RECOMMENDATION ITU-R SA.1632

Sharing in the band 5 250-5 350 MHz between the Earth exploration-satellite service (active) and wireless access systems (including radio local area networks) in the mobile service

(Question ITU-R 218/7)

(2003)

The ITU Radiocommunication Assembly,

considering

a) that the frequency band 5250-5350 MHz is allocated to the Earth exploration-satellite service (EESS) (active) and to the radiolocation service on a primary basis;

b) that some administrations have proposed to use the band 5250-5350 MHz for low power high speed wireless local area networks (WLANs), or radio local area networks (RLANs);

c) that these high speed WLANs are proposed to be deployed in the band as unlicensed devices, making regulatory control of their deployment density non-feasible,

recognizing

a) that studies are continuing in ITU-R with a view to facilitating sharing of wireless access systems (including RLANs) with EESS (active),

noting

a) that some administrations have adopted technical limits which permit wireless access systems (including RLANs) to operate with an e.i.r.p. power limit of 1 W, while other administrations have adopted more stringent e.i.r.p. limits,

recommends

1 that sharing between spaceborne active sensors of the EESS with the characteristics as given in Annex 1 and high speed WLANs in the 5250-5350 MHz band is feasible with wireless access systems (including RLANs) having constraints such as those given in Annex 2;

2 that the level of protection required for EESS systems as given in Annex 1 may also be achieved using alternative sets of operational and technical limits being studies under *recognizing* a).

Annex 1

Technical characteristics of spaceborne active sensors in the 5 250-5 570 MHz band

Technical characteristics of spaceborne active sensors in the 5.3 GHz frequency range are given in Tables 1 and 2.

TABLE 1

5.3 GHz typical spaceborne imaging radar characteristics

Parameter	Value			
	SAR1	**SAR2**	**SAR3**	**SAR4**
Orbital altitude (km)	426 (circular)	600 (circular)	400 (circular)	400 (circular)
Orbital inclination (degrees)	57	57	57	57
RF centre frequency (MHz)	5 305	5 405	5 405	5 300
Peak radiated power (W)	4.8	4 800	1 700	1 700
Polarization	Horizontal (HH)	Horizontal and vertical (HH, HV, VH, VV)	Horizontal and vertical (HH, HV, VH, VV)	Horizontal and vertical (HH, HV, VH, VV)
Pulse modulation	Linear FM chirp	Linear FM chirp	Linear FM chirp	Linear FM chirp
Pulse bandwidth (MHz)	8.5	310	310	40
Pulse duration (μs)	100	31	33	33
Pulse repetition rate (pps)	650	4 492	1 395	1 395
Duty cycle (%)	6.5	13.9	5.9	5.9
Range compression ratio	850	9 610	10 230	1 320
Antenna type (m)	Planar phased array 0.5 × 16.0	Planar phased array 1.8 × 3.8	Planar phased array 0.7 × 12.0	Planar phased array 0.7 × 12.0

TABLE 1 (*end*)

Parameter	Value			
	SAR1	SAR2	SAR3	SAR4
Antenna peak gain (dBi)	42.2	42.9	42.7/38 (full focus/beamspoiling)	42.7/38 (full focus/beamspoiling)
Antenna median side lobe gain (dBi)	–5	–5	–5	–5
Antenna orientation (degrees from nadir)	30	20-38	20-55	20-55
Antenna beamwidth (degrees)	8.5 (El), 0.25 (Az)	1.7 (El), 0.78 (Az)	4.9/18.0 (El), 0.25 (Az)	4.9/18.0 (El), 0.25 (Az)
Antenna polarization	Linear horizontal/vertical	Linear horizontal/vertical	Linear horizontal/vertical	Linear horizontal/vertical
Receiver front end 1 dB compression point ref to receiver input (dBW)	–62 input	–62 input	–62 input	–62 input
Allowable density of configuration saturation ref to receiver input	–114/–54 dBW input at 71/11 dB receiver gain	–114/–54 dBW input at 71/11 dB receiver gain	–114/–54 dBW input at 71/11 dB receiver gain	–114/–54 dBW input at 71/11 dB receiver gain
Receiver input max. power handling (dBW)	+7	+7	+7	+7
Operating time (%)	30 the orbit	30 the orbit	30 the orbit	30 the orbit
Minimum time for imaging (s)	9	15	15	15
Service area	Land masses and coastal areas	Land masses and coastal areas	Land masses and coastal areas	Land masses and coastal areas
Image swath width (km)	50	20	16/320	16/320

TABLE 2

5.3 GHz typical spaceborne radar altimeter characteristics

Jason mission characteristics	
Lifetime	5 years
Altitude	1 347 km ± 15 km
Inclination	66°
Poseidon 2 altimeter characteristics	
Signal type	Pulsed chirp. linear FM
C band pulse repetition frequency (PRF)	300 Hz
Pulse duration	105.6 μs
Carrier frequency	5.3 GHz
Bandwidth (BW)	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/maximum	–20 dB
Backside lobe level/maximum	–40 dB
Beam footprint at –3 dB	77 km
Interference threshold	–118 dBW

TABLE 3

5.3 GHz typical spaceborne scatterometer characteristics

Parameter	**Value**	
System name	Scatterometer 1	Scatterometer 2
Orbital altitude (km)	780	800
Inclination (degrees)	98.5	98.5
Centre frequency (GHz)	5.3	5.255
Pulse width	70 μs (mid) 130 μs (fore/aft)	8 ms (mid) 10.1 ms (fore/aft)
Modulation	Interrupted CW	Linear FM (chirp)
Transmitter BW (kHz)	15	500
PRF (Hz)	115 (mid) 98 (fore/aft)	29.4
Antenna type	Slotted waveguide	Slotted waveguide

TABLE 3 (*end*)

Parameter	Value	
Antenna gain (dBi)	31 (mid) 32.5 (fore/aft)	28.5 (mid) 29.5 (fore/aft)
Antenna mainbeam orientation (degrees)	Incidence angles: 18-47 (mid) 24-57 (fore/aft)	Incidence angles: 25.0-54.5 (mid) 33.7-65.3 (fore/aft)
Antenna beamwidth (–3 dB), elevation	24° (mid) 26° (fore/aft)	23.6° (mid) 23.9° (fore/aft)
Azimuth beamwidth	1.3° 0.8°	1.1° 0.8°
Instrument elevation angle (degrees)	29.3	37.6
Antenna polarization	Vertical	Vertical
Transmitter peak power	4.8 kW	120 W
Receiver noise temperature (dB)	Noise factor: 3	Noise factor: 3
Service area	Oceanic and coastal areas, land masses	Oceanic and coastal areas, land masses

Annex 2

Sharing constraints between spaceborne active sensors and high speed WLANs in the 5 250-5 350 MHz band

1 Introduction

This Annex presents the results of three sharing analyses for the band 5 250-5 350 MHz between the spaceborne active sensors and the high speed WLANs, or RLANs. The first study, given in § 2 of this Annex, uses high performance RLAN (HIPERLAN) type 1 classes B and C and HIPERLAN type 2 characteristics for the RLANs and uses SAR4 characteristics for the SAR. In this study, it is feasible for the indoor only HIPERLAN type 1 class B and HIPERLAN type 2 to share the 5 250-5 350 MHz band with SAR4, but is not feasible for the HIPERLAN type 1 class C to share the band, nor for any HIPERLAN type designed to be operated outdoors with the technical characteristics assumed in the study.

The second study, as given in § 3 of this Annex, uses three RLAN types, RLAN1, RLAN2, and RLAN3, and uses SAR2, SAR3, and SAR4 characteristics for the SARs. In this study, for the single transmitter deployed outdoors, the RLAN1 high speed WLAN transmitter interference was above the acceptable level for SAR4, the RLAN2 high speed WLAN transmitter interference was above the acceptable levels for both SAR3 and SAR4, and the RLAN3 high speed WLAN transmitter interference was above the acceptable level for SAR4. For indoors/outdoors RLAN deployment, it is feasible for the RLAN1, based on an assumption of only 12 active transmitters per km^2 within the

SAR (footprint) and a single frequency channel for the RLAN1, to share with SAR2, SAR3, and SAR4, but it is not feasible for the RLAN2, based on an assumption of 1 200 active transmitters per office space and 14 channels across a 330 MHz band, to share with SAR2, SAR3, and SAR4. For an indoor deployment and considering the interference from the RLAN3 configuration of high speed WLANs to the SARs, the analysis shows that any surface density less than 37-305 transmitters/km^2/channel will yield acceptable interference levels into the SAR, depending on the imaging SAR pixel S/N for an imaging SAR. The anticipated mean density is estimated to 1 200 transmitter/large office area and 250 transmitters/industrial area. The anticipated high density assumes 14 channels, each 23.6 MHz wide, over a 330 MHz band. For interference from the RLAN3 configuration of high speed WLANs to the SARs, the analysis shows that only for a surface density less than 518 to 4 270 transmitters/km^2 over 14 channels, will local area networks (LANs) yield acceptable interference levels into the SAR. For RLAN3 interference into SAR2 and SAR4, this would correspond to about 3 to 12 large office buildings or 15 to 60 industrial areas within the SAR footprint, depending on the SAR pixel S/N.

The third study, as given in § 4 of this Annex, uses the more critical HIPERLAN type 1 characteristics for the RLANs and uses the altimeter characteristics as given in Table 2 for the altimeter. The radar altimeter operation with a 320 MHz bandwidth around 5.3 GHz is compatible with HIPERLANs.

The fourth study, as given in § 5 of this Annex, uses the HIPERLAN type 2 characteristics for the RLANs and uses the scatterometer characteristics as given in Table 3 for the scatterometer. The scatterometer operation around 5.3 GHz is compatible with HIPERLANs operated indoors.

2 Study of HIPERLANs types 1 and 2 and SARs

2.1 Technical characteristics of the two systems

The technical characteristics of the WLANs used for the sharing analysis are those of the HIPERLAN type 1 and type 2, for which the European Telecommunications Standards Institute (ETSI) in Europe has published the relevant specifications: EN 300 652 for type 1 and TS 101 683 for type 2. For other study parameters (building attenuation, operational activity duty cycle, HIPERLAN density, etc.) the values used are those agreed by ETSI ERM for these studies in Europe.

HIPERLAN type 1:

It provides high speed RLAN communications that are compatible with wired LANs based on Ethernet and Token-ring Standards ISO 8802.3 and ISO 8802.5.

HIPERLAN/1 parameters:

e.i.r.p. (high bit rate (HBR), in 23.5 MHz, low bit rate (LBR), in 1.4 MHz):

	class A: 10 dBm maximum e.i.r.p.
	class B: 20 dBm maximum e.i.r.p.
	class C: 30 dBm maximum e.i.r.p.
Channel spacing:	30 MHz
Antenna directivity:	omnidirectional

Minimum useful receiver sensitivity: –70 dBm

Receiver noise power (23.5 MHz): –90 dBm

C/I for BER 10^{-3} at HBR: 20 dB

Effective range (class C): 50 m.

Only classes B (100 mW maximum e.i.r.p.) and C (1 W maximum e.i.r.p.) are considered for this study.

HIPERLAN type 2:

It provides high speed RLAN communications that are compatible with wired LANs based on ATM and IP standards.

HIPERLAN/2 parameters:

e.i.r.p.: 0.2 W (in the 5 250-5 350 MHz band)

Channel bandwidth: 16 MHz

Channel spacing: 20 MHz

Antenna directivity: omnidirectional

Minimum useful receiver sensitivity: –68 dBm (at 54 Mbit/s) to –85 dBm (at 6 Mbit/s)

Receiver noise power (16 MHz): –93 dBm

C/I: 8-15 dB

Effective range: 30-80 m.

In European countries, in the band 5 250-5 350 MHz, the e.i.r.p. is limited to 200 mW and the use of HIPERLANs is only allowed when the following mandatory features are realized:

– transmitter power control (TPC) to ensure a mitigation factor of at least 3 dB;

– dynamic frequency selection (DFS) associated with the channel selection mechanism required to provide a uniform spread of the loading of the HIPERLANs across a minimum of 330 MHz.

Currently HIPERLAN/1 does not support these two features.

The DFS does not only provide a uniform load spread, but it allows also each HIPERLAN system to detect interference from other systems and therefore is able to avoid co-channel operation with other systems, notably radar systems. The system senses which channel is free for use and automatically switches to it. This allows large numbers of HIPERLAN systems to operate in the same office environment.

It is to be noted that the numbers given in the deployment scenarios are based on the assumption of the availability of a total of 330 MHz band for WLANs. Assuming that this bandwidth will be available in two sub-bands (5 150-5 350 MHz and 130 MHz above 5 470 MHz) and given the channel spacing and the need to create a guardband at the boundaries of the two sub-bands, the assumed number of channels used in the study is 8 for type 1 and 14 for type 2.

Other HIPERLAN parameters used for this study are those agreed by ETSI:

- average building attenuation towards EESS instruments: 17 dB;
- active/passive ratio: 5%;
- percentage of outdoor usage: 15%;
- deployment scenarios: 1200 systems for large office buildings, 250 systems for industrial sites.

For the spaceborne active sensors are taken from the SAR characteristics in Annex 1 of this Recommendation. The SAR4 type is taken as example for the analysis of the interference from HIPERLAN into SAR, but similar results can be obtained for the other types. SAR types 2-4 have been used for the analysis of the interference from SAR into HIPERLAN.

2.2 Sharing analysis (from WLAN into SAR)

The sharing analysis is given in Table 4 for the three cases considered: HIPERLAN type 1 (class B and class C) and type 2.

Given the expected HIPERLAN density (1200 systems per large office building and 250 for industrial sites) the outdoor only or mixed indoor-outdoor cases do not represent a feasible sharing scenario for any of the three cases considered.

For the indoor use only, sharing is not feasible for the high power type 1 class C, while the type 1 class B and type 2 cases require further considerations.

In fact the 440 systems limit indicated in Table 4 for type 2 indoor only is per channel. Considering the DFS mechanism described above, one can make the hypothesis that the HIPERLAN type 2 systems can be spread across the 14 channels available, giving a theoretical upper limit of 6 160 systems within the 76.5 km^2 of the SAR footprint. Type 1 class B gives an upper limit of 5 208 systems.

TABLE 4

Permissible active HIPERLAN capacity in channels shared with SAR4

HIPERLAN type	**Type 1/Class B**		**Type 1/Class C**		**Type 2**	
Parameter	**Value**	**dB**	**Value**	**dB**	**Value**	**dB**
Max transmitted power (W) TPC effect on average	0.1 Not available	–10	1 Not available	0	0.2	–7 –3
Distance (km) and free space loss	425.7	–159.5	425.7	–159.5	425.7	–159.5
Additional transmit path loss (dB): – Outdoor only – Indoor only – Mixed (15% outdoor)		 0 –17 –7.8		 0 –17 –7.8		 0 –17 –7.8
Antenna gain, transmitter (dB)		0		0		0

TABLE 4 (*end*)

HIPERLAN type	Type 1/Class B		Type 1/Class C		Type 2	
Parameter	**Value**	**dB**	**Value**	**dB**	**Value**	**dB**
Antenna gain, receiver (dB)		42.7		42.7		42.7
Polarization loss (dB)		–3		–3		–3
SAR interference threshold ($I/N = -6$ dB), (dB(W/Hz))		–205.4		–205.4		–205.4
Power received (dB(W/channel)) (channel: 23.5 MHz type 1/16 MHz type 2): – Outdoor only – Indoor only – Mixed (15% outdoor)		–129.8 –146.8 –137.6		–119.8 –136.8 –127.6		–129.8 –146.8 –137.6
Power received (dB(W/Hz)): – Outdoor only – Indoor only – Mixed (15% outdoor)		–203.5 –220.5 –211.3		–193.5 –210.5 –201.3		–201.8 –218.8 –209.6
Margin dB/(Hz^{-1}): – Outdoor only – Indoor only – Mixed (15% outdoor)		–1.9 15.1 5.9		–11.9 5.1 –4.1		–3.6 13.4 4.2
SAR antenna footprint (km^2)	76.5	18.8	76.5	18.8	76.5	18.8
Permissible active HIPERLAN density (/km^2/ch): – Outdoor only – Indoor only – Mixed (15% outdoor)	0.0085 0.43 0.051	–20.7 –3.7 –12.9	0.00085 0.043 0.0051	–30.7 –13.7 –22.9	0.0058 0.29 0.034	–22.4 –5.4 –14.6
Active/passive ratio	5%	13	5%	13	5%	13
Permissible total (active + passive) HIPERLAN density (/km^2/ch): – Outdoor only – Indoor only – Mixed (15% outdoor)	0.17 8.51 1.02	–7.7 9.3 0.1	0.017 0.851 0.102	–17.7 –0.7 –9.9	0.11 5.75 0.69	–9.4 7.6 –1.6
Maximum number of active + passive HIPERLAN per channel within the SAR footprint (76.5 km^2): – Outdoor only – Indoor only – Mixed (15% outdoor)	13 651 78		1 65 8		8 440 53	

These values correspond to roughly five large office buildings in the 76.5 km^2 of the SAR footprint and, although far from being a worst case, can be considered a reasonable assumption for urban and suburban areas.

It can therefore be concluded that, although marginally, the two services can share the band when systems with the HIPERLAN type 2 or type 1 class B systems are deployed indoor.

The DFS mechanism will provide a uniform spread of the load across the available channels. If the channel selection is not based on a random choice, this hypothesis is likely to be incorrect and the conclusion needs to be revised.

2.3 Sharing analysis (from SARs into high speed WLANs)

The first step in analysing the interference potential from spaceborne SARs into high speed WLANs is to determine the signal power from a spaceborne SAR's side lobes onto the Earth's surface. For this analysis the median side lobe gain has been used since these side lobes give a substantially larger footprint than the peak gain and will result in a longer during interference. Next, the threshold of the high speed WLAN receiver is determined. Then, the interference margin can be calculated by comparing the SAR interference level with the LAN interference threshold. Table 5 shows the interference margin for the side lobes of SAR2-4 into wireless high speed local area networks with an outdoor deployment in the 5 250-5 350 MHz band. This Table shows a positive margin and would result in a positive sharing scenario.

TABLE 5

SAR side lobes to high speed WLANs

Parameter	SAR2		SAR3		SAR4	
	Value	**dB**	**Value**	**dB**	**Value**	**dB**
Transmitted power (W)	4 800.00	36.81	1 700.00	32.30	1 700.00	32.30
Antenna gain, transmitter (dB)	–5.00	–5.00	–5.00	–5.00	–5.00	–5.00
Antenna gain, receiver (dB)	0.00	0.00	0.00	0.00	0.00	0.00
Wavelength (m)	5.65×10^{-2}	–24.96	5.65×10^{-2}	–24.96	5.65×10^{-2}	–24.96
$(4\pi)^{-2}$	6.33×10^{-3}	–21.98	6.33×10^{-3}	–21.98	6.33×10^{-3}	–21.98
Distance (km)	638.51	–116.10	425.67	–112.58	425.67	–112.58
Bandwidth reduction (dB)	–12.87	–12.87	–12.87	–12.87	–3.98	–3.98
Power received (dBW)		–144.11		–145.09		–136.20
HIPERLANs interference threshold		–115.00		–115.00		–115.00
Margin (dB)		29.11		30.09		21.20

However, for SAR2-4, the peak antenna gains are 43-47.7 dB higher than the average side lobe levels of –5 dBi. Therefore for the duration of the flyover, which in the main beam of the SAR would be about 0.5-1.0 s, the SAR interference levels at the surface would be above the WLAN interference threshold worst case (HIPERLAN type 2: –115 dBW). This can be observed in Table 5 when looking at the margin which would become negative.

A more proper way to determine the maximum allowable interference level would be to take the *C*/*I* into account, which has to be greater than 15 dB. In case the RLAN transmitters are within 50 m of each other (worst-case scenario), this can raise the allowable interference level by 10 dB

(–105 dBW instead of –115 dBW). For SAR4 this analysis gives a worst case margin of –16.5 dB for outdoor equipment. Using indoor deployment of RLANs in this analysis (17 dB attenuation) would result in a marginally positive sharing scenario. The repeat period for the SAR is 8-10 days, although the SAR is not necessarily active for every repeat pass. Therefore, a given area on the Earth would be illuminated by a single SAR main beam no more often than 0.5-1.0 s every 8-10 days.

2.4 Conclusions

For the interference from WLANs to SAR, the analysis brings three main conclusions in the band 5 250-5 350 MHz:

- WLANs used only indoor are compatible with the operation of SARs, while outdoor operation of WLANs does not give compatibility with the operation of SARs.
- Indoor WLANs limited to a mean e.i.r.p.[1] of 200 mW (or 100 mW if TPC is not used) and mean e.i.r.p. density limit of 10 mW in any 1 MHz band are compatible with the operation of SARs.
- In addition to the above, two features are needed in the WLAN systems to achieve compatibility with the operation of SARs:
  - transmitter power control to ensure a mitigation factor of at least 3 dB; without the TPC feature, the mean e.i.r.p. should not exceed 100 mW in any 20 MHz channel;
  - DFS associated with the channel selection mechanism required to provide a uniform spread of the loading of the WLAN channels across a minimum of 330 MHz.

The analysis of the interference from SARs into WLANs brings positive results considering indoor deployment.

3 Study of RLANs and SARs

3.1 Technical characteristics of typical high speed WLANs

The technical characteristics for typical high speed WLANs at 5.3 GHz are given herein for three configurations. These high speed WLANs are sometimes referred to as radio LANs or RLANs. The characteristics chosen in this analysis for the configurations are those which would result in the worst-case interference to a SAR receiver. The information on the first configuration, RLAN1, of high speed WLANs was taken from the FCC Report and Order FCC 97-7, 9 January 1997, and on the HIPERLANs from Document 7C/54, 18 September 1996. These characteristics are summarized in Table 6. The information on the second configuration RLAN2 of high speed WLANs was taken from the Space Frequency Coordination Group (SFCG)-18/45, 8-17 September 1998. The second

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[1] The mean e.i.r.p. refers to the e.i.r.p. averaged over the transmission burst at the highest power control setting.

configuration, RLAN2, has a noticeable increase in high speed WLANs transmitter power, increase in the indoor/outdoor use ratio and resulting lower mean building attenuation, increase in the active/passive ratio, and increase in the anticipated deployment density. The information on the third configuration, RLAN3, of high speed WLANs was taken from the Space Frequency Coordination Group (SFCG)-19/39, 8-15 September 1999 and Document 7C/110 "Sharing constraints between spaceborne active sensors (SARs) and wireless high speed local area networks in the 5 250-5 350 MHz band", 17 February 1999. The third configuration, RLAN3, is restricted to indoor use only, with a medium anticipated deployment density.

TABLE 6

Technical characteristics of high speed WLANs at 5.3 GHz

Parameter	**Value**		
	RLAN1	**RLAN2**	**RLAN3**
Peak radiated power (W)	0.25	1.00	0.20
Deployment (%)	99 indoors/ 1 outdoors	85 indoors/ 15 outdoors	100 indoors/ 0 outdoors
Mean attenuation (dB)	17.0	7.8	17.0
Polarization	Random	Random	Random
Bandwidth (MHz)	23.6	23.6/channel (14 channels)	23.6/channel (14 channels)
Interference duty cycle into SAR (%)	100	100	100
Operational activity (active/passive ratio (%))	1	5	5
Mean density (transmitters/km^2)	12	1 200/office area (89 000/km^2/channel)	1 200/office area, 250/industrial area
Interference threshold (dBW)	−120	−120 (to be developed)	−100

3.2 Interference from high speed WLANs into SARs

The first step in analysing the interference potential from high speed WLANs into spaceborne SARs receivers is to determine the signal power from a single high speed WLAN transmitter at the spaceborne SAR. Then, the single interferer margin can be calculated by comparing the interference level with the SAR interference threshold. Knowing the SAR footprint, the allowable density of active high speed WLANs transmitters can then be calculated, using a conservative activity ratio for the fraction of transmitters operating at any one time.

3.2.1 Interference from a single RLAN transmitter located outdoors

Table 7 shows the interference from a single RLAN high speed WLAN transmitter in the 5 250-5 350 MHz band for SAR2-4. SAR1 was not used because this SAR1 system was designed to operate in the 5 150-5 250 MHz band. An omni antenna is assumed for RLAN1, RLAN2, and RLAN3. For SAR4, Table 7 shows negative margin for the RLAN1, RLAN2, and RLAN3 high speed WLAN transmitters. For SAR3, Table 7 shows a positive margin for the RLAN1 and RLAN3 transmitters, and negative margin for RLAN2. For SAR2, and interference from RLAN1, RLAN2, and RLAN3, there are positive margins for all three RLAN transmitters interference.

TABLE 7

Interference from a single outdoor RLAN transmitter to SARs

Parameter	**SAR2**		**SAR3**		**SAR4**	
	Value	**dB**	**Value**	**dB**	**Value**	**dB**
Transmitted power (W)						
RLAN1	0.25	–6.02	0.25	–6.02	0.25	–6.02
RLAN2	1.00	0.00	1.00	0.00	1.00	0.00
RLAN3	0.20	–6.99	0.20	–6.99	0.20	–6.99
Building attenuation (dB)		0.00		0.00		0.00
Antenna gain, transmit (dB)		0.00		0.00		0.00
Antenna gain, receiver (dB)		43.33		44.52		44.52
Polarization loss (dB)		–3.00		–3.00		–3.00
Wavelength (m)	5.65×10^{-2}	–24.96	5.65×10^{-2}	–24.96	5.65×10^{-2}	–24.96
$(4\pi)^{-2}$	6.33×10^{-3}	–21.98	6.33×10^{-3}	–21.98	6.33×10^{-3}	–21.98
Distance (km)	638.51	–116.10	425.67	–112.58	425.67	–112.58
Power received (dBW)						
RLAN1		–128.74		–124.03		–124.03
RLAN2		–122.72		–118.00		–118.00
RLAN3		–129.71		–124.99		–124.99
Noise figure (dB)		4.62		4.62		4.62
$k\,T$	4.00×10^{-21}	–203.98	4.00×10^{-21}	–203.98	4.00×10^{-21}	–203.98
Receiver bandwidth (MHz)	356.50	85.52	356.50	85.52	46.00	76.63
Noise power (dBW)		–113.84		–113.84		–122.73
SAR interference threshold ($I/N = -6$ dB)		–119.84		–119.84		–128.73
Margin (dB)						
RLAN1		8.90		4.19		–4.71
RLAN2		2.88		–1.83		–10.73
RLAN3		9.87		5.16		–3.74

3.2.2 Interference from an indoor deployment of RLAN transmitters

Table 8 shows the allowable configuration RLAN1 high speed WLANs density in the 5 250-5 350 MHz band for SAR2-4. For SAR4, Table 8 shows the allowable density of RLAN1 high speed WLANs to be about 118 transmitters/km^2, below which the interference level to the 40 MHz SAR4 is acceptable. Using information on the anticipated HIPERLANs deployment density from Document 7C/54, 18 September 1996, the HIPERLANs mean density over Europe was estimated at that time to be 12 transmitters/km^2. It was expected that the density in metropolitan and densely inhabited areas would be higher than the mean. Table 9 shows the allowable density of configuration RLAN2 high speed WLANs in the 5 250-5 350 MHz band for SAR2-4. For SAR4, Table 9 shows the allowable RLAN2 high speed WLANs density to be about 0.2 transmitters/km^2, or equivalently 1 transmitter/5 km^2, below which the interference level to the 40 MHz SAR4 is acceptable. This low allowable density is to be compared with the anticipated deployment density from Document SFCG-18/45, 8-17 September 1998, of 1 200 transmitters/office area; there is also the indoor RLAN2 capacity of 89 × 10^3/km^2/channel, for separation distances of 0.5 m. The anticipated high density uses 14 channels, each 23.6 MHz wide, over 330 MHz band. Table 10 shows the allowable density of configuration RLAN3 high speed WLANs in the 5 250-5 350 MHz band for SAR2-4. For SAR4, Table 10 shows the allowable RLAN3 high speed WLANs density to be about 37 transmitters/km^2/channel, below which the interference level to the 40 MHz SAR4 is acceptable. The anticipated high density uses 14 channels, each 23.6 MHz wide, over 330 MHz band. For 14 channels, the allowable density is then 518 transmitters/km^2. This low allowable density is to be compared with the anticipated deployment density from Document 7C/110, of 1 200 transmitters/large office area and 250 transmitters/industrial sites. Thus, for SAR4, the allowable density would be that for less than one large office area and about two industrial areas, which seems to be unrealistic. For SAR2 and SAR4, the allowable density over 14 channels would be 4 270 and 3 990 transmitters, respectively. This would correspond to about three large office buildings or 15 industrial areas which may be a slightly more reasonable assumption for urban and suburban areas.

For imaging SARs with *S*/*N* 8 dB or higher, the *I*/*N* can be 0 dB and still not degrade the pixel power standard deviation more than 10%. This increases the allowable transmitter density by a factor of 4. For RLAN3 interference into SAR2 and SAR4, this would correspond to about 12 large office buildings or 60 industrial areas within the SAR footprint. However, for interferometric SARs, the *I*/*N* must be less than –6 dB, independent of the *S*/*N*.

TABLE 8

Interference from RLAN1 high speed WLANS to SARs

Parameter	**SAR2**		**SAR3**		**SAR4**	
	Value	**dB**	**Value**	**dB**	**Value**	**dB**
Transmitted power (W)	0.25	–6.02	0.25	–6.02	0.25	–6.02
Building attenuation (dB)		–17.00	17.00	–17.00	17.00	–17.00
Antenna gain, transmitter (dB)		0.00	0.00	0.00	0.00	0.00
Antenna gain, receiver (dB)		43.33	44.52	44.52	44.52	44.52
Polarization loss (dB)		–3.00	3.00	–3.00	3.00	–3.00
Wavelength (m)	5.65×10^{-2}	–24.96	5.65×10^{-2}	–24.96	5.65×10^{-2}	–24.96
$(4\pi)^{-2}$	6.33×10^{-3}	–21.98	6.33×10^{-3}	–21.98	6.33×10^{-3}	–21.98
Distance (km)	638.51	–116.10	425.67	–112.58	425.67	–112.58
Power received (dBW)		–145.74		–141.03		–141.03
Noise figure (dB)		4.62	4.62	4.62	4.62	4.62
$k\,T$	4.00×10^{-21}	–203.98	4.00×10^{-21}	–203.98	4.00×10^{-21}	–203.98
Receiver bandwidth (MHz)	356.50	85.52	356.50	85.52	46.00	76.63
Noise power (dBW)		–113.84		–113.84		–122.73
SAR interference threshold ($I/N = -6$ dB)		–119.84		–119.84		–128.73
Margin (dB)		25.90		21.19		12.29
SAR footprint (km^2)	159.03	22.01	57.55	17.60	57.55	17.60
Mean surface power of HIPERLANs (dB(W/km^2))		3.88		3.59		–5.31
Active transmitter/km^2	9.78		9.14		1.18	
Active transmitter/km^2 at 1% activity ratio	978.40		913.56		117.88	

TABLE 9

Interference from RLAN2 high speed WLANS to SARs

Parameter	**SAR2**		**SAR3**		**SAR4**	
	Value	**dB**	**Value**	**dB**	**Value**	**dB**
Transmitted power (W)	1.00	0.00	1.00	0.00	1.00	0.00
Building attenuation (dB)		–7.80	7.80	–7.80	7.80	–7.80
Antenna gain, transmitter (dB)		0.00	0.00	0.00	0.00	0.00
Antenna gain, receiver (dB)		43.33	44.52	44.52	44.52	44.52
Polarization loss (dB)		–3.00	3.00	–3.00	3.00	–3.00
Wavelength (m)	5.65×10^{-2}	–24.96	5.65×10^{-2}	–24.96	5.65×10^{-2}	–24.96
$(4\pi)^{-2}$	6.33×10^{-3}	–21.98	6.33×10^{-3}	–21.98	6.33×10^{-3}	–21.98
Distance (km)	638.51	–116.10	425.67	–112.58	425.67	–112.58
Power received (dBW)		–130.52		–125.80		–125.80
Noise figure (dB)		4.62	4.62	4.62	4.62	4.62
$k\,T$	4.00×10^{-21}	–203.98	4.00×10^{-21}	–203.98	4.00×10^{-21}	–203.98
Receiver bandwidth (MHz)	356.50	85.52	356.50	85.52	46.00	76.63
Noise power (dBW)		–113.84		–113.84		–122.73
SAR interference threshold (I/N = –6 dB)		–119.84		–119.84		–128.73
Margin (dB)		10.68		5.97		–2.93
SAR footprint (km^2)	159.03	22.01	57.55	17.60	57.55	17.60
Mean surface power of HIPERLANs (dB(W/km^2))		–11.34		–11.63		–20.53
Active transmitter/km^2	0.07		0.07		0.01	
Active transmitter/km^2 at 5% activity ratio	1.47		1.37		0.18	

As far as a self-limiting density such that the surrounding high speed WLANs interfere unacceptably among themselves, for RLAN3, the high speed WLANs are assumed to occupy 14 channels, each 23.6 MHz wide, over a 330 MHz band, and the transmitters can be as close as 0.5 m, giving a possible density of 89×10^3/km^2/channel over small areas corresponding to the large office area. The LAN receiver no longer requires the interference to be lower than –100 dBW, but that the C/I be greater than 20 dB. This allows the transmitters to operate within 0.5 m of each other without mutual self-interference.

TABLE 10

Interference from RLAN3 high speed WLANs to SARs

Parameter	SAR2		SAR3		SAR4	
	Value	**dB**	**Value**	**dB**	**Value**	**dB**
Transmitted power (W)	0.20	–6.99	0.20	–6.99	0.20	–6.99
Building attenuation (dB)		–17.00		–17.00		–17.00
Antenna gain, transmitter (dB)		0.00		0.00		0.00
Antenna gain, receiver (dB)		43.33		44.52		44.52
Polarization loss (dB)		–3.00		–3.00		–3.00
Wavelength (m)	5.65×10^{-2}	–24.96	5.65×10^{-2}	–24.96	5.65×10^{-2}	–24.96
$(4\pi)^{-2}$	6.33×10^{-3}	–21.98	6.33×10^{-3}	–21.98	6.33×10^{-3}	–21.98
Distance (km)	638.51	–116.10	425.67	–112.58	425.67	–112.58
Power received (dBW)		–146.71		–141.99		–141.99
Noise figure (dB)		4.62		4.62		4.62
$k\,T$	4.00×10^{-21}	–203.98	4.00×10^{-21}	–203.98	4.00×10^{-21}	–203.98
Receiver bandwidth (MHz)	356.50	85.52	356.50	85.52	46.00	76.63
Noise power (dBW)		–113.84		–113.84		–122.73
SAR interference threshold ($I/N = -6$ dB)		–119.84		–119.84		–128.73
Margin (dB)		26.87		22.16		13.26
SAR footprint (km^2)	159.03	22.01	57.55	17.60	57.55	17.60
Mean surface power of HIPERLANs (dB(W/km^2))		4.85		4.56		–4.34
Active transmitter/km^2/channel	15.29		14.27		1.84	
Active transmitter/km^2/channel at 5% activity ratio	305.75		285.49		36.84	

3.3 Interference from SARs into high speed WLANs

The first step in analysing the interference potential from spaceborne SARs into high speed WLANs is to determine the signal power from a spaceborne SAR onto the Earth’s surface. Next, the threshold of the high speed WLAN receiver is determined. Then, the interference margin can be calculated by comparing the SAR interference level with the LAN interference threshold. For SAR1-4, the peak antenna gains are 40-50 dB higher than the average side lobe levels of –5 dBi. Therefore for the duration of the flyover, which in the main beam of the SAR would be about

0.5-1.0 s, the SAR interference levels at the surface would be well above the RLAN1 interference thresholds. However, for RLAN2, the level of –120 dBW is no longer the maximum allowable interference level, but rather that *C*/*I* be greater than 20 dB, which in the case of transmitters within 0.5 m of each other, can raise the allowable interference level by 50-80 dB.

The situation for RLAN3 is similar to that for RLAN2. For these typical SAR2-4, the peak antenna gains are 14-38 dB higher than the average side lobe levels of –5 dBi. Therefore for the duration of the flyover, which in the main beam of the SAR would be about 0.5-1.0 s, the SAR interference levels at the surface would be well above the RLAN3 interference thresholds. However, for RLAN3, the level of –120 dBW is no longer the maximum allowable interference level, but rather that *C*/*I* be greater than 20 dB, which in the case of transmitters within 0.5 m of each other, can raise the allowable interference level by 50-80 dB. The repeat period for the SAR is 8-10 days, although the SAR is not necessarily active for every repeat pass. Therefore, a given area on the Earth would be illuminated by the SAR beam no more often than 0.5-1.0 s every 8-10 days.

3.4 Conclusion

The potential interference between one configuration RLAN3 of high speed WLANs and spaceborne synthetic aperture radars in the band 5 250-5 350 MHz was analysed in this Recommendation for 1) a single RLAN1-3 transmitter deployed outdoors and 2) a density of RLAN3 indoors deployment. For the single transmitter deployed outdoors, the RLAN1 high speed WLAN transmitter interference was above the acceptable level for SAR4, the RLAN2 high speed WLAN transmitter interference was above the acceptable levels for both SAR3 and SAR4, and the RLAN3 high speed WLAN transmitter interference was above the acceptable level for SAR4.

For interference from the RLAN1 configuration of high speed WLANs to the SARs, the analysis shows that any surface density less than 32-128 transmitters/km^2 will yield acceptable interference levels into the SAR, depending on the imaging SAR pixel *S*/*N*. The anticipated mean density over Europe was in the past estimated to be only 12 transmitters/km^2. At a density of 0.32 active transmitters/km^2 (density of 32 active transmitters/km^2 with a 1% activity ratio) a typical high speed WLAN (0.25 W transmitter power) deployed outdoors will experience self-interference levels of −120 dBW, a level which the RLAN1 high speed WLANs hold as their interference threshold. For interference from the RLAN2 configuration of high speed WLANs to the SARs, the analysis shows that only for a surface density less than 0.2-1.5 transmitters/km^2 will LANs yield acceptable interference levels into the SAR, depending on the imaging SAR pixel *S*/*N*. The current anticipated mean density is 1 200 transmitters/office area, up to about 89 × 10^3/km^2/channel. The anticipated high density assumes 14 channels, each 23.6 MHz wide, over a 330 MHz band. For an indoor deployment and considering the interference from the RLAN3 configuration of high speed WLANs to the SARs, the analysis shows that any surface density less than 37-305 transmitters/km^2/channel will yield acceptable interference levels into the SAR, depending on the imaging SAR pixel *S*/*N* for an imaging SAR. The anticipated mean density is estimated to 1 200 transmitter/large office area and 250 transmitters/industrial area. The anticipated high density assumes 14 channels, each 23.6 MHz wide, over a 330 MHz band. For interference from the RLAN3 configuration of high speed WLANs to the SARs, the analysis shows that only for a surface density less than 518 to 4 270 transmitters/km^2 over 14 channels, will LANs yield acceptable interference levels into the SAR. For RLAN3 interference into SAR2 and SAR4, this would correspond to about 3 to 12 large office buildings or 15 to 60 industrial areas within the SAR footprint, depending on the SAR pixel *S*/*N*.

For interference from the spaceborne SARs into RLAN1 high speed WLANs in the 5 250-5 350 MHz band, the SAR interference levels at the surface for side lobes are 14-38 dB lower than the LAN interference threshold. For SARs peak antenna interference over the duration of the flyover, which in the main beam of the SAR would be about 0.5-1.0 s, the SAR interference levels at the surface would be well above the RLAN1 interference thresholds by 10-30 dB. However, for RLAN2 and RLAN3, the levels of –120 dBW and –100 dBW, respectively, are no longer the maximum allowable interference levels, but rather that C/I be greater than 20 dB, which in the case of transmitters within 0.5 m of each other, can raise the allowable interference level by 50-80 dB, so that the SAR even in the mainbeam may be below the LANs interference threshold. Since the repeat period for the SAR is 8-10 days, and the SAR is not necessarily active for every repeat pass, a given area on the Earth would be illuminated by the SAR beam no more often than 0.5-1.0 s every 8-10 days.

4 Study of RLANs and altimeters

4.1 Interference from RLANs into altimeters

For this analysis, we consider one RLAN of the HIPERLAN type in the altimeter main lobe.

The altimeter has an extended bandwidth of 320 MHz, while the HIPERLANs have a channel bandwidth ranging from 16 MHz (type 2) to 23.5 MHz (type 1) included within the altimeter bandwidth. The maximum HIPERLAN transmitted e.i.r.p. ($P_h G_h$) is 30 dBm (type 1) or 23 dBm (type 2). The altimeter antenna gain, G_0, is 32.2 dB, G_a is the off-axis antenna gain towards the HIPERLAN, with additional 1 dB input loss L. The altimeter is nadir pointing, antenna size is 1.2 m. R is the range of the altimeter from the HIPERLAN.

The power received by the altimeter from one HIPERLAN in the boresight of the SAR (i.e. $G_a = G_0$) is:

$$P_r = \frac{P_h G_h G_a \lambda^2}{(4\pi)^2 R^2 L} \tag{1}$$

Taking the more critical HIPERLAN type 1 parameters (given in § 2.2), we obtain a value for P_r of –108.3 dBm.

The altimeter interference threshold is –88 dBm; we can thus deduce that the altimeter can withstand the operation of a number of HIPERLANs simultaneously, since we have a 20.3 dB margin. Furthermore, the altimeter is built to provide measurements mainly over oceans and is not able to provide accurate data when a significant amount of land is in view of its antenna beam. From this analysis, it is clear that the altimeter will not suffer from the operation of HIPERLANs.

For completeness, the number of HIPERLANs in the –3 dB footprint that can be tolerated by the altimeter operating over land can be calculated. The methodology is described in § 4.1.1 of this Recommendation.

We obtain a range from 586 (outdoor use) to 4 664 (indoor use) HIPERLANs installed as a limit not to interfere into the altimeter. Extra margins remain in the fact that:

- No polarization loss or additional propagation losses have been taken into account (about 3 dB).
- Mitigation techniques such as transmitter power control are not considered (which is expected to provide at least 3 dB margin).
- The gain of the altimeter in the direction of HIPERLAN devices was overestimated in the simulation.

In addition it is expected that typically only HIPERLAN type 2 systems will be deployed in the frequency range used by the altimeters, improving therefore the situation thanks to the lower maximum e.i.r.p. (200 mW).

We can thus conclude that the altimeter will not suffer from interference from HIPERLANs when used over oceans. However, if it were to be operated over land the situation is marginal dependant on the final choice of parameters for the HIPERLAN. The expected margin may allow sharing even when altimeters are operating close to the land. Indoor-only and type 2-only HIPERLAN operation would strongly improve the sharing environment.

4.1.1 Estimation of the number of RLANs in the –3 dB footprint of an altimeter

For this analysis, we consider one HIPERLAN type 1 in the altimeter main lobe.

The altimeter has an extended bandwidth of 320 MHz, while the HIPERLANs have a 23.5 MHz bandwidth included within the altimeter bandwidth. The maximum HIPERLAN transmitted e.i.r.p. ($P_h G_h$) is 30 dBm. The altimeter antenna gain, G_0 is 32.2 dB, G_a is the off-axis antenna gain towards the HIPERLAN, with additional 1 dB input loss L. The altimeter is nadir pointing, antenna size is 1.2 m. R is the range of the altimeter from the HIPERLAN.

The power received by the altimeter from one HIPERLAN in the boresight of the SAR (i.e. $G_a = G_0$) is:

$$P_r = \frac{P_h G_h G_a \lambda^2}{(4\pi)^2 R^2 L} \tag{2}$$

From this we obtain a value for P_r of –108.3 dBm.

The altimeter interference threshold is −88 dBm; we can thus deduce that the altimeter can withstand the operation of a number of HIPERLANs simultaneously, since we have a 20.3 dB margin. Furthermore, the altimeter is built to provide measurements mainly over oceans and is not able to provide accurate data when a significant amount of land is in view of its antenna beam. From this analysis, it is clear that the altimeter will not suffer from the operation of HIPERLANs.

For completeness, the number of HIPERLANs in the –3 dB footprint that can be tolerated by the altimeter operating over land can be calculated; the computation is not straightforward since with a small change in the angle φ from altimeter boresight, the distance to ground, the gain and the surface element intercepted at ground level will vary.

Assuming a certain density of HIPERLAN devices, i.e. D, then the total number of HIPERLAN devices seen by a satellite (assuming the devices are evenly distributed over the Earth's surface) is given by $N = D \times A$, where A is the –3 dB footprint of the altimeter. Since the devices are not equidistant to the satellite, the visible Earth's surface is divided into concentric surface strips (as in Fig. 1), so that one can assume that all of the HIPERLAN devices within the i-th surface strip are at the same distance, d_i, to the satellite, and are seen with the same nadir angle, φ_i, and the same elevation angle, ε_i. The number of HIPERLAN devices within the i-th strip is given by:

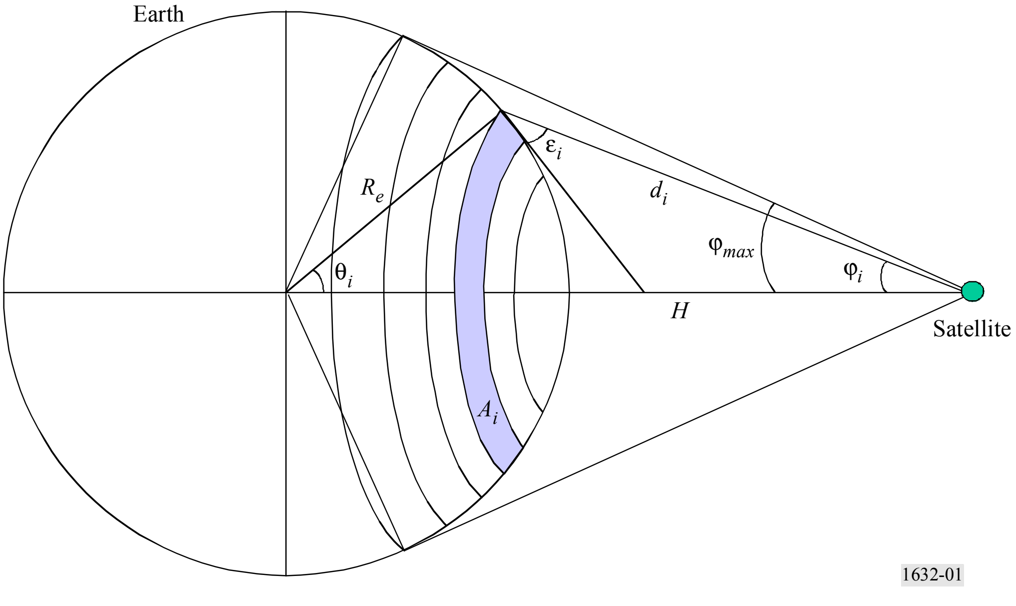
$$N_i = A_i \times (N/A) = A_i \times D \tag{3}$$

where:

$$A_i = 2\pi\, R_e^2 \times [\cos(\theta_{i-1}) - \cos(\theta_i)] \qquad \text{for } \theta_i > \theta_{i-1} \tag{4}$$

FIGURE 1

Geometry for aggregating the interference



The aggregate HIPERLAN interference power, I, at the altimeter is therefore given by summation of the i-th component I_i as below:

$$I(\mathrm{W}) = \sum_i I_i = \sum_i N_i \cdot \frac{\mathrm{le}\,(e.i.r.p./10)}{(4\,\pi\, d_i\, f_0 / c)^2} \cdot G(\varphi_i) \tag{5}$$

where:

e.i.r.p.: effective isotropic radiated power (dBW)

d_i: distance between the satellite and interferer on the Earth

f_0: RF centre frequency

$G(\varphi_i)$: satellite altimeter antenna receive gain which depends on the nadir angle φ_i, i.e. the angle between the sub-satellite point and the considered strip.

For this, a numerical computation has been done: a constant HIPERLAN power density at ground level per square metre has been assumed, and an antenna gain of the altimeter varying as $G_a = G_0$ $(\sin(\varphi)/\varphi)^2)$, φ being the angle between the vertical and the direction satellite to HIPERLAN, which is a worst case since the altimeter lobe will be much lower than this.

The integral of the received power at the altimeter level in the –3 dB footprint was then computed: the mean power acceptable by the altimeter is -60 dBm/m^2, or 0 dBm/km^2 ($D \times e.i.r.p.$).

Since the altimeters are nadir pointing an additional pathloss of 20 dB (due to roof and ceiling attenuation) is included when calculating the interference from indoor HIPERLANs. When considering the case of HIPERLANs which are restricted to indoor operation, it is assumed that at any given time 1% of the HIPERLAN devices will be operating outdoors – leading to an overall additional attenuation factor of 17 dB. For HIPERLANs which are permitted to operate outside, it is assumed that 15% of devices are outdoors at a given time – giving an additional attenuation factor of 8 dB. For both cases it is assumed that 5% of HIPERLANs will be transmitting at once.

TABLE 11

Calculation of number of terminals in –3 dB footprint

	Indoor	**Outdoor**
Power density ($D \times e.i.r.p.$) (dBm/km^2)	0	0
e.i.r.p. (dBm)	30	30
Percentage of HIPERLAN operating outdoor (%)	1	15
Additional margin (dB)	17	8
Active terminals/km^2	0.05	0.063
Active terminals (%)	5	5
Number of terminals/km^2	1.002	0.126
Number of terminals in the –3 dB footprint	4 664	586

We then obtain a range from 586 (outdoor use) to 4 664 (indoor use) HIPERLANs installed in the –3 dB footprint as a limit not to interfere into the altimeter.

4.2 Interference from altimeters into RLANs

In this case we consider a bandwidth reduction factor B_h/B_a, since the altimeter bandwidth B_a is much larger than the HIPERLANs bandwidth B_h. B_a has a value of 320 MHz and B_h is 23.5 MHz (type 1, worst case) or 16 MHz (type 2), hence a reduction factor of 11.34 dB is obtained for type 1 and of 13 dB for type 2. The HIPERLAN antenna gain G_h towards the vertical direction is 0 dB.

The power received by one HIPERLAN from the altimeter is:

$$P_r = \frac{P_a G_a G_h \lambda^2 B_h}{(4\pi)^2 R^2 L B_a} \tag{6}$$

The power transmitted by the altimeter into the HIPERLAN will then be, at the worst case (e.g. main beam of the altimeter, closest distance 1 347 km, outdoor HIPERLAN type 1), –103.64 dBm.

This case (altimeter main beam into HIPERLAN side lobes at the vertical) has to be considered as a worst case, since altimeter lobes decrease very quickly with boresight angle (they are at a –20 dB level 4° from nadir, and –40 dB 15° from nadir).

The calculation above produces a margin of 10 dB for the most critical case (type 1); it is therefore concluded that the altimeter will not interfere into HIPERLANs. The situation improves further in case of indoor HIPERLAN type 2 operation. Furthermore the altimeter is a pulsed radar; the low duty cycle, polarization and additional propagation losses, which provide additional margins, have not been taken into account.

4.3 Conclusion

It is concluded that radar altimeter operation with a 320 MHz bandwidth around 5.3 GHz is compatible with RLANs. Better margins are achieved with RLAN systems with characteristics similar to HIPERLAN type 2. These RLANs are expected to be the type typically deployed in the altimeter band. It is likely that sharing between RLANs and altimeters will also be feasible in the band above 5 460 MHz.

5 Study of RLANs and scatterometers

Nowadays, scatterometers are more often used for land applications and in the near future and with increasing resolution of these instruments even more applications of scatterometer systems above land are foreseen. This interference analysis therefore does not only restrict itself to the coastal areas, but can be seen on a global basis.

5.1 Interference from RLANs into scatterometers

In scatterometer systems, an estimate of the echo return signal power is made by first measuring the "signal + noise" power (i.e. the echo return plus the system noise contribution), and then subtracting the "noise-only" power (an estimate of the system noise alone, or "noise floor"). To optimize system performance, the "signal + noise" and the "noise-only" measurements are made over different bandwidths and/or different times. This strategy relies on the fact that the nominal system noise is inherently white during the measurement sequence (stationary, and with a flat spectral power distribution).

From the above situation, two different interference scenarios can be envisaged. One where the interference is a constantly present in the measurement sequence, i.e. white CW noise, and one where the interference is present in only one of both measurements, due to satellite motion (displacement of the footprint of one of the fan-beam antennas) or discontinuities in the signal of the interferer. This can also be dependent on the measurement techniques used in the scatterometer systems under consideration.

A wind speed of 3 m/s has been identified as the minimum performance criterion for scatterometers. For this wind speed, the amount of back-scattered signal is the smallest and thus is most sensitive to noise or interference. The estimated error that results from this second interference scenario can be described using a parametric value α that has a typical value for fan-beam antennas ($\alpha = 0.7$ dB) and is given as (Recommendation ITU-R SA.1166).

$$\alpha(\text{dB}) = 10 \log\{[N + (I_{s+n}/B_{s+n})] / [N + (I_n/B_n)]\} \tag{7}$$

where:

N: nominal noise floor power density (approximately –201 dB(W/Hz) at the scatterometer receiver input for fan-beam antennas)

B_{s+n}: "signal + noise" measurement bandwidth

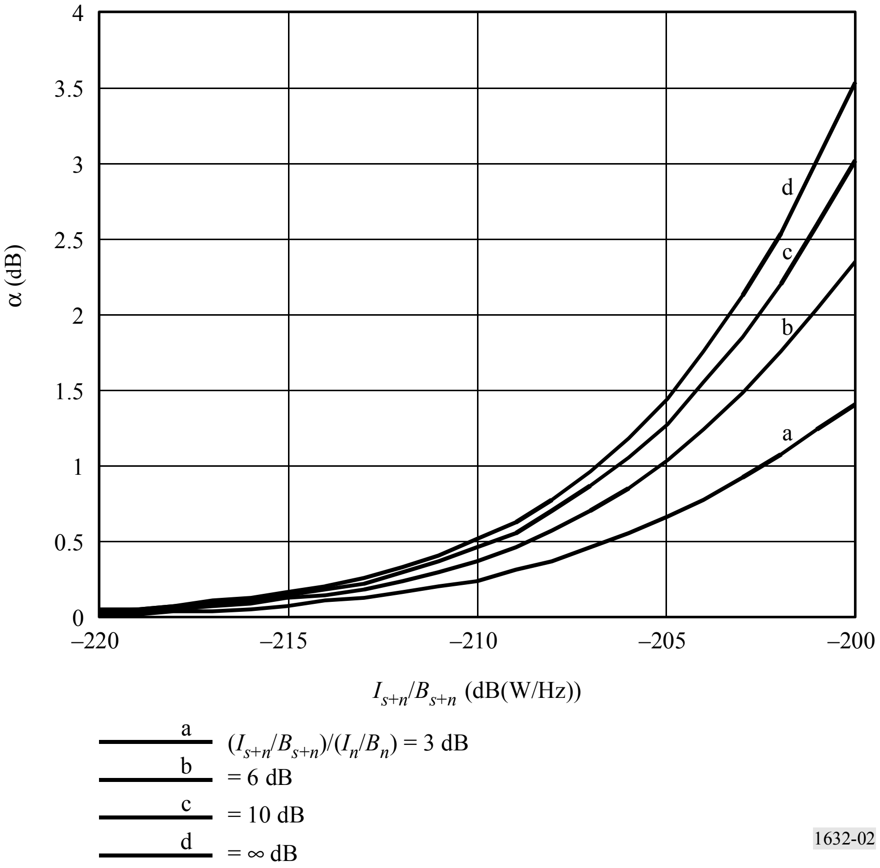
B_n: "noise-only" measurement bandwidth

I_{s+n}: average power from interfering source in B_{s+n} during the "signal + noise" measurement period

I_n: average power from interfering source in B_s during the "noise-only" measurement period.

Figure 2 is a plot of equation (1) for a scatterometer with a receiver noise floor of $N = -201$ dB(W/Hz). It shows α as a function of the power spectral density of the interfering signal I_{s+n}/B_{s+n}. Due to the narrow beamwidth of the fan-beam, changes of several dB in received interference levels should be expected as the scatterometer side lobes move through a transmitter beam. Engineering judgement has led to a value of 6 dB as the assumed maximum expected change in $10 \log [(I_{s+n}/B_{s+n})/(I_n/B_n)]$ during the measurement period. From Fig. 2, it is therefore concluded that the maximum interference power spectral density that any of the fan-beam antennas of the scatterometer can sustain without degraded measurement accuracy is –207 dB(W/Hz).

FIGURE 2



For CW white-noise like interference, the maximum acceptable interference spectral power density would be approximately –195 dB(W/Hz) at the input of the receiver.

The RLAN used in this sharing analysis is the HIPERLAN type 2 standard (parameters given in § 2.2). The most stringent acceptable interference level into the receiver of the scatterometer is –207 dB(W/Hz). For Scatterometer 1, an antenna gain of 31 dBi at 650 km across track distance has been used, which corresponds to a free-space loss of 167.3 dB.

The power received by the scatterometer from one HIPERLAN can be written as:

$$(P_r)\text{dB} = (P_h)\text{dB} - LFS + (G_s)\text{dB} - 3 \tag{8}$$

From this we obtain a value for P_r of –149.3 dB over a 16 MHz bandwidth, which corresponds to –221.3 dB(W/Hz). This gives a 14.3 dB margin. From this can be concluded that the interference from one HIPERLAN/2 into the receiver of a scatterometer does not cause harmful interference. Furthermore, as shown in Table 12, scatterometers are compatible with high density RLAN deployments, in particular when RLANs are deployed indoor.

TABLE 12

Permissible active HIPERLAN/2 capacity shared with Scatterometer 1

Sort of deployment	Outdoor only	Indoor only	Mixed (15% outdoor)
Transmitted power (dBW)	–10	–10	–10
Free space loss (dB)	–167.3	–167.3	–167.3
Antenna gain, receiver (dBi)	31	31	31
Polarization loss (dB)	–3	–3	–3
Additional path loss (dB)	0	–17	–7.8
Power received (dB(W/channel))	–149.3	–166.3	–157.1
Power received (dB(W/Hz))	–221.3	–238.3	–229.1
Scatterometer interference threshold	–207	–207	–207
Margin (dB/Hz)	14.3	31.3	22.1
Active/passive ratio (5%)	13	13	13
Permissible total of active + passive RLANs/km^2 (dB)	27.3	44.3	35.1

5.2 Interference from scatterometers into RLANs

In this case we consider interference from Scatterometer 1 into HIPERLAN type 2. Since this type of RLAN has dynamic frequency selection and the fact that the bandwidth of the scatterometer is relatively small, the scenario given here will only consider one of the side lobes of the scatterometer into one HIPERLAN. The peak power for this scatterometer system is 4.8 kW and again a side lobe value of 26 dBi has been used for this analysis.

The power received by one HIPERLAN from Scatterometer 1 is approximately –106.5 dB which is above the interference threshold of the HIPERLAN or the so-called minimum useful receiver sensitivity of –115 dB. Additional input or polarization losses have not been taken into account in this analysis, but these values will not change the result dramatically (in the order of a few dB). When the scatterometer flies over, the time a RLAN system is in view of one of the scatterometer's antenna side lobes typically is several seconds. Since this type of scatterometer uses several fanbeam antennas, the total interference time when the satellite passes over could even be around 20 s. As mentioned before, these HIPERLAN type 2 systems use dynamic frequency selection, which permits them to switch to another channel before actually transmitting data. This is therefore considered a useful tool to mitigate the interference problem.

A more proper way to determine the maximum allowable interference level would be to take the *C*/*I* into account, which has to be greater than 15 dB. In case the transmitters are within 50 m of each other (worst-case scenario), this can raise the allowable interference level by 10 dB (–105 dBW instead of –115 dBW). For Scatterometer 1 this analysis gives a positive margin of 1.5 dB for outdoor equipment. Using indoor deployment of RLANs in this analysis would give a better margin (18.5 dB).

TABLE 13

Scatterometer 1 to high speed WLANs

Parameter	Value	dB
Transmitted power (W)	4 800.00	36.81
Transmit path loss (dB)	0.00	0.00
Antenna gain, transmitter (dB)	26.00	26.00
Antenna gain, receiver (dB)	0.00	0.00
Wavelength (m)	5.65×10^{-2}	–24.96
$(4\pi)^{-2}$	6.33×10^{-3}	–21.98
Distance (km)	1 314.03	–122.37
Bandwidth reduction (dB)	0.00	0.00
Power received (dBW)		–106.50
HIPERLANs interference threshold		–115.00
Margin (dB) (outdoor)		–8.50
Building attenuation (dB)		17
Margin (dB) (indoor)		8.50

5.3 Conclusion

It is concluded that scatterometer operation around 5.3 GHz is compatible with RLANs in the same band. It is foreseen that in the operation of scatterometers, they do not get substantial interference from RLANs. For the interference from scatterometers into RLANs the study indicates that sharing is feasible for the indoor use of RLANs. It is noted that some RLANs with the characteristics of the HIPERLAN type 2 standard are planned to be equipped with DFS, i.e. dynamic frequency selection. These systems will have a lower chance of getting interference from scatterometer systems when operated outdoor.

6 Global conclusions about compatibility

From the sharing analysis contained in this Recommendation for typical spaceborne active sensors operating in the band 5 250-5 350 MHz and high speed WLANs proposed to be deployed in the same band, it could be globally concluded that the two services are compatible given certain RLAN characteristics:

– Indoor deployment (giving an attenuation of 17 dB with respect to outdoor systems).

– Mean e.i.r.p.[2] limit of 200 mW (or 100 mW if TPC is not used) and mean e.i.r.p. density limit of 10 mW in any 1 MHz band.

– TPC function to ensure a mitigation factor of at least 3 dB.

– Randomized channel selection function such as DFS function associated with the channel selection mechanism required to provide a uniform spread of the loading of the WLAN channels across the whole bandwidth available in the 5 GHz range (the assumptions made in the study for a total of 330 MHz give a density of 440 transmitters over a 20 MHz channel in the SAR footprint).

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[2] The mean e.i.r.p. refers to the e.i.r.p. averaged over the transmission burst at the highest power control setting.