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

COMPATIBILITY OF AUTOMOTIVE COLLISION WARNING SHORT RANGE RADAR OPERATING AT 79 GHZ WITH RADIOCOMMUNICATION SERVICES

Stockholm, October 2004

EXECUTIVE SUMMARY

This report considers the impact of automotive collision warning Short Range Radars (SRR) operating at 79 GHz on radiocommunication services with a primary allocation in the frequency range 77 to 81 GHz. It does not address the impact of radiocommunication services on SRR receivers; as the latter are expected to operate on a non-interference non-protected basis.

The following 3 primary radiocommunication services have been considered:
- Radiolocation Service
- Radio Astronomy Service
- Radio Amateur and Amateur Satellite Services.

Radiolocation Service

NATO informed the CEPT that there are no radiolocation systems operational in the 79 GHz frequency range and that there are currently no plans to introduce such systems. No compatibility studies were therefore conducted with radiolocation systems in this frequency range.

Radio Astronomy Service

The compatibility of SRR systems with the Radio Astronomy Service (RAS) around 79 GHz was studied on the assumption of a mean e.i.r.p. per SRR device of –3 dBm/MHz. The analysis shows that coexistence is dependent on the aggregated impact of SRR devices transmitting in the direction of a RAS station.

From the results based on the model used, with a maximum e.i.r.p. of –3 dBm/MHz per SRR device around 79 GHz, it is concluded that regulatory measures (e.g. automatic deactivation mechanism close to RAS observatory stations) are necessary to enable the coexistence between SRR and the RAS.

Radio Amateur and Amateur Satellite Services

The interference to Amateur Services (AS) stations operating around 79 GHz from SRR has been studied based on worst-case-assumptions of antenna gain and antenna patterns. A free space propagation model was considered. Attenuation by absorption and the scatter losses were not taken into account.

Current AS activities in this frequency range are focused on an experimental technological basis and the demonstration of long range communications. For this kind of experimental non-permanent usage in the 77.5 – 78 GHz range special locations on high positions (e. g. Mountain tops) are preferred. For the purpose of this study, the interference towards AS stations that operate point-to-point in the horizontal plane was taken as the worst case.

Without consideration of mitigation factors, the calculated separation distances obtained in the worst case scenarios - in the order of 2 km in the main lobe to main lobe case for 79 GHz SRR systems tend to show incompatibility with the Amateur and the Amateur Satellite service.

Although Amateur stations could operate in the vicinity of roads, the probability of interference as a result of SRR radiating through its antenna main lobe into the AS station antenna main lobe would however be considered very low. The occurrence of the main beam to side lobe interference scenario would still be expected to be low.

When considering the side lobe to side lobe case, the protection distance would be around 80 m.

Furthermore it should be mentioned that there are currently only some hundred of active AS stations inside CEPT (e.g. around 50 in Germany). In the future a greater number of AS stations could be expected (e.g. for linked stations).

It is further noted that Short Range Devices shall not cause harmful interference to a Radiocommunication service, in particular if operating on a Primary basis.

However, it was agreed within CEPT to extend the timescale for Radio Amateur Service on a primary basis within the band 75.5-76 GHz beyond 2006. This modification was made in the update of the European Common Allocation Table, January 2004 (footnote 5.559A). This was done to compensate potential incompatibility problems with the Amateur (Satellite) Service that operates with a primary status in the 77.5-78 GHz band.

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with radiocommunication services**

1   INTRODUCTION

The industry has responded to European Commission programs and has developed new Short Range Radar solutions for Road Safety and Intelligent Transport Systems. This is in support of such programs as *e*-Safety, IST, the EU Approach to Road Safety and Intelligent Transport systems (ITS) and RESPONSE, Project TR4022.

The objective and focus of "The EU Approach to Road Safety and Intelligent Transport systems (ITS)" (see bibliography in ECC Report 23) and "Intelligent Vehicle Systems" are defined as "Improve Safety, Security, Comfort and Efficiency in all Transport modes" and "Focusing on Advanced Pilot/Driver Assistance Systems (in support of vision, alertness, manoeuvring, automated driving compliance with the regulations, etc…)".

Based on the technical requirements on frequency range and power levels described in the initial System Reference document from ETSI (ETSI TR 102 263) the frequency band 77-81 GHz has been identified by the FM WG as the permanent frequency band for automotive collision warning Short Range Radars (SRR).

It was noted that the 76-77 GHz band used for Long Range Automotive Radars in accordance with ERC Recommendation 70-03 and ECC Decision ECC/DEC/(02)01 is not compatible with a SRR system within the same frequency band. Long Range Radars operating in the 76-77 GHz band are commercially available since 1999 from European vehicle manufacturers.

Based on the abovementioned technical requirements from the industry, Project Team SE24 of WGSE had carried out in 2003 initial compatibility studies on SRR operating at 79 GHz with radiocommunication services. For the purpose of these studies, only radiocommunication services with a primary allocation status within frequency band 77 – 81 GHz were considered, that is the Amateur and Amateur Satellite, the Radio Astronomy and the Radiolocation Services.

NATO informed the CEPT that there are no radiolocation systems operational in the 79 GHz frequency range and that there are currently no plans to introduce such systems. No compatibility studies were therefore conducted with radiolocation systems in this frequency range.

Preliminary conclusion for the Radio Astronomy Service was that regulatory measures could be identified enabling the coexistence between SRR within the band 77-81 GHz and the Radio Astronomy Service.

As for the Amateur (Satellite) Service, it was concluded that the use of 79 GHz SRR systems might be incompatible. WGFM agreed consequently to extend the timescales given in footnote 5.559A, which permits Radio Amateur Service on a primary basis within band 75.5-76 GHz beyond 2006. This change was included in the update of the European Common Allocation Table, January 2004. This Frequency Management solution compensates for potential incompatibility problems with the Amateur (Satellite) Service that operates with a primary status in the 77.5-78 GHz band.

The adoption and early implementation of the ECC Decision for the 79 GHz band was seen as critical to provide a clear indication to the automotive industry as well as the component industry that the required frequency bands will be made available on time and on a Europe-wide and permanent basis.
The Decision ECC/DEC/(04)03, designating the 79 GHz range for automotive short range radars, was finally adopted by the ECC at its meeting 15-19 March 2004.

This ECC Report presents the final compatibility studies for 79 GHz SRR systems.

This report considers the effects of SRR systems on allocated radiocommunication services operating in the frequency range 77 to 81 GHz. It does not consider interference from radiocommunication services into SRR or automotive EMC issues.

2   SHORT RANGE RADAR

2.1   Description

Automotive collision warning Short Range Radar (SRR) units operating at frequency band in the 79 GHz range (within 77-81 GHz) are planned for vehicle environmental sensing applications.

These units require a typical operating range of up to 30 m and are used for a number of applications to enhance the active and passive safety for all kind of road users. Applications that enhance passive safety include obstacle avoidance, collision warning, lane departure warning, lane change aid, blind spot detection, parking aid and airbag arming. SRR applications, which enhance active safety include "stop and follow", "stop and go", autonomous braking, firing of restraint systems and pedestrian protection. The combination of these functions is also referred to as a "safety belt" for cars.

Frequency band 76-77 GHz is already designated for vehicular and infrastructure radar systems under ECC Decision ECC/DEC/(02)01 on Road Transport and Traffic Telematic (RTTT) systems. Adaptive Cruise Control (ACC) systems today use Long Range Radar (LRR) units operating between 76 and 77 GHz in accordance with ECC/DEC/(02)01 with a maximum bandwidth of 1 GHz.. One or multiple narrow lobes control or scan the driving path in front of the car to determine the distance to the vehicle driving ahead for maintaining a constant minimum safety distance. RF radiated power (e.i.r.p.) is limited to 55 dBm peak and 50 dBm average power or 23.5 dBm average power for pulse radars. Detailed technical specifications are available in EN 301 091 v1.1.1 (1998-06).

Sharing studies conducted by the automotive industry have concluded that sharing is not achievable between Ultra Wide Band SRR and LRR. Because of foreseeable saturating interference from LRRs into SRRs (not vice versa) a common band allocation is not feasible. The SRRs would be jammed due to the lack of spatial separation. Therefore a spectral allocation for SRR systems in the frequency range 77-81 GHz was seen as necessary.

2.2   Technical characteristics

Technical characteristics and justification for spectrum requirements for 79 GHz SRR devices are detailed in the ETSI Technical Report TR 102 263 V1.1.2 (2004-02).

79 GHz SRR systems offer a combination of two functions. In particular, it allows a precise speed measurement with help of a CW Doppler emission. This speed measurement mode is combined with another mode, whereas wideband signals are used to provide precise radial range information of objects with a high range separation in order of approximately 5-10 cm. To obtain the required resolution, the SRR needs a large bandwidth of 4 GHz for the range measurement.

2.2.1   Technical parameters

The table below provides the main RF parameters for consideration in compatibility studies.

Frequency range of operation	77 to 81 GHz
Mean power spectral density (e.i.r.p.)	-15 to -3 dBm/MHz
Mean power (e.i.r.p.)	18 to 30 dBm
Peak power (e.i.r.p.)	46.2 to 55 dBm

Table 1: Main RF parameters for 79 GHz SRR

Emissions outside the necessary bandwidth are assumed being spurious emissions, for which the mean power spectral density (e.i.r.p.) shall be below -30 dBm/MHz.

The TX antenna pattern of 79 GHz SRR is expected to range up to 180° horizontally and 20° vertically without bumper. Carrier modulated UWB radar may require a narrow band allocation of 500 MHz at 79 GHz in the centre of the 77 – 81 GHz band for a residual carrier of 23.5 dBm e.i.r.p. The same narrow band could be used to perform Doppler speed measurements.

Possible types of spread spectrum techniques for automotive SRR, which also might be combined in hybrid concepts, are: Pulse Modulation, FHSS, BPSK, and Pulsed FMCW.

A further spreading of a pulse modulated signal can be achieved by additional FM of the carrier during the pulse (e.g. a pulse compression with a linear FM Chirp). The same effect can be obtained by discrete phase shifts of the pulse according to a barker code.

Independent from the modulation scheme, the e.i.r.p. of a SRR transmitter device shall be in conformance with the e.i.r.p. mask limit to be defined in the relevant ECC Decision.

2.2.2   *Mitigation factor*

Due to the use of multiple SRR sensors, cost, design constraints and bumper functionality requirements, special windows or specific bumper materials with very low attenuation may not be acceptable. Due to various impacts of bumpers material and metallic paint, a typical value of bumper loss equal 6 dB (one way propagation) may be assumed in compatibility studies.
This 6 dB mitigation factor has been taken into account in Annex D of this Report (Radio Amateur study).

2.2.3   *Number of SRR devices*

The aggregate power from a number of transmitting SRR devices can be evaluated based on average and/or instantaneous emitted power, antenna beam width, installation height and the occupied bandwidth of the modulation.

The complete coverage of the surround sensing of a car is expected to require between four and eight SRR devices.

3   VICTIM RADIOCOMMUNICATION SERVICES

The 77-81 GHz frequency band is allocated to radiocommunication services in accordance with the ITU Radio Regulations and the European Common Allocation Table (ECA) as indicated in Annex A of this report.

For the purpose of this ECC Report, only radiocommunication services with a primary allocation status within frequency band 77 – 81 GHz were considered, that is the Amateur & Amateur Satellite, the Radio Astronomy and the Radiolocation Service.

3.1   Radiolocation Service

NATO informed the CEPT that there are no radiolocation systems operational in the 79 GHz frequency range and that there are currently no plans to introduce such systems. No compatibility studies were therefore conducted with radiolocation systems in this frequency range.

Further details are provided in Annex B of this report.

3.2   Radio Astronomy Service

Compatibility study with the Radio Astronomy Service is presented in Annex C of this report.

3.3   Amateur and Amateur Satellite Services

Compatibility study with the Amateur and Amateur Satellite Services is presented in Annex D of this report.

4   CONCLUSIONS

The technical feasibility of coexistence between automotive collision warning SRR and the radio astronomy service in the frequency band around 79 GHz is dependent on the aggregated impact of SRR devices transmitting in the direction of a radio astronomy station.

From the results based on the model used, with a maximum e.i.r.p. of –3 dBm/MHz per SRR device around 79 GHz, it is concluded that regulatory measures (e.g. automatic deactivation mechanism close to radio astronomy observatory stations) are necessary to enable the coexistence between SRR and the radio astronomy service.

The interference to Amateur stations operating around 79 GHz from SRR has been studied based on worst-case assumptions of antenna gain and antenna patterns; which are applicable around 79 GHz. Consideration was given only to the free space attenuation. Attenuation by absorption and the scatter losses were not taken into account.

Without consideration of mitigation factors, the calculated separation distances obtained in the worst case scenarios - in the order of 2 km in the main lobe to main lobe case - for 79 GHz SRR systems tend to show incompatibility with the Amateur and the Amateur Satellite service.

However, although Amateur stations could in some situations operate in the vicinity of roads, the probability of interference as a result of SRR radiating through its antenna main lobe into the AS station antenna main lobe would be considered very low. The occurrence of the main beam to side lobe interference scenario would still be expected to be low.

It is further noted that Short Range Devices shall not cause harmful interference to a Radiocommunication service, in particular if operating on a Primary basis.

ANNEX A: FREQUENCY ALLOCATION WITHIN FREQUENCY BAND 74 – 81 GHZ IN ACCORDANCE WITH ITU RADIO REGULATIONS AND THE ECA TABLE

FREQUENCY BAND	ALLOCATIONS (ITU-RR)	ECA TABLE (feb 2004)
75.5 –76 GHz	FIXED FIXED-SATELLITE (space-to-Earth) MOBILE BROADCASTING BROADCASTING-SATELLITE Space research (space-to-Earth) 5.559A 5.561	FIXED FIXED-SATELLITE (space-to-Earth) MOBILE BROADCASTING BROADCASTING-SATELLITE Space research (space-to-Earth) 5.559A 5.561 EU2 EU35
76.0 – 77.5 GHz	RADIO ASTRONOMY RADIOLOCATION Amateur Amateur-Satellite Space Research (space-to-Earth) 5.149	RADIO ASTRONOMY RADIOLOCATION ECA note 1) Amateur Amateur-satellite SpaceResearch(space-to-Earth) 5.149 EU2
77.5 – 78.0 GHz	AMATEUR AMATEUR-SATELLITE RadioAstronomy Space Research (space-to-Earth) 5.149	AMATEUR AMATEUR-SATELLITE RadioAstronomy Space Research (space-to-Earth) 5.149
78.0 – 79.0 GHz	RADIOLOCATION Amateur Amateur-Satellite RadioAstronomy Space Research (space-to-Earth) 5.149	RADIOLOCATION Amateur Amateur-Satellite RadioAstronomy Space Research (space-to-Earth) 5.149
79.0 – 81.0 GHz	RADIOLOCATION Amateur Amateur-Satellite RadioAstronomy Space Research (space-to-Earth) 5.149	RADIOLOCATION Amateur Amateur-Satellite RadioAstronomy Space Research (space-to-Earth)5.149 EU2

5.149   In making assignments to stations of other services to which the bands: 76-86 GHz […], are allocated, administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service (see Nos. **4.5** and **4.6** and Article **29**). (WRC-2000)

5.559A   The band 75.5-76 GHz is also allocated to the amateur and amateur-satellite services on a primary basis until the year 2006. (WRC-2000)

EU2   Civil-Military sharing

EU35   The band 75.5-76 GHz is in Europe also allocated to the Amateur and Amateur Satellite services after year 2006

ECA note 1) RTTT : ECC DEC (02) 01; ERC REC 70- 03   Road Transport and Traffic Telematic 76- 77 GHz Radar

ANNEX B: COMPATIBILITY WITH THE RADIOLOCATION SERVICE

Following a liaison statement from WGSE, a request for information was issued to the members of the Military Frequency Group of the NATO Civil/Military Frequency Management Sub-Committee.

NATO indicated in its reply that nine NATO nations had reacted to the above-mentioned request.

The result of this investigation can be summarised as follows:

- •   Nobody provided details on existing or planned radiolocation systems in the concerned band. However, since the proliferation and release of equipment data for EMC studies remains, as a principle, foremost a national issue, this is without prejudice to any direct national input to CEPT.
- •   Most of the answering countries do not presently operate any radiolocation system in this band, do not have any present plan to do so, but do insist not to rule out any future military applications in the band.
- •   One country mentioned trial radars that have been operating in the concerned band, but that has not yet lead to any plan to use the band for military equipment; unfortunately, no technical details have been provided so far.
- •   One country favours, as a nationally co-ordinated position, the intention to introduce short range radars in the band.

Noting that no radiolocation systems are operational in the 79 GHz frequency range and in the absence of technical characteristics for planned military applications, the compatibility with the radiolocation service was not studied.

ANNEX C: COMPATIBILITY WITH THE RADIO ASTRONOMY SERVICE

1   Introduction

This annex addresses the technical feasibility of co-existence between automotive collision warning Short Range Radar (SRR) and the Radio Astronomy Service (RAS) in the frequency band around 79 GHz.

A mean e.i.r.p. power spectral density of -3 dBm/MHz for SRR operating around 79 GHz was taken for the calculations. This study does not consider the Doppler transmission mode of the SRR devices.

2   Allocation scenario for RAS

For the frequency range around 79 GHz, the frequency bands allocated to the RAS are limited to 76–84 GHz, see Table C-1. Table C-1 also identifies the European countries in which, at this moment, RAS stations use the frequency bands listed. Table C-1 also lists the levels of interference detrimental to RAS, determined using the methodology of ITU-R Recommendation **RA.769**.

RAS observing programs are a mixture of spectral line and continuum observations. Therefore, in discussions on the protection of RAS, the most stringent protection levels should always be taken into account.

3.   Protection of RAS

3.1.   General scenario

During an observation, a radio astronomy telescope points towards a celestial radio source at a specific right ascension and declination, corresponding with a specific azimuth and elevation at a certain moment in time. During this observation the pointing direction of the telescope is continuously adjusted to compensate for the rotation of the Earth. It is assumed that interference from a terrestrial transmitter is generally received through the side lobes of the RAS antenna.

The ITU-R Recommendations taken as a basis for the compatibility study carried out are the following:
- ITU-R RA.769-1:   "Protection Criteria used for Radioastronomical Measurements";
- ITU-R RA.1513-1:   "Levels of data loss to RAS observations and percentage-of-time criteria resulting from degradation by interference for frequency bands allocated to the RAS on a primary basis".
- ITU-R P.525-2:   "Calculation of Free Space Attenuation";
- ITU-R P.620-4:   "Propagation data required for the evaluation of coordination distances in the frequency range 100 MHz to 105 GHz ";
- ITU-R P.676-5:   "Attenuation by atmospheric Gases".

Recommendation ITU-R **RA.769** assumes that the interference is received in a side lobe of the antenna pattern, i.e. at a level of 0 dBi at ≥19º from bore sight (see also Recommendation ITU-R **SA.509**). It should be noted that a radio telescope is an antenna with a very high main beam gain, typically of the order of 70 dB. If interference is likely to be received via the main lobe of the antenna pattern, this high gain should also be taken into account. However, Recommendation ITU-R **RA.769** assumes that the chance that the interference is received by the main lobe of the antenna is low, and therefore uses the level of 0 dBi in the calculation of the levels of detrimental interference given in this Recommendation.

It is considered that the interference received at the radio telescope antenna shall not exceed the levels of detrimental interference given in Recommendation ITU-R **RA.769**.

For frequencies around 79 GHz, Recommendation ITU-R **P.620** applies to distances exceeding 45 km, whereas for smaller distances Recommendation ITU-R **P.525** is taken. Recommendation ITU-R **P.676** enables the estimation of the attenuation by atmospheric gases.

3.2.   Protection requirements

As noted above, the protection requirements for RAS observations are given in Recommendation ITU-R **RA.769**.
The protection criteria for the frequency bands around 79 GHz are given in Table C-1. For the frequencies between 76 and 84 GHz, RAS observing programs are dedicated to spectral line and continuum observations, which have different protection requirements. The most stringent protection levels should always be taken into account.

Frequency band (GHz)	CEPT countries with RAS stations operating at ~79 GHz	RR Allocation status	Protection level [1] (dB(Wm^{-2}Hz^{-1}))
76 – 77.5	Germany, France, Spain, Sweden	Primary (RR **5.149**)	-205 [2], -221 [3]
77.5 – 78	Germany, France, Spain, Sweden	Secondary (RR **5.149**)	-205 [2], -218 [3]
78 – 79	Finland, France, Spain, Sweden	Secondary (RR **5.149**)	-205 [2], -220 [3]
79 – 81	Finland, Spain, Sweden	Primary (RR **5.149**)	-205 [2], -221 [3]
81 – 84	Finland, Spain, Sweden	Primary (RR **5.149**)	-204 [2], -222 [3]

Table C-1: Frequency bands allocated to the RAS, their use in Europe and their protection requirements

Notes: [1]: calculated according to Recommendation ITU-R RA.769 using a Minimum antenna noise temperature of 30 K and Receiver noise temperature of 150 K
[2]: spectral line observations (narrow band)
[3]: continuum observations (broadband).

RR No. 5.149 states for the identified frequency bands that "administrations are urged to take all practicable steps to protect the RAS service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the RAS service (see Nos. 4.5 and 4.6 and Article 29)".

Based on these regulations, for the purpose of calculations presented in this report, it is assumed that for the frequencies around 79 GHz, RAS needs to be protected to a level of -222 dB(Wm^{-2}Hz^{-1}).

4.   Methodology used to determine the maximum tolerable e.i.r.p. per SRR device

The summation methodology was used to estimate the tolerable transmission power of an SRR device, for a given separation distance, protection criteria and some additional necessary parameters. It assumes that all SRR emitters are located on equally spaced concentric rings with the RAS antenna at the centre of the distribution, as shown in the figure below in this section. The SRR emitters are assumed to be evenly spaced from each other on each ring. Since all emitters on a specific ring have basically the same distance to the receiver, the path loss is the same for these emitters. The spectral power flux density (SPFD) is then calculated for all the emitters per ring and the total SPFD is the summation of the SPFD contributed by each ring.

Section 3.1 identifies the propagation models used in the calculations. As indicated, within 45 km from a RAS station Recommendation ITU-R **P.525** is used. For larger distances Recommendation ITU-R **P.620** is used. In the calculations specific conditions due to rain, clouds and fog were not taken into account since it is considered that the potential victim services require good propagation conditions for their applications. This scenario was taken to consider a worst-case situation for the victim service.

The assumptions for the protection of the RAS as used in Recommendation ITU-R **RA.769** apply to the calculations presented here.

For the fraction of acceptable data-loss due to interference a value of 2% is taken, which is considered the maximum acceptable percentage of time for data loss to RAS from an aggregate of interfering devices of a single system, like SRR radars (see Recommendation ITU-R **RA.1513**).

The density of devices transmitting in the direction of a RAS station is integrated in the calculation of the total interfering signal by summing (in power) the total power coming from concentric rings 1 km wide, starting at the minimum separation distance between an SRR device and the RAS station, taken to be 30 m.

The number of rings taken into account in the calculation is determined by using the relevant algorithm from Recommendation ITU-R **P.620**[1], and cover an area with a radius of up to the minimum separation distance + 500 km.

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[1] Recommendation ITU-R P.620 also gives an algorithm for the maximum distance limits to be used in the calculations.
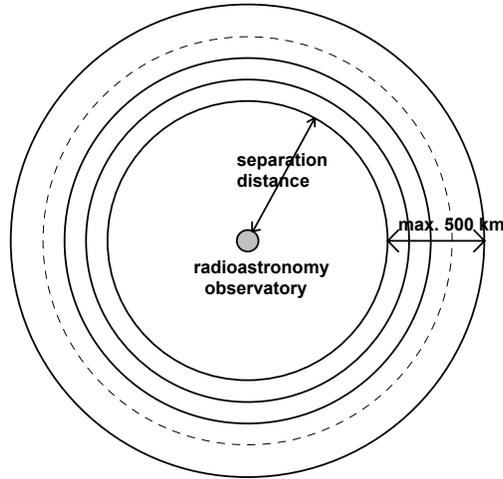
The required e.i.r.p. level is calculated for interference experienced during a certain percentage of the time.

If P_t is the average power emitted by a single transmitting device, the power received at the RAS observatory coming from the ring number i, Pr_i is then:

$$Pr_i = P_t - L(d_i, p_i) + 10 * log(N_i)$$

where   . d : required separation distance (km)
. d_i : distance between the transmitter and the RAS observatory : $di = d + (i\text{-}1)$
. $L(d_i, p_i)$: propagation attenuation between the ring i and the RAS observatory for interference during p_i% of
      time.
. N_i : number of transmitting devices in ring number i : $N_i = \pi * n [d_{i+1}^2 - d_i^2]$
. n : density of transmitting devices per km^2

The total interfering power at the RAS site is then, in dBW:

$$Pr = 10 * \log(\sum_{i=1}^{N_r} 10^{\frac{Pr_i}{10}})$$

with N_r : number of rings used for the simulations.

Using a uniform density of transmitting devices, and taking into account the probability of interference in the RAS band, thus leads to an e.i.r.p. which depends directly on the density of SRR devices.

The assumption of a uniform distribution of transmitting devices does not have a significant impact on the results of the calculations, as experiences with previous calculations of similar situations have shown.

5. Input parameters for the calculations

For compatibility studies applicable to all European RAS telescopes, it must be assumed that a radio telescope can point in any direction, i.e. its azimuth can vary between 0º and 360º and its elevation can vary between 0º and 90º. For terrestrial interferers, in the interference scenario an elevation of 0º is assumed.

With the input parameters given in Table C-2 an estimate was made of the maximum tolerable e.i.r.p. per SRR device as a function of the density of SRR devices per km^2.

Maximum permissible spectral power flux density	-222 dB(Wm^{-2}Hz^{-1})
RAS antenna gain	0 dBi
Frequency	79 GHz
Reference bandwidth	1 MHz
Geographic latitude of RAS station	52°
Elevation angle	0°
Measurement distance used to receiving antenna / minimum separation distance	30 m [1]
Fraction of acceptable data-loss due to interference	2%
Maximum distance for calculations	500 km

Table C-2: Input parameters

Note: [1] The smallest distance between a radio telescope and the edge of the territory of a RAS station. For European RAS stations this ranges from about 30 m to a few hundred meters. To ensure protection for all European RAS stations a typical value of 30 meter was taken.

The RAS antenna gain was taken as 0 dBi, since this is assumed in Recommendation ITU-R **RA.769**.

The calculations were done for a frequency of 79 GHz only, since it is not expected that significantly different results would be found for other frequencies between 76 GHz and 84 GHz.

An elevation angle of 0° was used to lead to a result applicable to all radio telescopes under all observing conditions.

The geographic latitude has been taken as 52°, which is representative for a RAS station in Europe.

RAS must be protected for all distances of the transmitting device to a radio telescope antenna, i.e. for SRR devices everywhere outside the extent of the RAS station territory, while SRR devices are not equipped with a facility to determine their position. Results are given for a measurement distance of 30 m.

6.   Result of the calculations

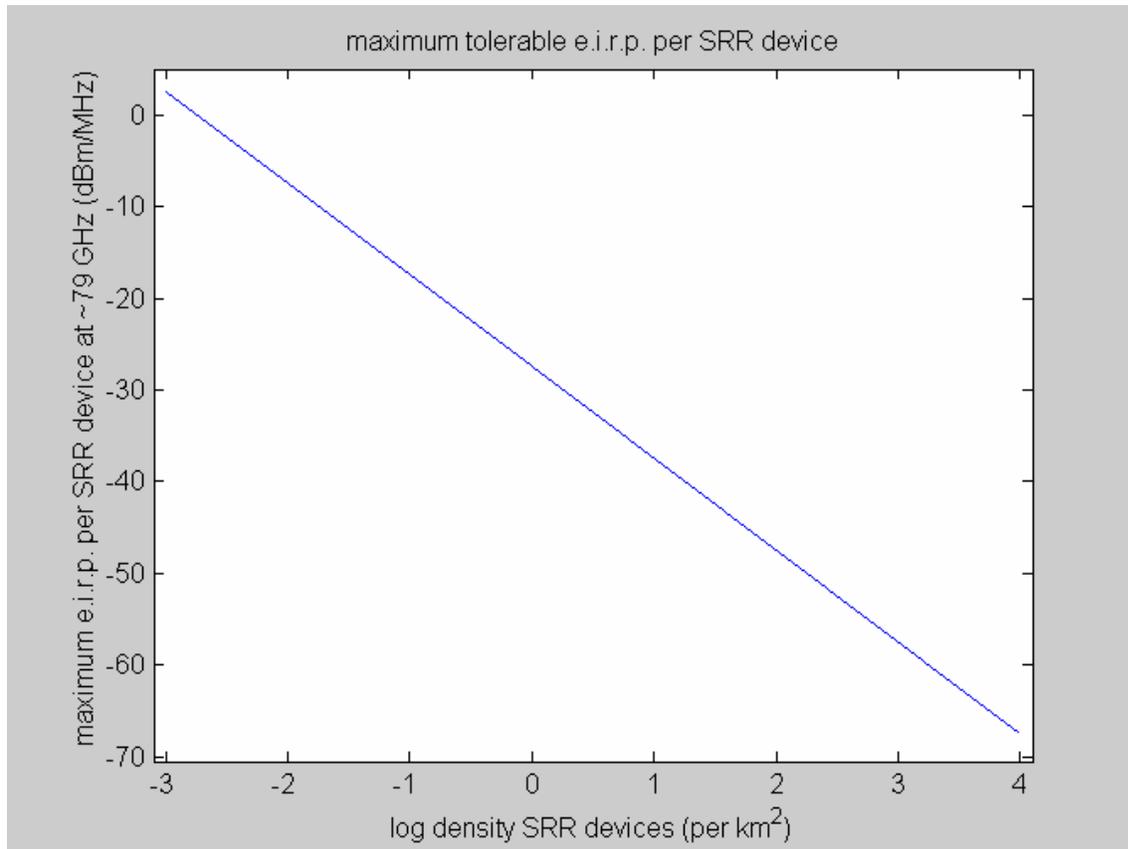The results of the calculations are given in Figure C-1.

Figure C-1: Maximum tolerable e.i.r.p. at a frequency of ~79 GHz per SRR device operating at 79 GHz as a function of SRR density in order not to exceed the protection criteria for RAS for continuum observations

These results lead to the following analytical expression for the maximum permissible e.i.r.p. per SRR device at frequencies around 79 GHz that will not exceed the protection criteria for continuum RAS observations:

$$\text{e.i.r.p.}_{max} = -10 * \log \rho - 27.5 \qquad \text{dBm/MHz}$$

where: ρ = number of SRR devices per km^2 operating at ~79 GHz from which emission is received by a RAS station.

Table C-3 below gives some examples of values for e.i.r.p. $_{max}$ as a function of density ρ of SRR devices per km^2 operating at around 79 GHz from which emission is received by a RAS station, with a minimum distance of such device to a RAS station of 30 m.

Density[1] of SRR devices, ρ (km^{-2})	e.i.r.p.$_{max}$ (dBm/MHz)(continuum)
0.01	-7.5
1	-27.5
100	-47.5
10000	-67.5

Table C-3: Examples of e.i.r.p.$_{max}$ at ~79 GHz as function of density of transmitting SRR devices per km^2, ρ

Note: [1] density of devices transmitting in the direction of a RAS station

If cars equipped with SRR will not have a facility to determine their position with sufficient accuracy nor an "off"-switch for their SRR device(s), any specific separation distance for RAS is irrelevant, since enforcement of such a condition is not possible.

These results apply to aggregation of SRR transmitting devices in a geographic area of large dimensions. Such large areas will include both the remote areas where RAS stations are assumed to be as well as urban areas.

For practical reasons it is assumed that all SRR devices have the same transmitting power. Obviously, the results apply only for those SRR devices transmitting in the direction of a RAS station without obstruction. This would imply, for example, that the total number of transmitting SRR devices is probably at least about 4 times larger than ρ per km^2, if a RAS station 'sees' emission from only ¼ of the transmitting SRR devices. It was not possible to give a precise, quantifiable estimate of the density of SRR devices to be used in practice, because of the possible mitigation factors that might be taken into account in the conversion of ρ to this number.

7.   Separation distances as a function of density of transmitting SRR devices

The summation methodology was used to estimate the separation distance for transmitting SRR devices having a e.i.r.p. of –3 dBm/MHz as a function of device density.

An example of the resulting estimates for continuum observations is given in Figure C-2 for 79 GHz. It should be noted, however, that if SRR devices will not have a facility to determine their position with sufficient accuracy, the enforcement of any specific separation distance outside the territory of a RAS station would not be possible in practice.
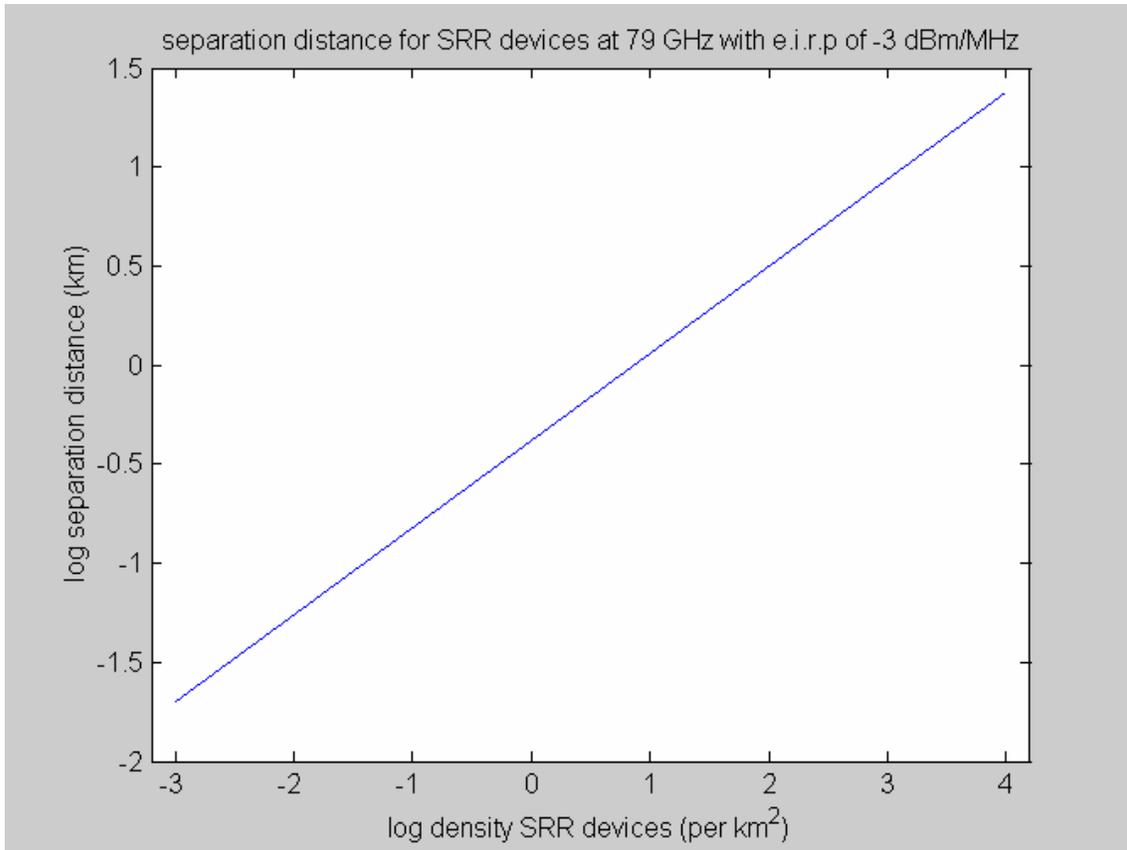
Figure C-2: separation distances necessary to protect RAS as function of the density of transmitting SRR devices having an e.i.r.p. of –3 dBm/MHz at a frequency of 79 GHz (for continuum observations)

This function corresponds to the following relation for continuum observations:

$$\log d(\rho) = 0.44 * \log \rho - 0.38$$

where: $d(\rho)$ = separation distance (in km) as function of density ρ;
ρ = number of SRR devices per km^2 from which emission is received by a RAS station;

Some examples of $d(\rho)$ are given in Table C-4 below.

density[1] of SRR devices ρ (km^{-2})	separation distance, $d(\rho)$ (km) (continuum)
0.01	0.05
1	0.4
100	3
10000	24

Table C-4: Examples of separation distance $d(\rho)$ at ~79 GHz as function of the density of transmitting SRR device per km^2, ρ, using an e.i.r.p. of –3 dBm/MHz per device

Note: [1] density of devices transmitting in the direction of a RAS station

The estimated separation distances imply that in daily practice the SRR devices must be at significantly large distances from RAS stations to avoid interference detrimental to RAS observations. If SRR devices are not equipped with facilities to accurately determine their positions, their deployment will lead to significant enforcement problems.

8.   Conclusion

The technical feasibility of co-existence between automotive collision warning SRR and the RAS service in the frequency band around 79 GHz is dependent on the aggregated impact of SRR devices transmitting in the direction of a RAS station.

From the results based on the model used, with a maximum e.i.r.p. of –3 dBm/MHz per SRR device around 79 GHz, it is concluded that regulatory measures (e.g. automatic deactivation mechanism close to RAS observatory stations) are necessary to enable the co-existence between SRR and the RAS service.

ANNEX D: COMPATIBILITY WITH THE RADIO AMATEUR AND AMATEUR SATELLITE SERVICES

1.   Introduction

At the WRC-2000, the frequency allocations to amateur service near 77 GHz were changed into the 75.5-81 GHz range, of which the segment 77.5-78 GHz and the 75.5-76 GHz till 2006 is allocated on a PRIMARY basis to the AMATEUR and the AMATEUR SATELLITE SERVICE. The possible allocation of 77-81 GHz to the SRR will then overlap with the primary amateur (satellite) allocation.

Previous studies at 24 GHz have shown that the most sensitive amateur activities in the microwave spectrum range are those using receivers with the lowest noise figure technologically attainable having a very small receiver bandwidth (0.5 or 2.5 kHz).

It is understood that the current operation mode of AS activities in this frequency range is focused on experimental technological activities and the demonstration of long range communications.

2.   The Amateur and Amateur Satellite Station

For this study only the receiving side of the amateur station is discussed. Moreover, the receivers in the amateur service and in the amateur-satellite service can be thought as identical, except for the (variable) elevation of the antenna of the satellite receiver.

For the purpose of this study, the potential interference towards Amateur stations that operate point-to-point in the horizontal plane was taken as the worst case.

2.1 Receiver properties

Currently the receiver noise figure (no pre-amplifiers yet being available) can be estimated to be in the order of 12-15 dB. It is argued, with respect to costs and availability for radio amateurs, that this noise figure will be valid for the next decade. The receiver bandwidth is 2.5 kHz. Although sometimes receivers with narrower bandwidth are used, this will be neglected as it does not influence the results.

It can be expected, however, that in the time frame foreseen for the possible application of 79 GHz SRR, pre*amplifiers will become available, thus lowering the receiver noise figure to about 4 dB.

Therefore two different noise figures of 12 dB and 4 dB were taken into account in this analysis.
Signals with rather small (S+N)/N ratios are common. A value of 3-5 dB is judged acceptable for many amateur contacts.

2.2 Antenna properties

Amateur stations use antennas optimized for gain and low sidelobe level, but at the same time limited in size, as the antenna will have to be pointed to different stations. Due to the gain requirements and the need for an adequate pattern and sidelobe level control, commonly used reflectors with primary feed are used. These antennas for radio amateur applications are also commercially available from specialized providers. High gain/narrow 3 dB-beamwidth and low sidelobe level antennas are in particular recommended for the radio amateur scatter contacts performed in this frequency range.

An example of a commercially available radio amateur antenna has the following technical parameters:
  -     76 GHz parabolic reflector with primary feed, completely mounted
  -     aperture diameter 25 cm
  -     gain 40dB
  -     3dB-beamwidth 1.5°.

These types of antenna systems produce shaped aperture illuminations, which produce first sidelobe levels lower than −17.6 dB below the main lobe level (worst-case value for uniform aperture illumination of circular apertures). In the present case, the assumption of a minimal sidelobe level of −20 dB below the main lobe seems to be adequate.

A different type of antenna is also considered in the calculations with a 36 dBi main lobe gain and a 21 dBi sidelobe gain and an aperture diameter of 10 cm.
For terrestrial amateur communications linear horizontal polarisation is used.

2.3 Antenna decoupling

Antennas are in general mounted on masts as high as practical, high buildings, hills or mountaintops in order to obtain the least obstruction towards the horizon in order to make long distance contacts possible. The interaction with these carriers and the reflection from neighbouring obstacles or from other antennas mounted on the same carrier is case sensitive for each installation and has thus to be studied individually (no generic scenario definable).

The mounting of antennas on high positions supports the assumption of a high decoupling factor to SRR's, which are installed on cars at a typical height of 50 cm over ground. Also SRRs are mounted to radiate horizontally, while the amateur receiver dishes are positioned high on top of buildings and hills for minimal obstruction towards the horizon.

3. SRR systems

The main RF parameters for 79 GHz SRR systems are recalled in Table D-1 below:

SRR Wideband Mode[1]	
Frequency	77 – 81 GHz
Mean PSD[2] (e.i.r.p)	– 3 dBm/MHz
Mean Power (e.i.r.p)	24 dBm
Peak Power (e.i.r.p)	55 dBm

Table D-1: Main RF parameters for 79 GHz SRR

Notes: [1] due to the narrow bandwidth of the amateur receivers, further information about the granularity of the wideband mode spectrum density would be required
[2] the radiated PSD can be assumed to be further reduced by 6 dB bumper attenuation

As the antennas are integrated with the SRR transmitter, the values given in the table above are e.i.r.p. values. There can be several SRR devices placed around the car circumference.

With regard to relevant emissions, the (one) sensor with the main beam directed towards the victim is primarily responsible for potential interference.

4. Propagation

For the distances under consideration (up to only a few km) –as a worst-case-scenario - the free space path loss L given by the distance r between amateur station and SRR is considered:

$$L(dB) = 20 \log (4 \pi * r/\lambda) , \qquad r \text{ expressed in } \lambda$$

For 79 GHz: $\qquad L = (70 + 20 \log r) \, dB , \qquad r \text{ expressed in m}$

5. Acceptable interference signal level

From the information in section D-2, it can be derived that interference by the SRR to the amateur receiver is acceptable as long as the effective noise level of the amateur receiver is **not increased by more than 3 dB**. This means, that the SRR power level should not exceed the receiver noise level.
Based upon the receiver/antenna data given in section 2 of this annex, the noise temperature of the receiver, taking into account an antenna temperature of 200 K, will be 200 K+14.84*290 K = 4504 K (@ F=12 dB, worst-case).

The equivalent noise power is $1.38 * 10^{-23}$ W/(Hz*K)* 4504 K = -162 dBm/Hz (@ F=12 dB) or -170 dBm/Hz (@ F= 4 dB). This is equal to the maximum SRR signal acceptable at the receiver.

6.   Resulting interference ranges R_{int}

6.1 Interference calculation

The following examples considered in this chapter are based on the unrealistic worst-case-assumption, that the amateur station and the SRR are mounted at the same height and that the SRR is thus able to radiate through its main lobe into the main lobe of the AS station (see Fig. D-1).
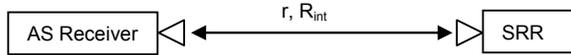

Fig. D-1: Worst-case-scenario: amateur station and SRR mounted on the same height

If (as a hypothetical assumption, which might not be true) the SRR signal has a flat spectrum in the band under consideration, its transmitted power is -69 dBm/Hz. The effective path loss $L_{eff} = L$ +- G (L including antenna gain G) between a single SRR and the amateur station, therefore, shall be $L_{eff} >= 93$ dB (@ F=12 dB), or Leff >=101 dB (@F=4dB) in order to fulfil the "acceptable interference signal level" described in section 5 of this Annex.

Thus, for an antenna gain G = 40 dBi the free space path loss must be L >= 133 dB, which is equivalent to an interference range of $R_{int} >= 1.4$ km, when SRR radiates through its main lobe into the amateur station antenna main lobe.

Off bore sight the effective antenna gain is 40dBi - 20dB = 20 dBi, requiring a free space path loss of L >= 113 dB, i.e an interference range of $R_{int} >= 140$ m.

Table D-2 below provides the calculated separation distances obtained for a single SRR interferer and with two different sets of parameters.

	Noise figure (F) = 12 dB Antenna main lobe gain = 40 dBi Side lobe gain = 20 dBi Current amateur stations	Noise figure (F) = 4 dB Antenna main lobe gain = 36 dBi Side lobe gain = 21 dBi Future amateur stations
Amateur service	Noise figure (F) = 12 dB Imax = -162 dBm/Hz Antenna main lobe gain = 40 dBi Side lobe gain AS = 20 dBi	Noise figure (F) = 4 dB Imax = -170 dBm/Hz Antenna main lobe gain = 36 dBi Side lobe gain AS = 21 dBi
SRR	PSD = -69 dBm/Hz Antenna main lobe gain = 0 dBi Side lobe gain = -13 dBi	PSD = -69 dBm/Hz Antenna main lobe gain = 0 dBi Side lobe gain = -13 dBi
SRR radiates through antenna main lobe into amateur station antenna main lobe	1.4 km	2.2 km
SRR radiates through antenna main lobe into amateurs station antenna sidelobes	140 m	385 m
SRR radiates through antenna sidelobes into amateur station antenna sidelobes	31 m	87 m

Table D-2: Separation distances

A special case of sidelobe to sidelobe interference scenario ('Mountain to mountain scenario'), which is not taken into account in the above table, is further developed in **Appendix 2** to this Annex.

6.2 Protection distance requirement

Based on free space loss and without consideration of mitigation factors, the calculated separation distances given in Table D-2 for 79 GHz SRR systems tend to show incompatibility with the Amateur and the Amateur Satellite service.

Amateur stations could in some situations operate in the vicinity of roads. The probability of interference as a result of SRR radiating through its antenna main lobe into the amateur station antenna main lobe would however be considered very low. The occurrence of the main beam to sidelobe interference scenario would still be expected to be low.

It is further noted that Short Range Devices shall not cause harmful interference to a Radiocommunication service, in particular if operating on a Primary basis.

7.   Additional factors not taken into account

This section provides information on additional attenuation or mitigating factors that could be taken into account in some scenarios.

In general, the probability that one SRR transmitter has its main beam directed to the amateur station is low. In general, amateur antennas are mounted as high as possible in order to obtain the least obstruction towards the horizon in order to make long distance contacts possible.

A further mitigation factor is the probability of interference of an AS station by SRR, which is discussed in **Appendix 1** to this Annex.

Additionally to the free space propagation loss L, the atmospheric absorption loss and scattering losses caused by the wave propagation through miscellaneous media have to be considered in a realistic scenario. This additional attenuation has to be added to the free space propagation loss L and either decreases the interference range R_{int} or provides an additional interference level margin.

In Table D-3 below the most important mitigation factors, respectively losses, are listed with representative value from [2]. The definition of a generic scenario is impossible, realistic studies require a case sensitive scenario definition.

Type of attenuation at 79 GHz	Representative value
Atmospheric absorption	0.8 dB/km
Rain scatter	Drizzle: 1 dB/km Rainfall rate 20mm/hr: 10 dB/km
Particles/smoke/aerosol scatter (dry)	Diameter 50 μm (vehicular): 2.0×10^{-5}(dB/m)/(g/m^3) Diameter 300 μm (explosion): 1.2×10^{-4}(dB/m)/(g/m^3)
Fog/haze scatter	Visibility 100 m: 1.2 dB/km
Trees/bushes scatter	N foliage: 1 dB/m Wth foliage: 5 dB/m
Shading by buildings/walls	> 20 dB

Table D-3: Attenuation by absorption and scatter losses

Evaluation of the data given in Table D-3 shows that considering the mentioned separation distances around 2 km and below, an additional attenuation of 5 dB (and, scenario dependant, by far higher attenuation) may occur. Due to the worst-case character of this study, however, this attenuation was not considered in the calculations.

On the other hand, the effect of the granularity of the SRR spectrum and of a large number of SRRs in the vicinity of radio amateur stations had not been taken into account either.

8   Conclusion

The interference to amateur stations operating around 79 GHz from SRR has been studied based on worst-case-assumptions of antenna gain and antenna patterns; which are applicable at ferquencies around 79 GHz. Consideration was given only to the free space attenuation. Attenuation by absorption and the scatter losses were not taken into account.

Without consideration of mitigation factors, the calculated separation distances obtained in the worst case scenarios - in the order of 2 km in the main lobe to main lobe case - for 79 GHz SRR systems tend to show incompatibility of SRR with the Amateur and the Amateur Satellite Services.

However, although amateur stations could in some situations operate in the vicinity of roads, the probability of interference as a result of SRR radiating through its antenna main lobe into the AS station antenna main lobe would be considered very low. The occurrence of the main beam to side lobe interference scenario would still be expected to be low.

Appendix 1 to Annex D:

Probability of interference of an Amateur station by SRR

Introductory note

The calculation of the probability of interference occurrence together with the calculation of the interference range is the basis for the conclusions of sharing studies between SRDs and primary and secondary services. The present case is comparable to the methodology of [1] and other compatibility reports as conducted by SE 24 and accepted by WGSE.

In compatibility studies usually interference ranges are defined, derived from permissible interference field strength or power levels at the receiver ports. Considering the interference of a victim by a larger number of potential interferers, an uniform distribution of the interferers within the considered area with distances between 5 m and 50 m, depending on the traffic situation, is assumed. Moreover, the possibility of a Line-of-Sight propagation between the interferers and the victim receiver is assumed. The influence of the topography on the distribution of the population and the resulting probability of interference is usually not considered. This is partially adequate for the interference study of the victim service with a great number of units located not far away from the interferers, e. g. SRR interference of FS stations mounted along roads. The investigation of interference from SRR into victim services with a sparse number of users distributed over a great area, e. g. of Amateur Service (in particular those amateurs, which are active in fields requiring a thorough technical expertise; like the mmW range) can yield a reasonable result only when considering the realistic probability of interference.

In the considered frequency range around 79 GHz – as well as considered in [1] - no "Plug-and-Play" radio amateur equipment is available. Thus, only amateurs with a thorough technical experience and expertise are able to operate an amateur station.

The handling of the mmW-technology and the design and integration of an amateur station is far more challenging as in the compared LF frequency range, where nevertheless only a sparse number of experienced amateurs is active.

Thus, it can be assumed, that the number of amateurs active in the mmW-range around 79 GHz is considerably lower than the number of those active in the LF range (at most is comparable to) which was assumed to be 1% of all amateurs in the CEPT countries in 2000 (see [1]).

At present around 75 amateurs in the CEPT countries are known, which conduct active work around 79 GHz.

Calculation of interference probability

The probability of interference to amateur service from SRR operating around 79 GHz is determined for the above noted reasons following an approach accepted by WGSE and ECC and introduced in [1]. To simplify the calculation, only the two-dimensional planar scenario is considered. From the interferers point of view this is a worst-case scenario. Consideration of the three-dimensional scenario increases the occurrence of interference through the sidelobes of the victim service antenna drastically, considering the different antenna mounting heights. Consequently, the probability of interference, which considers interference into the main lobe as well as into the side lobes, will decrease in comparison to the two-dimensional scenario.

The statistical number of interference cases, p_{int}, is set by the ratio of the SRR interfered area, A_{int}, and the populated area, A_{pop}, multiplied by the number of victim AS service users (or operators), N_{users} :

$$p_{\text{int}} = \frac{A_{\text{int}}}{A_{pop}} \cdot N_{users} \tag{1}$$

The populated area is smaller than the total geographical area, as given in [1] (Table 4), because of excluding scarcely populated areas as mountain sites, natural parks, etc, where neither SRR systems, nor amateur station operators will be present. It has also to be taken into account that even in rural areas the population is not distributed equally, but more or less is concentrated in groups of farms and family houses, leaving open spaces between them.

To take this into account, a populated area, A_{pop}, is defined as the product of the numbers of inhabitants, N_{pop}, and a population density factor, d:

$$A_{pop} = \frac{N_{pop}}{d} \qquad [d] = \frac{inhabitants}{km^2} \qquad (2)$$

Giving a basis for an estimated value of d, the average population density of a dense populated country (such as The Netherlands) is 387. This leads to an estimation of: $d = 400$.

The interfered area, A_{int}, is given by the number of all SRR interferers, N_{app}, and the interfered area caused by a single SRR interferer, $A_{app,single}$:

$$A_{int} = A_{app,single} \cdot N_{app} \qquad (3)$$

For a directional antenna, $A_{app,single}$ depends on the resulting interference ranges into the different spatial directions, R_{int}, determined by the levels of the antenna pattern and weighted by the covered spatial angle, Ω. Here, a simplified antenna pattern of a reflector antenna has been used (Fig. D-2).
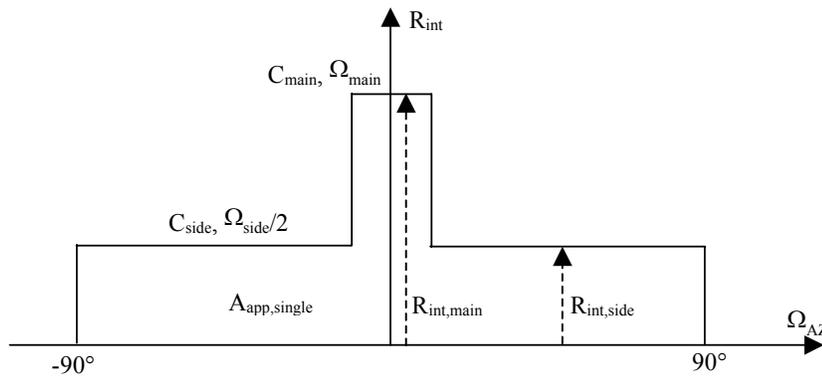

Fig. D-2: Interfered area of a single SRR interferer, given by a simplified azimuth (AZ) antenna pattern of a reflector antenna and the calculated interference ranges Rint

$A_{app,single}$ is given by:

$$A_{app,single} = \frac{R_{int,main}^2 \cdot \Omega_{main} + R_{int,side}^2 \cdot \Omega_{side}}{2} \qquad [\Omega] = rad \qquad (4a)$$

$$\Omega_{side} = 180° - \Omega_{main} \qquad (4b)$$

Further, the number of interference cases is affected by the duty cycle factor dc. For the duty cycle factor, following the methodology given in [1] the ON time of the carrier, *OTC*, is taken, multiplied by a mean modulation factor, *MMF*:

$$dc = OTC \cdot MMF \qquad (5)$$

MMF is set to 1 for high speed modes causing higher level modulation sidebands and to 0.3 for low speed modes with lower modulation levels.

From Eqns. (1) – (5), p_{int} is given by:

$$p_{int} = \frac{A_{app,single} \cdot N_{app}}{\dfrac{N_{pop}}{d}} \cdot dc \cdot N_{users} \qquad (6)$$

The interference probability to a single amateurs station from SRR, $prob_{int}$, is given by:

$$prob_{int} = \frac{p_{int}}{N_{users}} \qquad (7)$$

Finally, the condition is emphasised and explained, which is basis for above-shown derivation of interference probability:

$$A_{int} \cdot N_{users} << A_{pop} \qquad (8)$$

This condition incorporates two assumptions:

1. The interfered area, A_{int}, has in all cases to be much smaller than the populated area, A_{pop}. Otherwise the interference probability given in Eq. 7 could reach or exceed 1, which is not realistic due to the definition of A_{pop}.

2. The number of victim amateur service users (operators), N_{users}, is sparse related to the populated area, A_{pop}, so that the interference probability given in Eq. 7 is independent of that.

Results

With the data of [1] (Tables 4/5), information provided by the SARA Initiative and the interference ranges of presented in section D.6, an example of probability of interference to amateur service from SRR in the CEPT countries has been estimated below, considering pulse radars (consideration of FMCW radars would require a duty cycle of 1 and an appropriate choice of MMF << 1):

Population CEPT (N_{pop}):	283741824
Average density populated area (d):	400
Number potential victims in amateur service,	
1% of all amateurs in the CEPT countries (N_{users}):	4362 (e.g. at present only 75 are active)
AS antenna main lobe beamwidth (Ω_{main}):	1.5°
Interference range AS antenna main lobe ($R_{int,main}$):	1400m
Interference range AS antenna side lobe ($R_{int,side}$):	140m
Number SRR @ 79GHz, EU, in 2014 (N_{app}):	25x106
Duty Cycle SRR (MMF=1):	1.5x10-3

A_{pop} = 709355 km^2
A_{int} = 56187 m^2
$\rightarrow A_{int}$ x $N_{users} \approx 3x10^{-4}$ x A_{pop} (condition of Eq. 8 is fulfilled)

Total number of interference cases (p_{int}): 12.8
Probability of interference ($prob_{int}$): $2.9x10^{-3}$
(Note: this is a worst-case scenario: all interference cases are assumed to occur at the same time).

Concluding note to the calculation of probability of interference

The probability of interference to amateur service from SRR operating around 79 GHz in the CEPT countries has been estimated using a methodology derived from [1]. Despite the existing risk of interference of a single amateur station, the resulting low probability of interference enables a coexistence of amateur service stations and SRR.

Appendix 2 to Annex D:

Long range communication tests "Mountain-to-Mountain"

Due to the small number of specialized radio amateurs in the mmW-field, which are able to operate in the frequency range around 79 GHz, "normal" amateur activities with focus on "communication" are not occurring. The activities concentrate on the scientific/technical aspects. The main activity (which is frequently reported, e.g. in the "CQ DL" magazine of the "German AS Club (DARC)", at www.dubus.org, "UKW Berichte" et al) is the study of the wave propagation in this frequency range by carrying out long range communication link tests. To avoid fading effects by multipath propagation and to overcome the Earth curvature, due to the quasi-optical nature of propagation in this band, the transmission path is chosen from mountain to mountain. A possible scenario for studying the interference by SRR is sketched in Fig. D-3.
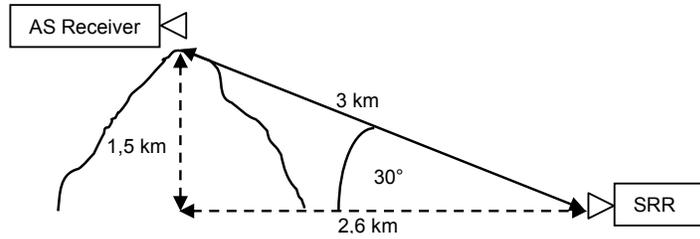

Fig. D-3: Possible scenario: long range communication tests mountain-to-mountain

Here, the SRR transmits through the sidelobe (sidelobe level 25 dB below the maximum) and the amateur station receiver receives through the sidelobe (sidelobe level 20 dB below the maximum; see section D.2).

Following the information in section D.5, the interference to the amateur service receiver from a single SRR is determined (calculation example for F = 12 dB):

$P_{SRR,transmit}$ -69 dBm/Hz
$P_{AS,receive,max}$ -162 dBm/Hz (@ F = 12 dB; see chapter D.5)
$\rightarrow L_{eff} = L-(G_{AS,sidelobe} + G_{SRR,sidelobe\ elevation})$ has to be 93 dB (free space attenuation L incl. consideration of antenna gains) in order to fulfil the requirement of chapter D.5)

$G_{AS,sidelobe}$ 20 dB below the antenna main lobe gain
$G_{SRR,sidelobe\ elevation}$ 25 dB below the antenna main lobe gain
$\rightarrow G_{AS,sidelobe}$ 20 dBi (@ $G_{AS,main}$ = 40 dBi)
$\rightarrow G_{SRR,sidelobe\ elevation}$ -13 dBi (@ $G_{SRR,main}$ = 12 dBi)

Calculation of interference range R_{int}
$\rightarrow L = L_{eff} + (G_{AS,sidelobe} + G_{SRR,sidelobe\ elevation}) = 93dB+(20dBi+(-13dBi)) = 100$ dB
$\rightarrow$ **Rint >= 31 m** < 2 km (required interference protection range)

For F = 4 dB the resulting interference range is Rint >= 79.5 m

Calculation available interference margin M for assumption d = 3000 m
from Fig.D-3 $\rightarrow$ d = 3000 m $\rightarrow$ L = 139 dB
$\rightarrow P_{AS,receive} = P_{SRR,transmit} + G_{SRR,sidelobe\ elevation} - L + G_{AS,sidelobe} = -201$ dBm/Hz
$\rightarrow$ **M = $P_{AS,receive,max} - P_{AS,receive}$ = 39 dB**

Concluding note to the calculations

For the "mountain-to-mountain" scenario shown in Fig. D-3 the interference range to be kept is 31 m (for the maximum SRR signal acceptable at the amateur station receiver as given in chapter D.5 and @F = 12 dB). The requirement of an interference protection range of 2 km is clearly fulfilled. The considered distance of 3000 m between amateur station receiver and SRR leads to an available interference margin of 39 dB, which is enough also for an aggregated interference scenario. Thus, a significant interference to the amateur service from the SRR is not to be expected.

References in Annex D:

[1] CEPT ECC Report 7, Compatibility between Inductive LF RFID Systems and Radio Communication Systems in the Frequency Range 135-148.5 kHz. Beaune: Feb. 2002.
Note: the methodology given in ECC Report 7 was considered as relevant for this compatibility analysis in the 79 GHz range.

[2] N. C. Currie, R. D. Hayes, R. N. Trebits, Millimeter-Wave Radar Clutter. Boston: Artech House, 1992.