ECC REPORT 110

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COMPATIBILITY STUDIES BETWEEN BROAD-BAND DISASTER RELIEF (BBDR) AND OTHER SYSTEMS

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0 EXECUTIVE SUMMARY

This Report addresses compatibility and sharing issues between BBDR systems and the other systems/services identified within the possible frequency bands under consideration for BBDR: 4940-4990 MHz, 5150-5250 MHz, 5470-5725 MHz, 5725-5875 MHz and 5875-5925 MHz.

The studies assumed specific deployment and technical characteristics for BBDR systems. In particular, possible channel bandwidths between 1.25 and 20 MHz were assumed, with maximum e.i.r.p. spectral density of 26 dBm/MHz for a BBDR Base Station (BS) and 13 dBm/MHz for BBDR User Equipment (UE).

For each of the possible frequency bands, the result of the studies is the following:

- **4940 – 4990 MHz**: The technical studies lead to the conclusion that BBDR operation is not compatible with FS links and RAS stations in the frequency band 4940-4990 MHz. Moreover, BBDR devices are not compatible with UAV operation under the mobile service in the vicinity of land base receiver station for the sub-band 4940-4950 MHz. It is therefore not recommended to use BBDR applications in this band in a country where FS links, UAV in the mobile service and/or RAS sites use this frequency band. The frequency band 4940-4990 MHz could however still be considered as an optional band for those countries not having any active RAS sites, UAV or FS usage in this band.
- **5150 – 5250 MHz**: The technical studies in this frequency band between BBDR and MSS or RLAN devices lead to the conclusion that compatibility could be achieved. Additional consideration has been given to compatibility between BBDR and aeronautical telemetry systems (AMT) for flight testing in case WRC-07 allocates aeronautical mobile service to this band. With the considered assumptions for AMT, some interference may occur in both directions, but with a very low probability due to the temporary nature of both applications and the low number of locations of these AMT systems within Europe.
- **5470 – 5725 MHz:** In the lower part of this band (5470-5570 MHz), BBDR operation is compatible with EESS altimeter. Nevertheless, the different results show that, any use of outdoor BBDR BS will lead to significant interference into SAR systems. In the whole band 5470-5725 MHz, compatibility with RLAN devices as well as radars could be achieved only with additional mitigation techniques, such as LBT for the coexistence with RLANs and an efficient DFS mechanism for the coexistence with radars. It should be noted that because of the expected high number of RLAN systems as well as DFS efficiency with frequency hopping radars, the operation of BBDR in this band does not seem to be appropriate.
- **5725 – 5875 MHz:** In this frequency band, deployment of BBDR networks may be possible providing mitigation techniques are integrated on BBDR devices to improve the compatibility with RTTT, SRD, ITS and BFWA. Further analysis is required on the applicability and relevance of LBT for each of these sharing scenarios.
  It could be noted that compatibility is achieved with FSS.
  In the co-channel interference assessment with radiolocation (i.e. below 5850 MHz), mitigation techniques such as an efficient DFS mechanism may improve the compatibility issue noting that frequency hopping radars may trigger on all available channels. For adjacent channel interference assessment with radiolocation (i.e. above 5850 MHz), unwanted power level of BBDR devices for all frequencies below 5850 MHz has to be below -54 dBm/MHz in order to protect radars. On the other way, BBDR devices may suffer from interference from radars in this frequency band.
- **5875 – 5925 MHz:** In this frequency band, deployment of BBDR networks may be possible providing mitigation techniques are integrated on BBDR to ensure compatibility with ITS. Further analysis is required on the applicability and relevance of LBT for this sharing scenario, taking due account of the potential difficulties created by the moving configuration between BBDR and ITS. It could be noted that compatibility is achieved with FSS. Compatibility with FS links above 5925 MHz may be achieved if the unwanted power of BBDR devices for all frequencies above 5925 MHz is below -64dBm/MHz. On the other way, BBDR devices may suffer from interference coming from these FS links.

This table intends to depict in a simple way an overview of the results of these interference assessments for the different frequency bands:

Band (MHz)						
4940-4990 (Note 1)	RAS	FS	MS			
5150-5250 (Note 2)	MSS	RLAN				
5470-5570	EESS	RLAN	Radar			
5570-5725	RLAN	Radar				
5725-5875	FSS	RTTT	SRD	BFWA	Radar below 5850 MHz	ITS above 5855 MHz
5875-5925	FSS	FS (above 5925 MHz)	ITS			

(Note 1) RAS use in this band is on a secondary basis and there is limited use of civil FS as this band is a harmonised NATO band for fixed and mobile usage. Hence, individual national administrations may wish to make specific provision to allow the use of BBDR for occasional/minimal use during disaster operation.

(Note 2) In the event that WRC-07 allocates this band to aeronautical mobile telemetry (AMT), initial consideration on compatibility between BBDR and AMT has been made. Special care should be given around the location of AMT ground stations.

Colour	Meaning
Green	Compatibility is achieved
Orange	Compatibility may be achieved with efficient mitigation techniques or restriction
Red	Compatibility is not achieved

Considering the potential incompatibilities and the uncertainties related to the development of mitigation techniques, the band 5150-5250 MHz may be considered as the primary and preferred option for the deployment of BBDR.

The frequency band 4940-4990 MHz could also be considered as an optional band for those countries not having any active RAS sites, UAV usage in the MS or FS usage in this band.

Other bands may also be considered as optional bands providing that mitigation techniques are implemented where it is considered as relevant to protect the other services. This consideration should be made, taking into account the importance of communications for emergency services during disasters. Additional studies would be required to properly define these mitigation techniques.

Table of contents

LIST OF ABBREVIATIONS

Abbreviation	**Explanation**
AMT	Aeronautical Mobile Telemetry
UAV	Unmanned Aeronautical Vehicle
BB	BroadBand
BBDR	Broadband Disaster Relief
BFWA	BroadBand Fixed Wireless Access
BS	Base Station
CAC	Channel Availability Check
CEPT	European Conference of Postal and Telecommunications
CS	Central Station
DFS	Dynamic Frequency Selection
DR	Disaster Relief
DVS	Digital Video Sender
ECC	European Electronic Communications
EESS	Earth Exploration Satellite Service
e.i.r.p.	Equivalent isotropically radiated power
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
FS	Fixed Service
FSS	Fixed Satellite Service
FWA	Fixed Wireless Access
GSO	Geo Stationary Orbit
ITU	International Telecommunication Union
ITS	Intelligent Transport System
LBT	Listen Before Talk
MCL	Minimum Coupling Loss
ML	Main Lobe
MSS	Mobile Satellite Service
NATO	North Atlantic Treaty Organisation
OoB	Out Of Band emissions
Pfd	Power Flux Density
P-MP	Point-to-Multipoint
P-P	Point-to-Point
PPDR	Public Protection and Disaster Relief
PSD	Power Spectral Density
RA(S)	Radio Astronomy (Service)
RL	Radiolocation Service
RLAN	Radio Local Area Network
RSSI	Received Signal Strength Indication
RSU	Road Side Unit
RTTT	Road Transport and Traffic Telematics
SAR	Synthetic Aperture Radar
SL	Side Lobe
SRD	Short Range Devices
TPC	Transmitter Power Control
TRR	Tactical Radio Relay
TS	Terminal Station
UE	User Equipment
WAS/RLANs	Wireless Access Systems including Radio Local Area Networks
WG SE	Working Group Spectrum Engineering
WRC	World Radio-communication Conference

Compatibility studies between Broad-Band Disaster Relief (BBDR) and other systems

1 INTRODUCTION

Following a request from ETSI and the development of ETSI TR 102 485 [1], System Reference Document on Broadband Disaster Relief (BBDR) systems, CEPT considered a number of possible frequency bands for BBDR systems: 4940-4990 MHz, 5150-5250 MHz, 5470-5725 MHz, 5725-5875 MHz and 5875-5925 MHz.

However, in all of these bands, there are compatibility and sharing issues that need to be addressed before the final identification of the preferred sub-bands. This report provides compatibility studies between BBDR and the services possibly affected by their deployment.

2 DESCRIPTION OF BBDR SYSTEMS

4.1 Overview

Disaster Relief (DR) emergency services require efficient rapid deployment of incident ad-hoc networks. Applications are used temporarily by emergency services in all aspects of disaster situations, including disaster prevention and post-event scenarios. For instance, they provide incident communications, video or robotic data applications, telecommand and telemetry parameters, critical data base queries, field reporting, data and location information exchange.

Users of such systems (e.g. fire-fighters) belong to a group of people having a very high risk associated with their work. Statistics show that it is comparable only to the coal extraction industry. There is evidence that such systems will significantly enhance the security and sustainability of life of persons involved in rescue measures and therefore will provide a socio-economic benefit.

Infrequent usage during large extraordinary local incidents may also employ broadband disaster communications. The equipment used for this is often the same as in disaster relief operations (PP2 usage as described in ITU-R M.2033) and also described in ECC Report 102.

Disaster prevention means that these systems may be temporarily deployed (not necessarily used) during very exceptional and high-risk events.

It is forecasted that up to 2400 BBDR networks/systems may exist in Europe, whereby this is the number of networks available to be deployed but not necessarily in use. A fixed/permanent installation should be tolerated for sensitive sites (e.g. at military headquarters).

The number of users per network is typically about 25 (more users per network are possible, but no impact is expected on the compatibility study, only influencing data throughput per user).

In order to increase the throughput per user in a given network, it might be advised to install a second BS operating on a different channel.

The size of the disaster relief hot spot is about 1 km².

The nature of the disaster relief application may cause limitations for the definition, the implementation and the efficiency of the mitigation techniques potentially used by BBDR to protect the other radio services and applications within the hot spot area in general, as well as outside in some cases.

Only one equipment unit (either one UE or one BS) for one network in a given hot spot will be transmitting in one channel at a given time.

Area	Example scenario	Assumptions
Urban area	Building fire 	75 % of all radios are inside of a building. User equipment is body worn.
Suburban or rural area	A traffic stop (huge accident, chemical truck involved, fire caused, …) Forest fire 	Vast majority of radios are outside of a building. This may be offset by larger protection distances. User equipment is body worn.
	Chemical plant explosion	25 % of all radios are inside of a building. Others are outdoor but experience shadowing caused by industrial installations/obstructions. User equipment is body worn.

Table 1: Illustration of BBDR applications

4.2 Unwanted emission level of BBDR devices

Figure 1 provides BBDR emission mask.

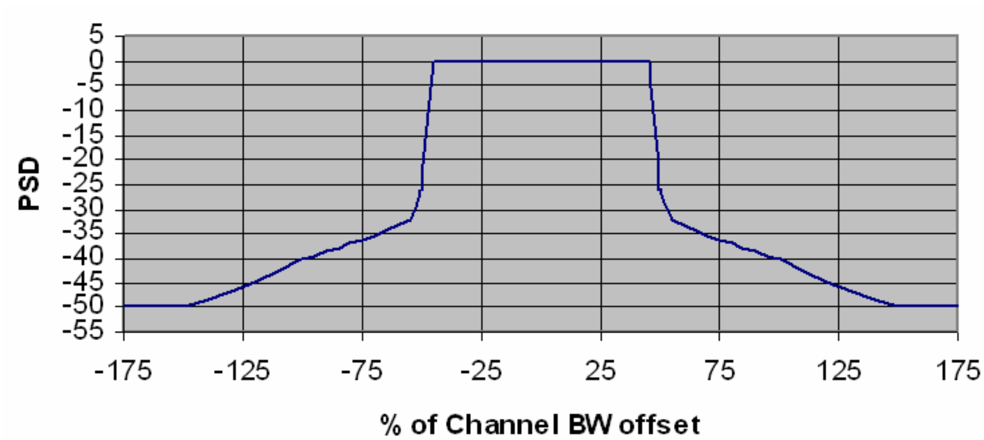

Figure 1: BBDR emission mask

The mask in Figure 1 is identical with the mask M as in FCC Rules Part 90 (selected in the US for the 4.9 GHz band). In addition, BBDR will fulfil the spurious emission requirements given in ERC REC 74-01 [2].

2.1 Antenna patterns for BBDR equipment

Antenna type	Antenna gain	Antenna height	Remarks
Base stations	Sectorised (typical) typically 9 dBi Max: 12 dBi Min: 2.2 dBi	from 5 to 15 meters	
User equipment	Omnidirectional typically 0 dBi Max: 2 dBi	1.5 meters	*User equipment may make use of beam forming resulting in an additional antenna gain, while still respecting the e.i.r.p. limits.*

Table 2: Antenna pattern

- Antenna pattern of the BBDR BS

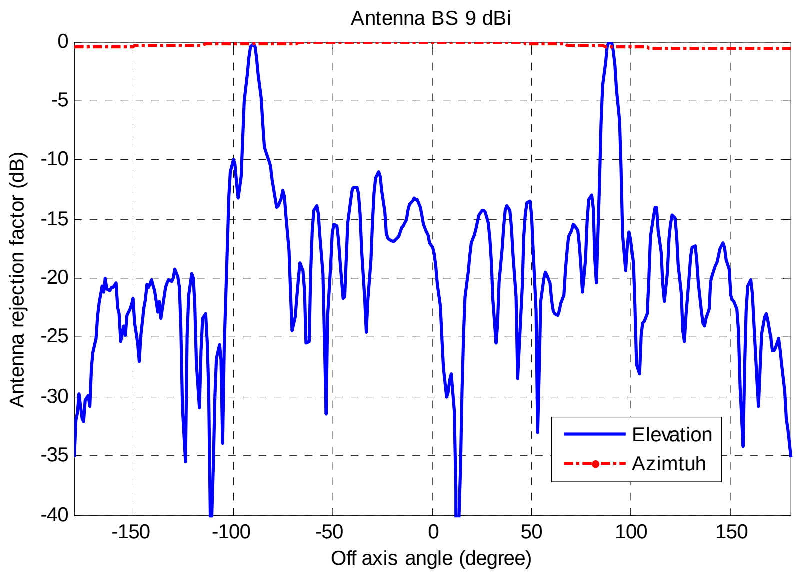

Figure 2: Antenna pattern for BBDR BS

- Antenna pattern of the BBDR UE

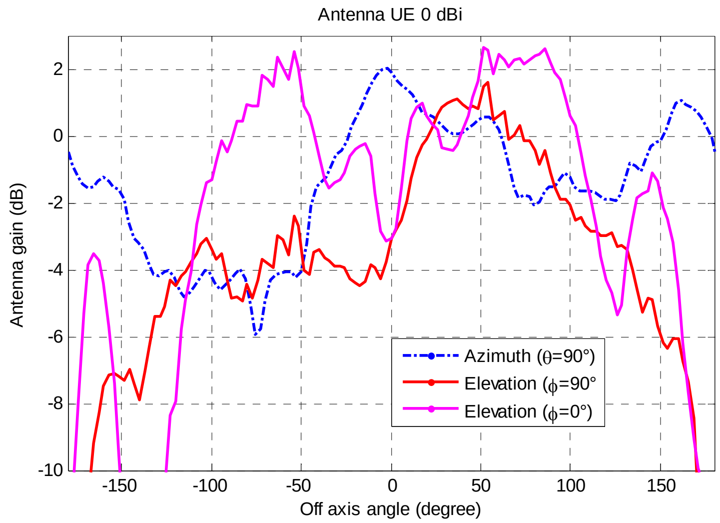

Figure 3: Antenna pattern for BBDR UE

2.2 Propagation model between terrestrial systems

The calculations developed in the different compatibility studies of this report used the same propagation model as in ECC Report 68 and 101 ([3], [4]). In the table 6.2.2 of the Report 68, data about BFWA Central Station (CS) is provided, representative of all BFWA devices located at high elevations, whereas the BFWA Terminal Station (TS) models BFWA devices deployed at low elevations.

It is then proposed to use the breakpoints and exponents corresponding to the TS case in this study.

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

$$L_{FS} = \begin{cases} 20Log\left(\frac{\lambda}{4\pi d}\right) & d \le d_0 \\ 20Log\left(\frac{\lambda}{4\pi d_0}\right) - 10n_0 Log\left(\frac{d}{d_0}\right) & \text{if } d_0 < d \le d_1 \\ 20Log\left(\frac{\lambda}{4\pi d_0}\right) - 10n_0 Log\left(\frac{d_1}{d_0}\right) - 10n_1 Log\left(\frac{d}{d_1}\right) & d > d_1 \end{cases} \quad (1)$$

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

Table 3: Parameters of propagation model

2.3 Parameters used for the interference assessment

The technical parameters of BBDR equipment used for interference assessment are given in Table 4.

Receiver Characteristics	**units**	**Value for BS**	**Value for UE**	**Remark**
Receiver bandwidth	MHz	10	10	Single frequency band for the whole mesh
Receiver sensitivity	dBm	-82 (-88 to -69)	-82 (-88 to -69)	Corresponding bit rate of 3 – 27 Mbps
Receiver Sensitivity at antenna input	dBm/MHz	-101 (-107 to -88)	-85 (-91 to -72)	Ignoring the cable loss
C/I	dB	6	6	
Allowable Interfering Power at receiver antenna input	dBm/MHz	-107	-91	
Transmitter Characteristics				
Bandwidth	MHz	10	10	
Transmitter e.i.r.p.	dBm	36	23	(see note)
Assumed value for TPC	dB	0	6	
Antenna Gain	dBi	9	0	
Body loss	dB	0	6	
Antenna loss due to portable usage	dB	0	1	
Note: e.i.r.p. level specified is for a 10 MHz channel. For other possible channel bandwidths (between 1.25 and 20 MHz), the maximum e.i.r.p. is derived from the power spectral density of 26 dBm/MHz for BS and 13 dBm/MHz for UE.				

Table 4: Technical requirements of BBDR devices

According to the different compatibility studies it would be needed to study either impact from/to BS or UE device:

- Attenuation for indoor to outdoor: a value of 15dB was taken into account.
- Information on the ratios of indoor versus outdoor systems is given in the Table 1.
- Attenuation for human loss: a value of 7 dB is given with 6 dB for body loss and 1 dB for portable coverage.

3 COMPATIBILITY STUDIES IN THE BAND 4940-4990 MHZ

3.1 Compatibility between BBDR and Mobile Service

This is an harmonized NATO band for fixed and mobile use. This band may be used by military unmanned aeronautical vehicles below 4950 MHz (**RR** 5.442). Typical characteristics of the land receiver station and mobile station are given in the table below.

	Characteristics	Value	Unit
	Carrier frequency	4940	MHz
Land receiver station	Receiver bandwidth	20	MHz
	Receiver noise level	-97	dBm
	Protection criterion (I/N)	-6	dB
	Antenna height	8	m
	Azimuth	0	°
	Elevation	1.43	°
	Antenna gain	29	dBi
	Antenna pattern	See graph below	
Airborne UAV transmission	Transmission power	40	dBm
	Antenna height	3000	m
	Azimuth	0	°
	Elevation	-1.43	°
	Antenna gain	13	dBi
	Communication range	120	km
	Propagation model	Free Space losses	
	Antenna sidelobe	0 dBi	

Table 5: Characteristics for Mobile Service Systems in the band 4940 – 4990 MHz

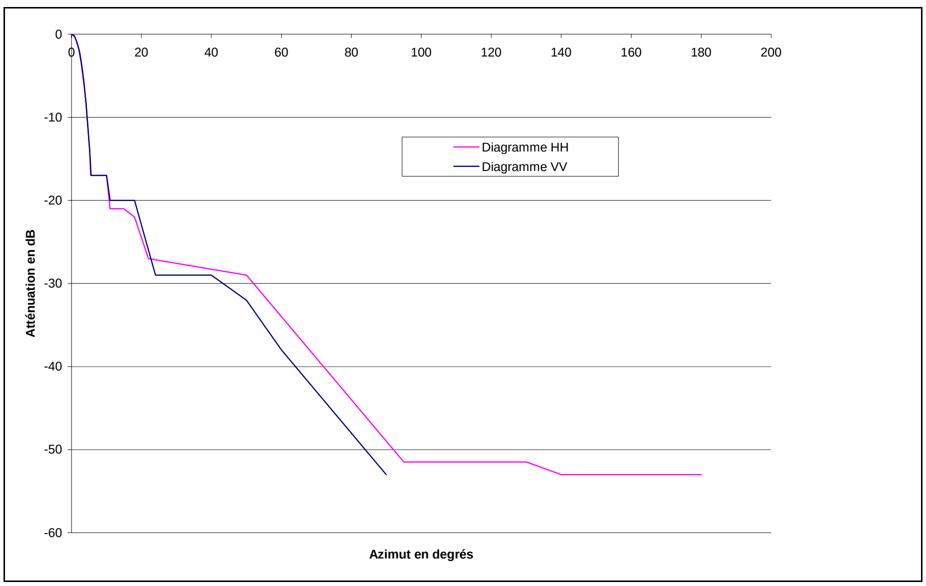

Figure 4 : Antenna patterns used by UAV land receiver station

The methodology to calculate separation distance is provided in the next section concerning the interference assessment between FS and BBDR devices.

Two interference scenarios have been considered:

- Interference from BBDR into the land base UAV receiver station,
- Interference from the UAV airborne transmitter into BBDR.

The calculations lead to the following results when applying the figures of **Table 5**. Values for antenna gains in sidelobe configurations are assumed to be 0 dBi.

	Prop model	URBAN	SUBURBAN	RURAL
BBDR to UAV land station	ML BBDR-ML BS UAV	7961	11681	11681
	ML BBDR-SL BS UAV	1597	3386	8118
	SL BBDR-ML BS UAV	3566	8403	11681
	SL BBDR-SL BS UAV	715	1364	2850
UAV to BBDR	ML UAV -ML BBDR	1097	2213	4974
	SL UAV -ML BBDR	547	1007	2008
	ML UAV -SL BBDR	491	892	1746
	SL UAV -SL BBDR	245	406	660

Table 6: Separation distances (m) between BBDR and UAV

These simple calculations show that an UAV flying at 3000m will not prevent BBDR from operating. There is only the configuration ML UAV-ML BBDR in rural areas which may create problems but it is unlikely to meet such a situation. On the other way, BBDR devices may not be used in the vicinity of the BS (reception part).

Therefore, BBDR is compatible with UAV operation except in the vicinity of the land base station.

3.2 Compatibility between BBDR and Fixed Service

This is an harmonized NATO band for fixed and mobile use. There is limited civil fixed service use.

Characteristics of the Fixed Service are available in Recommendation ITU-R Rec. F.758 [5]. Additional characteristics of tactical radio relays used for military applications are listed in the table below as follows:

Type	F.758	TRR Mode 1	TRR Mode 2
Frequency band (GHz)	4.4-5.0	4.4-5.0	4.4-5.0
Modulation	16-QAM		
Capacity	52 Mbit/s		
Channel spacing (MHz)	20	7.5	2.3
Antenna gain (maximum) (dBi)	42.5	21	21
Feeder/multiplexer loss (minimum) (dB)	T:7.0 R:4.0		
Antenna type	Horn		
Maximum Tx output power dBW)	–7.1		
e.i.r.p. (maximum) (dBW)	28.4	24	24
Receiver IF bandwidth (MHz)	16.65	7.5	7.5
Receiver noise figure (dB)	4.2		
Receiver thermal noise (dBW)	–128.1	–130	–135
Nominal Rx input level (dBW)	–73		

Table 7: Characteristics for Fixed Service Systems in the band 4940 – 4990 MHz

The required protection range is estimated using the maximum allowable interference at the antenna input when applying the long term interference criteria (-10 dB below the thermal noise).
It means that the required propagation loss L_{FS} is given by the following equation:

$$\begin{aligned} I &= e.i.r.p. - L_{FS} + G_r \\ \Rightarrow L_{FS} &= e.i.r.p. - I + G_r \end{aligned} \quad (2)$$

where

- I is the maximum interference power (-112dBm/MHz)
- G_r is the victim antenna gain in dBi (42.5dBi)
- *e.i.r.p.* is the e.i.r.p. of the interferer in dBm (with eventually a TPC factor)

It should be noted that propagation losses are limited to the extent of its radio electrical horizon (Horizon (m)=4130* $\sqrt{h}$ with h the altitude over the sea level of the interferer). The presented results hereafter are given for a 20m antenna height and leads to a radio horizon of 18470 m.

An additional factor can be integrated into this equation. This is the sidelobe attenuation factor if the transmission scheme does not imply the main beam of one of the studied devices.

- *Results*

	Prop model	URBAN	SUBURBAN	RURAL
BBDR to FS	ML BBDR-ML FS	18470	18470	18470
	ML BBDR-SL FS	1472	3089	7302
	SL BBDR-ML FS	9593	18470	18470
	SL BBDR-SL FS	659	1245	2564
FS to BBDR	ML FS-ML BBDR	2872	6579	18470
	ML FS-SL BBDR	197	318	474
	SL FS-ML BBDR	1286	2651	6124
	SL FS-SL BBDR	84	108	108

Table 8a: Separation distances (m) between BBDR and FS (F.758)

	Prop model	URBAN	SUBURBAN	RURAL
BBDR to FS	ML BBDR-ML FS	6001	15146	17028
	ML BBDR-SL FS	1949	4243	10526
	SL BBDR-ML FS	2688	6103	15998
	SL BBDR-SL FS	873	1710	3696
FS to BBDR	ML FS-ML BBDR	2912	6684	17028
	ML FS-SL BBDR	946	1872	4103
	SL FS-ML BBDR	1304	2693	6236
	SL FS-SL BBDR	424	754	1441

Table 8b: Separation distances (m) between BBDR and TRR Mode 1

	Prop model	URBAN	SUBURBAN	RURAL
BBDR to FS	ML BBDR-ML FS	5958	15024	17028
	ML BBDR-SL FS	1935	4209	10428
	SL BBDR-ML FS	2669	6054	15850
	SL BBDR-SL FS	867	1696	3662
FS to BBDR	ML FS-ML BBDR	3834	9122	17028
	ML FS-SL BBDR	1245	2555	5870
	SL FS-ML BBDR	1717	3676	8923
	SL FS-SL BBDR	558	1030	2061

Table 8c: Separation distances (m) between BBDR and TRR Mode 2

3.3 Compatibility between BBDR devices and Radioastronomy

The frequency band 4 800 – 4 990 MHz is allocated to the RAS on a secondary basis. The band 4 950 – 4 990 MHz is covered by footnote 5.149 [6]:

"…administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service (see Nos. **4.5** and **4.6** and Article **29**). (WRC-2000)"

Administrations may need to take into account the protection of RA sites operating in this band.

For this band, the level of acceptable interference has to be lower than -207dBW/10MHz (i.e. -187dBm/MHz) as stated in ITU-R Recommendation RA.769 [7].

The needed separation distance between BBDR and RA station is very important (several hundreds of km) according to an emitted power of 26dBm/MHz and a receiver antenna gain of 0 dBi, commonly used for such kind of calculation.

This leads to the conclusion that BBDR can not be deployed in countries, where the frequency band 4 940 – 4 990 MHz is used by the RA stations. The known locations of RA stations are shown in the table below.

Country	**Place**	**Status 4.8-5GHz**	**Country**	**Place**	**Status 4.8-5GHz**
Czech Republic	Ondrejov	not used	Russia	Zimenki	not used
France	Nançay	used		Petropavlovsk	used
Germany	Effelsberg	used	Sweden	Onsala	used
Greece	Pentele	used	Switzerland	Bleien	used
Italy	Medicina	used	Turkey	Kayseri	used
	Noto	used	Ukraine	Simeiz	Used
	Sardinia	used		Tzarichanka	Used
Netherlands	Westerbork	used	United Kingdom	Cambridge	Used
Russia	Badari	used		Darnhall	Used
	Kalyazin	used		Defford	Used
	Pushchino	used		Jodrell Bank	Used
	Svetloe	used		Knockin	Used
	Zelenchukskaya	used		Pickmere	Used

Table 9: Status of the usage of 4.8 to 5 GHz by RA stations within the CEPT

3.4 Discussion for the band 4940-4990 MHz

The technical studies lead to the conclusion that BBDR devices are not compatible with FS links and RA stations in the frequency band 4940-4990 MHz.
It is therefore not recommended to use BBDR devices in this band in a country where FS links and/or RAS sites use this frequency band but this is subject to discretion of individual national administrations who may wish to make specific provision to allow the use of BBDR for occasional/minimal use during disaster operation.
It is noted that this band is used for BBDR in countries in ITU-R Regions 2 and 3, with no reported interference.

4 COMPATIBILITY STUDIES IN THE BAND 5150-5250 MHZ

4.1 Compatibility between BBDR and Fixed Satellite (Earth-to-Space) for MSS feeder links

The frequency band 5 150 – 5 250 MHz is allocated to the FSS (E-s) on a primary basis in all ITU-R regions. The allocation is limited to MSS feeder links.

ERC Report 67 [8] provided methodologies which assess protection of ICO and Globalstar MSS feeder links from RLANs. It considered two methods to assess the number of systems in the MSS footprint:

- Increase of the noise temperature at satellite receiver;
- Increase of noise temperature on overall MSS link.

The Recommendation ITU-R S.1427 [9] states that in order to ensure the adequate protection for the non-GSO MSS feeder links from RLAN emissions in the band 5 150-5 250 MHz the aggregate $\Delta T_{satellite}/T_{satellite}$ should be no more than 3%. It has to be noted also that ITU-R Recommendation S.1432 [10] stated 'that error performance degradation due to interference at frequencies below 15 GHz should be allotted portions of the aggregate interference budget of 32% or 27% of the clear-sky satellite system noise in the following way:

– 25% for other FSS systems for victim systems not practising frequency re-use;

– 20% for other FSS systems for victim systems practising frequency re-use;

– 6% for other systems having co-primary status;

– 1% for all other sources of interference,'

The following Tables 8-9 provide the acceptable number of BBDR BSs for two apportionment figures (3% and 1%).

LINK BUDGET	Value	Units	**ICO**	**Globalstar**
Emission part: BBDR				
Bandwidth	10	MHz		
T_x out, e.i.r.p.	36	dBm	36	36
Tx Out e.i.r.p. per MHz	26	dBm/MHz	26	26
effect of TPC (dB)	0	dB	0	0
OoB Attenuation	0	dBr	0	0
Net T_x Out e.i.r.p.		dBm/MHz	26	26
Net T_x Out e.i.r.p. on a MSS channel		dBm	10	27
Antenna Gain	9	dBi		
Frequency (GHz)	5.10	GHz	5	5
Reception part: MSS				
Receiver bandwidth		MHz	0.025	1.230
T_{sat}		°K	400	550
Protection Criterion	3	%	0.03	0.03
Delta T		°K	12	16
Receiver sensitivity		dBm	-143.83	-125.53
Antenna gain		dBi	10.00	6.00
Feeder Loss		dBi	1.00	2.90
Pol discrimination	2	dB	2	2
I max at antenna input on a MSS channel		dBm	-151	-127
Propagation model				
Altitude		km	10355	1414
Att		dB	187	170
100% outdoor use, ($\Delta T_{satellite}/T_{satellite}$ = 3%)				
Allowable Interfering power level 'I' on the ground on a MSS channel		dBm	36	43
MAIN LOBE MSS - MAIN LOBE BBDR				
Number of BBDR networks in the main lobe of the MSS system			**402**	**40**
MAIN LOBE MSS - SIDE LOBE BBDR				
Sidelobe attenuation (dB)	15	dB	15	15
Number of BBDR networks in the main lobe of the MSS system			**12720**	**1268**
25% outdoor use, ($\Delta T_{satellite}/T_{satellite}$ = 3 %)				
Ratio of outdoor use	25%	%	25%	25%
Addition Attenuation for indoor use		dB	11	10.5
Mean Attenuation		dB	197	179
Allowable Interfering power level 'I' on the ground		dBm	46	52
MAIN LOBE MSS - MAIN LOBE BBDR				
Number of BBDR networks in the main lobe of the MSS system			**3899**	**347**
MAIN LOBE MSS - SIDE LOBE BBDR				
Sidelobe attenuation (dB)	15	dB	15	15
Number of BBDR networks in the main lobe of the MSS system			**123285**	**10985**

Table 10: Acceptable number of BBDR BSs for a criterion of 3%

If only 1% of apportionment is considered for allowable margin, the number of BBDR BSs in the main lobe of the MSS system is the following:

	Units	ICO	Globalstar
100% outdoor use, ($\Delta T_{satellite}/T_{satellite}$ = 1%)			
Allowable Interfering power level '*I*' on the ground on a MSS channel	dBm	31	38
MAIN LOBE MSS - MAIN LOBE BBDR			
Number of BBDR networks in the main lobe of the MSS system		**134**	**13**
MAIN LOBE MSS - SIDE LOBE BBDR			
Number of BBDR networks in the main lobe of the MSS system		**4240**	**423**
25% outdoor use, ($\Delta T_{satellite}/T_{satellite}$ = 1%)			
MAIN LOBE MSS - MAIN LOBE BBDR			
Number of BBDR networks in the main lobe of the MSS system		**1300**	**116**
MAIN LOBE MSS - SIDE LOBE BBDR			
Number of BBDR networks in the main lobe of the MSS system		**41095**	**3662**

Table 11: Acceptable number of BBDR BSs for a criterion of 1%

It should be noted that the number of BBDR systems forecasted to be deployed is not necessarily the number of active networks transmitting simultaneously. In addition, the UE would show an average power reduction of at least 6 dB.
Therefore the results of the Tables 8-9 should be interpreted as showing worst case numbers. Whatever the apportionment figure, the number of BBDR BSs is sufficiently high to give enough confidence for achieving compatibility based on a main lobe MSS- side lobe BBDR configuration.
Considering the antenna diagram provided for BBDR BS, the occurrence of ML-ML interference is very low and the figures provided in the tables for this scenario are not considered to be relevant.

Any discussion on the addition of further levels of interference from BBDR devices into MSS Feeder links should also consider the role that such MSS systems might play in the envisaged Disaster Relief activity. It can in particular be anticipated that there would be an increase in the usage of MSS in Disaster situations.

Interference from MSS earth stations into the BBDR was found not to be critical due to the low number of MSS uplinks gateways and their position within restricted sites.

In conclusion, compatibility between BBDR and MSS feeder links is expected to be feasible.

4.2 Compatibility between BBDR and Mobile (RLAN)

The ECC Decision (04)08 [11] designates the frequency bands 5 150 – 5 350 MHz and 5 470 – 5 725 MHz for WAS/RLANs and gives the technical conditions to be applied to WAS/RLANs.

Considering the various conditions of use of these bands by RLANs, it is expected that the most critical coexistence scenarios will occur in the 5470-5725 MHz band. This is due to the fact that RLANs shall be restricted to indoor use with a maximum mean e.i.r.p. of 200 mW in the band 5150-5250 whereas the outdoor operation with 1 W maximum mean e.i.r.p is authorized in the 5470-5725 MHz.

When applying the methodology described in section 5.3, the following results may be found considering a 15 dB for the wall attenuation:

- Calculations of the separation distances between RLAN as interferer and BBDR BS or UE devices as victims lead to the following results:

LINK BUDGET	**Urban**	**Suburban**	**Rural**
ML RLAN ->ML BBDR BS			
Separation distance (m)	164	258	358
ML RLAN ->SL BBDR BS			
Separation distance (m)	68	73	73
ML RLAN ->ML BBDR UE			
Separation distance (m)	64	65	65

Table 12: Separation distances to protect BBDR devices

- Calculations on the separation distances between BBDR BS or UE devices as interferers and RLAN equipment as victim lead to the following results:

LINK BUDGET	**Urban**	**Suburban**	**Rural**
ML BBDR BS – ML RLAN			
Separation distance (m)	735	1408	2956
ML BBDR UE - ML RLAN			
Separation distance (m)	183	291	421

Table 13: Separation distances to protect RLAN devices

It appears that it is unlikely that BBDR devices may receive interference from indoor RLAN devices operating in buildings in the vicinity of a BBDR deployment. On the other hand, outdoor BBDR devices in operation may create interference on RLAN devices in some cases. Mitigation technique may help to improve the compatibility.

4.3 Potential allocation of 5150–5250 MHz to Aeronautical Telemetry at WRC 07

WRC-07 Agenda item 1.5 seeks to identify spectrum that can be used to meet the demand for access to spectrum for the provision of aeronautical telemetry and telecommand systems (AMT). In particular, the band 5150-5250 MHz is envisaged as a potential band for AMT for flight testing.

4.3.1 Impact from AMT into BBDR

WP8B realized different compatibility studies in particular with RLAN devices (MS). These studies conclude that AMT receivers can not be protected from interference coming from RLAN devices and that AMT transmitters have to produce a Pfd level at the Earth surface lower than -79.4 dBW/(m².20 MHz)- G_{RLAN} where G_{RLAN} is the rejection factor (-6 dB maximum) below the maximum antenna gain of the RLAN device. The PFD level would be lower than -56.4 dBm/(m².MHz).
Therefore, the interference level *I* received by any BBDR device is given by the following equation:

$$Pfd + 10Log\left(\frac{\lambda^2}{4\pi}\right) + G_R = I \qquad (3)$$

$$\Rightarrow I = -83.4 dBm / MHz$$

where:

Pfd : Power flux density of AMT transmitter (dBm/m²/MHz)
λ : Wavelength
G_R : Receiver gain of the BBDR device (9 dBi)

This interference level exceeds the maximum allowable level I_{max}=-107dBm/MHz (see section 2.5) by 23.6 dB. This is consistent with the allowable level for indoor RLAN devices (I_{max}= -89dBm/MHz and including 15 dB wall loss).
Therefore, BBDR devices may receive interference during flight testing operations. However, BBDR may cope with such interference with mitigation techniques.

In addition, it should be noted that both BBDR and AMT flight testing operations are both temporary and therefore, the probability of simultaneous operation in the same area is low.

4.3.2 Impact from BBDR into AMT terrestrial stations

Only few AMT stations are intended to be deployed within CEPT for flight testing purposes.
Assuming an antenna gain of 40 dBi for AMT terrestrial stations, the antenna beamwidth is around 2.2°, both horizontally and vertically. The probability of collision of this antenna 'spot' with BBDR may be further reduced by shadowing effect. During a flight testing operation, the antenna will have to track the aircraft, having a velocity of several hundreds km/h and therefore, it is expected that the elevation and azimuth angles will change very rapidly. Consequently, most interference coming from BBDR networks will be received by AMT receiver from its sidelobes. The Table 12 below gives the needed separation distances for an assumed maximum value of 0 dBi for the AMT sidelobe antenna gain.

LINK BUDGET	**Urban**	**Suburban**	**Rural**
ML BBDR BS – SL AMT			
Separation distance (m)	1556	3289	7850
SL BBDR BS – SL AMT			
Separation distance (m)	697	1325	2756

Table 14: Separation distances to protect AMT systems from BBDR

From another point of view, such devices will be used much less extensively than indoor RLAN devices and one can expect that in most cases interference will occur first from RLAN devices and not from BBDR devices since the latter are intended to be used only during disaster management. As a consequence, AMT systems may have already some mitigation techniques to avoid interference from RLAN devices (e.g. with an available frequency band below 5150 MHz). This may help reducing interference impact from BBDR.

Therefore, it is unlikely that AMT land receivers will suffer from interference brought by BBDR devices noting that there are few AMT stations in Europe (less than 5) and BBDR are not permanently in operation.

4.4 Discussion in the band 5150-5250 MHz

The technical studies in this frequency band between BBDR and MSS or RLAN devices lead to the conclusion that compatibility could be achieved.
Additional consideration has been given to compatibility between BBDR and AMT systems for flight testing in case WRC-07 allocates aeronautical telemetry services to this band. With the considered assumptions for AMT, some interference may occur in both directions, but with a very low probability due to the temporary nature of both applications and the low number of locations of AMT systems within Europe.

5 COMPATIBILITY STUDIES IN THE BAND 5470-5725 MHZ

5.1 Impact of BBDR devices on EESS systems

The band 5250-5570 MHz is allocated to the Earth-Exploration Satellite Service (active).

Two types of EESS space sensors are operated in this band:
- Synthetic Aperture Radars (SAR),
- Altimeters.

Within this band, the sub-band 5470-5570 MHz is mainly used by wideband active sensors. The typical characteristics of these sensors are taken from Recommendation ITU-R M.1653 [12] and are provided below:

Parameter	Value	
	SAR2	SAR3
Orbital altitude	600 km (circular)	400 km (circular)
Orbital inclination	57 deg	57 deg
RF centre frequency	5 405 MHz	5 405 MHz
Peak radiated power	4 800 W	1 700 W
Polarization	Horizontal and vertical (HH, HV, VH, VV)	Horizontal and vertical (HH, HV, VH, VV)
Pulse modulation	Linear FM chirp	Linear FM chirp
Pulse bandwidth	310 MHz	310 MHz
Receiver bandwidth	320 MHz	320 MHz
Pulse duration	31 μs	33 μs
Pulse repetition rate	4 492 pps	1 395 pps
Duty cycle	13.9%	5.9%
Range compression ratio	9 610	10 230
Antenna type	Planar phased array 1.8 m × 3.8 m	Planar phased array 0.7 m × 12.0 m
Antenna peak gain	42.9 dBi	42.7/38 dBi (full focus/beamspoiling)
Antenna median side-lobe gain	–5 dBi	–5 dBi
Antenna orientation	20-38 deg from nadir	20-55 deg from nadir
Antenna beamwidth	1.7 deg (El), 0.78 deg (Az)	4.9/18.0 deg (El), 0.25 deg (Az)
Antenna polarization	Linear horizontal/vertical	Linear horizontal/vertical
System noise temperature	550 K	550 K
Receiver front end 1 dB compression point ref to receiver input	–62 dBW input	–62 dBW input
ADC saturation ref to receiver input	–114/–54 dBW input @71/11 dB receiver gain	–114/–54 dBW input @71/11 dB receiver gain
Receiver input maximum power handling	+7 dBW	+7 dBW
Operating time	30% the orbit	30% the orbit
Minimum time for imaging	15 s	15 s
Service area	Land masses and coastal areas	Land masses and coastal areas
Image swath width	20 km	16 km/320 km

Table 15: 5.4 GHz typical wideband spaceborne SAR characteristic

Jason mission characteristics	
Lifetime	5 years
Altitude	1 347 km ± 15 km
Inclination	66°
Poseidon 2 altimeter characteristics	
Signal type	Pulsed chirp linear frequency modulation
Pulse repetition frequency (PRF)	300 Hz
Pulse duration	105.6 μs
Carrier frequency	5.410 GHz
Bandwidth	320 MHz
Emission RF peak power	17 W
Emission RF mean power	0.54 W
Antenna gain	32.2 dBi
3 dB aperture	3.4°
Side-lobe level/Max	–20 dB
Back side-lobe level/Max	–40 dB
Beam footprint at –3 dB	77 km
Interference threshold	–118 dBW in 320 MHz
Service area	Oceanic and coastal areas

Table 16: 5.3 GHz typical wideband spaceborne altimeter characteristics

These characteristics and an approach similar to the one used in the ERC Report 72 [13] are used to calculate the number of BBDR systems in the footprint of the EESS active sensor assuming 100% and 25% outdoor use.

LINK BUDGET	Value	Units	SAR2	SAR3	Altimeter
Emission part: BBDR BS					
Bandwidth	10	MHz			
Tx out, e.i.r.p.	36	dBm	36	36	36
Tx Out e.i.r.p. per MHz	26	dBm/MHz	26	26	26
effect of TPC (dB)	0	dB	0	0	0
OoB Attenuation	0	dBr	0	0	0
Net Tx Out eirp	26	dBm/MHz	26	26	26
Antenna Gain	9	dBi			
Frequency (GHz)	5.47	GHz	5.47	5.47	5.47
Reception part: EESS					
Receiver bandwidth		MHz	320	320	320
Noise temperature		°K	550	550	
Noise level 'N'		dBm	-86.15	-86.15	
Antenna gain		dBi	42.9	42.7	32.3
Pol discrimination	3	dB	3	3	0
Protection criterion I/N	-6	dB	-6	-6	
Interference threshold		dBW/320MHz			-118
I max per MHz at antenna input		dBm/MHz	-157.1	-156.9	-113.1
Propagation model (free space)					
Altitude		km	600	400	1347
Att		dB	163	159	170
100 % outdoor use					
Allowable Interfering power level 'I' on the ground		dBm/MHz	6	2	57
MAIN LOBE EESS - MAIN LOBE BBDR					
Number of BBDR networks in the main lobe of the EESS system			0.01	0.004	1174
MAIN LOBE EESS - SIDE LOBE BBDR					
Sidelobe attenuation (dB)	15	dB	15	15	15
Number of BBDR networks in the main lobe of the EESS system			0.29	0.14	37116
25 % outdoor use					
Ratio of outdoor use	25%	%	25%	25%	25%
Addition Attenuation for indoor use	15	dB	15	15	15
Mean Attenuation		dB	177	173	184
Allowable Interfering power level 'I' on the ground		dBm/MHz	19	16	70
MAIN LOBE EESS - MAIN LOBE BBDR					
Number of BBDR networks in the main lobe of the EESS system			0.22	0.10	28130
MAIN LOBE EESS - SIDE LOBE BBDR					
Sidelobe attenuation (dB)	15	dB	15	15	15
Number of BBDR networks in the main lobe of the EESS system			7	3	889560

Table 17 : Interference from BBDR into SAR

These figures show that BBDR may be compatible with EESS altimeter. Nevertheless, the different results show that any use of outdoor BBDR BS will lead to significant interference into SAR systems.

5.2 Compatibility between BBDR devices and Amateur Service

The frequency band 5650 – 5850 MHz is allocated to the radio amateur services on a secondary basis, while the amateur satellite service uplink band is 5650 – 5668 MHz. See section 6.3.

5.3 Compatibility between BBDR and Mobile (RLAN)

The ECC Decision (04)08 [11] designates the frequency bands 5150 – 5350 MHz and 5470 – 5 725 MHz for WAS/RLANs and gives the technical conditions to be applied to WAS/RLANs.

The following characteristics related to RLANs in the 5470-5725 MHz band are used in the study.

PARAMETER	VALUE
Maximum e.i.r.p.	30 dBm
Maximum e.i.r.p. density	17dBm/MHz
Antenna gain omni	0 dBi
Antenna gain directional	6 dBi maximum
Transmitter power control	3 dB
Channel Bandwidth	20 MHz
Required I/N	-6 dB

Table 18 : RLAN parameters for use in sharing calculations

Calculations on the separation distances between RLAN equipment as interferer and BBDR BS or UE devices as victims lead to the following results:

LINK BUDGET	Urban	Suburban	Rural
ML RLAN ->ML BBDR BS			
Separation distance (m)	**520**	**952**	**1883**
ML RLAN ->SL BBDR BS			
Separation distance (m)	**233**	**384**	**611**
ML RLAN ->ML BBDR UE			
Separation distance (m)	**221**	**361**	**563**

Table 19: Separation distances to protect BBDR devices

Calculations on the separation distances between BBDR BS or UE devices as interferers and RLAN equipment as victim lead to the following results:

LINK BUDGET	Urban	Suburban	Rural
ML BBDR BS – ML RLAN			
Separation distance (m)	2206	4881	12367
ML BBDR UE - ML RLAN			
Separation distance (m)	548	1010	2015

Table 20: Separation distances to protect RLAN devices

It appears that in both directions, mitigation techniques would be needed to prevent interference.

However, in that case, considering the large separation distance to protect RLAN and the expected high number of RLAN systems, the operation of BBDR in this band does not seem to be appropriate.

5.4 Compatibility between BBDR devices and Maritime radionavigation service

Technical characteristics of radars operating in the maritime radionavigation service in the band 5470-5600 MHz are given in the Recommendation ITU-R M.1313 [14]. It is assumed that the coexistence will be addressed by considering the coexistence with radiolocation (see 5.5).

5.5 Compatibility between BBDR devices and Radiolocation service

The characteristics of Radiodetermination systems operating within the frequency range 5250-5850 MHz are provided in Recommendation ITU-R M.1638 [15].

It has to be noted that a number of these radiodetermination systems and other radars operated by administrations within CEPT (e.g. radars X, Y and Z in ECC Report 68 [3]) can operate in a frequency range including both bands 5470-5725 and 5725-5850 MHz or parts of them. Therefore, the analysis for the band 5470-5725 MHz equally applies to the 5725-5850 MHz band.

This section provides calculations of the interference level from a single BBDR device into a radar and identifies the need for mitigation techniques which are described in subsequent sections.

5.5.1 MCL calculations

The method used to calculate the potential interference to Radiolocation devices is based on the Minimum Coupling Loss (MCL) required between radars and BBDR systems as described in Recommendation ITU-R M.1461 [16]. This gives

$$MCL = P_{tr} + 10\log\{BW_{radar}/BW_{BBDR}\} - I_{rec} \qquad (4)$$

where:

- MCL Minimum Coupling Loss in dB
- P_{tr} Maximum Transmit Power, before antenna and feeders (BBDR) in dBW
- BW_{radar} Receiver Noise Bandwidth (Radar) in Hz
- BW_{BBDR} Transmitter Bandwidth (BBDR) in Hz
- I_{rec} Maximum Permissible Interference at Receiver after antenna and feeder (Radar) in dB

The MCL is then converted into the required propagation loss L as follows:

$$L = MCL + G_{tr} - L_{tr} + G_{rec} - L_{rec} \qquad (5)$$

where:

- G_{tr} Gain of the BBDR antenna in dBi
- L_{tr} BBDR feeder loss in dB
- G_{rec} Gain of Radar antenna in dBi
- L_{rec} Radar feeder loss in dB

The required separation distances d (in metres) can be calculated, assuming free space propagation loss, from:

$$d = \lambda/(4\pi) * 10^{L/20} \qquad (6)$$

where:

λ is the wavelength given in metres.

According to existing conclusions for other devices (RLAN in ERC Report 72 [13] and BFWA in ECC Report 68 [4]), it can be concluded that mitigation techniques are required to enable the sharing between BBDR systems and radars. The consideration of alternative parameters for BBDR systems will not change drastically the required separation distances and will not modify the main conclusion that mitigation techniques are required. This is the reason why no further details will be provided in this section.

5.5.2 Dynamic Frequency Selection

A dynamic frequency selection (DFS) will be needed to be implemented by BBDR systems in the bands 5470 to 5850 MHz to protect radars from interference. The general principle applied is that BBDR devices should detect any radar signal above a defined receiver threshold and make sure that the BBDR system shall not use those frequencies which were identified as being used by the radar. The DFS mechanism would then have the effect of protecting both the BBDR and Radar systems from harmful interference.

Within the context of the operation of the DFS function, a BBDR device shall operate in either master mode or slave mode. BBDR devices operating in slave mode (slave device) shall only operate in a network controlled by a BBDR device operating in master mode (master device).

For BBDR devices communicating in an ad hoc manner in a band where DFS is required, at least one of the devices shall operate as a master which means it has to employ DFS as applicable to a master.

Master devices:

a) The master device shall use a Radar Interference Detection function in order to detect radar signals.

b) Before initiating a network on a channel, the master device shall perform a Channel Availability Check to ensure that there is no radar operating on the channel.
c) During normal operation, the master device shall monitor the operating channel (In Service Monitoring) to ensure that there is no radar operating on the channel.
d) If the master device has detected a radar signal during In Service Monitoring, the master device shall instruct all its associated slave devices to stop transmitting on this channel.
e) The master device shall not resume any transmissions on this channel during a period of time after a radar signal was detected. This period is referred as the Non Occupancy Period.

Slave devices:

f) A slave device shall not transmit before receiving an appropriate enabling signal from a master device.
g) A slave device shall stop all its transmissions whenever instructed by a master device to which it is associated. The device shall not resume any transmissions until it has again received an appropriate enabling signal from a master device.

See Table 21 for an overview of the applicability of DFS requirements for each of the above mentioned operational modes.

It is proposed to derive the DFS specifications for BBDR from the DFS requirements identified for RLAN and BFWA (see EN 301893 v1.3.1 [17] and EN 302502 v1.1.1 [18] respectively).

For BBDR, the following set of DFS requirements is proposed:

Requirement	Operating mode	
	Master	Slave
Channel Availability Check	□	Not required
In-Service Monitoring	□	Not required
Channel Shutdown	□	□
Non-Occupancy Period	□	Not required
Uniform Spreading	Not required	Not required

Table 21: Applicability of DFS requirements for BBDR

The Channel Availability Check (CAC) is only performed at initial power up of the master unit. Considering the operational requirements for BBDR systems and the need to provide communications as quickly as possible, a value of 10 seconds for the CAC time is proposed.

In addition, some means should be found to avoid that the CAC is performed when the network has to move to a new channel to avoid a disruption of 10 seconds of the BBDR operation. This can be done, by identifying at power up or during normal operation several available channels free from radar operation.

It is assumed that the master is capable of detecting of any radar in its neighbourhood on behalf of the whole network and as such it is proposed to not mandate slave devices with a maximum spectral power density of 13 dBm/MHz to do radar detection. Requiring battery powered devices to perform continuous radar detection even during quiet periods would severely impact the battery autonomy of the user equipment.

Since the proposals related to the CAC and the requirements for slave devices can be seen as more relaxed than in the EN 301893 for RLAN and the EN 302502 for BFWA, additional consideration, including practical testing may be required to assess their impact on the efficiency of DFS.

Considering the low unit density of BBDR equipment within the "footprint" of radar, there is no need for uniform spreading for BBDR channels (although random selection of the operating channel would not be a problem).

The DFS detection threshold (T_h) in the BBDR receiver bandwidth at the antenna connector of the receiver is obtained by adding the gain of the BBDR receiver antenna to the interference threshold:

$$T_h = -69 + 23 - PD_{BBDR} + G_{BBDR} \qquad (7)$$

whereas:

T_h : DFS threshold level at the antenna connector [dBm] in the BBDR receiver bandwidth

PD_{BBDR}: BBDR eirp Spectral Density [dBm/MHz]

G_{BBDR}: BBDR antenna gain [dBi]

This formula is derived from the work carried out in ECC Report 68 where it was shown that a detection threshold of -69 dBm was necessary to protect radars from BFWA with 23 dBm/MHz (36 dBm in 20 MHz). Since the radars considered in this Report are the same than those which are considered in ECC Report 68, it is assumed that the analogy is feasible.

The methodology to develop the appropriate value of the detection threshold is provided in Annex 2.

For a BS with a 9 dBi antenna and a 26 dBm/MHz eirp spectral density, this results in a DFS threshold level T_h of -63 dBm in the BBDR bandwidth.

Frequency hopping radars may trigger DFS on all available channels within one band and as such could make a particular band unusable for BBDR operation. Therefore it is of extreme importance that there is always a second band available for BBDR, preferable a band where DFS is not required.

5.6 Discussion in the band 5470-5725 MHz

In the lower part of this frequency band (below 5570 MHz), BBDR devices are compatible with EESS altimeter. Nevertheless, the different results show that any use of outdoor BBDR BS will lead to significant interference into SAR systems. In the whole band 5470-5725 MHz, compatibility with RLAN devices as well as radars could be achieved only with additional mitigation techniques, such as LBT for the coexistence with RLANs and DFS for the coexistence with radars. It should be noted that because of the expected high number of RLAN systems and DFS efficiency issues with regards to frequency hopping radars, the operation of BBDR in this band does not seem to be appropriate.

6 COMPATIBILITY STUDIES IN THE BAND 5725-5875 MHZ

6.1 Compatibility between BBDR and FSS

All developments and results of section 7.1 are applicable to this section. It is expected that the compatibility will be achieved due to the low amount of devices.

6.2 Compatibility between BBDR and ITS

The band 5855-5875 MHz is envisaged for ITS use. Since the characteristics of ITS will be the same as for operation above 5875 MHz, all developments and results of section 7.3 are applicable to this section.

6.3 Compatibility between BBDR and Amateur Services

The frequency band 5650 – 5850 MHz is allocated to the radio amateur services on a secondary basis, while the amateur satellite service uplink band is 5650 – 5668 MHz.

No specific study has been carried out in this Report on the compatibility between BBDR and the Amateur service.

However, it is expected that the conclusions from the ECC Report 68 [4] for the compatibility between BFWA and the Amateur service can also apply for BBDR:

''The results of worst-case calculations show that interference would occur if the Amateur Service and FWA were to operate co-channel within close proximity (of the order of 100s of m or a few km). However, taking account of the various mitigation factors (identified in section 6.6.3) it is considered that sharing is feasible. The results are assumed to address also the case of the impact from FWA into the Amateur-Satellite (s-E) Service.''

6.4 Compatibility between BBDR and Road Transport and Traffic Telematics (RTTT)

ECC Decision (02)01 [19] designates the frequency bands 5 795-5 805 MHz, with possible extension to 5 815 MHz, for RTTT. The band 5 795 – 5 805 MHz is intended for road-to-vehicle systems, particularly (but not exclusively) road toll systems, with an additional sub-band, 5 805 – 5 815 MHz, to be used on a national basis for multi-lane road junctions. The regulatory parameters for RTTT are shown in CEPT Recommendation CEPT/ERC/REC 70-03 [20]. ETSI has developed standards - specifically EN 300 674 [21]- which define the technical characteristics of RTTT equipment.

The needed parameters for this interference assessment are provided in the following table. They correspond to a typical RSU used for road-toll collection:

RTTT Road Side Unit (RSU)	Value	Units
Receiver bandwidth	0.5	MHz
Receiver sensitivity	-104	dBm
Antenna gain	13	dBi
Bandwidth	5	MHz
Tx out, eirp	33	dBm
Transmit Power Control	0	dB
Protection criterion	6	dB
Frequency (GHz)	5.80	GHz

Table 22: Parameters for a typical RSU for road-toll collection

No effect on RTTT Onboard Units (OBU) is expected, i.e. repeated wake-up of the OBU causing a significant shortening of its battery lifetime, due to the temporary and local use of BBDR.

The following interference assessment identifies the separation distances between BBDR and RTTT systems which would be required to avoid interference from one system to the other:

- Calculations on the separation distances between RTTT RSU as interferer and BBDR BS as victim lead to the following results:

LINK BUDGET	Urban	Suburban	Rural
SL RTTT ->ML BBDR BS			
Separation distance (m)	331	570	1044
SL RTTT ->SL BBDR BS			
Separation distance (m)	148	226	305

Table 23: Separation distances to protect BBDR BS

- Calculations on the separation distances between BBDR BS as interferer and RTTT RSU as victim lead to the following results:

LINK BUDGET	Urban	Suburban	Rural
ML BBDR BS – SL RTTT			
Separation distance (m)	663	1252	2582
SL BBDR BS - SL RTTT			
Separation distance (m)	297	505	887

Table 24: Separation distances to protect RTTT devices

Mitigation technique would be required to improve the sharing situation between BBDR and RTTT RSU.

6.5 Compatibility between BBDR and Fixed Services

Within the frequency range of interest, 5850 MHz to 5875 MHz, there is a primary frequency allocation to the FS in the ITU-R Radio Regulations, Article S5 [6] for Region 1 and in the ERC Report 25 [22]. In both cases the allocation starts at 5850 MHz and extends up to 8500 MHz. However, the majority of FS usage is in the range above 5925 MHz, in accordance with the major utilisation as shown in ERC Report 25. The limited use of FS P-P links in the band 5850-5925 MHz includes, in some countries, ENG/OB applications.

6.6 Compatibility between BBDR and General (non-specific) short range devices

This section provides results of calculation for the separation distances to protect SRD in the band 5725– 5875 MHz from BBDR devices and to protect BBDR systems from SRD. The characteristics of SRD systems are provided in the following section.

- *General (Non-Specific) Short Range Devices characteristics*

The same approach as in ECC Report 68 [4] or ECC Report 101 [3] is used. As specified in Annex 1 of ERC Recommendation 70-03 [20], the frequency band 5725-5875 MHz is used by non-specific SRD. This use should comply with the technical characteristics as shown below.

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

Table 25: Technical characteristics of SRD

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

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

Table 26: Assumed SRD parameters

6.6.1 Impact of BBDR devices on SRD

This section provides results of calculation for the separation distance to protect the three kinds of SRD from BBDR devices. A protection criterion of I/N=0dB is considered for SRD Type I (narrow bandwidth). A protection criterion of C/I appears to be more suitable for interference assessment with the two other types of SRD.

	Prop model	URBAN	SUBURBAN	RURAL
SRD I	ML SRD-ML BBDR	433	686	1291
	ML BBDR-SL SRD	228	331	501
	SL BBDR-ML SRD	194	276	392
	SL BBDR-SL SRD	99	117	117
SRD II	ML SRD-ML BBDR	634	1191	2437
	ML BBDR-SL SRD	334	576	1055
	SL BBDR-ML SRD	284	480	829
	SL BBDR-SL SRD	149	229	309
SRD III	ML SRD-ML BBDR	659	1244	2563
	ML BBDR-SL SRD	347	601	1110
	SL BBDR-ML SRD	295	501	879
	SL BBDR-SL SRD	155	240	328

Table 27: Summary of the calculated separation distances to protect SRD

6.6.2 Impact of SRD on BBDR devices

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

- Outdoor use

	Scenario	Urban	Suburban	Rural
SRD to BBDR	Main Lobe to Main Lobe	316	540	974
	Main Lobe to Side Lobe	166	261	363
	Side Lobe to Side Lobe	69	74	74

Table 28: Protection ranges (m) to protect BBDR from outdoor SRD

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

	Scenario	Urban	Suburban	Rural
SRD to BBDR	Main Lobe to Main Lobe	141	213	284
	Main Lobe to Side Lobe	69	74	74
	Side Lobe to Side Lobe	13	13	13

Table 29: Protection ranges (m) to protect BBDR from indoor SRD

6.7 Compatibility between BBDR and BFWA devices

Broadband Fixed Wireless Access (BFWA) is used here to refer to wireless systems that provide local connectivity for a variety of applications and using a variety of architectures, including combinations of access as well as interconnection. ECC Report 68 [4] depicts the different architectures of BFWA and provides the relevant information on these different kinds of networks including technical parameters to ensure compatibility with other systems. The Table 30 below gives the main parameters for two BFWA architectures, Point to Multipoint (P-MP) and Mesh.

The 5.725-5.875 GHz band should be able to provide sufficient spectrum for commercial BFWA operations, even though exclusive frequency allocations and channel co-ordination is not envisaged in this band.

Device	Unit	BFWA P-MP	BFWA Mesh
e.i.r.p.	dBm	36	36
Bandwidth	MHz	20	20
Antenna Gain	dBi	18	10
Human losses	dB	0	0
Sidelobe attenuation	dB	15	15
TPC	dB	10	10
Sensitivity (at the antenna input)	dBm	-86	-86
Protection criterion	C/I	6 (BPSK)	6 (BPSK)

Table 30: Interferer and victim technical parameters

		Protection range (m) to meet the protection criterion		
	Scenario	**Urban**	**Suburban**	**Rural**
BBDR to BFWA	ML to ML	2257	5008	12739
	ML to SL	1011	2018	4473
	SL to SL	453	813	1570
BFWA to BBDR	ML to ML	485	879	1717
	ML to SL	217	354	548
	SL to SL	94	131	132

Table 31: Protection ranges for the compatibility between BFWA and BBDR

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

In a co-channel analysis, protection ranges have to be greater than few km. About one km is still needed when sidelobe rejection factor is taken into account. As a consequence, some mitigation techniques would be necessary if BFWA and BBDR devices had to share some part of the spectrum together. A LBT on the BBDR device would be helpful to detect any potential emission from BFWA devices.

6.8 Compatibility studies between BBDR and radiolocation systems

The co-channel interference assessment is already covered in section 5.5. This section intends also to deal with adjacent frequency interference assessment. Therefore, the impact of unwanted emissions of radar systems below 5850 MHz on BBDR located above 5850 MHz is considered. Most parameters and methodology are already introduced within section 5.5. However, additional parameters are needed for this adjacent band compatibility study, such as the propagation model (refer to section 2.4 for the formulas).

6.8.1 Allowable BBDR unwanted emission level to protect Radars

In this section, the maximum allowable unwanted power level for BBDR to protect the different radars considered in this study is looked for. It appears that a level of -54 dBm/MHz would be necessary to ensure sufficient protection of radars. Such a level may be compatible with spurious emission levels of BBDR. It means that a guard band of more than 20 MHz or additional filtering of BBDR devices would be needed.

Reception part: Radar									
Noise temperature	290	°K							
characteristics			**L**	**M**	**N**	**O**	**Q**	**X & Y**	**Z**
Receiver IF3dB bandwidth MHz		MHz	4.8	4	8	8	10	4	1
Antenna mainbeam gain		dBi	54	47	45.9	42	30	35	31.5
Radar feeder loss		dB	0	0	0	0	0	0	0
Receiver noise figure		dB	7	4	2.3	3	3	5	13
N=FkTB		dBm	-100.2	-104.0	-102.6	-101.9	-101.0	-103.0	-101.0
N per MHz		dBm/MHz	-107	-110	-112	-111	-111	-109	-101
BBDR unwanted emissions	-54	dBm/MHz							
Protection criterion		Radar	L	M	N	O	Q	X & Y	Z
I/N	-6	dB	-6	-6	-6	-6	-6	-6	-6
ML BBDR - ML RL			-54-(-107 **-6**-54)= 113dB	-54-(-110 **-6-**47)= 109dB	-54-(-112 **-6-**45.9)= 109.9dB	-54-(-111 **-6-**42)= 105dB	-54-(-111 **-6**-30)= 93dB	-54-(-109 **-6**-35)= 96dB	-54-(-101 **-6-31.5**)= 84.5dB
Separation distance BBDR->Radar		m	333	269	278	217	112	134	67
ML BBDR – SL RL									
Sidelobe attenuation (dB)		dB	20	20	22	22	25	40	40
Separation distance BBDR->Radar		m	112	88	81	59	10	3	1
SL BBDR - ML RL									
Sidelobe attenuation (dB)		dB	15	15	15	15	15	15	15
Separation distance BBDR->Radar		m	149	119	124	94	33	47	12
SL BBDR - SL RL									
Sidelobe attenuation (dB)		dB	35	35	37	37	40	55	55
Separation distance BBDR->Radar		m	33	21	18	10	2	0	0

Table 32: Protection ranges for urban area

The table below summarizes all results given by the different propagation models.

Prop model	**Radar**	**L**	**M**	**N**	**O**	**Q**	**X & Y**	**Z**
URBAN	ML RL-ML BBDR	333	269	278	217	112	134	67
	ML BBDR-SL RL	112	88	81	59	10	3	1
	SL BBDR-ML RL	149	119	124	94	33	47	12
	SL BBDR-SL RL	33	21	18	10	2	0	0
SUB URBAN	ML RL-ML BBDR	827	649	673	510	245	295	135
	ML BBDR-SL RL	245	185	168	59	10	3	1
	SL BBDR-ML RL	333	262	271	199	33	47	12
	SL BBDR-SL RL	33	21	18	10	2	0	0
RURAL	ML RL-ML BBDR	2439	1845	1924	1396	550	704	273
	ML BBDR-SL RL	550	396	353	59	10	3	1
	SL BBDR-ML RL	829	597	627	430	33	47	12
	SL BBDR-SL RL	33	21	18	10	2	0	0

Table 33 : Table of results (protection ranges in m) when applying the different propagation models with a BBDR unwanted power level of -54dBm/MHz

6.8.2 Separation distances to protect BBDR systems

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

This reduced level compared to the calculations realised in section 5.5 leads to the following results for the different propagation models.

Prop model	Radar	L	M	N	O	Q	X & Y	Z
URBAN	ML RL-ML BBDR	19193	11291	8680	4639	2620	2035	3517
	ML BBDR-SL RL	6577	3869	2975	1590	308	239	413
	SL BBDR-ML RL	8596	5057	3888	2078	1174	911	1575
	SL BBDR-SL RL	2946	1733	1332	712	138	105	185
SUB URBAN	ML RL-ML BBDR	56450	30969	22999	11319	5930	4455	8275
	ML BBDR-SL RL	16802	9217	6845	3369	525	395	733
	SL BBDR-ML RL	22747	12479	9268	4561	2389	1795	3335
	SL BBDR-SL RL	6770	3714	2758	1358	206	148	295
RURAL	ML RL-ML BBDR	207271	103822	73704	32580	15475	11132	22715
	ML BBDR-SL RL	51342	25718	18257	8070	937	635	1394
	SL BBDR-ML RL	72777	36454	25879	11439	5434	3909	7976
	SL BBDR-SL RL	18027	9030	6410	2834	273	163	429

Table 34: Table of results (protection ranges in m) when applying the different propagation models

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

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

Therefore, the frequency separation between the frequency range identified for BBDR and the radiodetermination band (below 5850 MHz) should be at least 2 times the necessary bandwidth of radiodetermination systems.

Between 5855 MHz and 5875 MHz, BBDR may suffer interference from radars.

6.9 Discussion in the band 5725-5875 MHz

In this frequency band, deployment of BBDR may be possible providing mitigation techniques are integrated in BBDR to improve the compatibility with RTTT, SRD, ITS and BFWA. Further analysis is required on the applicability and relevance of LBT for each of these sharing scenarios.

It could be noted that compatibility is achieved with FSS.

In the co channel interference assessment with radiolocation (i.e. below 5850 MHz), mitigation techniques such as DFS may improve the compatibility prospects, noting that frequency hopping radars may trigger DFS mechanism on all available channels. For adjacent channel interference assessment with radiolocation (i.e. above 5850 MHz), unwanted power level of BBDR devices for all frequencies below 5850 MHz has to be below -54 dBm/MHz in order to protect radars. On the other hand, BBDR devices may suffer interference from radars in this frequency band.

7 COMPATIBILITY STUDIES IN THE BAND 5875-5925 MHZ

7.1 Impact of BBDR on FSS

- *Method of calculating interference from BBDR devices on a FSS Satellite Receiver*

This study adopts the ΔT/T approach described in Appendix 8 of the ITU Radio Regulations [6] in order to assess the impact of interference from a large number of BBDR devices located within CEPT countries in the footprint of a satellite antenna. Although not directly suitable for use in the case of inter-service sharing, it does provide a very simple method of analysing the impact without much knowledge of the characteristics of the carriers used on the satellite network requiring protection. In this technique, the interference from the BBDR transmitters into the satellite receiver is treated as an increase in thermal noise in the wanted FSS network and hence is converted to a noise temperature (by considering the interference power per Hz) and compared with tolerable percentage increases in noise temperature.

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

$$\frac{\Delta T_{sat}}{T_{sat}} < Y\% \qquad (8)$$

where:

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

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

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

Therefore, the maximum allowable power coming from BBDR towards a satellite receiver is given by:

$$\begin{aligned} EIRP_{BBDR} &= 10Log(Y) - 29 - 10Log\left(\frac{g_{sat}}{T_{sat}}\right) \quad \text{dB(W.Hz}^{-1}\text{)} \\ &= 10Log(Y) - 29 - G_{sat} + 10Log(T_{sat}) \end{aligned} \qquad (9)$$

where:

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

Finally, the number of active devices N can be computed as

$$10Log(N) = EIRP_{BBDR_{channel}} - EIRP_{device_{channel}} \qquad (10)$$

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

- *Interference assessment for* $\Delta T_{sat}/T_{sat}$ *=3%*

The initial market penetration within the first 4 years is estimated to not exceed 20% of the target market in any case. This would assume 60 000 users in <u>2 400 ad-hoc BBDR systems</u>. Therefore, an average number of 25 BBDR devices is expected within each of this local area.

Satellite	Receiver Gain Gsat (dBi)	Satellite Receiving System Noise Temperature T_{sat} (K)	Allowable aggregate e.i.r.p. (dBW/Hz)	e.i.r.p (dBW/Hz) of BBDR	Off axis attenuation (dB)	TPC factor (dB)	Number of BBDR in use	Aggregate e.i.r.p of BBDR (dBW/Hz)	Margin (dB)
A	34	773	-49.3	-64	15	0	25	-65.0	15.7
B	26.5	1200	-39.9	-64	15	0	25	-65.0	25.1
C	32.8	700	-48.6	-64	15	0	25	-65.0	16.4
D	34	773	-49.3	-64	15	0	25	-65.0	15.7
E	32.8	700	-48.6	-64	15	0	25	-65.0	16.4
F	26.5	1200	-39.9	-64	15	0	25	-65.0	25.1
G	34	1200	-47.4	-64	15	0	25	-65.0	17.6
H	34.7	700	-50.5	-64	15	0	25	-65.0	14.5
I	32.8	700	-48.6	-64	15	0	25	-65.0	16.4

Table 35 : Calculations of the impact of 25 BBDR networks on FSS with $\Delta T_{sat}/T_{sat}$ *=3%*

This table shows that the aggregate effect of 25 BBDR simultaneously in use is below the permissible interference level. Therefore, it is not expected that BBDR transmitters will cause unacceptable interference to the satellite due to the limited number of devices deployed.

- *Interference assessment for* $\Delta T_{sat}/T_{sat}$ *=1%*

Satellite	Receiver Gain Gsat (dBi)	Satellite Receiving System Noise Temperature T_{sat} (K)	Allowable aggregate e.i.r.p (dBW/Hz)	e.i.r.p (dBW/Hz) of BBDR	Off axis attenuation (dB)	TPC factor (dB)	Number of BBDR in use	Aggregate eirp of BBDR (dBW/Hz)	Margin (dB)
A	34	773	-54.1	-64	15	0	25	-65.0	10.9
B	26.5	1200	-44.7	-64	15	0	25	-65.0	20.3
C	32.8	700	-53.3	-64	15	0	25	-65.0	11.7
D	34	773	-54.1	-64	15	0	25	-65.0	10.9
E	32.8	700	-53.3	-64	15	0	25	-65.0	11.7
F	26.5	1200	-44.7	-64	15	0	25	-65.0	20.3
G	34	1200	-52.2	-64	15	0	25	-65.0	12.8
H	34.7	700	-55.2	-64	15	0	25	-65.0	9.8
I	32.8	700	-53.3	-64	15	0	25	-65.0	11.7

Table 36: Calculations on the impact of 25 BBDR networks on FSS with $\Delta T_{sat}/T_{sat}$ *=1%*

7.2 Compatibility between BBDR and FS (above 5925 MHz)

The ECC Report 003 [23] concluded that the frequency band 5875-5925 MHz is not heavily used by the FS. Therefore, no compatibility study is needed.
However, FS is highly implemented in the band above 5925 MHz. Consequently, it is necessary to focus interference assessment of BBDR devices on the FS in the band 5925 MHz - 6425 MHz (adjacent channel).

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

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

Table 37: Typical system(1) parameters for point-to-point FS systems

(1) It should be noted that the parameters provided in this table are considered to be representative for the purpose of carrying out technical sharing studies. In some cases certain parameters may vary due to practical operating requirements.
(2) It is generally intended that the noise figure data include the duplexer filter losses, while the feeder/multiplexer loss row are related to feeder losses only.
(3) Omni, Yagi, Dish, Horn, Sectored, etc.
(4) Where regulatory limits apply, e.i.r.p. may not be equal to the maximum power plus the maximum gain (in decibels).
(5) Recommendation ITU-R F.1094 [24] provides the apportionment of the total degradation of an FS link due to interferences as it recommends 1% for the unwanted emissions.

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

This frequency band is mostly used for the purpose of RRL/trunk/infrastructure applications, as shown by the following quote from ECC Report 003 [20]:

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

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

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

ERC Recommendation 14-01 [24] gives the channel plan for the L6 band which provides for 8 x 29.65 MHz channels between 5 930.375 MHz and 6 167.575 MHz and a further 8 x 29.65 MHz channels between 6 182.415 MHz and 6 419.615 MHz, as shown in the figure below. Consequently, there is a guard band of 5.375 MHz between the beginning of the L6GHz band (5 925 MHz) and the first FS channel deployed.

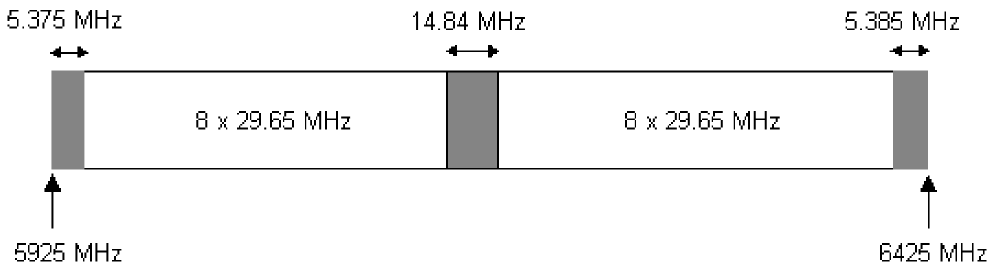

Figure 5: ERC Recommendation's 14-01 [25] FS channel plan

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

$$I = e.i.r.p. - L_{FS} + G_r$$
$$\Rightarrow L_{FS} = e.i.r.p. - I + G_r \quad (11)$$

where:

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

Two additional factors can be integrated into this equation. The first one is the OoB attenuation factor if the victim and interferer do not share the same active band. The second one is the sidelobe attenuation factor if the transmission scheme does not imply the main beam of one of the studied devices.
The following compatibility study considers one BBDR station with an expected unwanted attenuation factor higher than 90dBr.

- *Results*

	Prop model	URBAN	SUBURBAN	RURAL
BBDR to FS	ML BBDR-ML FS	280	472	811
	ML BBDR-SL FS	4	4	4
	SL BBDR-ML FS	125	182	229
	SL BBDR-SL FS	1	1	1
FS to BBDR	ML FS-ML BBDR	1172	2387	5426
	ML FS-SL BBDR	76	88	88
	SL FS-ML BBDR	525	962	1905
	SL FS-SL BBDR	16	16	16

Table 38: Separation distances between BBDR and FS above 5925 MHz

BBDR devices can operate in the closest channels to the FS allocation (>5925 MHz) if the out-of-band emission level of any BBDR device is lower than -64 dBm/MHz in the FS allocation (>5925 MHz). In order to avoid interferences to FS links, when BBDR is situated in the main lobe of FS transmitter, necessary separation distances are indicated in the Table 38.

On the other hand, BBDR devices could be deployed in most situations, but may suffer interference coming from FS if these devices are located in the main lobe of a FS link.

7.3 Compatibility between BBDR and ITS

ECC Report 101 provided compatibility assessment of ITS devices with other services. It comes from this report that the best allowable spectrum for these kinds of devices is between 5875-5905 MHz with a possible 20 MHz both in the lower and upper part of the spectrum.
Technical parameters for ITS are summarized in the following table.

Device	**Unit**	**ITS**
e.i.r.p.	dBm	33
Bandwidth	MHz	10
Antenna Gain	dBi	8
Sidelobe attenuation	dB	12
TPC	dB	8
Sensitivity (at the antenna input)	dBm	-82
Protection criterion	C/I	6 (BPSK)

Table 39 : ITS parameters

The calculation of the protection distances between BBDR and ITS leads to the following results:

		Protection range (m) to meet the protection criterion		
	Scenario	Urban	Suburban	Rural
BBDR to ITS	ML to ML	908	1787	3887
	ML to SL	477	863	1683
	SL to SL	214	348	536
ITS to BBDR	ML to ML	531	975	1935
	ML to SL	279	471	808
	SL to SL	125	181	228

Table 40: Protection ranges between ITS and BBDR

As a conclusion, it appears that the protection distances between ITS and BBDR could exceed several km in both directions in the rural scenarios whereas it is limited to hundreds of m in urban and suburban scenarios.

It should be noted that the number of ITS devices within the area of BBDR deployment depends on the nature of the BBDR use.

Compatibility may be improved by the use of appropriate mitigation techniques such as the LBT mechanism in BBDR transmitters to protect ITS systems. Nevertheless, further analysis is required on the applicability and relevance of LBT for this sharing scenario, taking into account the potential difficulties related to the high protection distances, the large TPC range and the mobility of ITS systems.

7.4 Discussion in the band 5875-5925 MHz

In this frequency band, deployment of BBDR networks may be possible providing appropriate mitigation techniques are integrated in BBDR equipment to ensure compatibility with ITS. Further analysis is required on the applicability and relevance of LBT for this sharing scenario.

It could be noted that compatibility is achieved with FSS.

Compatibility with FS links above 5925 MHz may be achieved if the unwanted power of BBDR transmitters for all frequencies above 5925 MHz is below -64dBm/MHz. On the other, BBDR equipment may suffer interference coming from these FS links.

8 DISCUSSION ON MITIGATION TECHNIQUES

A DFS mechanism is needed for BBDR equipment to achieve compatibility with radiolocation within the frequency range from 5470 MHz to 5850 MHz. Details of this are described in section 5.5.

The studies further show that, in some scenarios, compatibility may only be achieved if BBDR devices integrate other mitigation techniques to protect four different victims (as listed below).

Therefore, this section discusses the technical feasibility and the relevance of LBT for the following cases:

- RTTT (5795 MHz to 5815 MHz);
- SRD (5725 MHz to 5875 MHz);
- BFWA (5725 MHz to 5875 MHz);
- ITS (5855 MHz to 5925 MHz).

The BBDR BS would perform in all cases the “centralised” LBT function on behalf of the network.

8.1 Applicability of LBT for the compatibility with RTTT

The resulting separation distance required between BBDR and RTTT Roadside Units are in the range from several hundred m to about 2.5 km in the worst case (rural area) scenario.

In the urban and suburban scenarios it is noted that separation distances of several hundred m greatly overlap with the size BBDR hotspot (estimated in section 2.1 to be about 1 km², i.e. a spot radius of about 560 m). Inside the BBDR hotspot and in the surroundings (only rural case) priority could be given to BBDR before RTTT RSU due to the temporary nature during the disaster relief action time.

If LBT would be needed to be used for further protection of stationary RTTT RSU then a single interference check at the line-up of the BBDR network may be considered sufficient.

A RTTT RSU with an e.i.r.p. of 2 W and located at the edge of the BBDR hotspot pointing downwards will deliver equal or less than -73 dBm/10 MHz to the BBDR receiver antenna. If located at 2.5 km distance (maximum required separation distance), this will change to equal or less than -86 dBm/10 MHz.

In such a case, the use of LBT may improve the sharing situation, but its efficiency will be limited by the available BBDR receiver sensitivity.

8.2 Applicability of LBT for the compatibility with SRD

The required separation distances between BBDR BS and SRD almost completely overlap with the BBDR hotspot size. i.e. almost all SRD potentially benefiting from the LBT mechanism would not be able to operate within this area. Therefore, LBT on SRD will not improve the compatibility in this case, if BBDR would enjoy priority. Nevertheless, it can be argued that SRDs will not be in operation in a disaster area.

SRD devices inside the ISM band may employ many different modulation techniques from narrowband to spread spectrum using the whole band. In consequence, it may be difficult to find a proper technical solution to protect BBDR operations.

8.3 Applicability of LBT for the compatibility with BFWA

The required separation distance to protect BFWA from BBDR interference is generally greater than the hotspot radius for all different scenarios. Since BFWA is stationary, a single interference check at the line-up of the BBDR network may be considered. It is recommended to base a possible threshold of the BBDR BS’s LBT on its technical feasibility.

A typical value for a BBDR receiver sensitivity is -88 dBm/10MHz at the receiver input. It is suggested to set LBT threshold at least 6 dB above this value for a reliable detection of interference and to avoid false detections, i.e. -82dBm/10MHz.

8.4 Applicability of LBT for the compatibility with ITS

ITS is a highly mobile application. Useful protection could only be provided by nearly permanent and fast detection of vehicles approaching the disaster area.

In the frequency band 5855-5875 MHz, ITS will only operate for non-safety related applications. ITS will use LBT to protect BFWA and this may improve the compatibility with SRD. In the frequency band 5875-5925 MHz, ITS itself is not using LBT.

The required separation distances for the protection of ITS reach from about 200 m to almost 4 km. ITS itself uses a TPC with a range of 30 dB. This may greatly reduce the LBT efficiency since this mitigation technique will have to be extremely reactive and permanent. It may also increase the “hidden ITS receiver” problem. This moving configuration will likely increase the probability of facing temporary busy channels for the BBDR BS. In consequence, the BBDR network would need to be able to switch channels, or even the frequency band, continuously.

Based on existing solutions for the DFS mechanism, it seems technically feasible to install a fast and permanent listening function. Like with BFWA, the threshold level would be selected from the perspective of the feasible receiver sensitivity values. These values however will not cover the whole range that is needed for ITS protection (up to 4 km separation distance). This gap is made worse by the TPC of the ITS transmitter. In addition, the moving configuration between BBDR and ITS will make the LBT mechanism more difficult to establish than for other victims.

9 CONCLUSIONS

This Report addresses compatibility and sharing issues between BBDR systems and the other systems/services identified within the possible frequency bands under consideration for BBDR: 4940-4990 MHz, 5150-5250 MHz, 5470-5725 MHz, 5725-5875 MHz and 5875-5925 MHz.

The studies assume specific deployment and technical characteristics for BBDR systems. In particular, possible channel bandwidths between 1.25 and 20 MHz are assumed with maximum e.i.r.p. spectral density of 26 dBm/MHz for a BBDR Base Station (BS) and 13 dBm/MHz for BBDR User Equipment (UE).

For each of the possible frequency bands, the result of the studies is the following:

- **4940 – 4990 MHz**: The technical studies lead to the conclusion that BBDR operation is not compatible with FS links and RAS stations in the frequency band 4940-4990 MHz. Moreover, BBDR devices are not compatible with UAV operation under the mobile service in the vicinity of land base receiver station for the sub-band 4940-4950 MHz. It is therefore not recommended to use BBDR applications in this band in a country where FS links, UAV in the mobile service and/or RAS sites use this frequency band. The frequency band 4940-4990 MHz could however still be considered as an optional band for those countries not having any active RAS sites, UAV or FS usage in this band.
- **5150 – 5250 MHz**: The technical studies in this frequency band between BBDR and MSS or RLAN devices lead to the conclusion that compatibility could be achieved. Additional consideration has been given to compatibility between BBDR and aeronautical telemetry systems (AMT) for flight testing in case WRC-07 allocates aeronautical mobile service to this band. With the considered assumptions for AMT, some interference may occur in both directions, but with a very low probability due to the temporary nature of both applications and the low number of locations of these AMT systems within Europe.
- **5470 – 5725 MHz:** In the lower part of this band (5470-5570 MHz), BBDR operation is compatible with EESS altimeter. Nevertheless, the different results show that, any use of outdoor BBDR BS will lead to significant interference into SAR systems. In the whole band 5470-5725 MHz, compatibility with RLAN devices as well as radars could be achieved only with additional mitigation techniques, such as LBT for the coexistence with RLANs and an efficient DFS mechanism for the coexistence with radars. It should be noted that because of the expected high number of RLAN systems as well as DFS efficiency with frequency hopping radars, the operation of BBDR in this band does not seem to be appropriate.
- **5725 – 5875 MHz:** In this frequency band, deployment of BBDR networks may be possible providing mitigation techniques are integrated on BBDR devices to improve the compatibility with RTTT, SRD, ITS and BFWA. Further analysis is required on the applicability and relevance of LBT for each of these sharing scenarios.
  It could be noted that compatibility is achieved with FSS.

In the co-channel interference assessment with radiolocation (i.e. below 5850 MHz), mitigation techniques such as an efficient DFS mechanism may improve the compatibility issue noting that frequency hopping radars may trigger on all available channels. For adjacent channel interference assessment with radiolocation (i.e. above 5850 MHz), unwanted power level of BBDR devices for all frequencies below 5850 MHz has to be below -54 dBm/MHz in order to protect radars. On the other way, BBDR devices may suffer from interference from radars in this frequency band.

- **5875 – 5925 MHz:** In this frequency band, deployment of BBDR networks may be possible providing mitigation techniques are integrated on BBDR to ensure compatibility with ITS. Further analysis is required on the applicability and relevance of LBT for this sharing scenario, taking due account of the potential difficulties created by the moving configuration between BBDR and ITS. It could be noted that compatibility is achieved with FSS. Compatibility with FS links above 5925 MHz may be achieved if the unwanted power of BBDR devices for all frequencies above 5925 MHz is below -64dBm/MHz. On the other way, BBDR devices may suffer from interference coming from these FS links.

This table intends to depict in a simple way an overview of the results of these interference assessments for the different frequency bands:

Band (MHz)						
4940-4990 (Note 1)	RAS	FS	MS			
5150-5250 (Note 2)	MSS	RLAN				
5470-5570	EESS	RLAN	Radar			
5570-5725	RLAN	Radar				
5725-5875	FSS	RTTT	SRD	FWA	Radar below 5850 MHz	ITS above 5855 MHz
5875-5925	FSS	FS (above 5925 MHz)	ITS			

(Note 1) RAS use in this band is on a secondary basis and there is limited use of civil FS as this band is a harmonised NATO band for fixed and mobile usage. Hence, individual national administrations may wish to make specific provision to allow the use of BBDR for occasional/minimal use during disaster operation.

(Note 2) In the event that WRC-07 allocates this band to aeronautical mobile telemetry (AMT), initial consideration on compatibility between BBDR and AMT has been made. Special care should be given around the location of AMT ground stations.

(green)	Compatibility is achieved
(orange)	Compatibility may be achieved with efficient mitigation techniques or restriction
(red)	Compatibility is not achieved

Considering the potential incompatibilities and the uncertainties related to the development of mitigation techniques, the band 5150-5250 MHz may be considered as the primary and preferred option for the deployment of BBDR.

The frequency band 4940-4990 MHz could also be considered as an optional band for those countries not having any active RAS sites, UAV usage in the MS or FS usage in this band.

Other bands may also be considered as optional bands providing that mitigation techniques are implemented where it is considered as relevant to protect the other services. This consideration should be made, taking into account the importance of communications for emergency services during disasters. Additional studies would be required to properly define these mitigation techniques.

ANNEX 1: REFERENCES

[1] ETSI SRDoc TR 102 485 'Technical characterisitics for BroadBand Disaster Relief applications (BBDR) for emergency services in disaster situations'

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[3] ECC Report 101: "Compatibility studies in the band 5855-5925 MHz between intelligent transport systems (ITS) and other systems"

[4] ECC Report 68: "Compatibility studies in the band 5725-5875 MHz between Fixed Wireless Access (FWA) systems and other systems"

[5] ITU-R Recommendation F.758: "Considerations in the development of criteria for sharing between the terrestrial fixed service and other services"

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

[7] ITU-R Recommendation RA.769: "Protection criteria used for radio astronomical measurements"

[8] ERC Report 67: "Study of the Frequency sharing between HIPERLANs and MSS feeder links in the 5 GHz band"

[9] ITU-R Recommendation S.1427: "Methodology and criterion to assess interference from radio local area network (RLAN) transmitters to non-GSO MSS feeder links in the band 5150-5250 MHz"

[10] ITU-R Recommendation S.1432: "Method fro determining coordination distances, in the 5 Ghz band, between the international standard microwave landing system stations operating in the aeronautical radionavigation service and non-geostationary mobile satellite service stations providing feeder uplink services"

[11] ECC Decision (04)08: "ECC Decision of 9 July 2004 on the harmonised use of the 5 GHz frequency bands for the implementation of Wireless Access Systems including Radio Local Area Networks (WAS/RLANs)"

[12] ITU-R Recommendation M.1653: "Operational and deployment requirements for wireless access systems (WAS) including radio local area networks (RLANs) in the mobile service to facilitate sharing between these systems and systems in the Earth exploration-satellite service (active) and the space research service (active) in the band 5 470-5 570 MHz within the 5 460-5 725 MHz range"

[13] ERC Report 72: "Compatibility studies related to the possible extension band for HIPERLAN at 5 GHz"

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

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[17] EN 301 893: "Broadband Radio Access Networks (BRAN);5 GHz high performance RLAN;Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive"

[18] EN 302502: "Broadband Radio Access Networks (BRAN); 5,8 GHz fixed broadband data transmitting systems; Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive"

[19] ECC Decision (02)01: "ECC Decision of 15 March 2002 on the frequency bands to be designated for the coordinated introduction of Road Transport and Traffic Telematic Systems"

[20] Recommendation 70-03: "Relating to the use of Short Range Devices (SRD)"

[21] EN 300 674: “Road Transport and Traffic Telematics (RTTT);Technical characteristics and test methods for Dedicated Short Range Communication (DSRC) transmission equipment (500 kbit/s / 250 kbit/s) operating in the 5,8 GHz Industrial, Scientific and Medical (ISM) band”

[22] ERC Report 25: “The European table of frequency allocations and utilisations covering the frequency range 9 kHz to 275 GHz”

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

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

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

[26] ECC Report 102: "Public Protection and Disaster Relief Spectrum Requirements"

ANNEX 2: Determination of the DFS detection threshold to protect radars at 5 GHz

This Annex provides the methodology based on link budget analysis, that is used for the determination of the DFS detection threshold to protect radars. Such a methodology has been used to determine DFS detection thresholds for RLAN and BFWA at 5 GHz and is also considered in this report for the BBDR detection threshold.

The threshold is determined from two link budget analyses, (1) and (2) whose description is provided below. This is based on the assumption of a symmetrical propagation path between the interfering system with DFS (this system is quoted as *Int* in this Annex, it can be either BBDR, BFWA or RLAN) and the radar (RL) and also that the transmitter and receiver bandwidths of the radar are the same:

(1): The link budget gives the propagation losses *PL* to limit the interference level coming from the interfering system *Int* towards the radar receiver below the noise level minus 6dB (I/N=-6dB). Let *d* be the separation distance.

(2): The link budget gives the propagation losses *PL* to allow the interferer *Int* to detect at the distance *d* the presence of a radar. Therefore, the interference level coming from the radar towards the receiver of the *Int* system will be used as the detection threshold at the antenna connector (*Th*).

Note that:

P^0_{Int} : spectral density of the interferer (dBm/MHz)

G_{Int} : Antenna gain of the interferer

B_{Int} : Bandwidth of the interferer

$P_{Int} = P^0_{Int} + 10Log(B_{Int})$: power of the interferer (dBm)

$N^0 = 10\,Log\,(kTB_0) + F$: Ambient noise (dBm/MHz) with noise temperature of T=290°K, a reference bandwidth B_o=1 MHz and *F* the noise figure in dB

$I^O = N^0 - 6$ the maximum allowable level of interference on the RL

P^0_{Radar} : spectral density of the radar (dBm/MHz)

G_{radar} : Antenna gain of the radar

B_{radar} : Bandwidth of the radar

$P_{radar} = P^0_{radar} + 10Log(B_{radar})$: power of the radar (dBm)

Th^0 : Detection threshold at the antenna connector (dBm/MHz)

$Th = Th^0 + 10\,Log\,(B_{Int})$: Detection threshold at the antenna connector (dBm) in the bandwidth of the interferer

PL: Propagation losses

If B_{Int}>B_{Radar}

(1) $P^0_{Int} + G_{Int} + PL + G_{radar} = I^O = N^0 - 6$

(2) $P_{radar} + G_{radar} + PL + G_{Int} = Th$

$$PL = N^0 - 6 - G_{radar} - G_{Int} - P^0_{Int} = Th - G_{Int} - G_{radar} - P_{radar}$$

=> $\Rightarrow N^0 - 6 - P^0_{Int} = Th - P_{radar}$

$$\Rightarrow Th = \left(N^0 - 6 + P_{radar}\right) - P^0_{Int}$$

If BInt<BRadar

(1) $P_{Int} + G_{Int} + PL + G_{radar} = I = N - 6$

(2) $P^0_{radar} + G_{radar} + PL + G_{\text{int}} = Th^0$

$$PL = N - 6 - G_{radar} - G_{Int} - P_{Int} = Th^0 - G_{Int} - G_{radar} - P^0_{radar}$$
$$\Rightarrow N - 6 - P_{Int} = Th^0 - P^0_{radar}$$
$$=> \Rightarrow Th = Th^0 + 10Log(B_{Int}) = (N - 6 + P^0_{radar}) - (P_{Int} - 10Log(B_{Int}))$$
$$\Rightarrow Th = (N^0 - 6 + P_{radar}) - P^0_{Int}$$

Finally, these calculations lead to the same formula

$$Th = \underbrace{(N^0 - 6 + P_{radar})}_{\lambda} - P^0_{Int}$$ in dBm over the bandwidth of the interferer

When applying to the different radars and an example BFWA device, one can find:

		T=	290	°K			
Characteristics of the Radars	**L**	**M**	**N**	**O**	**Q**	**X & Y**	**Z**
Tx power into antenna peak (kW)	2800	1200	1000	165	285	12	70
Tx power into antenna peak (dBm)	94.47	90.79	90.00	82.17	84.55	70.79	78.45
Noise figure (dB)	7	4	2.3	3	3	5	13
Characteristics of a BFWA device							
FWA e.i.r.p (dBm) outdoor	36						
Bandwith (MHz)	20						
Antenna gain (dBi)	0						
FWA spectral density power (dBm/MHz) at the antenna connector	22.99						
Characteristics of the DFS	**L**	**M**	**N**	**O**	**Q**	**X & Y**	**Z**
Noise level (dBm/MHz)	-106.98	-109.98	-111.68	-110.98	-110.98	-108.98	-100.98
Λ	-18.51	-25.19	-27.68	-34.80	-32.43	-44.19	-28.53
DFS Detection threshold Th (dBm)	-41.50	-48.18	-50.67	-57.79	-55.42	**-67.18**	-51.52

The ECC Report 68 indicated that an appropriate detection threshold Th_{FWA} should be -69dBm (close to -67.18dBm) over the BFWA bandwidth.

For another interferer, such as BBDR device, one can derive the new detection threshold *Th*.
Noting that:

$$Th_{FWA} = \lambda - P^0_{FWA} = \lambda - 23 = -69$$
$$\Rightarrow \lambda = -69 + 23$$

The new detection threshold *Th* at the antenna connector would be :

$$Th = \lambda - P^0_{Int} = -69 + 23 - P^0_{BBDR}$$
$$= -69 + 23 - (eirp^0_{BBDR} - G_{BBDR})$$

where $eirp^0_{BBDR}$ is the e.i.r.p. spectral density of the BBDR.

For BBDR devices with eirp of 26 dBm/MHz and antenna gain of 9 dBi, the detection threshold level *Th* would be -63 dBm at the antenna connector over the bandwidth of the BBDR whatever it is.