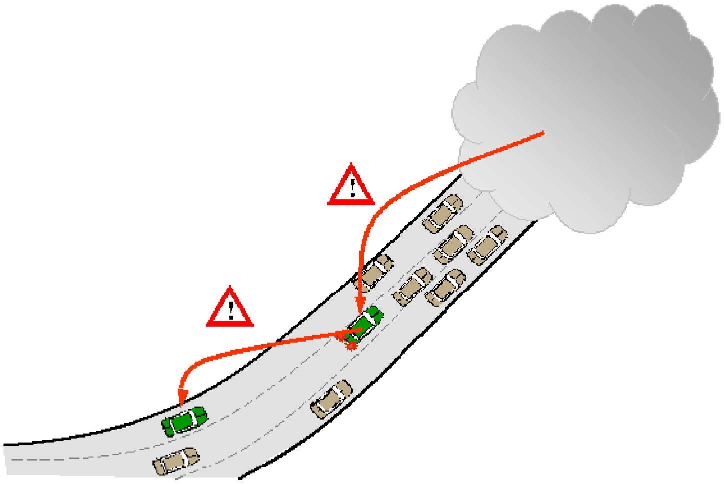


Figure 2: Hazard warning

2.2 Technical description

Parameter	Value	Comments
Frequency stability	1ppm	This figure takes account of the frequency tolerance allowed by IEEE 802.11a [4], together with the expected Doppler variation from a vehicle closing speed of 400 km/h.
Maximum radiated power (e.i.r.p.)	Equipment classes: A 10 dBm B 20 dBm C 33 dBm	Transmitter power control (TPC) with a 30 dB range.
Antenna beam shape/gain	RSU: 10 dBi OBU: 5; 8 dBi	See section 2.5
Polarization	TBD	Circular and linear polarisations each have certain benefits. Some degree of rejection of emissions from oppositely travelling vehicles may be required.
Modulation scheme	BPSK QPSK 16QAM 64QAM	This is the standard set within IEEE 802.11a [4] and p [5].
Data rates	3/4.5 /6/9/ 12/18 /24/27 Mbit/s	This is the standard set within IEEE 802.11a [4], j [6] and p [5]. As an option two channels may be combined to produce double data rates (up to 54 Mbit/s). Default data rate is 6Mbit/s.
Channel Bandwidth	10 MHz, option 20 MHz	This is the standard set within EEE 802.11a [4], j [6] and p [5].
Communication mode	Half-duplex, broadcast	Half-duplex and broadcast are believed to be adequate for the applications considered to date.
Receiver sensitivity	-92dBm/MHz	Based on a -82 dBm for a bandwidth of 10 MHz
Protection criterion	C/I=6dB	For a classical BPSK signal

Table 1: Systems parameters (not exhaustive)

Communication channels will be open for the applications within the respective usage category (either road safety related or not, i.e. used for traffic management).

The required power levels (e.i.r.p.) range from 3 dBm to 33 dBm to achieve communication distances of up to 1000 m.

2.3 Premises on ITS spectrum

Part 1 of the SRDoc [2] covered the minimum requirements for critical road safety communication with a 10 MHz channel for control and traffic, and a 10 MHz channel for traffic only. These channels should be designated as contiguous channels. The frequency bands are intended for both IVC (Inter-Vehicle Communications) and RVC (Roadside-to-Vehicle) communication but with the emphasis on IVC communication.

Part 2 of the SRDoc [3] includes 30 MHz of additional spectrum requirements for road safety and traffic efficiency applications for both IVC and RVC communication with the emphasis being on RVC communications, while the Part 1 focuses on IVC communications. This spectrum is needed in a predictable sharing situation and should therefore have spectrum designations above the ISM band. Furthermore Part 2 includes additional requirements for 20 MHz of spectrum for non-safety related IVC and RVC communication. For this part of the requirement a predictable sharing situation is not important and the frequencies could be designated within the ISM band.

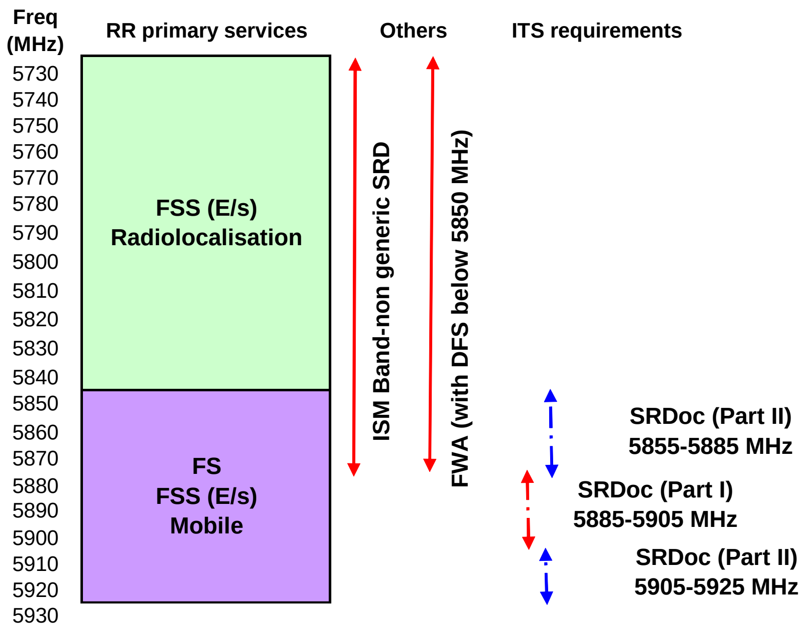


Figure 3: ITS spectrum requirements

This proposal provides an alignment with the existing frequency allocation in US (see FCC Regulation [7]), Canada and Mexico.

2.4 Unwanted emission level of ITS devices

Unwanted emission levels are given by Rec. ITU-R SM.1541 [8] for the out of band domain and SM.329 [9] and ERC Recommendation 74-01 [10] for the spurious domain.

Table 2 provides unwanted emissions for ITS , which are considered in the following sections of this report.

	E.i.r.p (dBm/MHz)	±4,5 MHz Offset (dBr)	±5,0 MHz Offset (dBr)	±5,5 MHz Offset (dBr)	±10 MHz Offset (dBr)	±25 MHz Offset (dBr)	>±25 MHz Offset (dBr)
Class A	0	0	-10	-20	-28	-40	-60
Class B	10	0	-16	-20	-28	-40	-60
Class C	23	0	-26	-32	-40	-50	-70

Table 2: Attenuation (dBr) below the e.i.r.p. (dBm/MHz)

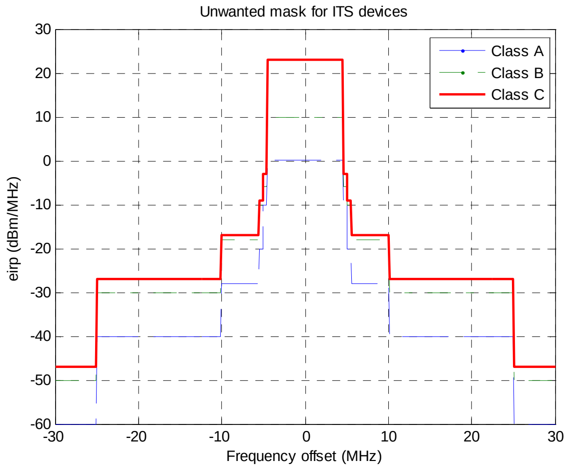


Figure 4: Power spectral density of ITS device

2.5 Antenna pattern

2.5.1 Typical antenna pattern

Two kinds of ITS devices are considered:

- OBU (On Board Unit): mobile ITS device mounted on a car;
- RSU (Road Side Unit): fixed ITS device placed on the ground.

The antenna patterns for these two devices are shown in Fig. 5.

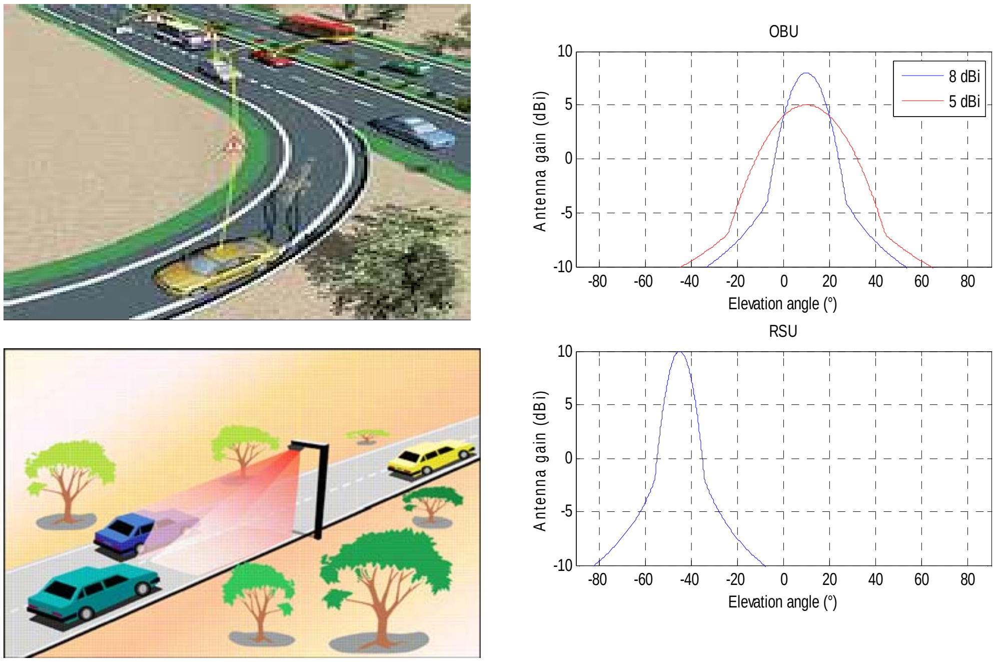


Figure 5: OBU and RSU antenna patterns

It is an essential design feature of communications between vehicles, or between vehicles and local infrastructure beacons, that they are directed more or less horizontally in a typical omni-directional pattern with typically 8dBi gain in the horizontal plane.

2.5.2 Conformity of existing antennas to Rec. ITU-R F.1336 antenna patterns

Following Rec. ITU-R F.1336 [11], the expression of antenna gain in dBi at elevation angle θ in degrees is given by:

$$G(\theta) = \max\left[G_1(\theta), G_2(\theta)\right] \tag{1}$$

with

$$G_1(\theta) = G_0 - 12\left(\frac{\theta}{\theta_3}\right)^2 \tag{2}$$

$$G_2(\theta) = G_0 - 12 + 10\log\left[\left(\max\left\{\frac{|\theta|}{\theta_3}, 1\right\}\right)^{-1.5} + k\right] \tag{3}$$

where:

θ: absolute value of the elevation angle relative to the angle of maximum gain (degrees)

θ_3: the 3 dB beamwidth in the vertical plane (degrees)

k= 1.2 the sidelobe factor

The relationship between the gain (dBi) and the 3 dB beamwidth in the elevation plane (degrees) is:

$$\theta_3 = 107.6 \times 10^{-0.1\,G_0} \qquad \text{for omni-directional antenna} \qquad (4)$$

There are commercially developed, roof mount antennas for the US DSRC spectrum from 5850 MHz to 5925 MHz. Figure 7 shows how such an antenna is fixed on the vehicle roof. The antenna pattern for this assembly is shown in Figure 6. The Omni-directionality is fully achieved and the elevation beam peak is near 10°.

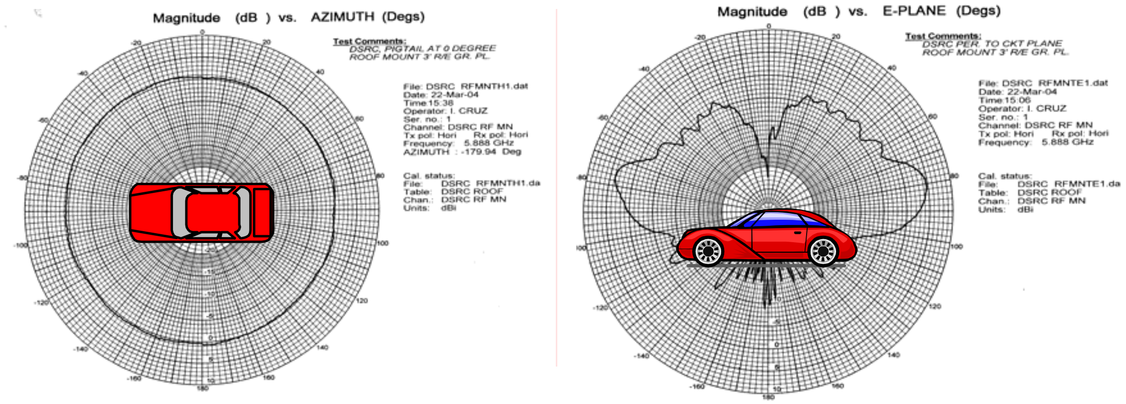


Figure 6: Example of a commercially developed antenna pattern

The figure below shows the agreement of this existing antenna to the antenna patterns recommended by ITU-R F.1336 [11] with k=1.2 as a relevant sidelobe factor.

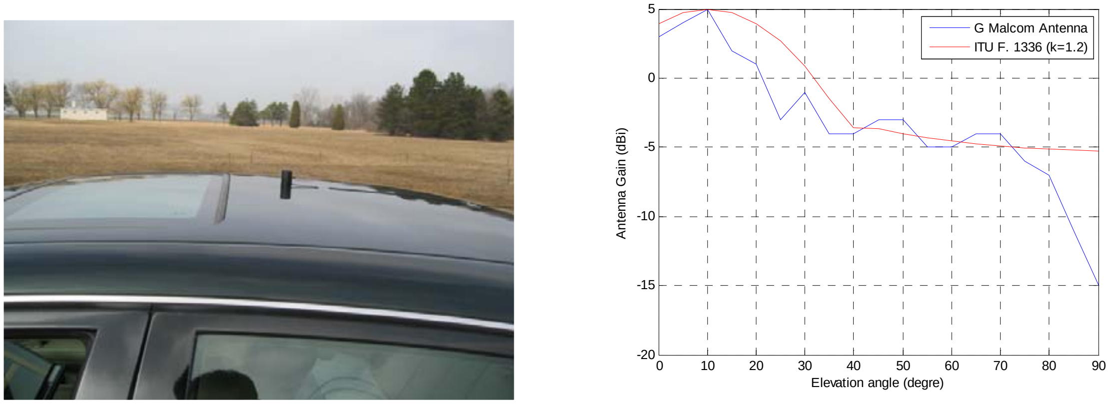


Figure 7: Ground-plane radio antenna with magnet roof mount (left side) and agreement of antenna's pattern with the ITU F.1336 omni directional pattern (right side)

2.6 Propagation model

The calculations developed in the different compatibility studies used the same propagation model as in ECC Report 68 [11]. In the table 6.2.2 of this report, data about FWA Central Station (CS) is provided, representative of all FWA devices located at high elevations, whereas the FWA Terminal Station (TS) models FWA devices deployed at low elevations. It is then proposed to consider ITS system as TS, therefore the breakpoints and exponents corresponding to the TS case will be used.

It means that propagation losses L_{FS} are considered as the conventional expression up to d_0 and corrected expression beyond.

$$L_{FS} = \begin{cases} 20Log\left(\frac{\lambda}{4\pi d}\right) & d \le d_0 \\ 20Log\left(\frac{\lambda}{4\pi d_0}\right) - 10n_0 Log\left(\frac{d}{d_0}\right) & \text{if } d_0 < d \le d_1 \\ 20Log\left(\frac{\lambda}{4\pi d_0}\right) - 10n_0 Log\left(\frac{d_1}{d_0}\right) - 10n_1 Log\left(\frac{d}{d_1}\right) & d > d_1 \end{cases} \quad (5)$$

Another propagation model is also proposed in the ITS SRDoc ETSI TR 102 492-1 [2] [3]. Assumptions are a first breakpoint distance d_o at 15m and exponent beyond $n_o=2.7$. Separation distances presented below will investigate both cases.

	Urban	**Suburban**	**Rural**	**ETSI**
Breakpoint distance d_0 (m)	64	128	256	15
Pathloss factor n_0 beyond the first break point	3.8	3.3	2.8	2.7
Breakpoint distance d_1 (m)	128	256	1024	1024
Pathloss factor n_1 beyond the second breakpoint	4.3	3.8	3.3	2.7

Table 3: Parameters of propagation

2.7 Parameters used for the interference assessment

The technical parameters used for interference assessment are given in the following table.

Receiver Characteristics		
Receiver bandwidth	10	MHz
Receiver sensitivity	-82	dBm
Antenna gain (see note 1)	8	dBi
Receiver sensitivity at antenna input	-100	dBm/MHz
C/I	6	dB
Allowable Interfering Power at receiver antenna input	-106	dBm/MHz
Transmitter Characteristics		
Bandwidth	10	MHz
Tx_{out}, e.i.r.p	33	dBm
Tx_{out} e.i.r.p per MHz	23	dBm/MHz
Assumed value for TPC (see note 2)	8	dB
Net Tx_{out} e.i.r.p	15	dBm/MHz
Antenna Gain	8	dBi

Table 4 : Technical requirements of ITS devices

Note 1: The value of 5 dBi was also used in the sections dealing with FSS (see sections 3.2.1 and 3.2.2). The value of 8 dBi was used when considering emissions received or transmitted in the main beam of the ITS.

Note 2: When addressing the impact of ITS on FSS the value of TPC was calculated to account of all ITS that may be located in the footprint of the considered satellites. In the compatibility studies dealing with a single case interference scenario, a TPC factor of 8 dB is taken into account. ITS are expected to communicate with an average range of 500m instead of 1000m which imply a reduced emitted power (TPC factor about 14dB with an average range of 300m).

3 COMPATIBILITY BETWEEN ITS AND OTHER SERVICES/SYSTEMS

RR Article 5 [13] depicts the frequency allocations for the frequency ranges between 5830-6700 MHz.

<table>
<tr><th colspan="3">Allocation to services</th></tr>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td>5 830-5 850
FIXED-SATELLITE (Earth-to-space)
RADIOLOCATION
Amateur
Amateur-satellite (space-to-Earth)
5.150 5.451 5.453 5.455 5.456</td><td colspan="2">5 830-5 850
RADIOLOCATION
Amateur
Amateur-satellite (space-to-Earth)
5.150 5.453 5.455</td></tr>
<tr><td>5 850-5 925
FIXED
FIXED-SATELLITE (Earth-to-space)
MOBILE
5.150</td><td>5 850-5 925
FIXED
FIXED-SATELLITE (Earth-to-space)
MOBILE
Amateur
Radiolocation
5.150</td><td>5 850-5 925
FIXED
FIXED-SATELLITE (Earth-to-space)
MOBILE
Radiolocation
5.150</td></tr>
<tr><td>5 925-6 700</td><td colspan="2">FIXED
FIXED-SATELLITE (Earth-to-space)
MOBILE
5.149 5.440 5.458</td></tr>
</table>

Table 5: Frequency Allocations (RR) 5830-6700 MHz

In addition to these radiocommunications services, the reported compatibility studies are also dealing with some specific applications, like FWA and SRD. The list of considered scenarios is given in the following table, with references to the relevant sub-sections of this report.

Victim	Interferer	Section of this report
Radio Amateur	ITS	3.1
FSS	ITS	3.2
Radiolocation	ITS	3.3
SRD	ITS	3.4
FWA	ITS	3.5
RTTT	ITS	3.6
FS	ITS	Section 3.7 and An.2

Table 6: List of compatibility studies considered in this report

3.1 Compatibility between ITS and the amateur service

This issue was already dealt with in ECC Report 68 [12] for the case of FWA devices. The finding of that report:

‘‘The results of worst-case calculations show that interference would occur if the Amateur Service and FWA were to operate co-channel within close proximity (of the order of 100s of m or a few km). However, taking account of the various mitigation factors (identified in section 6.6.3) it is considered

that sharing is feasible. The results are assumed to address also the case of the impact from FWA into the Amateur-Satellite (s-E) Service.''

Additionally noting that the ITS and the amateur service would co-exist not co-channel but in adjacent bands, the same conclusion is valid.

3.2 Compatibility between ITS and FSS

3.2.1 Impact of ITS on FSS

This section provides methods and results concerning the impact of ITS on geostationary satellite networks of the Fixed Satellite Service (FSS) in the frequency band 5875-5925 MHz.

The proposed methodology is mainly derived from that of ECC Report 68 [12] on compatibility studies between FWA and other systems. Section 3.2.1.1 is dealing with all further ITS assumptions involved in the aggregate effect for the interference assessment not presented in section 2.7. Section 3.2.1.2 describes the methodology to achieve interference level from ITS devices at the FSS satellite receiver. Section 3.2.1.3 carries out the compatibility study for eight satellites whose characteristics come from the ITU MIFR. Finally, Table 13 summarises all these results. Annex 1 exhibits some antenna footprints over the European area.

3.2.1.1 Impact of the traffic density on ITS parameters

The European Automobile Manufacturers Association (ACEA - Association des constructeurs Européens d'Automobiles) estimates a number of vehicles in Europe being 214 million. The assumptions here lead to an approximately 4.5 million of active OBUs. Expected number of RSUs is 500 000. The number of infrastructure RSUs is lower than OBUs. In addition, the infrastructure antennas are mostly high-gain (more than 12 dBi), directed at an angle towards the ground. This means that direct lobes towards GSO will be very low. Therefore, the overall noise contribution from RSUs is minimal and the interference from OBUs will be totally dominant as noise contributors.

The number of ITS devices per country is derived from initial ETSI analysis and updated with the available figures for 2005 [14]. Table 7 shows the main concentration of vehicles in the five main EU market (Germany, France, Italy, UK and Spain).

Country	Number of Cars (x1000)	Percentage %
Austria	4335	2.02
Belgium	5330	2.48
Denmark	2301	1.07
Finland	2506	1.17
France	35144	16.38
Germany	48225	22.48
Great Britain	31971	14.91
Greece	4765	2.22
Ireland	1681	0.78
Italy	37682	17.57
Netherlands	7894	3.68
Portugal	5140	2.40
Spain	23048	10.75
Sweden	4466	2.08
UE15	214489	100.00

Table 7: Number of Cars in Europe

The table below provides some interesting figures concerning length of total road network per category and country in 2002 (in thousand km) [15] http://www.erf.be/

Country	Motorway	Principal road	Major road	Minor road	Total (x1000 km)
Austria	1.6	10.3	23.7	98	**133.6**
Belgium	1.7	12.6	1.3	133.3	**149**
Denmark	0.9	0.7	10	60.2	**71.8**
Finland	0.6	13.3	28.4	36.4	**78.7**
France	12	26.1	358	586	**982.1**
Germany	11.7	41.3	177.9	NA	**230.9**
Great Britain	3.4	48.2	113.1	207.3	**371.9**
Greece	0.7	9.1	31.3	75.6	**116.7**
Ireland	0.1	5.3	11.6	78.7	**95.7**
Italy	6.6	46	114.9	312.1	**479.6**
Netherlands	2.2	6.7	57.5	59.4	**125.8**
Portugal	1.7	12	59		**72.6**
Spain	11.2	24.5	139.3	489.7	**664.6**
Sweden	1.5	15.4	82.9	115	**214.8**

Table 8: Length of total road network (European Road Statistics 2005)

3.2.1.1.1 Activity factor AF

Let N_{ITS} be the amount of ITS devices which can be allowed on a 10 MHz channel bandwidth. An activity factor is incorporated to take into account the fact that all vehicles are not generally in use 24 hours/24hours.

It consists on considering the activity factor hourly along a day. One can expect a number of vehicles (and consequently a number of active ITS devices) which not remains constant during the day. For example, most people are concerned by an early trip on the morning and come back on the evening.

As an example, the table below presents some data [16] concerning the 24-hour hourly traffic distribution observed by the New Jersey Department of Transportation. These values are based on existing 24-hour weekday traffic volumes. These percentages are used in this present study to estimate some levels of traffic densities and hence activity factor.

Hour (AM)	Interstates, Freeways, and Other Expressways	Principal Arterials	Major Arterials	Minor Arterials	Hour (PM)	Interstates, Freeways, and Other Expressways	Principal Arterials	Major Arterials	Minor Arterials
12-1	1.3	1.2	0.7	0.8	12-1	5.2	5.8	6.2	5.8
1-2	0.8	0.6	0.4	0.4	1-2	5.2	6.0	6.1	5.8
2-3	0.7	0.5	0.3	0.2	2-3	5.6	5.9	6.6	6.2
3-4	0.7	0.5	0.3	0.2	3-4	6.5	6.3	7.3	7.4
4-5	0.9	0.8	0.4	0.4	4-5	7.4	6.5	7.5	8.0
5-6	1.9	1.9	1.1	1.2	5-6	7.5	6.8	7.3	7.1
6-7	4.6	4.1	3.6	4.6	6-7	6.1	5.9	6.0	6.1
7-8	6.6	6.4	6.8	7.7	7-8	4.6	5.0	4.7	4.9
8-9	6.8	7.0	7.4	7.3	8-9	3.9	4.1	3.4	3.6
9-10	5.4	5.6	5.9	5.3	9-10	3.4	3.6	2.9	3.1
10-11	4.9	5.2	5.6	4.7	10-11	2.8	2.7	2.1	2.3
11-12	5.1	5.7	5.9	5.3	11-12	2.1	1.9	1.5	1.6

Table 9: Hourly traffic density tables per types of roads

The corresponding drawings are presented below.

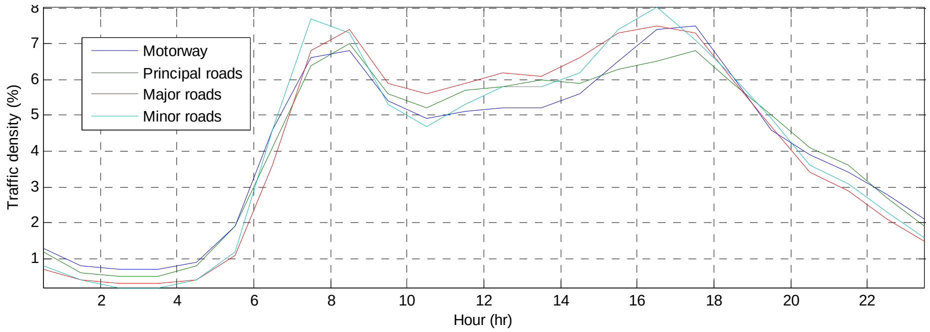


Figure 8 : Hourly traffic density

A total of 268 million vehicles were in circulation at the beginning of 2003 within the EU accounting for 79.8% of this figure [17].

Vehicle density on the entire European road network is 46.6 vehicles/km. Vehicle density in the EU is higher (mean of 56 vehicles/km) with the largest figures seen in Germany (208 vehicles/km, considering only main roads and 77 vehicles/km also considering urban and local roads), Italy (78.4 vehicles/km), United kingdom (77.1) and the lowest in Ireland (17.8 vehicles/km) and Sweden (21).

Country	Length (x1000 km)	Vehicle density (/km)	Number of vehicle on the road network	Peak traffic density (%)	Car park in use (x1000)	AF (%)
Austria	133.6	*56*	7481600	8	4335	13.81
Belgium	149	*56*	8344000	8	5330	12.52
Denmark	71.8	*56*	4020800	8	2301	13.98
Finland	78.7	*56*	4407200	8	2506	14.07
France	982.1	*56*	54997600	8	35144	12.52
Germany	230.9	77	17779300	8	48225	2.95
Great Britain	371.9	77.1	28673490	8	31971	7.17
Greece	116.7	*56*	6535200	8	4765	10.97
Ireland	95.7	17.8	1703460	8	1681	8.11
Italy	479.6	78.4	37600640	8	37682	7.98
Netherlands	125.8	*56*	7044800	8	7894	7.14
Portugal	72.6	*56*	4065600	8	5140	6.33
Spain	664.6	*56*	37217600	8	23048	12.92
Sweden	214.8	21	4510800	8	4466	8.08
EU15	3787.8	*56*	212116800	8	214489	7.91

Table 10: Estimation of a typical activity factor per country (European Road Statistics 2005)

The table above aims to detail the calculation of the activity factor AF. The second column recalls the length of the road network for each country as depicted in Table 10. The next column gives some typical vehicle density. If no figure is available, the average vehicle density (56 vehicles/km) is chosen. By multiplying these two numbers, one can find an estimation of the number of vehicle on the road network. This stands for the volume of traffic. By multiplying this figure with the peak traffic density (as shown in *Figure 8*), one can calculate the number of active ITS devices. The activity factor is then calculated considering the ratio of this quantity over the number of cars in use. So, this activity factor AF aims to reflect that at a given time, all cars are not on the road network and do not move together.

One has to mention that these figures could be refined with more consistent data on density vehicles per country. For the time being, an average figure was considered. 8% represents an average *AF* estimation.

Hence, the amount of active ITS devices is equal to:

$$N_{ITS}.AF \qquad (6)$$

One has to highlight that it is important to develop realistic traffic flow model to estimate some figures like number of vehicles/road length unit, hourly traffic density or intensity.

3.2.1.1.2 TPC estimation

The link budget described in SRDoc ETSI TR 102 492-1 [2] is calculated in dBm as:

$$P_e = P_s + G_s + G_e + L \qquad (7)$$

where P_e is the received power in dBm, P_s is the transmit power in dBm, G_s is the transmit antenna gain in dBi, G_e is the receive antenna gain in dBi, and L is the path loss in dB. Note that e.i.r.p. = $P_s + G_s$. Propagation losses follow the ETSI model laws as depicted in section 2.7.

For example, with an e.i.r.p. of 33 dBm, $G_s = G_e = 5$ dBi, and $d = 1000$ m we obtain a received power of $P_e = -82$ dBm. This stands for the ITS sensitivity. With an average range of 300m more appropriate for urban areas, the left margin allows the introduction of a 14dB TPC factor.

3.2.1.1.3 An estimation of duty cycle

Some typical values for the density of vehicles in urban/suburban areas are:

- Paris: 167 – 186 vehicle/km^2
- Munich: 145 – 160 vehicle/km^2
- Berlin: 145 – 160 vehicle/km^2

A typical density *De* could then be considered. Let *De* be 170 vehicles/km². Each active transmitter occupies a circular area with a radius given by the communication range (300m). This means an area of $S = \pi r^2 = 0.3 km^2$ with $N=S.De\sim 50$ vehicles.

As a basic function of the ad hoc networking each unit keeps a neighbourhood table, where all the units are listed, which can be reached by single hop communication. For the updating of the neighbourhood table each unit has to send once per second a Beacon-message.

The duration of this message is about 400 µs. Units which have sent an application message, do not send a Beacon, because the all the required information for the neighbourhood table is also part of each application message. The duration of an application messages can be assumed to be 500 µs on average. The retransmission of an application message, e.g. as required for the application Cooperative Collision Warning, will be typically 1/sec.

As a consequence, each ITS device transmits one message (either a beacon or an application one) during 500µs every second. It is assumed that all ITS devices located within a cell whose centre is a given emitting ITS, are not able to transmit anything at the same time. Otherwise, for one emission, one can estimate a potential of *N* relays. It means that the number of communication links increases exponentially following a law as N^{Nhops} where N^{Nhop} stands for the number of hops since the beginning of the transmission. This potential is quite unlimited and could cause some congestion problems.

Hence, the resulting duty cycle is the possibility for active ITS devices to transmit messages simultaneously. It is then assumed that this duty cycle *dc* is:

$$dc=1/N \tag{8}$$

where N is the number of ITS devices located within a single cell whose radius is related to the average communication range (300m).

Finally, considering an amount of N_{ITS} devices located within Europe, it is assumed that the whole quantity of <u>active</u> devices <u>simultaneously</u> in use is:

$$dc.N_{ITS}.AF = \frac{N_{ITS} AF}{N} \tag{9}$$

One has to observe that the lower the average transmission range, the higher TPC, the higher duty cycle.

3.2.1.2 Method of calculating interference from ITS devices on a FSS Satellite Receiver

3.2.1.2.1 Methodology

This study adopts the T/T approach described in Appendix 8 of the ITU Radio Regulations [13] in order to assess the impact of interference from a large number of ITS devices located within CEPT countries in the field-of-view of a satellite antenna beam. Although not directly suitable for use in the case of inter-service sharing, it does provide a very simple method of analysing the impact without much knowledge of the characteristics of the carriers used on the satellite network requiring protection. In this technique, the interference from the ITS into the satellite receivers is treated as an increase in thermal noise in the wanted FSS network and hence is converted to a noise temperature (by considering the interference power per Hz) and compared with tolerable percentage increases in noise temperature.

Consequently, the limitation of increase of equivalent noise temperature is expressed by the following relationship:

$$\frac{\Delta T_{sat}}{T_{sat}} < Y\% \qquad (10)$$

where:

- ΔT_{sat} : apparent increase in the receiving system noise temperature at the satellite, due to an interfering emission (K);
- T_{sat} : the receiving system noise temperature at the satellite referred to the output of the receiving antenna of the satellite (K)
- Y : noise increase allowed (1% and 6%).

3.2.1.2.2 High elevation angle

In the case under consideration here, ΔT_{sat} is the contribution of aggregate emissions from ITS devices at the input of satellite receiver.

Assuming that ITS interference can be treated similarly to thermal noise, the following relationship can be assumed (linear scale, not dB):

$$\Delta T_{sat} = \frac{eirp_{ITS}\, g_{sat}}{kl} \qquad \text{°K} \qquad (11)$$

where:

- $eirp_{ITS}$: the aggregate e.i.r.p. spectral density of the ITS transmitters in the satellite beam and in the direction of the satellite (W/Hz);
- g_{sat} : the gain of receiving antenna of the satellite in the direction of ITS interferer (linear ratio, relative to isotropic);
- k : Boltzmann's constant (1.38×10^{-23} J.K^{-1});
- l : uplink Free Space path loss (linear power ratio). Note that this could also include gaseous attenuation due to absorption by water vapour and oxygen molecules;

Combining the equations (10) and (11), we find:

$$eirp_{ITS} = Y\left(\frac{g_{sat}}{T_{sat}}\right)^{-1} kl \qquad \text{W.Hz}^{-1} \qquad (12)$$

For a nominal range of 38 000 km (distance from Europe to a satellite at the same longitude) and a carrier frequency of 5.9 GHz, the propagation loss *L=10Log(l)* is about 200 dB.

The logarithmic form of equation (12) is then:

$$\begin{aligned} EIRP_{ITS} &= 10Log(Y) - 29 - 10Log\left(\frac{g_{sat}}{T_{sat}}\right) \qquad \text{dB(W.Hz}^{-1}\text{)} \qquad (13) \\ &= 10Log(Y) - 29 - G_{sat} + 10Log(T_{sat}) \end{aligned}$$

where:

- $EIRP_{ITS}=10Log(eirp_{ITS})$ dBW/Hz the expression of $eirp_{ITS}$ in dB,
- Y: noise increase allowed (1%),
- $G_{sat}=10Log(g_{sat})$ the value in dB of the linear satellite antenna gain
- G_{sat}/T_{sat} is the figure of merit "G/T" at the satellite receiver input derived from the values of G_{sat} and T_{sat} given in Table 1

A particular value of *L=200dB included eventually gas attenuation about 0.5 dB,* a carrier frequency of 5900 MHz and a distance of 38000 km have been assumed to establish the second term of the right-hand side of equation (13): An additional propagation loss factor is taken into account due to attenuation given by NLOS conditions and more especially brought by absorbers. Let 5 dB be this additional loss. It is applied when elevation angle is lower than 20°.

One can note that allowable aggregate interference is then directly linked with apportionment factor Y% and FSS receiver characteristics (figure of merit).

The maximum aggregate power towards satellite from ITS devices in one channel can be computed as:

$$EIRP_{ITS_{channel}} = EIRP_{ITS} + 10Log(B_{Hz})\ dBW \tag{14}$$

where B_{Hz} is the channel bandwidth in Hz.

Assuming that only one type of ITS device is considered (Class C for example), the number of active devices *N* (transmitting simultaneously in only one channel) can be computed as

$$10Log(N) = EIRP_{ITS_{channel}} - EIRP_{device_{channel}} \tag{15}$$

where e.i.r.p.$_{\text{device-channel}}$ is the e.i.r.p. in dBW/channel of one single ITS device in the direction of the satellite.

3.2.1.2.3 Low elevation angles

For low elevation satellites (e.g. those at longitudes further East that require quite low elevation angles from some countries in north-west Europe) directivity of ITS antennas in elevation plane becomes much more significant because the satellite may easily lie within the main lobe of the ITS antenna. In this case, it is more appropriate to consider the following parameters as variables: i) the e.i.r.p. of the devices; ii) the path loss to the satellite; iii) the receive gain of the satellite.

This results in a more generalised equation where the link noise temperature contribution from a single ITS device can be expressed from Eq. (11) as follows:

$$\Delta T_{sat\ j} = \frac{G_{sat_j}\, eirp_{ITS_j}(\theta_j)}{kl_j} \quad \text{K} \tag{16}$$

then,

$$\Delta T_{sat\ j} = \sum_j \Delta T_{sat\ j} = \frac{1}{k}\sum_j \frac{G_{sat_j}\, eirp_{ITS_j}(\theta_j)}{kl_j} \quad \text{K} \tag{17}$$

where:

- $eirp_{ITS_j}(\theta_j)$: the e.i.r.p. spectral density of a *single* ITS transmitting antenna in the satellite beam and in the direction of the satellite (W.Hz^{-1}))
- θ: the off-axis angle of the ITS antenna towards the satellite in the elevation plane (degrees).
- N : the total number of ITS devices within the satellite footprint.

Here, the e.i.r.p. for each ITS device must be calculated in the direction of the satellite.

Note that G_{satj} and l_j will not be constant, but will vary with the position of ITS device within the satellite beam and its distance to the satellite. For completeness, this can also be taken into account if more information is available.

Equation (17) is then used to aggregate the interference e.i.r.p from all ITS devices until T_{sat} given by equation (10), divided by T_{sat}, reaches the specified threshold.

3.2.1.3 Interference assessment

3.2.1.3.1 Description of the scenario

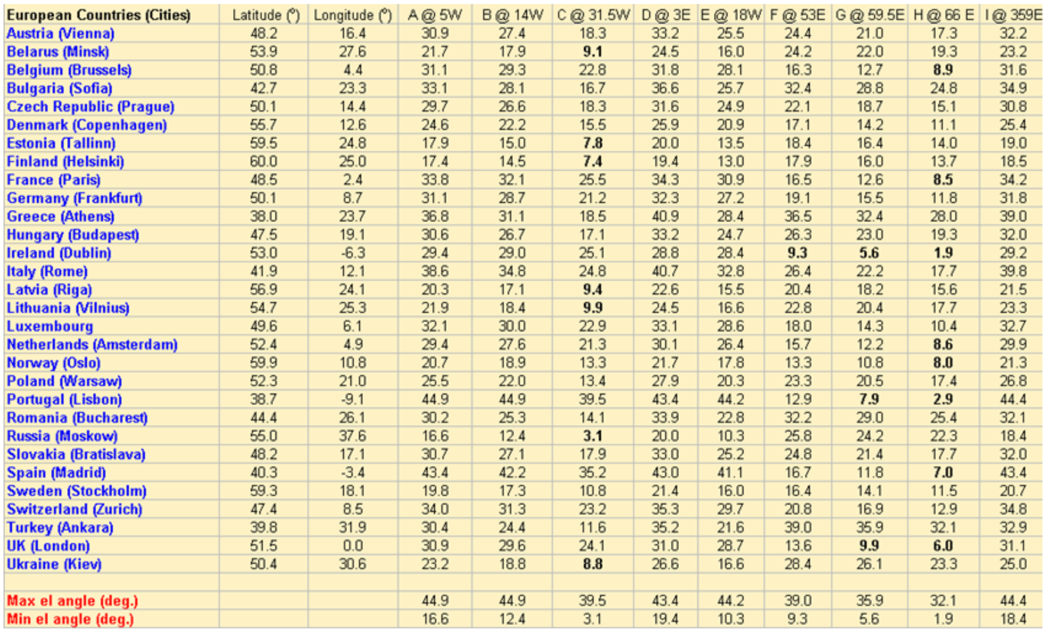
The value of the aggregate e.i.r.p. spectral density permitted for the 1% noise increase at the satellite receiver is then calculated by applying directly equations 13 and 17 with the satellite parameters provided in Table 11.

Satellite	Satellite orbital position	Receiver Gain, G_{sat} (dBi)	Satellite Receiving System Noise Temperature T_{sat} (K)	Aggregate e.i.r.p. dB(W Hz^{-1}) from ITS for $\Delta T_{sat}/T_{sat}$=1%	Satellite Name	Administration	Beam
A	5° West	34	773	-54.1	TELECOM-2B	Fr	MET
B	14° West	26.5	1200	-44.7	EXPRESS-2	RUS	ZER
C	31.5° West	32.8	700	-53.3	INTELSAT8	USA	9Z3
D	3° East	34	773	-54.1	TELECOM-2C	Fr	MET
E	18° West	32.8	700	-53.3	INTELSAT8	USA	9Z3
F	53° East	26.5	1200	-44.7	EXPRESS-5	RUS	ZER
G	59.5° East	34	1200	-52.2	No longer existing		
H	66° East	34.7	700	-55.2	INTELSAT9	USA	9Z1
I	359° East	32.8	700	-53.3	INTELSAT8	USA	9Z3

Table 11: Derivation of acceptable aggregate e.i.r.p. from interferers in the satellite beam

3.2.1.3.2 Deployment of ITS devices

ITS devices are spread in each of the main city of the EU15 countries taking into account the ITS antenna discrimination in the elevation plane in the direction of the chosen satellite.
Table 12 provides the elevation angles from most countries in Europe to the satellites listed in Table 11, using the latitude and longitude of a representative city in each country.



European Countries (Cities)	Latitude (°)	Longitude (°)	A @ 5W	B @ 14W	C @ 31.5W	D @ 3E	E @ 18W	F @ 53E	G @ 59.5E	H @ 66 E	I @ 359E
Austria (Vienna)	48.2	16.4	30.9	27.4	18.3	33.2	25.5	24.4	21.0	17.3	32.2
Belarus (Minsk)	53.9	27.6	21.7	17.9	**9.1**	24.5	16.0	24.2	22.0	19.3	23.2
Belgium (Brussels)	50.8	4.4	31.1	29.3	22.8	31.8	28.1	16.3	12.7	**8.9**	31.6
Bulgaria (Sofia)	42.7	23.3	33.1	28.1	16.7	36.6	25.7	32.4	28.8	24.8	34.9
Czech Republic (Prague)	50.1	14.4	29.7	26.6	18.3	31.6	24.9	22.1	18.7	15.1	30.8
Denmark (Copenhagen)	55.7	12.6	24.6	22.2	15.5	25.9	20.9	17.1	14.2	11.1	25.4
Estonia (Tallinn)	59.5	24.8	17.9	15.0	**7.8**	20.0	13.5	18.4	16.4	14.0	19.0
Finland (Helsinki)	60.0	25.0	17.4	14.5	**7.4**	19.4	13.0	17.9	16.0	13.7	18.5
France (Paris)	48.5	2.4	33.8	32.1	25.5	34.3	30.9	16.5	12.6	**8.5**	34.2
Germany (Frankfurt)	50.1	8.7	31.1	28.7	21.2	32.3	27.2	19.1	15.5	11.8	31.8
Greece (Athens)	38.0	23.7	36.8	31.1	18.5	40.9	28.4	36.5	32.4	28.0	39.0
Hungary (Budapest)	47.5	19.1	30.6	26.7	17.1	33.2	24.7	26.3	23.0	19.3	32.0
Ireland (Dublin)	53.0	-6.3	29.4	29.0	25.1	28.8	28.4	**9.3**	**5.6**	**1.9**	29.2
Italy (Rome)	41.9	12.1	38.6	34.8	24.8	40.7	32.8	26.4	22.2	17.7	39.8
Latvia (Riga)	56.9	24.1	20.3	17.1	**9.4**	22.6	15.5	20.4	18.2	15.6	21.5
Lithuania (Vilnius)	54.7	25.3	21.9	18.4	**9.9**	24.5	16.6	22.8	20.4	17.7	23.3
Luxembourg	49.6	6.1	32.1	30.0	22.9	33.1	28.6	18.0	14.3	10.4	32.7
Netherlands (Amsterdam)	52.4	4.9	29.4	27.6	21.3	30.1	26.4	15.7	12.2	**8.6**	29.9
Norway (Oslo)	59.9	10.8	20.7	18.9	13.3	21.7	17.8	13.3	10.8	**8.0**	21.3
Poland (Warsaw)	52.3	21.0	25.5	22.0	13.4	27.9	20.3	23.3	20.5	17.4	26.8
Portugal (Lisbon)	38.7	-9.1	44.9	44.9	39.5	43.4	44.2	12.9	**7.9**	**2.9**	44.4
Romania (Bucharest)	44.4	26.1	30.2	25.3	14.1	33.9	22.8	32.2	29.0	25.4	32.1
Russia (Moskow)	55.0	37.6	16.6	12.4	**3.1**	20.0	10.3	25.8	24.2	22.3	18.4
Slovakia (Bratislava)	48.2	17.1	30.7	27.1	17.9	33.0	25.2	24.8	21.4	17.7	32.0
Spain (Madrid)	40.3	-3.4	43.4	42.2	35.2	43.0	41.1	16.7	11.8	**7.0**	43.4
Sweden (Stockholm)	59.3	18.1	19.8	17.3	10.8	21.4	16.0	16.4	14.1	11.5	20.7
Switzerland (Zurich)	47.4	8.5	34.0	31.3	23.2	35.3	29.7	20.8	16.9	12.9	34.8
Turkey (Ankara)	39.8	31.9	30.4	24.4	11.6	35.2	21.6	39.0	35.9	32.1	32.9
UK (London)	51.5	0.0	30.9	29.6	24.1	31.0	28.7	13.6	**9.9**	**6.0**	31.1
Ukraine (Kiev)	50.4	30.6	23.2	18.8	**8.8**	26.6	16.6	28.4	26.1	23.3	25.0
Max el angle (deg.)			44.9	44.9	39.5	43.4	44.2	39.0	35.9	32.1	44.4
Min el angle (deg.)			16.6	12.4	3.1	19.4	10.3	9.3	5.6	1.9	18.4

Table 12: Latitude/Longitude of representative cities in European countries & Elevation Angle in degrees to the satellites given in Table 11

One can consider that propagation losses and discrimination angle would be quite the same for all location in a same country. Spreading ITS devices in a given country does not bring any significant impact. Otherwise, some little variations could be observed from one country to another.

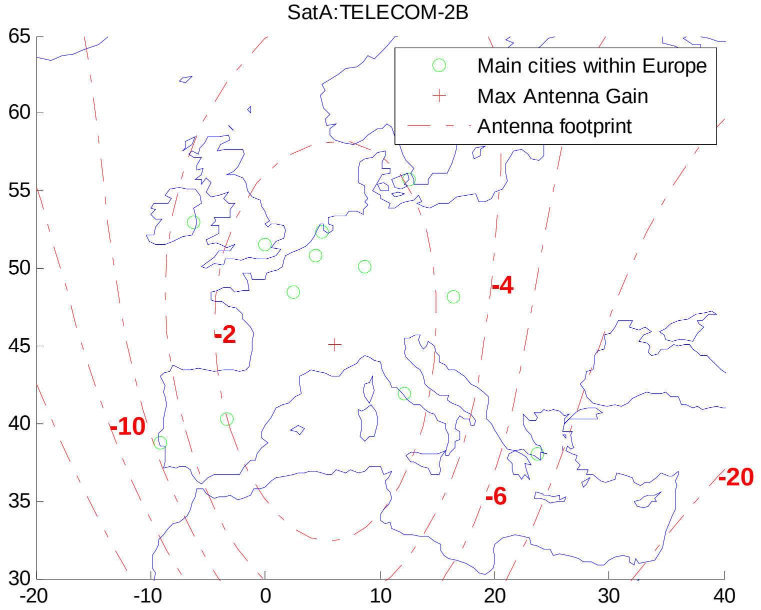


Figure 9: Impact of ITS location within Europe for the satellite A

The Annex 1 shows the same impact on the other satellites (from B to I).

Satellite footprints are given by available figures on the ITU MIFR. One could access to these data with the ITU GIMS software.

The e.i.r.p. of each ITS device in the direction of satellite was calculated by deriving the transmit power from the on-axis e.i.r.p. and then adding the gain (in dBi) in the elevation plane for the appropriate elevation angle from the country being considered (see section 3.2.1.2.2 and 3.2.1.2.3 for further details).

The effects of power control (TPC factor), activity ratio (duty cycle) are then taken into account to improve the total amount of ITS devices in CEPT countries.

3.2.1.3.3 Results

Table 13 summarises existing results for Satellites A to I except G. The shown values are the greatest amount of ITS devices that can be deployed in the whole EU15 area. These results are obtained using the assumptions outlined earlier.

One has to recall that the results of the first two rows stands for the number of equipments which can be implemented on board vehicles, the next two for the number of active equipments which means ITS devices able to transmit something and the last two for the number of active equipments which can transmit simultaneously. All these figures are relating to a single channel (10 MHz bandwidth).

	Max # of ITS in satellite beam (millions) **per 10 MHz channel**		Max # of ACTIVE ITS in satellite beam (millions) **per 10 MHz channel**		Max # of ACTIVE ITS in satellite beam (millions) **per 10 MHz channel simultaneously in use**	
	e.i.r.p. = 33 dBm (OBU Gmax=5dBi)		e.i.r.p. = 33 dBm (OBU Gmax=5dBi)		e.i.r.p. = 33 dBm (OBU Gmax=5dBi)	
Satellite	$\frac{\Delta T_{sat}}{T_{sat}} = 1\%$	$\frac{\Delta T_{sat}}{T_{sat}} = 6\%$	$\frac{\Delta T_{sat}}{T_{sat}} = 1\%$	$\frac{\Delta T_{sat}}{T_{sat}} = 6\%$	$\frac{\Delta T_{sat}}{T_{sat}} = 1\%$	$\frac{\Delta T_{sat}}{T_{sat}} = 6\%$
A	>300	>300	>30	>30	>0.6	>0.6
B	>300	>300	>30	>30	>0.6	>0.6
C	>300	>300	>30	>30	>0.6	>0.6
D	195	>300	19.3	>30	0.4	>0.6
E	>300	>300	>30	>30	>0.6	>0.6
F	>300	>300	>30	>30	>0.6	>0.6
G	NA	NA	NA	NA	NA	NA
H	>300	>300	>30	>30	>0.6	>0.6
I	128	>300	12.6	>30	0.26	>0.6

Table 13 : Maximum number of ITS devices (Class C) in Europe to meet T_{sat}/T_{sat} noise temperature thresholds for Satellites A to I

One has to recall that an additional propagation loss (up to 5 dB) is considered if elevation angle of the satellite from the ITS device is lower than 20°.

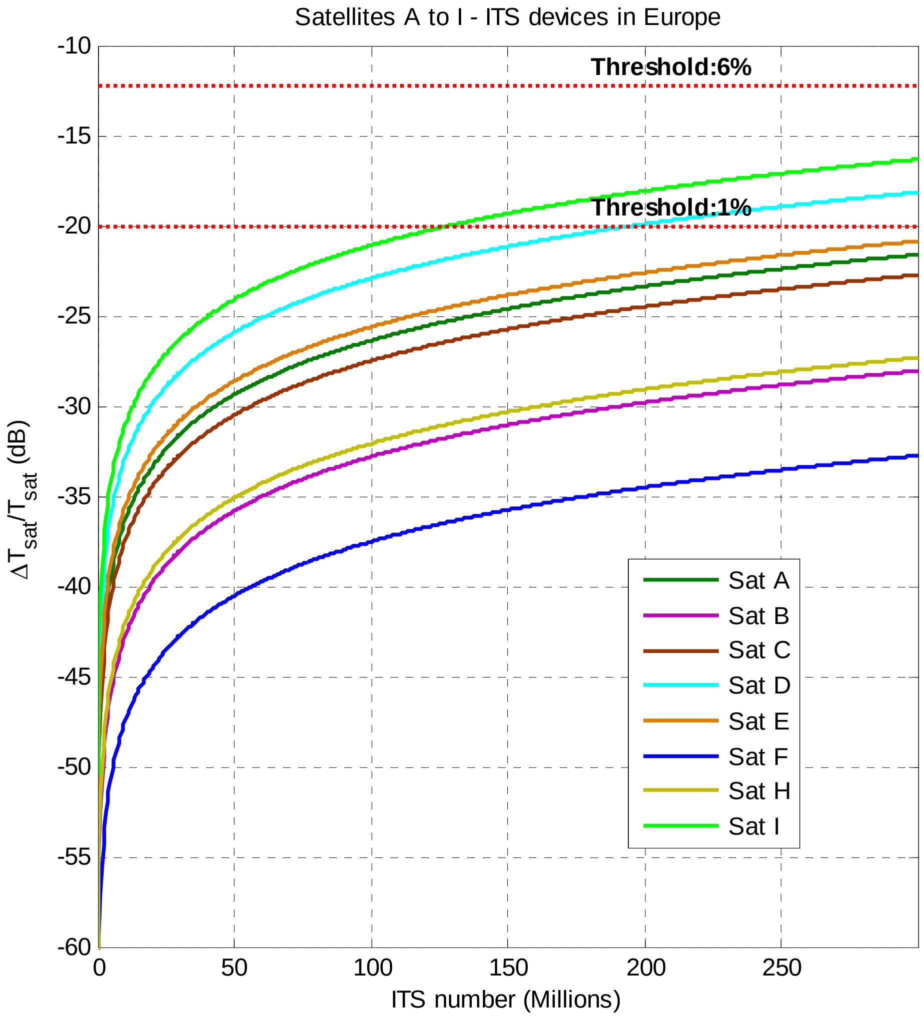


Figure 10: Estimation of noise improvement given by different densities of ITS devices

3.2.1.4 Conclusion

The results of this part of the study provide information about the total allowable number of ITS devices over the whole European region, which could share with FSS networks.

The ACEA provides the number of vehicles in Europe of 214 million. With an equipment penetration of 50%, estimated number of OBU is then 107 million.

Considering ITS requirements of SRDoc part I, especially the 2x10 MHz above 5875 MHz, one can conclude that compatibility between FSS and ITS devices is achieved even for an 1% interference apportionment factor.

3.2.2 Impact of FSS on ITS

3.2.2.1 Technical characteristics of FSS earth stations

C-band (3.625-4.2 GHz space to Earth direction and 5.850-6.725 GHz Earth to space direction) is currently used mainly for regional and intercontinental connections for various services such as public commuted network, audio-visual transport services or multimedia services, which require a high quality of services.

As far as Europe is concerned, the majority of transmitting FSS earth stations are "large" gateways in rural environment (medium-size to large antennas used to provide international connectivity with other countries or territories), even if there is also "small" gateways in rural and sub-urban environment (small to medium-size antennas often used to connect remote areas to the Internet backbone and other telecommunications networks). VSAT networks in rural, sub-urban and even urban areas (e.g. corporate network) represent very few deployments in Europe.

FSS parameters considered in this study covers the various deployment that can be found in Europe. Consequently to the presentation in the previous section, 4 representative earth station antenna diameters are considered: 2.4, 4.6, 16 and 32.5 m. Two types of elevation angle have been chosen, one representing a quite extreme case of 10°, where the earth station is pointing at a low satellite, and the other representing a common one for Europe at 33°, where the earth station is pointing towards a satellite up to Europe.

Article 21 of the Radio Regulation indicates an e.i.r.p. limit in the considered bandwidth for a transmitting earth station of:

+40 dBW in any 4 kHz band for $\theta \leq 0°$

+40 + 3 θ dBW in any 4 kHz band for $0° < \theta \leq 5°$;

No restriction for $5° < \theta$ (RR- Article 21.9)

where θ is the angle of elevation of the horizon viewed from the centre of radiation of the antenna of the earth station and measured in degrees as positive above the horizontal plane and negative below it.

However, operational e.i.r.p. of transmitting earth station is most of the time significantly below this limit. The limit proposed at these angles is about the maximum e.i.r.p. in the main direction. Consequently, e.i.r.p. proposed here are operational ones.

The following table summarises the generic FSS parameters that has been used in the study:

Earth Station	ST1	ST2	ST3	ST4
Elevation (deg)	10	10	33	33
Antenna Diameter (m)	4.6	32.5	4.6	32.5
Power (dBW/MHz)	21.3	2.0	21.3	2.0
Max antenna gain (dBi)	47.8	63	47.8	63
Height (m)	4.3	18.25	4.3	18.25
Antenna pattern	ITU-R Rec. S.465 [18]			

Table 14: Assumed FSS parameters

3.2.2.2 Methodology

The C/I criteria and the sensibility defined in the previous section enable to determine the maximum allowable interference into ITS as follow:

$$I_{\max} = C_{\min} - \frac{C}{I} \tag{18}$$

where:

- I_{max} in dBm/MHz
- C_{min} in dBm/MHz, sensitivity at the output off the antenna, i.e. -92 dBm/MHz
- C/I en dB

This value can be compared to the received interference from an FSS transmitting earth station with the following calculation:

$$I = P_e + G_e(\varphi) + G_r(\sigma) \text{ - Aff} \tag{19}$$

where:

- I (en dBm/MHz) ;
- P_e : Earth station transmitting power (dBm/MHz);
- $G_e(\varphi)$: Earth station antenna gain (dBi);
- $G_r(\theta)$: ITS antenna gain (dBi)
- Aff : Propagation loss (dB)

Recommendation ITU-R P.452-7 [19] has been used in order to assess the propagation loss.

For this simulation, an FSS transmitting earth station is considered in the centre of a simulation zone. Interference is calculated in each point of the simulation zone as a potential location of an ITS system (as presented in figure 11).

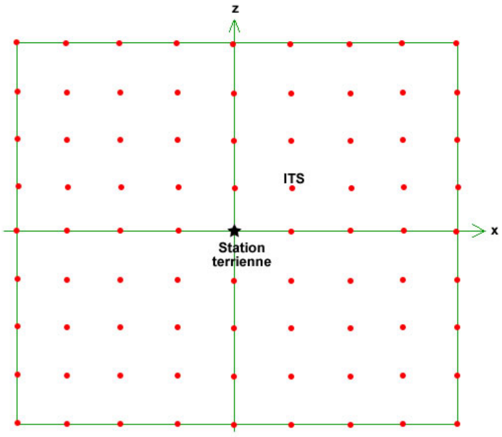


Figure 11 : Representation of the simulation zone

Comparing this calculation with I_{max} value, it enables to determine, from the FSS earth station, where the sensitivity criteria level for ITS system is exceeded. It visualises a sort of potential interference zone around the earth station.

In order to be as generic as possible, a flat terrain model has been considered. Indeed the terrain model, which has an important impact on sharing calculation, is too specific to each location. However, in order to estimate the sensibility of the use of the terrain model, section 3.2.2.4. shows the improvement of the separation distances when an example of real terrain model is taken into account..

3.2.2.3 Separation distances considering a flat terrain

Computed results give the following type of figure. In one side, the graph represents the interference value (I in dBm/MHz) and the other side the limit distance (in km).

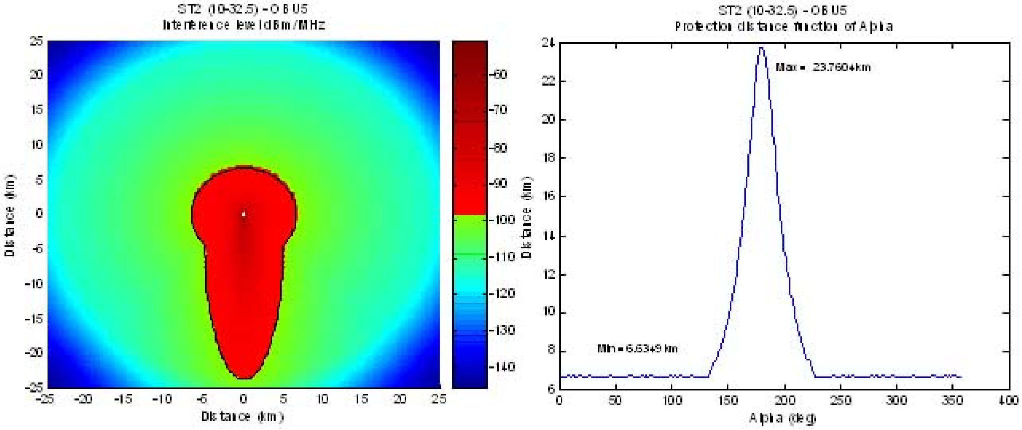


Figure 12 : 2D representations of the interference (dBm/MHz) and Limit distance for I_{max} in the case ST2 and OBU G_{max}=5dBi

Results for each case are presented in Annex 3 of this document. The following table summarises the minimum and the maximum distances where the ITS interference threshold is exceeded, the results of the sharing study for the various cases:

Interference distances	OBU Gmax = 5 dBi		OBU Gmax = 8 dBi		RSU	
	d_{max} (km)	d_{min} (km)	d_{max} (km)	d_{min} (km)	d_{max} (km)	d_{min} (km)
ST1(10° / 4.5m)	**22.1**	**16.6**	**22.1**	**16.6**	**25.1**	**18.7**
ST2 (10° / 32.5m)	**23.8**	**6.6**	**23.7**	**6.6**	**21.1**	**3.73**
ST3(33° / 4.5m)	**17.9**	**16.6**	**17.9**	**16.6**	**20.9**	**18.8**
ST4 (33° / 32.5m)	**9.3**	**6.6**	**9.3**	**6.6**	**6.1**	**3.7**

Table 15 : Interference distance

The maximum distance from the earth station, at which an ITS system is interfered, varies and may be up to 25 km depending on various cases.

Through these results, it can be noticed first that interference created by the sidelobes of the FSS earth stations remains at the same level for a given distance whatever the azimuth angle. Moreover, low elevation angle is only for two azimuth directions, taking into account that earth stations have to point towards the geostationary orbital arc. Differences on the three kinds of receivers are mainly given by the different heights which change the geometrical configuration of the transmission. For example, it explained why the protection distance for RSU is higher than that one for OBU although its antenna gain towards the FSS earth station is smaller.

More over, the results vary significantly between the earth station diameters for high elevation angles. However, the different transmitting power values are more predominant in these variations than the antenna gain values. Indeed, the received interference is mainly produced by off axis emissions of the earth station.

It has been assumed in this study that the ITS are pointing towards the earth station, including the tilt of the earth station. For OBU systems whose antenna is omni-directional, another relative position wouldn't improve the sharing situation. But in the RSU case, the interference may be reduced considering a better relative pointing direction of the RSU system. Moreover, the planning of RSU systems may take into account the location of FSS earth station on a national basis, in order to improve the sharing situation.

3.2.2.4 Separation distances considering a real terrain model

This section aims at providing results of this sharing study but taking into account a real location of earth station and thus showing the impact of a real terrain model. However, due to the specificity of the location, the results remain as examples.

The chosen location is the one of a C-Band FSS teleport in France. The following figure shows the representation of the associated terrain model of this location.

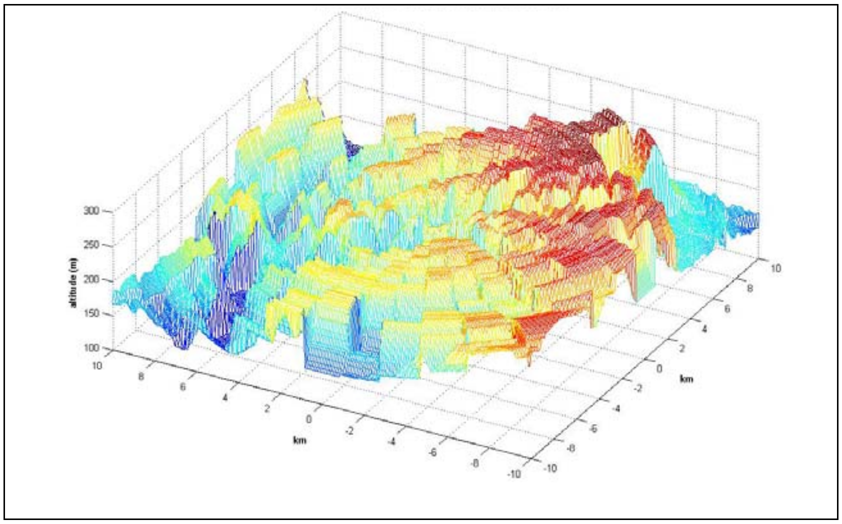


Figure 13: Representation of the used real terrain model

Due to operational reality, for an elevation of 10°, the azimuth is 112° and for an elevation of 33°, the azimuth is 8°.

One example of the results is given in the following figures. The representation is the same as for the flat terrain results from the previous section. Results for all cases are presented in Annex 3 of this report.

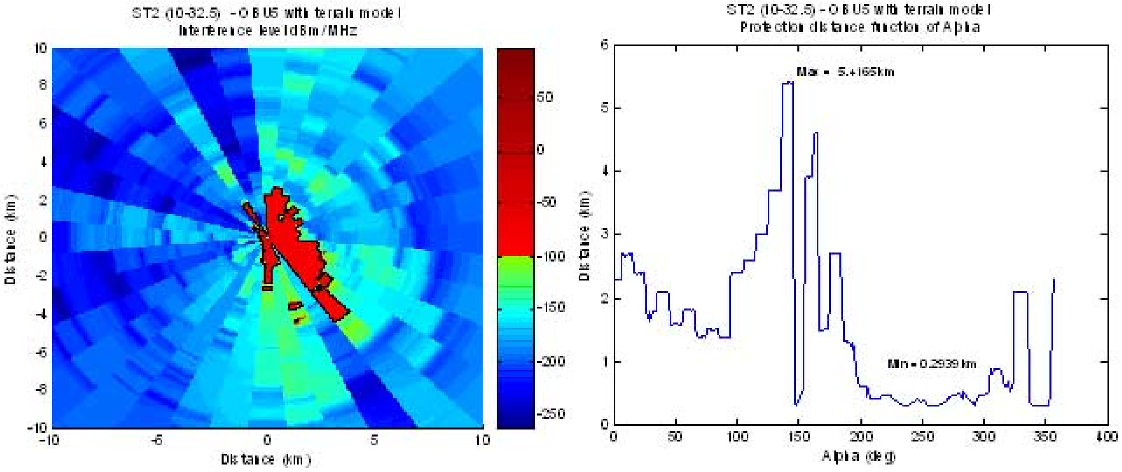


Figure 14: 2D representations of the interference (dBm/MHz) and Limit distance for Imax in the case ST2 and OBU G_{max}=5dBi

This calculation enables to note that the consideration of a real terrain model has a significant impact on the size of the exclusion zone.

3.2.2.5 Conclusion

The size of the zone around the FSS transmitting earth station, where the interference received by ITS exceeds the interference criterion, varies up to about 9 km.

However, even if these estimated distances (with a flat terrain model) seem large, the consideration of a real terrain model for a given location may reduce drastically, in most of the azimuth directions, the protection distances. A reduction factor of about 5 is expected in that matter, depending on the location. Moreover, the number of transmitting FSS earth stations in this band will remain low. In addition, an appropriate choice of location and direction for RSU systems taking into account the exact ambient noise levels through real measurements should improve the sharing situation.

3.3 Compatibility between ITS and radiolocation systems

This section provides results of calculation for the separation distance to protect primary radars for frequencies below 5850 MHz from unwanted emissions of ITS and to protect ITS from unwanted emissions of radiodetermination systems. The characteristics of Radiodetermination systems are provided in section 3.3.1. The ITS characteristics are provided in section 2.7.

Methodology and most assumptions came from ECC Report 68 [11] dedicated to FWA devices. It is recalled that this study is a nearby frequency interference assessment. It implies that the lower frequency of ITS devices is above 5855 MHz.

Section 2.4 provides a description of the unwanted emissions for ITS.

For ITS, the attenuation in the side lobes, is taken equal to 12 dB. The side lobe rejections for radar systems are provided in Table 14.

3.3.1 Radiolocation service

The bands between 5 725 and 5 850 MHz are allocated to the Radiolocation service on a primary basis.

3.3.1.1 Technical characteristics

Recommendation ITU-R M.1638 [20] provides characteristics of radars operating under the Radiolocation services in the frequency range 5250-5850 MHz. Within this range, the band between 5 725 and 5 850 MHz is used by many different types of radars on fixed land-based, ship borne and transportable platforms. It should be noted that most of these radars are designed to operate not only in the 5725-5850 MHz band but in a larger portion of the band 5250-5850 MHz.

Table 16 contains technical characteristics of representative systems deployed in this band. This includes a subset of the radars contained in Recommendation ITU-R M.1638 [20], which are relevant for the frequency band 5725-5850 MHz (radars L, M, N, O and Q) and three additional radars operated by administrations within CEPT (X, Y and Z). This information is generally sufficient for calculation to assess the compatibility between these radars and other systems.

Characteristics	Radar L	Radar M	Radar N	Radar O	Radar Q	Radar X& Y (Note 1)	Radar Z
Function	Instrumentation				Surface and air search		Search
Platform type	Ground				Ship	Ground /Vehicle	
Tuning range (MHz)	5 350-5 850		5 400-5 850		5 450-5 825	5400 – 5850	5250 – 5850
Modulation	None	None	Pulse/chirp pulse	Chirp pulse	None	None	Non-Linear FM
TX power into antenna	2.8 MW	1.2 MW	1.0 MW	165 kW	285 kW	12 kW peak	70 kW
Pulse width (µs)	0.25, 1.0, 5.0	0.25, 0.5, 1.0	0.25-1 (plain) 3.1-50 (chirp)	100	0.1/0.25/1.0	4-20	3.5/6/10
Pulse rise/fall time (µs)	0.02-0.5	0.02-0.05	0.02-0.1	0.5	0.03/0.05/0.1	No detail	N/A
Pulse repetition rate (pps)	160, 640	160, 640	20-1 280	320	2 400/1 200/750	1000-7800	2500/3750
Chirp bandwidth (MHz)	N/A	N/A	4.0	8.33	N/A	No detail	
RF emission bandwidth (MHz) at: -3 dB	0.5-5	0.9-3.6	0.9-3.6	8.33	5.0/4.0/1.2	5	
-20 dB		6.4-18	6.4-18	9.9	16.5/12.5/7.0		
Antenna pattern type	Pencil	Pencil	Pencil	Pencil	Fan	N/A	N/A
Antenna type	Parabolic	Parabolic	Phased Array	Phased Array	Travelling wave feed horn array	N/A	Phased Array
Antenna polarization	Vertical/Left-hand circular				Horizontal	Vertical	Horizontal
Antenna main beam gain (dBi)	54	47	45.9	42	30.0	35	31.5
Antenna elevation beamwidth (degrees)	0.4	0.8	1.0	1.0	28.0	N/A	43.8
Antenna azimuth beamwidth (degrees)	0.4	0.8	1.0	1.0	1.6	N/A	1.75
Antenna rejection (1st SLs and remote SLs) (dB)	-20	-20	-22	-22	-25	-40	N/A (Note 2)
Antenna height (m)	20	8-20	20	20	40	10	6 – 13
Receiver IF 3 dB bandwidth (MHz)	4.8, 2.4, 0.25	4, 2, 1	2-8	8	1.2,10	4	N/A
Receiver noise figure (dB)	5	5	11	5	10	5	≤ 13dB

Table 16: Characteristics of radiolocation systems

Note 1: Radars X and Y can operate both in fixed frequency and in hopping mode.

Note 2: No value is provided in Recommendation ITU-R M.1368, therefore for the compatibility analyses a value of -40dB was considered.

The analysis considers the impact of the unwanted emissions of the radiodetermination system; therefore the level of the unwanted emissions of the radiodetermination systems was taken 60dBpp below the maximum value of the peak power, measured in a 10 MHz reference bandwidth (see RR Appendix 3).

The following table provides some additional information used for the calculations of the separation distances to protect ITS.

Emission part: Radiolocation	Value	Units	Type of Radar						
			L	**M**	**N**	**O**	**Q**	**X & Y**	**Z**
e.i.r.p radar		dBm	148.5	137.8	135.9	124.2	114.5	105.8	110
Receiver IF3dB bandwidth MHz		MHz	4.8	4	8	8	10	4	1
E.i.r.p radar		dBm/MHz	141.7	131.8	126.9	115.2	104.5	99.8	110.0
Unwanted attenuation factor (Spurious)	60	dBpp	60.0	60.0	60.0	60.0	60.0	60.0	60.0
e.i.r.p radar in the ITS band		dBm/MHz	81.7	71.8	66.9	55.2	44.5	39.8	50.0
Noise Temperature		°K	290	290	290	290	290	290	290

Table 17: Characteristics for Radiolocation Systems

3.3.1.2 Protection criteria for Radiodetermination systems

The de-sensitising effect on radars operated in this band from other services of a CW or noise-like type modulation is predictably related to its intensity. In any azimuth sectors in which such interference arrives, its power spectral density can simply be added to the power spectral density of the radar receiver thermal noise, to within a reasonable approximation. If power spectral density of radar-receiver noise in the absence of interference is denoted by N_0 and that of noise-like interference by I_0, the resultant effective noise power spectral density becomes simply I_0+N_0. An increase of about 1 dB for the Radiolocation radar would constitute significant degradation. Such an increase corresponds to an $(I+N)/N$ ratio of 1.26, or an I/N ratio of about –6 dB.

3.3.2 Separation distances to protect Radiodetermination Systems

This section provide results on separation distances according to the appropriate protection criterion for different kinds of radars presented in section 3.3 and different propagation models (see 2.6).

The required protection range is estimated in two steps. Firstly, a required propagation loss or attenuation is estimated with a budget link. After, a distance is calculated following assumptions of different propagation models as described in Table 3 in section 2.6.

The required propagation loss L_{FS} is given by the following equation:

$$S = \frac{I}{N} = e.i.r.p. + 10Log\left(\frac{B_{radar}}{B_{ITS}}\right) + G_{radar} - L_{radar} - L_{FS} - N$$

$$\Rightarrow L_{FS} = S - e.i.r.p. - 10Log\left(\frac{B_{radar}}{B_{ITS}}\right) - G_{radar} + L_{radar} + N \tag{20}$$

where:

- $S=I/N$ is the protection criterion (-6dB)
- *e.i.r.p. is the e.i.r.p. of the ITS device in dBm*
- B_{radar} is the receiver bandwidth of the radar in MHz
- B_{ITS} is the ITS bandwidth in MHz
- G_{radar} is the receiver antenna gain in dBi
- L_{radar} is the receiver feeder loss in dB
- N is the received noise on the radar in dBm

3.3.2.1 Urban area

This table gives the protection ranges to protect the different kinds of radars from an ITS device located at 5855 MHz. It leads to an unwanted power within the radiodetermination allocation of -11 dBm/MHz.

	Radar	**L**	**M**	**N**	**O**	**Q**	**X & Y**	**Z**
Protection criterion: I/N	dB	-6	-6	-6	-6	-6	-6	-6
MAIN LOBE ITS - MAIN LOBE RL								
Sidelobe attenuation (dB)	dB	0	0	0	0	0	0	0
Allowable Interfering power level '*I*' on the antenna port	dBm/MHz	**-167**	**-163**	**-164**	**-159**	**-147**	**-150**	**-138**
Required Attenuation (dB)	dB	**-156**	**-152**	**-153**	**-148**	**-136**	**-139**	**-127**
Attenuation at first break point	dB	-87	-87	-87	-87	-87	-87	-87
Margin (dB)	dB	-69	-65	-66	-61	-49	-52	-41
Attenuation at second break point	dB	-98	-98	-98	-98	-98	-98	-98
Margin (dB)	dB	-58	-54	-55	-50	-38	-41	-29
Separation distance ITS->Radar	m	**2844**	**2296**	**2371**	**1853**	**975**	**1145**	**618**
MAIN LOBE ITS - SIDE LOBE RL								
Sidelobe attenuation (dB)	dB	20	20	22	22	25	40	40
Allowable Interfering power level '*I*' on the antenna port	dBm/MHz	**-147**	**-143**	**-142**	**-137**	**-122**	**-110**	**-98**
Required Attenuation (dB)	dB	**-136**	**-132**	**-131**	**-126**	**-111**	**-99**	**-87**
Separation distance ITS->Radar	m	**975**	**787**	**730**	**571**	**256**	**134**	**67**
SIDE LOBE ITS - MAIN LOBE RL								
Sidelobe attenuation (dB)	dB	12	12	12	12	12	12	12
Allowable Interfering power level '*I*' on the antenna port	dBm/MHz	**-155**	**-151**	**-152**	**-147**	**-135**	**-138**	**-126**
Required Attenuation (dB)	dB	**-144**	**-140**	**-141**	**-136**	**-124**	**-127**	**-115**
Separation distance ITS->Radar	m	**1496**	**1207**	**1247**	**975**	**513**	**602**	**325**
SIDE LOBE ITS - SIDE LOBE RL								
Sidelobe attenuation (dB)	dB	32	32	34	34	37	52	52
Allowable Interfering power level '*I*' on the antenna port	dBm/MHz	**-135**	**-131**	**-130**	**-125**	**-110**	**-98**	**-86**
Required Attenuation (dB)	dB	**-124**	**-120**	**-119**	**-114**	**-99**	**-87**	**-75**
Separation distance ITS->Radar	m	**513**	**414**	**384**	**300**	**134**	**65**	**24**

Table 18: Protection ranges for urban area

3.3.2.2 Summary of results

Prop model	Radar	L	M	N	O	Q	X & Y	Z
URBAN	ML RL-ML ITS	**2844**	2296	2371	1853	975	1145	618
	ML ITS-SL RL	**975**	787	730	571	256	134	67
	SL ITS-ML RL	**1496**	1207	1247	975	513	602	325
	SL ITS-SL RL	**513**	414	384	300	134	65	24
SUB URBAN	ML RL-ML ITS	**6507**	5106	5296	4007	1937	2323	1157
	ML ITS-SL RL	**1937**	1520	1396	1057	426	199	96
	SL ITS-ML RL	**3145**	2468	2559	1937	936	1123	559
	SL ITS-SL RL	**936**	735	675	511	199	90	24
RURAL	ML RL-ML ITS	**17222**	13028	13585	9855	4266	5259	2358
	ML ITS-SL RL	**4266**	3227	2927	2123	704	263	96
	SL ITS-ML RL	**7455**	5640	5881	4266	1847	2277	1020
	SL ITS-SL RL	**1847**	1397	1267	902	263	90	24
ETSI	ML RL-ML ITS	**16268**	11566	12174	8223	2955	3817	1431
	ML ITS-SL RL	**2955**	2101	1865	1260	350	126	47
	SL ITS-ML RL	**5847**	4157	4375	2955	1062	1372	514
	SL ITS-SL RL	**1062**	755	670	453	126	45	17

Table 19 : Table of results (protection ranges in m) when applying the different propagation models with an ITS unwanted power of -11dBm/MHz

3.3.2.3 Conclusion

This section provided results of calculation for the separation distance to protect primary radars for frequencies below 5850 MHz from unwanted emissions of ITS located above 5855 MHz.

One has to be aware that this section is an adjacent frequency interference assessment.

This Table 19 indicates the different protection ranges when considering the unwanted spectrum of ITS device (see section 2.4). These distances are greater than several km.

Table 20 gives the protection ranges when considering an unwanted power lower than -55dBm/MHz (instead of -11 dBm/MHz in the previous section), which corresponds to ITS operating above 5875 MHz.

Prop model	Radar	L	M	N	O	Q	X & Y	Z
URBAN	ML RL-ML ITS	**270**	218	225	176	89	106	60
	ML ITS-SL RL	**89**	69	86	51	9	2	1
	SL ITS-ML RL	**142**	113	117	89	40	57	15
	SL ITS-SL RL	**40**	25	22	13	2	1	0
SUB URBAN	ML RL-ML ITS	**452**	355	368	279	161	151	60
	ML ITS-SL RL	**161**	101	86	51	9	2	1
	SL ITS-ML RL	**213**	161	168	161	40	57	15
	SL ITS-SL RL	**40**	25	22	13	2	1	0
RURAL	ML RL-ML ITS	**765**	550	578	396	161	227	60
	ML ITS-SL RL	**161**	101	86	51	9	2	1
	SL ITS-ML RL	**285**	255	273	161	40	57	15
	SL ITS-SL RL	**40**	25	22	13	2	1	0
ETSI	ML RL-ML ITS	**382**	271	286	193	69	90	34
	ML ITS-SL RL	**69**	49	44	30	9	2	1
	SL ITS-ML RL	**137**	98	103	69	25	32	15
	SL ITS-SL RL	**25**	18	16	13	2	1	0

Table 20: Table of results (protection ranges in m) when applying the different propagation models with an ITS unwanted power of -55dBm/MHz

This proposed level of -55dBm/MHz will ensure the compatibility between ITS and radiodetermination systems. Such a level can be achieved with:

- an introduction of a guard band between RL and ITS (25 MHz);
- an additional and more efficient filtering of the ITS spectrum outside the necessary bandwidth.

3.3.3 Separation distances to protect ITS

The calculation considered only the spurious emissions of radar systems, therefore a rejection of 60 dBpp is applied compared to the wanted signal.

3.3.3.1 Protection ranges for the urban case

Radar Type :		**L**	**M**	**N**	**O**	**Q**	**X & Y**	**Z**
Protection criterion : C/I	dB	6	6	6	6	6	6	6
Allowable Interfering power level '*I*' at receiver antenna input	dBm/MHz	**-106**	**-106**	**-106**	**-106**	**-106**	**-106**	**-106**
Wall loss (building penetration)	dB	0	0	0	0	0	0	0
MAIN LOBE ITS - MAIN LOBE RL								
Allowable Interfering power level at receiver antenna input	dBm/MHz	-106	-106	-106	-106	-106	-106	-106
Required Attenuation (dB)		**-188**	**-178**	**-173**	**-161**	**-151**	**-146**	**-156**
Attenuation at first break point		-84	-84	-84	-84	-84	-84	-84
Margin (dB)		-104	-94	-89	-77	-67	-62	-72
Attenuation at second break point		-95	-95	-95	-95	-95	-95	-95
Margin (dB)		-92	-82	-77	-66	-55	-50	-61
Separation distance ITS->RL (m)		**17903**	**10532**	**8097**	**4327**	**2444**	**1898**	**3281**
MAIN LOBE ITS - SIDE LOBE RL								
Sidelobe attenuation (dB)	dB	20	20	22	22	25	40	40
Allowable Interfering power level at receiver antenna input	dBm/MHz	-86	-86	-84	-84	-81	-66	-66
Required Attenuation (dB)		**-168**	**-158**	**-151**	**-139**	**-126**	**-106**	**-116**
Separation distance ITS->RL (m)		**6135**	**3609**	**2493**	**1332**	**641**	**223**	**385**
SIDE LOBE ITS - MAIN LOBE RL								
Sidelobe attenuation (dB)	dB	12	12	12	12	12	12	12
Allowable Interfering power level at receiver antenna input	dBm/MHz	-94	-94	-94	-94	-94	-94	-94
Required Attenuation (dB)		**-176**	**-166**	**-161**	**-149**	**-139**	**-134**	**-144**
Separation distance ITS->RL (m)		**9416**	**5539**	**4258**	**2276**	**1285**	**998**	**1726**
SIDE LOBE ITS - SIDE LOBE RL								
Sidelobe attenuation (dB)	dB	32	32	34	34	37	52	52
Allowable Interfering power level at receiver antenna input	dBm/MHz	-74	-74	-72	-72	-69	-54	-54
Required Attenuation (dB)		**-156**	**-146**	**-139**	**-127**	**-114**	**-94**	**-104**
Separation distance ITS->RL (m)		**3227**	**1898**	**1311**	**701**	**337**	**116**	**203**

Table 21: Separation distance for Urban area

3.3.3.2 Summary of the results

Prop model	Radar	L	M	N	O	Q	X & Y	Z
URBAN	ML RL-ML ITS	**17903**	10532	8097	4327	2444	1898	3281
	ML ITS-SL RL	**6135**	3609	2775	1483	287	223	385
	SL ITS-ML RL	**9416**	5539	4258	2276	1285	998	1726
	SL ITS-SL RL	**3227**	1898	1459	780	151	116	203
SUB URBAN	ML RL-ML ITS	**52175**	28624	21257	10462	5481	4117	7649
	ML ITS-SL RL	**15529**	8519	6327	3114	486	365	678
	SL ITS-ML RL	**25216**	13834	10273	5056	2649	1990	3697
	SL ITS-SL RL	**7505**	4117	3058	1505	232	167	327
RURAL	ML RL-ML ITS	**189303**	94822	67315	29755	14134	10167	20746
	ML ITS-SL RL	**46892**	23488	16674	7371	842	571	1273
	SL ITS-ML RL	**81945**	41046	29139	12880	6118	4401	8980
	SL ITS-SL RL	**20298**	10167	7218	3191	314	198	493
ETSI	ML RL-ML ITS	**304618**	130854	86084	31739	12777	8543	20424
	ML ITS-SL RL	**55337**	23771	15638	5766	422	282	674
	SL ITS-ML RL	**109474**	47026	30937	11406	4592	3070	7340
	SL ITS-SL RL	**19887**	8543	5620	2072	152	101	242

Table 22: Table of results (protection ranges in m) when applying the different propagation models

3.3.3.3 Conclusion

It can be seen that for high power radar systems (i.e. Type L), even in the case of side lobe to side lobe configuration, the separation distances are quite high.

In case of lower power radars (i.e. Type X&Y), the separation distances are lower but in the case where the radar system is pointing in the ITS direction, it can be seen that the resulting separation distances will still be quite high.

From this, it may be concluded that the frequency separation between the frequency range identified for ITS and the radiodetermination band (5850 MHz) should be at least in the order of the out-of-band domain of the radiodetermination system (i.e. 2 times the necessary bandwidth of radiodetermination systems), which means a lower frequency for ITS devices above 5875 MHz.

Between 5855 MHz and 5875 MHz, ITS may suffer interference.

3.4 Compatibility between ITS and SRD

This section provides results of calculation for the separation distances to protect SRD in the band 5865 – 5875 MHz from ITS and to protect ITS from SRD. The characteristics of SRD systems are provided in section 3.4.1. The ITS characteristics are provided in section 2.7.

3.4.1 General (Non-Specific) Short Range Devices characteristics

The same approach as in ECC Report 68 [12] is used. As specified in Annex 1 of ERC Recommendation 70-03 [21], the frequency band 5725-5875 MHz is used by non-specific SRD. From ERC Decision (01)06 [22], this use should comply with the technical characteristics as shown below.

Frequency Band	Power	Antenna	Channel Spacing	Duty Cycle (%)
5725-5875 MHz	25 mW e.i.r.p.	Integral (no external antenna socket) or dedicated	No channel spacing - the whole stated frequency band may be used	No duty cycle restriction

Table 23: Technical characteristics of SRD

In addition to these regulatory technical characteristics, assumptions on some parameters had to be made in order to carry out compatibility studies. Three kinds of SRD are considered for the interference assessment (see the following table).

Parameter	**SRD I (min BW)**	**SRD II (max BW)**	**SRD III (DVS)**	**Comments**
Typical bandwidth BW (MHz)	0.25 MHz	20 MHz	8MHz	Note 1, Note 2.
TX Power, dBm e.i.r.p.	+14	+14	+14	
Ant. Gain, dBi	2 to 20	2 to 24	2	
Ant. Polarization	Circular	Circular	Vertical	
Receiver sensitivity, dBm	-110	-91	-84	
Receiver noise dBm/MHz	-114	N/A	N/A	
Protection criterion, dB	I/N=0dB	C/I=8dB	C/I=20dB	
SRD Noise figure F	9.00 dB	N/A	N/A	
FkTB	-105 dBm/MHz	N/A	N/A	
Max OoB RX interference : dBm	-35	-35	-35	e.g. Limit for RX blocking
Duty cycle : %	Up to 100%	Up to 100%	100%	
RX wake-up time (if applicable)	1 sec	1 sec	N/A	For battery operated equipment
Note 1: The given bandwidths are for non-spread spectrum modulation. *Note 2: For spread spectrum modulation (FHSS, DSSS and other types) the bandwidth can be up to 100 MHz*				

Table 24: Assumed SRD Parameters

Digital Video sender (DVS) System Planned for use in 5.8GHz Band

The UK Digital TV Group (DTG) Wireless Home Networks group have looked at feasibility studies into using the 5.8 GHz band for Digital Video Senders to re-broadcast DVB-T signals throughout home. They have concluded that the 5.8 GHz band can be used to offer a relatively simple and low cost means of delivering digital TV services to 2nd and 3rd TV's in typical UK homes if both transmit delay diversity and MRC receive diversity processing are used. Transmit delay diversity only would be sufficient if the transmit e.i.r.p. could be increased by 3dB.

Figure 15 below shows a block diagram of the proposed DVS system (without any diversity processing).

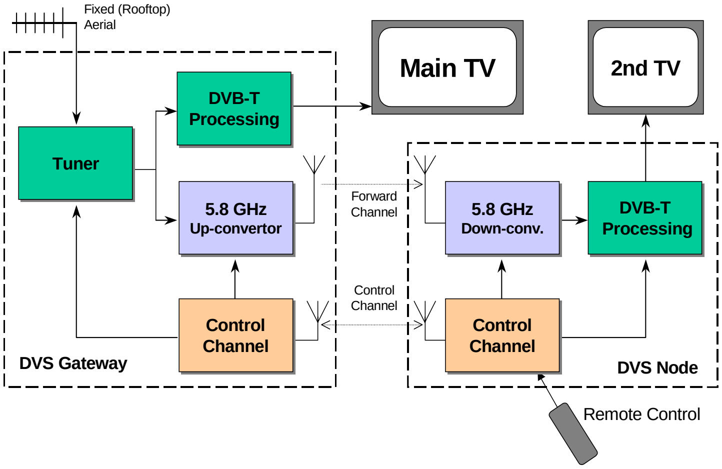


Figure 15: DVS System

3.4.2 Separation distances to protect SRD

This section provides results of calculation for the separation distance to protect the three kinds of SRD presented in section 3.4.1 operating in the band 5865 – 5875 MHz from ITS (e.i.r.p. of 33 dBm on a 10 MHz bandwidth). A protection criterion of I/N=0dB is considered for SRD Type I (narrow bandwidth). A protection criterion of C/I appears to be more suitable for interference assessment with the two other types of SRD (see Table 27).

To be consistent with average behaviour of ITS, communication range is closer to 500m than 1000m. It implies a 8 dB TPC factor for the same sensitivity (-82 dBm).

3.4.2.1 SRD I

Model		**Urban**	**Suburban**	**Rural**	**ETSI**
Protection criterion : I/N	dB	0	0	0	0
Allowable Interfering power level '*I*'	dBm/MHz	**-107**	**-105**	**-105**	**-107**
Wall loss (building penetration)	dB	15	15	15	15
MAIN LOBE ITS - MAIN LOBE SRD					
Allowable Interfering power level at receiver antenna input - Indoor use	dBm/MHz	-92	-90	-90	-92
Required Attenuation (dB)		**-107**	**-105**	**-105**	**-107**
Separation distance ITS->SRD (m)		**237**	**346**	**531**	**310**
MAIN LOBE ITS - SIDE LOBE SRD					
Sidelobe attenuation (dB)	dB	12	12	12	12
Allowable Interfering power level at receiver antenna input - Indoor use	dBm/MHz	-80	-78	-78	-80
Required Attenuation (dB)		**-95**	**-93**	**-93**	**-95**
Separation distance ITS->SRD (m)		**124**	**157**	**179**	**111**
SIDE LOBE ITS - MAIN LOBE SRD					
Sidelobe attenuation (dB)	dB	12	12	12	12
Allowable Interfering power level at receiver antenna input - Indoor use	dBm/MHz	-80	-78	-78	-80
Required Attenuation (dB)		**-95**	**-93**	**-93**	**-95**
Separation distance ITS->SRD (m)		**124**	**157**	**179**	**111**
SIDE LOBE ITS - SIDE LOBE SRD					
Sidelobe attenuation (dB)	dB	24	24	24	24
Allowable Interfering power level at receiver antenna input - Indoor use	dBm/MHz	-68	-66	-66	-68
Required Attenuation (dB)		**-83**	**-81**	**-81**	**-83**
Separation distance ITS->SRD (m)		**57**	**45**	**45**	**40**

Table 25: Interference assessment for SRD type I

3.4.2.2 SRD II

Model		**Urban**	**Suburban**	**Rural**	**ETSI**
Protection criterion : C/I	dB	8	8	8	8
Allowable Interfering power level '*I*' at receiver antenna input	dBm/MHz	**-114**	**-114**	**-114**	**-114**
Wall loss (building penetration)	dB	15	15	15	15
MAIN LOBE ITS - MAIN LOBE SRD					
Allowable Interfering power level at receiver antenna input - Indoor use	dBm/MHz	-99	-99	-99	-99
Required Attenuation (dB)		**-114**	**-114**	**-114**	**-114**
Separation distance ITS->SRD (m)		**346**	**601**	**1108**	**569**
MAIN LOBE ITS - SIDE LOBE SRD					
Sidelobe attenuation (dB)	dB	12	12	12	12
Allowable Interfering power level at receiver antenna input - Indoor use	dBm/MHz	-87	-87	-87	-87
Required Attenuation (dB)		**-102**	**-102**	**-102**	**-102**
Separation distance ITS->SRD (m)		**182**	**290**	**419**	**204**
SIDE LOBE ITS - MAIN LOBE SRD					
Sidelobe attenuation (dB)	dB	12	12	12	12
Allowable Interfering power level at receiver antenna input - Indoor use	dBm/MHz	-87	-87	-87	-87
Required Attenuation (dB)		**-102**	**-102**	**-102**	**-102**
Separation distance ITS->SRD (m)		**182**	**290**	**419**	**204**
SIDE LOBE ITS - SIDE LOBE SRD					
Sidelobe attenuation (dB)	dB	24	24	24	24
Allowable Interfering power level at receiver antenna input - Indoor use	dBm/MHz	-75	-75	-75	-75
Required Attenuation (dB)		**-90**	**-90**	**-90**	**-90**
Separation distance ITS->SRD (m)		**92**	**128**	**128**	**73**

Table 26: Interference assessment for SRD type II

3.4.2.3 SRD III

Model		**Urban**	**Suburban**	**Rural**	**ETSI**
Protection criterion : C/I	dB	20	20	20	20
Allowable Interfering power level '*I*' at receiver antenna input	dBm/MHz	**-115**	**-115**	**-115**	**-115**
Wall loss (building penetration)	dB	15	15	15	15
MAIN LOBE ITS – MAIN LOBE SRD					
Allowable Interfering power level at receiver antenna input - Indoor use	dBm/MHz	-100	-100	-100	-100
Required Attenuation (dB)		**-115**	**-115**	**-115**	**-115**
Separation distance ITS->SRD (m)		**366**	**639**	**1190**	**621**
MAIN LOBE ITS - SIDE LOBE SRD					
Sidelobe attenuation (dB)	dB	12	12	12	12
Allowable Interfering power level at receiver antenna input - Indoor use	dBm/MHz	-88	-88	-88	-88
Required Attenuation (dB)		**-103**	**-103**	**-103**	**-103**
Separation distance ITS->SRD (m)		**192**	**309**	**456**	**223**
SIDE LOBE ITS - MAIN LOBE SRD					
Sidelobe attenuation (dB)	dB	12	12	12	12
Allowable Interfering power level at receiver antenna input - Indoor use	dBm/MHz	-88	-88	-88	-88
Required Attenuation (dB)		**-103**	**-103**	**-103**	**-103**
Separation distance ITS->SRD (m)		**192**	**309**	**456**	**223**
SIDE LOBE ITS - SIDE LOBE SRD					
Sidelobe attenuation (dB)	dB	24	24	24	24
Allowable Interfering power level at receiver antenna input - Indoor use	dBm/MHz	-76	-76	-76	-76
Required Attenuation (dB)		**-91**	**-91**	**-91**	**-91**
Separation distance ITS->SRD (m)		**98**	**138**	**144**	**80**

Table 27: Interference assessment for SRD type III

3.4.2.4 Conclusion

	Prop model	URBAN	SUBURBAN	RURAL	ETSI
SRD I	ML SRD-ML ITS	**237**	346	531	310
	ML ITS-SL SRD	**124**	157	179	111
	SL ITS-ML SRD	**124**	157	179	111
	SL ITS-SL SRD	**57**	45	45	40
SRD II	ML SRD-ML ITS	**346**	601	1108	569
	ML ITS-SL SRD	**182**	290	419	204
	SL ITS-ML SRD	**182**	290	419	204
	SL ITS-SL SRD	**92**	128	128	73
SRD III	ML SRD-ML ITS	**366**	639	1190	621
	ML ITS-SL SRD	**192**	309	456	223
	SL ITS-ML SRD	**192**	309	456	223
	SL ITS-SL SRD	**98**	138	144	80

Table 28: Summary of the calculated Separation Distances

Configuration with a transmission scheme that imply side lobe attenuation factor suits well for RSU unit. It is expected that SRD device would be located outside the main beam of this unit. In that case, compatibility could be achieved.

For OBU, the protection range will depend on the configuration and could be critical for the special case main lobe to main lobe.

3.4.3 Separation distances to protect ITS

The impact of a SRD type III is given in the following table.

- Outdoor use

	Scenario	Urban	Suburban	Rural	ETSI
SRD to ITS	Main Lobe to Main Lobe	**294**	**500**	**875**	**439**
	Main Lobe to Side Lobe	**155**	**239**	**326**	**158**
	Side Lobe to Side Lobe	**77**	**90**	**90**	**57**

Table 29: Protection ranges to protect ITS from outdoor SRD

- Indoor use (15 dB attenuation for the wall losses)

	Scenario	Urban	Suburban	Rural	ETSI
SRD to ITS	Main Lobe to Main Lobe	**132**	**194**	**254**	**122**
	Main Lobe to Side Lobe	**64**	**64**	**64**	**44**
	Side Lobe to Side Lobe	**16**	**16**	**16**	**16**

Table 30: Protection ranges to protect ITS from indoor SRD

It is assumed that there is no problem of compatibility if ITS are operating above 5875 MHz.

Mitigation techniques are required in the frequency range 5855 – 5875 MHz such as LBT to avoid interference to ITS. It is considered that the majority of SRD are likely to be operated indoors and that the number of SRD currently using this band is very low.

3.5 Compatibility between ITS and FWA

3.5.1 Presentation of FWA devices

Fixed Wireless Access (FWA) is used here to refer to wireless systems that provide local connectivity for a variety of applications and using a variety of architectures, including combinations of access as well as interconnection. ECC Report 68 [12] depicts five different kinds of architectures (Mesh, Point-to-Multipoint (P-MP), Point-to-Point (P-P) and Any Point-to-Multipoint (AP-MP) considered to be a hybrid of Mesh and P-MP).

Relevant information on these different kinds of networks can be found in the ECC Report 68. Nevertheless, it has to be noted for the purpose of this contribution that FWA devices can use both omni and directional antenna depending on their function (base station, terminal station, mesh, backhaul…). Therefore, interference created or received by the main beam or sidelobe of such equipment has to be studied.

The considered FWA systems may typically use 5 MHz, 10 MHz or 20 MHz channelisation, which is necessary to obtain sufficiently high data rates.

The 5.725-5.875 GHz band should be able to provide sufficient spectrum for commercial operations, even though exclusive frequency allocations and channel co-ordination is not envisaged in this band. ITS expect to use frequency ranges from 5850 to 5925 MHz. As a consequence, two main interference scenarios can occur. The first one when ITS devices will operate under 5875 MHz (co channel interference) and the second one if not (nearby channel interference).

For convenience and analysis these different systems fall into 5 main groups or variants thereof. Here we present an overview of deployment scenarios for these Groups and identify the typical parameters that characterise the groups and those factors that were key in supporting these sharing studies.

Group	*Description/Reference*
Group 1	Point-to-Multipoint, using Sectored Central Stations including systems based on ETSI HIPERMAN TS 102 177
Group 2	“HIPERMAN Any-point to multipoint” (AP-MP) (as defined by ETSI BRAN in ETSI Technical Report 102079), using “Root Nodes”, “Branch Nodes” and “Leaf Nodes”
Group 3	“HIPERMAN Mesh” network (as defined by ETSI BRAN in ETSI Technical Report 102079), in which all stations (nodes) use omni-directional antennas
Group 4	Directional Mesh (as defined in ETSI TM4 Work Item 04152), in which all stations (nodes) use directional antennas
Group 5	Point-to-Point network, in which all stations use directional antennas

Table 31: Description of the different kinds of FWA devices

3.5.2 Technical parameters used for the interference assessment

Device	Unit	FWA P-MP	FWA Mesh	ITS
e.i.r.p.	dBm	36	36	33
Bandwidth	MHz	20	20	10
Antenna Gain	dBi	18	10	8
Sidelobe attenuation	dB	15	15	12
TPC	dB	10	10	8
Sensitivity (at the antenna input)	dBm	-86	-86	-82
Protection criterion	C/I	6 (BPSK)	6 (BPSK)	6 (BPSK)
OoB attenuation mask (below e.i.r.p level in dBm/MHz)	dBr	40	40	26

Table 32 :Interferer and victim technical parameters

Unwanted mask is coming from ETSI EN 302 502 [23] for FWA device and ETSI TR 102 492-1 [2] (2005-06) for ITS device – see section 2.4.

3.5.3 Separation distances to protect FWA systems

3.5.3.1 Methodology

The required protection range is estimated in two steps. Firstly, a required propagation loss or attenuation is estimated with a classic budget link. After that, the separation distance is calculated following assumptions of propagation model as described in section 2.6.
The required propagation loss L_{FS} is given by the following equation:

$$\begin{gathered} S = \frac{C}{I} = C + 10Log\left(\frac{B_i}{B_v}\right) - G_v - L_{FS} - e.i.r.p. \\ \Rightarrow L_{FS} = C + 10Log\left(\frac{B_i}{B_v}\right) - G_v - e.i.r.p. - S \end{gathered} \tag{21}$$

where

- $S=C/I$ is the protection criterion (=6dB)
- C is the sensitivity of the victim at the antenna input in dBm
- B_i is the receiver bandwidth of the interferer in MHz
- B_v is the bandwidth of the victim in MHz
- G_v is the victim antenna gain in dBi
- *e.i.r.p.* is the e.i.r.p. of the interferer in dBm (with eventually a TPC factor).

Two additional factors can be integrated into this equation. The first one is the OoB attenuation factor if the victim and interferer do not share the same active band. The second one is the sidelobe attenuation factor if the transmission scheme does not imply the main beam of one of the studied devices.

3.5.3.2 Results

				Protection range (m) to fit with protection criterion						
	Applicable		ITS Freq.	<5875 MHz				>5875 MHz		
	RSU	OBU	Scenario	Urban	Suburban	Rural	ETSI	Urban	Suburban	Rural
ITS to FWA		X	ML[1] to ML	1252	2570	5913	4404	311	532	950
	X	X	ML to SL[2]	600	1100	2250	1300	150	220	300
	X	X	SL to SL	300	500	900	440	70	70	70

Table 33: Protection ranges to protect FWA from ITS

3.5.3.3 Conclusion

The above analysis applies for a P-MP and mesh FWA system, but the results can be considered to be representative for all types of FWA systems.

It comes also from spectrum considerations that FWA and ITS devices can interfere on a co channel or adjacent channel case. As a consequence, Table 34 summarises all needed protection ranges for these different scenarios.

In a co-channel analysis, protection ranges have to be greater than few km. About one km is still needed when sidelobe rejection factor is taken into account. As a consequence, some mitigation techniques would be necessary if FWA and ITS devices have to share some part of the spectrum together. They are needed to avoid excessive interference.

The second conclusion is that these protection ranges decrease drastically if ITS and FWA do not share the same frequency range. A 26 to 40 dB typical OoB rejection factor allows limiting protection ranges below a few hundred m.

3.5.4 Separation distances to protect ITS

				Protection range (m) to fit with protection criterion					
	Applicable?		ITS Freq.	<5875 MHz			>5875 MHz		
	RSU	OBU	Scenario	Urban	Suburban	Rural	Urban	Suburban	Rural
FWA to ITS		X	ML to ML	**460**	**800**	**1600**	**37**	**37**	**37**
	X	X	ML to SL	**220**	**370**	**580**	**8**	**8**	**8**
	X	X	SL to SL	**100**	**150**	**170**	**2**	**2**	**2**

Table 34: Protection ranges to protect ITS from FWA

Figures for the case ML to SL are the mean of the two cases interference assessments when considering respectively ML ITS- SL FWA and ML FWA- SL ITS.

The figures in Table 34 show that ITS will not receive excessive interference from FWA devices if they do not share the same frequency band. It means that in the frequency range 5855-5875 MHz ITS may suffer from interference.

3.6 Compatibility between ITS and RTTT

ECC Decision (02)01 designates the frequency bands 5795-5805 MHz, with possible extension to 5815 MHz, for RTTT. The band 5795-5805 MHz is for use by initial road-to-vehicle systems, in particular road toll systems, with an additional sub-band, 5805-5815 MHz, to be used on a national basis to meet the requirements of multi-lane road junctions.

---

[1] Main Lobe

[2] Side Lobe

Although there is at least 40 MHz of guard band between ITS and RTTT systems, the potentially close vicinity in the deployment of both systems may raise some coexistence problems.
Three main types of potential problems have been identified:

- interference from the RTTT Road-side Unit (RSU) on the ITS. It comes from these calculations as developed in annex 4 that RTTT RSU may be able to create interference on ITS OBU in particular when the car would be below the RTTT RSU in the main lobe to main lobe configuration. Such a situation is unlikely to occur during a short time since the RTTT device is pointed towards the ground and ITS devices presents a tilt about 5°.
- interference from the ITS on the RTTT RSU. It comes from these calculations that ITS OBU will not create interference on RTTT RSU if the unwanted level of ITS devices is lower than -65dBm/MHz within the RTTT frequency band (5795-5815 MHz). Alternatively, a mitigation technique would be to switch off ITS while within the RTTT communications zone.
- impact from the ITS on the RTTT On-board Unit (OBU). The OBU requires a -60 dBm signal to be waken up and to understand commands from the RTTT RSU. The unwanted emission level of ITS devices is unlikely to reach such low sensitivity (44 dB higher than RTTT RSU). However such situation may occur within the ITS band if the RTTT OBU receiver is not filtered and is too sensitive outside its identified band.

3.7 Compatibility between ITS and FS (above 5925 MHz)

3.7.1 Fixed service

3.7.1.1 Technical characteristics

The following FS parameters considered in the next study are provided in table 35.

Frequency band (GHz)	**5.925-6.425GHz**	
Modulation	128QAM	RBQPSK
Channel spacing (MHz)	29.65	90
TX output power (maximum) (dBW)	3	6
Feeder/multiplexer loss (minimum) (dB) (2)	3.3	4
Antenna type (3) and gain (maximum and minimum) (dBi)	44.8 / 34.5 (dish)	45
EIRP (4) (dBW)	44.5	47
Receiver noise bandwidth (MHz)	22.3	56
Receiver noise figure (dB) (2)	4.0	6
Rx input level for 1×10^{-6} BER (dBW)	-99.0	-
Nominal long-term interference (dBW in Rx noise bandwidth) (5)	-146.5	-142
Nominal long-term interference (dBW/MHz)	-160.0	-159

Table 35: Typical system(1) parameters for point-to-point FS systems

(1) It should be noted that the parameters provided in these tables are considered to be representative for the purpose of carrying out technical sharing studies. In some cases certain parameters may vary due to practical operating requirements.

(2) It is generally intended that the noise figure data include the duplexer filter losses, while the feeder/multiplexer loss row are related to feeder losses only.

(3) Omni, Yagi, Dish, Horn, Sectored, etc.

(4) Where regulatory limits apply, EIRP may not be equal to the maximum power plus the maximum gain (in decibels).

(5) Recommendation ITU-R F.1094 [25] provides the apportionment of the total degradation of an FS link due to interferences as It recommends 1% for the unwanted emissions.

The calculation assumed that the gain in the side lobes is about -5dB i.e. the rejection between the main beam and the side lobes is about 44 dB.

This frequency band is mostly used for the purpose of RRL/trunk/infrastructure applications, as shown by the following quote from ECC Report 003 (see also Table 2 [1]):

“The sub-bands 5925-6425 MHz and 6425-7125 MHz are used for FS quite extensively across Europe, mostly for medium and high-capacity (between 34-155 Mb/s) trunk and Public Mobile Networks infrastructure support links.

Another recently appearing trend shows not an increase in numbers of links, but increase in their transmission capacities beyond 155 Mb/s (up to 4 x STM-1 SDH streams). This should be mostly due to the fact that the supra-regional backbone configuration does not have to change with the densification of served network. Therefore, most operators choose to use more efficient modulation technologies over existing links rather than building new ones. Many responders predicted further growth in use of this band.

The average current hop length of the PP links in this band is 37 km.”

3.7.1.2 FS Channel Plan

ERC Recommendation 14-01 [26] gives the channel plan for the L6 band which provides for 8 x 29.65 MHz channels between 5 930.375 MHz and 6 167.575 MHz and a further 8 x 29.65 MHz channels between 6 182.415 MHz and 6 419.615 MHz, as shown in Figure 16 below.” Consequently, there is a guard band of 5.375 MHz between the beginning of the L6GHz band (5 925 MHz) and the first FS channel deployed.

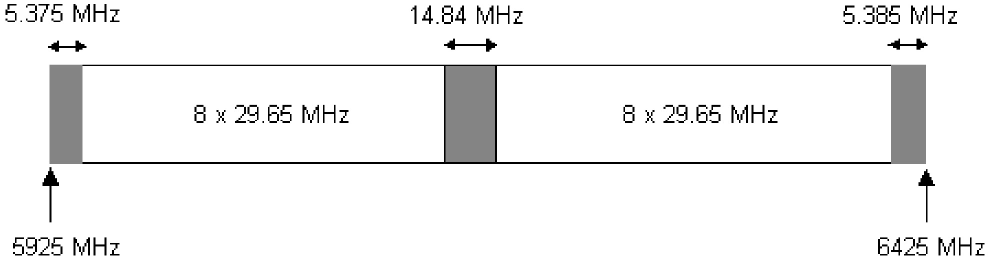


Figure 16: ERC Recommendation 14-01 channel plan

It was also indicated by one country that they use FS systems with 90 MHz channel spacing in this band with the centre frequency of the first channel being 5987.5 MHz as in Rec. ITU-R F.383 Annex 1 [27].

3.7.1.3 FS Unwanted Emissions Mask

It is necessary to develop assumptions on the level of unwanted emissions of Fixed Service systems. Recommendation ITU-R SM-1541 (see Annex 12) [8], dealing with out-of band emissions, provides a mask for Fixed Service systems.

In the past, when using some of the mask given in Recommendation ITU-R SM.1541, it has been found that they led to overestimate the amount of unwanted emissions falling into the neighbouring bands. Therefore it may be necessary to consider mask more representative of the unwanted emissions of the FS systems operating in this band. It has therefore to be noted, that the band 5.925-6.425 MHz is now covered in Annex B of ETSI EN 302 217-2-2 [28], where a number of masks for low and high capacity may be found.
STM-1 (2xSTM-1 in frequency reuse) systems are widely deployed in this band corresponding to systems called B.2 and B.3.

The comparison of these two masks (see Figure below) with the mask given in Rec. ITU-R SM.1541 confirms that the masks given in EN are effectively more realistic for the FS systems in this band. In addition, for a frequency off-set larger than 20 MHz (FS guard band of 5.375 MHz + 29.65MHz/2) the mask corresponding to B.2 systems allows covering the case of B.1 systems.

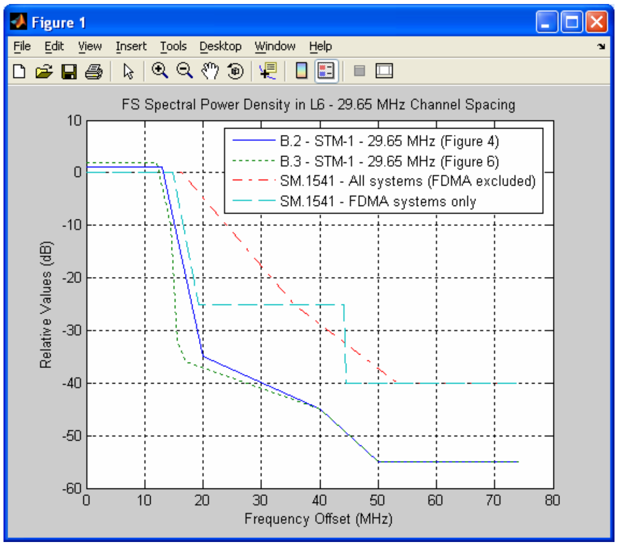


Figure 17: Comparison of FS masks – 29.65 MHz case

It is then proposed to consider the mask corresponding to B.2 systems when assessing the impact of FS on ITS (frequency offset of at least 20 MHz).

In case of systems using 90 MHz channel spacing, the following mask was provided.

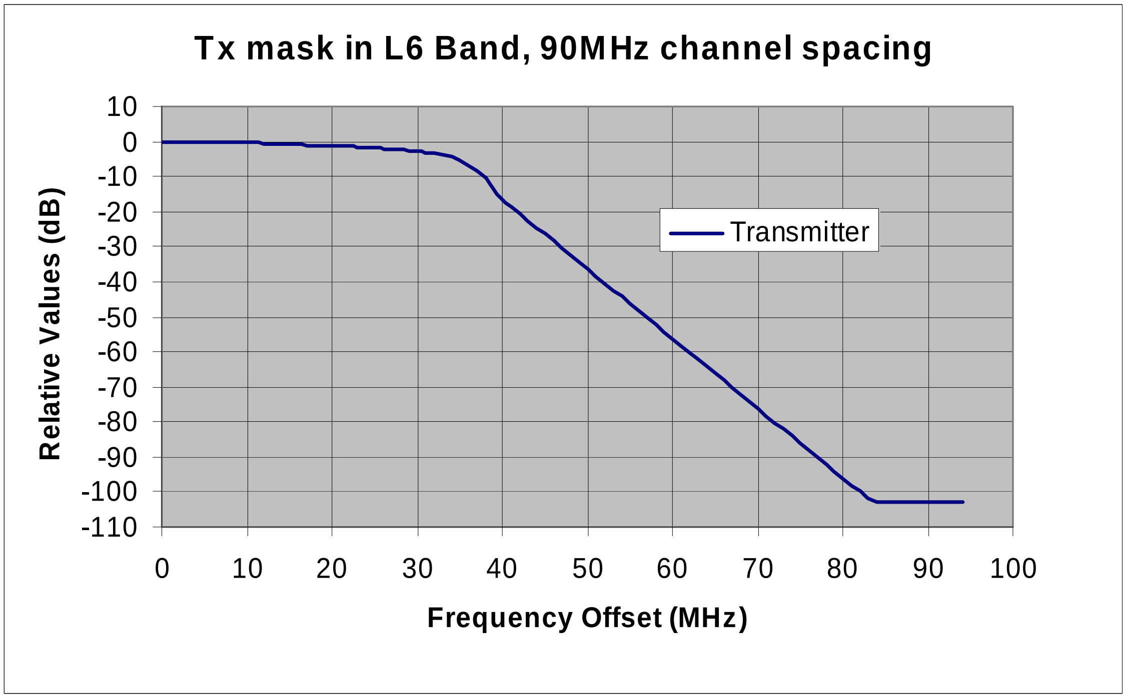


Figure 18: Emission mask for 90 MHz FS

3.7.2 Separation distances to protect ITS devices

The required propagation loss L_{FS} is given by the following equation:

$$\begin{aligned} I &= e.i.r.p. - L_{ITS} + G_r \\ \Rightarrow L_{ITS} &= e.i.r.p. - I + G_r \end{aligned} \qquad (22)$$

where

- I is the maximum interference power (-106dBm/MHz)
- G_r is the victim antenna gain in dBi
- *e.i.r.p.* is the e.i.r.p. of the interferer in dBm (with eventually a TPC factor – no TCP is assumed in the case where the ITS is "victim").

Two additional factors can be integrated into this equation. The first one is the OoB attenuation factor if the victim and interferer do not share the same active band. The second one is the sidelobe attenuation factor if the transmission scheme does not imply the main beam of one of the studied devices.

3.7.2.1 Results for 29.65 MHz channel spacing

The following table provides the calculated separation distances and it was found that the separation distances (for the sidelobe of the ITS) become less than 500 m for an "frequency separation" of about 42 MHz (corresponding to about 11dBm/MHz unwanted emission into the ITS channel).

Model		**Urban**	**Suburban**	**Rural**	**ETSI**
Protection criterion: C/I	dB	6	6	6	6
Allowable Interfering power level '*I*' at receiver antenna input	dBm/MHz	**-106**	**-106**	**-106**	**-106**
Wall loss (building penetration)	dB	0	0	0	0
MAIN LOBE ITS - MAIN LOBE RL					
Allowable Interfering power level at receiver antenna input	dBm/MHz	-106	-106	-106	-106
Required Attenuation (dB)		**-117**	**-117**	**-117**	**-117**
Separation distance ITS->FS (m)		**406**	**720**	**1365**	**734**
MAIN LOBE ITS - SIDE LOBE FS					
Sidelobe attenuation (dB)	dB	50	50	50	50
Allowable Interfering power level at receiver antenna input	dBm/MHz	-56	-56	-56	-56
Required Attenuation (dB)		**-67**	**-67**	**-67**	**-67**
Separation distance ITS->FS (m)		**9**	**9**	**9**	**9**
SIDE LOBE ITS - MAIN LOBE FS					
Sidelobe attenuation (dB)	dB	12	12	12	12
Allowable Interfering power level at receiver antenna input	dBm/MHz	-94	-94	-94	-94
Required Attenuation (dB)		**-105**	**-105**	**-105**	**-105**
Separation distance ITS->FS (m)		**214**	**348**	**536**	**264**
SIDE LOBE ITS - SIDE LOBE FS					
Sidelobe attenuation (dB)	dB	62	62	62	62
Allowable Interfering power level at receiver antenna input	dBm/MHz	-44	-44	-44	-44
Required Attenuation (dB)		**-55**	**-55**	**-55**	**-55**
Separation distance ITS->FS (m)		**2**	**2**	**2**	**2**

Table 36: Separation distances – ETSI Mask – ITS operating in 5895-5905 MHz

3.7.2.2 Results for 90 MHz channel spacing

The EIRP in 1 MHz is calculated – as a worst case – using the receiver IF bandwidth of 56 MHz. This gives: 47-10 x $\log_{10}$ (56) = 29 dBW/MHz. Then, at the edge of the FS band (5925 MHz), the attenuation is about 55dB (offset of 60 MHz). The radiated power will be then 29 dBW/MHz – 55dB = -26 dBW/MHz or 4dBm/MHz, i.e.

below the power used for the calculations in Table 36 to derive the separation distances. It means that these FS systems will have no impact on the ITS.

Separation distances to protect FS systems

3.7.2.3 Methodology

The required protection range is estimated using the maximum allowable interference at the antenna input when applying the long term interference criteria. It indicates the interference level which can be received by any FS station for less than 20% of the time.
It means that the required propagation loss L_{FS} is given by the following equation:

$$I = e.i.r.p. - L_{FS} + G_r$$

$$\Rightarrow L_{FS} = e.i.r.p. - I + G_r$$

where

- I is the maximum interference power (-174dBm/MHz)
- G_r is the victim antenna gain in dBi
- *e.i.r.p.* is the e.i.r.p. of the interferer in dBm (with eventually a TPC factor)

Two additional factors can be integrated into this equation. The first one is the OoB attenuation factor if the victim and interferer do not share the same active band. The second one is the sidelobe attenuation factor if the transmission scheme does not imply the main beam of one of the studied devices.
The following compatibility study considers an ITS device with an expected unwanted attenuation factor will be higher than 80dBr.

3.7.2.4 Results

LINK BUDGET	Value	Units	**Urban**	**Suburban**	**Rural**	**ETSI**
Emission part: ITS						
Bandwidth	10	MHz				
TX out, e.i.r.p	33	dBm	33	33	33	33
TX Out e.i.r.p per MHz	23	dBm/MHz	23	23	23	23
effect of TPC (dB)	8	dB	8	8	8	8
OoB Attenuation	80	dBr	80	80	80	80
Net TX Out e.i.r.p		dBm/MHz	**-65**	**-65**	**-65**	**-65**
Antenna Gain	8	dBi				
Frequency (GHz)	5.90	GHz				
Reception part: FS						
Receiver Noise bandwidth	22.6	MHz	22.60	22.60	22.60	22.60
Long term interference criteria	-116.5	dBm	-116.50	-116.50	-116.50	-116.50
Antenna gain	44	dBi	44.00	44.00	44.00	44.00
Allowable Interfering power level '*I*' at receiver antenna input		dBm/MHz	**-174**	**-174**	**-174**	**-174**
Protection criterion						
MAIN LOBE ITS - MAIN LOBE FS						
Allowable Interfering power level at receiver antenna input		dBm/MHz	-174	-174	-174	-174
Required Attenuation (dB)			**-109**	**-109**	**-109**	**-109**
Separation distance ITS->FS (m)			**265**	**444**	**747**	**372**
MAIN LOBE ITS - SIDE LOBE FS						
Sidelobe attenuation (dB)	50	dB	50	50	50	50
Allowable Interfering power level at receiver antenna input		dBm/MHz	-124	-124	-124	-124
Required Attenuation (dB)			**-59**	**-59**	**-59**	**-59**
Separation distance ITS->FS (m)			**4**	**4**	**4**	**4**
SIDE LOBE ITS - MAIN LOBE FS						
Sidelobe attenuation (dB)	12	dB	12	12	12	12
Allowable Interfering power level at receiver antenna input Indoor use		dBm/MHz	-162	-162	-162	-162
Required Attenuation (dB)			**-97**	**-97**	**-97**	**-97**
Separation distance ITS->FS (m)			**140**	**209**	**278**	**134**
SIDE LOBE ITS - SIDE LOBE FS						
Sidelobe attenuation (dB)	62	dB	62	62	62	62
Allowable Interfering power level at receiver antenna input Indoor use		dBm/MHz	-112	-112	-112	-112
Required Attenuation (dB)			**-47**	**-47**	**-47**	**-47**
Separation distance ITS->FS (m)			**1**	**1**	**1**	**1**

Table 37: Separation distances to protect FS systems

3.7.3 Conclusions

The results in section 3.7.2 show that ITS devices may be operated without being impacted by the unwanted emissions of FS links operating above 5925 MHz if the ITS devices are located below 5905 MHz. This implies also that the last two channels (5905-5925 MHz) may suffer from excessive interference coming from FS links.

On the other hand, section 0 is dealing with the effect of ITS operating in the closest adjacent channel to an FS system. As a result of this study, it is observed that the unwanted level of any ITS device has to be lower than -65 dBm/MHz in the FS allocation (>5925 MHz).

4 CONSIDERATIONS ON LBT

Listen before talk (LBT) of the IVC and R2V communication system is based on IEEE 802.11p [5].

As a fundamental method for channel access a carrier sense multiple access with collision avoidance procedure (CSMA/CA) is defined for communication units. LBT is part of this procedure. In the clear channel assessment (CCA) it is evaluated whether the energy at the antenna exceeds a certain threshold. A channel is marked as busy as long as the energy is sensed. If the channel is not busy, its status is called idle.

For IEEE 802.11p the channel is indicated to be busy with a probability > 90 % if the receive level is:

-82 dBm for a 20MHz channel within 4 µs and

-85 dBm for a 10MHz channel within 8 µs,

which means it takes 4 µs or 8 µs respectively to determine the status of the channel.

The CSMA/CA controls the contention of the channel access as presented in the following figure.

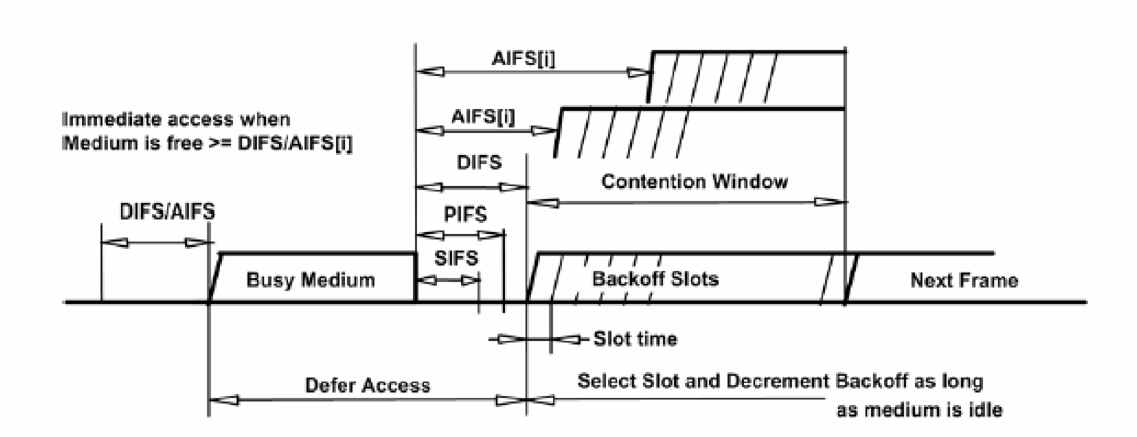


Figure 18: Channel Access (IEEE 802.11 Rev. of version 1999)

Before a node starts a transmission it the channel has to stay idle for a fixed time. If the channel is idle the node instantly starts its transmission after the expiration of this time interval (e.g. DIFS, AIFS). Otherwise, if the channel is busy, the access is deferred.

After the channel turn idle all waiting nodes have to stay sensing the channel for the fixed time interval. Afterwards, if the channel is still idle, a random back-off procedure will follow. In this procedure the node has to continue sensing the channel for a random number of slots (Back-off Slots) drawn from a contention window. The size of the contention window will be changed depending on failed transmissions. If the channel is still idle for the back-off time the node will start its transmission. Otherwise the channel access is deferred.

The length of the fixed time interval depends on the priority of the pending message. This priority mechanism is used to prioritise different types of system messages, e.g. data or acknowledgement, but also to prioritise data messages of different applications. Typically values for data messages are

34 µs for the 20MHz channel and

58 µs for the 10MHz channel.

For the back-off procedure typically average waiting intervals are

67,5 µs for a 20MHz channel and

97,5 µs for a 10MHz channel.

Considering the whole channel access procedure the average listening time is

101,5 µs for a 20MHz channel and

155,5 µs for a 10MHz channel

before a node starts transmission.

It has to be noted that LBT may not always be efficient to protect other services such as FWA and SRD since it may not always be capable to detect the FWA transmission.

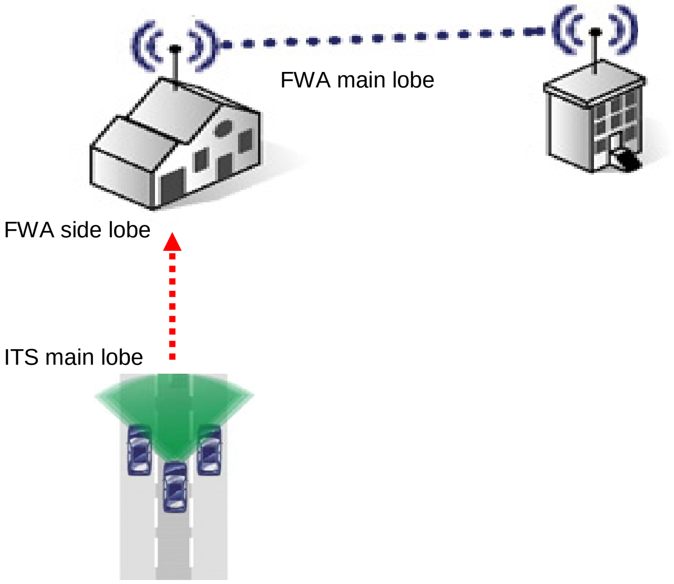


Figure 19: Case where LBT may not detect the FWA transmission

5 CONCLUSIONS

The table below provides an overview of the different compatibility studies showing the most relevant aspects.

Services and applications	Section of the report	ITS as interferer	ITS as victim
Radio Amateur	3.1	Compatibility is achieved.	Compatibility is achieved.
FSS	3.2	Compatibility is achieved.	Compatibility is achieved in most cases, taking into account the limited number of earth stations and real terrain shielding.
Radiolocation	3.3	Compatibility assumed with ITS unwanted power of -55dBm/MHz below 5850 MHz.	Between 5855 and 5875 MHz ITS may suffer from interference.
SRD	3.4	Compatibility is assumed if ITS are operating above 5875 MHz. Mitigation techniques are required in the frequency range 5855 – 5875 MHz.	Mitigation techniques are needed in the frequency range 5855 – 5875 MHz. LBT may help avoiding interference to ITS.
FWA	3.5	Compatibility is achieved if ITS are operating above 5875 MHz. Mitigation techniques are required in the frequency range 5855 – 5875 MHz.	Mitigation techniques are needed in the frequency range 5855 – 5875 MHz. LBT may help avoiding interference to ITS.
RTTT	3.6	Compatibility is achieved if ITS are operating with unwanted power less than -65dBm/MHz below 5815 MHz	Interference depend to the antenna beams alignment and is limited to the RTTT communication zone.
FS	3.7 and Annex 2	Co-frequency: no study needed since few systems exist [1] Adjacent band: ITS unwanted power less than -65dBm/MHz, above 5925 MHz (frequency separation[1] or filtering required).	ITS within the band 5905-5925 MHz may suffer from interference.

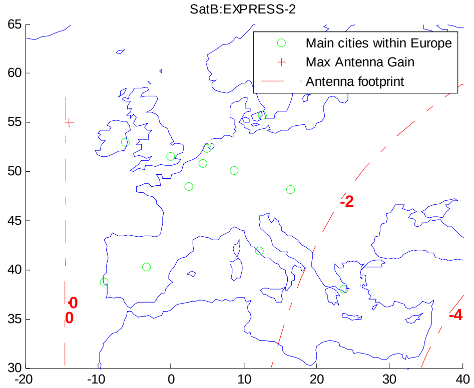
Table 38: Conclusions of compatibility studies

Between 5875 MHz and 5905 MHz ITS will not suffer from excessive interference resulting from other systems/services.

Between 5855 MHz and 5925 MHz, ITS are compatible with all services providing:

- their unwanted emissions power below 5850 MHz is less than -55dBm/Hz;
- their unwanted emissions power below 5815 MHz is less than -65dBm/MHz or Alternatively, a mitigation technique would be to switch off ITS while within the RTTT communications zone;
- the unwanted emissions power above 5925 MHz is less than -65dBm/MHz;
- mitigation techniques are implemented by ITS in the frequency range 5855-5875 MHz to ensure compatibility with FWA and SRD equipments.

ANNEX 1: SATELLITE FOOTPRINTS FOR SATELLITES B TO I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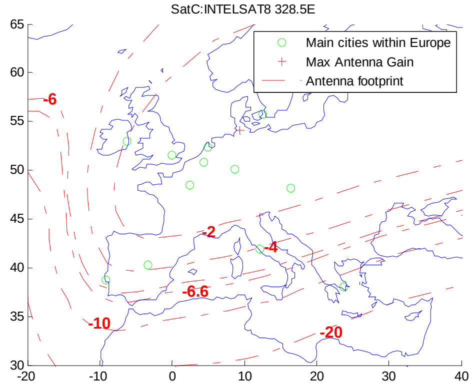
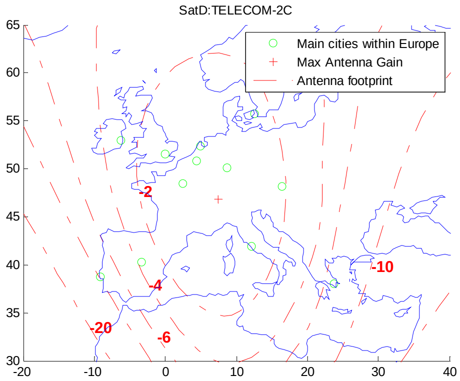
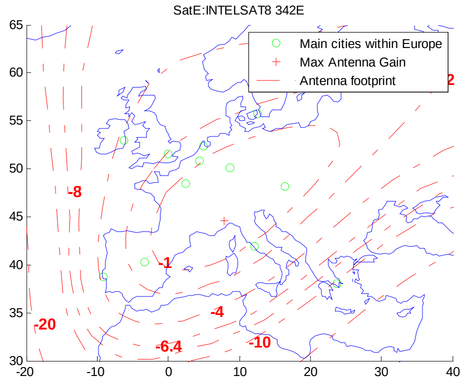

SatC:INTELSAT8 328.5E


SatD:TELECOM-2C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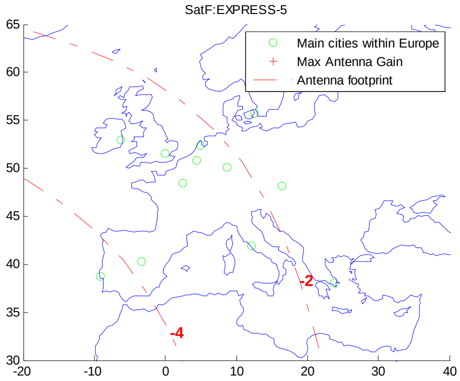
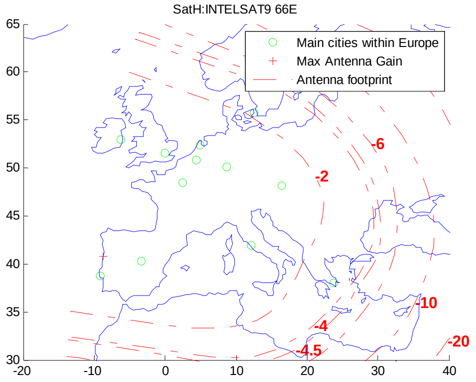

SatF:EXPRESS-5

G no longer existing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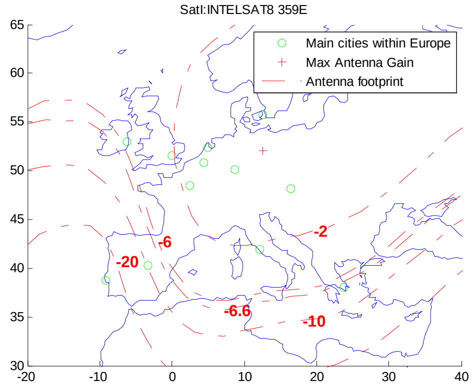

SatI:INTELSAT8 359E

ANNEX 2: P-P FIXED SERVICE SYSTEMS OPERATING IN THE BAND 5875 – 5925 MHZ

General (typical) characteristics of P-P fixed service station in the 5670-6170 MHz band.

Parameter	Analogue	Digital
Rx sensitivity, dBW	-104..-106	-94..-123
Protection ratio, dB	50	30
Receiver Noise, dBW	-154..-156	-124..-153
Noise Factor, dB	5	4
Maximum TX power, dBW	10	10
Channel bandwidth, MHz	28	28
Antenna gain, dB	41..43,5	35..43,5
Polarization	vertical and horizontal	vertical and horizontal
Feeder loses, dB	0,02..0,05	0,02..0,05

Table 1

Rx selectivity

Rx selectivity, dB	**0**	**-3**	**-30**	**-50**
ΔF (MHz) [Analogue]	0	± 20	± 28	± 35
Rx selectivity, dB	**0**	**-3**	**-30**	**-50**
ΔF (MHz) [Digital]	0	± 15	± 22.5	± 28

Table 2

TX spectrum

TX spectrum, dBc	**0**	**-3**	**-35**	**-50**
ΔF (MHz) [Analogue]	0	± 6	± 14	± 19
TX spectrum, dBc	**0**	**-3**	**-30**	**-50**
ΔF (MHz) [Digital]	0	± 14.5	± 22.5	± 56

Table 3

Separation distances were calculated taking into account the receiver noise of -156dBW in 28 MHz or -170 dBW/MHz as the maximum acceptable interfering power (the same methodology as in section 3.6.3 was used).

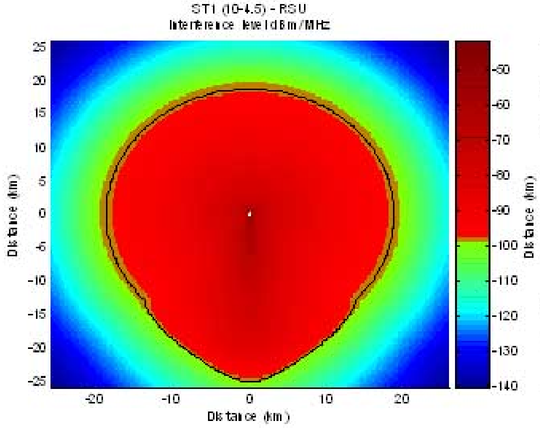
Model		**Urban**	**Suburban**	**Rural**	**ETSI**
Allowable Interfering power level '*I*' at receiver antenna input	dBm/MHz	**-140**	**-140**	**-140**	**-140**
Wall loss (building penetration)	dB	0	0	0	0
MAIN LOBE ITS - MAIN LOBE RL					
Allowable Interfering power level at receiver antenna input	dBm/MHz	-140	-140	-140	-140
Required Attenuation (dB)		**-155**	**-155**	**-155**	**-155**
Attenuation at first break point		-84	-90	-96	-71
Margin (dB)		-71	-65	-59	-84
Attenuation at second break point		-95	-100	-113	-121
Margin (dB)		-60	-56	-43	-35
Separation distance ITS->FS (m)		**3189**	**7408**	**19995**	**19524**
MAIN LOBE ITS - SIDE LOBE FS					
Sidelobe attenuation (dB)	dB	50	50	50	50
Allowable Interfering power level at receiver antenna input	dBm/MHz	-90	-90	-90	-90
Required Attenuation (dB)		**-105**	**-105**	**-105**	**-105**
Attenuation at first break point		-84	-90	-96	-71
Margin (dB)		-21	-15	-9	-34
Attenuation at second break point		-95	-100	-113	-121
Margin (dB)		-10	-6	7	15
Separation distance ITS->FS (m)		**219**	**358**	**557**	**275**
SIDE LOBE ITS - MAIN LOBE FS					
Sidelobe attenuation (dB)	dB	12	12	12	12
Allowable Interfering power level at receiver antenna input	dBm/MHz	-128	-128	-128	-128
Required Attenuation (dB)		**-143**	**-143**	**-143**	**-143**
Attenuation at first break point		-84	-90	-96	-71
Margin (dB)		-59	-53	-47	-72
Attenuation at second break point		-95	-100	-113	-121
Margin (dB)		-48	-44	-31	-23
Separation distance ITS->RL (m)		**1677**	**3580**	**8655**	**7017**
SIDE LOBE ITS - SIDE LOBE FS					
Sidelobe attenuation (dB)	dB	62	62	62	62
Allowable Interfering power level at receiver antenna input	dBm/MHz	-78	-78	-78	-78
Required Attenuation (dB)		**-93**	**-93**	**-93**	**-93**
Attenuation at first break point		-84	-90	-96	-71
Margin (dB)		-9	-3	3	-22
Attenuation at second break point		-95	-100	-113	-121
Margin (dB)		2	6	19	27
Separation distance ITS->RL (m)		**114**	**163**	**191**	**99**

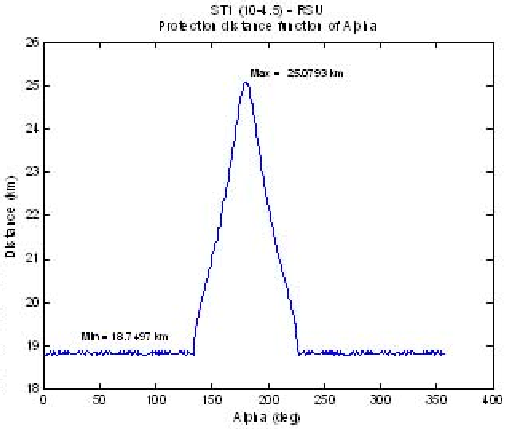
Table 4

ANNEX 3: RESULTS OF THE SHARING SIMULATION CONSIDERING A FLAT TERRAIN MODEL

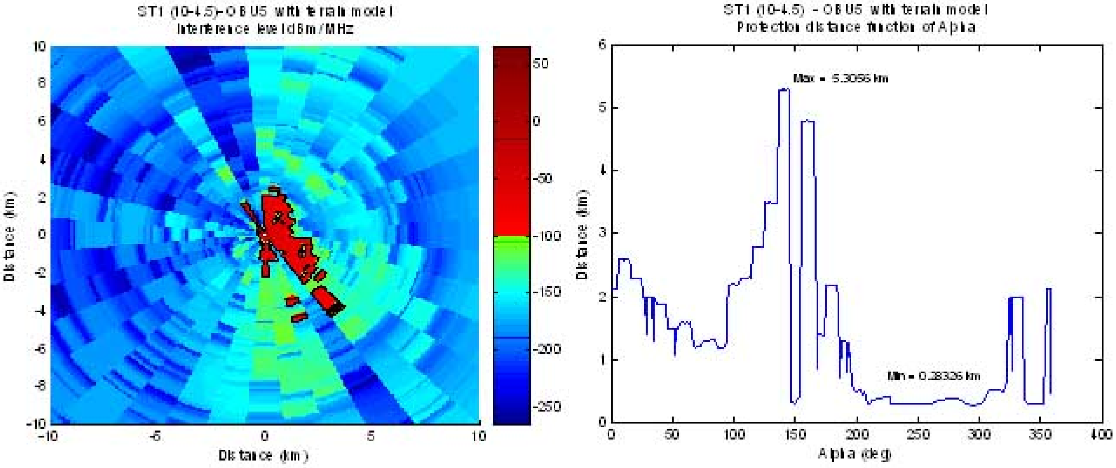
This section provides results of the simulation for all given cases defined in section 3.2.2 of this report.

ST1 Case: 2D representations of the Interference and limit distance for Imax function of azimuth angle around the earth station:

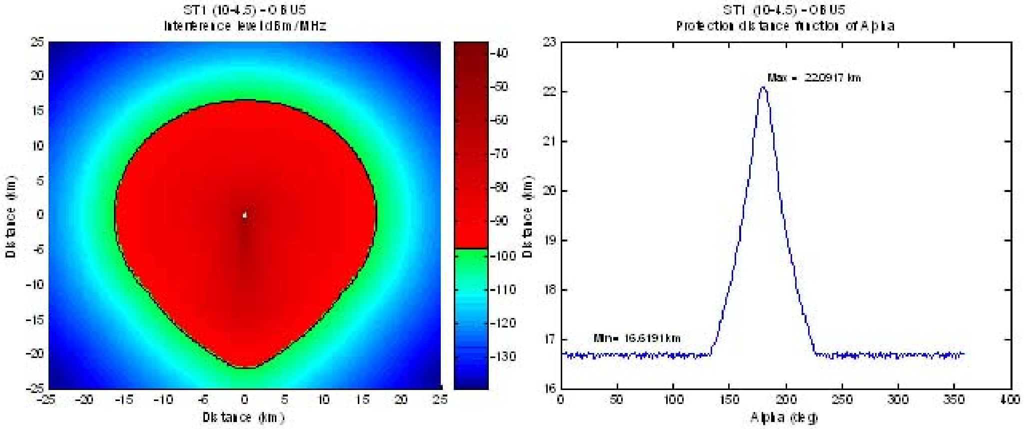




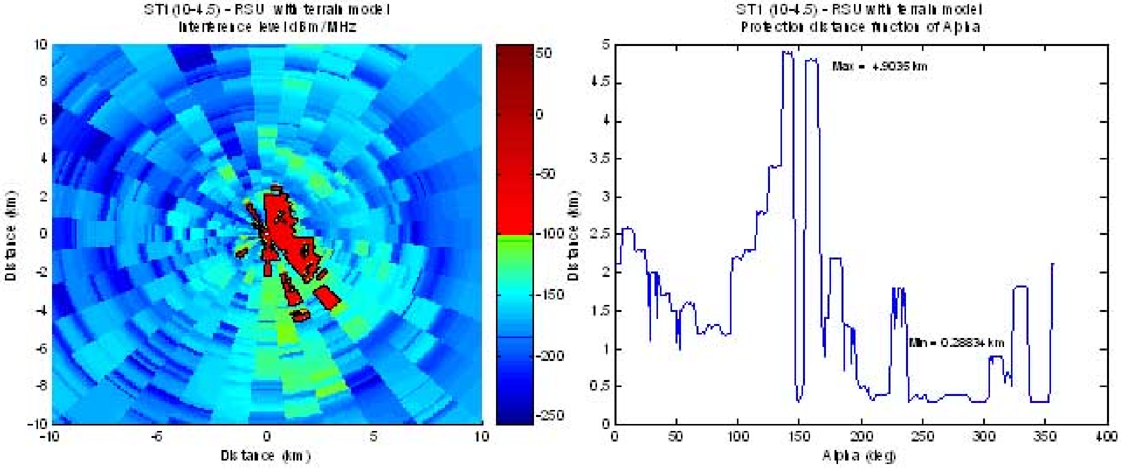
OBU G_{max}=5dBi case (flat model)



OBU G_{max}=5dBi case (real terrain model)

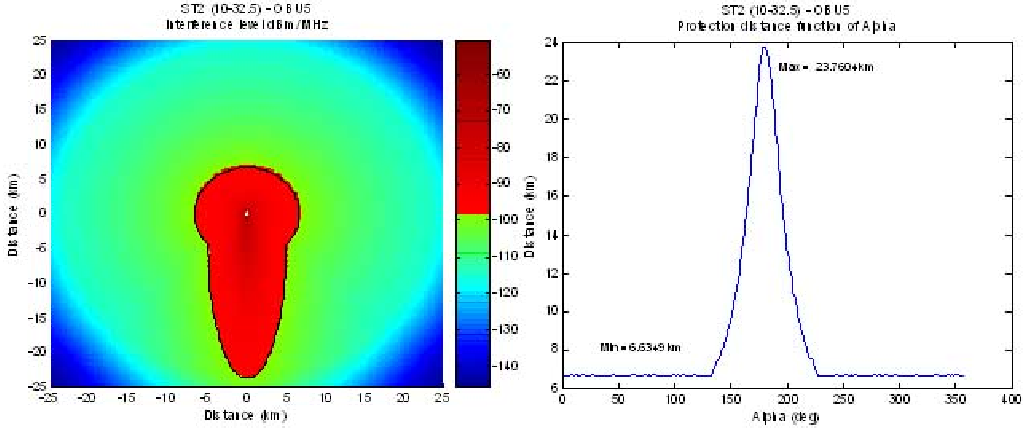


RSU case

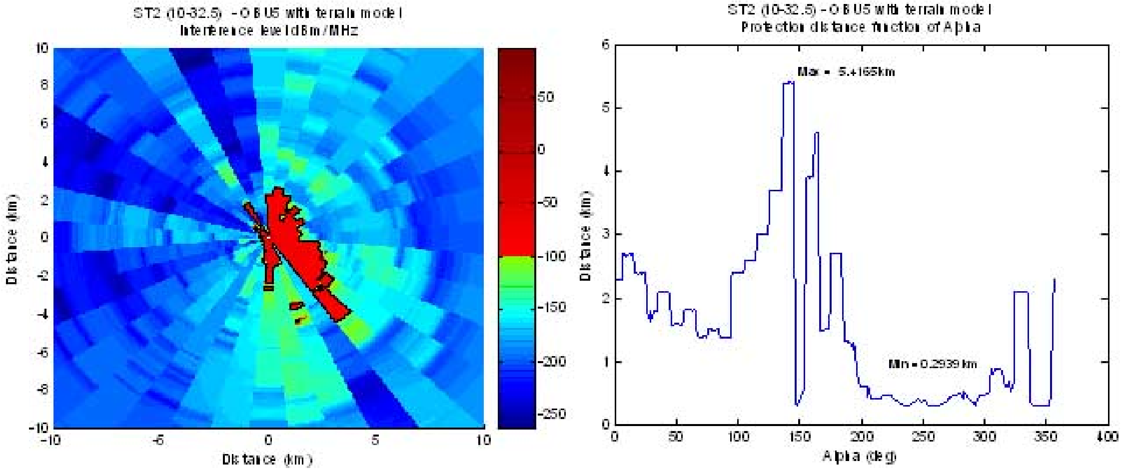


RSU case (real terrain model)

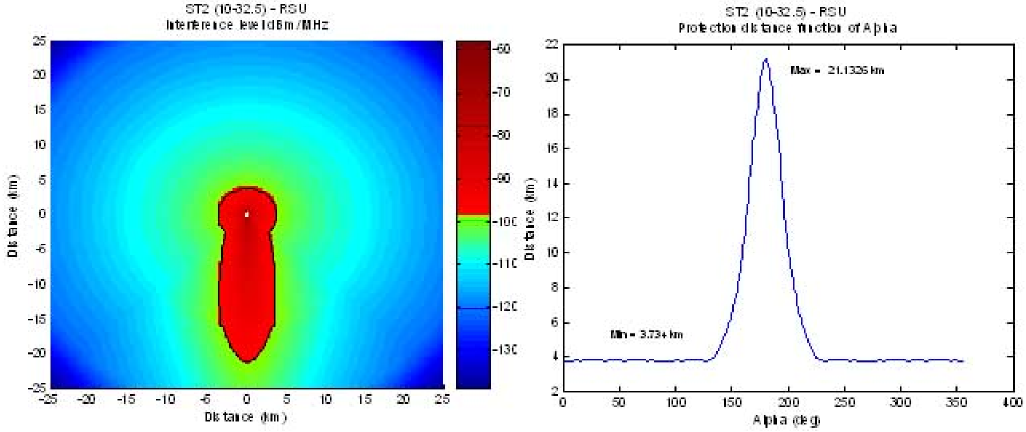
ST2 Case: 2D representations of the Interference and limit distance for Imax function of azimuth angle around the earth station:



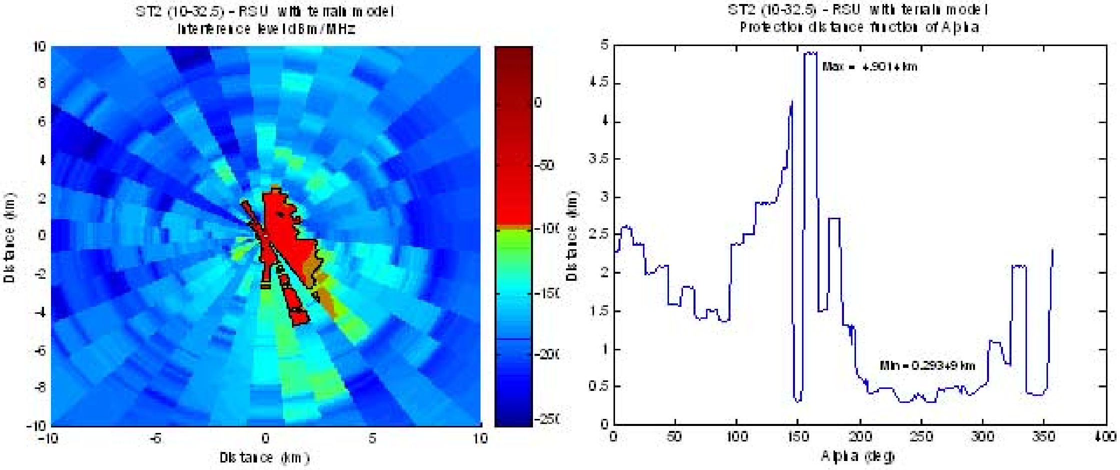
OBU G_{max}=5dBi case (flat model)



OBU G_{max}=5dBi case (real terrain model)

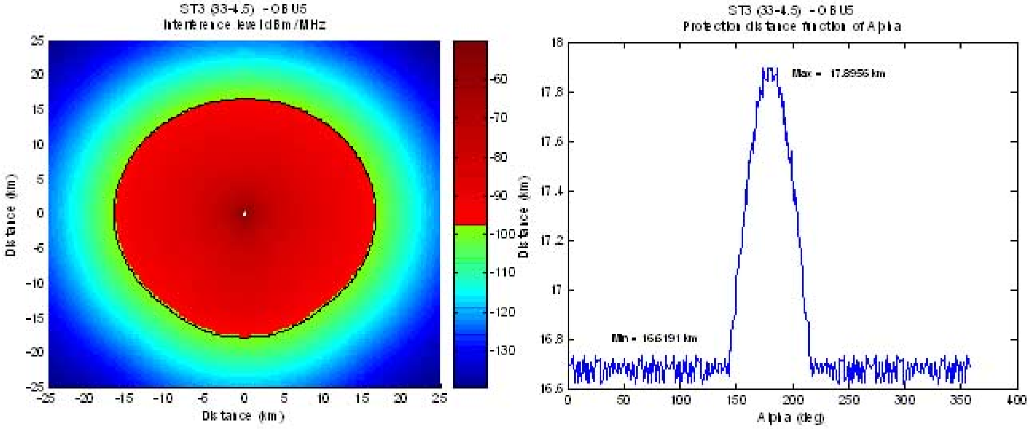


RSU case (flat model)

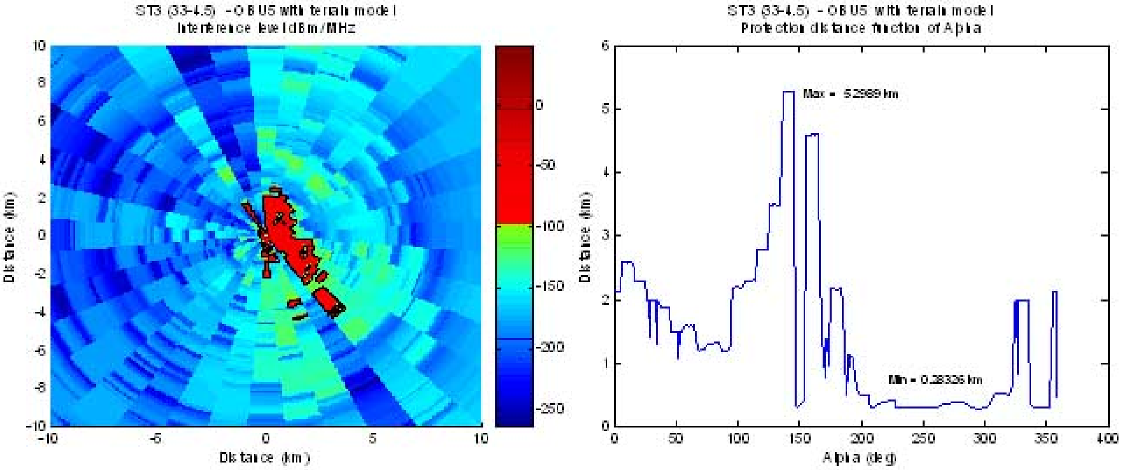


RSU case (real terrain model)

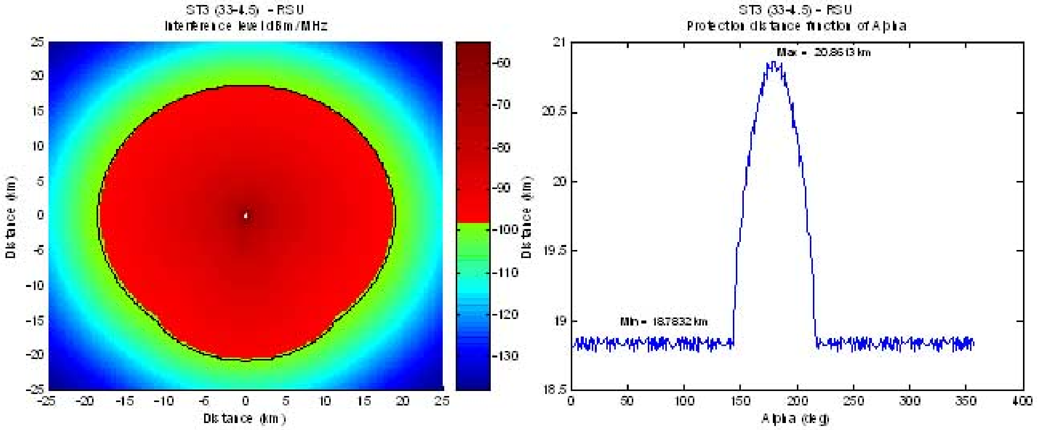
ST3 Case: 2D representations of the Interference and limit distance for Imax function of azimuth angle around the earth station:



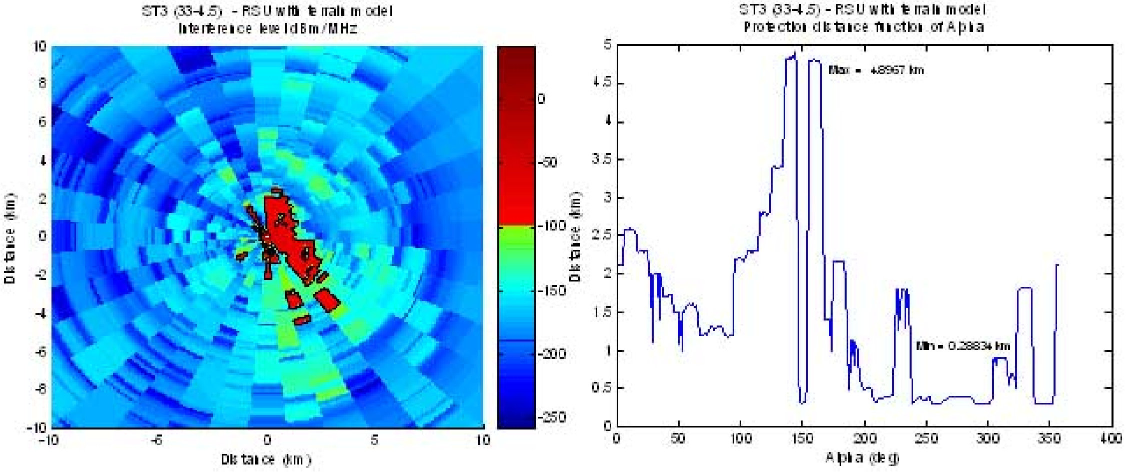
OBU G_{max}=5dBi case (flat model)



OBU G_{max}=5dBi case (real terrain model)

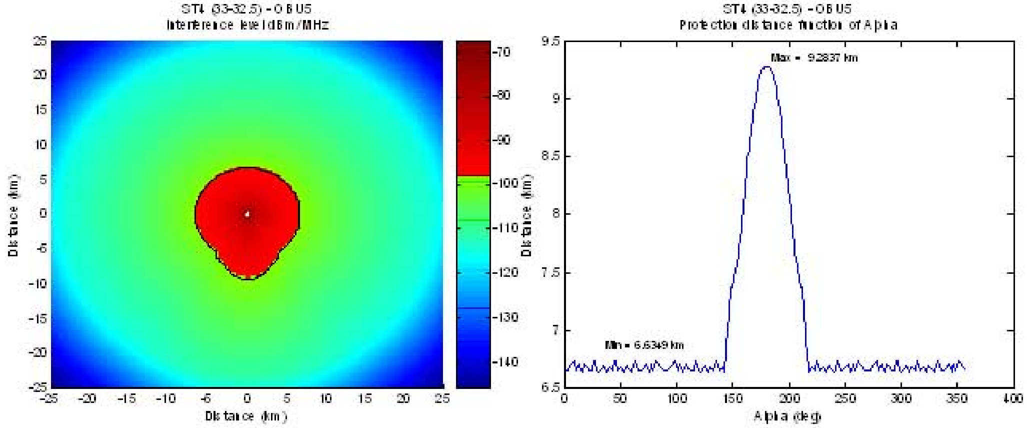


RSU case (flat model)

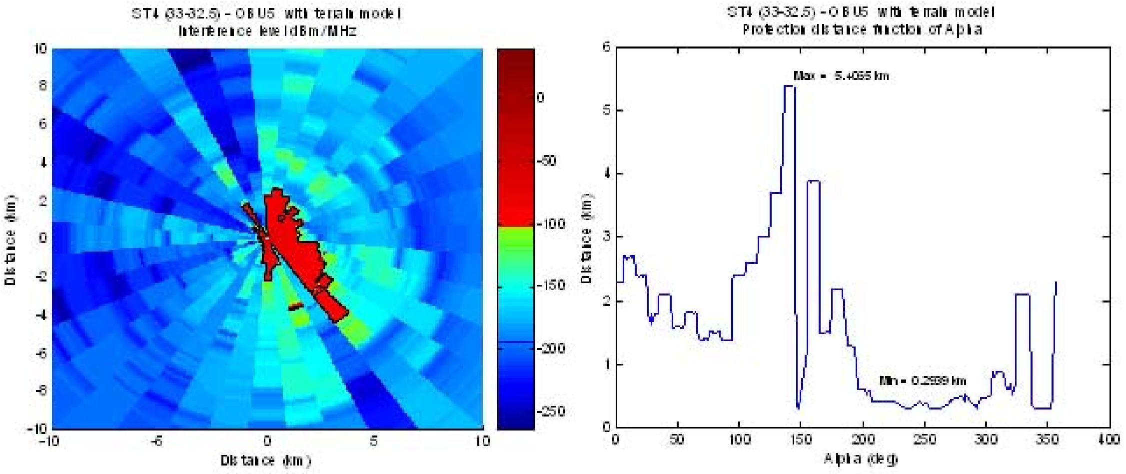


RSU case (real terrain model)

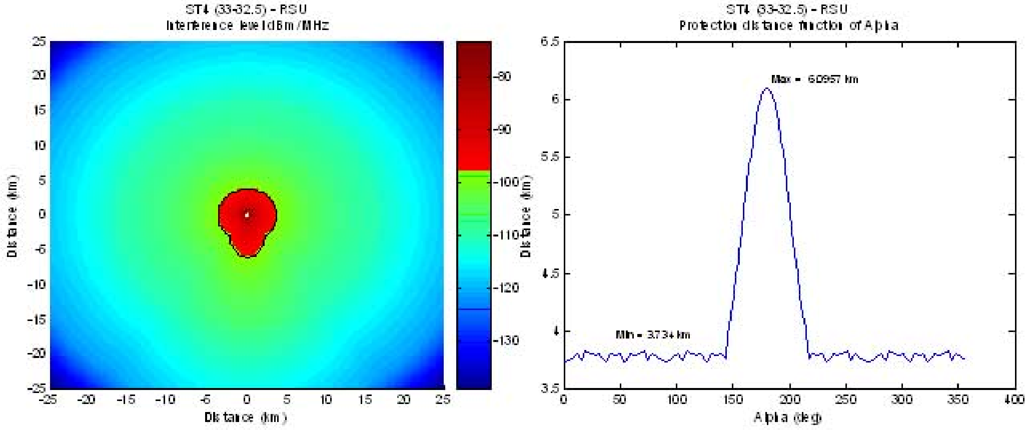
ST4 Case: 2D representations of the Interference and limit distance for Imax function of azimuth angle around the earth station:



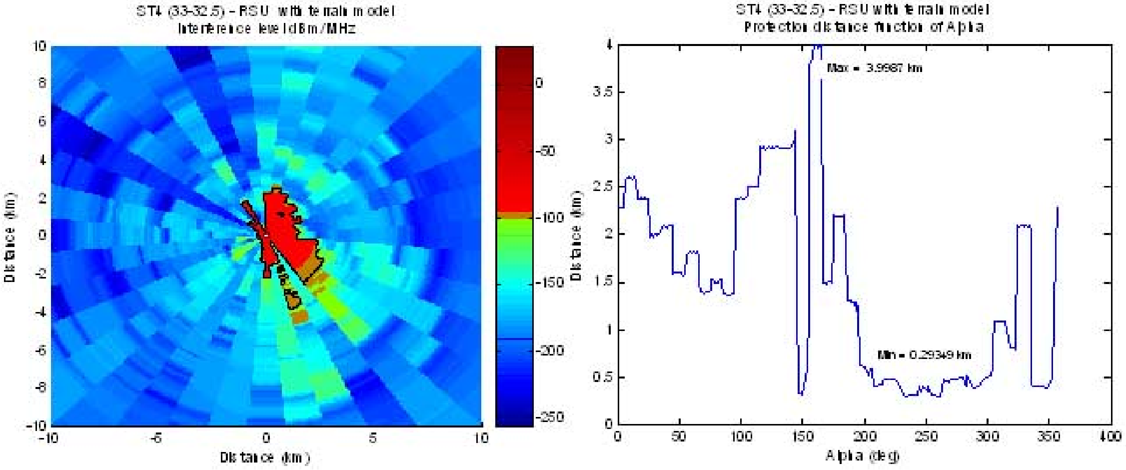
OBU G_{max}=5dBi case (flat model)



OBU G_{max}=5dBi case (real terrain model)



RSU case (flat model)



RSU case (real terrain model)

ANNEX 4: COMPATIBILITY BETWEEN ITS AND RTTT

ECC Decision (02)01 designates the frequency bands 5795-5805 MHz, with possible extension to 5815 MHz, for RTTT. The band 5795-5805 MHz is for use by initial road-to-vehicle systems, in particular road toll systems, with an additional sub-band, 5805-5815 MHz, to be used on a national basis to meet the requirements of multi-lane road junctions.

Although there is at least 40 MHz of guard band between ITS and RTTT systems, the potentially close vicinity in the deployment of both systems may raise some coexistence problems.
Three main types of potential problems have been identified:

- interference from the RTTT Road-side Unit (RSU) on the ITS,
- interference from the Its on the RTTT RSU,
- impact from the ITS on the RTTT On-board Unit (OBU)

- Parameters and protection criteria of RTTT systems

The regulatory parameters (maximum power levels) for RTTT are given in Annex 5 of ERC Recommendation 70-03. The RTTT parameters used in this Report are taken from the EN 300 674 developed by ETSI and the EN12253 developed by CENELEC. It should be noted that the EN 300 674 deals with both Road Side Units (RSU) and On-Board Units (OBU) and is divided in two parts, the part 1 providing general characteristics and test methods, the part 2 containing the essential requirements under article 3.2 of the R&TTE Directive.

	Road Side Units	**On Board Units**
Carrier frequencies (MHz)	5797.5, 5802.5 (5807.5, 5812.5 MHz for multi-lane road junctions at a national level)	
e.i.r.p.	2 W (33 dBm) standard for -35°≤θ≤35° 18 dBm for θ > 35° 8 W (39 dBm) optional	Maximum re-radiated sub-carrier e.i.r.p.: -24 dBm (Medium data rate) -14 dBm (High data rate)
Antenna gain	10-20 dB (assumed front-to-back ratio of 15 dB)	1-10dB (assumed front-to-back ratio of 5dB)
Transmitter Bandwidth	1 MHz	500 kHz
Receiver bandwidth	500 kHz	200 MHz – 1.4 GHz (not used)
Polarization	left circular	left circular
Receiver sensitivity (at the receiver input)	-104 dBm (BPSK)	-60dBm
Co-channel C/I (dB)	6 for 2-PSK, 9 for 4-PSK, 12 for 8-PSK	Not defined

Table 39 : Summary of characteristics of the RTTT systems

The technical requirements of the RTTT DSRC devices are split into two categories :

- the Road Side Unit is an active device with a high level of emission and the sensitivity value can be compared to the value of ITS devices (see Table 3 and Table 4)
- the On Board Unit is a passive device with reduced level of emission (back-scattering uplink communication) and poor level of sensitivity (downlink communication).

It has to be noted that this analysis ignored the additional protection provided by the specific modulation and coding from a wanted downlink Wake-Up Signal. Therefore, it was assumed that any signal above the Wake-Up threshold produced by the ITS device will trigger a false wake-up. Separation distances have been calculated to ensure false wake-up triggers do not occur.

- Interference from the RTTT Road-side Unit on the ITS

LINK BUDGET	Value	Units	**Urban**	**Suburban**	**Rural**	**ETSI**
Emission part: RSU RTTT						
Bandwidth	5	MHz				
Tx out, eirp	33	dBm	33	33	33	33
Tx Out eirp per MHz	26	dBm/MHz	26	26	26	26
effect of TPC (dB)	0	dB	0	0	0	0
OoB Attenuation	56	dB	56	56	56	56
Net Tx Out eirp (spurious level)		dBm/MHz	**-30**	**-30**	**-30**	**-30**
Antenna Gain	13	dBi				
Frequency (GHz)	5.80	GHz				
Reception part: OBU ITS						
Receiver bandwidth	10	MHz	10.00	10.00	10.00	10.00
Receiver sensitivity	-82	dBm	-82.00	-82.00	-82.00	-82.00
Antenna gain	8	dBi	8.00	8.00	8.00	8.00
C min per MHz at antenna input		dBm/MHz	-100	-100	-100	-100
Protection criterion						
Criterion C/I	6	dB	6	6	6	6
Allowable Interfering power level '*I*' at receiver antenna input		dBm/MHz	**-106**	**-106**	**-106**	**-106**
MAIN LOBE ITS - MAIN LOBE RTTT						
Allowable Interfering power level at receiver antenna input		dBm/MHz	-106	-106	-106	-106
Separation distance RTTT->ITS (m)			**26**	**26**	**26**	**23**
MAIN LOBE ITS - SIDE LOBE RTTT						
Sidelobe attenuation (dB)	20	dB	20	20	20	20
Separation distance RTTT->ITS (m)			**3**	**3**	**3**	**3**
SIDE LOBE ITS - MAIN LOBE RTTT						
Sidelobe attenuation (dB)	12	dB	12	12	12	12
Separation distance RTTT->ITS (m)			**7**	**7**	**7**	**7**
SIDE LOBE ITS - SIDE LOBE RTTT						
Sidelobe attenuation (dB)	32	dB	32	32	32	32
Separation distance RTTT->ITS (m)			**1**	**1**	**1**	**1**

It comes from these calculations that RTTT RSU may be able to create interference on ITS OBU in particular when the car would be below the RTTT RSU in the main lobe to main lobe configuration. Such a situation may occur during a short time since the RTTT device is pointed towards the ground and ITS devices presents a tilt about 5°.

- Interference from the ITS on the RTTT Road-side Unit

LINK BUDGET	Value	Units	**Urban**	**Suburban**	**Rural**	**ETSI**
Emission part: OBU ITS						
Bandwidth	10	MHz				
Tx out, eirp	33	dBm	33	33	33	33
Tx Out eirp per MHz	23	dBm/MHz	23	23	23	23
effect of TPC (dB)	8	dB	8	8	8	8
OoB Attenuation	80	dBr	80	80	80	80
Net Tx Out eirp		dBm/MHz	**-65**	**-65**	**-65**	**-65**
Antenna Gain	8	dBi				
Frequency (GHz)	5.90	GHz				
Reception part: RSU RTTT						
Receiver bandwidth	0.5	MHz	0.50	0.50	0.50	0.50
Receiver sensitivity	-104	dBm	-104.00	-104.00	-104.00	-104.00
Antenna gain	13	dBi	13.00	13.00	13.00	13.00
C min per MHz at antenna input		dBm/MHz	-114	-114	-114	-114
Propagation models						

Protection criterion						
Criterion C/I	6	dB	6	6	6	6
Allowable Interfering power level 'I' at receiver antenna input		dBm/MHz	**-120**	**-120**	**-120**	**-120**
MAIN LOBE ITS - MAIN LOBE RTTT						
Separation distance ITS->RTTT (m)			**2**	**2**	**2**	**2**
MAIN LOBE ITS - SIDE LOBE RTTT						
Sidelobe attenuation (dB)	20	dB	20	20	20	20
Separation distance ITS->RTTT (m)			**0**	**0**	**0**	**0**
SIDE LOBE ITS - MAIN LOBE RTTT						
Sidelobe attenuation (dB)	12	dB	12	12	12	12
Separation distance ITS->RTTT (m)			**1**	**1**	**1**	**1**
SIDE LOBE ITS - SIDE LOBE RTTT						
Sidelobe attenuation (dB)	32	dB	32	32	32	32
Separation distance ITS->RTTT (m)			**0**	**0**	**0**	**0**

It comes from these calculations that ITS OBU will not create interference on RTTT RSU if the unwanted level of ITS devices is lower than -65dBm/MHz within the RTTT frequency band.

- Impact from the ITS on the RTTT On-board Unit

The OBU requires a -60 dBm signal to be waken up and to understand commands from the RTTT RSU. The unwanted emission level of ITS devices is unlikely to reach such low sensitivity (44 dB higher than RTTT RSU). However such situation may occur within the ITS band if the RTTT OBU receiver is not filtered and is too sensitive outside its identified band.

ANNEX 5: REFERENCES

[1] ECC Report 003: “Fixed service in Europe current use and future trends POST-2002”

[2] SRDoc Part I: ETSI TR 102 492-1 V1.1.1 (2005-06): “Electromagnetic compatibility and Radio spectrum Matters (ERM); Intelligent Transport Systems (ITS): Part 1: 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”

[3] SRDoc Part II: ETSI TR 102 492 – 2: “Electromagnetic compatibility and Radio spectrum Matters (ERM): Intelligent Transport Systems (ITS); Part 2: Technical characteristics for pan-European harmonized communications equipment operating in the 5 GHz frequency range intended for road safety and traffic management, and for non-safety related ITS applications”

[4] IEEE 802.11a: "Information Technology - Telecommunications and Information Exchange Between Systems - LAN/MAN - Specific Requirements"

[5] IEEE 802.11p: "Wireless Access for Vehicular Environments - Draft standard"

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[7] FCC Rules and Regulations (August 3, 2004): “Regulations governing the licensing and use of frequencies in the 5850 - 5925 MHz band for Dedicated Short Range Communications Service”

[8] ITU-R Recommendation SM.1541: “Unwanted emissions in the out-of-band domain”

[9] ITU-R Recommendation SM.329: “Unwanted emissions in the spurious domain”

[10] CEPT/ERC/Recommendation 74-01E: “Spurious Emissions”

[11] ITU-R Recommendation F.1336-1: “Reference radiation patterns of omni-directional, sector and other antennas in point-to-multipoint systems for use in sharing studies in the frequency range from 1 GHz to about 70 GHz”

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[13] RR: Radio Regulations, Edition of 2004 (www.itu.int)

[14] www.acea.be

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[19] Recommendation ITU-R P.452-7: “Prediction procedure for the evaluation of microwave interference between stations on the surface of the Earth at frequencies above about 0.7 GHz”

[20] Recommendation ITU-R M.1638: “Characteristics of and protection criteria for sharing studies for radiolocation, aeronautical radionavigation and meteorological radars operating in the frequency bands between 5 250 and 5 850 MHz”

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[22] ERC Decision (01)06: “ERC Decision of 12 March 2001 on harmonised frequencies, technical characteristics and exemption from individual licensing of Non-specific Short Range Devices operating in the frequency band 5725 - 5875 MHz”

[23] ETSI EN 302 502: “Broadband Radio Access Networks (BRAN); 5,8 GHz fixed broadband data transmitting systems; Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive”

[24] ECC Report 003 : “Fixed service in Europe current use and future trends POST-2002”

[25] Recommendation ITU-R F.1094: “Maximum allowable error performance and availability degradations to digital radio-relay systems arising from interference from emissions and radiations from other sources”

[26] ERC Recommendation 14-01: “Radio-frequency channel arrangements for high capacity analogue and digital radio-relay systems operating in the band 5925 MHz - 6425 MHz”

[27] Recommendation ITU-R F.383: “Radio-frequency channel arrangements for high capacity radio-relay systems operating in the lower 6 GHz band”

[28] ETSI EN 302 217-2: “Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas”