



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

**ECC REPORT 158**

**THE IMPACT OF 26 GHz SRR  
APPLICATIONS USING ULTRA-WIDEBAND (UWB)  
TECHNOLOGY ON RADIO SERVICES**

**Cardiff, January 2011**

## 0 EXECUTIVE SUMMARY

CEPT was mandated by the European Commission to:

- consider the continuing relevance of the initial technical assumptions concerning the operation of automotive short-range radar in the 24 GHz range. All necessary technical compatibility studies between automotive SRR systems and other radio services should be undertaken, re-using or confirming the results of previous studies where still relevant<sup>1</sup> ;
- consider the development of the automotive SRR technology in the 79 GHz range and report on whether there are any technical barriers to the uptake of the 79 GHz band as the permanent band for automotive SRR in the medium term;
- where any alternative bands are to be considered for automotive short-range radar systems, propose appropriate technical and regulatory measures to ensure the protection of existing radio services in or near any such bands. .

The necessity for the Mandate was given by the fundamental review of the EC Decision on the 24 GHz band (required by Article 5 No. 2 of EC Decision 2005/50/EC). During this review process some automotive interests also proposed consideration of possible move to 24-29 GHz band with a view to avoiding in band sharing problems with some radio services before moving to the 79 GHz band.

This Report addresses the sharing and compatibility issues between SRR and other services in the 24-29 GHz band.

### Fixed service

Regarding the compatibility of 26 GHz SRR, all protection objectives and scenarios given in ECC Report 023 have been considered and are still valid. In addition, the “single-car” interference case (intended as a continuous stream of cars crossing the Fixed Service (FS) link path) has also been considered as common case with high occurrence probability; this was not present in ECC Report 023, but later on was added in Report ITU-R SM.2057.

According to the first release of SRdoc ETSI TR 102 664 V1.1.1, which simply proposed frequency shift to 26 GHz band without changing any other technical SRR system parameters, it was concluded that the results of ECC Report 023 are still valid and 26 GHz SRR will not be compatible with FS links in 26 and 28 GHz bands. However, some preliminary simulations, taking into account more detailed both the mean and peak emission characteristics, have shown that with a reduction of the e.i.r.p. density and limited Duty Cycle there might be some room for improvement; in addition, the simulations highlighted some problems related to high peak-to average and narrower pulse bandwidth.

Based on those initial considerations ETSI provided a revised version of the SRdoc TR 102 664 V1.2.1, (see table B.2.4), which was further examined in the development of this report. The results show some improvement compared to the original proposal (see section 2.2.7), in particular, for the “single-car” entry case. For the other cases violation of the FS objectives are still possible as follows;

- 1) The substantial reduction of the Peak power significantly reduces the amount of performance degradation of the FS victim receiver even when the mean power I/N objectives are slightly exceeded.
- 2) In the “single-car”<sup>2</sup> scenario, considering the DC improvement over the BER (averaged for 1 second according the ITU recommendations), the estimated degradation of the BER threshold (~0.05 dB) may be considered within the objectives (degradation of the ITU error performance and availability objectives 0.5% to 1%). The most severe “instantaneous” BER degradation, which occurs with the minimum DC, appears to be within a range manageable by typical FS demodulator without risk of loss of synchronisation.
- 3) In the “most scenario”<sup>3</sup> aggregated conditions, the estimated degradation of the BER threshold is ~0.15 dB which is equivalent to an availability objective degradation of about 1.2% to 3.5% depending on the link length, rain rate and availability objectives.

<sup>1</sup> Notably the CEPT Report to the EC under the SRR Mandate (see doc. RSCOM 04-41 of September 15<sup>th</sup> 2004).

<sup>2</sup> According to Report ITU- R SM.2057

<sup>3</sup> From ECC Report 23: “However, on the basis of the whole range of calculation results, it can be concluded that with an e.i.r.p. density of -60 dBm/MHz the FS protection criteria (-20 dB I/N) for „**all scenarios**“ considered in these studies is respected, whilst with an e.i.r.p. density of -50 dBm/MHz, this protection criteria would be met in „**most scenarios**“. Some administrations are of the opinion that it is necessary that SRR meets the -20 dB I/N protection criteria in all cases. Some other administrations are of the opinion that an excess of the protection criteria by 10 dB, which still corresponds to an I/N of -10 dB, is acceptable.”

- 4) In the “all scenario”<sup>3</sup> aggregated conditions, the estimated degradation of the BER threshold is ~2.4 dB which is equivalent to an availability objective degradation of about 25% to 106% depending on the link length, rain rate and availability objectives. This is still significantly exceeding the objectives. Nevertheless, also due to the reduced peak power impact, when compared with the expected BER threshold degradations with the original 24 GHz SRR characteristics, the improvement is about 13 dB.
- 5) When a 10% market penetration of 26 GHz UWB SRR would be reached; the aggregation impact, provided that the new limits proposal have significantly reduced the peak e.i.r.p., can be assumed to be ~10 dB lower than mentioned above as follows:
  - The “most scenarios” conditions would be reduced to about 0.02 dB BER threshold degradation and an availability objective degradation of less than 0.5% objective in any link conditions.
  - The “all scenarios” conditions would be reduced to about 0.2 dB BER threshold degradation and an availability objective degradation of about 3.5% to 6% depending on the link length, rain rate and availability objectives. An availability degradation of 6% corresponds to an increase of the unavailability of about 3 minutes per average year for a FS link planned with an availability of 99.99%.
- 6) The above conclusions for the aggregated scenarios should be considered together with all other mitigations (e.g. production spreads, geographical occurrence probability, etc...).
  - If a value of 2.5 dB is considered for the production spread in the “all scenarios” conditions together with a reduction of the market penetration to 10% the BER threshold degradation would be about 0.11 dB with an availability objective degradation of about 3%. An availability degradation of 3% corresponds to an increase of the unavailability of about 1.5 minutes per average year for a FS link planned with an availability of 99.99%.

Also the issue of the occurrence probability of those scenarios within the territory of one administration was also considered. This administration produced a geographical study on 14.000 FS links in the band 24-29 GHz showing that the occurrence of the assumed worst cases of ECC Report 023 would be negligible, and that the impact on real deployed FS links may be about 15 dB less critical as assumed as worst case in ECC Report 023. However, it has been considered that the geographical situation in one country would not be representative of situations in other countries, which may have different deployment rules/habits for FS links, therefore the findings of this analysis by one administration may not be applicable to most other administrations.

Open field radiated tests have also been performed (see Annex 4), they have shown consistency with the laboratory conducted tests reported in ECC Report 023.

Finally, the issue of short links (possible in some cases and in some countries) was examined, but its conversion into actual “error performance and availability degradation” is more complex because such shorter hops in these frequency bands may bring new technical elements into consideration. Here some administrations are of the view that such FS links (e.g. 100 m hop length together with Tx power values less than -31 dBm and a link margin of 3 dB) are not realistic, while other administrations reported the deployment of short links in their country and therefore they are concerned with the deployment of SRR on their territory.

#### **EESS and SRS earth stations 25.5-27 GHz**

The compatibility analysis which has been conducted addresses the protection of EESS and SRS space earth stations from 26 GHz SRR emissions including those in the passive band 23.6-24 GHz.

Concerning the protection of EESS and SRS space earth stations, based on an exhaustive list of earth stations deployed within Europe, the analysis of the new limit proposal, as contained in Table 1, concluded that the expected benefit in terms of the mean power aggregation scenarios is 9 dB (based on a mean power of -50 dBm/MHz/s). In that case, an average mean power of -50 dBm/MHz implies that compatibility is achieved for EESS and SRS, space earth stations.

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*The above consideration when the new limits (-50 dBm/MHz) is applied would correspond to ;*

*I/N = -10dB for „all scenarios“ and I/N = -20dB for „most scenarios“.*

*However the simulation made for this study have also considered a combination of the peak and mean e.i.r.p. permitted within the flexibility of the new limit proposal, while ECC Report 23 considered only the mean power effect.*

**EESS and Radioastronomy in the band 23.6-24 GHz**

The compatibility of SRR 26 GHz with EESS passive was investigated by ECC in detail. It was agreed that the following limits would fulfil the protection requirements of EESS passive:

- a) Direct emission limit in the main beam will not exceed -73 dBm/MHz e.i.r.p.
- b) Additional average antenna attenuation above 30° elevation to be separately measured will be at least 20 dB.

Radio compatibility issues between SRR and the radio astronomy service (RAS) in the band 23.6-24 GHz were not studied in detail, because it has been assumed that the limit derived for the protection of the earth exploration-satellite service (passive), would also be sufficient for the protection of the RAS.

In addition, Decides-5 of Decision ECC/DEC/(04)10 for 24 GHz SRR defines a level of -74 dBm/MHz for the protection of the RAS without the necessity for a deactivation mechanism. Therefore, in addition to the constraint given in (b), the limit for the direct emissions was set to -74 dBm/MHz for the band 23.6-24 GHz to protect EESS passive and the RAS.

**Military systems**

Specific compatibility studies between SRR applications within 24-29 GHz and fixed or mobile military systems within 26.5-27.5 GHz have not been carried out because of lack of data for military systems, especially for expected future military systems. The frequency band 26.5-27.5 GHz has been identified as a harmonised military band for fixed and mobile systems in ERC Report 025 and also in the NATO Joint civil/military Frequency Agreement (NJFA) 2002 (“harmonised NATO band type 2”). It was assumed that the results of the compatibility studies on the fixed service may be applicable for some of the military systems.

**Compatibility conclusions**

In conclusion, the limitation of the market penetration for SRR to about 10 % may be considered in order to allow the deployment of 26 GHz UWB SRR with the proposed new limits given in the following Table 1.

SRR Frequency Range	24.25-27.5 GHz
Peak e.i.r.p.	-7dBm/50MHz (for iBW≥50MHz) or -7dBm - 20*log(50MHz / iBW) measured with RBW = iBW (for iBW<50MHz)
Mean e.i.r.p. @ 1MHz/1s	-50 dBm/MHz
Duty Cycle (DC)	2% to 10% per 50 MHz and per sec
Additional limits in the band 23.6-24 GHz	Direct emission limit in the main beam : -74 dBm/MHz e.i.r.p.
	Additional average antenna attenuation above 30° elevation: 20 dB.
SRR Market penetration	10%

**DC** = Ton/(Ton + Toff) % per 50 MHz and per sec with:

Ton defined as the duration of a burst irrespective of the number of pulses contained.

Toff defined as the time interval between two consecutive bursts when the UWB emission is kept idle.

**iBW** = instantaneous bandwidth of each single pulse, defined to be the inverse of the pulse duration.

**Table 1: limits for SRR at 26 GHz**

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## LIST OF ABBREVIATIONS

AR	Availability Ratio
BER	Bit Error Rate
DC	Duty Cycle
EESS	Earth Exploration Satellite Service
e.i.r.p.	effective isotropically radiated power
EPO	Error performance
ES	Error seconds
EESS	Earth Exploration Satellite Service
FH	Frequency Hopping
FMCW	Frequency modulated Continuous Wave signal
FS	Fixed Service
FWA	Fixed wireless Access
I/N	Interference-to-Noise ratio
$I_{\text{peak}}$	interference power measured with peak detector
$I_{\text{rms}}$	interference power measured with rms detector
LOS/LoS	Line-Of-Sight
MCL	Minimum Coupling Loss method
NLOS	Non-Line-Of-Sight
NJFA	NATO Joint civil/military Frequency Agreement
PDH	Plesiochronous Digital Hierarchy
PFH	Pulsed Frequency Hopping System
PLL	Phase Lock Loop
PMP	Point-to-Multipoint system in Fixed Service
PP	Point-to-Point links in Fixed Service
PPM	Pulse position modulation
PRF	Pulse Repetition Frequency
RA	Radio Astronomy
RAS	Radio Astronomy Service
rms	Root-Mean-Square
RSL	Received Signal Level
Rx	Receiver
SDH	Synchronous Digital Hierarchy
SEAMCAT	Spectrum Engineering Advanced Monte-Carlo modelling Tool, a software tool, see: <a href="http://www.seamcat.org">www.seamcat.org</a>
SES	Severe Error seconds
SEB	Severely Errorred Blocks
S/N	Signal to Noise ratio
SRdoc	ETSI System Reference Document, e.g. TR 102 601 for LPR applications
SRR	Short Range Radar
SRS	Space Research Service
UWB	Ultra-Wideband technology

## The impact of SRR 26 GHz Applications using Ultra-Wide-Band (UWB) Technology on Radio Services

### 1 INTRODUCTION AND BACKGROUND

#### 1.1 24 GHz SRR current regulatory situation

ECC developed ECC Report 023 (May 2003) “*Compatibility of automotive collision warning Short Range Radars operating at 24 GHz with FS, EESS and Radio Astronomy*” [1]. These UWB SRR devices, according ETSI proposal (ETSI TR 101 982 [2]), were expected to use the band 22-29 GHz with a mean power density of  $-41.3$  dBm/MHz (as already permitted in US by FCC).

The report concluded that there was no compatibility on the long-term deployment (i.e. with 100% vehicles market penetration of these devices), because of the potential interference to three Services considered caused by aggregation of the assumed large number of SRR devices. The ECC consequently designated, with ECC/DEC/(04)03 [3], the band 77-81 GHz as permanent allocation for these applications.

However, considering the European automotive industries need for a temporary use in the market of the 22-29 GHz band, permitting the initial deployment of existing 24 GHz technology, ECC produced ECC/DEC/(04)10 [4] and, consequently, EC produced Decision 2005/50/EC [5], which, based on ECC Report 023 finding, permit the 24 GHz SRR deployment up to a vehicle market penetration of less than 7 %, beyond which the protection criteria of Primary services in these bands would be exceeded. In any case, no new 24 GHz SRR should be employed beyond 1<sup>st</sup> July 2013.

Further mention should be done to the later-on work in ITU-R, which led in 2005 to the publication of a similar Report ITU-R SM.2057 [6], which made broader the evaluation of the impact of the possible mitigation factors based on different regional deployment practices/scenarios.

#### 1.2 26 GHz SRR band (24-29 GHz)

ETSI produced a new SRdoc (ETSI TR 102 664 V1.1.1 2009-04 [7]) limiting the operating band of 24-29 GHz (hereby called 26 GHz SRR), which avoided the EESS and Radio Astronomy band 23.6-24 GHz. However, no other technical parameters (notably mean and peak power density) have been changed from the original 24 GHz SRR characteristics. A draft revised version of this system reference document (draft ETSI TR 102 664 V1.2.1) has been provided by ETSI. This revised system reference document describes improved technologies for UWB 26 GHz SRR applications with more stringent limits and the frequency band has been limited to 24.25-27.5 GHz. This new set of limits is explained in chapter 2.2.7 and the 26 GHz band is further considered in this report.

#### 1.3 Impact of 26 GHz SRR on FS systems

The 26 GHz SRR application, while solving the in band compatibility issue with EESS and with the FS in 23 GHz band (22-23.6 GHz), would maintain unresolved the compatibility with FS in the 26 GHz (24.25-26.5 GHz) and 28 GHz (27.5-29.5 GHz) bands. FS in those bands, already been considered by ECC Report 023, will be potentially interfered to the same extent.

Therefore, in principle, without any change in SRR system technical parameters/limitations the 26 GHz SRR solution would also not be compatible with the FS in 26 GHz and 28 GHz bands in the long term. This report provides the impact on FS of revised more stringent limit proposal in ETSI TR 102 664 V1.2.1 and gives some additional elements for considerations for administrations for a risk assessment about the impact of any identification of spectrum to SRR at 26 GHz.

The investigations are detailed in chapter 2 of this document.



#### 1.4 Impact of 26 GHz SRR on EESS/SRS earth stations 25.5-27 GHz

For all 3 regions, according to Article 5 of the RR [8], the allocations for the band 25.5-27 GHz are as follows:

- The band 25.5-27.0 GHz is allocated to the EESS (space-to-Earth), the SRS (space-to-Earth) and the 25.25-27.50 GHz band is allocated to the inter-satellite service<sup>4</sup> (ISS); the 25.5-27 GHz band is planned to be used by EESS missions for various Earth observing, Earth exploration, and climate monitoring missions.
- The 25.5-27.0 GHz band is an important downlink band for the EESS and SRS. This band is planned to be used to support EESS satellites, such as NPOESS, as well as SRS missions, which could operate at any distance from a low Earth orbit to the Sun-Earth Lagrange points. Availability of this band is crucial to many near Earth SRS and EESS missions since it is the only band available that can support data downlink bandwidth requirements in excess of 10 MHz below 37 GHz. The availability of the 25.5-27.0 GHz band is crucial to near-Earth SRS and EESS missions for various Earth observing, Earth exploration, and climate monitoring objectives, with high data rate requirements.

Frequency range in GHz	RR allocations for all 3 regions
25.5-27	EARTH EXPLORATION-SATELLITE (space-to-Earth) 5.536B FIXED INTER-SATELLITE 5.536 MOBILE SPACE RESEARCH (space-to-Earth) 5.536C Standard frequency and time signal-satellite (Earth-to-space) 5.536A

**Table 2: Extract of the RR article 5 for the 25.5-27 GHz band**

**5.536** Use of the 25.25-27.5 GHz band by the inter-satellite service is limited to space research and Earth exploration-satellite applications, and also transmissions of data originating from industrial and medical activities in space.

**5.536A** Administrations operating earth stations in the Earth exploration-satellite service or the space research service shall not claim protection from stations in the fixed and mobile services operated by other administrations. In addition, earth stations in the Earth exploration satellite service or in the space research service should be operated taking into account Recommendations ITU-R SA.1278 and ITU-R SA.1625, respectively. (WRC-03).

**5.536B** In Germany, Saudi Arabia, Austria, Belgium, Brazil, Bulgaria, China, Korea (Rep. of), Denmark, Egypt, United Arab Emirates, Spain, Estonia, Finland, France, Hungary, India, Iran (Islamic Republic of), Ireland, Israel, Italy, the Libyan Arab Jamahiriya, Jordan, Kenya, Kuwait, Lebanon, Liechtenstein, Lithuania, Moldova, Norway, Oman, Uganda, Pakistan, the Philippines, Poland, Portugal, the Syrian Arab Republic, Dem. People's Rep. of Korea, Slovakia, the Czech Rep., Romania, the United Kingdom, Singapore, Sweden, Switzerland, Tanzania, Turkey, Viet Nam and Zimbabwe, earth stations operating in the Earth exploration satellite service in the band 25.5-27 GHz shall not claim protection from, or constrain the use and deployment of, stations of the fixed and mobile services. (WRC-07).

**5.536C** In Algeria, Saudi Arabia, Bahrain, Botswana, Brazil, Cameroon, Comoros, Cuba, Djibouti, Egypt, United Arab Emirates, Estonia, Finland, Iran (Islamic Republic of), Israel, Jordan, Kenya, Kuwait, Lithuania, Malaysia, Morocco, Nigeria, Oman, Qatar, Syrian Arab Republic, Somalia, Sudan, Tanzania, Tunisia, Uruguay, Zambia and Zimbabwe, earth stations operating in the space research service in the band 25.5-27 GHz shall not claim protection from, or constrain the use and deployment of, stations of the fixed and mobile services. (WRC-03).

Compatibility between SRR and EESS/SRS earth stations is further considered in chapter 3 of this document.

<sup>4</sup> Use of the 25.25-27.5 GHz band by the inter-satellite service is limited to space research and Earth exploration-satellite applications.

### **1.5 Impact of 26 GHz SRR emissions in the band 23.6-24 GHz (passive band)**

As indicated in section 1.2, ETSI produced a new SRdoc (ETSI TR 102 664 V1.1.1 2009-04 [7]) based on the proposed limitation of the operating band of 26 GHz SRR, thus avoiding the EESS and Radio Astronomy band 23.6-24 GHz. The possible impact of the SRR emissions is further considered in chapter 4.

The characteristics of EESS operating in this band are provided in Annex D to ECC Report 023 [1].

With regard to the protection of the RAS, footnote 5.340 applies in the band 23.6-24 GHz. European radio astronomy stations where observations are currently made in the frequency range 22-24 GHz are found in France, Germany, Italy, Spain, Sweden and the United Kingdom.

### **1.6 Military systems**

Specific compatibility studies between SRR applications within 24-29 GHz and fixed or mobile military systems within 26.5-27.5 GHz have not been carried out because of lack of data for military systems, especially for expected future military systems. The frequency band 26.5-27.5 GHz has been identified as a harmonised military band for fixed and mobile systems in ERC Report 025 [9] and also in the NATO Joint civil/military Frequency Agreement (NJFA) 2002 (“harmonised NATO band type 2”). It was assumed that the results of the compatibility studies on the fixed service may be applicable for some of the military systems.

## **2 THE IMPACT OF SRR ON THE FIXED SERVICE**

As mentioned in the introduction, the conclusions of ECC Report 023 [1] are still numerically valid as reference for the impact assessment.

In addition, Report ITU-R SM.2057, besides similar conclusions of ECC Report 023 [1] with respect to aggregate interference, contains also specific study on the “single-car entry”, not included in ECC Report 023, as well as budgetary considerations about mitigation factors (for both propagation and regional geometric/geographic point of view).

The importance of the “single-car entry” has been highlighted in Report ITU-R SM.2057 also frequently occurring and representing the “lower bound” for any further SRR aggregated interference, Annex 1 reports relevant considerations about the “single-car entry” impact.

It should be noted that both ECC and ITU-R Reports deal with FS PP and PMP (Central Stations) systems, of which the PP case resulted more critical by few dB; in addition FWA in these bands is no longer popular. Therefore, only the PP results are summarised and considered; nevertheless, from the point of view of the occurrence probability of interference, PMP CS might be more probably affected due to the wide angle sectored antennas, covering a larger geographical area.

The summary of results of available studies is reported in chapter 2.1 with details in Annexes 1 and 6.

Chapter 2.2 contains new investigations in relation to FS with details in Annexes 2 and 7.

In chapter 2.3 an analysis is provided in order to quantify the impact of 26 GHz SRR on the EPO and availability of a P-P FS system; the new limit proposal shown in chapter 2.2.7 was derived from these investigations. Details are also contained in Annexes 3 and 5.

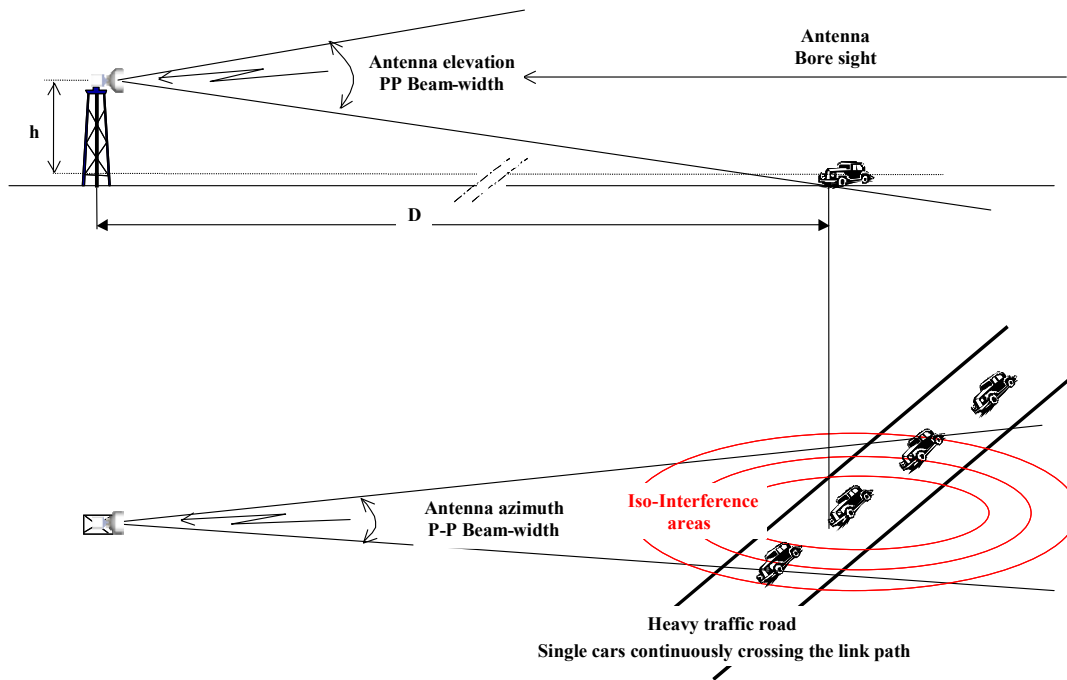
Finally, chapter 2.4 provides the results of a measurement campaign (details are provided in Annex 4) and chapter 2.5 gives a summary and conclusion.

### **2.1 Summary of studies contained in Report ITU-R SM.2057**

#### **2.1.1 Single-car entry PP**

Unlike the “aggregation” case, where ECC Report 023 [1] took care of FS deployments potentially highly impacted by aggregation derived from traffic-jammed segments of highways parallel to the FS links, the “single-car entry” situation may happen in any deployment situation, in particular also with a SRR sensor along the bore-sight direction of the radio link. This situation is exemplified in Figure 1 where a high traffic road crosses the

path of a radio link; single cars are continuously crossing the path where the antenna gain is maximum, generating the same effect of a continuous interference.



**Figure 1: “single-car entry” generic interference scenario**

Report ITU-R SM.2057 [6] Figure 210 gives the graphical result of such interference, coming from a single reference car (two front and two rear SRR) placed along the boresight direction of the FS link; it is limited to FS antenna height of 20 m and above.

Table 3 summarises the expected values in term of the  $I_{\text{mean}}/N \leq -20$  dB (or  $I_{\text{peak}}/N \leq +5$  dB/50MHz) objective violation.

	<b>I/N objective violation (+dB) or margin (-dB)</b>				
<b><math>h_{\text{rx}}</math> (m)</b>	10	20	30	40	50
<b><math>\Delta I/N</math> (dB)</b>	+7 (note 1)	-3 (note 2)	-6 (note 2)	-10 (note 2)	-12 (note 2)
Note 1: This value, not shown in graphic form in SM.2057, was separately calculated by a different proponent. Note 2: For a possible error in applying the SM.2057 assumptions into the graphics development, these values, for antenna heights higher than 10 m, are underestimated by 3 dB (see Annex 1).					

**Table 3: objective of  $I/N = -20$  dB exceeded by x dB; Single-car entry, -41 dBm/MHz (Report ITU-R SM.2057 Figure 210)**

The results are nearly independent on the distance because the higher the distance the more the SRR comes to the mainbeam of the PP antenna and on the antenna gain because the lower is the gain the wider is the beamwidth gathering interference at closer range; nearly flat result is experienced for relatively large distance span (from few hundred m to few km depending on antenna gain and height).

**2.1.2 Aggregation PP, road parallel to the PP link**

Report ITU-R SM.2057 [6] contains extensive calculation of the aggregation potential of a significant number of cars equipped with SRR driving, during heavy traffic periods, along straight section of roads parallel to the PP link direction, results are practically equal to those in ECC Report 023 [1].

The results, in term of deviations from the  $I/N = -20$  dB protection objective are summarised, for the several set of different parameters (rain attenuation, FS antenna height and offset from the road and car distance in the cue), in Table 4. Assumed PP antenna gain = 41 dBi (0.6 m size).

Report ITU-R SM.2057 contains two deployment scenarios due to regional deployment/geographical and other considerations. In Table 4 yellow cells represent Deployment case 1, which is consistent with ECC Report 023, while green cells were represent Deployment case 2.

Rain atten. on the SRR interfering path (dB/km)	Average Distance between cars in the lines (m)	PP Antenna offset (hoff) from road (m)	Deviation from the $I_{max} \leq -128$ dBm/MHz objective (dB)						
			PP Antenna height hrx (m)						
			10	18	25	30	40	50	60
0.6	20	10	19	16					
		30		11					
	50	10	16						
		40			2				
	100	10	13	10					
30			6						
2	20	20		6		3			
		40			1				
		60		-1		-3			
	50	10			6				
		20			4				
		40		1	0	-1	-3	-5	-7
		60			-4				
		90			-7				
	100	20		4		0			
		40			-2				
		60		-5		-7			
	150	40			-24				
	3	20	10	15	12	10			
			30			5			
		50	30			2			
40					-2				
100		10	10	6	4				
		30			0				
150	30			-1					

Table 4: objective of  $I/N = -20$  dB exceeded by x dB; (Report ITU-R SM.2057 Figures 211 to 225)

2.1.3 Aggregation PP, Impact of the pointing of the PP link in respect to the road

Angle between road and FS link	Deviation from the $I_{max} \leq -128$ dBm/MHz objective (dB)		
	Road length		
	500m	1km	3km
-10°	-2	-2	-2
0°	-2	1	6
+10°	-12	-12	-12

Table 5: objective of  $I/N = -20$  dB exceeded by x dB; Impact of the pointing of the FS PP Link with respect to the road from SM.2057 Figure 225 (2dB/km, 18m height, 20m offset, 20m distance)

### 2.1.4 Summary of studies in Report ITU-R SM.2057

Table 6 summarises the deviation from the  $I_{\max} \leq -128$  dBm/MHz objective (dB).

I/N Objective	-20 dB	PP deviation from the $I_{\max} \leq -128$ dBm/MHz objective (dB)	
Deployment Case 1	Best case	0	Hrx=25m, off=30m, 3dB/km, 50m distance
	Worst case	19	Hrx=10m, off=10m, 0.6dB/km, 20m distance
Deployment Case 2	Best case	-6	Hrx=30m, off=60m, 3dB/km, 50m distance
	Worst case	6	Hrx=18m, off=20m, 2dB/km, 20m distance
Single car entry	Best case	-12	Hrx 60m
	Worst case	7	Hrx 10m

**Table 6: PP I/N results for -41 dBm/MHz e.i.r.p. without additional mitigations**

### 2.1.5 Conclusion of Report ITU-R SM.2057

It should be noted that the assumptions and conclusions of Deployment Case 1 are perfectly in line with the ECC Report 023 [1].

Quoting from Report ITU-R SM.2057 [6] conclusions:

*“The above study, while evaluating a number of potentially impacting aggregation scenarios, has shown that the case in § 1.5.8.2 of FS P-P link parallel to a major road or highway is ~7 dB worse than the FS P-MP FWA link; therefore the final conclusions are based on the FS P-P link scenario.*

*The above studies have shown that the SRR emission limits, for not impacting on FS, strongly depend on external circumstances that are in any case of imprecise or even unpredictable nature.*

#### Deployment Case 1 study

*From the FS Deployment Case 1 study, which might be of interest for countries where the deployment of P-P links, with low FS receiver antenna height, is frequent along high traffic density roads, and extensive use of these bands for FS links in mobile network infrastructure may occur, an average SRR e.i.r.p. power emission limit of at least -50 dBm/MHz is necessary; however, where the joint concurrence probability of the more severe deployment situations (i.e., lower FS antenna heights closer to a road) is considered, an e.i.r.p. density limit of -60 dBm/MHz is necessary for long term interference avoidance.*

#### Deployment Case 2 study

*The FS Deployment Case 2 study, which might be of interest for countries where less stringent infrastructural requirements regarding the FS receiver height and distance to the road might prevail, the SRR e.i.r.p. power emission limit of -41.3 dBm/MHz may be considered appropriate when other mitigation factors (unpredictable but anyhow, in most cases, present), depicted in Table 104, are taken into account. This will, however, increase the risk of interference from SRR to the FS in case those more unfavourable circumstances might occur.*

#### Further considerations

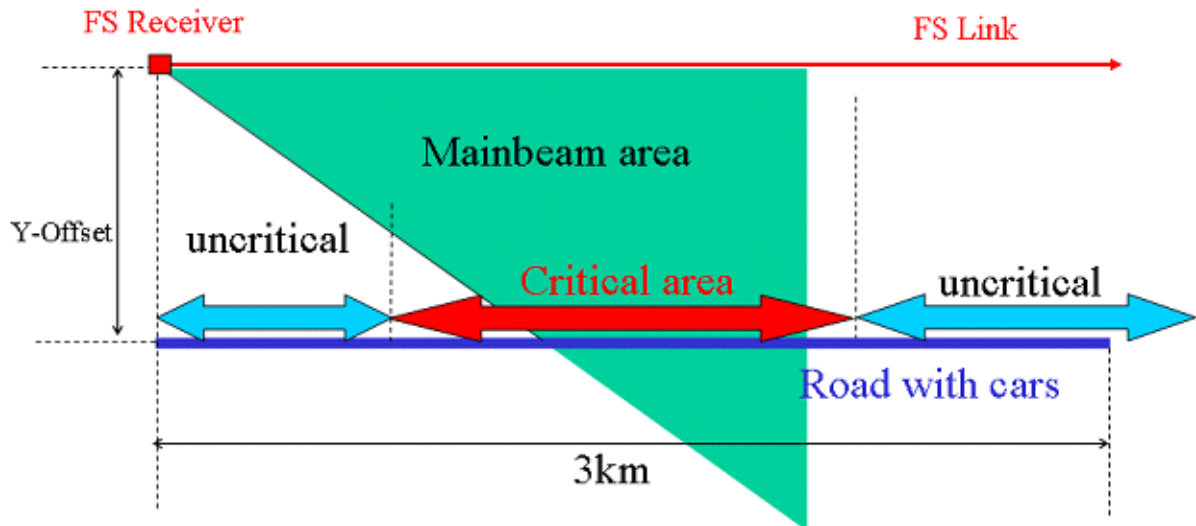
*It should also be noted that, besides sharing requirements with co-primary services, there are no internationally adopted limitations for the deployment and use of FS systems in their primary allocated bands; risky deployment situations, even if presently considered not existing in some Administrations, might occur at a later stage, unless appropriate guidance will be given for future FS use and deployment. Therefore, the recommended limits would also depend on the degree of risk that Administrations wish to take on the probability of incurring interference in their assumed reasonable worst case and on possible measures taken for minimising that risk also in the future. Finally, attention should be given to the “single car” contribution studied in § 1.5.8.1 showing that, with an unfavourable (which, nevertheless, could happen) placement of a car (e.g. when a small portion of busy road would cross, with any angle, the FS P-P link direction in full LoS of its antenna), the given interference is very close or, in case of lower antenna heights ( $\leq 20$  m), is already exceeding the objective, giving small or no room for any aggregation.”*

## 2.2 Further investigations not contained in existing studies

### 2.2.1 Aggregation scenario analysis

Studies of ECC Report 023 [1] and Report ITU-R SM.2057 [6] have assumed a scenario, which impact characteristics are summarised in Figure 2.

#### Scenario ECC Report 23 and ITU-R SM.2057



**Figure 2: Impact characteristics of the scenario in available studies**

The scenario assumes a 3 km, or at least ~2 km at critical distance, segment of straight road will occur in parallel to the path of a PtP fixed link, which receiver antenna is sufficiently low (i.e. less than about 20 m) so as to become subject of potential aggregate interference higher than the protection objectives.

The mutual geometrical parameters of the FS link and the road segment plays a significant role in the determination of possible interference. While, in principle, any combination of worst case parameters is possible and would be impossible to reach 100% confidence that they cannot exist as these parameters vary from country to country. However, neither ECC Report 023 nor Report ITU-R SM.2057 gives information on actual deployment situation in any country.

The impact of the geometrical position, length and the angular direction of the road in respect to the FS link has been analysed with more detailed parameters variance and the results can be found in Annex 2.1 of this document.

While confirming the Report 023 values, the results show as expected variation when the road angle departs from 0°; noting that the angle departure may frequently be generated, besides different azimuth, also by different elevation.

### 2.2.2 Examples of practical deployment scenarios in one administration

One administration has made a specific evaluation of the existing 14.000 FS links in the 26 and 28 GHz bands. Those with antenna height lower than 20 m have been analyzed in detail with respect to “major” roads (in terms of height, distance, road course, road length, elevation angle road and FS link,...).

Figure 3 shows the distribution in height over ground of all FS stations in this administration.

Number of FS antennas 24-29 GHz dependent on the antenna height over ground

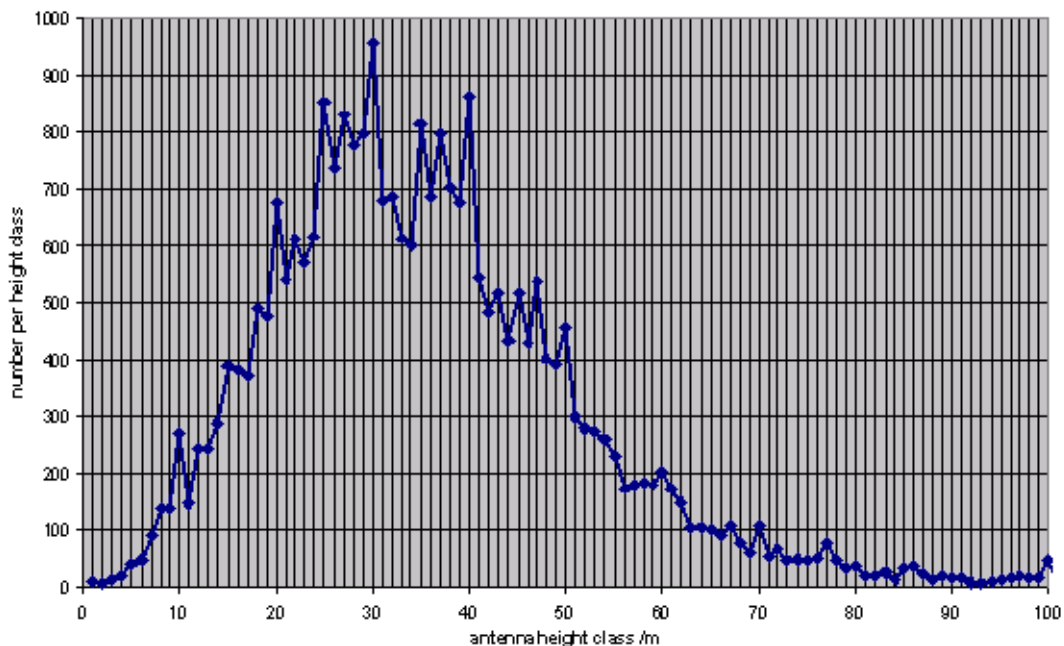


Figure 3: FS antenna height in one administration

To avoid a manual analysis of 28.000 stations the following filtering process has been applied:

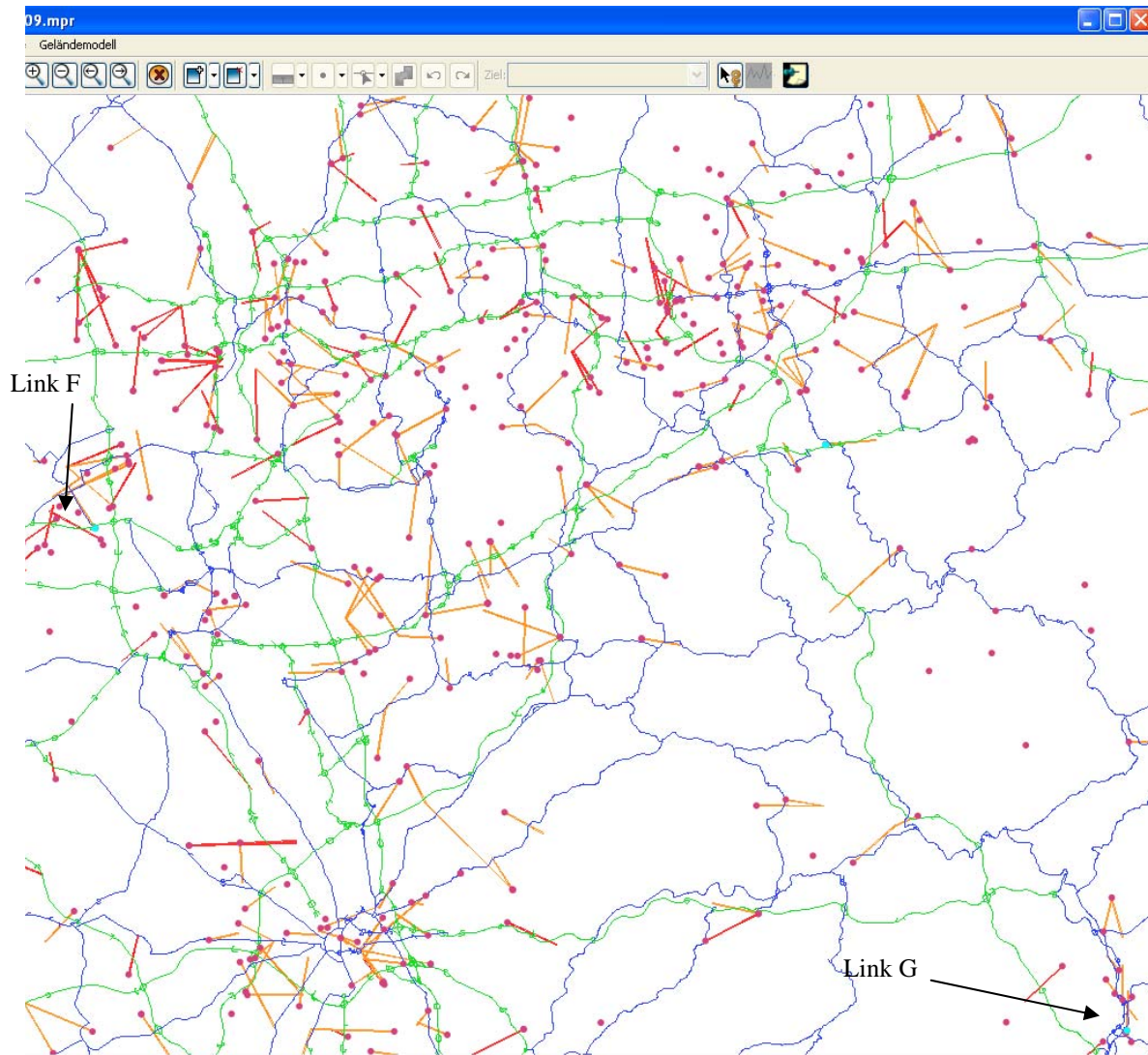
1. only FS antenna heights below 20m were further analysed (reducing the number of cases from 28.000 to about 4.500)
2. the FS links identified from step 1 (assumed as a 100m wide path for taking into account possible inaccuracies of the available maps.) which are parallel/crossing motorway and/or highways (also assumed 100m wide) were further analysed (reducing the number of cases from 4500 to about 3500)
3. the remaining 3500 links were manually (optically, see Figure 4 as example) analysed on the screen; here a number of links are identified as “critical” (see links A through I in Annex A2.2) if they meet the following criteria, which were used based on the experience from existing studies and the calculations in ideal scenario reported in Annex A2.1:
  - a. nearly parallel road to the FS link with an offset to the link of less than 50m
  - b. roads with a straight course and a length of more than some hundred meters and in a distance from the FS receiver of less than 5km

This process reduced the potential “critical links” to about 9.

Remaining critical FS links/roads have been further analysed on the possible aggregated impact with same calculations and assumptions as in Report ITU-R Report 2057 [6].

Only “geographical” mitigations, in particular the impact of the vertical profile of the road, were considered, further mitigation factors as clutter loss from buildings, bridges, or others, were not considered in this analysis. Annex A2.2 shows the details of the most critical links analysed.





**Figure 4: Example of about 100x100km in one administration with the critical Links F and G (green: motorways, blue: highways, red points: FS stations  $\leq 20\text{m}$ , yellow line: FS links highway crossing, red line: FS links motorway crossing)**

The result shows that:

- the interference protection objective ( $I/N = -20\text{dB}$ ) is not expected to be exceeded by more than 5 dB (to be compared with the 20 dB from existing studies).
- the number of links potentially affected is limited to 5 (i.e. the 0.03% of the total)

This simplified analysis concluded that generally, the combination of worst case parameters assumed in ECC Report 023 [1] are not presently applicable, in this administration.

However, it has also been noted that, as described in Report ITU-R SM.2057 [6], the impact of an additional “single-car entry” should have been considered in the aggregation. Therefore the above filtering process for links may not necessarily represent the true potential of interference even in this administration.

In addition, concerns were expressed with regard to the possible higher impact when the “geography” of others countries such as in another country (with more highly populated areas on completely flat land), would be considered. Therefore the findings of this analysis by one administration may not be applicable to most other administrations.



### 2.2.3 Additional considerations on the aggregation analysis in ideal and practical links scenario

The data shown in previous section are certainly increasing the confidence on the very low occurrence probability of worst cases in one administration; however, for practical reasons, the ~28 000 P-P terminals could not be analysed one by one; the simplification of analysing only those with P-P antenna height  $\leq 20$  m is certainly effective but not exhaustively valid for all cases. The following section describes the possible limitations.

#### 2.2.3.1 The “Ideal” scenario

The aggregation potential is a purely statistical matter, based on a large number of variables, for most of which the variance is unpredictable in practice.

To solve the problem ECC Report 023 [1] and Report ITU-R SM. 2057 [6] already give an extensive evaluation, on a “ideal” interference scenario, of the aggregated interference and a number of variable mitigation factors.

While the study intent is “statistical”, in practice the ideal scenario is “deterministic” based on three specific “geometrical” parameters of the FS antenna location:

- Distance from the close-by road
- Height of the antenna
- Angle between boresight and road direction (deviation from parallel direction)

#### 2.2.3.2 The “Actual” scenarios

The above description of the “ideal” scenario, in other words, means that, in real cases, the three mentioned parameters are not “significant” for uniquely define if the interference probability i.e.:

- There may be cases where, even with low FS masts closer to the road, interference would never happen (see cases B and D in Figure 5);
- There may be cases where, even with high FS masts far from the road, interference may happen (see cases A and C in Figure 5);

It should be noted that the investigation in section 2.2.2 takes into account any distance of the FS mast from the roads but not possible impact of antenna height  $>20$  m (see case C in Figure 5), which would have needed an 100% of the 14 000 links analysis.

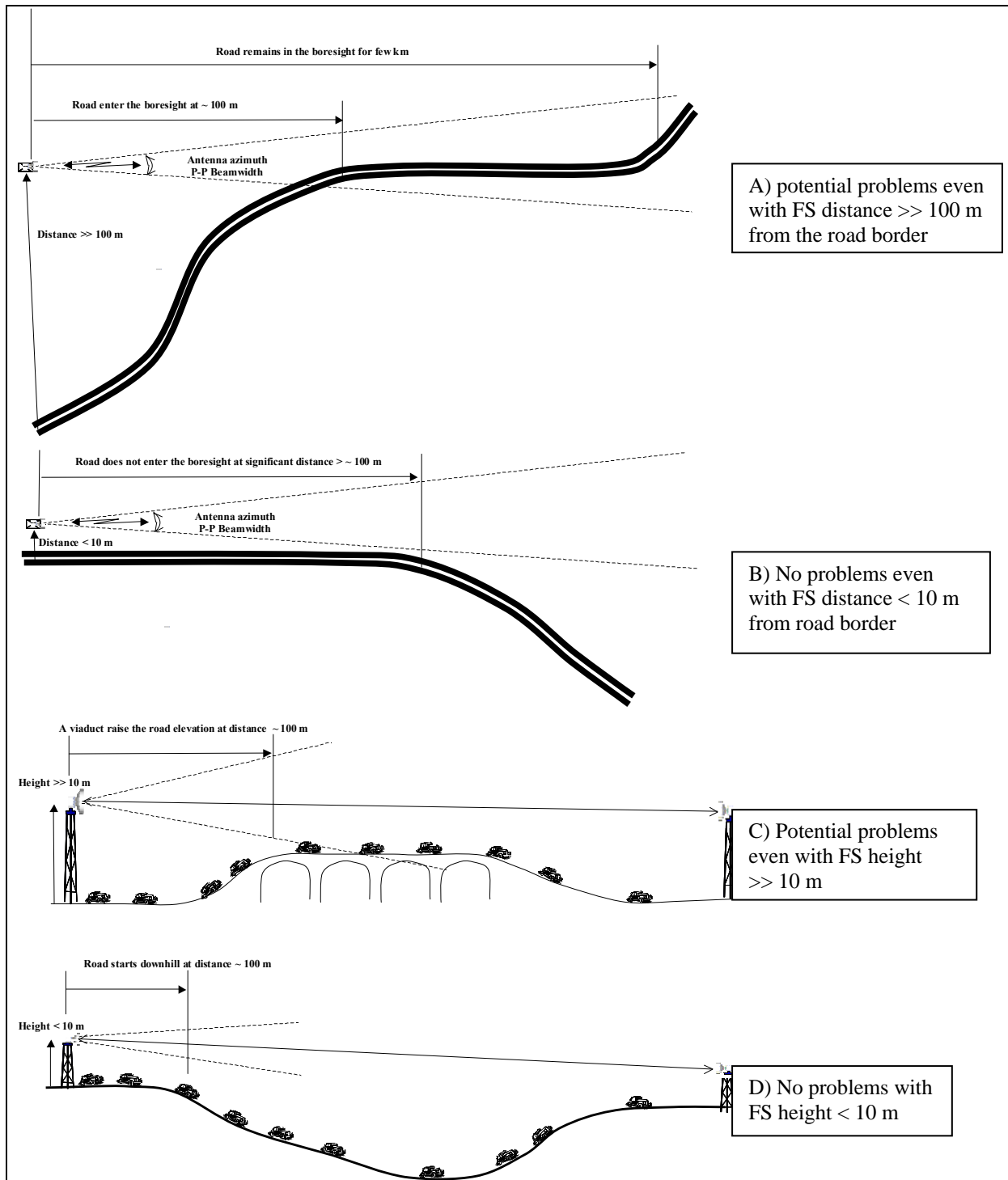


Figure 5: Impact of real scenario over ideal study characteristics

#### 2.2.4 Study provided by one administration

A new study provided by one administration suggested there are scenarios, which may present more severe interference potential beyond those envisaged in the original ECC Report 023, which assumed that links shorter than about 2 km were not present.

This study provided Monte-Carlo analysis (see Annex 7.3) shows that the expected worst aggregated impact of ECC Report 023 may be exceeded by further 7 dB if assuming 3 SRR sensors in line of sight on the first lane (ECC Report 023 uses 1 sensor in LOS while a second one was shadowed) and assuming a FS noise figure of 4dB (6dB was used ECC Report 023).

The static analysis (see Annex 7.1) considers a very short FS link of 100 m in line of sight to a SRR sensor and shows about 20dB bigger impact than the single entry calculations of Report ITU- R SM.2057 [6].

Another administration carried out analysis (see Annex 7.2) to check the impact of SRR on BER performance of these FS links for 128 QAM transmissions (Rec. ITU-R F.1101 [10]) with the relevant FS link parameters assuming that the available fade margin will be available to mitigate interference from SRR. This administration is of the view that with a FS link fade margin of 10 dB the BER performance will not be degraded, even for the very low Tx power values (-31 dBm) while with a FS link fade margin of 3dB the Link could be blocked by SRR. Another administration is of the view that it is generally not appropriate to assume that fade margins in fixed links are available for the purpose of mitigating interference as the fade margins are assigned to maintain the relevant performance and availability objectives for the appropriate propagation conditions.

It is recognised that such very short range FS links may also be realised by other means (e.g. higher frequencies, optical links), but there is possibility to deploy such sort of links in a number of administrations. With regard to the short FS link there is a need to add the following clarifications:

- Most Administrations at present include a minimum fade margin of 8 - 20 dB also in case where the actual rain induced “availability” objective (i.e. in term of Severely Errorred Seconds, SES, or Blocks, SEB) would require less; this is retained necessary to ensure also that the link quality (i.e. in term of Errorred Seconds, ES, or Blocks, EB) meets the required level. This fade margin is required to ensure the link quality level and may not necessarily be available to mitigate interference. Furthermore some private spectrum licensees owners have proposed using lower fade margins. While this could result in lower quality links, this could be acceptable to some commercial customers and would permit higher densities of fixed link deployments.
- There are diverging views about available lowest Tx power of FS link equipment and the type of antenna used; one administrations is of the view that Tx power values assumed for this link (-31 and -37 dBm) are not practically available and consequently the desired 3dB link margin hardly practical; with -15 dBm (lowest transmit power available) the BER performance would not be impacted by the expected level of interference. In addition a large 60 cm antenna (42.7 dBi) was assumed in this scenario; with a more appropriate 30cm antenna with 37 dBi the impact would be reduced by about 6dB.

### **2.2.5 FS loss of synchronisation**

The impact of interference from SRR into the FS will depend upon the level of both the mean and the maximum or peak e.i.r.p. This can affect the FS receiver in a number of ways, including an increase of BER and a possible loss of synchronisation.

The work undertaken to date within ECC has focussed on the increase in BER, mostly taking into account the mean power. Work undertaken has also noted that if there is a high peak to rms ratio then the level of peak power can in addition impact the link error performance.

In addition to this interference mechanism, there is the potential for the peak e.i.r.p. from an SRR burst to cause interference into FS receivers that could lead to synchronisation loss. This can occur when the  $C/(N+I)$  derived using the peak e.i.r.p. is significantly below the threshold required, in absence of interference, by the availability objectives. This effect would be more significant in the case of very short links described in section 2.2.4. No studies have been undertaken within ECC as to at what point synchronisation loss would occur because the synchronisation mechanism is “implementation depending” and no definite rule can be drawn.

It is noted that a low Duty Cycle while maintaining average mean power would effectively increase the burst power and this would possibly increase the risk of synchronisation loss. Therefore a minimum Duty Cycle limit (2%) has also been introduced (see Table 7) to reduce the risk of synchronisation loss.

### **2.2.6 Additional Mitigations**

On a production line, the peak and mean powers measured in average are by about 2.5 dB below the limits, this would result in 2.5dB reduction of SRR impact in aggregation due to typical production data.

Results are provided assuming that all the SRR are deployed at 26 GHz, however, additional mitigations may result from a possible technology split and the usage of alternative bands (24 GHz and 79 GHz) or alternative

technologies (optical, narrow band radars, WLAM...). These two possible additional mitigation techniques are not considered in the numerical evaluations conducted in the following sections.

**2.2.7 New limit proposal**

Noting that the e.i.r.p. density limits provided by ECC/DEC/(04)10 [4] are incompatible with FS, industry proposed new parameters for 26 GHz SRR, which are contained in ETST TR 102 664 1.2.1 [7] and shown in Table 7. This proposal has been based on typical Frequency Hopping (FH) SRR, however, the proposed final limits are generally applicable and the silent gating period (Duty Cycle %) in any 50 MHz bandwidth can be satisfied either by FH SRR (emitting in different frequency slots during the silent periods) or by Pulse Position Modulation (PPM) SRR (actually stopping any emission during the silent periods). Table 7 along with some clarifying notes shows this new set of limits in comparison to the original proposal from the SRdoc.

Parameter	Limit	
<b>Original limit proposal of the SRdoc ETSI TR 102 664 V.1.1.1</b>		<b>Resulting Mitigation compared to current regulation</b>
SRR Frequency Range	24-29 GHz (5 GHz)	The passive band is avoided
Mean e.i.r.p. @ 1MHz/ms	-41.3dBm/MHz	None
Peak e.i.r.p. @ 50MHz	0 dBm	None
Duty Cycle (DC)	No limit (up to 100%)	None
<b>Revised limits proposed in draft ETSI TR 102 664 V.1.2.1</b>		<b>Resulting Mitigation compared to current regulation</b>
Note 1		
SRR Frequency Range	24.25-27.5 GHz (3.25GHz)	The passive band is avoided and the overall bandwidth for SRR is reduced by 1.75 GHz
Peak e.i.r.p.	-7dBm/50MHz (for iBW≥50MHz) or -7dBm - 20*log(50MHz / iBW) measured with RBW = iBW (for iBW<50MHz)	7dB
Mean e.i.r.p. @ 1MHz/1s	-50 dBm/MHz	8.7 dB for mean power aggregation (Note 2) 10dB (DC=10%) to 17dB (DC=2%), in average, for peak power aggregation (additional to 7dB mitigation due to the peak power reduction) (Note 2)
Duty Cycle (DC)	2% to 10% per 50MHz and per sec	
<b>Definitions:</b>		
<b>DC</b> = Ton/(Ton + Toff) % with: Ton defined as the duration of a burst irrespective of the number of pulses contained. Toff defined as the time interval between two consecutive bursts when the UWB emission is kept idle.		
<b>iBW</b> = instantaneous bandwidth of each single pulse, defined to be the inverse of the pulse duration.		
Note 1: The revised proposal takes account of the new study which has shown that the peak power interference increase would have more impact than an equivalent means power interference increase. The benefit of a reduced Duty Cycle implies the burst-like nature of the SRR application; therefore a suitable burst limitation is proposed.		
Note 2: This improvement has been theoretically calculated from the proposed Duty Cycle limitation and would further limit the possible worst case interference due to undesired peak impact on a wideband victim receiver.		

**Table 7: Proposed SRR parameters**

## 2.3 Impact analysis of rms and peak I/N with and without further Duty Cycle mitigation

### 2.3.1 Expected worst case aggregated interference (ECC Report 023)

ECC Report 023 [1] conclusions for FS indicated that:

*“The results of the studies with all assumptions described above show that the protection criteria of the FS is exceeded by 0 to 20 dB depending on the scenario and on the combination of the factors.*

*..... However, on the basis of the whole range of calculation results, it can be concluded that with an e.i.r.p. density of -60 dBm/MHz the FS protection criteria (-20 dB I/N) for all scenarios considered in these studies is respected, whilst with an e.i.r.p. density of -50 dBm/MHz, this protection criteria would be met in most scenarios.”*

Provided that the conclusions of ECC Report 023 [1] are still considered valid as far as conventional PPM SRR without any DC mitigation are concerned, the above concepts of “ALL SCENARIOS” and “MOST SCENARIOS” will be used in this report with the following definition:

- ALL SCENARIOS: an interference situation that would lead to an I/N (rms) = - 1.3 dB considering SRR mean e.i.r.p. density = -41.3 dBm/MHz with 100% DC.
- MOST SCENARIOS: an interference situation that would lead to an I/N (rms) = - 11.3 dB considering SRR mean e.i.r.p. density = -41.3 dBm/MHz with 100% DC.

The I/N (rms) for different mean e.i.r.p. density in the same scenarios will be linearly derived from power reduction and/or DC limitation.

Report 023 sets the protection criteria for FS links for both rms density interference and , supported by specific test campaign, wide-band peak density interference as:

- $I/N_{rms} \leq -20 \text{ dB}$  (evaluated in 1 MHz)
- $I_{peak}/N_{rms} \leq +5 \text{ dB}$  (evaluated in ~50 MHz)

Both limits were assumed to independently produce the same impact on the link budget degradation. Annex 3 shows the detailed description of those limits background.

Assuming, as requested by the SRDoc TR 102 664 (v1.1.1) to allow a 100% penetration of SRR at -41.3 dBm/MHz (rms) and/or 0 dBm/50MHz (peak) and the linear relationship assumed for both rms and peak power densities aggregation, it should be formally assumed that the expected interference can become:

#### a) “all scenarios” conditions- worst case (aggregated interference)

- $I/N \text{ (rms)} \leq -1.3 \text{ dB}$  (evaluated in 1 MHz)
- $I_{peak}/N_{rms} \leq +23.7 \text{ dB}$  (evaluated in ~50 MHz)

#### b) “most scenarios” conditions (aggregated interference)

- $I/N_{rms} \leq -11.3 \text{ dB}$  (evaluated in 1 MHz)
- $I_{peak}/N_{rms} \leq +13.7 \text{ dB}$  (evaluated in ~50 MHz)

### 2.3.2 Impact of rms interference objective violation

#### 2.3.2.1 Analysis

It is commonly assumed that rms-like interference (of whichever nature) would add in power to the rms power of the receiver thermal noise.

This was also confirmed by test campaign in ECC Report 023; e.g. an I/N (rms) of -10 dB will cause ~0.5 dB BER thresholds degradation of the FS receiver and an I/N (rms) of 0 dB will cause 3 dB degradation.

From the above evaluation it clearly appears that the “single-car entry” case becomes severe for any FS antenna height lower than ~30 m, “grazing” the protection objective at 20 m (thus leaving little or no room for further aggregation) and with 10 m height even exceed the objective by about 7 dB.

This suggests that, unless the aggregation potential of the SRR is kept minimal with actual “built-in” mitigations (e.g. low LDC), the SRR e.i.r.p. should be kept lower than -41.3 dBm/MHz.

### 2.3.3 Impact of wide-band peak interference objective violation

#### 2.3.3.1 Analysis

More careful consideration should be given to the peak power impact.

ECC Report 023 has somehow “validated” the SRR wide-band peak limitation to 0 dBm/50 MHz (as proposed also by FCC) corresponding to an estimated protection criterion of  $I_{\text{peak}}/N_{\text{rms}} = + 5 \text{ dB}/50\text{MHz}$ .

However, the impact of wide-band peak, in particular when considering the “quality” of the link (in term of “errored seconds”) rather than the “availability” (in term of link budget reduction), is also strongly depending on the capability of the actual FS implemented error correction algorithm.

The “quality” aspect was not in the scope of the test campaign mentioned in ECC Report 023 [1] (the FS system used was considered an “average” example and could not have been representative for extracting dedicated guidance).

Consequently, the impact of the wide-band peak interference power on the “quality” could not be defined at this stage and we should rely only on the potential link budget variation. Therefore, the impact analysis should consider the peak impact much more carefully than in ECC Report 023.

#### 2.3.3.2 Effects on BER vs RSL behaviour of FS receiver

When the FS Receiver Signal Level (RSL) drops, the signal to noise (S/N) ratio drops consequently which produces errors.

Being the noise and the interference uncorrelated, the total error probability for given S/N is the convolution of the two probabilities as shown in Annex 3 Figure 34.

As raw approximation, the overall probability may be assumed as the envelope of the two noise and interference curves.

Annex 3 shows the exact theoretical evaluation of the BER for the simple example of an uncoded BPSK FS modulation affected by conventional PPM pulsed interference with different PRF and consequent  $I_{\text{peak}}/I_{\text{rms}}$  (50 MHz) ratio.

This means that with  $I/N(\text{rms}) = -20 \text{ dB}$  the overall envelope (and the BER) is still that of the noise, but, when the  $I/N$  increases, significant deviation ( $\cong \text{dB/dB}$ ) appears as the peak/rms power ratio increases and the BER would more steeply pass from  $\sim 0$  to a very high value.

From the example calculated in Annex 3, it is evident that a possible violation of the  $I/N(\text{rms}) = -20 \text{ dB}$  criterion would result in significant differences according to the permitted  $I_{\text{peak}}/I_{\text{rms}}$  wide-band ratio.

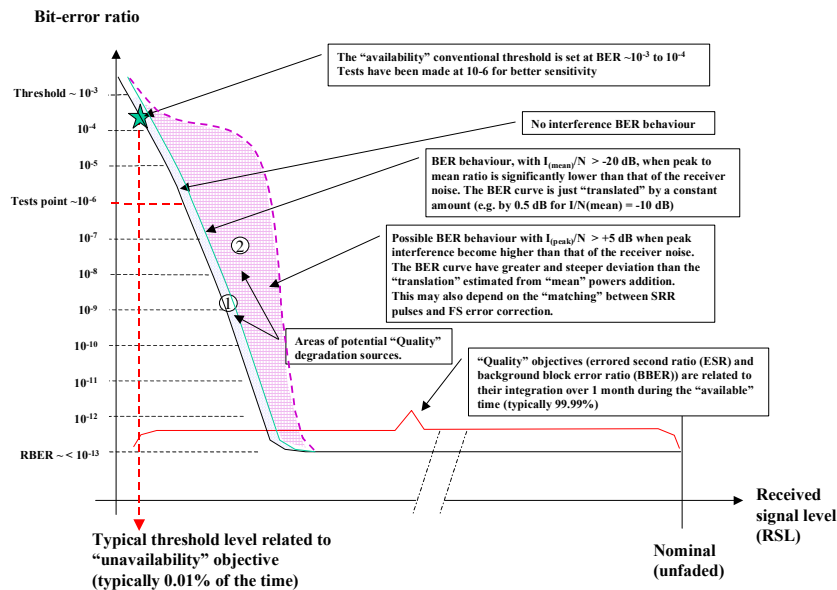
For example a 10 dB violation of the  $I/N(\text{rms})$  (i.e.  $-10 \text{ dB}$ ) would remain nearly negligible only if the corresponding  $I_{\text{peak}}/I_{\text{rms}}$  (50 MHz) wide-band ratio is kept  $\sim 10 \text{ dB}$  lower than the maximum presently permitted by all generic UWB and SRR regulations, i.e. the present  $23.7 \text{ dB}/50 \text{ MHz}$  ( $0 - (-41.3) + 10 \log 50$ ) should be reduced to  $\sim 14 \text{ dB}/50 \text{ MHz}$ .

Annex 5 reports an analysis of the impact on the link availability calculation and its degradation as function of the possible  $I/N$  (mean and peak) objectives violation.

#### 2.3.3.3 Impact on FS availability and error performance objectives (EPO)

Recommendation ITU-R F.1094 [13] defines the permitted degradation, due to interference, of both “availability ratio” (AR) objective, according to Recommendation ITU-R F.1703 [14], and “error performance” objectives (EPO), according to Recommendation ITU-R F.1668 [15]. However, only the first has been used (because more impacting) in ECC Report 023 for assessing the “availability” part of the degradations; in this case also the second criterion should be considered.

Figure 6 shows a qualitative behaviour of the BER of a typical FS link versus the rain induced reduction of received signal level (RSL) without interference and in presence of pulsed interference, with  $I_{\text{peak}}/I_{\text{rms}}$  higher or lower than the “marginal” ratio of 24 dB/50 MHz previously discussed.



**Figure 6: Qualitative impact on the FS BER behaviour in presence of pulsed interference**

The “availability” degradation is evaluated only for RSL at  $\text{BER} \cong 10^{-3}$  to  $10^{-4}$ ; the “EPO” degradation should be evaluated as an integral over a period of time (typically one “worst” month) of all errors events generated by the system at any RSL.

The two areas ① and ② in Figure 6 represent the BER variations in presence of similar excess of the rms or wide-band peak I/N objectives.

It is evident that an I/N (rms) variation (e.g.  $I/N = -10$  dB) of a low peak interfering signal causes the degradation ① (e.g. 0.5 dB for  $I/N$  (rms) = -10 dB), which would mostly impact the “availability” threshold only; on the contrary it is also evident that an I/N (wide-band peak) variation (e.g.  $I/N = +15$  dB/50 MHz) of a high peak interfering signal causes the far significant degradation ② (see Annex 3 Figure 35, Figure 36, Figure 37, Figure 38, which would more severely impact both the “availability” and the EPO performances).

### 2.3.4 The impact of a reduced Duty Cycle (DC) on the P-P FS systems

#### 2.3.4.1 General background

Note that, in this context, the DC concept is, in principle, the same of the Activity Factor (AF %) used in both Report ITU-R SM.2057 and ECC Report 64 (assumed ~ 1% for generic lower bands communication UWB) and the same of the “gating factor” used for 24 GHz SRR in both ITU-R SM.2057 and ECC Report 023 (assumed 100% because SRR industries were, at that time, not in position to accept any limit).

ETSI TR 102 664 (v1.2.1) [7] formally proposed specific power reduction (both mean and peak e.i.r.p.) and DC limitations ( $2\% < \text{DC} < 10\%$ ). Chapter 2.2.7 shows the new limits in comparison to the original ones.

It should be noted that the DC is intended, similarly to ECC/DEC/(06)12, as the activity factor generated in any 50 MHz victim bandwidth by “bursts” of emissions (during a Ton period) followed by silent periods (during a Toff period) so as  $\text{DC}\% = \text{Ton}/(\text{Ton}+\text{Toff}) \times 100$ . In FH-SRR the Ton and Toff periods, within a 50 MHz band, are generated by the bandwidth ratio between a 50 MHz victim bandwidth and the total hopping bandwidth (THBw), taking also into account the actual pulse bandwidth during the burst activity.

No additional requirement is posed for the bursts composition (pulse duration and PRF); however, the instantaneous e.i.r.p. during the activity burst can be derived as follows:

$$\# \text{ DC}=10\%: \text{ e.i.r.p.rms}/50\text{MHz} = -50+10\log(50)-10\log(0.1) = -23\text{dBm}/50\text{MHz}$$

$$\# \text{ DC}=5\%: \text{ e.i.r.p.rms}/50\text{MHz} = -50+10\log(50)-10\log(0.05) = -20\text{dBm}/50\text{MHz}$$

$$\# \text{ DC}=2\%: \text{ e.i.r.p.rms}/50\text{MHz} = -50+10\log(50)-10\log(0.02) = -16\text{dBm}/50\text{MHz}$$

$$\# \text{ DC}=1\%: \text{ e.i.r.p.rms}/50\text{MHz} = -50+10\log(50)-10\log(0.01) = -13\text{dBm}/50\text{MHz}$$

ECC/DEC/(04)12, based on ECC Report 94, describes a well defined time limited Low DC (LDC) mitigation technique for UWB effective for the protection of FWA systems only (i.e. P-MP terminals such as e.g. WiMax).

For determine whether similar LDC limitation to SRR may offer possible improvement to P-P Fixed Links (i.e. PP SDH or PDH systems) protection, the following technical characteristics of P-P systems (dissimilar from FWA terminals), need to be considered in this respect:

- They continuously receive valid information, so that they cannot benefit of data re-transmission features as in FWA applications; error correction codes have limited capability of error burst correction.
- They are synchronised through direct tracking of the received carrier clock and frequency (through narrow band digital/analogue PLL) and detecting a proprietary frame structure. For example, all SDH and PDH frame structures have a 125 $\mu$ s frame length and frame recognition should always be ensured. Usually P-P systems create another proprietary frame (with frame duration of the same order) where SDH or PDH are embedded, adding Error Correction codes.
- They are subject to high ITU-T/ITU-R “error performance” and availability requirements for the fixed networks (i.e. similar to any Fibre Optic connection), which can’t be traded by the operator.
- Error correction code capability is define in term of number of consecutive errors per frame that can be corrected.
- When subject to a LDC UWB interference the errors potentially generated are managed only by the error correction capabilities over each frame; once the duration of the interference burst exceed that capability, errors goes out from the system and, if larger peak error-rate happen, the system may even loose synchronism with more detrimental phenomena.
- Unlike in the FWA context, where large consumer market of the terminals requires interoperability among different supplier (i.e. standardisation of the radio interface), the P-P market is highly professional and the above specific techniques are not standardised, but rather are “proprietary” and part of the market competition. Therefore, the definition of a specific “matched” LDC limitation, as done in ECC Report 94 for WiMax-like FWA terminals, can hardly be envisaged.

Therefore, it should not be expected that the introduction of a DC limitation would be as much decisive for P-P links as it is for WiMax terminals interference.

Nevertheless, the amount of expected interference in the P-P links/SRR scenario is considerably lower than that in the WiMax Terminals/UWB scenario; therefore, the consequences of a possible DC restriction to SRR system could be, in average, positive if the DC limitation is combined with additional limitation in term of peak power reduction so that its adverse effect shown in section 2.3.3.3 is also minimised.

The improvement would result from the fact that the FS “performance and availability” parameters are based on “seconds” averaging of the BER, so that, provided that the SRR bursts would not result in synchronism loss, the higher BER during “Ton” periods are averaged down during the “T<sub>off</sub>” periods.

It should be noted that, when the DC is produced by a frequency hopping (FH) methodology the DC limits should also be referred to the reference victim bandwidth (e.g. the usually assumed 50 MHz would better fulfil the task).

#### 2.3.4.2 DC % only impact

The introduction of a DC% parameter by itself would not be very effective unless associated to an actual reduction of the mean power generated by the sensors; for example, associating a 5% DC to the same -41.3 dBm/MHz would result in 13 dB improvement in the “time domain” of the interference but also 13 dB increase of the e.i.r.p. density during the T<sub>on</sub> periods. The total energy/s would not change.



These two factors (less time and higher e.i.r.p. dimensions) does not have the same effect on the victim receiver and are not completely mutually excluding themselves; nevertheless, intuitively, the difference from a PPM-SRR (100% DC) would be negligible.

In addition, the significant increase of the power during the burst would generate instantaneous degradation of the S/(I+N) ratio in the victim receiver, consequently increasing the risk of undesirable effects on the error corrections and carrier/synchronism recovery resulting in loss of synchronism (and a consequent number of SES) even when the receiver signal level is still relatively higher than the threshold.

In particular, the lower becomes the DC% (as permitted by the new proposal) the higher becomes the e.i.r.p. rms density during the burst; the risk for the synchronism further increases.

Therefore, also a lower limit for the DC%/50MHz should be envisaged.

#### 2.3.4.3 Combined DC % and e.i.r.p. reduction impact

If an e.i.r.p. rms density reduction is also associated (e.g.  $-50$  dBm/MHz), the 13 dB improvement in the 5%DC “time domain” of the interference is partially reduced by  $(13-50+41.3) = 4.3$  dB burst power increase. The total energy/s would be 8.7 dB less than the original PPM-SRR case.

An additional reduction of the peak e.i.r.p./50 MHz would further reduce the e.i.r.p. Peak/rms ratio, which has been shown (see Annex 3) to play a significant adverse role in the BER degradation (it should be remembered that the BER behaviour, even if generally described in term of  $S/N_{(rms)}$  is generated by peaks of the noise within its Gaussian amplitude distribution).

#### 2.3.4.4 Evaluation Methodology

In previous sections we have analysed the differences between current PPM-SRR limits and the new FH-SRR limits resulting in a DC limitation of less than 10%. However, the differences in term of peak and rms e.i.r.p. density should be transferred in term of BER degradation, depending on the actual combination of all three parameters (peak, rms and DC), which are variable according the flexibility of the proposed regulatory parameters.

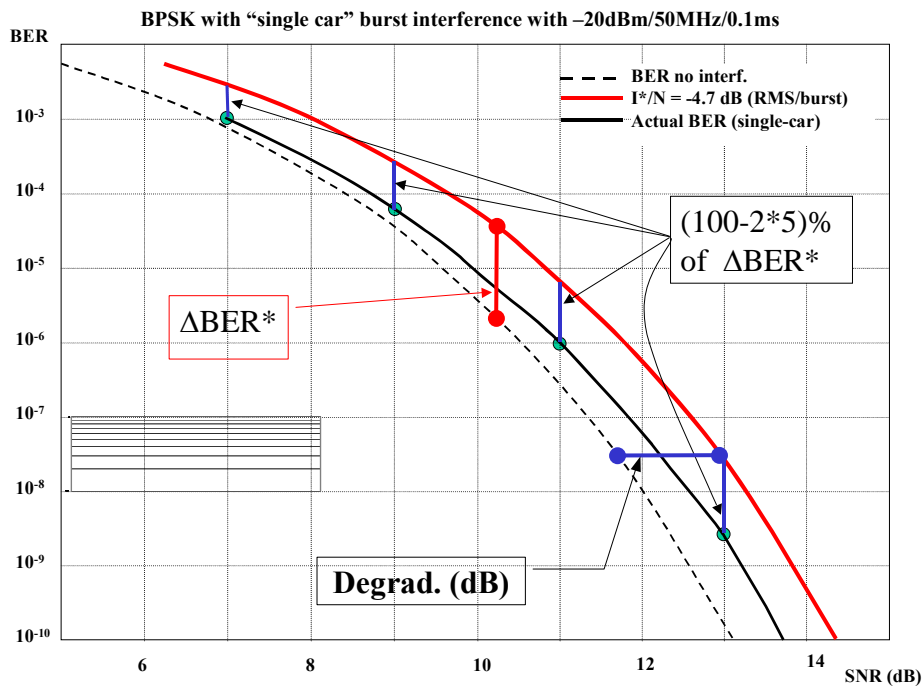
For this comparison the same simulation is used (on an ideal BPSK demodulator) as shown in Annex 3 with various examples of PPM-SRR (100% DC) and different combination of I/N and Peak/rms ratio.

For simulating the further DC impact the following approach is used:

1. Consider the results of ECC Report 023 and of “single-car” entry (see Annex 1) in term of maximum violation of the I/N =  $-20$  dB objective, calculated with an e.i.r.p. density of  $-41.3$  dBm/MHz in the various scenarios. For single-car entry (2 PPM sensors) corresponding to 7 dB violation of the objective (with FS antenna height 10 m).
2. Further consider that when FH-SRR sensors are concerned, the “single-car” entry violation would become 4 dB only (due to uncorrelation of the Ton periods of the two sensors) but the DC would double (i.e. DC/car = 2+ DC/sensor)
3. Calculation of the actual e.i.r.p.<sub>rms</sub> and maximum  $P_{peak}/P_{rms}$  ratio in the victim Bw during the burst (i.e. the true instantaneous interference to which the FS receiver is subject during the Ton)
4. Defining the worst case PRF generating that maximum  $P_{peak}/P_{rms}$  ratio (assumed as worst case)
5. Calculation of the actual I\*/N during the burst (i.e. the true instantaneous interference to which the FS receiver is subject during the Ton)
6. Calculation of the “no interference” **BER<sub>0</sub>** vs S/N
7. Calculation of the “Degraded” **BER\*** vs S/N assuming that the I\*/N and maximum  $P_{peak}/P_{rms}$  ratio are maintained for 100% of the time
8. Calculation of the **BER<sub>(1s)</sub>** with DC improvement (permitted by the 1 s averaging time recommended by ITU on BER measurement) on the BER vs S/N from the simple equation

$$\mathbf{BER}_{(1s)} = \mathbf{BER}^* - (\mathbf{BER}^* - \mathbf{BER}_0) \times (1-\mathbf{DC})$$

Figure 7 graphically shows the principles of the method.



**Figure 7: Example of impact of a 5%/sec “single-car entry” burst interference (rms power density = -13 dBm/50 MHz, averaged on 20μs burst duration)**

2.3.4.5 Comparison with methodology used in ECC Report 023 studies

The new theoretical evaluation of the overall impact of “Duty Cycle-based” SRR affecting FS receiver in this report is much more detailed than that of ECC Report 023 and, for better understanding the possible slight difference with ECC Report 023 conclusions, the following differences should be underlined:

1. ECC Report 023 impact to FS receivers was based purely on (N+I) power addition caused  $I_{\text{mean}}/N$  ratio; no specific evaluation has been made on the impact of peak interference, besides setting the well known maximum limit of 0 dBm/50MHz, derived as safeguard from laboratory test subject to very difficult calibration.
2. ECC Report 023 considered only “conventional” UWB SRR based on generic Pulse Position Modulation (PPM) without any DC applied; therefore, the impact of “bursty” interference caused by the DC were never considered.
3. In this report a theoretical analysis has been developed, using a more detailed combination of both peak and mean power of the SRR devices in both “single-car” entry and “aggregation” scenarios; this new approach has to be developed for taking into account the DC impact, not possibly described using only the “mean power” approach. Therefore, even if the theory still well fit, in general, with the results of ECC Report 023, an exact “numerical” comparison with them (in term of pure  $I_{\text{mean}}/N$  ratio) is not possible. In particular, considering a  $I_{\text{mean}}/N = -20$  dB (which was “derived” in ECC Report 023 as the ratio giving the “true objective” of 0.04 dB degradation of the BER thresholds) and applying this theory to the conventional PPM SRR, when combined also with the maximum permitted peak/mean e.i.r.p. ratio (24.3 dB/50 MHz), the new simulations, as expected, gives a threshold degradation of ~0.15 dB, higher than the objective (eventually corresponding to  $I/N(\text{mean}) = -14.5$  dB with ECC Report 023 more simplified methodology).
4. With regards to the complex aggregation method for the “highway scenario” used in ECC Report 023, the new method does not enter in the integration calculation. It assumes the “equivalence” between the large aggregation scenario (where all sensor contributes with different weight due to different distance and path attenuation) and a defined number of single entry (all at equal level). This is appropriate because the relative variation of “aggregated  $I/N$ ” with respect to the “single-car  $I/N$ ” is purely based on

the “geometrical” characteristics of the scenario. Therefore, this “geometrical” equivalence may be assumed to be maintained whichever are the emission characteristics of the SRR sensors; the problem of aggregation of the FH/DC sensors in the ECC Report 023 scenarios can be reduced to the study of aggregation of “n” sensors with the same specific emission characteristics (i.e. n = 3.2 or 32 for the cases defined in Report 023 as “MOST SCENARIOS” and “ALL SCENARIOS” cases, respectively).

#### 2.3.4.6 Single-car interference

##### 2.3.4.6.1 PPM SRR

For proper evaluation of the potential improvement generated by a limited DC SRR emission, also the generic PPM SRR (100% DC) case, considered in Report 023 and Report ITU-R SM.2057, has been re-evaluated with the new methodology.

##### Case A) Current provisional limits (rms –41.3 dBm/MHz; peak 0dBm/50MHz)

Considering the aggregation of 2 sensors/car of –41.3 dBm/MHz led to 7 dB violation of the objective (with FS antenna height 10 m) the expected I\*/N is:

$$I^*/N = -20 + 7 = -13 \text{ dB} \quad (\text{maintained for 100\% of the time})$$

The worst case would be when also the maximum permitted  $P_{\text{peak}}/P_{\text{rms}}|_{50\text{MHz}} = 24.3 \text{ dB}$  is met; this happens when:

$$PRF(\text{MHZ}) \geq 10^{\frac{10 \log 50 - \left[ \frac{P_{\text{peak}}}{P_{\text{rms}}} \right]_{50\text{MHz}}}{10}} = 0.1853 \text{ MHz} \quad (\text{Pulse bandwidth} \geq 50 \text{ MHz})$$

When pulse bandwidth  $\geq 50 \text{ MHz}$  (as always is in PPM-SRR) the pulse duration in a 50 MHz receiver  $T_D$  is:

$$T_D = 20 \text{ ns} \quad (\text{constant lower bound after the FS RX 50 MHz filter; see Annex 3 for background})$$

For simplification the pulses are still assumed rectangular even if, when the original pulse duration is  $\ll 1/50 \text{ MHz}$ , they would become triangular.

##### Case B) Reduced limits as proposed for FH (–50 dBm<sub>rms</sub>/MHz; –7dBm<sub>peak</sub>/50MHz; DC 100%)

For additional information a check of what would be the impact of conventional PPM SRR if they would operate with the reduced mean and peak power proposed for the FH SRR, but with no DC applied.

The expected I\*/N is therefore :

$$I^*/N = -20 + 7 - (50 - 41.3) = -21.7 \text{ dB} \quad (\text{maintained for 100\% of the time})$$

The worst case would be when also the maximum permitted  $P_{\text{peak}}/P_{\text{rms}}|_{50\text{MHz}} = 26 \text{ dB}$  is met; this happens when:

$$PRF(\text{MHZ}) \geq 10^{\frac{10 \log 50 - \left[ \frac{P_{\text{peak}}}{P_{\text{rms}}} \right]_{50\text{MHz}}}{10}} = 0.125 \text{ MHz} \quad (\text{Pulse bandwidth} \geq 50 \text{ MHz})$$

The pulse duration still remains constant  $T_D = 20 \text{ ns}$ .

##### 2.3.4.6.2 FH SRR

In this case we would make reference, for the typical pulse and burst composition, to one specific FH SRR system, and changing the PRF in order to meet the proposed minimum  $P_{\text{peak}}/P_{\text{rms}}|_{50\text{MHz}}$  permitted by the draft proposed limitation (–7dBm/50 MHz peak with –13 dBm/50 MHz rms (1%DC) or –20 dBm/50MHz (5%DC)).

Note: the specific FH SRR system has a pulse bandwidth of 50 MHz; however, it is considered that the pulse bandwidth can become lower than the 50 MHz currently assumed as worst case victim Bw; in such case, provided that both peak and rms e.i.r.p. would not be reduced until the measurement bandwidth becomes  $\leq$  pulse bandwidth, the worst case would become a FS receiver with the same bandwidth (because N is lower and the I/N becomes higher. Therefore,:

Worst case victim bandwidth = Pulse bandwidth

**Case C) Burst power: -20 dBm/50 MHz rms (5%DC)**

**Case C.1) Pulse bandwidth ≥ 50 MHz**

The pulse duration, after the 50 MHz filter remains constant  $T_D = 20$  ns.

In this case only 1 sensor/car is active at the same time; therefore, considering that a single-sensor entry of -41.3 dBm/MHz (-24.3 dBm/50MHz) power shows to 4 dB only violation of the objective with FS antenna height 10 m, the expected I\*/N is:

$$I^*/N = -20 + 4 + (-20 - (-41.3 + 10 \log 50)) = -11.7 \text{ dB} \quad (\text{peak I/N maintained for 5\% of the time for each sensor, therefore the aggregated DC would be 10 \%})$$

The worst case would be when also the maximum permitted  $P_{\text{peak}}/P_{\text{rms}}|_{50\text{MHz}} = (-7+20) = 13$  dB is met; this happen when:

$$PRF \geq 10^{\frac{10 \log 50 - \left[ \frac{P_{\text{peak}}}{P_{\text{rms}}} \right]_{50\text{MHz}}}{10}} = 2.5 \text{ MHz} \quad \text{for Pulse duration} \leq 20 \text{ ns}$$

This PRF figure is around half the specific FH SRR system described above.

**Case C.2) Pulse bandwidth < 50 MHz**

The pulse duration, after the 50 MHz or any victim filter bandwidth ≥ pulse bandwidth, remains constant  $T_D = 1/\text{Pulse Bw}$ .

When evaluated within a 50 MHz victim bandwidth the expected  $I^*/N|_{50\text{MHz}}$  remains as in case C.1. However, would the victim Bw be narrower (e.g. 20 MHz), while the I/N in the PPM case (or any FH with pulse Bw ≥ 20 MHz) would remain the same of a 50 MHz victim (i.e. both  $I_{\text{rms}}$  and N in the lesser Bw will drop by the bandwidth factor), the I/N of a FH with pulse bandwidth = 20 MHz would increase (i.e.  $I_{\text{rms}}$  remains constant and only N will drop by the bandwidth factor).

Therefore, FS victims with narrower bandwidth should considered as worst cases. However, also the DC should be evaluated in the narrower bandwidth; therefore, the expected  $I^*/N|_{20\text{MHz}}$  is:

$$I^*/N|_{20\text{MHz}} = -20 + 4 + (-20 - (-41.3 + 10 \log 20)) = -7.7 \text{ dB}|_{20\text{MHz}} \quad (\text{peak I/N maintained for } 5/(50/20)=2\% \text{ of the time for each sensor, therefore the aggregated DC/car would be 4 \%})$$

The worst case would be when also the maximum permitted  $P_{\text{peak}}/P_{\text{rms}}|_{20\text{MHz}} = (-7+20) = 13$  dB is met; this happen when:

$$PRF(\text{MHz}) \geq 10^{\frac{10 \log \left( \frac{1}{P_{\text{duration}}(\mu\text{s})} \right) - \left[ \frac{P_{\text{peak}}}{P_{\text{rms}}} \right]_{50\text{MHz}}}{10}}$$

For example, with pulse duration = 50 ns the above formula leads to PRF = 1 MHz.

**Case D) Burst power: -13 dBm/50 MHz rms (1%DC)**

**Case D.1) Pulse bandwidth ≥ 50 MHz**

With the same considerations of section B.1, the expected I\*/N is:

$$I^*/N = -20 + 4 + (-13 - (-41.3 + 10 \log 50)) = -4.7 \text{ dB} \quad (\text{peak I/N maintained for 1\% of the time for each sensor, therefore the aggregated DC/car would be 2 \%})$$

The maximum permitted  $P_{\text{peak}}/P_{\text{rms}}|_{50\text{MHz}} = (-7+13) = 6$  dB is met; this happen when:

$$PRF = 12.5 \text{ MHz} \quad \text{for Pulse duration} \leq 20 \text{ ns}$$

This figure is around twice the specific FH SRR system described above.

**Case D.2) Pulse bandwidth < 50 MHz**

With the same considerations of case D.1, the expected I\*/N is:

- when evaluated within a 50 MHz victim bandwidth the expected  $I^*/N|_{50\text{MHz}}$  remains as in case D.1:
- when evaluated in the narrower bandwidth; therefore, the expected  $I^*/N|_{20\text{MHz}}$  is:

$I^*/N|_{20\text{MHz}} = -20 + 4 + (-13 - (-41.3 + 10\log 20)) = -0.7 \text{ dB}|_{20\text{MHz}}$  (peak I/N maintained for  $1/(50/20)=0.4\%$  of the time for each sensor, therefore the aggregated DC/car would be 0.8 %)

The maximum permitted  $P_{\text{peak}}/P_{\text{rms}}|_{20\text{MHz}} = (-7+20) = 6 \text{ dB}$  is met.  
For example, with pulse duration = 50 ns, the formula used in case D.1 above leads to PRF = 5 MHz.

### 2.3.4.6.3 Graphical results

Table 8 summarises the parameters used for the simulations of the above described cases.

Case N° ⇒	A	B	C.1	D.1	C.2	D.2
SRR type ⇒	PPM-SRR (100%DC)	PPM-SRR (100%DC)	FH-SRR (5%DC/50MHz)	FH-SRR (1% DC/50MHz)	FH-SRR (5%DC/50MHz)	FH-SRR (1% DC/50MHz)
SRR Parameter ↓	current limits	proposed FH power limits	$P_{\text{dur}} \leq 20\text{ns}$ (5%DC/50MHz)	$P_{\text{dur}} \leq 20\text{ns}$ (1%DC/50MHz)	$P_{\text{dur}} = 50\text{ns}$ (2%DC/20MHz)	$P_{\text{dur}} = 50\text{ns}$ (0.4%DC/20MHz)
$P_{\text{rms}}$ (dBm/50MHz)	-24.3	-33	-20	-13	(-20)	(-13)
$P_{\text{rms}}$ (dBm/20MHz)	(-28.3)	(-37)	(-24)	(-17)	-20	-13
$P_{\text{peak}}$ (dBm/50MHz)	0	-7	-7	-7	(-7)	(-7)
$P_{\text{peak}}$ (dBm/20MHz)	(-8)	(-15)	(-15)	(-15)	-7	-7
PRF (MHz) ( $P_{\text{peak}}/P_{\text{rms}} _{\text{Victim Bw}}$ )	0.1853	0.125	2.5	12.5	1	5
$P_{\text{duration}}$ (ns); $P_{\text{Bw}}$ (MHz)	$\leq 20$ ; $\geq 50$	$\leq 20$ ; $\geq 50$	$\leq 20$ ; $\geq 50$	$\leq 20$ ; $\geq 50$	50 20	50 20
Victim Bw (MHz)	50	50	50	50	20	20
$I^*/N$ (dB) 50 MHz Bw	-13	-21.7	-11.7	-4.7	(-11.7)	(-4.7)
$I^*/N$ (dB) 20 MHz Bw	(-13)	(-21.7)	(-11.7)	(-4.7)	-7.7	-0.7
$P_{\text{period}}$ (ns)	5396	7943	400	80	1000	200
$P_{\text{peak}}/P_{\text{rms}}$ (dB/50MHz)	24.3	26	13	6		
$P_{\text{peak}}/P_{\text{rms}}$ (dB/20MHz)					13	6
Burst duration (120 pulses) (µs)			48	9.6	120	24
Burst interval (µs) / DC per car			960 / 2×5% DC	960 / 2×1% DC	6 000 / 2×2% DC	6 000 / 2×0.4% DC

**Table 8: Summary of simulation parameters (Single entry)**

With the above parameters, an evaluation of the degradation of an ideal BPSK system due to the various FH-SRR or conventional PPM-SRR with combined rms & peak power effect has been made.

It shall be underlined that these are “theory ideal” impacts on a very simple format; real links are far different due to more complex modulation formats (e.g. 128 QAM) and the presence of error correction coding.

Therefore, the impact on real links might be different, but not far from it.

In particular, adverse disruptive phenomena of loss of synchronism due to peaks of interference cannot be predicted because it strongly depends on the FS receiver implementation. This can only be “qualitatively” controlled by analysing the “instantaneous” BER degradation at the BER threshold (e.g. around the S/N ratio for BER=10<sup>-4</sup> without interference), the lesser is the BER increase, the lesser is the sync-loss probability.

The figures show:

- Figure 8a, “instantaneous BER degradation” (i.e. FH cases are treated as having 100% DC), and improvement due to DC averaging.
- Figure 8b, enlarged portion of Figure 8a around BER  $10^{-4}$  with the DC averaging improvement applied to the FH case, showing the actual link budget degradation experienced (assuming that synchronism is never lost).
- Figure 9a, “instantaneous BER degradation” (i.e. FH cases are treated as having 100% DC) and improvement due to DC averaging. Comparison of the 5%/50MHz DC FH with different pulse durations. Effects of pulse duration 20 ns on 50 MHz victim’s bandwidth and pulse duration 50 ns on 20 MHz victim’s bandwidth.
- Figure 9b, the enlarged portion of Figure 9a around BER  $10^{-4}$  with the DC average improvement applied to the FH case, showing the actual link budget degradation experienced (assuming that synchronism is never lost).

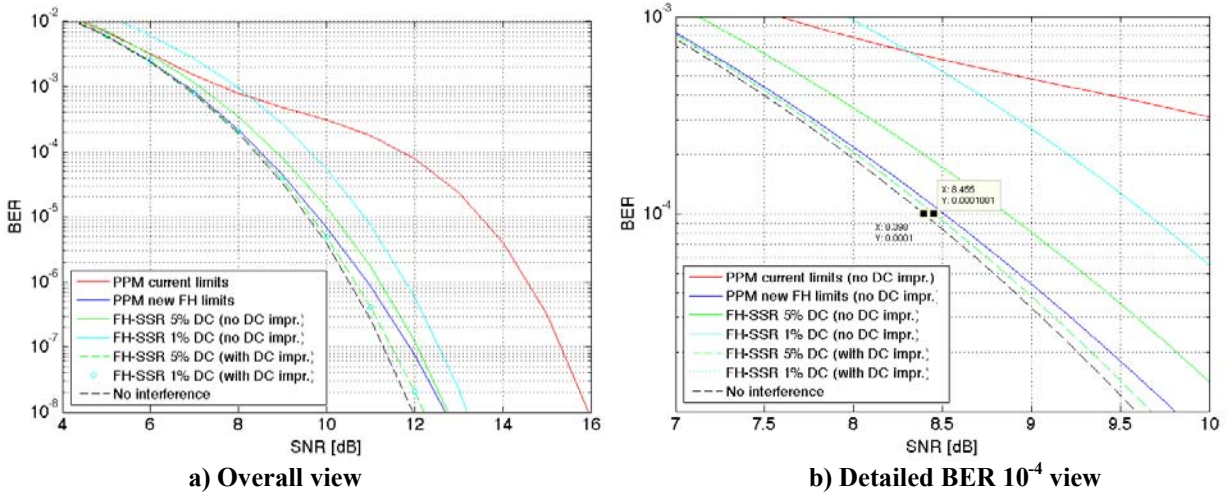


Figure 8: BER degradation over ideal BPSK system (50 MHz bandwidth) Instantaneous (100% DC) and with DC averaging

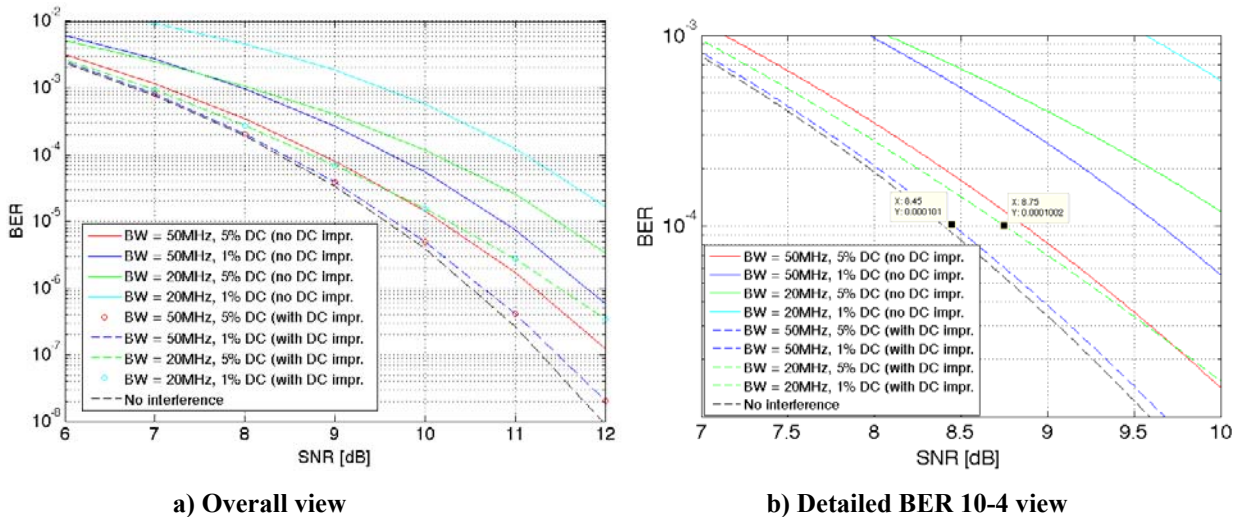


Figure 9: BER degradation over ideal BPSK system with: 50 MHz bandwidth for Pulse Bw 50 MHz (20ns duration) 20 MHz bandwidth for Pulse Bw 20 MHz (50ns duration)

### 2.3.4.7 Aggregated interference

Also in this case, for proper evaluation of the potential improvement generated by a limited DC SRR emission, the generic PPM SRR (100% DC) case, considered in ECC Report 023 [1] and Report ITU-R SM.2057 [6], has been re-evaluated with the new methodology.

For this evaluation it was considered that:

- In PPM-SRR the aggregated interference would maintain the  $P_{\text{peak}}/P_{\text{rms}}$  ratio of the single sensor (i.e. both rms and peak power are assumed to increase by  $10\log(\text{Number of sensors})$  factor).
- In FH-SRR (or PPM + DC) the aggregated interference, at least for a limited number of sensors, would maintain a certain “bursty” behaviour maintaining the  $P_{\text{peak}}/P_{\text{rms}}$  of the single sensor over the burst; however, both rms and peak power in the bursts are assumed to increase only by  $10\log(\text{Number of sensors} \times \text{DC})$  factor.

#### 2.3.4.7.1 PPM SRR (No DC mitigation)

In PPM case the rms power and the peak are assumed to increase at the same rate ( $10\log$  factor) and their ratio remains the same; therefore, it may be simulated with the same BPSK program used for the “single-car” just adjusting the expected  $I^*/N$ .

Based on the Report 023 final conclusions we should consider that the SRR study led to the following still valid assumptions:

A.1) With the original limit of  $-41.3$  dBm/MHz we had:

$$I/N \leq -11.3 \text{ dB} \quad (I/N = -20 \text{ dB with e.i.r.p.} = -50 \text{ dBm}) \quad \text{for “MOST SCENARIOS”}$$

$$I/N \leq -1.3 \text{ dB} \quad (I/N = -20 \text{ dB with e.i.r.p.} = -60 \text{ dBm}) \quad \text{for “ALL SCENARIOS”}$$

A.2) With the new proposed limit of  $-50$  dBm/MHz we now have:

$$I/N \leq -20 \text{ dB} \quad \text{for “MOST SCENARIOS”}$$

$$I/N \leq -10 \text{ dB} \quad \text{for “ALL SCENARIOS”}.$$

#### 2.3.4.7.2 FH SRR (DC mitigation)

For the new evaluation of the DC of the FH with respect to the conventional PPM (with reduced power limits) we have to consider that:

- From the “single-car” evaluation in the previous sections, we exclude the 1% DC case for its dangerous effect on synchronisation. A 10% DC case has been added following request from industry for more flexibility; being not critical in the “single entry” it will be analysed only as aggregation, possibly giving there the worse situation.
- In DC case we have to look to more parameters (one peak and two rms power); for a simplified evaluation we could assume an equivalence between the complex aggregation case (based on rms value) in Report 023 that had shown that:
  - # in “MOST SCENARIOS” situation a violation of  $\cong 9$  dB of the  $I/N = -20$  dB objective. This correspond to 2 dB (i.e. 9-7) worse than the “single-car” entry;
  - # in “ALL SCENARIOS” situation a violation of  $\cong 19$  dB of the  $I/N = -20$  dB objective. This correspond to 12 dB (i.e. 19-7) worse than the “single-car” entry.
 Therefore:
  - the “MOST SCENARIOS” situation could be considered equivalent to  $10^{0.2} = 1.6$  cars (3.2 sensors).
  - the “ALL SCENARIOS” situation could be considered equivalent to  $10^{1.2} = 16$  cars (32 sensors).

This kind of “equivalence” between the large aggregation scenario (where all sensor contributes with different weight due to different distance and path attenuation) and a defined number of single entry (all at equal level) is purely based on “geometrical” characteristics of the scenario. Therefore, this “geometrical” equivalence may be assumed to be maintained whichever are the emission characteristics of the SRR sensors; the problem of aggregation of the FH/DC sensors in the ECC Report 023 scenarios can be reduced to the study of aggregation of “n” ( $n = 3.2$  or  $32$ ) sensors with the same specific emission characteristics.

In a tentative evaluation of some “instantaneous” degradation effect of the FH case (similar to that more clearly evident in single entry case) we would take the following approach:

- We focus the attention to one instant, when one sensor is affecting the 50 MHz victim bandwidth; in the same instant, there is a certain average probability that the remaining “n-1” sensors are also affecting the same slot, adding their power to the first one.
- In “MOST SCENARIOS” situation, in practice, the 3.2 sensors would evenly spread in the (100/DC%) available 50 MHz slots. Therefore, in comparison to the “single-sensor” effect, the other 2.2 sensors would contribute to the burst power as additional (2.2\*100/DC%) sensors.  
The aggregate DC would become (3.2 × DC%) or 100%, whichever is lower.
- In “ALL SCENARIOS” situation, in practice, the 32 sensors would evenly spread in the (100/DC%) available 50 MHz slots. Therefore, in comparison to the “single-sensor” effect, the other 31 sensors would contribute to the burst power as additional 31\*100/DC% sensors.  
The aggregate DC would become (32 × DC%) or 100%, whichever is lower.

#### 2%/50MHz DC case ( $P_{rms}/50\text{MHz}/\text{burst} = -16\text{dBm}$ )

- In “MOST SCENARIOS” situation the 3.2 sensors would evenly spread in the 50 slots.  
Therefore, when evaluating the “instantaneous” BER degradation (100%DC) of one sensor we should consider:
  - #  $2.2/50 = 0.044$  additional sensors (Note 1)
  - # aggregate signal power 1.044 times worse than the single sensor.
  - # the  $P_{rms}/50\text{ MHz/s}$  would become  $(-50+10\log 50+10\log 3.2) = -28\text{ dBm}/50\text{MHz}$
  - # the  $P_{rms}/\text{burst}$  would become  $(-16+10\log 1.044) = -15.8\text{ dBm}/50\text{MHz}/\text{burst}$
  - # the  $P_{peak}/P_{rms}$  ratio remains constant at 9 dB
  - # the residual DC on the aggregated signal is  $2*3.2 = 6.4\%$ ;
  - #  $I*/N$  would be 0.2 dB higher than that of “single-sensor/car” entry
 Note 1: The fractional number of additional sensors makes more sense when considering that in the practical implementations the actual number of frequency time slots affecting a 50 MHz bandwidth is significantly higher (~25 different pulse “orthogonal” centre frequency ~1 MHz apart); therefore, there might be “partial overlapping” between the operating bands of different sensors.

- In “ALL SCENARIOS” situation the 32 sensors would evenly spread in the 50 slots.  
Therefore, when evaluating the “instantaneous” BER degradation (100%DC) of one sensor we should consider:
  - #  $31/50 = 0.62$  additional sensors
  - # aggregate signal power 1.62 times worse than the single sensor.
  - # the  $P_{rms}/50\text{ MHz/s}$  would become  $(-50+10\log 50+10\log 32) = -18\text{ dBm}/50\text{MHz}$
  - # the  $P_{rms}/\text{burst}$  would become  $(-16+10\log 1.62) = -14\text{ dBm}/50\text{MHz}/\text{burst}$
  - # the  $P_{peak}/P_{rms}$  ratio remains constant at 9 dB
  - # the residual DC on the aggregated signal is  $32/2 = 64\%$
  - #  $I*/N$  would be 2 dB higher than that of “single-sensor/car” entry

#### 5%/50MHz DC case ( $P_{rms}/50\text{MHz}/\text{burst} = -20\text{dBm}$ )

- In “MOST SCENARIOS” situation, the 3.2 sensors would evenly spread in the 20 slots.  
Therefore, when evaluating the “instantaneous” BER degradation (100%DC) of one sensor we should consider:
  - #  $2.2/20 = 0.11$  additional sensors
  - # aggregate signal power 1.11 times worse than the single sensor.
  - #  $P_{rms}/\text{burst}$  would become  $(-20+10\log 1.11) = -19.5\text{ dBm}/50\text{MHz}/\text{burst}$
  - # the  $P_{peak}/P_{rms}$  ratio remains constant at 16 dB
  - # residual DC on the aggregated signal DC =  $5*3.2 = 16\%$ ;
  - #  $I*/N$  would be 0.5 dB higher than that of “single-sensor/car” entry
- In “ALL SCENARIOS” situation, the 32 sensors would evenly spread in the 20 slots.  
Therefore, when evaluating the “instantaneous” BER degradation (100%DC) of one sensor we should consider:
  - #  $31/20 = 1.55$  additional sensors
  - # aggregate signal power 2.55 times worse than the single sensor.
  - # the  $P_{rms}/50\text{ MHz/s}$  would still become  $(-50+10\log 50+10\log 32) = -18\text{ dBm}/50\text{MHz}$
  - # the  $P_{rms}/\text{burst}$  would become  $(-20+10\log 2.55) = -16\text{ dBm}/50\text{MHz}/\text{burst}$
  - # the  $P_{peak}/P_{rms}$  ratio remains constant at 13 dB
  - # no residual DC on the aggregated signal is present
  - #  $I*/N$  would be 4 dB higher than that of “single-sensor/car” entry



**10%/50MHz DC case ( $P_{rms}/burst = -23dBm/burst$ )**

- In “MOST SCENARIOS” situation, the 3.2 sensors would evenly spread in the 10 slots. Therefore, when evaluating the “instantaneous” BER degradation (100%DC) of one sensor we should consider:
    - #  $2.2/10 = 0.22$  additional sensors
    - # aggregate signal power 1.22 times worse than the single sensor.
    - #  $P_{rms}/burst$  would become  $(-23+10\log 1.22)=-22.2$  dBm/50MHz/burst
    - # the  $P_{peak}/P_{rms}$  ratio remains constant at 16 dB
    - # residual DC on the aggregated signal DC =  $10*3.2 = 32\%$ ;
    - #  $I^*/N$  would be 0.8 dB higher than that of “single-sensor/car” entry
  - In “ALL SCENARIOS” situation, the 32 sensors would evenly spread in the 10 slots.(Note 2). Therefore, when evaluating the “instantaneous” BER degradation (100%DC) of one sensor we should consider:
    - #  $31/10 = 3.1$  additional sensors
    - # aggregate signal power 4.1 times worse than the single sensor.
    - # the  $P_{rms}/50$  MHz/s would still become  $(-50+10\log 50+10\log 32)=-18$  dBm/50MHz
    - # the  $P_{rms}/burst$  would become  $(-23+10\log 4.1)=-17$  dBm/50MHz/burst
    - # the  $P_{peak}/P_{rms}$  ratio remains constant at 16 dB
    - # no residual DC on the aggregated signal is present
    - #  $I^*/N$  would be 6.2 dB higher than that of “single-sensor/car” entry
- Note 2: From the peak aggregation point of view, it should be remembered that that in the practical implementations the actual number of frequency time slots affecting a 50 MHz bandwidth is significantly higher (~25 different pulse “orthogonal” centre frequency ~1 MHz apart); therefore, the 4.1 devices, in average affecting the same 50 MHz slot, are further distributed in those 25 frequency, remaining highly uncorrelated.

**20%/50MHz DC case ( $P_{rms}/burst = -26dBm/burst$ )**

This case is not considered by the new proposed limits, it is presented only for trend line exploration.

- In “MOST SCENARIOS” situation, , the 3.2 sensors would evenly spread in the 5 slots. Therefore, when evaluating the “instantaneous” BER degradation (100%DC) of one sensor we should consider:
  - #  $2.2/5 = 0.44$  additional sensors
  - # aggregate signal power 1.44 times worse than the single sensor.:
  - #  $P_{rms}/burst$  would become  $(-26+10\log 1.44)=-24.4$  dBm/50MHz/burst
  - # the  $P_{peak}/P_{rms}$  ratio remains constant at 19 dB
  - # residual DC on the aggregated signal DC =  $20*3.2 = 64\%$ ;
  - #  $I^*/N$  would be 1.6 dB higher than that of “single-sensor/car” entry
- In “ALL SCENARIOS” situation, the 32 sensors would evenly spread in the 5 slots. Therefore, when evaluating the “instantaneous” BER degradation (100%DC) of one sensor we should consider:
  - #  $31/5 = 6.2$  additional sensors
  - # aggregate signal power 7.2 times worse than the single sensor.
  - # the  $P_{rms}/50$  MHz/s would still become  $(-50+10\log 50+10\log 32)=-18$  dBm/50MHz
  - # the  $P_{rms}/burst$  would become  $(-26+10\log 7.2)=-17.4$  dBm/50MHz/burst
  - # the  $P_{peak}/P_{rms}$  ratio remains constant at 19 dB
  - # no residual DC on the aggregated signal is present
  - #  $I^*/N$  would be 8.6 dB higher than that of “single-sensor/car” entry

Figure 10 shows the trend-lines for the “ALL SCENARIOS” situation of the  $P_{rms}$  and the  $P_{peak}/P_{rms}$  per “equivalent burst” as function of the single-sensor DC. With DC 20%, the rms power already converges to that of a PPM case ( $-18$  dBm/50MHz), but the  $P_{peak}/P_{rms}$  is still significantly lower (19 dB with respect to 26 dB).

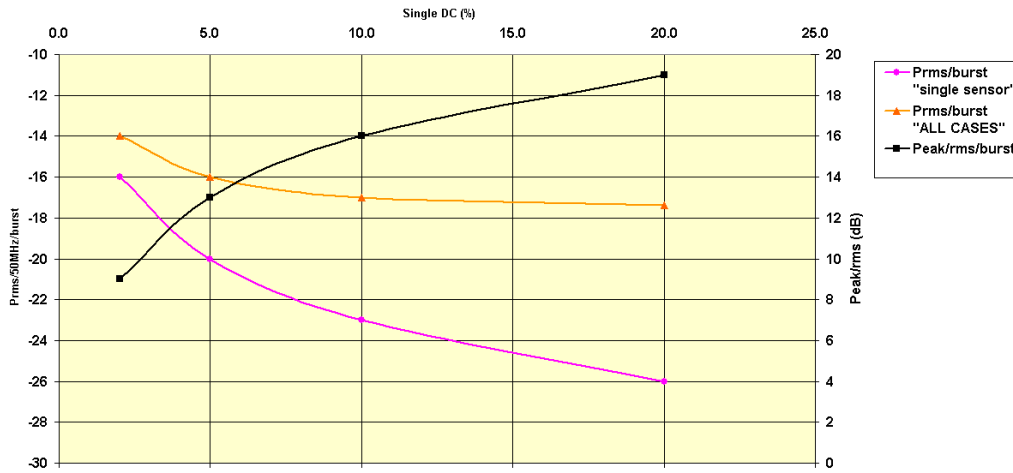


Figure 10: "ALL SCENARIOS" aggregation trend-lines vs DC

2.3.4.7.3 Graphical results

8summarises the parameters used for the actual simulations carried over among the above described cases.

SRR type ⇒ SRR Parameter ↓	PPM-SRR (100%DC) current limits		PPM-SRR (100%DC) proposed FH power limits		FH-SRR (10%DC/50MHz) P <sub>dur</sub> ≤ 20ns		FH-SRR (2% DC/50MHz) P <sub>dur</sub> ≤ 20ns	
	"most scenarios"	"all scenarios"	"most scenarios"	"all scenarios"	"most scenarios"	"all scenarios"	"most scenarios"	"all scenarios"
Single device P <sub>rms</sub> (dBm/50MHz)	-24.3	-24.3	-33	-33	-23	-23	-16	-16
Single device P <sub>peak</sub> (dBm/50MHz)	0	0	-7	-7	-7	-7	-7	-7
PRF (MHz) (P <sub>peak</sub> /P <sub>rms</sub> /Victim Bw)	0.1853	0.1853	0.125	0.125	1.25	1.25	6.25	6.25
P <sub>duration</sub> (ns); P <sub>Bw</sub> (MHz)	<< 20; >> 50	<< 20; >> 50	<< 20; >> 50	<< 20; >> 50	≤ 20; ≥ 50	≤ 20; ≥ 50	≤ 20; ≥ 50	≤ 20; ≥ 50
Victim Bw (MHz)	50	50	50	50	50	50	50	50
Aggregated I*/N (dB) 50 MHz Bw	-11.3	-1.3	-20	-10	-14.7+0.8 =-13.9	-14.7+6.2 =-8.5	-7.7+0.2 =-7.5	-7.7+2 =-5.7
P <sub>period</sub> (ns)	5396	5396	7943	7943	800	800	160	160
P <sub>peak</sub> /P <sub>rms</sub> (dB/50MHz)	24.3	24.3	26	26	16	16	9	9
Single device Burst duration (120 pulses) (μs)					96	96	19.2	19.2
Burst interval (μs) / Aggregated DC					960 / 32% DC	960 / 100% DC	960 / 6.4% DC	960 / 64% DC

Table 9: Summary of simulation parameters (aggregation)

With the above parameters, an evaluation of the degradation of an ideal BPSK system due to the various FH-SRR or conventional PPM-SRR with combined rms & peak power effect has been made.

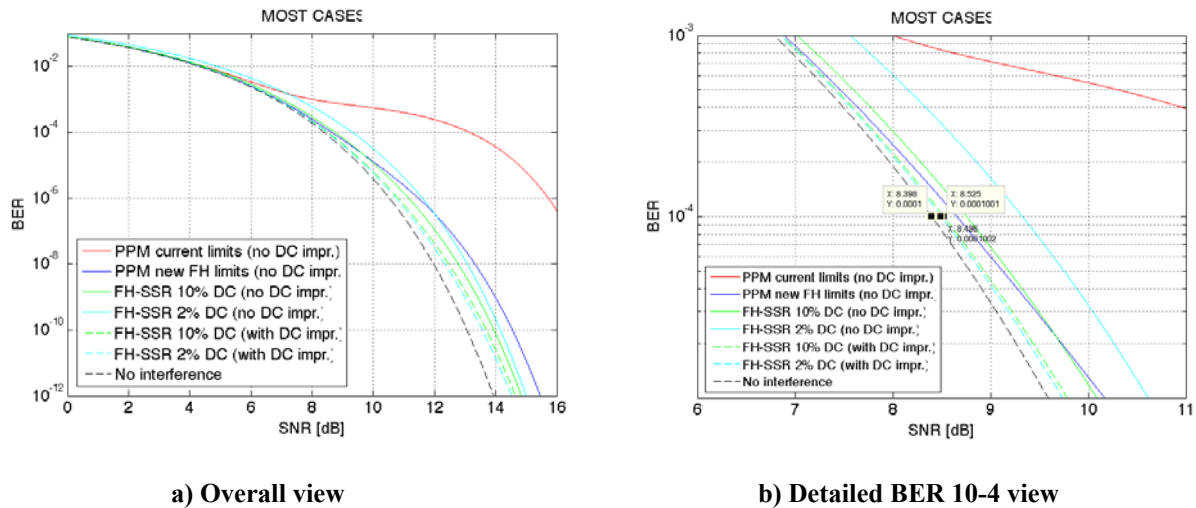


Figure 11: BER degradation over ideal BPSK system (50 MHz bandwidth) "Most scenarios" aggregation situation: Instantaneous (average) and with residual DC averaging degradation

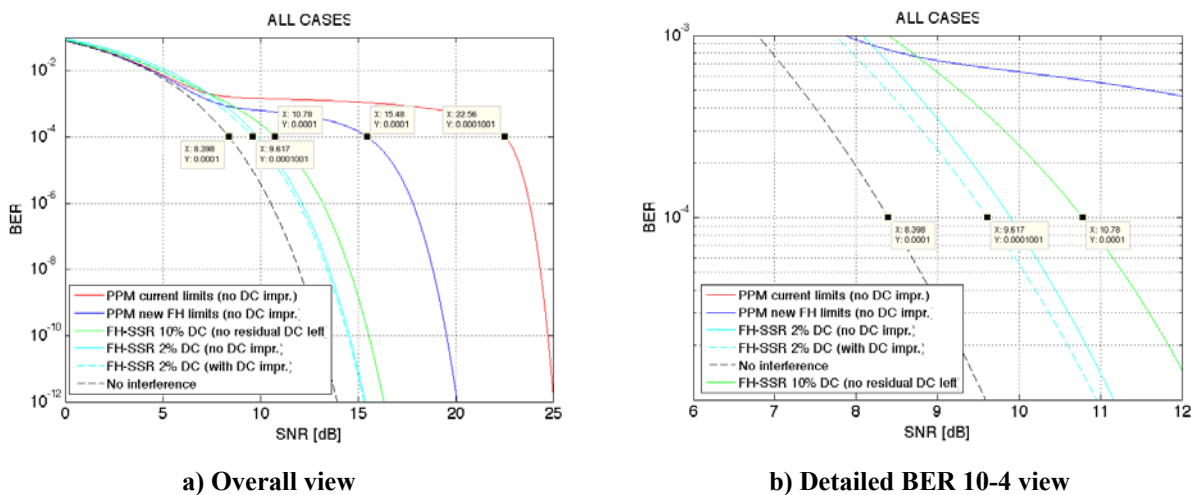


Figure 12: BER degradation over ideal BPSK system (50 MHz bandwidth) "All scenarios" aggregation situation: Instantaneous and with residual DC averaging degradation

### 2.3.5 Results of the impact analysis

#### 2.3.5.1 Single-car entry

From the considerations and graphs in Figure 8 and Figure 9 the following arguments and improvements can be proposed for consideration:

- From Figure 8a it is apparent that the reduction in DC (permitted by the proposed set of regulation) is increasing the instantaneous BER degradation and consequently the risk of sync-losses. The 1% DC seems already not advisable.  
Possible solution: provided that the 1% DC/50MHz can be produced only with 5 GHz system bandwidth (i.e. operating on the whole 24-29 GHz); from side discussions with some SARA representatives the actual needed bandwidth might be far less. For example, if the maximum system bandwidth would be limited to 2.5 GHz, the DC would automatically limited to 2.5% minimum. The BER degradation would become closer to the 5% case.
- From Figure 8b, the "average BER" degradation (i.e. in 1 second as required by ITU Recommendations) seems to remain, in practice, within the objectives (~0.04 dB for degradation ~0.5% and ~0.1 dB for degradation ~1%) in any case with reduced power (independently if PPM with 100% DC or FH with DC improvement).

- 3) From Figure 9 it is confirmed that when the pulse bandwidth becomes narrow (also permitted by the proposed set of regulation), the worst FS victim case is no longer the widest assumed 50 MHz, but it happens when (pulse Bw) = (victim Bw).  
Possible solution: the peak power may be further reduced when the pulse bandwidth becomes <50 MHz (by the logical factor  $20\log(50\text{MHz}/\text{pulse Bw})$ ); it seems that the FCC regulations already foresee similar reduction of the peak power linked to the pulse bandwidth.
- 4) Significant finding is that a PPM (100%) with reduced power would behave as FH 5% (maybe even better as far as the instantaneous I/N is concerned; however, worse behaviour is obviously expected for aggregation scenarios).

#### 2.3.5.2 *Aggregation scenarios*

From the considerations and graphs in Figure 11 and Figure 12 the following arguments can be proposed for consideration:

- 1) From Figure 11, the estimated degradation of the BER threshold (0.15 dB, equivalent to an availability objective degradation of about 1.2% to 3.5% depending on the link length, rain rate and availability objectives) in the “MOST SCENARIOS” conditions confirms what ECC Report 023 [1] shows as slightly worse than a “single-car” entry; the higher “instantaneous” BER degradation remains under control.
- 2) From Figure 12, the estimated degradation of the BER threshold (up to 2.4 dB, equivalent to an availability objective degradation of about 25% to 106% depending on the link length, rain rate and availability objectives) in the “ALL SCENARIOS” conditions is still significantly exceeding the objectives. When compared with the expected degradations with the original 24 GHz SRR characteristics, the improvement is about 12 dB.

#### 2.3.5.3 *Expected degradation of ITU-R availability objective*

For determining the expected margin degradation, due to joint violations of peak and mean I/N objectives (see background in section 2.3.2), we could refer to the graphs in Figure 11 (single-car entry) and Figure 12 (aggregation) at  $\sim\text{BER}=10^{-4}$ , which is suitable for block-based PDH or SDH paths; Table 8 shows the expected range of the degradation from the worst case (note) among the links examined (3 km; 22 mm/h; 99.99% availability) to a typically better case of link (6 km; 32 mm/h; 99.995%).

Note: From Figure 41 in Annex 5 it is evident that the major impact of the interference (giving a fixed amount of margin degradation) is on the shorter hops, with the lowest rain rate and less demanding objectives (less steep curves).

The evaluation is made on the nominal link budget necessary for the required availability objective, without considering any possible margin that, in average, any P-P link may have over the nominal BER threshold. The green-filled cells represent the situations where, de facto, the degradation would remain within the objectives.

Annex 5 gives some more detailed information about FS link performance and availability evaluation based on ITU R Recommendations; Table 10 summarises the margin degradation.

Single-car entry	PPM SRR (100% DC)				DC limited SRR			
Limits	Current e.i.r.p. limits (-41.3 dBm mean 0 dBm peak)		Reduced e.i.r.p. limits (-50 dBm mean -7 dBm peak)		Reduced e.i.r.p. limits (-50 dBm mean -7 dBm peak) DC = 1% (note)		Reduced e.i.r.p. limits (-50 dBm mean -7 dBm peak) DC = 5%	
Estimated margin degradation (dB)	3.3		0.1		0.06		0.06	
Availability degradation	unacceptable proposition		0.9% to 2.8%		0.5% to 1.7%		0.5% to 1.7%	
Availability degradation (min/year)	unacceptable proposition		0.24 to 1.47		0.13 to 0.9		0.13 to 0.9	
NOTE: Even if the 1s averaged degradation is the same of 5%, the DC 1% implies a large instantaneous degradation (see 2.3.3.6); consequently, the minimum DC has been assumed to be limited to 2%.								
Aggregated interference	PPM SRR (100% DC)				DC limited SRR			
Limits	Current e.i.r.p. limits (-41.3 dBm mean 0 dBm peak)		Reduced e.i.r.p. limits (-50 dBm mean -7 dBm peak)		Reduced e.i.r.p. limits (-50 dBm mean -7 dBm peak) DC = 2%		Reduced e.i.r.p. limits (-50 dBm mean -7 dBm peak) DC = 10%	
Scenarios	MOST SCENARIOS	ALL SCENARIOS	MOST SCENARIOS	ALL SCENARIOS	MOST SCENARIOS	ALL SCENARIOS	MOST SCENARIOS	ALL SCENARIOS
Estimated margin degradation (dB)	5.4	14	0.25	7	0.1	1.2	0.15	2.4
Availability degradation	unacceptable proposition	unacceptable proposition	2.3% to 7%	unacceptable proposition	0.9% to 2.8%	11.6% to 41%	1.2% to 3.5%	25% to 106%
Availability degradation (min/year)	unacceptable proposition	unacceptable proposition	0.6 to 3.68	unacceptable proposition	0.24 to 1.47	3 to 25.7	0.32 to 1.84	6.57 to 55.7

**Table 10: Evaluation of the degradation of ITU-R objectives for the various SRR limits and DC% examined**

In addition Table 11 summarizes the long term objectives degradations evaluated in Table 10 in conjunction with the expected occurrence probability estimated over the Germany population of 26 GHz links (see section 2.2.2).

Scenario	Expected I/N (dB) (mean) (Note 1)	SRR assumed limits			Example of practical impact in one administration		Unavailability time range for 0.005% to 0.01% objectives (Additional to the 26.3 or 52.5 minutes per year) (Note 2)	Unavailability exceeded by (Note 1)
		Mean e.i.r.p. dBm/ MHz	Peak e.i.r.p. dBm in 50 MHz	Duty Cycle (Gating Factor)	Geographical estimated probability of interference (percentage of relevant FS links)	Average estimated number of possibly affected links		
ECC Report 023 aggregation All scenarios	I/N = -1.3	-41.3	0	100%	<0.0001%	0	unacceptable proposition	unacceptable proposition
ECC Report 023 aggregation Most scenarios	I/N = -11.3	-41.3	0	100%	<0.001%	1	unacceptable proposition	unacceptable proposition
Estimated Worst case aggregation Germany	I/N = -16.3	-41.3	0	100%	0.03%	5	~6.5 to 55	~25% to ~100%
ECC Report 023 aggregation All scenarios	I/N = -10	-50	-7	100%	<0.0001%	0	unacceptable proposition	unacceptable proposition
ECC Report 023 aggregation Most scenarios	I/N = -20	-50	-7	100%	<0.001%	1	0.6 to 3.68	2.3% to 7%
Estimated worst case aggregation Germany	I/N = -25	-50	-7	100%	0.03%	5	< 0.5	< 1%
ECC Report 023 aggregation All scenarios	I/N = -10	-50	-7	10%	<0.0001%	0	6.57 to 55.7	25% to 106%
ECC Report 023 aggregation Most scenarios	I/N = -20	-50	-7	10%	<0.001%	1	0.32 to 1.84	1.2% to 3.5%
Estimated Worst case Aggregation Germany	I/N = -25	-50	-7	10%	0.03%	5	< 0.25	< 0.5%
Single-car (10m ant.) Annex 1	I/N=-13	-41.3	0	100%	-	many	unacceptable proposition	unacceptable proposition
Single-car (10m ant.) Annex 1	I/N=-21.7	-50	-7	100%	-	many	0.24 to 1.47	0.9% to 2.8%
Single-car (10m ant.) Annex 1	I/N=-24.7 (Note 3)	-50	-7	10% (Note 3)	-	many	0.13 to 0.9	0.5% to 1.7%

**Table 11: Expected degradations and their occurrence probability in one country**

Note 1: The mean I/N ratio is mentioned for reference and comparison among the various SRR limitations; the actual degradations are calculated also on the basis of DC % and instantaneous peak and mean I/N ratios.

Note 2: The range comes also from the different link length (3-6km) and rain rate (22-32mm/h)

Note 3: Due to the DC limit the aggregation of 2 front sensors is not applicable (sensors not synchronised).

## 2.4 Measurement campaign by one administration

A measurement campaign was initiated by one administration (details see Annex 4). The measurements took place at a test track using a temporary installed FS link operating in the 26 GHz band.

In this most sensitive FS link mode (BER 1e-6) the measurements with activated SRR-system show an increase of the bit error rate by a factor between 10 and 100 (reflecting, on the BER behaviour of a QPSK system without any error correction code, a possible fade margin degradation between 1 and 2 dB), for SRR sensors in compliant mode. The BER of SRR sensors with 10dB less power are difficult to differentiate from the reference results, but still visible, confirming the “single-car entry” evaluated in Annex 1. It should also be noted the when

both limits (mean and peak) are just met (i.e. in the compliance mode) the degradation becomes higher because the two effects adds up.

It should be noted the sensible degradation when average and peak power are both just “compliant”; even if, in average market composed of many manufacturer’s technologies this would not frequently happen, this further enforce the need of containing the peak power of the sensors.

Two measurements each 15 minutes were performed also with 10dB less attenuation in the FS link (10 dB margin in comparison to the  $10^{-6}$  BER link configuration). The reference measurement in this configuration was not possible due to the missing bit errors. The BER with activated SRR sensors in compliant mode in a distance of 1000m was nearly not measurable (just 26 sporadic bit errors over 30 minutes) and in a range of  $1e-8$  and  $5e-10$ ; the errors are possibly due to adverse phase situation of the sensor and noise peaks. More conclusive measurement would need much more time for long-term recording. This shows that a FS link in a typical situation (>99% of time) would not be interfered by SRR in term of “availability”, but it can have problem in meeting the error performance requirements (i.e. ES and BER objectives required by Recommendation F.1668 [15]).

In principle the results of this campaign confirms the theoretical worst case calculations which are based on a protection criterion of  $I/N = -20\text{dB}$ .

### **3 EESS/SRS EARTH STATIONS IN THE BAND 25.5-27 GHz**

This section addresses the compatibility analysis between SRS and EESS earth stations and SRR emissions.

#### **3.1 Characteristics of the victim (SRS and EESS Earth stations)**

Victims are SRS and EESS stations. SRS missions include GSO, non-GSO or Lagrange point satellites. EESS stations are either pointing towards a GSO satellite or tracking non-GSO satellites.

##### ***3.1.1 Locations of the currently known Earth stations within Europe***

The locations of the currently known EESS earth stations and SRS Earth stations within Europe are updated in Table 12 and Table 13 respectively.

For each earth station, the appropriate car density was derived. Three car densities are considered (123, 330 or 453 cars per  $\text{km}^2$ ). An additional type of density has been added for rural remote locations (about 50 or 10 cars per  $\text{km}^2$  depending on the area).

Location	Latitude	Longitude	Country	Type of location	Expected car density per km <sup>2</sup>
Kiruna:	67° 51' 66" N	21° 57' 57" E	Sweden	Rural	50
Svalbard:	78° 13' 18" N	15° 24' 03" E	Norway (Langobard Island)	Remote (very remote)	No cars
Villafranca	40° 26' 14" N	03° 57' 36" W	Spain	Rural	123
Maspalomas, located top of a hill	27° 45' 40" N	15° 38' 68" W	Spain (Canary Islands)	Suburban/urban	50
Redu	50° 00' 64" N	05° 08' 24" E	Belgium	Rural	Between 10 and 50
Monte da Flores	36° 59' 49" N	25° 08' 09" W	Portugal (Azores)	Few cars	10
Aussaguel	43° 25' 26" N	01° 30' 22" E	France	Rural/highway	123
Neustrelitz	53° 19' 47" N	13° 04' 12" E	Germany	highway	123
Usingen	50° 20' 03" N	11° 26' 51" E	Germany	Rural	50
Darmstadt, EUMETSAT	49° 41' 55" N	8° 37' 36" E	Germany	Suburban and urban	330/453

Table 12: list of EESS earth stations

Location	Latitude	Longitude	Country	Type of location	Expected car density per km <sup>2</sup>
Kiruna: SRS earth station planned in the future	67° 51' 66" N	21° 57' 57" E	Sweden	Rural	50
Villafranca	40° 26' 14" N	03° 57' 36" W	Spain	Highway	123
Cebreros	40° 27' 68" N	04° 22' 03" W	Spain	Rural	Between 10 and 50
Robledo: restricted area around the NASA earth station	40° 25' 43" N	04° 14' 57" W	Spain	Small road	Between 10 and 50
Maspalomas	27° 45' 40" N	15° 38' 68" W	Spain (Canary Islands)	Located at the top of a hill, highway	50
Redu	50° 00' 64" N	05° 08' 24" E	Belgium	Rural	Between 10 and 50
Weilheim	47° 53' 15" N	11° 05' 04" E	Germany	highway	10

Table 13: list of SRS earth stations



### 3.1.2 Protection criteria

The protection criteria are the following:

- SRS: -156 dBW/MHz from Recommendation ITU-R SA.609 [17]
- GSO EESS: -145 dBW/MHz from Recommendation ITU-R SA.1161-1 [18],
- Non GSO EESS: -136 dBW/MHz from Recommendation ITU-R SA.1026-4 [19].

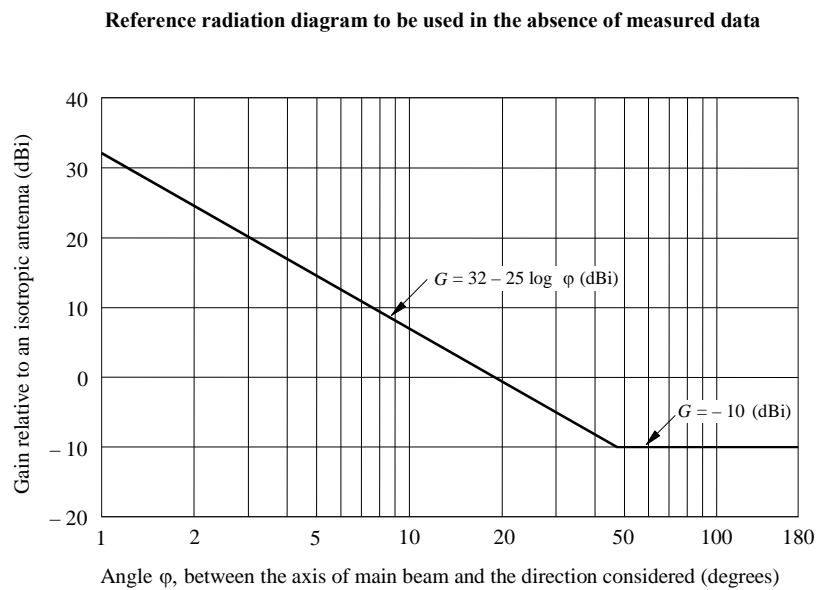
When taking into account an apportionment of 1% in accordance with Recommendation ITU-R SA.1027-4 [20] for EESS, and Recommendation ITU-R SM.1757-4 [21] for SRS, the final protection levels become respectively:

- SRS: -176 dBW/MHz
- GSO EESS: -165 dBW/MHz,
- Non GSO EESS: -156 dBW/MHz.

### 3.1.3 SRS antenna pattern

According to Recommendation ITU-R SA.509-2 [22], in the absence of measurements on side-lobe levels of a space research earth station or radio astronomy antenna subject to interference analyses or coordination procedures, the reference radiation pattern of Figure 13 may be used to represent the antenna side-lobe response. This reference radiation pattern has to be used only for antennas the diameters of which are greater than 100 wavelengths, for angles greater than 1° from the main beam axis and for frequencies between about 1 and 30 GHz. This last condition is usually fulfilled for SRS earth stations.

Therefore the antenna gain below is used for compatibility analysis.



0509-01

**Figure 13: Reference radiation diagram**

### 3.1.4 GSO/non GSO antenna pattern for EESS

It is recommended to use the antenna pattern described in Recommendation ITU-R F.1245 [23] for EESS at 26 GHz, with 58.2 dBi maximum gain and 3.9 m diameter for non-GSO EESS, and 60.1 dBi maximum gain and 4.8m diameter for GSO stations.

However, since the results are very similar for both antennas, the same antenna pattern for both GSO and non GSO EESS was input in SEAMCAT simulations, derived from Recommendation ITU-R F.1245 [23] at 26 GHz with 60 dBi maximum gain and 4.8 m diameter (see Figure 14).

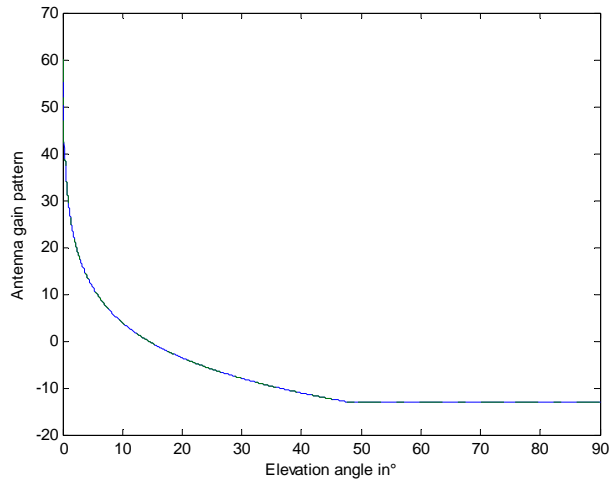


Figure 14: Antenna pattern used in SEAMCAT for GSO and non GSO EESS stations

### 3.1.5 SEAMCAT parameters

Table 14 summarizes the victim parameters used in the SEAMCAT simulations.

	SRS	GSO EESS	Non GSO EESS
<b>Antenna height</b>	ESA near earth : height 11m, diameter 15m ESA Deep space : height 21 m, diameter 35m	5m	5m
<b>Antenna pointing elevation</b>	5°	10°	3°
<b>Antenna pointing azimuth</b>	0°	0°	0°
<b>Noise floor</b>	-126 dBm	-115 dBm	-106 dBm
<b>Protection criterion</b>	I/N=-20 dB	I/N=-20 dB	I/N=-20 dB
<b>Antenna pattern</b>	Fig 1	Fig 2	Fig 2
<b>Reception bandwidth</b>	1000 kHz	1000 kHz	1000 kHz

Table 14: Victim parameters in SEAMCAT

## 3.2 Characteristics of the interferer (SRR)

The ETSI SRdoc indicates that one benefit of the proposed alternative bandwidth 24-29 GHz is that there is no expiry date (essential condition for the planning safety for the automotive industry) mainly because the in-band emissions avoid the exclusive passive band 23.6-24 GHz.

### 3.2.1 Power emissions

According to ETSI standards, the average e.i.r.p. PSD is -41.3dBm/MHz. An omni directional antenna of 0 dBi is considered.

### 3.2.2 Mitigation factors

A bumper attenuation of 3 dB is taken into account, supposing that the SRR is located behind the vehicle bumper. A mitigation factor of  $10 \log(90^\circ/360^\circ) = 6$  dB is considered for the limitation of SRR emissions to angles of 90°. This mitigation is annihilated by the fact that there are 4 radars in operation per car, as mentioned below, therefore it does not appear in the SEAMCAT inputs.

Shadowing effects, complex to model, are not considered. However this factor may be considered at a later stage on a case by case basis, depending on the victim location and configuration.

Theoretical studies have shown that the usage of frequency hopping radars would result in a 9 dB improvement for compatibility purposes with Space Research Earth stations. A limit of -50 dBm/MHz/s was introduced and confirmed and was used in the studies (see 2.2.7).

### 3.2.3 Car densities and interferer-victim link configuration

According to Recommendation ITU-R SM.1757 [21], the aggregate interference study should be based on the following assumptions in terms of density of cars/km<sup>2</sup>:

- SRR on 100% of cars
- Cars are equipped with up to 8 short range radars (SRRs)
- Car density of 123 for rural environment, 330 for suburban environment, and 453 for urban environment. Car densities around 10 and 50 are used for rural remote areas depending on the area where the earth station is implemented.

In reality, each radar has an activity factor of 50% which is equivalent to 4 radars in operation per car, leading to 3dB increase of the emission power per car in one direction.

Nevertheless, due to the location of the victim stations, it is proposed to run SEAMCAT simulations with the following car densities:

- SRS stations, car densities of 10, 50 and 123/km<sup>2</sup>, uniformly spread over an annulus with inner and outer radii of 1.5km and 3km, respectively.
- EESS stations, car densities of 50, 123, 330 and 453/km<sup>2</sup>, uniformly spread over an annulus with inner and outer radii of resp. 0.5km and 3km.

Table 15 summarizes the interferer parameters used in the SEAMCAT simulations.

	<b>SRR</b>
<b>Frequency</b>	25 500 MHz
<b>Power</b>	-44,3 dBm
<b>Antenna height</b>	0.5m
<b>Antenna pointing azimuth</b>	0°
<b>Antenna pattern</b>	Omni directional 0 dBi
<b>Interferer location</b>	Uniform density - Protection distance of 0,5km - Nb of active transmitters depending on the density (10, 50, 123, 453/km <sup>2</sup> ) to get a simulation radius of 3km
<b>Propagation model</b>	Free space

**Table 15: Interfering link parameters**

## 3.3 SEAMCAT results

### 3.3.1 SRS stations

Table 16 indicates the SEAMCAT input and statistical results for SRS stations based on 200 simulations (200 SEAMCAT events).

Parameters SEAMCAT inputs	Unit	SRS Near Earth		SRS Deep Space		Robledo station
Antenna gain	dBi	50				
Antenna pattern		SA.509				
Antenna height	m	11	11	21	21	11
Elevation	deg	5				
Inner radius	km	0.5				0.05
Outer radius	km	3				
area	km <sup>2</sup>	27.5				28.3
Device density	/km <sup>2</sup>	123	10 - 50	123	10 - 50	10 - 50
Active devices		3381	275 -1375	3381	275 - 1375	283 - 1413
UWB power e.i.r.p.	dBm/MHz	-41,3				
Bumper loss	dB	3,0				
Simulated uwb power	dBm/MHz	-44,3				
Density	/km <sup>2</sup>	123	10 - 50	123	10 - 50	10 - 50
Activity factor		1				
Probability		1				
Active devices		3381	275 - 1375	3381	275 - 1375	283 - 1413
Protection radius	km	0,5				0,05
Interference criterion	dBm/MHz	-146				
Simulation radius	km	2,99				
Mean iRSS	dBm/MHz	-135.1	-146 / - 139	-135.4 / - 139.4	-146.6	-143.7 / - 136.2
Probability of interference		100%	45% / 100%	100%	30% / 100%	91,5% / 100%
UWB power for proba < 1%	dBm/MHz	-56	-46,2 / - 52.5	-55.6	-45.5 / - 52.1	-48.6 / - 56.9
Margin	dB	-11.7	-5.1 / -8.2	-11.3	-4.2 / -7.8	-7,3 / -12.6

**Table 16: SEAMCAT results for SRR vs SRS**

For ESA Near Earth stations (11m height), the mean interference levels are -135.1 dBm and -139 dBm for car densities of 123/km<sup>2</sup> and 50/km<sup>2</sup>, leading to negative margins of -11.7 dB and -8.2 dB respectively. The results are worse for ESA Deep Space stations at 21m height and Robledo station.

Theoretical studies (Annex 6) have shown that the usage of frequency hopping radars would result in a 9 dB improvement for compatibility purposes with Space Research Earth stations (see chapter 2.2.7).

### 3.3.2 EESS stations

Table 17 indicates the SEAMCAT input and statistical results for EESS stations based on 200 SEAMCAT events.

	Parameters SEAMCAT inputs	Unit	GSO	GSO	GSO	Non GSO	Non GSO	Non GSO
	Antenna gain	dBi	60	60	60	58	58	58
	Antenna pattern		F.1245	F.1245	F.1245	F.1245	F.1245	F.1245
*	Antenna height	m	5	5	5	5	5	5
*	Elevation	deg	10	10	10	3	3	3
	Inner radius	km	0,5	0,5	0,5	0,5	0,5	0,5
	Outer radius	km	3	3	3	3	3	3
	Area	km <sup>2</sup>	27,49	27,49	27,49	27,49	27,49	27,49
	Device density	/km <sup>2</sup>	453,00	123,00	50,00	453,00	123,00	50,00
	Active devices		12452,5	3381,1	1374,4	12452,5	3381,1	1374,4
	UWB power e.i.r.p.	dBm/MHz	-41,3	-41,3	-41,3	-41,3	-41,3	-41,3
	bumper loss	dB	3,0	3,0	3,0	3,0	3,0	3,0
*	Simulated UWB power	dBm/MHz	-44,3	-44,3	-44,3	-44,3	-44,3	-44,3
*	Density	/km <sup>2</sup>	453	123	50	453	123	50
*	Activity factor		1	1	1	1	1	1
*	Probability		1	1	1	1	1	1
*	Active Devices		12452,5	3381,1	1374,4	12452,5	3381,1	1374,4
*	Protection radius	km	0,5	0,5	0,5	0,5	0,5	0,5
*	Interference criterion	dBm/MHz	-135	-135	-135	-126	-126	-126
	Simulation radius	km	2,99	2,99	2,99	2,99	3,00	3,00
	Mean iRSS	dBm/MHz	-136	-142	-146	-129	-135	-139
	Probability of interference		100%	0%	0%	0%	0%	0%
	UWB power for 0%	dBm/MHz	-43,3	-37,7	-33,8	-41,3	-35,5	-32
	Margin	dB	1,0	6,6	10,5	3,0	8,8	12,3

Table 17: SEAMCAT results for SRR vs EESS

For EESS-GSO stations, the mean interference level ranges from -136 dBm for car densities of 453/km<sup>2</sup> to -146 dBm for car densities of 50/km<sup>2</sup>, leading to positive margins from 1 dB to 10 dB.

For EESS-non GSO stations, the mean interference level ranges from -129 dBm for car densities of 453/km<sup>2</sup> to -139 dBm for car densities of 50/km<sup>2</sup>, leading to positive margins from 3 dB to 12 dB.

## 4 EESS AND RADIOASTRONOMY IN THE BAND 23.6-24 GHz

### 4.1 EESS passive

As the proposed new automotive short range radar is planned to operate within the band 24-29 GHz, it is therefore expected that unwanted emissions would fall within the passive band 23.6-24 GHz. As a consequence, this band under RR n°5.340 requires protection and specific studies have to be conducted to derive unwanted emission limits. The technical basis for deriving unwanted emission limits for SRR 24 GHz within the band 23.6-24 GHz is contained within Recommendation ITU-R SM.1757 [21], Annex 1, §1.1.1.6.1 Earth exploration-satellite service (EESS), section A6.1.4.

One can in particular note that the protection of EESS is thereby ensured by both a maximum **e.i.r.p.** limit (-76.2 dBm/MHz) and an antenna discrimination of 35 dB above 30° from the horizontal plane. The 35 dB attenuation is found within the initial FCC regulation. It is equivalent to indicate that the radiated power within the band 23.6-24 GHz equals  $-76 - 35 = -111$  dBm/MHz **e.i.r.p.**

On the other side ECC Report 023, which was produced by CEPT some years before Report ITU-R SM.2057, concludes that compatibility of SRR with EESS can be achieved using both a maximum **e.i.r.p.** limit of -52.1

dBm/MHz and an antenna discrimination of 35 dB above 30° from the horizontal plane. The discrepancy between the results of ECC Report 023 and Report ITU-R SM.2057 [6] is clarified in this Report.

Following technical discussion, a proposal based on a direct e.i.r.p. limit within the band 23.6-24 GHz of -73 dBm/MHz and of an average antenna attenuation of 20 dB above 30° of elevation has been submitted to CEPT administrations. Therefore, the equivalent resulting radiated power within the band 23.6-24 GHz equals -73-20=-93 dBm/MHz e.i.r.p for elevation angles greater than 30°.

**4.1.1 Impact of antenna attenuation on the compatibility**

The Report ITU-R SM.2057 [6] contains detailed calculations that are very helpful to understand the connection between the total radiated power and the direct/reflected paths. Table 18 shows the corresponding negative margins if the corresponding SRR antenna attenuation above 30° within the band 23.6-24 GHz is decreased.

<b>CONICAL SCAN INSTRUMENTS</b>					
<b>SRR e.i.r.p. requirement in dBm/MHz (report SM.2057)</b>	-76,10	-76,10	-76,10	-76,10	-76,10
SRR antenna pattern attenuation above 30° of elevation in dB	35,00	30,00	25,00	20,00	15,00
e.i.r.p. scattered in dBm/MHz	-133,60	-133,60	-133,60	-133,60	-133,60
e.i.r.p. direct in dBm/MHz including antenna attenuation	-150,10	-145,10	-140,10	-135,10	-130,10
<b>Total: scattered + direct</b>	-133,50	-133,30	-132,72	-131,28	-128,50
Difference		0,20	0,78	2,23	5,01
<b>NADIR INSTRUMENTS</b>					
<b>SRR e.i.r.p. requirement in dBm/MHz (report SM.2057)</b>	-76,10	-76,10	-76,10	-76,10	-76,10
SRR antenna pattern attenuation above 30° of elevation in dB	35,00	30,00	25,00	20,00	15,00
e.i.r.p. scattered in dBm/MHz	-133,60	-133,60	-133,60	-133,60	-133,60
e.i.r.p. direct in dBm/MHz including antenna attenuation	-144,10	-139,10	-134,10	-129,10	-124,10
<b>Total: scattered + direct</b>	-133,23	-132,52	-130,83	-127,78	-123,64
Difference		0,71	2,40	5,45	9,59

**Table 18: Impact of antenna attenuation on the compatibility**

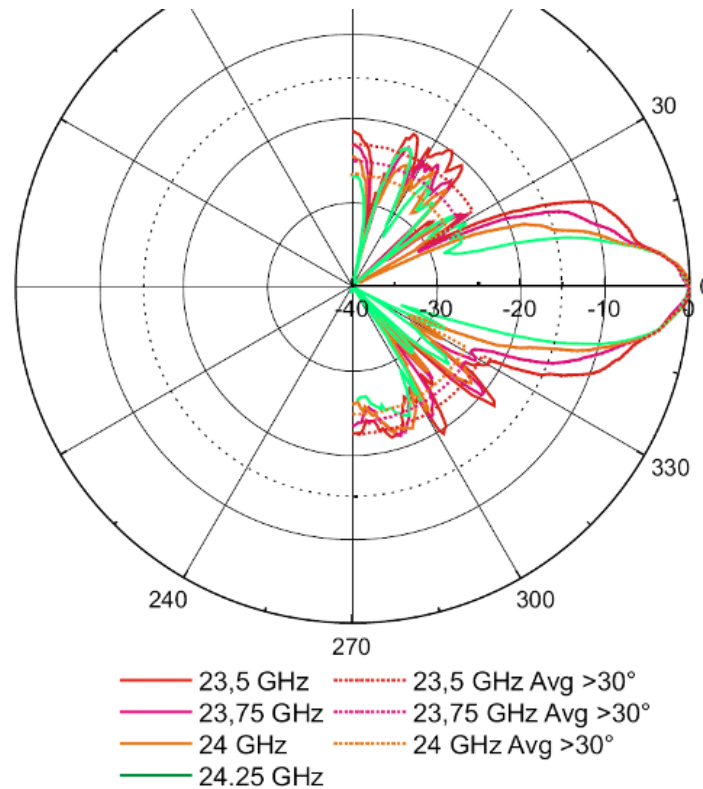
This table shows that for conical scan instruments, the degradation is limited (less than 1 dB) if the antenna attenuation is relaxed by 10 dB: for nadir instruments, the degradation equals 2.4 dB.

**4.1.2 Antenna design issues**

According to the automotive industry, the antenna rejection of 35dB for elevations >30° in the band 23.6-24 GHz seems to be difficult to achieve.

In Figure 17 a typical transmit antenna elevation pattern is displayed. It is obvious that for frequencies below 24GHz the sidelobe performance degrades. The elevation pattern has so called “shoulders” and higher sidelobes at angles greater than ±30°. For safeguard reasons a limit of -15dB is proposed to have some margin to the peak sidelobes and for unit to unit variations.

However, some administration argued that the proposed 15 dB attenuation is not acceptable to protect the passive band and the automotive industry (SARA) was invited to provide better attenuations.



**Figure 15: Typical antenna elevation pattern for a 26GHz SRR in the passive band and the averaged elevation pattern above 30°**

According to Figure 15, the resulting discrimination in the passive band is in the order of -30 to -15 dB with respect to the main beam direction, with an average above 30° of about -20 dB. Therefore it is proposed to use -20 dB for the average antenna discrimination above 30°.

**4.1.3 Comparison ECC Report 023 and ITU-R SM.2057**

ECC Report 023 indicates that the required limit for protection of SRR is -52.1 dBm/MHz, while Recommendation ITU-R SM.1757 [21] (based on Report ITU-R SM.2057 [6]) requests a limit of -76.2 dBm/MHz e.i.r.p. The basis for this difference is explained within Table 19.

	<b>ECC Report 023 [1]</b>	<b>Report ITU-R SM.2057 [6]</b>
<b>EESS interference threshold</b>	-166 dBW/200 MHz	-166 dBW/200 MHz
<b>Apportionment of this threshold</b>	100 %	1%
<b>Car density per km<sup>2</sup></b>	Highway: 123 Urban/suburban: 330	Highway: 123 Urban/suburban: 330 Urban: 453
<b>EESS(passive) radiometer characteristics</b>	Conical scan instruments: MEGHA-TROPIC, AMSR-E Nadir instruments: Push broom, AMSU	Conical scan instruments: MEGHA-TROPIC, AMSR-E, CMIS Nadir instruments: Push broom, AMSU, ATMS

**Table 19: Differences between ECC Report 023 and Report ITU-R SM.2057**

**4.1.4 Conclusion for EESS in the band 23.6-24 GHz**

Technical discussions and studies have concluded to the following compromise concerning the protection of the passive band 23.6-24 GHz from out of band emissions from SRR operating at 26 GHz:

- a) Direct emission limit in the main beam will not exceed -73 dBm/MHz e.i.r.p.
- b) Additional average antenna attenuation above 30° elevation to be separately measured will be at least 20 dB.

## 4.2 Radioastronomy

The protection of RAS in the band 23.6-24GHz was not evaluated in detail, because of the following reasons:

- SRR will operate outside the relevant RAS frequency band (23.6-24 GHz)
- Decides 5 of ECC/DEC/(04)10<sup>5</sup> for 24 GHz SRR provides a limit of -74 dBm/MHz within the band 23.6-24 GHz for the protection of RAS without a deactivation mechanism.

Therefore the emission limit of -74 dBm/MHz e.i.r.p. is assumed to be sufficient for protection of RAS.

## 5 SUMMARY AND CONCLUSION

### Fixed service

Regarding the compatibility of 26 GHz SRR, all protection objectives and scenarios given in ECC Report 023 have been considered and are still valid. In addition, the “single-car” interference case (intended as a continuous stream of cars crossing the FS link path) has also been considered as common case with high occurrence probability; this was not present in ECC Report 023, but later on was added in ITU-R Report SM.2057.

According to the first release of SRdoc ETSI TR 102 664 V1.1.1, which simply proposed frequency shift to 26GHz band without changing any other technical SRR system parameters, it was concluded that the results of ECC Report 023 are still valid and 26 GHz SRR will not be compatible with FS links in 26 and 28 GHz bands. However, some preliminary simulations, taking into account more detailed both the mean and peak emission characteristics, have shown that with a reduction of the e.i.r.p. density and limited Duty Cycle there might be some room for improvement; in addition, the simulations highlighted some problems related to high peak-to-average and narrower pulse bandwidth.

Based on those initial considerations ETSI provided a revised version of the SRdoc TR 102 664 V1.2.1, (see table B.2.4), which was further examined in the development of this report. The results show some improvement compared to the original proposal (see section 2.2.7), in particular, for the “single-car” entry case. For other cases violation of the FS objectives are still possible as follows;

- 1) The substantial reduction of the Peak power significantly reduces the amount of performance degradation of the FS victim receiver even when the mean power I/N objectives are slightly exceeded.
- 2) In the “single-car”<sup>6</sup> scenario, considering the DC improvement over the BER (averaged for 1 second according the ITU recommendations), the estimated degradation of the BER threshold (~0.05 dB) may be considered within the objectives (degradation of the ITU error performance and availability objectives 0.5% to 1%). The most severe “instantaneous” BER degradation, which occurs with the minimum DC, appears to be within a range manageable by typical FS demodulator without risk of loss of synchronisation.
- 3) In the “most scenario”<sup>7</sup> aggregated conditions, the estimated degradation of the BER threshold is ~0.15 dB which is equivalent to an availability objective degradation of about 1.2 % to 3.5 % depending on the link length, rain rate and availability objectives.

<sup>5</sup> “that 24 GHz SRR systems transmitting in the band 23.6-24 GHz with an e.i.r.p. higher than -74 dBm/MHz or in any band listed in considering ee) with an e.i.r.p. higher than -57 dBm/MHz, shall be fitted with an automatic deactivation mechanism to ensure protection of Radio Astronomy sites as well as manual deactivation to ensure that emissions are restricted only to those countries that have implemented the temporary solution. In order to allow an early implementation of 24 GHz SRR Systems the automatic deactivation shall be made mandatory from 1 July 2007. Before that date, manual deactivation is required.”

<sup>6</sup> According to Report ITU- R SM.2057

<sup>7</sup> From ECC Report 23: “However, on the basis of the whole range of calculation results, it can be concluded that with an e.i.r.p. density of -60 dBm/MHz the FS protection criteria (-20 dB I/N) for „**all scenarios**“ considered in these studies is respected, whilst with an e.i.r.p. density of -50 dBm/MHz, this protection criteria would be met in „**most scenarios**“. Some administrations are of the opinion that it is necessary that SRR meets the -20 dB I/N protection criteria in all cases. Some other administrations are of the opinion that an excess of the protection criteria by 10 dB, which still corresponds to an I/N of -10 dB, is acceptable.”

The above consideration when the new limits (-50 dBm/MHz) is applied would correspond to ;



- 4) In the “all scenario”<sup>3</sup> aggregated conditions, the estimated degradation of the BER threshold is ~2.4 dB which is equivalent to an availability objective degradation of about 25 % to 106 % depending on the link length, rain rate and availability objectives. This is still significantly exceeding the objectives. Nevertheless, also due to the reduced peak power impact, when compared with the expected BER threshold degradations with the original 24 GHz SRR characteristics, the improvement is about 13 dB.
- 5) When a 10% market penetration of 26 GHz UWB SRR would be reached; the aggregation impact, provided that the new limits proposal have significantly reduced the peak e.i.r.p., can be assumed to be ~10 dB lower than mentioned above as follows:
  - The “most scenarios” conditions would be reduced to about 0.02 dB BER threshold degradation and an availability objective degradation of less than 0.5% objective in any link conditions.
  - The “all scenarios” conditions would be reduced to about 0.2 dB BER threshold degradation and an availability objective degradation of about 3.5% to 6% depending on the link length, rain rate and availability objectives. An availability degradation of 6% corresponds to an increase of the unavailability of about 3 minutes per average year for a FS link planned with an availability of 99.99%.
- 6) The above conclusions for the aggregated scenarios should be considered together with all other mitigations (e.g. production spreads, geographical occurrence probability, etc...).
  - If a value of 2.5 dB is considered for the production spread in the “all scenarios” conditions together with a reduction of the market penetration to 10% the BER threshold degradation would be about 0.11 dB with an availability objective degradation of about 3%. An availability degradation of 3% corresponds to an increase of the unavailability of about 1.5 minutes per average year for a FS link planned with an availability of 99.99%.

Also the issue of the occurrence probability of those scenarios within the territory of one administration was also considered. This administration produced a geographical study on 14.000 FS links in the band 24-29 GHz showing that the occurrence of the assumed worst cases of ECC Report 023 would be negligible, and that the impact on real deployed FS links may be about 15 dB less critical as assumed as worst case in ECC Report 023. However, it has been considered that the geographical situation in one country would not be representative of situations in other countries, which may have different deployment rules/habits for FS links, therefore the findings of this analysis by one administration may not be applicable to most other administrations.

Open field radiated tests have also been performed (see Annex 4), they have shown consistency with the laboratory conducted tests reported in ECC Report 023.

Finally, the issue of short links (possible in some cases and in some countries) was examined, but its conversion into actual “error performance and availability degradation” is more complex because such shorter hops in these frequency bands may bring new technical elements into consideration. Here some administrations are of the view that such FS links (e.g. 100 m hop length together with Tx power values less than -31 dBm and a link margin of 3 dB) are not realistic, while other administrations reported the deployment of short links in their country and therefore they are concerned with the deployment of SRR on their territory.

### **EESS and SRS earth stations 25.5-27 GHz**

The compatibility analysis which has been conducted address the protection of EESS and SRS space earth stations from 26 GHz SRR emissions including those in the passive band 23.6-24 GHz.

Concerning the protection of EESS and SRS space earth stations, based on an exhaustive list of earth stations deployed within Europe, the analysis of the new limit proposal, as contained in Table 1, concluded that the expected benefit in terms of the mean power aggregation scenarios is 9 dB (based on a mean power of -50 dBm/MHz/s). In that case, an average mean power of -50 dBm/MHz implies that compatibility is achieved for EESS and SRS, space earth stations.

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*I/N = -10dB for „all scenarios“ and I/N = -20dB for „most scenarios“.*

*However the simulation made for this study have also considered a combination of the peak and mean e.i.r.p. permitted within the flexibility of the new limit proposal, while ECC Report 23 considered only the mean power effect.*

**EESS and Radioastronomy in the band 23.6-24 GHz**

The compatibility of SRR 26 GHz with EESS passive was investigated by ECC in detail. It was agreed that the following limits would fulfil the protection requirements of EESS passive:

- a) Direct emission limit in the main beam will not exceed -73 dBm/MHz e.i.r.p.
- b) Additional average antenna attenuation above 30° elevation to be separately measured will be at least 20 dB.

Radio compatibility issues between SRR and the radio astronomy service (RAS) in the band 23.6-24 GHz were not studied in detail, because it has been assumed that the limit derived for the protection of the earth exploration-satellite service (passive), would also be sufficient for the protection of the RAS.

In addition, Decides-5 of Decision ECC/DEC/(04)10 for 24 GHz SRR defines a level of -74 dBm/MHz for the protection of the RAS without the necessity for a deactivation mechanism. Therefore, in addition to the constraint given in (b), the limit for the direct emissions was set to -74 dBm/MHz for the band 23.6-24 GHz to protect EESS passive and the RAS.

**Military systems**

Specific compatibility studies between SRR applications within 24-29 GHz and fixed or mobile military systems within 26.5-27.5 GHz have not been carried out because of lack of data for military systems, especially for expected future military systems. The frequency band 26.5-27.5 GHz has been identified as a harmonised military band for fixed and mobile systems in ERC Report 025 and also in the NATO Joint civil/military Frequency Agreement (NJFA) 2002 (“harmonised NATO band type 2”). It was assumed that the results of the compatibility studies on the fixed service may be applicable for some of the military systems.

**Compatibility conclusions**

In conclusion the limitation of the market penetration for SRR to about 10% may be considered in order to allow the deployment of 26 GHz UWB SRR with the proposed new limits given in the following Table 20.

SRR Frequency Range	24.25-27.5 GHz
Peak e.i.r.p.	-7dBm/50MHz (for iBW≥50MHz) or -7dBm - 20*log(50MHz / iBW) measured with RBW = iBW (for iBW<50MHz)
Mean e.i.r.p. @ 1MHz/1s	-50 dBm/MHz
Duty Cycle (DC)	2% to 10% per 50MHz and per sec
Additional limits in the band 23.6-24 GHz	Direct emission limit in the main beam : -74 dBm/MHz e.i.r.p.
	Additional average antenna attenuation above 30° elevation: 20 dB.
SRR Market penetration	10%

**DC** = Ton/(Ton + Toff) % per 50 MHz and per sec with:

Ton defined as the duration of a burst irrespective of the number of pulses contained.

Toff defined as the time interval between two consecutive bursts when the UWB emission is kept idle.

**iBW** = instantaneous bandwidth of each single pulse, defined to be the inverse of the pulse duration.

**Table 20: limits for SRR at 26 GHz**

## ANNEX 1 : SINGLE CAR ENTRY ANALYSIS

Unlike the more recent ECC Report 64 [24] “*The protection requirements of Radiocommunication systems below 10.6 GHz from generic UWB applications*”, ECC Report 023 [1] does not contain an “introductory” evaluation of “single-car entry” interference impact on the victim service.

This is of utmost importance when mitigation factors to the aggregation of large number of devices are drawn. Those mitigations cannot physically result in an aggregated interference lower than that produced by a “single-car entry” interference.

From this basis, further aggregation studies might only add additional data on the potential interference enhancement. However, as all “statistical” evaluations they can only offer a “degree of confidence” that, from the single entry starting point, can never reach 100 %.

### A.1.1 SCENARIO AND “SINGLE-CAR ENTRY” EVALUATION

Unlike the “aggregation” case, where ECC Report 023 [1] has taken care of FS deployments potentially highly impacted by aggregation derived from traffic-jammed segments of highways parallel to the FS links, the “single-car entry” situation may happen in any deployment situation, in particular also with a SRR sensor along the bore-sight direction of the radio link. This situation is exemplified in **Error! Reference source not found.** where an high traffic road crosses the path of a radio link; single cars are continuously crossing the path where the antenna gain is maximum, generating the same effect of a continuous interference.

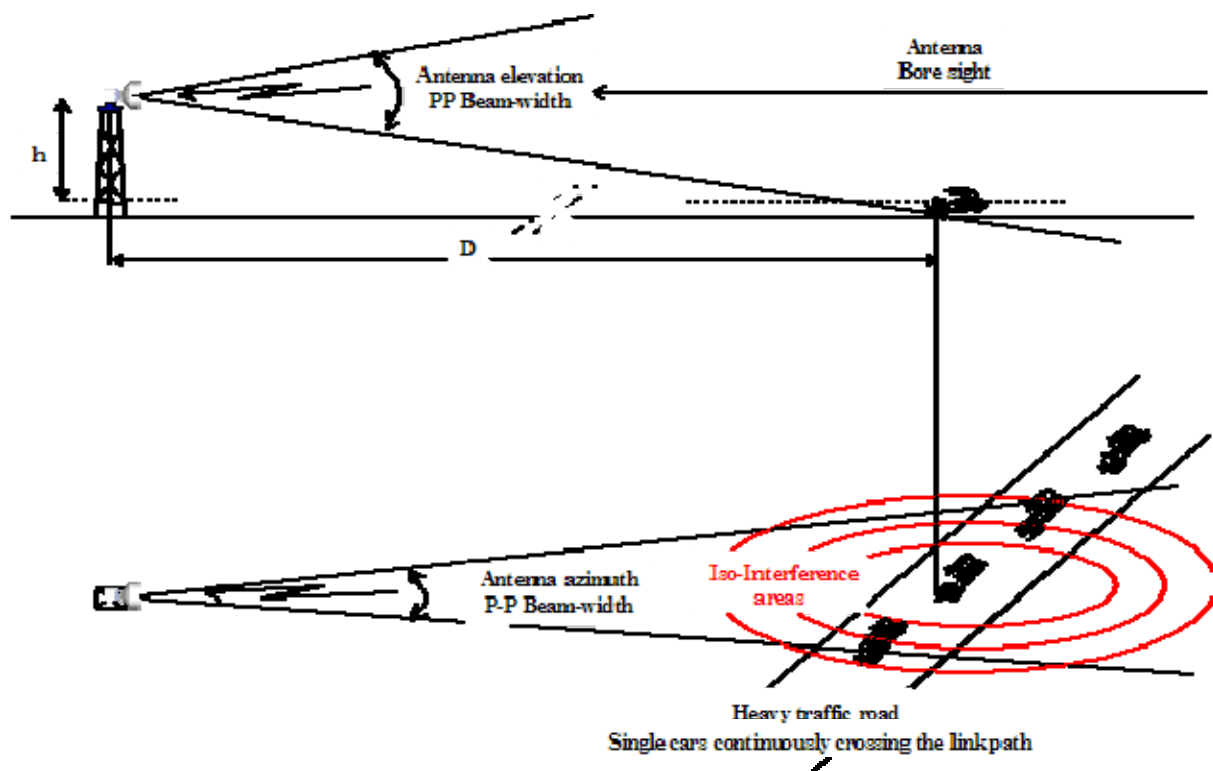


Figure 16: “single-car entry” generic interference scenario

ECC Report 023 considered FS antenna height ranging down to a minimum of 10 m.

Figures A12 to A1.3 show, for antenna height 10, 20 and 30 m, respectively, the interference generated by a single SRR sensor, with the following assumptions:

- $-41.3$  dBm/MHz e.i.r.p., in free space condition as function of the antenna size and distance  $D$ . This is equivalent to considering a single “average car” (described in both ECC Report 023 [1] and Report ITU-R SM.2057 [6] as having 4 SRR, two in the front and two in the back corners of the

car) that in the generic scenario of Figure always shows two SRR, which are attenuated by 3 dB due to the average bumper losses (Report SM.2057 assumption).

- According ECC Report 023, the interference objective level is assumed  $-128$  dBm/MHz.
- FS antenna RPE and gain is taken from Recommendation ITU-R F.699 [25].
- A specific attenuation of 0.6 dB/km (minimum adopted by both ECC and ITU-R reports) due to rain correlation between wanted and unwanted paths has been introduced.
- The specific attenuation is an average value evaluated on the basis of ITU-R Recommendations P.452 [26] and P.530 [27], which shows, depending on the hop length and rain cell relative position, a variation from 0.1 to 3.7 dB/km. The evaluation was made for 23 GHz and for rain rate 28 mm/h (the latter being not the worst case because links subject to lower rain rate are more critical). In principle the extension to 26 GHz is proportional (in dB) to the variation of the  $\gamma_R$  parameter (in P.838 [27]). The variation is evaluated as 25% to 30%; therefore, the assumed 0.6 dB/km should become  $\sim 0.8$  dB/km with an estimated improvement of  $\sim 0.5$  dB over the aggregation and far less for “single-car entry” (effective since  $\sim 1$  km or even less); these variation is negligible in term of margin degradation. In conclusion, no sensible variation can be obtained from the change of frequency band.
- SRR antenna elevation RPE “future” more stringent option (i.e.  $-0.86$  dB/degree or  $-35$  dB max).

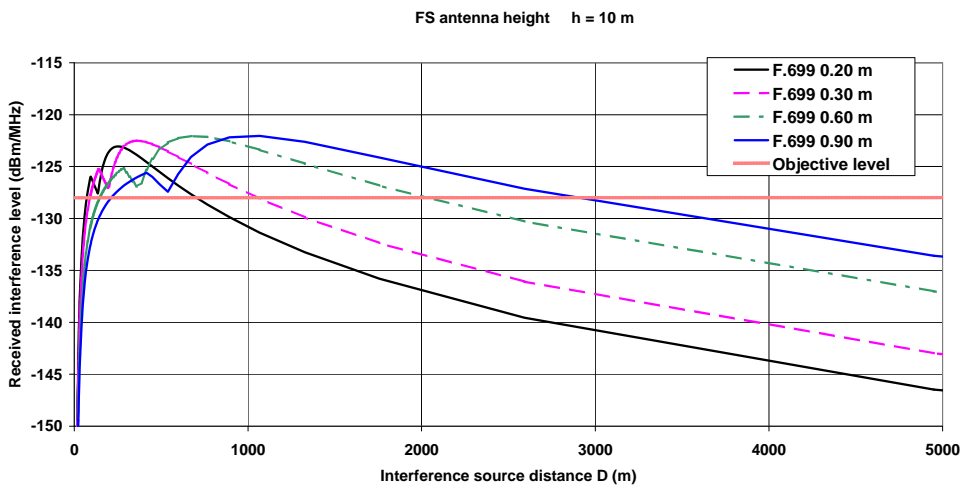


Figure 17: 26 GHz “single-car entry” interference with FS antenna height = 10 m

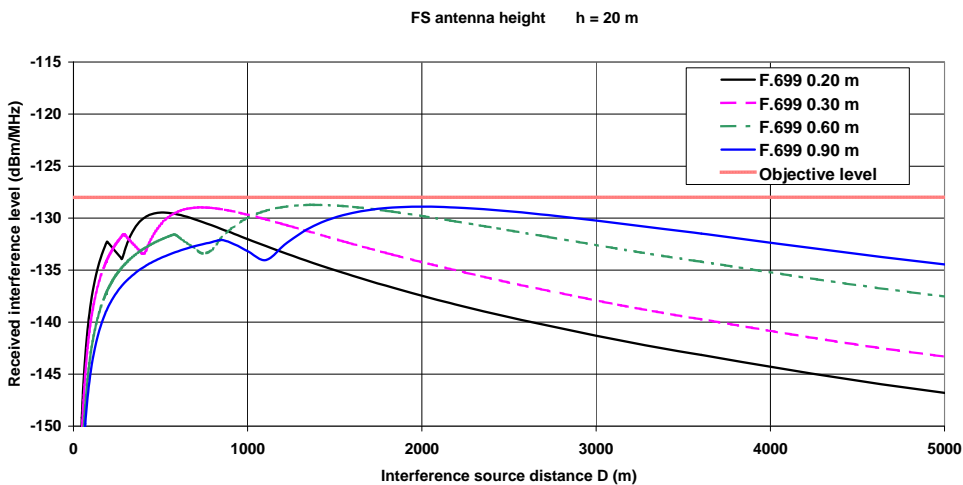


Figure 18: 26 GHz “single-car entry” interference with FS antenna height = 20 m

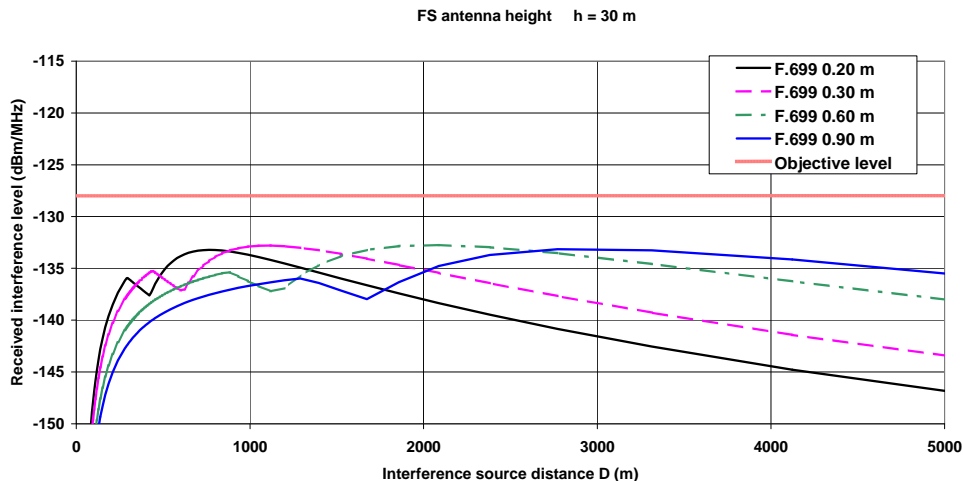


Figure 19: 26 GHz “single- car entry” interference with FS antenna height = 30 m

It should be noted that, with reference to Figure 19, at the distance where the interference is maximum the antenna main lobe encompasses an iso-interference area of  $\sim 30$  m width, which is of the same order of magnitude of the expected distance between cars in most traffic situations. This further supports the assumption that the “single-car entry” case may be considered a continuous interference situation.

In section A1.2 a more close comparison at 23 GHz is made.

## A1.2 COMPARISON OF SINGLE ENTRY DATA IN REPORT ITU-R SM.2057

### A1.2.1 Abstract from annex 2 of Report ITU R SM.2057

#### Single car interference

“

For final evaluation of the aggregate interference, it might be helpful having interference level data also from a “single car” placed along side the main beam (e.g. for P-P in a  $\sim 1^\circ$  beam area of  $\sim 0.2$  km<sup>2</sup> when considering that the interference level is contained within  $\sim 5$  dB for SRR distances up to 3 km or more from the FS antenna).

In this case the interference source is not bounded to any road nearby; interference might come from any car on any road within the beam area that appear to be in LoS with the FS antenna.

Each car, independently from the actual orientation of the road in respect to the FS link, will show at least two sensors to the victim, the 3 dB bumper loss will balance the two sensors aggregation.

The interference from single car may represent a “lower bound” for the “P-P along highway worst-case”; any mitigation parameters on that scenario if resulting in aggregate interference lower than the above-mentioned additional scenario would not be relevant to the interference study.

The interfering power density from a single car (two visible sensors and bumper loss included), at a distance  $D$  from the victim receiver, is given in Figs. 209 and 210 for the FWA CS and P-P cases, respectively.

“

...

“

Figure 210 shows that, in case the 24 GHz SRR will use a long-term e.i.r.p. density of  $-41.3$  dBm/MHz, the following conclusions may be derived:

- one single car (even with 20 m height P-P antenna), may already give interference power that almost reaches the overall limit, so giving no allowance for any aggregation effect;
- evaluation with P-P FS antenna height = 10 m give  $\sim 10$  dB worse result, but the probability of LoS situation might not be relevant.

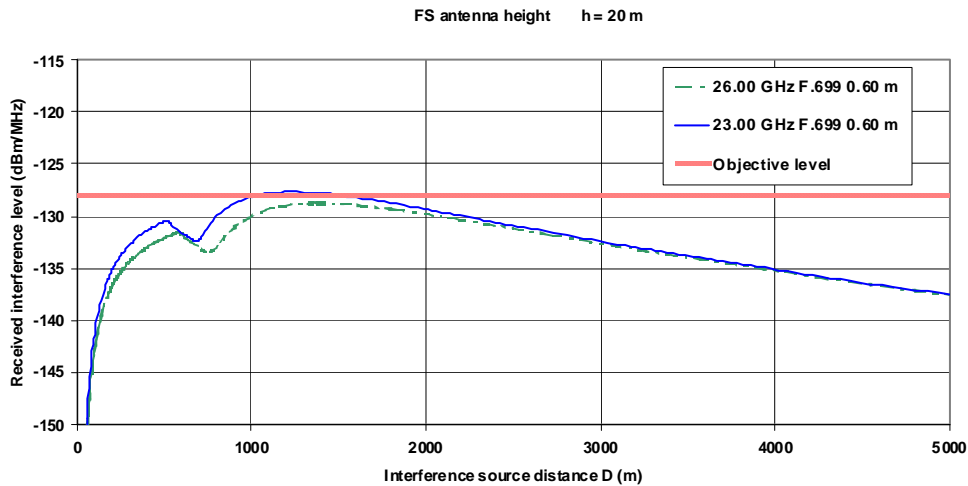
”

**A1.2.2 Comparison with new detailed re-calculations**

When comparing the specific results in Figure 18 and Figure 19 with Figure 210 in SM.2057, we note two significant differences, not justified by the mere difference (23/26 GHz) in frequency band (see Figure 20).

- The interference values for 20 m FS height is ~3 to 4 dB higher than those in Report ITU-R SM.2057 (maximum -127.5 vs -131 dBm/MHz and -132 vs -136 dBm/MHz at 3000 m distance).
- The increase between Figure 18 and Figure 17 from 20 to 10 m FS height is ~ 7 dB while Report ITU-R SM.2057 claims to be 10 dB, but does not show a graphic for 10 m.

The only explanation may be that different assumptions, not specifically identified, has been made in Report ITU-R SM.2057. Some more detailed investigation is here carried on with closer comparison at 23 GHz.



**Figure 20: Comparison between FS an23 and 26 GHz for FS antenna height = 20 m**

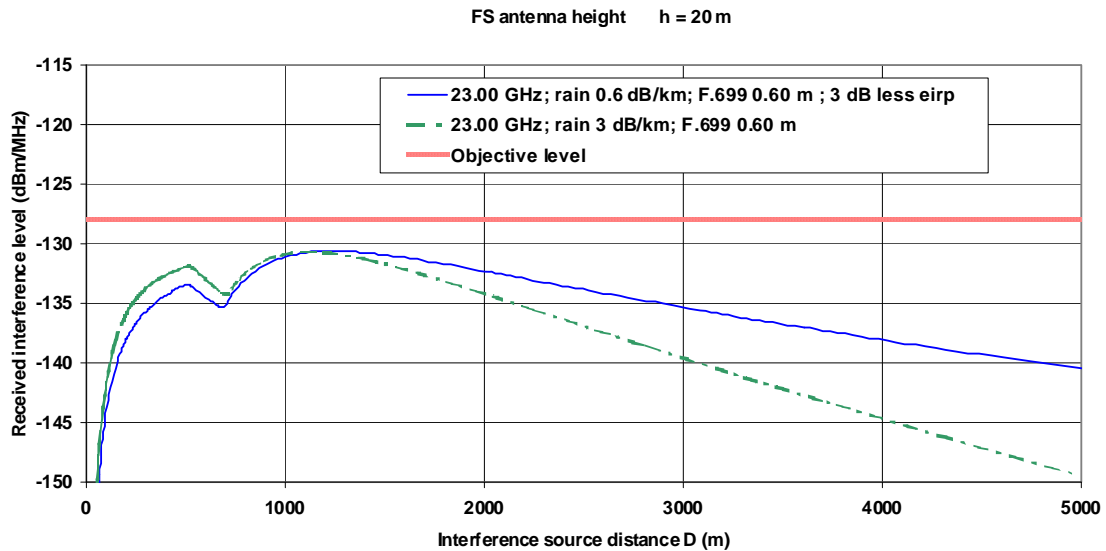
A comparison of the input data of the two cases is shown in Table 21.

Parameter	Re-calculation in this report	SM.2057	Notes
FS Centre frequency	23.00 GHz	See the note	Variance in the band 22-23.6 GHz is $\sim \pm 0.5$ dB
FS/SRR differential height	19.5 m	19.5 m	0.5 m is the conventional SRR height
FS antenna gain	41 dBi	41 dBi	Coherent with F.699
FS antenna RPE	F.699	F.699	For 0.6 m
SRR antenna elevation pattern	0.86 dB / degree	0.66 dB / degree	The 0.66 dB is the most likely used in SM.2057 but no definite statement is present. However, SM.2057 recognise that SRR RPE is “absolutely negligible” on FS interference
Rain correlation attenuation	0.6 dB/km	See the note	SM.2057 gives a range from 0.6 to 3 dB/km, for case 1 study the 0.6 dB/km should be used but 3 dB/km was also used for comparison. In addition 2 dB/km was used for case 2 study. There is no definite evidence on which one was used for the unique “single entry” evaluation (the most likely should still be 0.6 dB/km).
SRR number/Bumper loss	2 SRR / 3 dB	2 SRR / 3 dB	Cross check with SM.2057 actual graphic implementation likely shows 3 dB error in SM.2057 input data.

**Table 21: Parameters used for single-car entry evaluation**

The possibility of varying ~ 3 dB on the maximum interference may derive either from the rain intensity (i.e. 0.6 to 3 dB/km or by an error of 3 dB deriving from mixing up the number of SRR (1 or 2) and the bumper losses (3 dB).

Figure 21 shows the comparison of these two possibility; as it can be seen, while both possibility fit with the maximum of the interference shown in SM.2057, only the 3 dB e.i.r.p. reduction (solid blue curve) fits the whole SM.2097 curve (e.g. at 3000 m and at ~ 500 m). In addition, this also explain the 10 dB variation that SM.2057 claims from 20 m to 10 m FS antenna height (at that time, the 10 m and 20 m calculations were made by two different organisations), aligning the relative difference to 7 dB.



**Figure 21: Comparison between rain attenuation 0.6 and 3 dB/km (23 GHz antenna height = 20 m)**

From the above analysis, it has been assumed that the graphs in Report ITU-R SM.2057 [6] underestimate by 3 dB the potential interference of “single car” generically placed along the boresight of the PP link. The error in Figure 210 of Report ITU-R SM.2057 probably lays in the mixing up, in the graph, the 3 dB bumper losses and the claimed aggregation of two SRR per car clearly explained in the SM.2057 text. This would also align the difference from 10 to 20 m FS antenna height to the 7 dB shown in the re-calculation made for this report.

## ANNEX 2

: FURTHER ANALYSIS ON AGGREGATION IMPACT

A2.1 IDEAL AGGREGATION

The impact of the ideal geometrical position, length and the angular direction of the road in respect to the FS link has been analyzed with more detailed parameters variance according Figure 22.

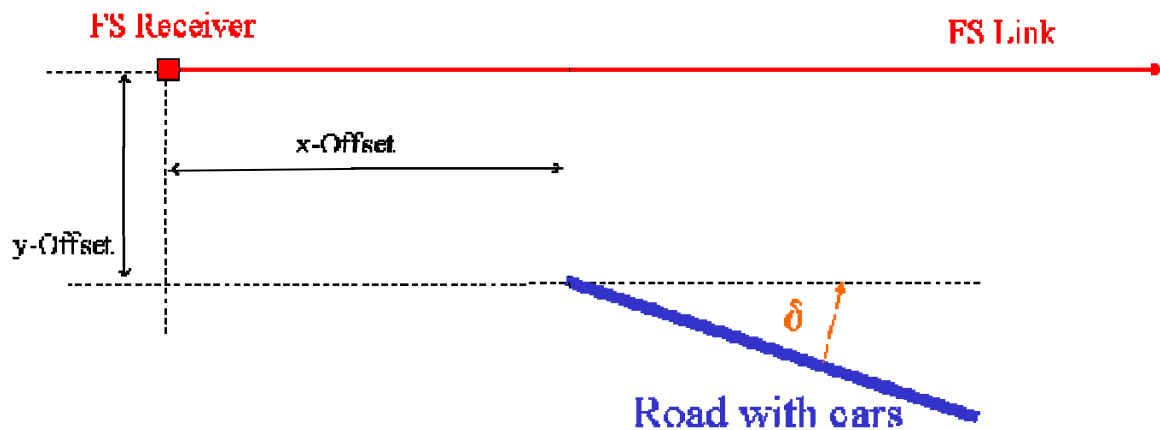


Figure 22: Parameters for the geographical impact evaluation

The basic constant assumptions for this detailed analysis are the same of Report 023:

- SRR power level -41.3 dBm/MHz e.i.r.p.
- Bumper loss 3dB
- Car length 4m
- Car width 2m (one sensor at the left side and one at the right side)
- Gating (activity factor) 100%
- Shadowing is just assumed for the left sensor, the right one has LOS conditions
- shadowing model from ECC Report 023 [1]
- 1 single lane
- Radar height over ground 0.5m
- Car height 1.5m (relevant just for the shadowing of the left sensor)
- FS antenna pattern from ITU-R F.1245-1 [23]
- FS max antenna gain 41 dBi
- FS antenna diameter 0.65m
- FS interference objective -128 dBm/MHz

In addition, the worst case parameters regarding cars distance in the lane (20 m) and rain attenuation on the interference path (0.6 dB/km) have been fixed.

f	X offset	Y offset	$\delta$	hrx		Road length	Interference exceeds the objective of $I_{max}=-128$ dBm/MHz by X dB
Worst case Scenario ECC Report 023 and ITU-R SM.2057							
23 GHz	0	10m	0°	10m		3km	18 dB
			-10°				-2.5 dB
			+10°				-8.7 dB
Other frequency and angle (-0.5° is the worst case for the offset of 10m)							
26 GHz	0	10m	0°	10m		3km	16.2 dB
			-0.5°				18 dB
Other x offset							
26 GHz	0m	10m	0°	10m		3km	16.2 dB
	500m						16.25 dB
	1000m						15.5 dB



	2000m							12.4 dB
Shorter roads								
26 GHz	500m	10m	0°	10m			3km	16.25 dB
							2km	15.47 dB
							1km	13.07 dB
							500m	9 dB
							300m	5.4 dB
							100m	-0.9 dB
Shorter roads with another angle								
26 GHz	500m	10m	0°	10m			300m	5.4 dB
			-1°					8 dB
			-3°					10.1 dB
			-4°					9.8 dB
			-10°					5.6 dB
			-45°					-2.3 dB
			1°					3 dB
			4°					0.3 dB
			10°					-2.4 dB
26 GHz	1000m	10m	0°	10m			300m	8.6 dB
			-5°					9.8 dB
			-6°					9.4 dB
			-10°					7.6 dB
			-45°					2 dB
			1°					7.7 dB
			4°					4.5 dB
			10°					1.4 dB
Other antenna height and angle								
26 GHz	1000m	10m	0°	18m			300m	3.8 dB
			-5°					4.9 dB
			-6°					4.4 dB
			-10°					2.4 dB
			-45°					-3.5 dB
			1°					2.7 dB
			4°					-0.5 dB
			10°					-3.1 dB
Other offset								
26 GHz	1000m	10m	0°	18m			300m	3.8 dB
26 GHz	1000m	20m	0°	18m			300m	-1.5 dB
			-5°					4.1 dB
			-6°					4.2 dB
			-10°					3 dB
			-45°					-3.2 dB
			1°					-2.5 dB
			4°					-4.2 dB
			10°					-6.4 dB

**Table 22: Summary of aggregation variance with geometrical parameters**

## A2.2 THE GEOGRAPHICAL IMPACT OF SRR ON EXISTING FS LINKS IN GERMANY

This annex reports the practical results of the detailed evaluation of the “critical links” identified by the investigation of about 28.000 FS stations (about 14.000 links) in the frequency range between 24-29 GHz described in section 2.2.2. The most critical links are presented and the aggregated impact from SRR inline with the worst case ECC Report 023 scenario calculated.

Link A

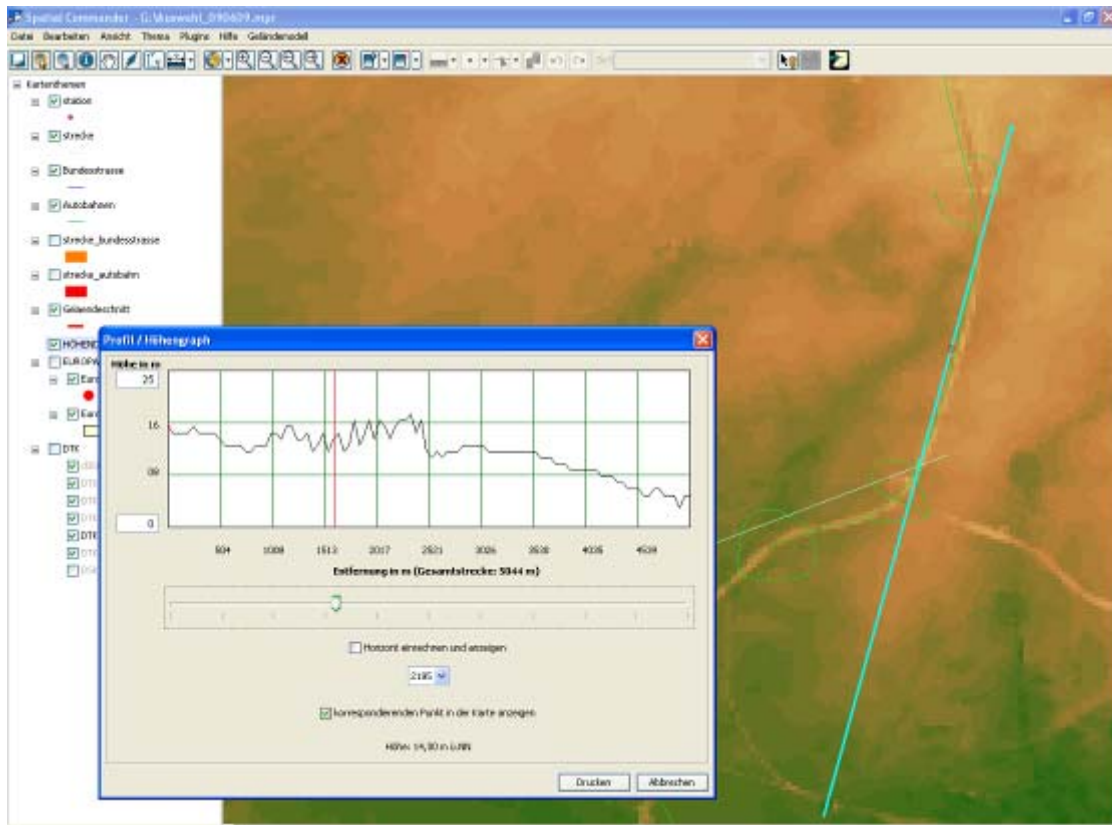


Figure 23: Link A - h= 18,5m; d: 50m; crossing: 1000m and 2500m; elevation 0.19°

f	X offset	Y offset	$\delta$	hrx	Car distance	Rain att.	Road length	Interference exceeds the objective of $I_{max} = -128$ dBm/MHz by X dB
25 GHz	1km	0m	-4°	18.5 m	20m	0.6dB /km	800m	+4.6 dB
	1.8km	50m	+4°	18.5 m	20m	0.6dB /km	800m	-7.3 dB
							sum	+4.8 dB

Table 23

**Result:**

Assuming a flat vertical road profile this scenario exceeds the interference objective by about **5dB**  
The vertical profile of the road in the critical distance range is nearly flat ( $\pm 4$ m) but changes several times about 3m in height over 100m length; due to this **some additional dB** may be expected (shadowing) as additional mitigation

**Objective exceeded by less than 5dB**

Link B

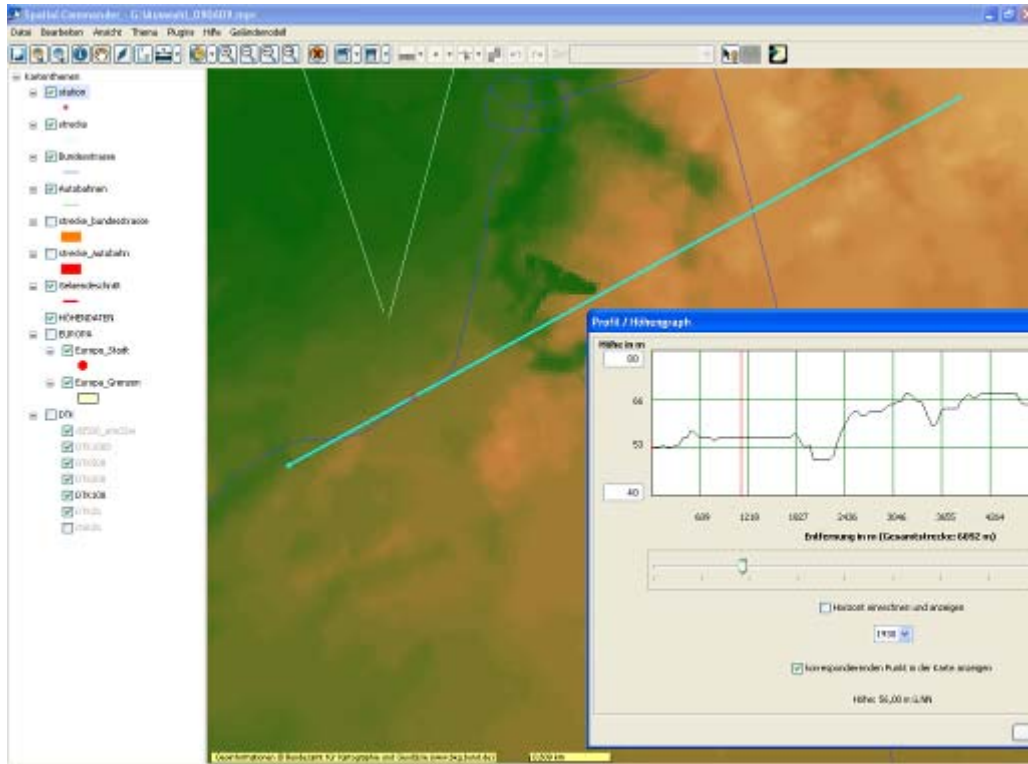


Figure 24: Link B - h= 10m; crossing; 500m, 1300m; elevation: 0.98°

F	X offset	Y offset	$\delta$	hrx	Car distance	Rain att.	Road length	Interference exceeds the objective of $I_{max} = -128$ dBm/MHz by X dB
25 GHz	350m	-75m	16°	10m	20m	0.6dB /km	500m	+4.6 dB
	600m	75m	-4°	10m	20m	0.6dB /km	1000m	+6 dB
							sum	+8.4 dB

Table 24

**Result:**

Assuming a flat vertical road profile this scenario exceeds the interference objective by about **8dB**  
 The vertical profile of the road in the critical distance range is nearly flat; but the FS antenna has a elevation of about 1° (up-tilt) with an expected mitigation of **at least 3dB** compared to the 0° elevation  
**Objective exceeded by less then 5dB**

Link C

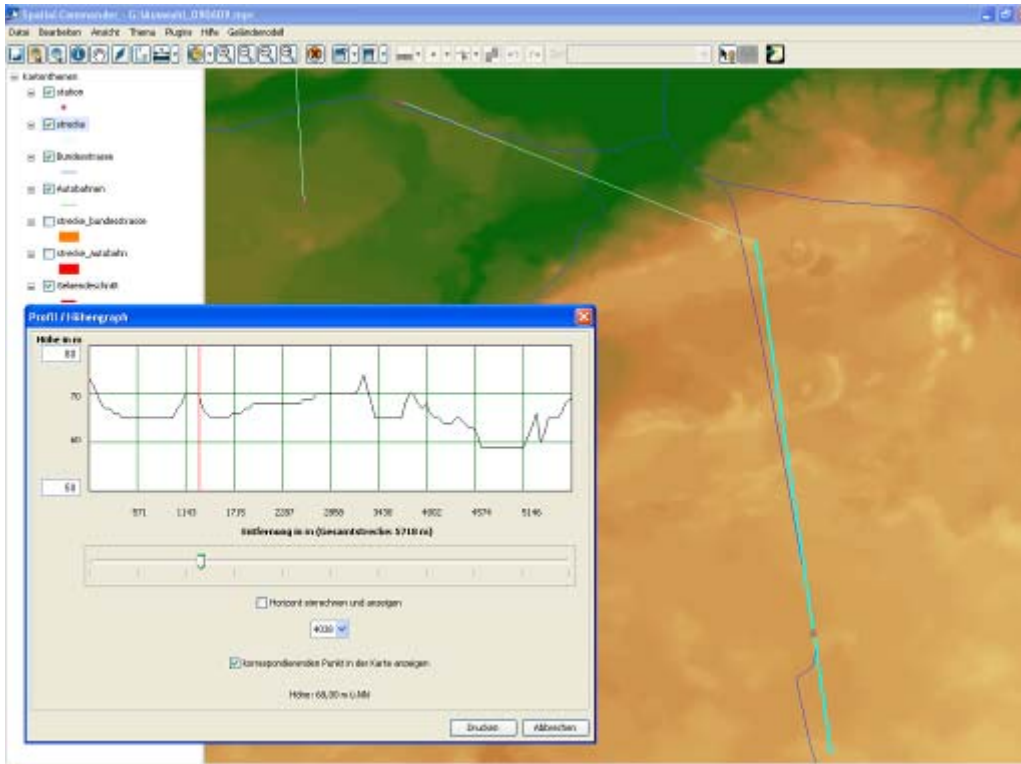


Figure 25: Link C- h= 6m; crossing: 1200m; elevation: 0.48°; Y-Offset at the end 150m

f	X offset	Y offset	$\delta$	hrx	Car distance	Rain att.	Road length	Interference exceeds the objective of $I_{max} = -128 \text{ dBm/MHz}$ by X dB
25 GHz flat	1200m	0m	2.3°	6m	20m	0.6dB /km	3800m	+12.7 dB
							sum	+12.7 dB
25 GHz adjusted	2000m	50m	2.3°	6m	20m	0.6dB /km	1000m	-4.7 dB

Table 25

**Result:**

Assuming a flat vertical road profile this scenario exceeds the interference objective by about **13 dB**. The vertical profile of the road in the critical distance range is not flat; LOS conditions to the FS receiver is just expected in distances between 2000m and 3000m; at 2km distance the Y Offset is about 50m; without taken into account the FS antenna elevation the interference objective is fulfilled even with a positive margin of about 5dB. **Objective fulfilled**

Link D

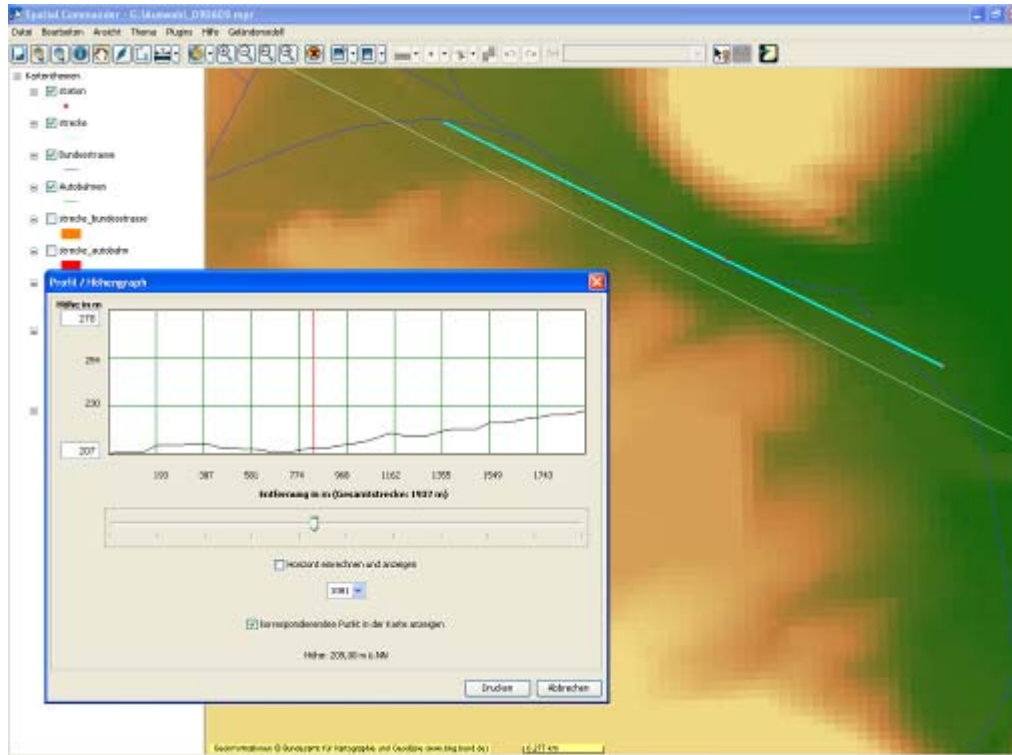


Figure 26: Link D- h= 18,7m; crossing 700m; elevation: 1,57°; Y-Offset at the end 50m

F	X offset	Y offset	$\delta$	hrx	Car distance	Rain att.	Road length	Interference exceeds the objective of $I_{max}=-128$ dBm/MHz by X dB
25 GHz flat	700m	0m	3.2°	18.7m	20m	0.6dB /km	900m	+2.7 dB
							sum	+2.7 dB

Table 26

**Result:**

Assuming a flat vertical road profile this scenario exceeds the interference objective by about **3 dB**. An additional mitigation of about 3dB is expected from the FS antenna elevation of 1.7° which is higher than the road inclination of about 0.6° (due to the rising road level with about 20m/2000m=0.6° in relation to the FS antenna elevation of 1.6°).

**Objective fulfilled**

Link E

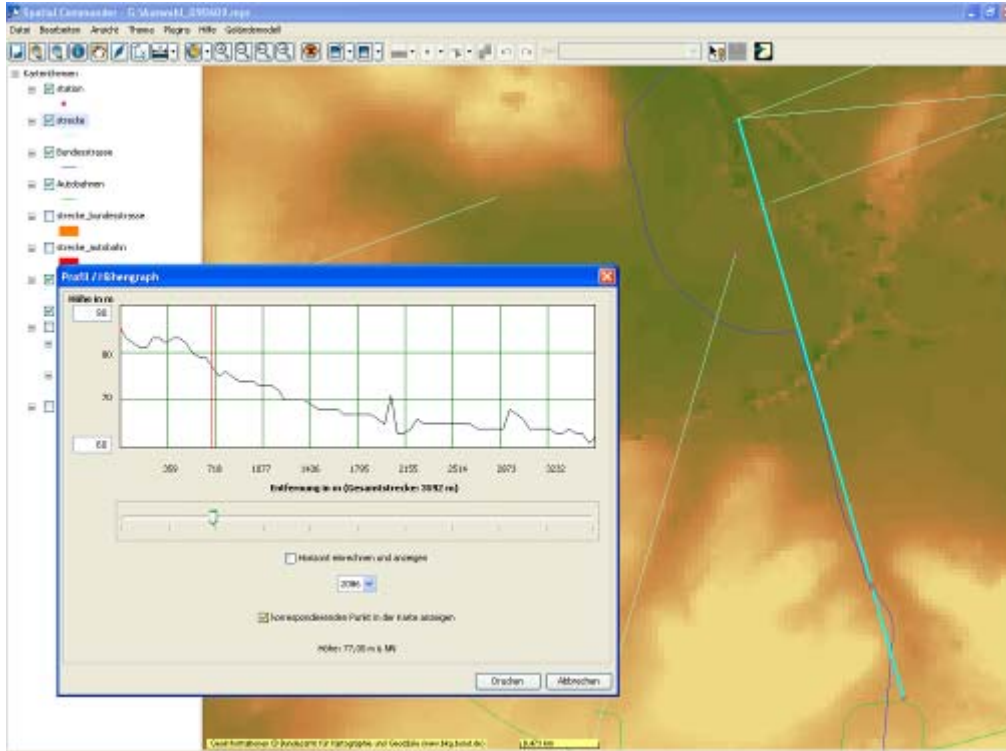


Figure 27: Link E- h= 19m, crossing 700m; Elevation 0.51°

f	X offset	Y offset	$\delta$	hrx	Car distance	Rain att.	Road length	Interference exceeds the objective of $I_{max}=-128$ dBm/MHz by X dB
25 GHz flat	700m	0m	-5.7°	19m	20m	0.6dB /km	500m	-0.2 dB
25 GHz flat	1300m	-50m	+2.9°	19m	20m	0.6dB /km	1000m	+6.3 dB
							sum	+7.2 dB

Table 27

**Result:**

Assuming a flat vertical road profile this scenario exceeds the interference objective by about **7 dB**

An additional mitigation of at least 3dB is expected from the FS antenna elevation of 0.51° which is higher than the road inclination of about -0.7° (due to the decreasing road level with about 20m/2000m=-0.7° in relation to the FS antenna elevation of 0.51°).

**Objective exceeded by less than 4dB**

Link F

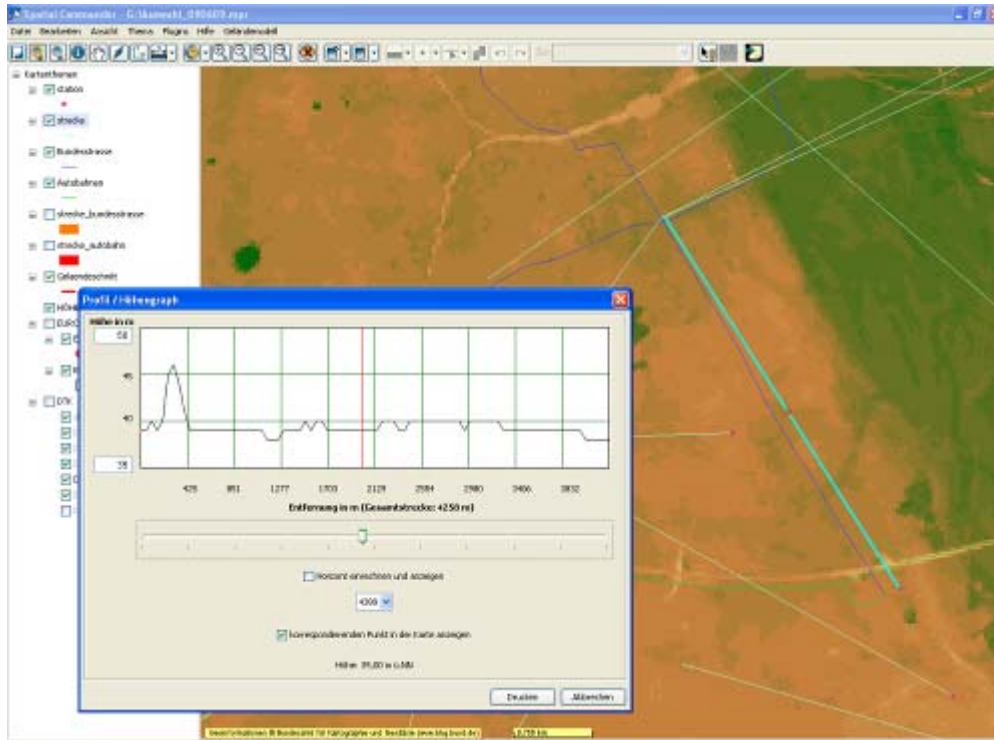


Figure 28: Link F - h= 19m; d: 150m; elevation: 0,36°

F	X offset	Y offset	$\delta$	hrx	Car distance	Rain att.	Road length	Interference exceeds the objective of $I_{max} = -128$ dBm/MHz by X dB
25 GHz flat	0m	150m	-1.3°	19m	20m	0.6dB /km	4200m	+0.2 dB
							sum	+0.2 dB

Table 28

**Result:**

Assuming a flat vertical road profile this scenario exceeds the interference objective by about 7 dB  
Objective is fulfilled



Link G

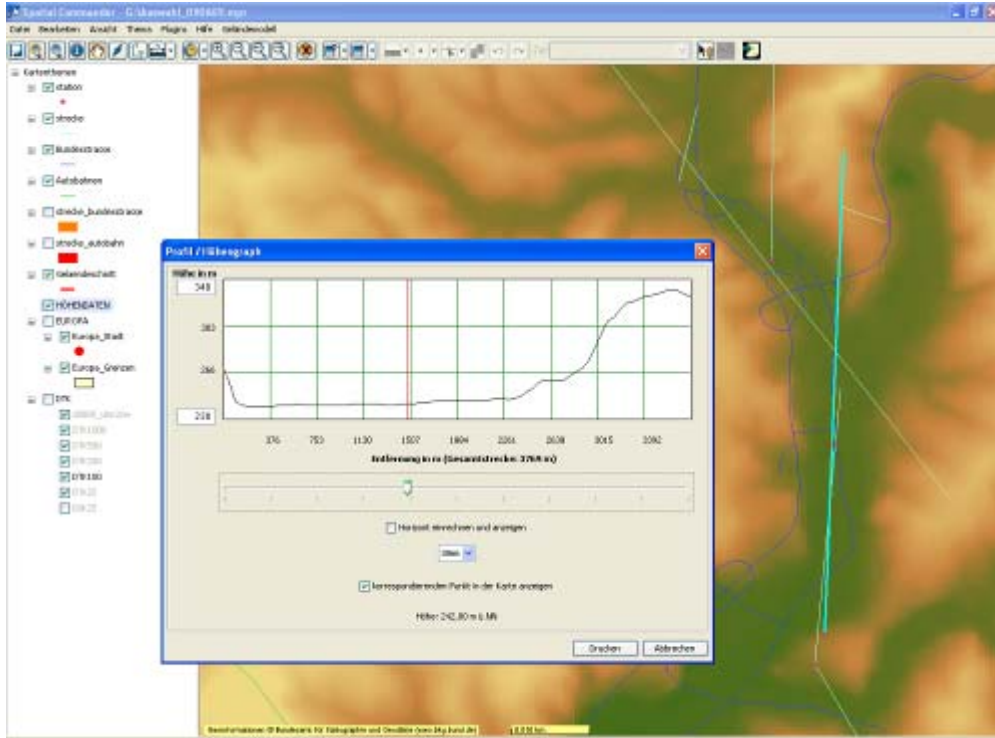


Figure 29: Link G - h= 17m; elevation: 1,34°

f	X offset	Y offset	$\delta$	hrx	Car distance	Rain att.	Road length	Interference exceeds the objective of $I_{max}=-128$ dBm/MHz by X dB
25 GHz flat	1500m	0m	0°	17m	20m	0.6dB /km	1300m	+11.6 dB
							sum	+11.6 dB
25 GHz	1500m	0m	0°	37m	20m	0.6dB /km	1300m	+4.7dB

Table 29

**Result:**

Assuming a flat vertical road profile this scenario exceeds the interference objective by about **12 dB**

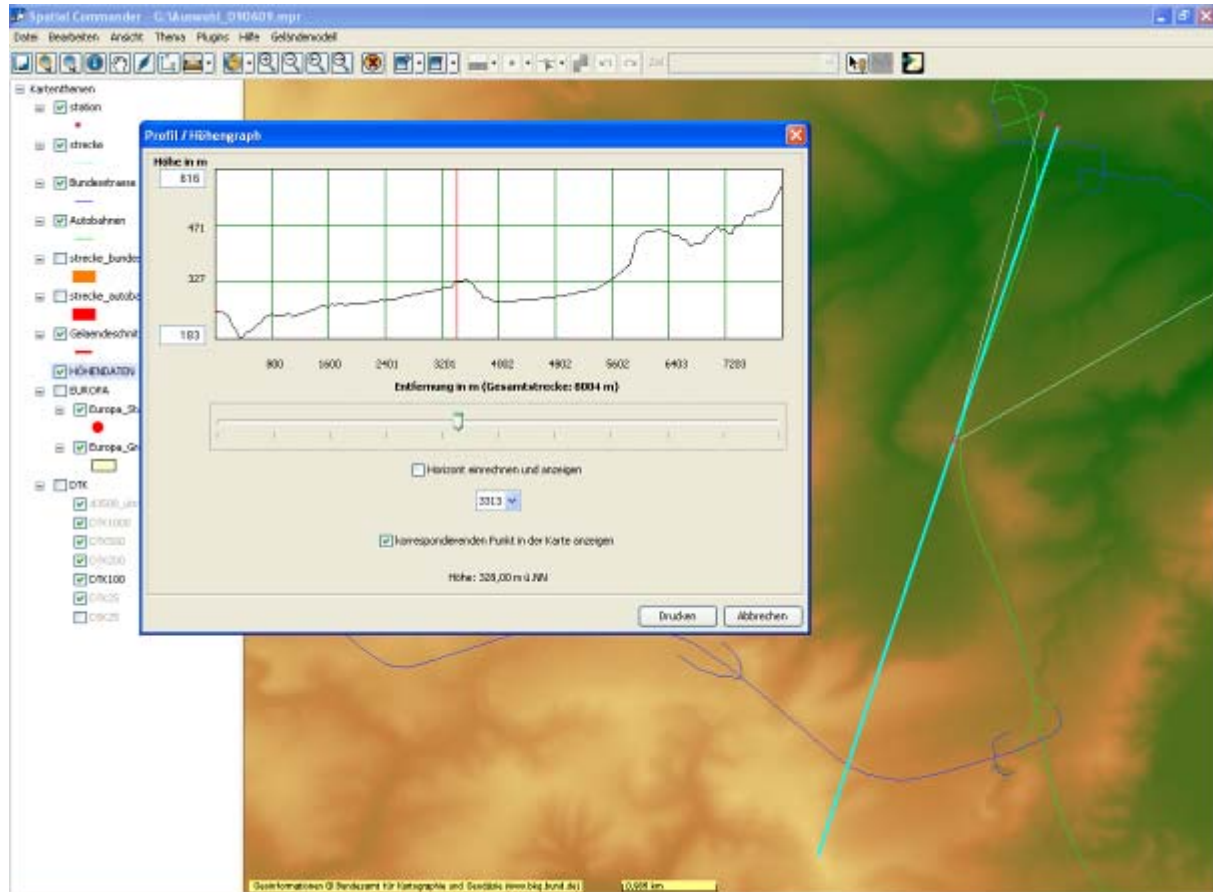
The critical road section is at elevation levels about 20m below the FS receiver; therefore the FS receiver height in this case has a virtual height of about 37m above the relevant road section; this gives an **mitigation of about 7dB**

An **additional mitigation of about 3dB** is expected from the FS antenna elevation of 1.34° which is higher than the road inclination of about 0.3° (due to the increasing road level with about 10m/2000m=0.3° in relation to the FS antenna elevation of 1.34°).

**Objective fulfilled**



## Link H

Figure 30: Link H –  $h = 11,4\text{m}$ ; crossing 700m and 3400m; elevation:  $2,67^\circ$ 

F	X offset	Y offset	$\delta$	hrx	Car distance	Rain att.	Road length	Interference exceeds the objective of $I_{\text{max}} = -128 \text{ dBm/MHz}$ by X dB
25 GHz flat	700m	0m	$-3.6^\circ$	11.4m	20m	0.6dB /km	800m	+8.7 dB
25 GHz flat	1500m	-50m	$+1.5^\circ$	11.4m	20m	0.6dB /km	1900m	+9.0 dB
							sum	+11.9 dB
25 GHz	700m	0m	$-3.6^\circ$	44m	20m	0.6dB /km	800m	-6 dB
25 GHz	1500m	-50m	$+1.5^\circ$	44m	20m	0.6dB /km	1900m	+2.5 dB
							sum	+3 dB

Table 30

**Result:**

Assuming a flat vertical road profile this scenario exceeds the interference objective by about **12 dB**

The beginning of the critical road section at 700m distance is at the same elevation level as the FS receiver; with this the height of the FS link at 700m distance from the receiver is virtually about 32m higher ( $700\text{m} \cdot \tan 2.67^\circ$ ); therefore the FS receiver height in this case has a virtual height of about 44m ( $11.4 + 32.6\text{m}$ ) above the beginning of the relevant road section; this gives an **mitigation of about 9dB**

An **additional mitigation of about 3dB** is expected from the FS antenna elevation of  $2.67^\circ$  which is higher than the road inclination of about  $1^\circ$  (due to the increasing road level with about  $50\text{m}/2700\text{m} = 1^\circ$  in relation to the FS antenna elevation of  $2.67^\circ$ ).

**Objective fulfilled**

Link I

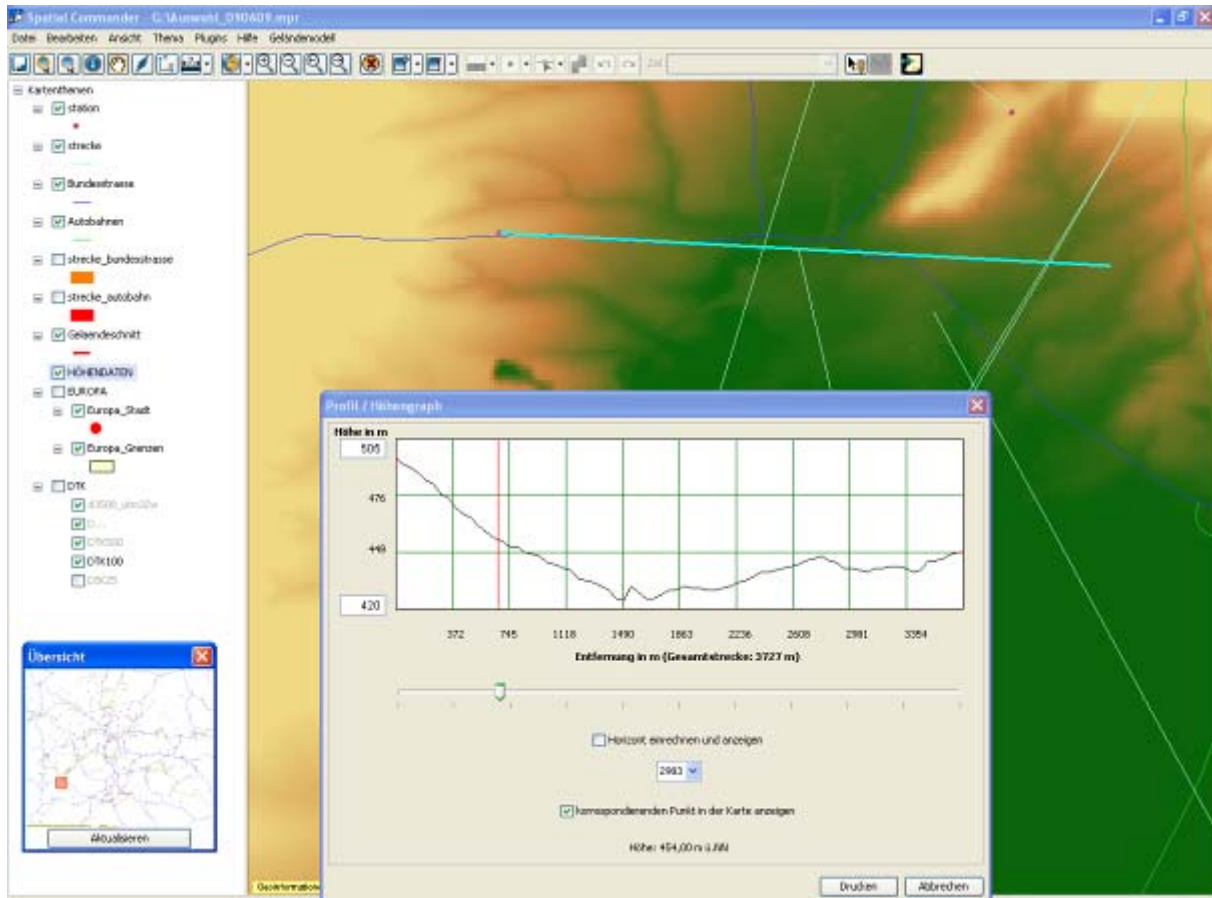


Figure 31: Link I - h: 7m; elevation: -0,46°

f	X offset	Y offset	$\delta$	hrx	Car distance	Rain att.	Road length	Interference exceeds the objective of $I_{max} = -128$ dBm/MHz by X dB
25 GHz flat	0m	0m	0°	7m	20m	0.6dB /km	1300m	+19.5 dB
							sum	+19.5 dB
25 GHz	0m	0m	2.5°	7m	20m	0.6dB /km	1300m	+5.5 dB

Table 31

**Result:**

Assuming a flat vertical road profile this scenario exceeds the interference objective by about **20 dB**. An **additional mitigation of about 14dB** is expected from the FS antenna elevation of  $-0.46^\circ$  which is higher than the road inclination of about  $-31^\circ$  (due to the decreasing road level with about  $70m/1300m = -3^\circ$  in relation to the FS antenna elevation of  $-0.46^\circ$ ). Here the virtual angle between road and FS link is  $-2.5^\circ$ . **Objective exceeded by about 5 dB**

**Summary**

For the worst case links in Germany the interference objective for the protection of the FS is exceeded with maximum 5 dB compared with the 20 dB from existing studies.

**ANNEX 3 : IMPACT ON FS PROTECTION OBJECTIVES (RMS AND WIDE-BAND PEAK)  
BACKGROUND AND EVALUATION**

**A3.1 ECC REPORT 023 TEST CAMPAIGN FINDINGS ANALYSIS**

UWB SRR emissions were of pulsed type with a spectral emission content characterised by multiple-lines spaced by PRF. Besides the different pulse duration and PRF, the emission characteristics and the basic considerations about their effect on FS receivers should be considered equivalent to those of any pulsed radar.

Those tests had demonstrated that the impact on the FS receiver can be reduced to the simple noise-floor increase due to the rms content of the SRR emission related to the assumed I/N ratio, provided that the peak of the interfering signal within the wide-band FS receiver does not exceed a certain value.

In practice it was estimated that the interference may be assumed noise like until the ratio:

$$\rightarrow (I_{\text{Peak}}/50 \text{ MHz})/(I_{\text{rms}}/1\text{MHz}) < 42 \text{ dB}$$

Therefore, ECC/REP 023 (Section C.3.3.3) have set the two independent protection criteria for rms and peak interference levels:

$$\rightarrow I_{\text{rms}}/N_{\text{rms}} \leq -20 \text{ dB within 1MHz:}$$

rms densities ratio within 1MHz (which is the usual FS protection criteria for interference other than co-primary).

$$\rightarrow I_{\text{Peak}}/N_{\text{rms}} \leq + 5 \text{ dB within 50 MHz:}$$

Additional criteria for wide-band peaking protection; the  $I_{\text{Peak}}$  to  $N_{\text{rms}}$  ratio within 50 MHz, derived from the tests, equivalent an interference peak lower than the noise peak (band-limited Rayleigh distribution) for a probability  $p > \sim 4\%$ .

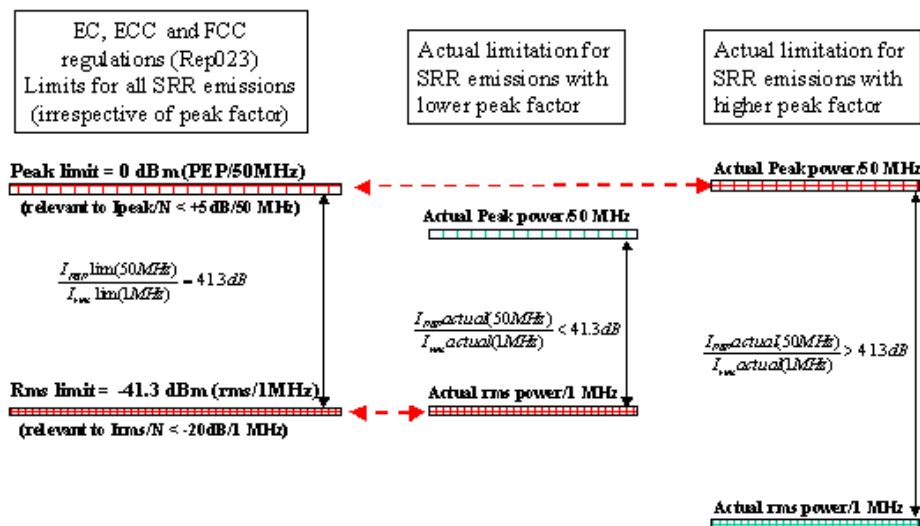
The above limits have been adopted also in all subsequent studies for UWB pulsed emissions compatibility with FS and resulted in confirming the initial FCC/NTIA studies and in the adoption by EC, ECC and ITU-R of the “generic” (i.e. when impact assessment permits) UWB and SRR power limitations:

$$\rightarrow \text{Power density (peak)} \leq - 0 \text{ dBm within 50 MHz}$$

$$\rightarrow \text{Power density (rms)} \leq - 41.3 \text{ dBm within 1 MHz}$$

These limits are considered “independent” objectives and applicable to UWB and SRR emissions with any peak factor. Depending on whether the ratio  $P_{\text{peak}}(50 \text{ MHz})/P_{\text{rms}}(1 \text{ MHz})$  is higher or lower than 41.3 dB, the first or the second becomes the most stringent

Figure 32 graphically show the above concept applied to UWB and SRR emissions.



**Figure 32: Interpretation of the dual limitation of pulsed SRR emissions**

In addition, it is evident from the test graphs C.2 and C.3 presented in Report 023 that, while the threshold degradation caused by excess “rms” interference only is “smoothly” increasing (power adding law), the degradation caused by excess “peak” interference only is “sharply” increasing reaching very soon a dB/dB behaviour.

### **A3.2 THEORY JUSTIFICATION**

#### **A3.2.1 Peak to rms ratio and PRF relationship**

SRR devices approaching both prescribed limits for rms and peak levels have a wide-band peak/rms ratio of:

$$\frac{P_{\text{peak}} | 50\text{MHz}}{P_{\text{rms}} | 50\text{MHz}} \cong \frac{P_{\text{peak}} | 50\text{MHz}}{P_{\text{rms}} | 1\text{MHz}} - 10\text{Log}50 = 0\text{dBm} - (-41.3\text{dBm}) - 10\text{Log}50 = 24.3\text{dB} \quad (1)$$

It can also easily demonstrated (comparing power and voltage sums of the spectral lines within 50 MHz bandwidth) that for pulsed UWB devices:

$$\frac{P_{\text{peak}} | 50\text{MHz}}{P_{\text{rms}} | 50\text{MHz}} \cong 10\text{Log}50 - 10\text{LogPRF} \quad (2)$$

from (1) and (2) we could derive that devices having “rms” impact only should have a PRF higher than a minimum:

$$10\text{Log}50 - 10\text{LogPRF} \leq 24.3 \text{ dB; i.e.}$$

$$PRF \geq 10^{\frac{-7.3}{10}} = 0.186 \text{ MHz} \quad (3)$$

Devices with lower PRF would mostly have “peak” impact only.

Please note that the above “time-domain” considerations, valid for amplitude pulse trains can be extended in the “frequency-domain” for frequency hopping emissions just considering the “hopping period” instead of PRF.

It should also be noted that ECC Report 023 [1] assumed that, due to uncorrelated emissions, the aggregation factor of SRR peaks was also assumed to follow the 10 x Log law, but, on probabilistic basis, a higher aggregation factor might occur from time to time.

#### **A3.2.2 Receiver noise level statistic and BER versus S/N ratio**

The band-limited Gaussian noise (Rayleigh distribution) have a level distribution as follows [28]:

$$N(p) \text{ (dB)} = 10 \cdot \text{LOG}(-\ln(p)) \quad (4)$$

the rms level is obtained for  $p = 1/e$

The distribution is independent from the actual receiver bandwidth (i.e. the  $N_{\text{peak}}(p)/N_{\text{rms}}$  ratio is constant whichever is the bandwidth).

Provided that errors statistic in digital receivers is directly related to the noise level statistic, the (4) is proportional to the actual BER versus S/N ratio behaviour and, in particular, is closely correspond to a BPSK and QPSK (uncoded) behaviour (see Figure 34).

#### **SRR level statistic**

Analysing a pulsed UWB interference with  $PRF \cong 0.2 \text{ MHz}$  (close to the limit in (3)), which peak/rms ratio is exactly 24 dB, their effect to a 50 MHz FS receiver is shown in Figure 33.

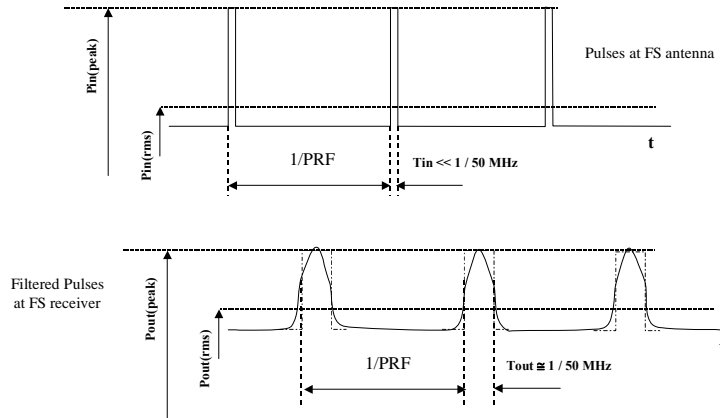


Figure 33: Pulses at antenna and FS receiver

with reference to Figure 33, UWB pulse duration is  $T_{in} \ll 1/(50 \text{ MHz})$ ; therefore, whichever is  $T_{in}$ :

$$T_{out} \cong 1/50 \text{ MHz} \cong 20 \text{ nsec}$$

The ideal two level probability function of the interference level into the 50 MHz FS receiver is easily derived as:

$$P_{out} = -\infty \text{ dB} \quad \text{for } p \leq T_{out} \times \text{PRF} \cong 4 \times 10^{-3}$$

$$P_{out} = P_{out}(\text{peak}) \text{ dB} \quad \text{for } p > T_{out} \times \text{PRF} \cong 4 \times 10^{-3}$$

Figure 34 shows, added to the noise level probability, also that of the interference levels relative to the cases where the I/N (rms) ratios are set at -20 dB, -10 dB and 0 dB.

Obviously, the corners are smoothed (dashed lines), as are the actual pulse shape. Note also that:

$$P_{out}(\text{rms}/50 \text{ MHz}) = P_{out}(\text{peak}/50 \text{ MHz}) - 24 \text{ dB}$$

$$P_{out}(\text{rms}/\text{MHz}) = P_{in}(\text{rms}/\text{MHz}).$$

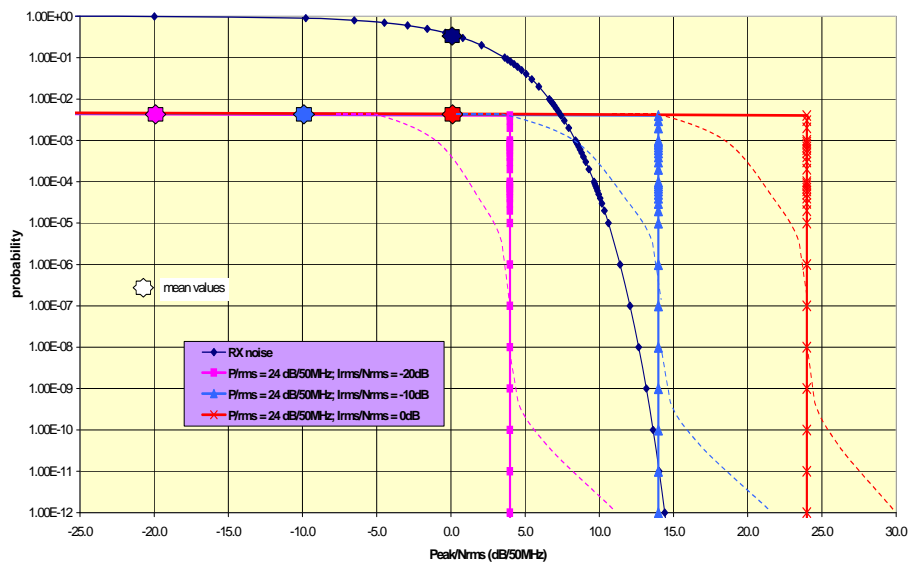


Figure 34: Probability of the noise and interference levels at FS receiver (50 MHz)

**A3.2.3 Theoretical BER versus S/N ratio with different interference PRF and I<sub>peak</sub>/I<sub>rms</sub>**

The principles described in section 1.3.2 applied to an ideal uncoded 50 Mbit/s BPSK demodulator (50 MHz bandwidth) lead to Figure 35 through Figure 38 derived with the following parameters:

Figure A3.4: PRF = 200 kHz producing  $I_{\text{peak}}/I_{\text{rms}} \cong 24 \text{ dB}/50 \text{ MHz}$

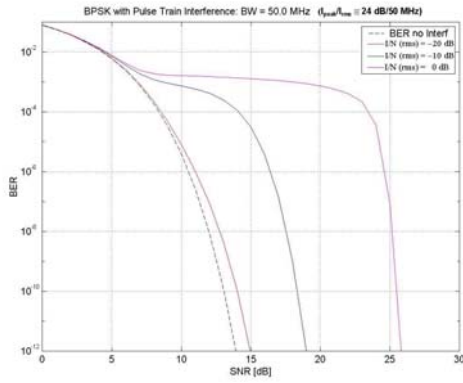
Figure A3.5: PRF = 50 kHz producing  $I_{\text{peak}}/I_{\text{rms}} \cong 30 \text{ dB}/50 \text{ MHz}$

Figure A3.6: PRF = 800 kHz producing  $I_{\text{peak}}/I_{\text{rms}} \cong 18 \text{ dB}/50 \text{ MHz}$

Figure A3.7: PRF = 3.2 MHz producing  $I_{\text{peak}}/I_{\text{rms}} \cong 12 \text{ dB}/50 \text{ MHz}$

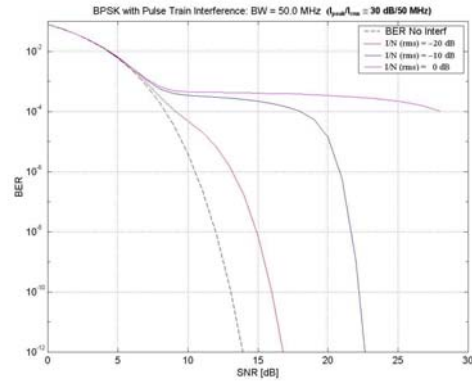
It is evident that a possible violation of the  $I/N$  (rms) = -20 dB criterion would result in significant differences according the permitted  $I_{\text{peak}}/I_{\text{rms}}$  wide-band ratio.

It should be noted that, comparing Figure 35 with Figure 37, and also the combined tests reported in Annex 4, it should also be noted that when both  $I/N$  limits are exactly compliant, the degradation is slightly worse than when only one limit is just reached. This is far more evident when some violation of the “mean” power  $I/N$  objective might happen; only if the peak to mean power ratio is reduced the degradation remains constant.



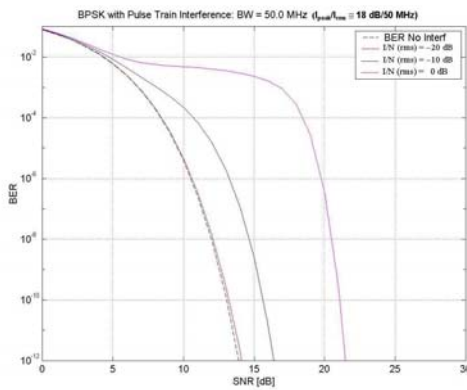
I/N(rms) violation	Corresponding I/N(peak) violation
0 dB	0 dB
+10 dB	+10 dB
+20 dB	+20 dB

Figure 35: 50 Mbit/s BPSK BER behaviour with pulse train PRF = 200 kHz ( $I_{\text{peak}}/I_{\text{rms}} \approx 24 \text{ dB}/50 \text{ MHz}$ )



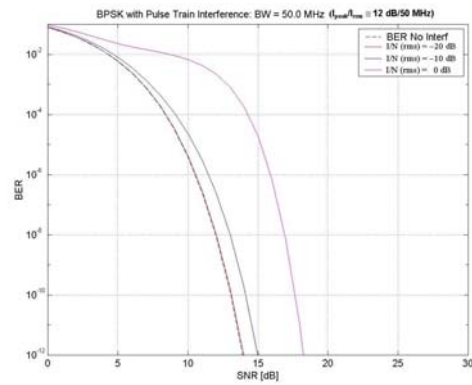
I/N(rms) violation	Corresponding I/N(peak) violation
0 dB	+6 dB
+10 dB	+16 dB
+20 dB	+26 dB

Figure 36: 50 Mbit/s BPSK BER behaviour with pulse train PRF = 50 kHz ( $I_{\text{peak}}/I_{\text{rms}} \approx 30 \text{ dB}/50 \text{ MHz}$ )



I/N(rms) violation	Corresponding I/N(peak) violation
0 dB	-6 dB
+10 dB	+4 dB
+20 dB	+14 dB

Figure 37: 50 Mbit/s BPSK BER behaviour with pulse train PRF = 800 kHz ( $I_{\text{peak}}/I_{\text{rms}} \approx 18 \text{ dB}/50 \text{ MHz}$ )



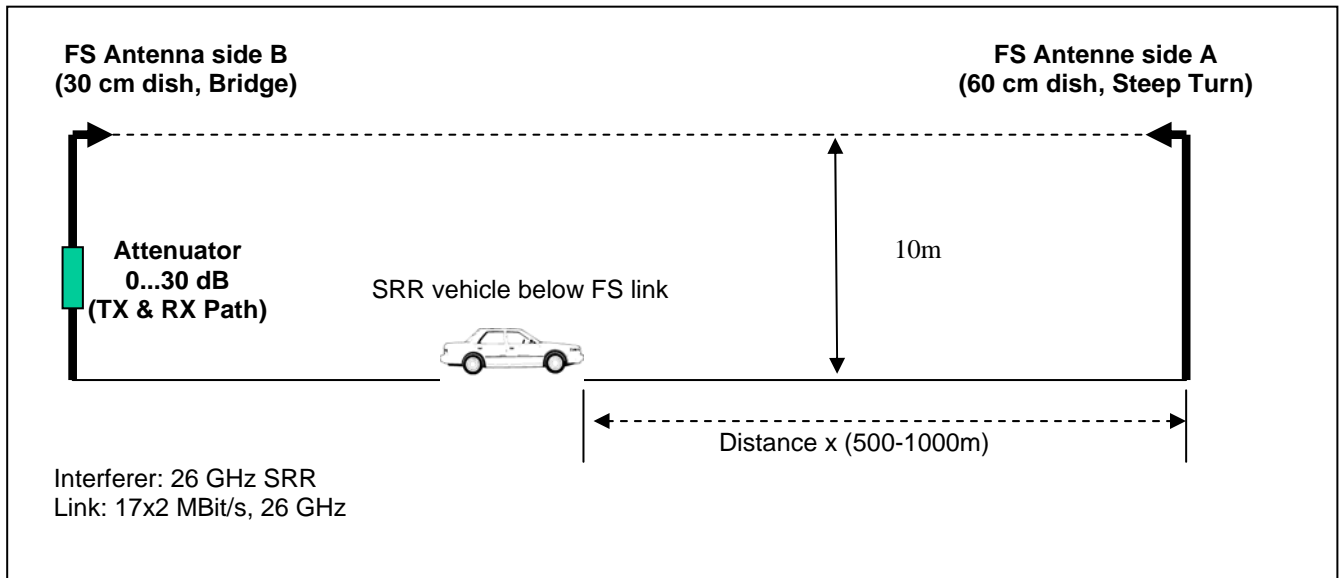
I/N(rms) violation	Corresponding I/N(peak) violation
0 dB	-12 dB
+10 dB	-2 dB
+20 dB	+8 dB

Figure 38: 50 Mbit/s BPSK BER behaviour with pulse train PRF = 3.2 MHz ( $I_{\text{peak}}/I_{\text{rms}} \approx 12 \text{ dB}/50 \text{ MHz}$ )

## ANNEX 4 : FIELD TEST ON SRR IMPACT ON FS P-P LINK

## A4.1 TEST SETUP

The measurement setup is shown in . The path attenuation of the microwave link was increased (using the wave guide attenuators on location B) until the link reached a BER of about  $10^{-6}$ . This was done to simulate a microwave link at its operational limit and thus make it vulnerable for interference.



**Figure 39: Measurement setup for single interferer at 26 GHz**

The 26 GHz sensor was mounted on a test vehicle but not behind a bumper. Therefore the 3 dB attenuation by the bumper material is not taken into account in the measurements.

## A4.1.1 FS Link Data

The test link has the following parameters:

Lower Band:	Center Frequency 25347 MHz (Rx at position A, steep turn)
Upper Band:	Center Frequency 26355 MHz
Channel Band Width:	28 MHz (+- 14 MHz)
Modulation Method:	QPSK
Error Correction Method:	FEC (not used for measurements)
RX Antenna Diameter:	0,6 m (on RX location only)
RX Antenna height above ground:	10 m (Site A - TX), 12 m (Site B - RX)
RX Elevations angle ( $0^\circ$ = horiz.):	Site A: $0,12^\circ$ up; Site B: $0,13^\circ$ down
FS Link length:	2.26 km

The RX/TX antenna pattern and gain are shown in Figure 40.



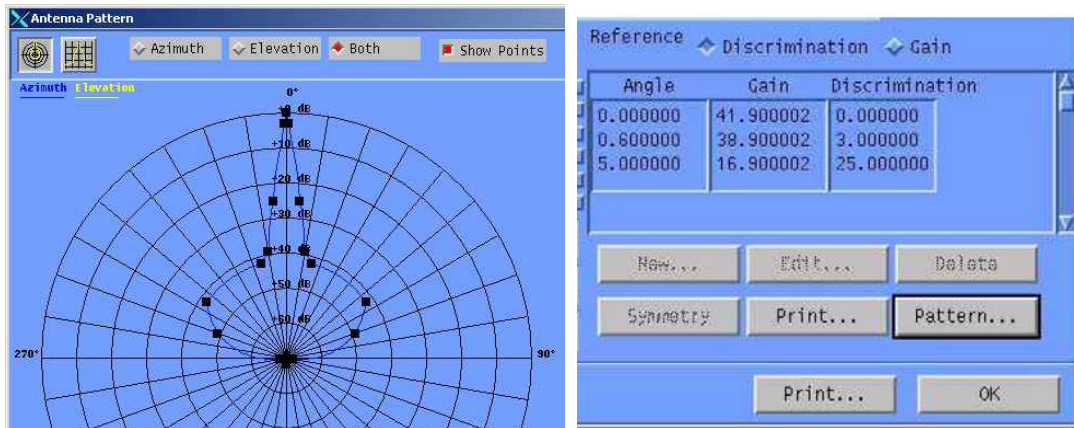


Figure 40: Antenna pattern of antenna A (60 cm dish)

To assure that the link from location A to location B was undisturbed during the whole measurement time, the link output power in location A was set to +18dBm (maximum output power) and location B was set to +13 dBm. With this setup one direction of the link was running with the desired bit error rate of  $10^{-6}$  while the other direction was running error-free (see Figure 41).

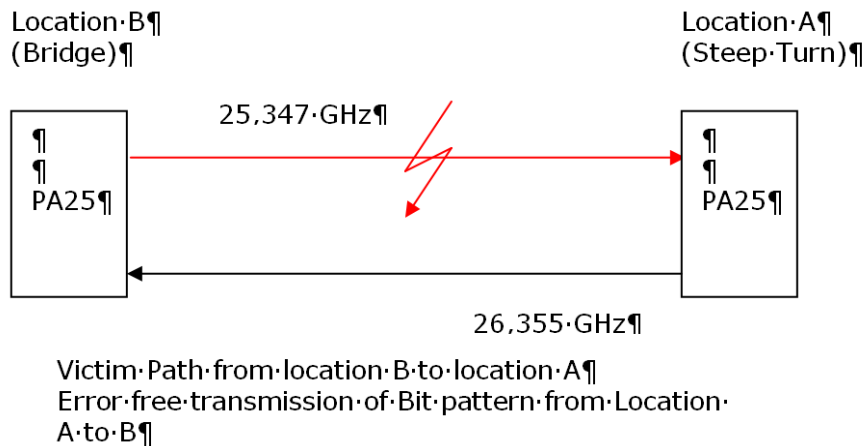


Figure 41: FS link setup

**A4.1.2 SRR Parameter**

For a precise measurement and related preparation of the results a synthetic interfering source is used. The interfering source has a waveguide interface to measure average power (PSD – power spectral density) and peak power. A horn antenna is available with similar pattern response as the used 26 GHz sensor and known gain data. Once a test parameter is set, the power at the source can be measured directly and the antenna is connected to the source module. The gain and TX power set the e.i.r.p. of the interferer. The following parameters of the interfering source can be varied.

- Modulation type: Pulsed FM
- Pulse Width: 20ns
- Pulse Repetition Frequency (PRF): 0.1 – 25 MHz
- Pulse Repetition Interval (PRI): 10  $\mu$ s – 370 ns
- Number of frequency points: 2048
- Number of pulses per frequency bin: 1-1000
- Modulation Bandwidth: 2 GHz
- TX Power Avg. (e.i.r.p.): -50dBm/MHz < -41.3dBm/MHz < -10dBm/MHz
- (External Amplifier required)
- TX Power Peak (e.i.r.p.): -10dBm/50MHz < 0dBm/50MHz < 30dBm/50MHz

The interferer substitution antennas have the following characteristics:

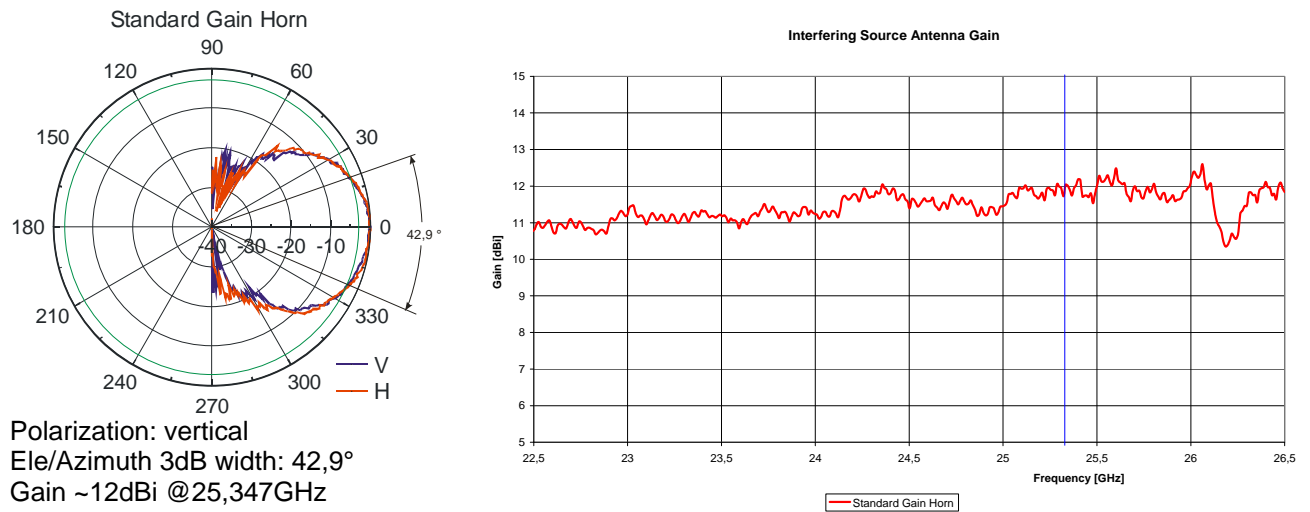


Figure 42: Antenna pattern & gain of interfering horn antenna

The synthetic interfering source consists of a DSP board which controls a wideband VCO, switch and amplifier. The components are installed in a housing with a waveguide (WR42) interface. The antenna can be easily removed for power direct measurements.

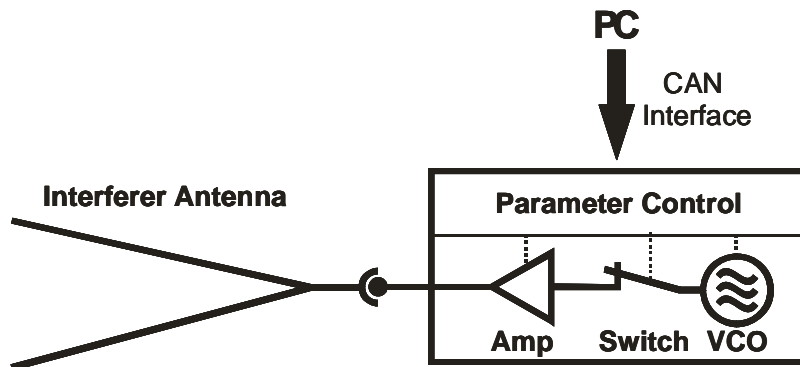


Figure 43: Block diagram of interfering source

The modulation is a frequency modulated pulsed type, where a random frequency sequence of 2048 points is generated within a cycle time of 40ms. The centre frequency is 25.25GHz and the modulation bandwidth is 2 GHz. On each of the 2048 frequency bins a pulse train according to the parameter Table 32 below is transmitted. The internal amplifier has a dynamic range of ~25dB.

The typical transmit spectrum is shown in Figure 44. The blue curve is average power, the black curve is the peak power measured in 10MHz RBW. The traces have a 15dB offset to account for antenna gain (standard gain horn ~12dBi) and cable loss (3dB).

For the test campaign the following settings have been used.

Mode	Peak Power	Average Power	Pulse Width	PRF	PRI
Compliant Mode	0dBm/50 MHz	-41,3dBm/MHz	20ns	2.7 MHz	370ns
Compliant Mode (-10dB Peak Power)	-10dBm/50 MHz	-41,3dBm/MHz	6ns	25 MHz	40ns
Compliant Mode (-10dB Average Power)	0dBm/50 MHz	-51,3dBm/MHz	20ns	100 kHz	10µs

Table 32

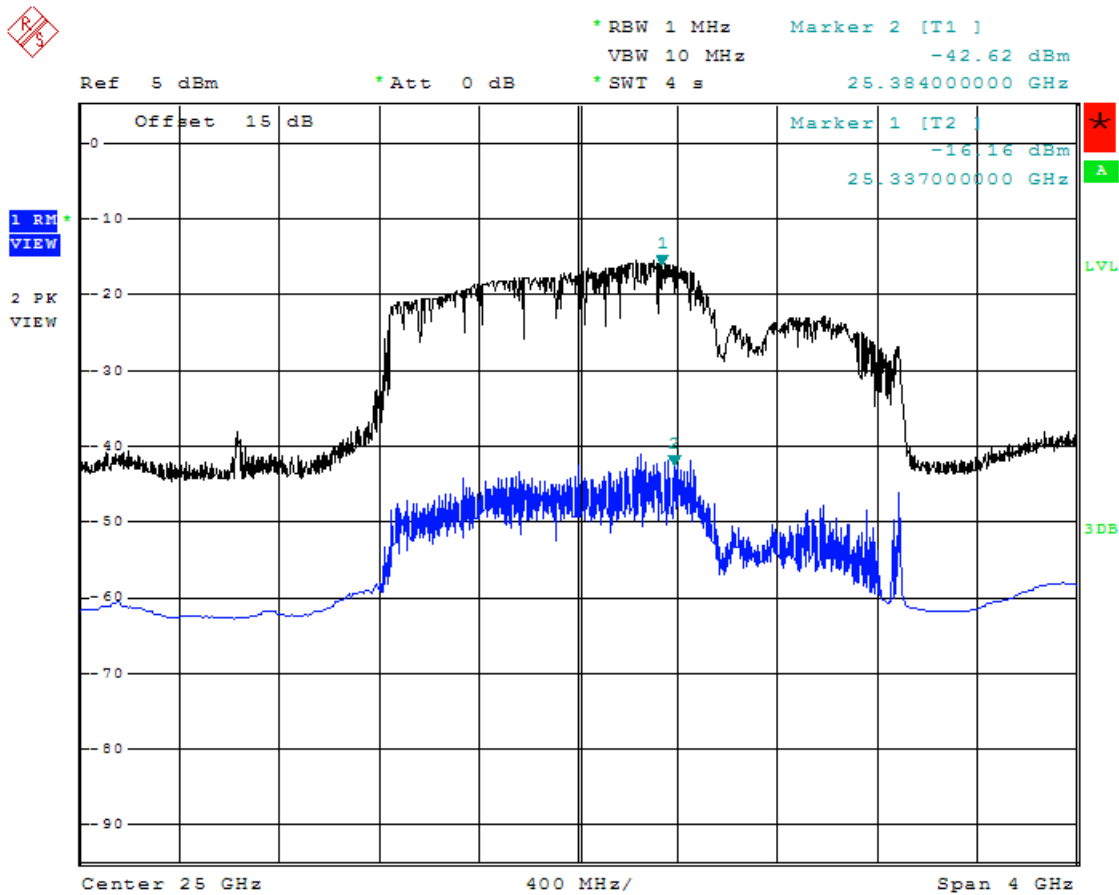


Figure 44: Transmit spectrum of interfering source (blue curve RMS detector 1MHz RBW, black curve peak detector 10MHz RBW)

The spectrum analyzer display was adjusted to 4000 pixel to ensure that with a frequency span of 4 GHz and a sweep time of 4s, the dwell time per frequency bin was about 1ms.

For the aggregated measurements SRR UWB equipped cars are used.

#### A4.2 MEASUREMENT RESULTS

The synthetic 26 GHz SRR was placed in the most critical distances 500...1000 m between interferer and victim. The BER was monitored with the test setup shown in Figure 45.

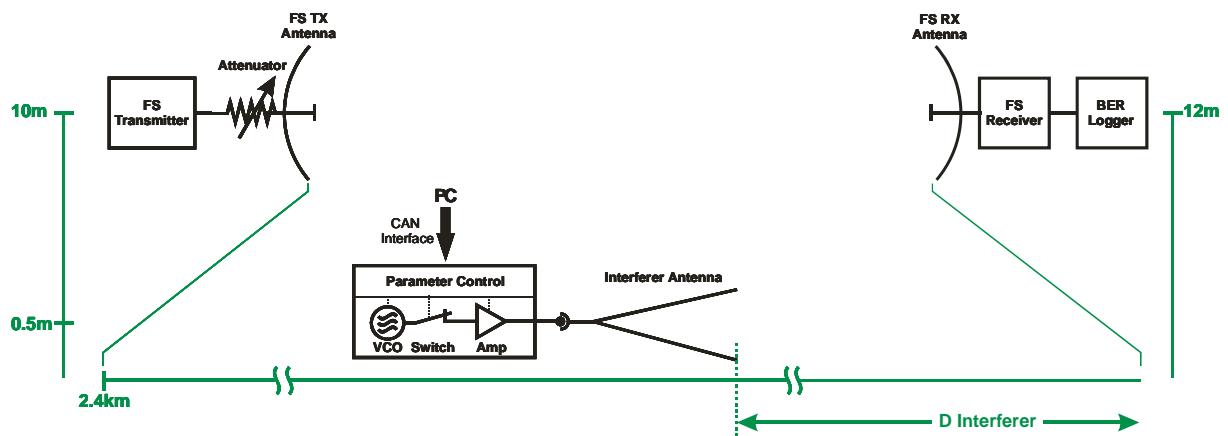
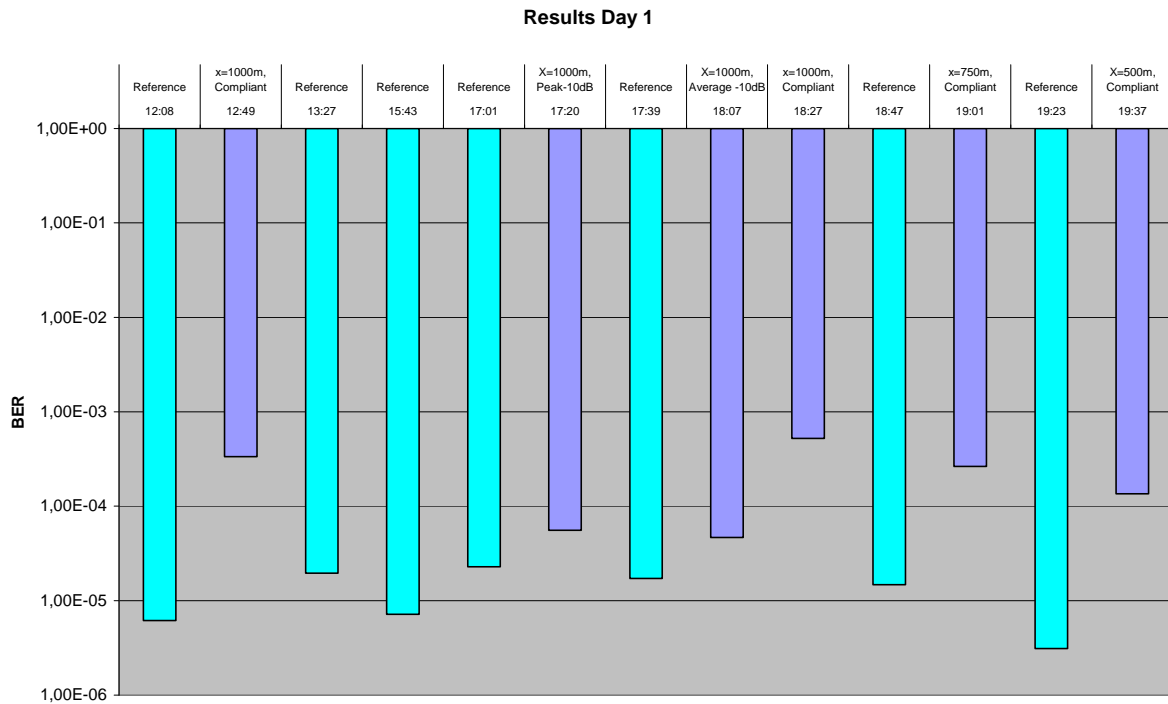


Figure 45: Measurement setup for 26 GHz SRR

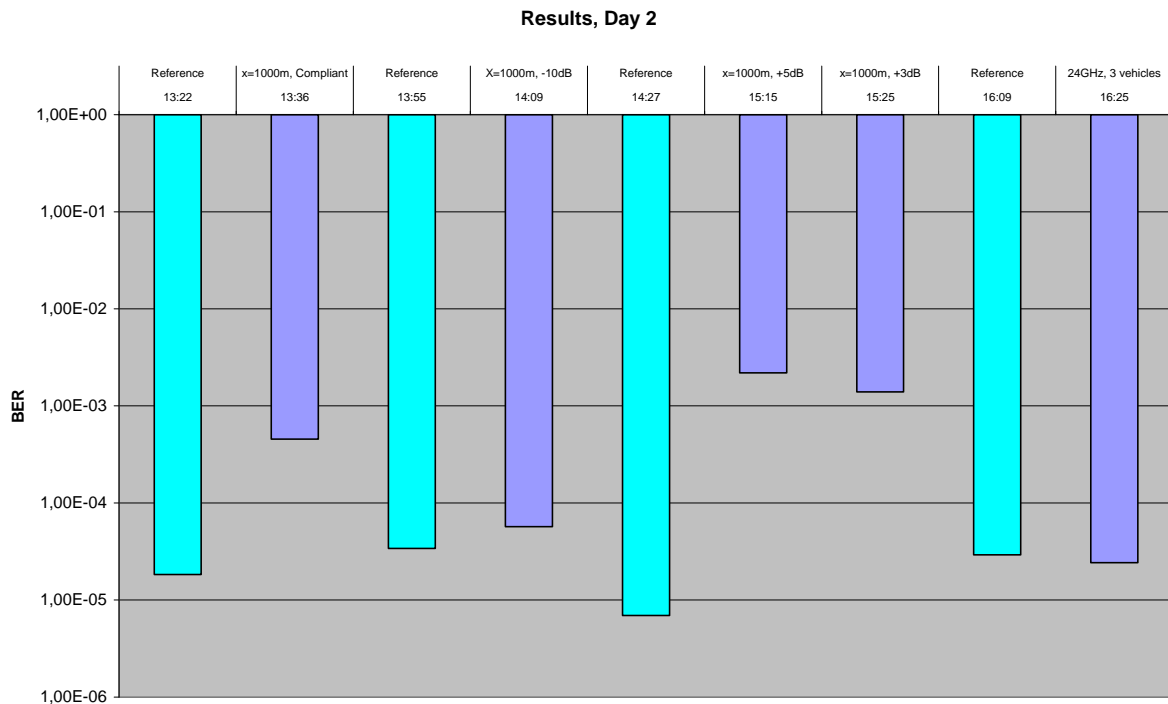
To ensure a bit error rate of  $10^{-6}$  independent of changing environmental conditions, several reference measurements each 15 minutes with optional correction of the path attenuation have been done (blue results in A4.8 and A4.9). These reference measurements have been done without active interference between both locations and have been repeated between each test to ensure comparable test conditions.

The violet results in A4.8 and A4.9 shows the BER rates with active SRR sensor; the measurements were done over 15 minutes each and in different distance x (500, 750, 1000m) with the 3 SRR power modes described in Table 32 above.

The FS Rx level at the location A (victim receiver) was set to -80 dBm and the attenuator for simulating the most critical fading situation was set to 36.4 dB (to get the reference BER of about  $10^{-6}$ ).



**Figure 46: results from day 1**



**Figure 47: Results from day-2**

The bit error rate without active interference (Reference Measurements) was always within the range of  $3e-6$  to  $3e-5$ . The fluctuation was most probably caused by changing environmental conditions.

The results of measurements with activated SRR-system are summarised in Table 33.

	Both +5dB	Compliant mode	peak - 10dB	Mean - 10dB	-10dB
Mean power dBm/MHz e.i.r.p.	-36	-41	-41	-51	-51
Peak power dBm/50MHz e.i.r.p.	+5	0	-10	0	-10
Reference BER	$3e-6/3e-5$				
1000m	$2e-3$	$4e-4$	$6e-5$	$5e-5$	$5e-5$
750m		$3e-4$			
500m		$1e-4$			

**Table 33: summary of results**

### A4.3 CONCLUSIONS

In principle the results of this campaign confirms the theoretical worst case calculations which are based on a protection criterion of  $I/N = -20dB$ .

## ANNEX 5 : EVALUATION OF AVAILABILITY FOR P-P LINKS AND DEGRADATION DUE TO I/N OBJECTIVES VIOLATION

### A5.1 INTRODUCTION

The methodology for deriving the error performance and availability degradation objectives due to SRR interference is based on the relevant ITU-R Recommendations.

Depending on the kind of traffic carried and the relevant network requirement established by the operators for fulfilling the total path availability set by ITU-R F. 1703 [14] (composed by various factors, rain outage on a number of cascaded links, failure rates (MTTF) and mean time to repair (MTTR) etc.) P-P links are designed for unavailability ranging from 0.001% to 0.01%. Obviously the higher is the availability the higher is the cost of the link.

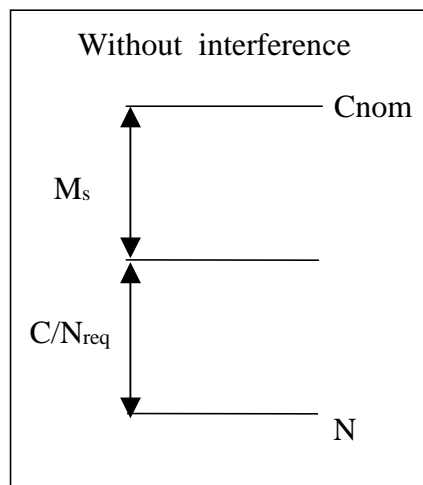
### A5.2 FS DESIGN

Performance of FS links are controlled by two different factors :

- Availability (or unavailability), derived from Recommendation ITU-R F.1703 [14]
- Error performance objectives (EPO), derived from Recommendation ITU-R F.1668 [15]

In the bands where the fading is controlled by rain (>about 17 GHz), the design of the FS links is based on availability, with typical values of 99.99% or 99.999% depending on the type of application and the operator requirements.

The FS link budget is therefore determined as given on Figure 48 below.



**Figure 48: Link budget evaluation**

where :

- N : is the total noise =  $kTBF$
- C/Nreq : is the value of the required C/N of the FS receiver,
- Ms : is the fade margin for a the required availability (calculated upon Rec. ITU-R P.530 [27])
- Cnom : is the resulting value of the C level in clear sky (C nominal)

In presence of interference for the same FS link, the situation is such as summarised on Figure 49 below.

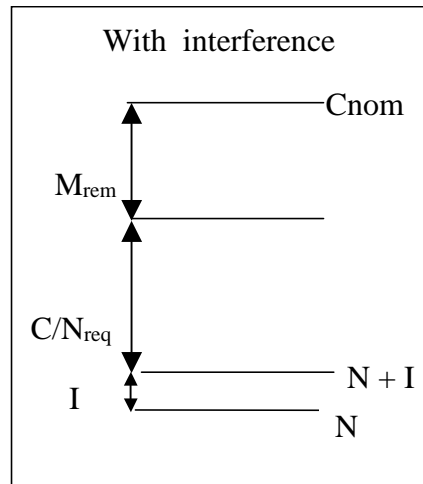


Figure 49: Link budget with interference

where :

$I$  : is the increase of noise due to interference

$N+I$  : is the resulting level of total noise,

$M_{rem}$  : is the remaining margin =  $M_s - I$

It can be seen from this Figure 49 that two cases can be differentiated:

- Case 1 ( $M_{rem} > 0$ ) : The interference level is relatively low : the link is still in an availability position and, in absence of fading, no Error performance objective can be expected. However, the lower remaining margin implies that the availability is degraded compared to the situation without interference. This is typically the situation that occurs with regards to long-term interference.
- Case 2 ( $M_{rem} < 0$ ) : The interference level is high and the link is out of service. In the case for which the interference duration is higher than 10s, the FS link enter in unavailability regime. If the duration of the interference is lower than 10s, it degrades the quality of service, i.e. the error performance objectives. This is typically the situation that occurs with regards to short-term interference for which the whole fade margin can be given to interference.

Standing the relatively low expected interference from SRR, the methodology for defining the protection objectives have been based only on “case 1” (long-term).

A representative example, with the current SRR objectives ( $I_{rms}/N = -20$  dB;  $I_{peak}/N = +5$  dB/50 MHz) is shown in Figure 50.

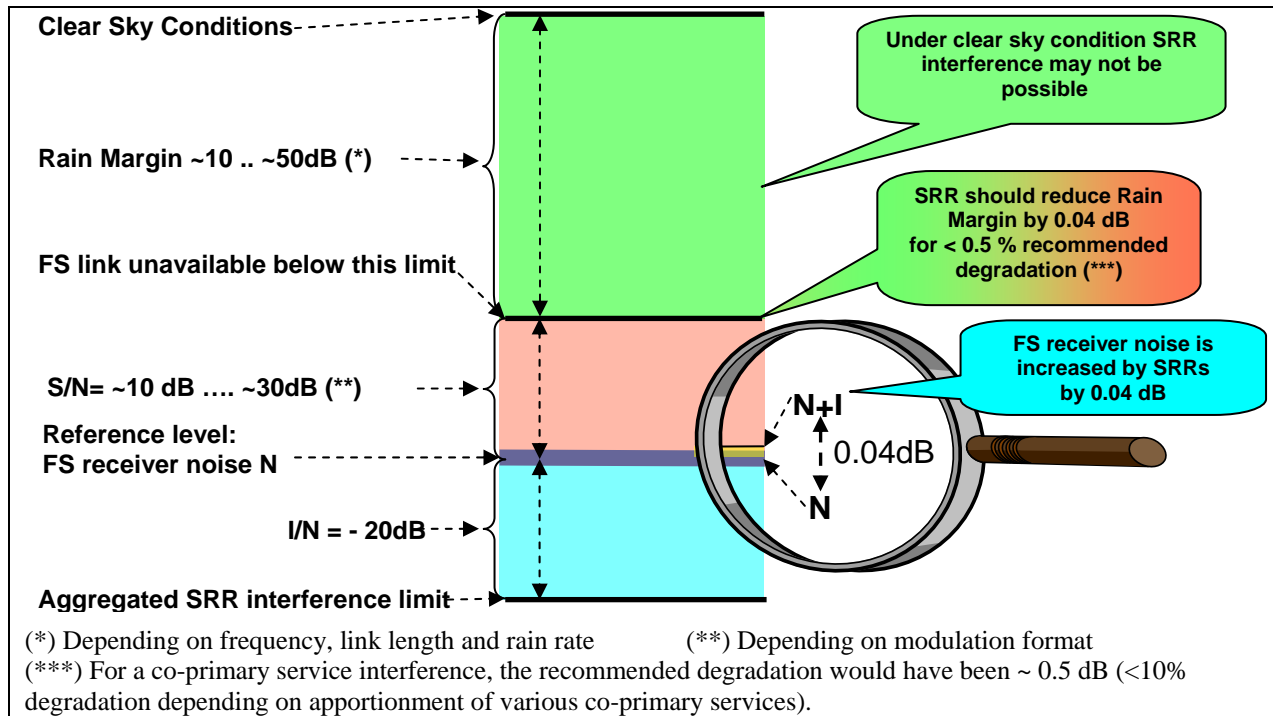


Figure 50: generic example of link budget with SRR interference

### A5.3 23 AND 26 GHZ BANDS FS PROTECTION CRITERIA

The definition of short-term FS protection criteria in both 23 and 26 GHz band is based on the case 2 above for which it can be clearly seen that it is dependent on the value of the fade margin.

The following discussion, recovered from specific contribution to ECC Report 023 development (but not there reported) is useful for better understanding the effect of interference on the of long-term availability objective degradation for FS link.

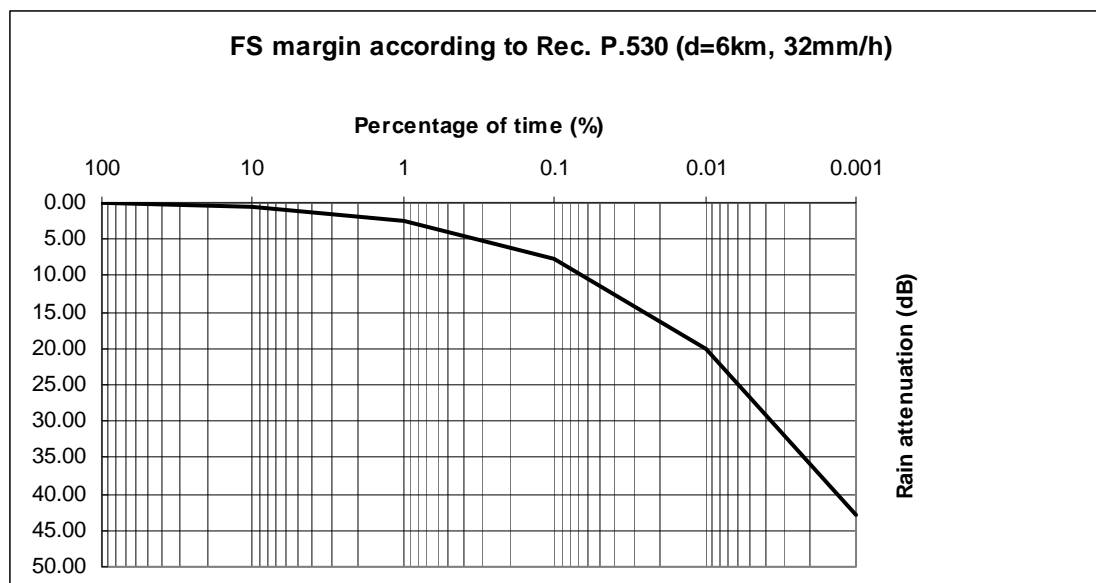
As stated in section A5.2 above, an FS link fade margin is given, for the required availability, by Recommendation ITU-R P.530 [27] which provides for a given hop length and a given level of precipitation (depending on the FS location) the expected rain attenuation exceeded for an associated percentage of time.

On the example of Figure 51 for the 23 GHz band, the fade margin for 99.99% availability should be 20 dB (0.01% of rain attenuation) where the fade margin for 99.999% availability should be about 42 dB (0.001% of rain attenuation)

For the FS link designed on this basis for 99.99% availability (20 dB margin), in case of long-term interference (let say a margin degradation of 5 dB), it can be seen on Figure 51 that the remaining margin of 15 dB protect the link from rain attenuation up to 0.025% of the time which is equivalent to a degraded availability of 99.975% and represents in this case an availability performance degradation of  $(0.025-0.01)/0.01 = 150\%$  !

Based on the same principle, but for lower margin degradation or lower availability degradation, it is hence possible to calculate the impact in terms of availability degradation of long-term interference produced by SRR 24 GHz.





**Figure 51: Example of rain attenuation occurrence for a specific 23 GHz link**

Recommendation ITU-R F.1094 [13] provides the apportionment of the total degradation of an FS link as:

- 89 % for the intra service interference
- 10% for the co-primary services interference
- 1% for the secondary services interference, the unwanted emissions and the unwanted radiations.

Even though Recommendation ITU-R F.758 [11] stipulates on a general basis that the interference from secondary services interference, unwanted emissions and unwanted radiations should not degrade the overall availability, it would mean, in bands above 17 GHz that no interference can be accepted from the above mentioned types of interference.

It is therefore proposed, as a worst case assumption, to assess the impact of the long-term interference from SRR on the basis of a 1% availability degradation. Nevertheless, as mentioned in Recommendation F.1094, this 1% degradation has to be apportioned between aggregate interference from secondary services and all sources of unwanted emissions. There are no secondary services in the bands 23 and 26 GHz band but it seems reasonable not to give the whole degradation to the unwanted emissions from only one service in one particular band and hence, the impact of the long-term interference from SRR has also been assessed on the basis of a 0.5%.

On this basis, Table 34 below gives the corresponding levels of degraded unavailability for the two typical availability levels of 99.99% and 99.999%.

Nominal availability	Corresponding unavailability	Unavailability for 1% degradation	Unavailability for 0.5 % degradation
99.99%	0.01%	0.0101%	0.01005%
99.999%	0.001%	0.00101%	0.001005%

**Table 34**

Then, on the basis of Recommendation ITU-R P.530 [27], the following Table 35 and Table 36 give the values of fade margin degradation corresponding to these levels of unavailability for the following cases at 23 GHz :

- FS hop length of 3 and 6 km,
- Rain zones E (22 mm/h), F (28), G(30) and H(32).

Rain zone	Required availability	Nominal margin (dB)	Margin for 1% degradation (dB)	Margin for 1% degradation (dB)	Margin for 1% availability degradation (dB)	Margin for 0.5% availability degradation (dB)
Zone H 32 mm/h	99.99%	11.25	11.18	11.21	0.07	0.04
	99.999%	24.06	23.99	24.02	0.07	0.04
Zone G 30 mm/h	99.99%	10.53	10.47	10.49	0.06	0.04
	99.999%	22.53	22.46	22.49	0.07	0.04
Zone F 28 mm/h	99.99%	9.81	9.76	9.78	0.05	0.03
	99.999%	20.99	20.93	20.96	0.06	0.03
Zone E 22 mm/h	99.99%	7.65	7.6	7.62	0.05	0.03
	99.999%	16.36	16.31	16.33	0.05	0.03

Table 35: margin degradation for a 3 km hop length FS link at 23 GHz

Rain zone	Required availability	Nominal margin (dB)	Margin for 1% degradation (dB)	Margin for 1% degradation (dB)	Margin for 1% availability degradation (dB)	Margin for 0.5% availability degradation (dB)
Zone H 32 mm/h	99.99%	20.06	19.95	19.98	0.11	0.08
	99.999%	42.9	42.78	42.84	0.12	0.06
Zone G 30 mm/h	99.99%	18.83	18.73	18.76	0.1	0.07
	99.999%	40.28	40.17	40.23	0.11	0.05
Zone F 28 mm/h	99.99%	17.6	17.5	17.53	0.1	0.07
	99.999%	37.64	37.53	37.59	0.11	0.05
Zone E 22 mm/h	99.99%	13.82	13.75	13.77	0.07	0.05
	99.999%	29.57	29.48	29.53	0.09	0.04

Table 36: margin degradation for a 6 km hop length FS link at 23 GHz

It can be seen from these tables that although the nominal fade margins for all different cases are different, the margin degradation values depend, to a high extent, neither on the required availability nor on the rain zone. There is a small variability of the results due to the hop length but which is obviously not representative.

The calculated values ranges from 0.03 dB to 0.12 dB which corresponds to respectively  $I/N = -21.6$  and  $I/N = -15.5$  dB and definitively justify and support the long-term criteria of  $-20$  dB  $I/N$  contained in Report 023 and also in SM.2057.

#### A5.4 EFFECT OF I/N OBJECTIVES VIOLATION

##### A.5.4.1 Evaluation made for 23 GHz band with 24 GHz SRR

One example (see Table 37) of the impact of a violation of the  $I/N$  objective with  $I/N = -12.5$  dB, corresponding to a 0.24 dB margin degradation is reported.

Table 37 gives the corresponding availability performance degradation, in percentages, for two typical 23 GHz hop length and European rain zones, which clearly exceed the 0.5 % (or even the 1%) allowance by a large extent, ranging from 2% to 8.3% (i.e. exceeding the 0.5% objective by 4 times to 16.6 times).

Rain zone	Required availability	Availability degradation for 0.24 dB margin degradation for 3 km hop length (%)	Availability degradation for 0.24 dB margin degradation for 6 km hop length (%)
Zone H 32 mm/h	99.99%	5.3	2.7
	99.999%	3	2
Zone G 30 mm/h	99.99%	5.8	2.9
	99.999%	4	2
Zone F 28 mm/h	99.99%	6.2	3.2
	99.999%	4	2
Zone E 22 mm/h	99.99%	8.3	4.2
	99.999%	5	3

Table 37: 23 GHz availability performance degradation for a 0.24 dB margin degradation

#### A.5.4.2 Extension to 26 GHz band for 26 GHz SRR interference

The evaluation made at 23 GHz clearly shows that the SRR impact is as worse as the link is short, the rain intensity is lower and the availability objective is higher. This also mean that at 26 GHz, assuming the same link length, the impact is expected to be somehow lower due to the higher rain attenuation.

Figure 52 shows the 26 GHz rain attenuation occurrence probability for the same 3 km and 6 km hop lengths with the extremes 22 mm/h and 32 mm/h rain rates.

In the impact evaluation made in Table 37 for 23 GHz is based on the margin degradation, it does not depend on the peak and/or mean interference power, which has generated the degradation. As shown in Annex 3, we cannot separately judge the margin degradation from a violation of the  $I/N_{\text{peak}}$  or the  $I/N_{\text{mean}}$  objectives; common assumptions should be made.

The ITU-R recommended degradation due to SRR, based on the 50% apportionment of the maximum degradation (1%) recommended, for not-co-primary sources interference, by Recommendation ITU-R F.1094 :

- Links designed for 99.99% availability (maximum unavailability 52 minutes/year):  
the consequent degradation objective of 0.00005 % / year, corresponds to < 16 seconds increase over the availability.
- Links designed for 99.995% availability (maximum unavailability 26.3 minutes/year):  
the consequent degradation objective of 0.000025 % / year, corresponds to < 8 seconds increase over the availability.

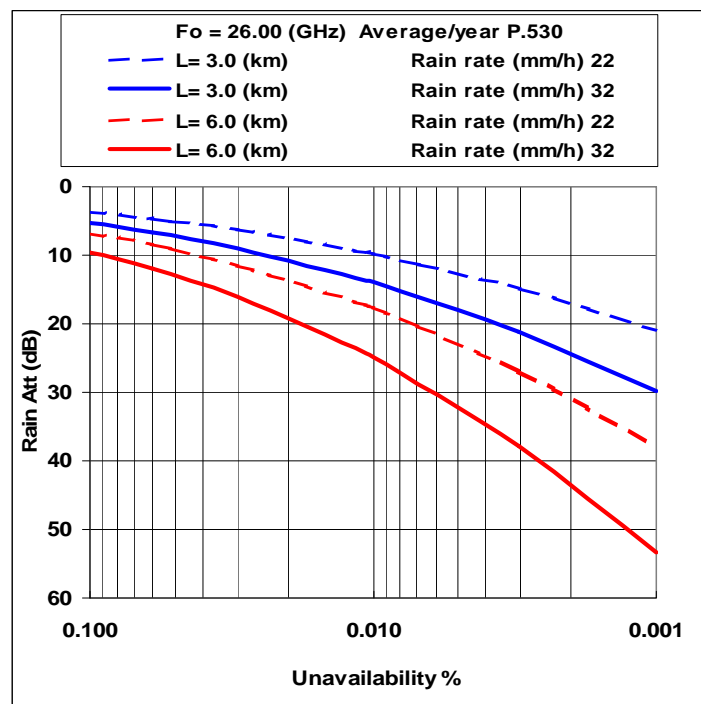


Figure 52: Examples of rain attenuation occurrence for specific 26 GHz links

It should be noted that in Figure 52 it is evident that the major impact of the interference (giving a fixed amount of margin degradation) is on the shorter hops, with the lowest rain rate and less demanding objectives (less steep curves).

For determining the expected margin degradation, due to joint violations of peak and mean  $I/N$  objectives (see background in section 2.3.2), we could refer to the graphs in section 2.3.4.6.3 (single-car entry) and 2.3.4.7.3 (aggregation) at  $\sim\text{BER}=10^{-4}$ , which is suitable for block-based PDH or SDH paths; Table 10 (section 2.3.5.3) shows the expected range of the degradation from the worst case link examined (3 km; 22 mm/h; 99.99% availability) to a typically better case of link (6 km; 32 mm/h; 99.995%).

## ANNEX 6 : EFFECT OF A BURST DUTY CYCLE REGARDING THE INTERFERENCE FROM BURST-LIKE SIGNALS

The current development of ultra wideband (UWB) short range radar (SRR) sensors has led to new system concepts that do not instantaneously cover the entire system bandwidth but successively operate in narrow frequency slots. Typical examples are pulsed frequency hopping (PFH) radars and (pulsed) frequency modulated continuous wave (FMCW) radars. From the perspective of a narrowband receiver the interference caused by such devices shows a burst-like structure, i.e. an activity of the interfering device is only present for a limited fraction of the total averaging time. In this Annex the effect of the burst duty cycle on the peak and average interference power both for the single interferer scenario as well as for the case of aggregated interference will be discussed. Finally, the improvement achieved by the new limit proposal will be calculated.

### A6.1 BURST DUTY CYCLE DEFINITION

The duty cycle (DC) is the ratio of the time period, during which an activity is detected by a victim receiver (with less bandwidth than the radar system), and the total measurement duration. Assuming a burst-like signal structure with a burst bandwidth larger than the victim bandwidth and a cyclic frequency pattern with non-overlapping bursts, the duty cycle corresponds to the ratio of the burst duration  $T_{burst}$  and the total cycle duration  $T_{cycle}$

$$DC = \frac{T_{burst}}{T_{cycle}}. \quad (1)$$

### A6.2 INTERFERENCE FROM A SINGLE DEVICE

The signal emitted from a radar device is characterized by the peak power  $P_{peak}$  and the average burst power  $P_{avg,burst}$ , which is the average power that would be measured by an RMS detector when averaging over the burst duration. Regarding the peak power emitted from a single device a duty cycle will provide no improvement. However, the average power detected from the single device will show a significant reduction, as soon as the averaging duration becomes much larger than the burst duration. For an averaging duration  $T_{avg}$  that is larger than the cycle duration of the radar, the measured average power  $P_{avg}$  reduces by the duty cycle

$$P_{avg} = DC \cdot P_{avg,burst}, \quad T_{cycle} \ll T_{avg}. \quad (2)$$

### A6.3 AGGREGATED INTERFERENCE

Since the duty cycle limits the temporal activity of the single device, multiple devices will only be active at the same time with a limited probability. This effect reduces both the aggregated peak power and the aggregated average power from systems that use burst-like signals. The probability  $p(k)$  that  $k$  out of a total amount of  $N$  devices are simultaneously active follows a binomial distribution and amounts

$$p(k) = \binom{N}{k} DC^k (1 - DC)^{N-k}. \quad (3)$$

The expectancy for the number of simultaneously active device is

$$E\{p(k)\} = DC \cdot N. \quad (4)$$

Assuming that all devices contribute the same amount of power, the resulting aggregated peak  $P_{peak,agg}$  and average power  $P_{avg,agg}$  from a high number of devices amount

$$P_{peak,agg} = DC \cdot N \cdot P_{peak} \quad (5)$$

$$P_{avg,agg} = DC \cdot N \cdot P_{avg,burst} = N \cdot P_{avg}. \quad (6)$$

Hence the aggregated peak and average interference power in average exactly reduce by the duty cycle. The typical deviation from the average is described by the variance. For the binomial distribution the variance amounts

$$\text{Var}\{p(k)\} = N \cdot DC(1 - DC). \quad (7)$$

Since the variance also linearly grows with the number of devices  $N$ , the relative variance is independent from the number of devices, which guarantees that the actual interference will not differ much from the expectancy even in the presence of a high number of sensors.

#### **A6.4 IMPROVEMENT ACHIEVED BY THE NEW LIMIT PROPOSAL**

The new limit proposal specifies in addition to the current average power limit of -41.3 dBm/MHz an additional duty cycle limit of 1% minimum and 5% maximum as well as a long-term average limit of -50 dBm/MHz measured over an averaging time of one second. Moreover, in the new limit proposal the peak power limit is reduced by 7 dB from 0 dBm to -7 dBm measured in 50 MHz bandwidth.

Regarding the improvement of the aggregated average power, the reduction caused by the duty cycle only applies to the burst power (5). The basis for average power aggregation is the new long term average limit of -50 dBm/MHz, which gives a reduction of 8.7 dB compared to the current limit of -41.3 dBm/MHz.

According to (6) a limited duty cycle results in a true reduction of the aggregated peak power. With the maximum duty cycle limit of 5% in the new limit proposal, the peak power aggregation is reduced by at least 13 dB compared to the current regulation. Taking into account the additional reduction of the peak power limit of 7 dB, the new limit proposal guarantees a reduction of at least 20 dB of the aggregated peak power.

## ANNEX 7 : ANALYSIS OF INTERFERENCE FROM SRR DEVICES INTO THE FIXED SERVICE

In this Annex a study is described which undertook interference analysis using both static and Monte Carlo methodologies.

### A7.1 STATIC ANALYSIS

The analysis provided by one administration started with a static analysis of the potential for a single SRR device to cause interference.

The assumptions were taken as within the likely range for equipment deployed in this band – such as 60 cm dish and noise figure of 4 dB – and the resulting calculations are given in Table 38.

Frequency (GHz)	28
Power (dBm/MHz)	-41
Separation distance (m)	100
Path loss (dB)	101.4
Clutter loss (dB)	3
RX dish size (m)	0.6
RX antenna efficiency	0.6
RX gain (dBi)	42.7
RX signal (dBW/MHz)	-131.7
Noise figure (dB)	4.0
RX noise (dBW/MHz)	-140.0
I/N (dB)	+7.3

**Table 38**

It can be seen that with the assumptions above a single SRR device could cause harmful interference with an I/N = +7.3 dB. This is 27.3 dB above the threshold for secondary services of an I/N = -20 dB.

This analysis is plausible in urban areas where there are many flyovers whereby large volumes of traffic cross at heights of ~10m above terrain level where there could be FS receivers as part of short haul links (e.g. for dog-legs to avoid obstructions such as buildings).

It should be noted that in some administrations there are no minimum hop length restrictions. As well as support for mobile infrastructure, such links could be used for high speed inter-building communications, in which case path lengths could be very low.

This case is shown in the Figure 53 below.

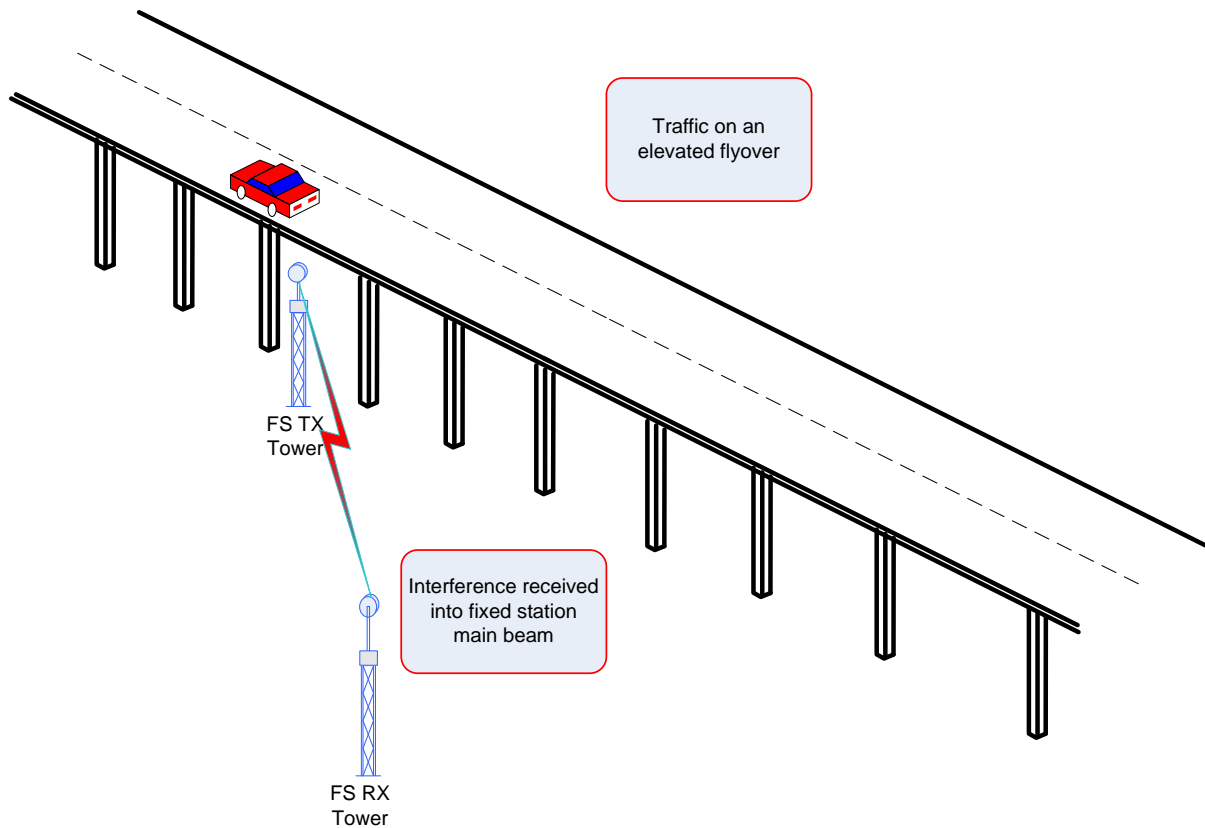


Figure 53

A more detailed analysis would test the sensitivity of this result to a range of values of these parameters. However it is not safe to assume that there are significant mitigation factors in all cases. We need to take into account the aggregation from multiple SRR devices and multiple vehicles.

For example it is likely that FS networks will be deployed such that there are multiple cars each with multiple SRR devices transmitting within the main beam of a receiver, as in Figure 54.

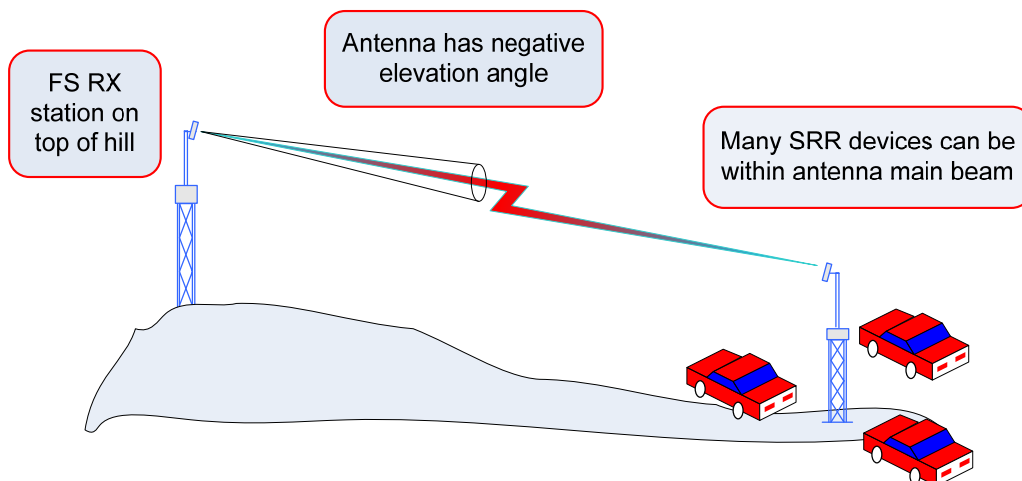


Figure 54

It was also noted that the SRR contributions there would be mitigation to reduce interference, such as clutter. However they ignored the reflection of SRR signals off vehicles that may result in even higher levels of interference.

In addition a typical application for fixed links in these bands is back-haul for mobile services which are often deploy their base stations by roads at locations with minimal clutter and hence more likely to be line of sight to vehicles.

**A7.2 FURTHER CONSIDERATIONS TO SECTION A7.1**

Another administration carried out analysis to check the impact of the scenario provided in A8.1 on BER performance of these FS links for 128 QAM transmissions (Rec. ITU-R F.1101 [12]) with the relevant FS link parameters assuming that the available fade margin will be available to mitigate interference from SRR.

The FS link parameters of those short FS links are shown in Table 39 (Link A was first presented and later Link B).

FS Link Planning	Link A	Link B	Notes
Frequency (MHz)	28,000	28,000	
Bandwidth (MHz)	56	56	High capacity link
Hop length (km)	0.1	0.1	As per single interferer example
Dish gain (dBi)	42.7	42.7	As per single interferer example
Noise figure (dB)	4.0	4.0	As per single interferer example
C/N required (dB)	29.5	29.5	For 128-QAM from Rec. ITU-R F.1101 for BER = 10 <sup>-6</sup>
Link margin (dB)	10.0	3.0	For fading and to support BER better than = 10 <sup>-6</sup> and not available for interference (see below)
System losses (dB)	4.0	4.0	Implementation margin and de-pointing
Interference margin (dB)	2.0	2.0	See note below
Derived			
Path loss (dB)	101.4	101.4	
Noise in bandwidth (dBW)	-122.3	-122.3	
RSL faded (dBW)	-90.8	-90.8	RSL = Received Signal Level
RSL unfaded (dBW)	-80.8	-87.8	
Transmit power (dBW)	-60.9	-67.9	
Transmit power (dBm)	-30.9	-37.9	
Transmit e.i.r.p. (dBm)	11.8	4.8	

**Table 39: Detailed study parameters**

Additionally the results for the interfering power I and the values for I, I+N, and C/(N+I) are given in Table 40.



Noise evaluation	Link A	Link B	
Rx Noise N (dBW)	-122.3	-122.3	
SNR faded dB (RSL faded – Rx Noise)	31.5	31.5	
SNR unfaded dB (RSL unfaded – Rx Noise)	41.5	34.5	
<b>Interference evaluation</b>			
Interfering power I dBW	-115.5	-115.5	-41.3dBm/MHz e.i.r.p. at100m, 42.7dBi, 3dB guard rail attenuation
I/N dB	6.8	6.8	
I+N dBm	-114.8	-114.8	
S/(I+N)=SINR faded dB (RSL faded – Rx Noise)	24	24	
S/(I+N)=SINR unfaded dB (RSL unfaded – Rx Noise)	34	27	
<b>Rain fade margin evaluation</b>			
required rain fade margin=max rain attenuation dB/link length (32mm/h=5.8 dB/km)	0.58dB	0.58dB	

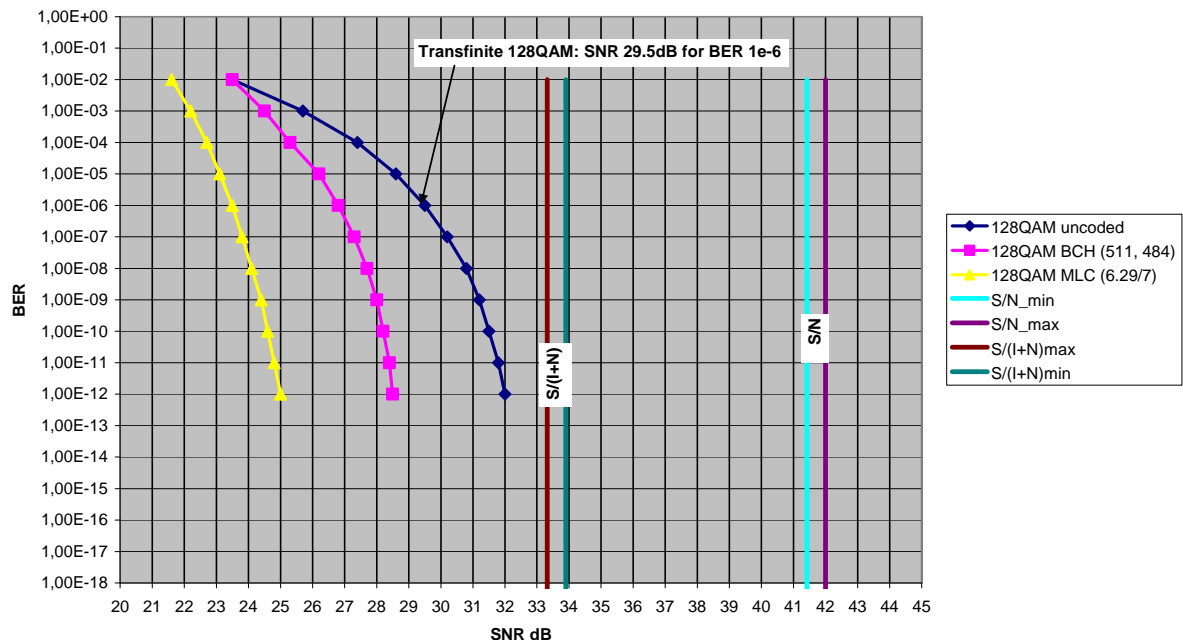
**Table 40: Evaluation of noise and interference levels**

with this it is obvious that

- the I/N for this scenario is about 7dB
- the unfaded SINR with 10dB link margin is 34 dB
- the unfaded SINR with 3dB link margin is 27 dB

Figure 55 and Figure 56 are showing the BER of some 128QAM coded formats (from Rec. ITU-R F.1101 [10]). Figure 55 contains additionally the calculated SINR for the 100 m link with 10dB margin and Figure 56 contains additionally the calculated SINR for the 100m link with 3dB margin.

**128QAM BER ITU-R F.1101**



**Figure 55: 10 dB link margin**

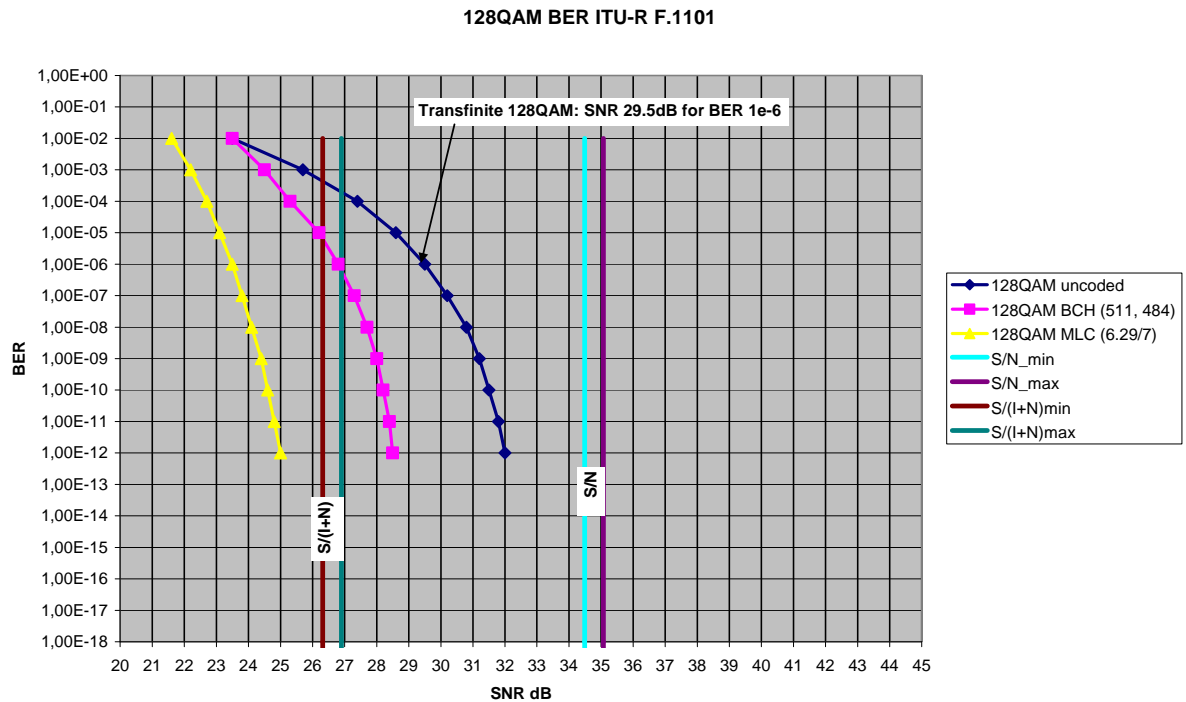


Figure 56: 3 dB link margin

With this there seems to be no impact on the BER performance for Link A with 10dB link margin but an impact on Link B with 3dB link margin.

This administration is of the view that with a FS link fade margin of 10 dB the BER performance will not be degraded, even for the very low Tx power values (-31 dBm) while with a FS link fade margin of 3dB the Link could be blocked by SRR. Another administration is of the view that it is generally not appropriate to assume that fade margins in fixed links are available for the purpose of mitigating interference as the fade margins are assigned to maintain the relevant performance and availability objectives for the appropriate propagation conditions.

### A.7.3 MONTE CARLO ANALYSIS

This section describes a method for the assessment of the statistics on aggregate interference based on a Monte-Carlo simulation<sup>8</sup>. Some results are given based on a realistic scenario that is far from worst case. Results clearly show that the potential to cause very high levels of interference exist.

One of the principal markets for fixed link spectrum in these bands is to provide backhaul for mobile networks. By their nature these are deployed around busy areas such as roads and motorways.

Base stations are therefore likely to be:

- Deployed close to roads
- Have back-haul links along side roads
- Linked to another base station in order to aggregate data from remote cells
- Be deployed in locations giving best coverage - hence have minimal clutter or obstructions around the base station antennas

Therefore the probability of a deployment that could suffer harmful interference cannot be ignored.

We therefore undertook detailed analysis using realistic geometry and Monte Carlo methods to model traffic on an averagely loaded motorway.

. [The simulation file is attached to this report.]

<sup>8</sup> The analysis was performed using Visualyse Professional 7

The basic configuration is shown in Figure 57 and Figure 58.

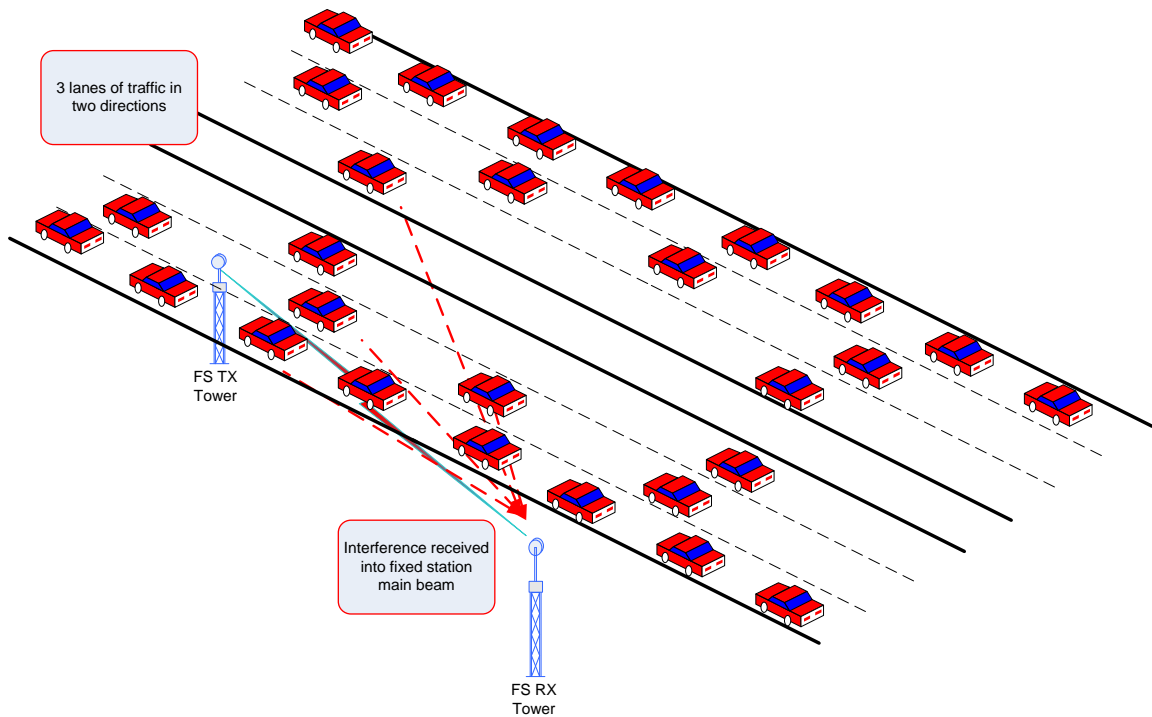


Figure 57

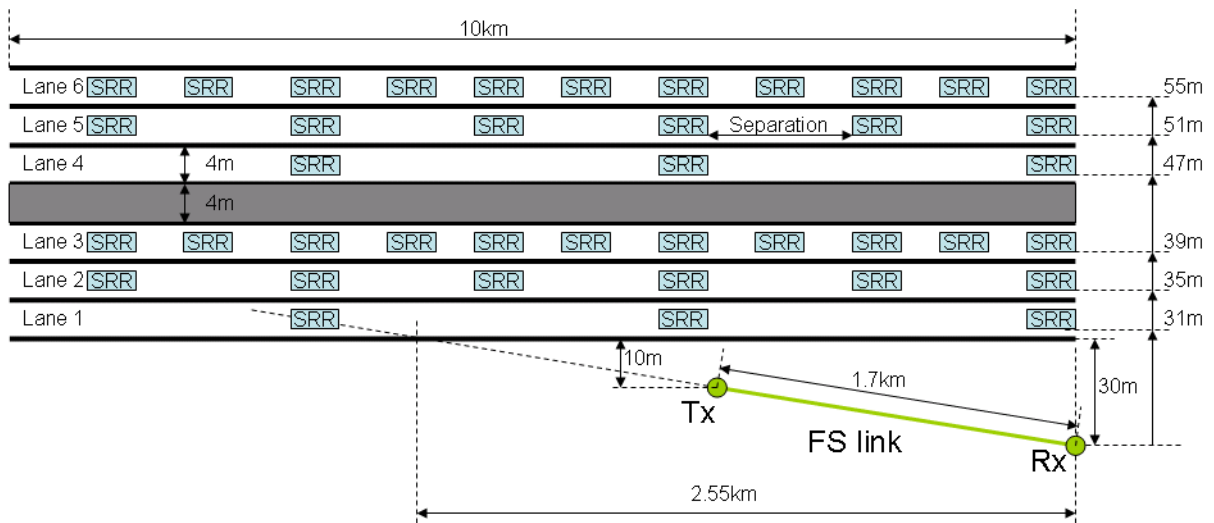


Figure 58

It was assumed that a FS network was deployed to support a mobile base station providing coverage of the road. The road was modelled as having 6 lanes – three in each direction.

A 10 km stretch of the road was modelled with traffic flow for 10% SRR market penetration assumed to be as in Table 41. The vehicles were located at random along the 10 km of simulated road.

Lanes	Average Vehicle Spacing	Number vehicles
Slow: 1 and 6	200 m	50
Medium: 2 and 5	400 m	25
Fast: 3 and 4	800 m	12 or 13

Table 41

Each lane was 4 m wide with a 4 m central reservation. The heights of both of the FS stations was 10m as identified in ECC Report 023 which is quite common in some administrations with path roughly along side the road. The SRR devices were at a height of 0.5m.

The hop length was about 1.7 km with the transmitter offset 10m from the road and the receiver 30m. The antenna at both the TX and RX station was assumed to meet the ITU-R Recommendation F.1245 gain pattern.

It was assumed that 10% of vehicles used SRR with 4 devices per vehicle of which 3 were visible to the FS receiver at any one time as in Figure 59.

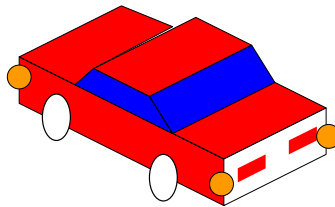


Figure 59

Additional analysis is be required to consider SRR penetration ratios other than 10% and more devices per vehicle. It is noted that there could be more devices i.e. up to 10 per vehicle.

The transmit spectral power density was taken as -41.3 dBm/MHz per device with three of the four devices per vehicle with direct line of sight to the FS receiver. The transmit e.i.r.p. per vehicle was therefore assumed to be -66.5 dBW/MHz. It was assumed as per ECC Report 023 that there would be 3 dB of bumper loss. Hence the e.i.r.p. per vehicle was -69.5 dBW / MHz.

A smaller number of SRR devices were deployed at random over the test area to model vehicles on minor roads. It was noted that ECC Report 023 included scenarios with additional lanes of traffic, which would result in higher levels of interference than those in this simulation.

A dual slope propagation model was used with initial slope 2 and then after a distance of 2 km increased to 3 (this could be considered conservative for the station heights involved). In addition gaseous absorption as per ITU-R Rec.P.676 was included. The role of rain loss and fading is discussed further below.

Shielding due to other cars was considered based upon ECC Report 023 [1] as follows:

- There is likely to be no shielding for the nearside lane (i.e. lane 1)
- For traffic with separation 30m the loss would be 7.5 dB (i.e. lanes 2 and 5)
- For traffic with separation above 30m 6 dB of shielding (i.e. lanes 3 and 4)
- In some cases shielding could give 12 dB advantage (i.e. lane 6)

Analysis was done at 28 GHz using a noise figure of 4 dB, calculating statistics of I/N during the run of 10,000 Monte Carlo samples, as per the screen shot in Figure 60.

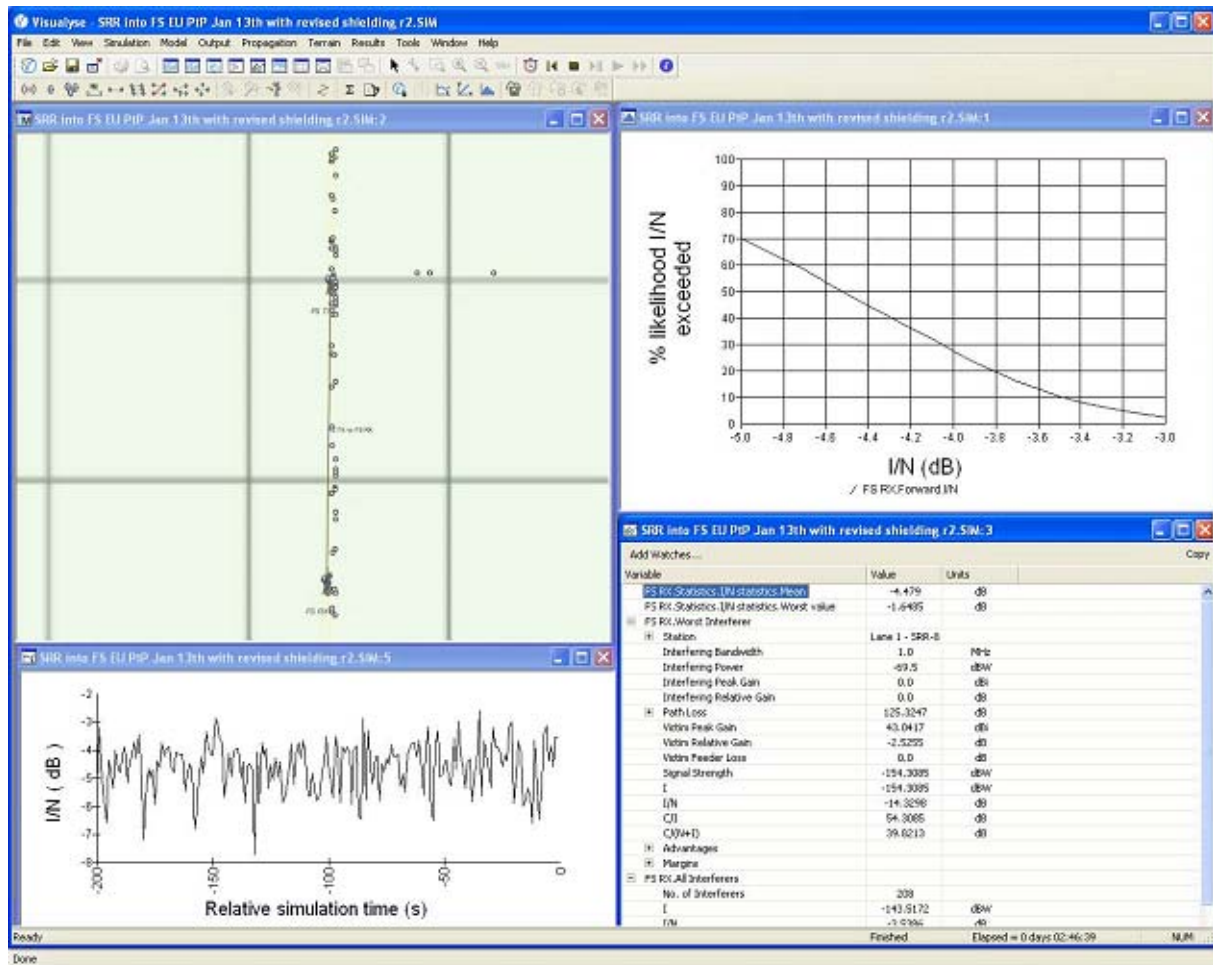


Figure 60

The analysis showed that:

- The worst I/N was -1.6 dB
- The average I/N was -4.5 dB
- An I/N of -3.8 dB was exceeded for around 20% of the time.

This shows that there are real interference issues for realistic deployment scenarios even taking into account the mitigation factors in ECC Report 023 with an SRR penetration rate of only 10%.

The scenario used is far from being the worst possible case as the traffic density was relatively low: therefore there could be significantly higher levels of interference than calculated here even with a national deployment percentage of 10% because:

- There could be stationary traffic with much lower separation distances
- Urban areas are likely to be richer and hence more likely to be able to purchase cars that include SRR features

As the threshold for long-term interference from another co-primary service is -10 dB this level of interference would be unacceptable even if SRR had a primary allocation.

As SRR is meant to operate as a secondary service it should meet the tighter threshold of an I/N = -20 dB

The analysis suggests that the SRR transmit powers should be decreased by 16.2 dB from -41.3 dBm/MHz to -57.5 dBm/MHz.

This is about 7dB more stringent than the conclusion of the ECC Report 023 analysis that suggested that a sharing would be feasible with an e.i.r.p. = -41.3 dBm/MHz if the SRR penetration rate was 10% penetration rate and if a protection objective of I/N -10dB would be acceptable.

In order to analyse the impact of higher penetration rates than 10%, the number of cars on each of the 6 lanes of the road was doubled. It was noted that the interference level for 20% of time increased by a factor of 3 dB, consistent with the prediction that interference was proportional to penetration rate.

Therefore, with a penetration rate of 100% (i.e. SRR long term home in the 28 GHz band) the interference is expected to exceed the threshold by about 26 dB.

The difference of 7dB to the worst case result of ECC Report 023 of 19 dB interference above the objective of I/N=-20dB are described in Table 42.

	This study	ECC Report 023	difference
Number of sensors in LOS on first lane without shadowing	3	1	4.77dB
Max interfering power I max	-130 dBm/MHz (NF=4dB, Feeder loss =0dB)	-128 dBm/MHz (NF= 4dB, feeder loss 2dB)	2 dB
Objective exceeded for the worst case scenario	26 dB	19 dB	7 dB

**Table 42**

This analysis suggests that the proposals in ECC Report 023 would not give sufficient protection for fixed links in bands around 28 GHz and ECC Report 023 results as presently stand are not worst case. Therefore, there is no scope for any further relaxation in the findings already contained in ECC Report 023.

**ANNEX 8 : LIST OF REFERENCES**

- [1] ECC Report 023: Compatibility of automotive collision warning Short Range Radars operating at 24 GHz with FS, EESS and Radio Astronomy
- [2] ETSI TR 101 982: Radio equipment to be used in the 24 GHz band; System Reference Document for automotive collision warning Short Range Radar
- [3] ECC/DEC/(04)03: ECC Decision of 19 March 2004 on the frequency band 77-81 GHz to be designated for the use of Automotive Short Range Radars
- [4] ECC/DEC/(04)10: ECC Decision of 12 November 2004 on the frequency bands to be designated for the temporary introduction of Automotive Short Range Radars (SRR)
- [5] Decision 2005/50/E: Harmonisation of the 24 GHz range radio spectrum band for the time-limited use by automotive short-range radar equipment in the Community
- [6] Report ITU-R SM.2057: Studies related to the impact of devices using ultra-wideband technology on radiocommunication services
- [7] ETSI TR 102 664: Road Transport and Traffic Telematics (RTTT); Short range radar to be used in the 24 GHz to 29 GHz band; System Reference document
- [8] RR: Radio Regulations
- [9] ERC Report 025: European Common Allocation Table (ECA)
- [10] Recommendation ITU-R F.1101: Characteristics of digital fixed wireless systems below about 17 GHz
- [11] Recommendation ITU-R F.758: Considerations in the development of criteria for sharing between the terrestrial fixed service and other services
- [12] ETSI EN 302 217-2-2: Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 2-2: Digital systems operating in frequency bands where frequency co-ordination is applied; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive
- [13] Recommendation ITU-R F.1094-2: Maximum allowable error performance and availability degradations to digital fixed wireless systems arising from radio interference from emissions and radiations from other sources
- [14] Recommendation ITU-R F.1703: Availability objectives for real digital fixed wireless links used in 27 500 km hypothetical reference paths and connections
- [15] Recommendation ITU-R F.1668: Error performance objectives for real digital fixed wireless links used in 27 500 km hypothetical reference paths and connections
- [16] ECC Report 094: Technical Requirements for UWB LDC Devices to ensure the Protection of FWA Systems
- [17] Recommendation ITU-R SA.609: Protection criteria for radiocommunication links for manned and unmanned near-Earth research satellites
- [18] Recommendation ITU-R SA.1161-1: Sharing and coordination criteria for data dissemination and direct data readout systems in the Earth exploration-satellite and meteorological-satellite services using satellites in geostationary orbit
- [19] Recommendation ITU-R SA.1026-4: Aggregate interference criteria for space-to-Earth data transmission systems operating in the Earth exploration-satellite and meteorological-satellite services using satellites in low-Earth orbit
- [20] Recommendation ITU-R SA.1027-4: Sharing criteria for space-to-Earth data transmission systems in the Earth exploration-satellite and meteorological-satellite services using satellites in low-Earth orbit
- [21] Recommendation ITU-R SM.1757-4: Impact of devices using ultra-wideband technology on systems operating within radiocommunication services
- [22] Recommendation ITU-R SA.509-2: Space research earth station and radio astronomy reference antenna radiation pattern for use in interference calculations, including coordination procedures
- [23] Recommendation ITU-R F.1245: Mathematical model of average radiation patterns for line-of-sight point-to-point radio-relay system antennas for use in certain coordination studies and interference assessment in the frequency range from 1 GHz to about 70 GHz
- [24] ECC Report 064: The Protection Requirements of Radiocommunications Systems below 10.6 GHz from generic UWB Applications
- [25] Recommendation ITU-R F.699: Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to about 70 GHz
- [26] Recommendation ITU-R P.452: Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz
- [27] Recommendation ITU-R P.530: Propagation data and prediction methods required for the design of terrestrial line-of-sight systems
- [28] J.D. Parsons "The Mobile Radio Propagation Channel." (John Wiley & Sons Ltd)