European Radiocommunications Committee (ERC)
within the European Conference of Postal and Telecommunications Administrations (CEPT)

COMPATIBILITY STUDIES RELATED TO THE POSSIBLE EXTENSION BAND FOR HIPERLAN AT 5 GHz

Menton, May 1999

Executive Summary

In 1996 ERC Decision ERC/DEC/(96)03 designated the frequency band 5150 – 5250 for HIPERLANs conforming to ETS 300 652. The conditions for the use of the band by HIPERLANs are set out in CEPT/ERC/REC 70-03 Annex 3. Furthermore CEPT Recommendation T/R 22-06 designates the frequency band 5150 – 5250 MHz for HIPERLANs and the band 5250 – 5300 MHz on a national basis. In this recommendation the EIRP of HIPERLANs shall not exceed 0 dBW and the equipment is intended to be used indoors.

Due to new applications including multi-media, wireless ATM and Internet as well as new uses, including possible broadband access to UMTS networks and services, the ETSI project on Broadband Radio Access Networks (BRAN) requested the European Radiocommunications Committee (ERC) to study the possibility of extending the currently designated band.

PT SE24/SE24H carried out compatibility studies in the frequency range 5250 – 5875 MHz in order to identify a possible extension band for HIPERLANs based on the estimated data rate requirement from ETSI BRAN project. Some parameters of HIPERLANs could not be unequivocally determined and in these cases several values of the relevant parameters were used. The study shows that HIPERLANs need 330 MHz from the 5 GHz frequency band. The current designation of spectrum in CEPT countries is 100 MHz, with a further 50 MHz on a national basis.

In order to facilitate uncoordinated band sharing it is proposed that HIPERLANs should be designated additional spectrum beyond the requirement for 330 MHz; such additional spectrum in combination with dynamic frequency selection (DFS) allows HIPERLANs to avoid co-channel operation with incumbent services (e.g. radars, RTTT) without the need for frequency coordination. The additional spectrum provides additional mitigation of interference due to the lower densities of HIPERLANs per channel, this is particularly beneficial in the case of sharing with the satellite services. The DFS process would need to follow some algorithm, which would spread uniformly the loading over all the available channels, it could even be tailored to reduce loading in some more critical areas, if needed. The conclusion on sharing between HIPERLANs and terrestrial services will only be valid provided DFS has been carefully specified, tested and proved efficient.

WG SE indicates that BRAN should implement a protocol of power control for up and downlink and to define it in the standards: this will have a major impact in reducing the interference into other services.

A summary of the results of the studies can be seen in **Annex 1** and overleaf is shown an extract of the table that summarises the results of the study:

<table>
<tr><th>Frequency band (MHz)</th><th>CEPT allocation</th><th>Requirements for possible HIPERLAN use</th></tr>
<tr><td>5250 – 5255</td><td>RADIOLOCATION
EESS (active)
SPACE RESEARCH</td><td rowspan="2">Sharing is feasible with restrictions – see Note 1</td></tr>
<tr><td>5255 – 5350</td><td>RADIOLOCATION
EESS (active)
SPACE RESEARCH (active)</td></tr>
<tr><td>5350 – 5450</td><td>AERONAUTICAL RADIONAVIGATION
EESS (active)</td><td rowspan="3">Sharing is not feasible</td></tr>
<tr><td>5450 – 5460</td><td>AERONAUTICAL RADIONAVIGATION
EESS (active)</td></tr>
<tr><td>5460 – 5470</td><td>RADIONAVIGATION
S5.449 AERONAUTICAL: (Annex 1)</td></tr>
<tr><td>5470 – 5650

5600 – 5650</td><td>MARITIME RADIONAVIGATION

S5.452 METEROLOGICAL RADARS</td><td rowspan="2">1 W EIRP
Indoor and Outdoor use
Dynamic Frequency Selection</td></tr>
<tr><td>5650 – 5725</td><td>RADIOLOCATION</td></tr>
<tr><td>5725 – 5850

5795 – 5805</td><td>FSS (E-to-S)
RADIOLOCATION
RTTT</td><td rowspan="2">Sharing is feasible with restrictions – see Note 1</td></tr>
<tr><td>5850 – 5875</td><td>FIXED
FSS (E-to-S)
MOBILE</td></tr>
</table>

Table 0.1: Summary of the results

Note 1: As far as the satellite services (EESS in the band 5250-5350 MHz and FSS in the band 5725-5875 MHz) are concerned, the sharing feasibility depends on the number of channels which can be identified for HIPERLANs (the higher the number of channels the easier is the sharing). If the total required amount of spectrum (i.e. 330 MHz) can be identified, sharing between HIPERLAN and satellite services is feasible under the following conditions:

- HIPERLANs are limited to **indoor use;**
- The power is limited to an **EIRP of 200 mW** (The power here refers to the EIRP averaged over the transmission burst at the highest power control setting);
- **Transmitter power control** shall be defined in the ETSI standard to ensure a mitigation factor of at least 3 dB on the average output power of the devices under the coverage area of a satellite.
- **Dynamic Frequency Selection** is to be used.

These conditions are sufficient provided that the DFS process is capable to ensure the uniform spreading of the loading over all the available channels. If this cannot be ensured, more spectrum or a reduction in power is needed .

Compatibility with short range devices were not studied in detail due to the difficulty to predict the possible applications which could be developed in future, however problems are only expected where these devices are operated in close proximity.

The amateur service, which operates on a secondary basis, was not studied.

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COMPATIBILITY STUDIES RELATED TO THE POSSIBLE EXTENSION BAND FOR HIPERLAN AT 5 GHz

1 INTRODUCTION

In 1996 ERC Decision ERC/DEC/(96)03 designated the frequency band 5150 – 5250 for HIPERLANs conforming to ETS 300 652. The conditions for the use of HIPERLANs are set out in CEPT/ERC/REC 70-03 Annex 3. Furthermore CEPT Recommendation T/R 22-06 designates the frequency band 5150 – 5250 MHz for HIPERLANs and the band 5250 – 5300 MHz for use on a national basis. In this recommendation the EIRP of HIPERLANs shall not exceed 0 dBW and equipment is intended to be used indoors.

Due to new applications including multi-media, wireless ATM and Internet and possible broadband access to UMTS networks and services, the ETSI project on Broadband Radio Access Networks (BRAN) requested the ERC to study the possibility of extending the currently designated band.

PT SE24H was tasked to carry out compatibility studies related to the request for additional spectrum for HIPERLANs. The terms of reference for SE24H stated that the study shall contain a technical analysis of the need to use the 5 GHz frequency band, identification of the current services in the band 5250 – 5875 MHz and an estimate of the sharing feasibility between each service and HIPERLANs. Finally, SE24H should identify possible frequency bands as extension bands for HIPERLANs.

While this study was going on in PT SE24H, other studies in PT SE28 showed that there could be a sharing problem in the current HIPERLAN band (5.15 – 5.25 GHz) between HIPERLANs and MSS feeder links. The outcome of SE28 ERC Report 67 should also be taken into account when considering additional spectrum for HIPERLANs.

This study gives an overview of HIPERLANs and their expected data rate and spectrum requirements. For the interference calculations information on propagation aspects was required, especially indoor to outdoor propagation effects. The propagation figures used in the report as well as some HIPERLAN parameters were discussed in great detail and the values used are the figures most accepted by different bodies. If there was no agreed figure, calculations were carried out with different figures to show the range of the results.

In the beginning of the compatibility studies, all of the existing studies were reviewed. When there was new information, especially about HIPERLANs, the studies were modified accordingly. New studies were carried out between HIPERLANs and Road Transport and Traffic Telematics (RTTT) and between HIPERLANs and the fixed satellite service (FSS). General (i.e. non-specific) short range devices operating according to CEPT/ERC/REC 70-03 E were also considered. Sharing studies were not carried out with the radio amateur services, which operates on a secondary basis, nor with the fixed service (FS) because of the very limited use of the FS in this frequency band.

The studies which have not been published elsewhere are annexed to this report.

2 OVERVIEW OF HIPERLANs

2.1 Summary of HIPERLANs

The increasing demand for ‘anywhere, anytime’ communications and the merging of voice, video and data communications create a demand for broadband wireless networks. ETSI created the BRAN project to develop standards and specifications for broadband radio access networks that cover a wide range of applications and are intended for different frequency bands. This range of applications covers systems for licensed and licence exempt use.

The categories of systems covered by the BRAN project are summarised as follows:

HIPERLAN/1 provides high speed (24 Mb/s typical data rate) radio local area network communications that are compatible with wired LANs based on Ethernet and Token ring standards ISO 8802.3 and ISO 8802.5. Restricted user mobility is supported within the local service area only. The technical specification for HIPERLAN/1, ETS 300 652, was published by ETSI in 1997.

HIPERLAN/2 provides high speed (25 Mb/s typical data rate) communications between portable computing devices and broadband ATM and IP networks and is capable of supporting multi-media applications. The typical operating environment is indoors. Restricted user mobility is supported within the local service area; wide area mobility (e.g. roaming) may be supported by standards outside the scope of the BRAN project. A new type of use has emerged recently: HIPERLAN/2 as a possible access network for UMTS. In this type of use HIPERLANs would be used both indoors and outdoors, and would be controlled by a licensed network operator. This new requirement increases the need for a spectrum designation that allows outdoor use by at least a part of the HIPERLAN devices.

Hiperlan/2 is a centrally controlled system. This means that all communication is made between a central point, called the Access Point, and the mobile terminals.

For the purposes of this report, HIPERLAN/1 and HIPERLAN/2 are treated as basically the same except for one difference: HIPERLAN/1 uses a special modulation during the Low Bit rate part of its transmission that leads to an apparent increase in the emitted power spectral density of about 6 dB in a 1.4 MHz bandwidth.

HIPERACCESS, previously known as HIPERLAN Type 3, provides outdoor, high speed (25 Mb/s typical data rate) fixed radio access to customer premises and is capable of supporting multi-media applications (other technologies such as HIPERLAN/2 might be used for distribution within the premises). HIPERACCESS will allow an operator to rapidly roll out a wide area broadband access network to provide connections to residential households and small businesses. HIPERACCESS can be operated in either licensed or licence exempted spectrum. The BRAN project is not considering the use of HIPERACCESS in the 5 GHz band.

HIPERLINK, previously known as HIPERLAN Type 4 provides very high speed (up to 155 Mb/s data rate) radio links for static interconnections and is capable of multi-media applications; a typical use is the interconnection of HIPERACCESS networks and/or HIPERLAN access points into a fully wireless network. It should be noted that for HIPERLINK the intended operation frequency is 17 GHz. HIPERLINK is outside of the scope of this report.

This document is only concerned with spectrum considerations relating to HIPERLANs in the 5 GHz range.

2.2 Standardisation Schedule

Broadband radio access networks will be needed in the early years of the next century, so time is short. The BRAN project is saving time by focusing only on those elements which need to be standardised for radio access, looking to bodies like ETSI System Protocols and Signalling (ETSI SPS), the ATM Forum and Internet Engineering Task Force (IETF) to help to define the overall system. The objective is to develop standards for the data link control and physical layers, and the interworking functions which are needed to fit them in to existing network models. The project schedule is shown below.

Table of deliverables		
Standard	**Deliverable**	**Date**
HIPERLAN/1	**Functional Specifications EN 300 652** **Test Specifications ETS 300 836**	**April 1997** **April 1998**
HIPERLAN/2	**Functional Specifications** **Test Specifications**	**June 1999** **January 2000**

Table 2.1: The schedule of the BRAN project

2.3 International Co-operation

A number of international bodies work on similar subjects– including the Japanese Multi-Media Mobile Access Communications Promotion Council (MMAC), IEEE 802.11 and WIN Forum (US). BRAN co-operates with these bodies. The objective is to reduce the number of separate standards for broadband systems as much as possible and to facilitate common world-wide spectrum designations. Regulatory authorities also co-operate with these industry groups.

3 SPECTRUM REQUIREMENTS

The data rate requirements and the interference potential in a large office environment determine the spectrum requirement. A designation of one frequency band or a few closely spaced frequency bands for all types of HIPERLANs would allow flexible sharing of the available spectrum according to local demand. ETSI should develop the required access procedures for such sharing.

The following analysis is based on the analysis of new applications and the impact of new telecommunications technologies as given in ETSI Technical Report 101-031. This work is undergoing review within ETSI in order to incorporate the demands and use of broadband access to the Internet. However, the spectrum requirement is not expected to be significantly affected in terms of the required capacity. Nevertheless, the increasing interest in using HIPERLANs as broadband access to UMTS networks and services makes outdoor use – and spectrum that allows outdoor use – necessary.

The calculations do not distinguish between the different types of HIPERLAN. Instead it proceeds from user and application requirements to derive the amount of spectrum needed, taking into account the technical parameters that determine the required interference distances.

3.1 Data Rate Requirement

In the ETSI Technical Report on HIPERLAN, TR 101 031, three different deployment scenarios are envisaged:

1. Office HIPERLAN deployment scenario covering applications such as multimedia conference, asymmetric video, telephone, Internet browsing, teleworking, etc.
2. Industrial HIPERLAN deployment scenarios including Gatelink, manufacturing applications and industrial monitoring.
3. Other HIPERLAN deployment scenarios (e.g. high quality audio and video access and distribution, database services, etc.).

A summary of the data rate requirements based on the example deployments listed is given in **Table 3.1**. The table is obtained from the above mentioned ETSI Technical Report and it contains reasonable assumptions for the numbers of HIPERLAN terminals that could exist in each deployment scenario and shows how the total data rate is calculated in each case. The table also includes factors for the efficiency of the network protocol (e.g. TCP/IP) and for the protocol efficiency of the air interface that takes into account the signalling traffic generated by the HIPERLAN link level protocol. The 'network access duty cycle' in **Table 3.1** refers to the time people actually use their systems to access the network. It is noted that this factor is different from the 'transmit/silent time ratio' used in interference calculations.

Deployment example:	**Average data rate required per HIPERLAN**	**Number of HIPERLANs per deployment**	**Network access duty cycle**	**Useful data rate required per deployment**	**Network protocol overhead**	**HIPERLAN protocol efficiency**	**Total data rate required per deployment**
	bits/s/HIPERLAN		%	bits/s/deployment	%	%	bits/s/deployment
	D_u	N_h	A_u	$D_u*N_h*A_u$	P_a	P_e	$D_u*N_h*A_u/(P_a*P_e)$
Office	1.1438E+06	1200	10%	1.3725E+08	65%	50%	4.2232E+08
Industrial	2.2920E+05	250	100%	5.7301E+07	65%	50%	1.8909E+08
Other	1.2693E+05	60	100%	7.6156E+06	65%	50%	2.5131E+07

Table 3.1: Summary of data rate requirements for HIPERLANs.

3.2 Spectrum Requirement

The spectrum requirement is based on the data rate requirements during the busy hour in **Table 3.1** for a large office area with an access to the wired network. The large office environment is considered to represent the upper limit for the spectrum need.

Total area:	100 m * 120 m = 12000 m^2
No. of users:	1200 (1 user/10 m^2)
Total data rate:	422 Mbit/s
Modulation efficiency[1]:	1 bit/s/Hz (includes coding)
Channel bandwidth:	23.5 MHz
No. of access points:	422 / 23.5 = 18
Access point spacing:	$\sqrt{12000m^2/18} = 26$ m, range (d_0) is then 13 m

Interference distance d:

$$C/I = 3.5*10\lg\left(d/d_0\right) \Leftrightarrow d = d_0 * 10^{\left(\frac{C/I}{35}\right)} = 49m \qquad (3.1)$$

where: C/I = 20 dB
d_o = 13 m
3.5 = propagation exponent at 5 GHz [2)]

No. of channels needed: $49^2/13^2 = 14$

The total spectrum requirement: **14 * 23.5 MHz = 330 MHz**

Notes:
1) The modulation efficiency is assumed to be 1 bit/s/Hz, which is considered as achievable for different modulation and channel coding schemes specified for HIPERLANs.
2) The propagation exponent 3.5 is based on the work of ETSI RES 10 and the BRAN project.
3) The bandwidth used in the calculations in this report is the HIPERLAN/1 value of 23.5 MHz.

The ERC Decision ERC/DEC/(96)03 designates 100 MHz for HIPERLANs and CEPT/ERC/REC 70-03 E (and CEPT Recommendation T/R 22-06) recommends the designation of another 50 MHz for HIPERLANs on a national basis. If these frequency bands are available, a further 180 MHz extension band is needed to fulfil the HIPERLAN requirements.

In another study (SE24H(98)11) the spectrum requirement was further investigated. System level simulations were performed and the results are very similar to the calculations above. It was shown that, in an office environment, at least 12 channels are needed to achieve an acceptable C/I level in 95% of the coverage area. It was also stated that in open space areas, such as exhibition halls, as many as 16 channels are needed (i.e. 377 MHz), due to severe line of sight interference. Furthermore, the study showed that if separate frequency bands are to be used, these bands should be as close as possible to each other due to reasons of implementation and performance.

3.3 The need for 5 GHz spectrum

The ERC has designated the frequency band 17.1-17.3 GHz for HIPERLANs in CEPT Recommendations T/R 22-06 and CEPT/ERC/REC 70-03, and CEPT Recommendation T/R 22-03 further provisionally designates a band for RLANs in general at 60 GHz. Due to the following reasons these bands cannot fulfil the needs of the BRAN request and additional spectrum around 5 GHz is needed:

- The 17 GHz frequency band is suitable for fixed point-to-point communication when directional antennas can be used to obtain adequate coverage. The spectrum requirement in chapter 3.2 is for portable HIPERLANs with omni directional antennas and the 5 GHz frequency bands have suitable propagation conditions for this use;

- The cost of the radio frequency technology goes up rapidly with increasing operating frequency;
- The power consumption of radio devices goes up with increasing frequency and this mitigates against the use of higher frequencies in portable, battery driven devices;
- The current allocation for HIPERLANs is in the 5 GHz band. Since the practically achievable tuning range for portable applications is limited to a few hundred MHz, additional spectrum in the 5 GHz band is preferable over spectrum elsewhere;
- A common, world-wide frequency designation for HIPERLANs would facilitate world-wide circulation of equipment. The FCC in the US has designated 300 MHz in the frequency bands 5150 - 5350 MHz and 5725 - 5825 MHz for HIPERLAN-like systems, the technical specifications of those systems are, however, different from HIPERLAN. Japan is considering the designation of frequencies for a HIPERLAN-like system in the 5 GHz band.

3.4 Sharing of spectrum between HIPERLAN/1 and HIPERLAN/2

The industrial and office HIPERLAN deployment scenarios foresee many equipment of different types close to each other in the same office building or plants. The uncoordinated use of the spectral resource will lead to situations where different types of HIPERLANs located in the same area have to operate on the same spectrum.

HIPERLAN/1 and HIPERLAN/2 are designed with different access protocols which are incompatible and do not allow co-channel sharing between co-located systems. This does not imply that some parts of the band cannot be shared by two different systems because it is unlikely that in real deployment the two systems are always co-located. Co-channel operation will normally be avoided by the DFS mechanism in HIPERLAN/2.

At the time of this study there is no prediction available of the relative market shares of the different types of HIPERLAN operating in the 5 GHz band. Even if relative market shares could be projected, they could be applied only to large scale deployment and not to local conditions which could be significantly different from the large scale statistics. Band sharing based on fixed allocations of channels to different HIPERLAN types is therefore likely to be inefficient in most cases.

HIPERLANs operate on defined RF channels. This allows automatic sharing of the available spectrum since each HIPERLAN system can ‘search’ for the least occupied channel among those available. Such a mechanism is considered as necessary for licence exempt systems that are intended for uncoordinated deployment by users in close proximity. A similar approach (e.g. DFS) can be used to facilitate sharing with some other services (DECT is an example of a system designed for automatic frequency sharing, but its dynamic channel allocation (DCA) mechanism may not be applicable to HIPERLANs due to protocol differences).

A generic channel access procedure should be developed to allow different types of HIPERLAN to co-exist in the same frequency band.

3.5 Facilities for selective use of frequency bands

BRAN proposes that the indoor use limitation could be satisfied by:

- Portable HIPERLAN devices, capable of operating on 'indoor only' frequencies, will only operate at the frequency channels on which they receive the transmissions of access points.
- There will be no restrictions or markings put on portable devices and implementations.
- HIPERLAN Access Points capable of operating on the 'indoor-only' frequencies only will be labeled “for indoor use only”.
- HIPERLAN Access Points capable of operation on both indoor and outdoor frequencies shall be labeled “If used outdoors, this device must be specifically configured”. The method of configuration shall be left to the manufacturer and clearly explained in the instructions. The configuration will ensure that frequencies reserved for indoor use, are not used outdoors.

The original HIPERLAN spectrum designation included a part of spectrum the use of which was left to national discretion. In order to support the free movement of portable equipment like HIPERLAN devices between countries with different national regulations, it is necessary to provide a mechanism that assures that these nationally controlled frequencies are used only when allowed. Already ETSI has developed such a mechanism for HIPERLAN/1 similar to the indoor use restriction described above and a similar mechanism could be developed for HIPERLAN/2.

4 PROPAGATION ASPECTS

This section outlines the propagation models, which were used to conduct the various compatibility studies. As described below, two different approaches were used and the choice depended on the type of system for which the sharing study was being performed:

Model A - used to estimate the average building attenuation between an individual HIPERLAN with specified parameters and another individual, generally ground-based system (e.g. RTTT equipment). A building attenuation figure of 13.4 dB is used for the Model A scenarios;

Model B - used to estimate the average additional pathloss (with respect to free-space propagation) between HIPERLANs and spaceborne systems with a large footprint (e.g. satellite systems) where the aggregate effect of the power from a large number of HIPERLAN devices is important rather than the power levels from an individual device. A range of values of 10 to 20 dB is used for the additional pathloss in these scenarios, depending on the system under consideration.

Both the models are concerned only with the additional pathloss with respect to free-space propagation and deal mainly with effects such as building attenuation and interbuilding screening. Beyond relatively local effects such as these, it is assumed that free-space propagation occurs. The longer distance propagation of microwave frequencies can improve during certain meteorological conditions (e.g. temperature inversion) which give rise to effects such as ducting. Conversely rain and fog will cause increased signal attenuation. However, the overall potential effect of these additional - and very complex - aspects (which also vary on a daily and seasonal basis) has not been considered in the models used here.

Model <u>A: Propagation aspects relevant to terrestrial systems</u>

In this case, it is assumed that free-space propagation occurs outside buildings. Therefore, it considers the worst case sharing situation of another system operating in the immediate vicinity of a building containing HIPERLANs. Within buildings it is assumed that additional pathloss arises due to the penetration losses through building materials and the multipath environment. Therefore, for indoor HIPERLANs an additional average pathloss estimated at 13.4 dB is used in the compatibility calculations. This additional 13.4 dB is made up of two components:

- average penetration loss at the external wall/window;
- average additional pathloss due to penetration losses at internal walls and a higher decay index (i.e. greater than 2) created by the multipath, non-line-of-sight environment.

This figure is based on specific working assumptions for building materials and layouts which are detailed in **Annex 2**. Case A is applicable to the compatibility studies for RTTT, radar, Fixed Service and some Amateur systems.

Model <u>B: Propagation aspects relevant to spaceborne systems</u>

This section looks at the average additional pathloss (with respect to free space) which would be associated with a large number of HIPERLAN devices found in various different environments and viewed from a spaceborne platform. The additional pathloss is due to building shielding effects - i.e. material penetration losses and indoor propagation multipath effects - and to the screening of outdoor signals by surrounding buildings (i.e. building clutter) and terrain and foliage (i.e. terrain clutter). The values of these additional pathloss factors are dependent on the angle of elevation between the HIPERLANs and the system of interest for the compatibility study (e.g. satellite network). An average combined figure for these additional pathloss factors is obtained by integrating the values for different elevation angles across the field of view of the system of interest. Different pathloss values are associated with different systems owing to the different altitudes, locations, beam widths, etc. of the systems. Furthermore, ranges of loss values arise from the assumptions made about typical building materials, building layouts and typical urban construction.

For Fixed-Satellite Service (FSS) systems which have large footprints - encompassing Europe, for example - a continental average pathloss has to be used which also takes into account the likely distibution of HIPERLANs between city and rural environments. In the FSS compatibility studies a range of 10 - 20 dB was chosen as representing a range of plausible values for the additional path loss which represents good working assumptions . SE24H has examined a number of studies for this sharing case and concluded that to derive a single figure from this type of very complex and scenario dependant methodology is impractical.

For Earth Exploration-Satellite Service (EESS) altimeters, the relatively small effective area visible to the satellite is seen at a few degrees off the vertical. In this case only the roof/ceiling building attenuation is taken into account, leading to a figure of 20 dB for the additional pathloss.

For EESS synthetic aperture radar (SAR) systems, the relatively small area of visible at any one time lies between the elevation angles of about 30-70 degrees which correspond to different levels of building shielding and other screening effects. The range of elevation angles for SARs is time dependent due to instrument scanning. In order to simplify the analysis and presentation a value of 17 dB is used for the additional pathloss in the EESS SAR compatibility studies. It is to be noted, however, that for the SAR study as in the FSS case, the analysis of the pathloss can lead to a large range of plausible values similar to the FSS range (i.e. 10 - 20 dB); although in the SAR case the range is not only due to the propagation model assumptions but also to the time dependency of the elevation angle.

5 HIPERLAN PARAMETERS AND DEPLOYMENT SCENARIOS

5.1 Technical Parameters

This section gives the main technical parameters for HIPERLAN/1 and HIPERLAN/2. The parameters are from the available specifications. However, in the case of HIPERLAN/2 the specifications are still in development at ETSI and assumptions have been made.

HIPERLAN/1 Parameters (ref: EN 300 652)

Transmit power (high bit rate (HBR), in 23.5 MHz, low bit rate (LBR), in 1.4MHz):

	class A: 10 dBm max EIRP
	class B: 20 dBm max EIRP
	class C: 30 dBm max EIRP
Antenna directivity:	typically omni-directional
Minimum Useful Rx 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
Radio access:	modified listen before talk
Packet length/duration:	992 bits < x < 19844 bits / 42 µs to 851 µs

HIPERLAN/2 Parameters (assumed)

Transmit power:	30 dBm max EIRP
	Dynamic transmit power management
Antenna directivity:	typically omni-directional
Required Rx sensitivity	-70 dBm
Receiver noise power (23.5MHz):	-90 dBm
C/I for BER 10^{-3}:	20 dB[1]
Effective range:	50 m
Radio access:	TDD/TDMA

In this report the effective range and radio access are not used in the studies, but are provided for information.

[1] The advanced technology developed in the ACTS Magic WAND requires 25dB.This means that the value of 20dB might be considered an optimistic value.

5.2 Deployment scenarios

The correspondence between the propagation models and the sharing scenarios for which HIPERLAN compatibility studies have been performed is given in **Table 5.1**.

Scenario	EESS	Radar	FSS	RTTT	FS
A		Applied		Applied	Applied
B	Applied		Applied		

Table 5.1: Relationship between propagation models and the studied systems

HIPERLAN/1 and HIPERLAN/2

Average transmit power HIPERLAN/1	23 dBm (45% class A and B, 10% class C equipment)
Average transmit power HIPERLAN/2	dynamic power control
Low bit rate transmission (LBR):	10.6 % of transmission time (HIPERLAN/1)
Environment:	1…15 % outdoors*
Typical antenna height:	1.5 m
Transmit/silent ratio:	average 5%**

*) The calculations were carried out with 1% and 15 % outdoor usage values to represent two different scenarios.

**) The figure of 5% for the transmit to silent time ratio typical of HIPERLAN devices was provided by ETSI ERM.

However, EP BRAN argued that, on the basis of heavy utilisation scenarios as provided by the EP BRAN project, 1% would be more plausible as a large scale average whereas the 5% figure may be relevant as a local "hot spot" value.

6 COMPATIBILITY STUDIES IN THE BAND 5250 - 5875 MHz

A summary of the services in the 5 GHz frequency range and the conclusions of the compatibility study are in **Annex 1**. The following services and systems are covered within this study:

6.1 Earth Exploration-Satellite Service (EESS) and Space Research Service
6.2 Radars
6.3 Radio Amateurs
6.4 Road Transport and Traffic Telematics (RTTT)
6.5 Fixed-Satellite Service (FSS)
6.6 Fixed Service and Electronic News Gathering/Outside Broadcast (ENG/OB).
6.7 General (non-specific) short range devices

6.1 EESS and Space Research

Background

Following WRC-97, the Earth Exploration-Satellite (active) service has world-wide primary allocations in the bands from 5250 - 5460 MHz. There have been various types of EESS instruments in use within these allocations since 1991: spacebourne radar altimeters; synthetic aperture radars (SARs) and scatterometers, the main use is for SAR.

Within the frequency range under consideration for additional spectrum for HIPERLAN, these bands are of great interest. The band 5250 - 5300 MHz has already been designated as an extension band for HIPERLAN, on a national basis, by ERC Recommendations T/R 22-06, CEPT/ERC/REC 70-03 E, and is identified within ERC/DEC/(96)03 in the considerings. There could be an advantage in identifying spectrum adjacent to the existing allocations from an equipment design point of view.

This band is the most widely used band for the SAR. This use goes beyond scientific and technological development. With all weather imaging capability it is recognised that the instruments operating around 5 GHz are important for public, commercial and tactical services such as cartography, agriculture, hydrology, disaster management, meteorology, environmental monitoring, geology, mineralogy, urban planning, navigation through ice, tactical reconnaissance and many others.

The decision at WRC-97 to upgrade this service to primary status and extend the allocation to allow wider bandwidth operation, in line with European proposals, allows an increased spatial resolution and continuity of data availability.

Methodology

SE24H examined various existing studies related to compatibility of the EESS (active) service with HIPERLANs, mainly done in preparation for WRC-97 in connection with the proposals to modify the allocations around 5.3 GHz. Two categories of sensor were considered: Spaceborne Radar Altimeters, which provide measurements mainly over oceans (and are isolated from land-based HIPERLANs); and the more common Synthetic Aperture Radar/Scatterometer, which provides measurements over land and sea. The results of these studies were then developed further to take account of current knowledge of the systems concerned.

Spaceborne Radar Altimeters

1. Interference from HIPERLANs into altimeters:

For this analysis, we consider one HIPERLAN 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 EIRP (P_hG_h) is 30 dBm. The altimeter antenna gain (G_o) is 32.5 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 meters. 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. $G_a = G_o$) is:

$$P_r = \frac{P_h G_h G_a \lambda^2}{(4\pi)^2 R^2} L \qquad (6.1)$$

From this we obtain a value for P_r of -108 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 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 per square kilometre 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.

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 $G_a = G_o (\mathrm{Sin}(\varphi)/\varphi)^2$, 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 was then computed: the mean power acceptable by the altimeter is -60 dBm/m^2, or 0 dBm/km^2.

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 30% of devices are outdoors at a given time - giving an additional attenuation factor of 5.1 dB. For both cases it is assumed that 5% of HIPERLANs will be transmitting at once.

We then obtain a range from 0.065 (outdoor use) to 1.002 (indoor use) HIPERLANs installed per square kilometre as a limit not to interfere into the altimeter. Extra margins remain in the fact that no polarisation loss or additional propagation losses have been taken into account.

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.

2. Interference from altimeters into HIPERLANs:

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, hence a reduction factor of 11.34 dB is obtained.

The altimeter transmitted power P_a is 40 Watts, at the output of the power amplifier.
The altimeter antenna gain G_a is 32.5 dB, with 1 dB output losses L.
The HIPERLAN antenna gain G_h towards the vertical direction is 0 dB.
The interference threshold of HIPERLANs is -94 dBm in the worst case, i.e. the most sensitive case.

The power received by one HIPERLAN from the altimeter is:

$$P_r = \frac{P_a G_a G_h \lambda^2}{(4\pi)^2 R^2 B_a} B_h L \qquad (6.2)$$

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 1344 km, outdoor HIPERLAN), -103.34 dBm.

This case (altimeter main beam into HIPERLAN sidelobes 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 9 dB; it is therefore concluded that the altimeter will not interfere into HIPERLANs. Furthermore the altimeter is a pulsed radar; the low duty cycle, polarisation and additional propagation losses, which provide additional margins, have not been taken into account.

It is concluded that radar altimeter operation with a 320 MHz bandwidth around 5.3 GHz is compatible with HIPERLANs. It is noted that the lower limit of the radar operation is 5.15 GHz, the conclusion of this study is therefore also relevant to the existing HIPERLAN band.

Synthetic Aperture Radars/Scatterometers

SE24H examined existing studies related to SAR compatibility:

- document SF15-48/D ‘Preliminary sharing study between HIPERLANs and the Earth Exploration-Satellite service in the 5250 - 5350 MHz band’ prepared by the UK Radiocommunications Agency and presented to the SFCG-15 meeting in Bangalore;
- document SE30(96)20 ‘Sharing between Type 1 HIPERLANs and the Earth Exploration-Satellite Service in the 5250 - 5350 MHz band’ (this study develops the study previously mentioned using more up to date characteristics, originally for the studies in SE30); and,
- document ITU-R 7-8R/91-E ‘Analysis of potential interference to spaceborne SARs from wireless high speed local area networks around 5.3 GHz’ a US contribution to ITU-R Study Group 7.

Document SF15-48/D was a preliminary study carried out before completion of either the ETSI standard for HIPERLAN or the definition of the SAR and scatterometer characteristics and interference criteria within ITU-R Joint Working Party 7-8R. The study considers an estimated population of HIPERLANs operating within the half power bandwidth (HPBW) area of two types of sensor, SAR and scatterometer, carried on the ERS-1 satellite. In the case of the SAR the HPBW equates to a ground area of 671 km^2, in the case of the scatterometer this area is 30,000 km^2; the study does not take account of the effect of HIPERLANs operating outside this ‘footprint’. Using the assumed parameters available at that time, the study produces results in terms of the maximum area within which HIPERLANs can be operated at maximum system capacity. The conclusion of the study, for both types of instrument, was that there is good potential for sharing, but there could be difficulties if large numbers of Class A HIPERLANs (0 dBW EIRP) were operating.

In the case of the SAR/scatterometer interfering with HIPERLAN, the study initially considers the worst case scenario of a HIPERLAN located outdoors, in the boresight of the sensor and with the whole bandwidth of the transmission within the receive bandwidth of the HIPERLAN; in this case the possibility for sharing is poor. However, taking account of the pulsed nature of the sensor transmission and the probability of visibility of the satellite, the sharing potential is considered to be good.

Document SE30(96)20 develops earlier studies using the interference criteria for the EESS (active) sensors developed within ITU-R Study Group 7, in terms of interference within the HPBW of the sensor and interference to an SAR resolution pixel. The methodology for the HPBW scenario is basically the same as used in document SE24(98)28, but the results are presented in terms of the percentage of the HPBW area usable at full HIPERLAN system capacity (which in this case is taken as 500 Mbits/Hectare). The analysis of the interference to an individual SAR resolution pixel is based on information supplied by ESA to SE30. Using this method the interference to the SAR can be characterised by the number of degraded pixels; however, it is stated in the study that it does not take into account the permissible outage times for the sensor, i.e. interference levels can be exceeded for less than 1% of the images of the sensor coverage area and the results of the analysis at pixel level are therefore more pessimistic than the HPBW method. However, SE24H notes that the allowance could already be used to facilitate sharing with other primary services, as described later in this report.

Document ITU-R 7-8R/91-E is a study carried out by the United States of America using information on wireless high speed LANs taken from the FCC Report and Order FCC 97-7 and information on HIPERLANs presented to ITU-R JWP 7-8R. This study derives maximum densities of wireless high speed LAN equipment, and also considers a maximum density of operational LANs (outdoors) limited by self-interference, which is significantly lower. A revised version of this document, produced after the WRC-97, was also considered by SE24H; this study includes static and dynamic analysis, and consideration of interference to HIPERLANs.

The studies referenced above were carried out in preparation for WRC-97 in connection with the proposals to modify the EESS (active) allocations. The conclusion contained in the CPM report (chapter 5.5.2.4.2) reads:

> *".... based on the assumed characteristics of the wireless high speed local area networks (i.e., an eirp of -6dBW toward the sensor, a 1% activity factor and 1% of the transmitters outdoor) spaceborne SARs can operate in the presence of emissions from planned wireless high speed local area networks......This conclusion is based on the parameters used in the analysis. Other values could lead to a different conclusion...."*

SE24H agreed that although the subject had been extensively studied, most results were either inconclusive, depended on various assumptions, or both. It was felt that the parameters used in the studies could be updated with the benefit of current knowledge, particularly for HIPERLAN deployment scenarios and other factors, for example:

- The building shielding loss used in all of these studies is 20 dB. However, for this study it is appropriate to take account of the recent work on building shielding loss, including MSS/HIPERLAN studies in SE28: as outlined in section 4, an additional attenuation figure of 17 dB will be assumed for the additional pathloss for indoor HIPERLANs;
- The outdoor use should be 1% where there is a restriction to indoor use only;
- The outdoor use should be 15% where outdoor use is permitted;
- The transmit/silent ratio should be 5%;
- The studies should take account of the range of power outputs of HIPERLANs.

It must be remembered that the EESS (active) service is already sharing these bands with other primary services. When considering the outage criteria for the sensors, allowance must be made for any interference already caused by other services, principally radiolocation, before any allowance can be made for interference due to HIPERLAN. For the purposes of this work it is assumed that the allowance is used to enable sharing between the primary services, and is not taken into account for the HIPERLAN case.

Using a range of values as indicated above, the following analysis considers the compatibility with four types of SAR:

PARAMETER	VALUE			
	SAR1	**SAR2**	**SAR3**	**SAR4**
Orbital Altitude	426 km (circular)	600 km (circular)	400 km (circular)	400 km (circular)
Orbital Inclination	57 deg	57 deg	57 deg	57 deg
RF Centre Frequency	5305 MHz	5305 MHz	5305 MHz	5300 MHz
Peak Radiated power	4.8 Watts	4800 Watts	1700 Watts	1700 Watts
Polarisation	Horizontal (HH)	Horizontal & Vertical (HH,HV,VH,VV)	Horizontal & Vertical (HH,HV,VH,VV)	Horizontal & Vertical (HH,HV,VH,VV)
Pulse Modulation	Linear FM chirp	Linear FM chirp	Linear FM chirp	Linear FM chirp
Pulse Bandwidth	8.5 MHz	310 MHz	310 MHz	40 MHz
Pulse Duration	100 µs	31 µs	33 µs	33 µs
Pulse Repetition Rate	650 pps	4492 pps	1395 pps	1395 pps
Duty Cycle	6.5 %	13.9 %	5.9 %	5.9 %
Range Compression Ratio	850	9610	10230	1320
Antenna Type	Planar phased array 0.5m x 16.0m	Planar phased array 1.8m x 3.8m	Planar phased array 0.7m x 12.0m	Planar phased array 0.7m x 12.0m
Antenna Peak Gain	42.2 dBi	42.9 dBi	42.7/38 dBi (full focus/beamspoiling)	42.7/38 dBi (full focus/beamspoiling)
Antenna Median Sidelobe Gain	-5 dBi	-5 dBi	-5 dBi	-5 dBi
Antenna Orientation	30 deg from nadir	20-38 deg from nadir	20-55 deg from nadir	20-55 deg from nadir
Antenna Half-power Beamwidth	8.5 deg (El), 0.25 deg (Az)	1.7 deg (El), 0.78 deg (Az)	4.9/18.0 deg (El), 0.25 deg (Az)	4.9/18.0 deg (El), 0.25 deg (Az)
Antenna Polarization	Linear horizontal/vertical	Linear horizontal/vertical	Linear horizontal/vertical	Linear horizontal/vertical
System Noise Temperature	550 K	550 K	550 K	550 K
Receiver front end 1 dB compression point ref to receiver input	-62 dBW input	-62 dBW 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	-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	+7 dBW	+7 dBW
Operating time	30 % of the orbit	30 % of the orbit	30 % of the orbit	30 % of the orbit
Minimum Time for Imaging	9 sec	15 sec	15 sec	15 sec
Service Area	land masses & coastal areas	land masses & coastal areas	land masses & coastal areas	land masses & coastal areas
Image swath width	50 km	20 km	16 km/ 320 km	16 km/ 320 km

Table 6.1: Typical spaceborne Imaging Radar Characteristics at 5.3 GHz

<u>Performance and Interference Criteria for the spaceborne SAR:</u>

For both the SAR imaging missions and the topographic missions, a minimum signal-to-noise ratio (SNR) is defined, below which the radar image pixels, and/or differential phase measurements are unacceptably degraded. The following interference criteria are from ITU-R JWP 7-8R:

– the degradation of the normalised standard deviation of power received from a pixel should be less than 10% in the presence of interference;
– the aggregate interference power-to-noise power ratio (corresponding to a pixel SNR of 0 dB) should be less than -6 dB;
– These levels may be exceeded upon consideration of the interference mitigation effect of SAR processing discrimination and the modulation characteristics of the radiolocation/ radionavigation systems operating in the band;
– The maximum allowable interference level should not be exceeded for more than 1% of the images in the sensor service area for systematic occurrences of interference and should not be exceeded for more than 5% of the images in the sensor service area for random occurrences of interference.

The data loss criteria have been fully utilised to achieve sharing with the radiodetermination service. This study therefore uses the degradation interference criteria to derive the sharing constraints on HIPERLANS. Assuming that the interfering signal distribution is white Gaussian noise the maximum acceptable interference signal is indicated in the table below:

Signal Type	**Input Power dBW**			
	SAR1	**SAR2**	**SAR3**	**SAR4**
Noise (dBW)	-129.5	-113.8	-113.8	-122.7
Minimum Desired Signal (dBW)	-189.7	-198.6	-187.1	-187.0
Maximum Acceptable Interfering signal (dBW)	-135.5	-119.8	-119.8	-128.7
Receiver Bandwidth (MHz)	9.8	356.5	356.5	46
Maximum Acceptable Interfering spectral power density (dBW/Hz)	-205.4	-205.4	-205.4	-205.4

Table 6.2: Typical 5.3 GHz SAR input/output signal characteristics

PARAMETER	VALUE			
	SAR1	**SAR2**	**SAR3**	**SAR4**
Ground Illumination Area	93 km (elevation), 2.2 km (azimuth)	At 20° from nadir: 20 km (elevation), 8.7 km (azimuth)	At 20° from nadir: 40 km (elevation) 2 km (azimuth)	At 20° from nadir: 40 km (elevation) 2 km (azimuth)

Table 6.3: Calculated ground illumination area of SAR 1 to 4

The SAR1 has the more stringent requirements, although the differences are not large, and so this type is considered in the following assessment.

Parameter / HIPERLAN type	**Class B** **Value**	 **dB**	**Class C** **Value**	 **dB**	**250 mW** **Value**	 **dB**
Transmitted Power, Watts	0.1	-10	1	0	0.25	-6
Distance (km) and Free space loss	491.9	-160.8	491.9	-160.8	491.9	-160.8
Additional Transmit Path Loss, dB Case i (combined building attenuation proportion of 1% outdoor use) Case ii		-15.3		-15.3		 -17
Antenna Gain, Transmitter, dB		0		0		0
Antenna Gain, Receiver, dB		42.2		42.2		42.2
Polarization Loss, dB		-3		-3		-3
Power received, dBW/Hz **Case i** **Case ii**		**-220.1** **-**		**-210.1** **-**		 **-218.4**
SAR Interference threshold (I/N=-6dB), dBW/Hz		**-205.36**		**-205.36**		**-205.36**
Margin , dB/Hz **i** **ii**		**14.74**		**4.74**		 **13**
SAR antenna footprint, sq km	181.5	22.59	181.5	22.59	181.5	22.59
Active/passive ratio Case i and ii	5%	13	5%	13	1%*	20
Permissible HIPERLAN density (/ sq.km /ch) **i** **ii**	**3.27**	5.15	**0.33**	-4.85	 **11.0**	 10.4
Maximum number of HIPERLAN within the SAR footprint assuming a restriction to indoor use only **i** **ii**	**8,316**		**831**		 **27,951***	
Additional transmit path loss, dB for 15% outdoor use **i**		-6.5 dB		-6.5 dB		
Maximum number of HIPERLAN within the SAR footprint with outdoor use permitted **i**	**943**		**94**			

Table 6.4: Permissible active HIPERLAN capacity in channels shared with SAR1

Case i: 17 dB Building Shielding Loss

Case ii: 20 dB Building Shielding Loss / 1% Outdoor use (original figures used in the ITU-R studies, for comparison purposes)*Note: case ii uses a transmit/silent ratio of 1% as used in the ITU-R studies for comparison purposes, this result (i.e. 27,951) was accepted as showing that sharing was feasible in the European preparations for WRC-97.

It should be noted that the maximum density given does not take account of the characteristics of the sensor antenna, the effects of power summation of the HIPERLANs or the contribution from HIPERLANs outside the sensor footprint. However, these factors would tend to cancel each other to some extent and so the result is seen as a reasonable estimate, particularly in view of the uncertainty over the HIPERLAN operational scenarios.

Considering the most difficult case, Class C HIPERLANs, produces a density of 0.33 HIPERLANs/km^2 /ch, or 94 (outdoor use permitted) or 831 (indoor use only) in the footprint of the SAR assuming 14 channels as described in section 3.2. This can be compared, unfavourably, to the scenarios given in section 3.2 of 1200 users for an office, 250 for an industrial unit and 60 for a studio. The previously considered parameters, where sharing was considered feasible, are shown for comparison purposes as 250 mW power and case iii parameters; these give a figure of 27,951 HIPERLANs in the sensor footprint. Taking account of the 5% transmit/silent ratio and using the 17 dB building shielding loss leads to a restriction to 25 mW to achieve the same conclusion.

It should be noted that the distribution of HIPERLANs follows the distribution of people and is therefore concentrated in urban and industrial areas. Here, the permissible number of HIPERLANs/ km^2 will be exceeded for many image pixels. In rural areas this is not the case since the number of HIPERLANs / km^2 is typically less than 0.05 / km^2 (assuming 5% of all HIPERLANs are operated in 90% of the surface area of Europe). Further, the use of HIPERLANs will typically follow the human activity cycle – most of it will be concentrated during the working day hours.

Space Research

Based on information supplied by ESA, the requirements for protection of the EESS are sufficient to also protect the space research service. Therefore this service has not been studied in detail.

Conclusion

The results of the studies show that whilst sharing is considered to be feasible under certain conditions (99% indoor use, 20 dB Building attenuation, 1% active/passive ratio, 250 mW power), significantly exceeding these values indicates that significant satellite image corruption would result, notably in urban and industrial areas primarily during business hours.

SE24H proposes limiting HIPERLANs to indoor use with an EIRP[2] of 200 mW, taking account of the additional mitigation assuming:

- Transmitter power control shall be defined in the ETSI standard to ensure a mitigation factor of at least 3 dB on the average output power of the devices under the coverage area of a satellite.
- Dynamic Frequency Selection is to be used.

It should also be noted that it is only proposed to introduce HIPERLANs in a proportion of the total EESS bandwidth.

In order to simplify the analysis and presentation a figure of 17 dB is used for the additional pathloss in the EESS SAR compatibility studies. It is to be noted, however, that for the SAR study as in the FSS case, the analysis of the pathloss can lead to a large range of plausible values similar to the FSS range (i.e. 10 - 20 dB).

6.2 Radars

Background

This section of the report examines the prospects of co-channel sharing between radar systems and HIPERLANs operating in frequency bands around 5 GHz. These radar systems include terrestrial, aeronautical, maritime and meteorological radars for civil and military use.

The above subject was investigated and documented in ERC Report 15 which was approved in October 1992. At the time very little was known about the parameters for HIPERLANs (referred to as RLANs in Report 15) being proposed for the bands around 5 GHz. Although these parameters are known now from the current specifications the main conclusion of the report remains the same: due to the high EIRP of the radar systems, co-channel sharing is feasible only beyond the radio horizon. It has to be noted that Report 15 only deals with the possibility of interference from radars into RLANs and this is probably the reason why no parameters are given on the maximum level of interfering power tolerable by radar receivers. NATO indicated a requirement for protection in terms of I/N of -6 dB, in line with the assumptions on radars in current ITU-R studies. This section of the report explains that HIPERLANs are capable of avoiding the channel used by radar and consequently allowing interference to be avoided.

[2] The power here refers to the EIRP averaged over the transmission burst at the highest power control setting

Methodology

The method used to calculate the potential interference to HIPERLANs is based on the Minimum Coupling Loss (MCL) required between radars and HIPERLANs as described in ERC Report 15 (1992) and the separation distances were calculated with the free space propagation model. Only interference from radars to HIPERLANs was analysed in that report due to the limited information available on radar receivers at that time. The methodology is recalled here:

Interference from radars into HIPERLANs

The method used to calculate the potential interference to HIPERLANs is based on the Minimum Coupling Loss required between radars and HIPERLANs as described in ERC Report 15 (1992) with:

$$MCL=P_{tr}+10\ \log\{BW_{Hip}/Bw_{radar}\} - I_{rec}$$

where

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

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

$$L= MCL + G_{tr} - L_{tr} + G_{rec} - L_{rec}$$

where

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

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

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

where λ is the wavelength given in metres.

PARAMETER	VALUE
Maximum eirp	30 dBm
Antenna gain	0 dBi
Channel Bandwidth (BW_{Hip})	23.5 MHz
Maximum Tolerable Interference (I_{rec})	-120 dBW/23.5 MHz
Required C/I	20 dB
Receiver Threshold	-70 dBm

Table 6.5: HIPERLAN parameters for use in sharing calculations

Radar type	A	B	C	D	E	F
Peak EIRP	98,6 dBW	26 dBW	60 dBW	93 dBW	97 dBW	50 dBW
Emission	3M00PON	15M5PON AN	30M00PON	14M00PON	3M00PON	N/A
Bandwidth (Bw_{radar})	3 MHz	15 MHz	30 MHz	14 MHz	3 MHz	
PRF	300 pps	1200-1300pps	160-1650 pps	2-3000pps	300 pps	
Pulse With	5 µs	0,5-1 µs	0,25-1 µs	0,25 µs	2 µs	
Antenna gain	40 dBi	0 dBi	46 dBi	43 dBi	43 dBi	
Tuning range (MHz)	5300-5600	5700-5800	5400-5820	5250-5850	5600-5650	
Use	Transportable long range	Airborne	Fixed long range	Transportable multi-function	Fixed long range	Airborne
Operational or training	both	operational	Operational	both	operational	Operational
MCL (Db)	178.6	146	132	170	174	143
Gain + feeder loss (dBi)	40	0	46	43	43	27
Propagation loss (dB)	218	146	178	213	217	170
Propagation loss less shielding of 13.4 dB (dB)	204.6	132.6	164.6	199.6	203.6	156.6
Distance d (km) f=5,5 GHz	74 069	19	741	41 652	66 014	295
Distance to radio horizon (km)[1)]	51.4	346.6	51.4	51.4	51.4	346.6
Resulting separation distance	**51.4 km**	**19 km**	**51.4 km**	**51.4 km**	**51.4 km**	**295 km**

Table 6.6: Required distance separations for HIPERLAN sharing with various radar systems using the methodology from ERC Report 15.

[1)] See ERC Report 15, ITU-R Rec. M. 1313

As can be seen from **Table 6.6** the determining factor is the radio horizon of the radars – its range is far below the calculated interference distances. Slight changes in parameters of either systems will not affect the results.

High RF power level emitted by radar systems (Type A,C,D,E) will create a de facto exclusion zone within which HIPERLANs would not operate satisfactorily on a co-channel basis. A determining factor is the radio horizon of the radars – its range is far below the calculated interference distances. Slight changes in parameters of either systems will not affect the results.

It should be noted that meteorological radars (Type E) are typically installed on high buildings and the operation is a three dimensional scanning of the sky, therefore main beam interference is less likely.

2. Interference from HIPERLANs into RADARs

The high RF power level emitted by a typical radar system will create a de facto exclusion zone within which HIPERLANs would not operate satisfactorily on a co-channel basis.

The horizon of the radars would be relevant for HIPERLANs working on a co-channel basis. In reality, HIPERLANs use DFS. This implies that it is likely that a Hiperlan device/cell will be able to avoid the channels used by a radar. In this case the likelihood of interference between the two systems is significantly reduced. This would also protect mobile radars, if an appropriate DFS mechanism is applied (i.e. regular check of the channel, many times per hour, taking into account the characteristics of radar system).

In this case it is recommended that HIPERLANs should only be introduced in the bands shared by radars if the HIPERLANs are capable of detecting and avoiding the presence of a strong interferer.
A basic calculation of interference to radars is shown in the table below. This calculation assumes a noise figure of 5 dB. This is backed up by information provided by the US (SE24H(98)35), also a building shielding loss of 13.4 dB is taken into account.

The calculations show that separations up to 625 km are needed to ensure that a HIPERLAN operating at saturation does not exceed an I/N ratio of -6 dB into the main beam of a radar signal.

Radar types	Type A	Type B	Type C	Type D	Type E	Type F	HIPERLAN
Tx Output Power W							1.0
Tx Output Power (dBW)							0.0
Tx / Rx Antenna Gain (dB)	40.0	0.0	46.0	43.0	43.0		0.0
EIRP dBW	98.6	26.0	60.0	93.0	97.0	50.0	0.0
Tx / Rx Antenna Height (m)							
Opening angle (deg)							
Occupied Bandwidth (MHz)	3.0	15.0	30.00	14.0	3.0		
Rx bandwidth (MHz)	3.0	15.0	30.00	14.0	3.0		23.5
Rx noise factor (dB)	5.0	5.0	5.0	5.0	5.0		
Noise (dBW)	-134.2	-127.2	-124.2	-127.5	-134.2		
Minimum I/N (dB)	-6.0	-6.0	-6.0	-6.0	-6.0		
On-tune rejection	-8.9	-1.9	0.0	-2.2	-8.9		
Maximum Interference dBW	-131.3	-131.3	-130.2	-131.3	-131.3		
Free-space interference range (km)	354.2	3.5	625.4	500.3	500.3		
Frequency (MHz)	5562.5	= (5250+5875)/2					
Distance to geostationary orbit (km)	38400.0						
Thermal noise (dBW/Hz)	-204.0						
Shielding loss (dB)	13.4						

Table 6.7: Calculation of interference from HIPERLANs to Radars

Conclusions

Referring to **Table 6.6** (Required distance separations for HIPERLAN sharing with various radar systems using the methodology from ERC Report 15), the minimum tolerable separation distances between HIPERLANs and all types of radar assessed are well beyond the radio horizon except the case of interference from type B and F (aeronautical) radars to HIPERLANs, where the radio horizon is 346.6 km and the separation distances are 19 km and 295 km respectively. Beyond the radio horizon the interference caused is assumed to drop off very rapidly. However, this gives the worst case view of the sharing possibilities. In practice there are many mitigating factors which can improve the situation significantly. For instance terrain attenuation is not taken into account. **Table 6.7** (Calculation of interference from HIPERLANs to Radars) provides detailed results which show separation distances between 3.5 km (type B) and 625 km (type C).

There was no information available about the radar densities although it was noted that radar density has a significant influence on the feasibility of sharing, as does the nature of the radar i.e., whether it is fixed or transportable.

The final conclusions of the sharing study are presented in **Table 6.8.** The following principles were used in reaching the conclusions:

- Ground based radar are protected by the implementation of DFS, which ensures that HIPERLANs will change channel and will not interfere with the radar receiver;
- HIPERLAN can operate in the radar band if the density of radars is low enough, provided that sufficient spectrum is available;
- The feasibility of sharing with meterological radars would be dependent on the density of these devices, and any decision to allow HIPERLANs to use this band would have to take account of the future plans for radar deployment;

- Concerning Maritime radars in the band 5470-5600 MHz, it is noted that ITU-R Rec. M. 629, in its considering (d), indicates that "Only a small number of these types of radars operate in the band 5470-5650 MHz". Moreover HIPERLANs are not likely to be deployed in the same geographical environment as those radars. This implies a situation particularly favourable for sharing;
- It is understood by SE24H that Aeronautical Radionavigation might request particular protection for safety reasons, and, even if the sharing would seem possible from the technical point of view, it is preferable to avoid the bands allocated to this kind of service.

In conclusion, it is proposed that HIPERLANs implement DFS which together with the provision of sufficient spectrum will ensure there are no problems for their coexistence with radars (excluding aeronautical radars).

Frequency band (MHz)	CEPT allocation	Feasibility of sharing
5250 – 5255	RADIOLOCATION	Yes
5255 – 5350	RADIOLOCATION	Yes
5350 – 5450	AERONAUTICAL RADIONAVIGATION	No
5450 – 5460	AERONAUTICALRADIONAVIGATION	No
5460 – 5470	RADIONAVIGATION S5.449 AERONAUTICAL (Annex 1)	No
5470 – 5650 5600 - 5650	MARITIME RADIONAVIGATION S5.452 METEROLOGICAL RADARS	Yes
5650 – 5725	RADIOLOCATION	Yes
5725 – 5850	RADIOLOCATION	Yes

Table 6.8: Conclusions on the compatibility between radars and HIPERLANs

6.3 Amateur Services

The frequency band 5650 – 5850 MHz is allocated to the radio amateur services on a secondary basis. While noting that the amateur satellite service uplink band is 5650 – 5668 MHz, SE24H has concentrated on studies related to the primary services and has not studied the amateur service.

6.4 Road Transport and Traffic Telematics (RTTT)

Background

This section summarises the compatibility analysis between Road Transport and Traffic Telematics (RTTT) systems and HIPERLANs operating at frequencies around 5.8 GHz. In CEPT ERC Decision ERC/DEC/(92)02, CEPT has designated spectrum in the band 5795 - 5805 MHz for use by RTTT systems for road to vehicle systems. An extension band 5805-5815 MHz may also be used on a national basis at multi-lane road junctions. The regulatory parameters for RTTT are shown in CEPT Recommendation CEPT/ERC/REC 70-03 E. The RTTT allocation falls within a band which is globally allocated for ISM applications (5725 - 5875 MHz). ETSI has developed standards - specifically EN 300 674 - which define the technical characteristics of RTTT equipment.

Methodology

The Minimum Coupling Loss (MCL) technique has been used to determine the separation distances between HIPERLAN devices and RTTT systems which would be required to avoid interference from one system to the other.

A summary of the analysis results is given in **Table 6.8** below. The analysis considers both indoor and outdoor HIPERLAN devices and terrestrial propagation model A (described in Section 4) is used to provide a figure (13.4 dB) for the building shielding loss. In general the worst case sharing parameters were assumed for the calculations, i.e.:

HIPERLAN/1 systems transmitting at their maximum permissible power;
Co-channel operation of both systems;
No additional antenna gains or feeder losses;
Free-space propagation is assumed, with the addition of building loss where appropriate.

(Further details of the parameters used for the analysis are given in **Annex 3**.)

	Indoor HIPERLANs		Outdoor HIPERLANs	
Systems under consideration:	**Minimum coupling loss (in dB)**	**Required separation distance (in metres)**	**Minimum coupling loss (in dB)**	**Required separation distance (in metres)**
Interference from HIPERLANs to RTTT systems				
HIPERLAN to 10 MHz Bandwidth RTTT Roadside Unit	99.9	406	113.3	1,901
HIPERLAN to 5 MHz Bandwidth RTTT Roadside Unit	96.9	288	110.3	1,344
HIPERLAN to RTTT On-Board Unit	72.9	18	86.3	85
Interference from RTTT systems to HIPERLANs				
RTTT Roadside Unit, Class II to HIPERLAN	115.6	2,480	129	11,601
RTTT Roadside Unit, Class I to HIPERLAN	109.6	1,243	123	5,814
RTTT On-Board Unit to HIPERLAN	62.6	6	76	26

Table 6.9: Separation distances between HIPERLANs and RTTT

HIPERLAN/1 uses a low bit rate mode transmitting short bursts in a 1.4 MHz bandwidth. When these bursts are centered on the RTTT band, the overall interference from HIPERLAN to RTTT is increased by 2.5 dB which increases the separation distances required by a factor of about 1.33.

In the case of interference from HIPERLANs to RTTT systems there are a number of mitigating factors, and the most significant of these factors are outlined below:

- DFS would enable HIPERLANs to avoid the RTTT transmission;
- The calculations have been based on the current maximum permissible EIRP levels for HIPERLANs; if the HIPERLANs used transmitter power control techniques or there were lower power limits then the MCL values would be reduced accordingly. For example, if the HIPERLAN transmit levels were reduced by 6dB from 1 W to 250 mW, then the required separation distances would be halved for the cases considering the interference effect to RTTT units;
- RTTT unit antennas will be circularly polarised thus providing further protection against linearly polarised signals or those with an opposite polarisation to the wanted signal. Figures for cross-polar discrimination of between 6 and 15 dB are quoted for the various RTTT units; but, due to the unpolarised nature of HIPERLAN signals, the level of cross-polar discrimination will not exceed 3dB in practice and will typically be around 1-2 dB;
- Robust coding protocols will be employed in RTTT systems which are designed to withstand interference;

Conclusion

The analysis shows that there may be interference problems between RTTT systems and HIPERLANs deployed in the RTTT allocation of 5795 - 5805 MHz. Of the two systems, the HIPERLAN should be more sensitive to the presence of an RTTT system and hence could avoid using the affected channel(s).

To avoid the effects of interference from RTTT roadside units, outdoor HIPERLANs would need to be separated from them by distances of between 5.8 km and 11.6 km (depending on the class of RTTT unit). The corresponding separation distances for indoor HIPERLANs are 1.2 km to 2.5 km.

When considering the effect of interference from HIPERLANs on the most prone RTTT units, the required separation distances are between 0.4 km (indoor HIPERLANs) and 1.9 km (outdoor HIPERLANs).

Although there are potential interference problems - particularly with outdoor HIPERLANs - sharing may be possible between HIPERLANs and RTTT systems provided that HIPERLANs are required to avoid the RTTT band (5795 - 5805 MHz) if they detect the presence of an RTTT transmission. Given the small band designated to the RTTT systems, it would be expected that, at most, two HIPERLAN channels would coincide with the RTTT allocation and therefore two channels could potentially be unavailable for HIPERLAN systems in the vicinity of RTTT units (e.g. adjacent to busy road junctions).

6.5 Fixed Satellite Service

Background

This section examines the sharing possibilities between HIPERLANs and the Fixed Satellite Service (FSS). The frequency band 5725-6425 MHz has been allocated to FSS for communications in the direction from Earth to space. It has to be noted that the band 5725-5850 MHz has been allocated to FSS in Region 1 only. In this section the risk of interference from HIPERLAN devices into the satellite receiver is evaluated. The calculation has been produced in the case of the French Telecom 3 network, but several other networks have been declared at the ITU, in particular by the Russian administration and by Intelsat.

Methodology

The aim of the calculation is to evaluate the maximum number of HIPERLAN devices that can be deployed, without harmfully affecting the operation of an FSS network. First the maximum allowable interference power to the satellite receiver is determined. The method used to determine the maximum allowable aggregate interference power (seen by satellite) from the HIPERLAN devices to the satellite receiver is based on Appendix S8 of the ITU Radio Regulations. After determining the maximum allowable interference power it is possible to calculate the maximum number of HIPERLAN devices under the satellite footprint.

Calculating the maximum allowable interference power from the HIPERLAN devices into the satellite receiver

Appendix S8 gives the calculation method to determine when co-ordination is required between two FSS networks sharing the same frequency bands. The method of Appendix S8 is based on the concept that the interference power is seen at the receiver as an increase of the equivalent noise temperature of the victim. With reference to the case I of the Appendix S8 (same transmission direction), the co-ordination is not required if

$$\Delta T_{sat}/T_{sat} < 6\ \%, \qquad (6.3)$$

in the case of regenerative satellite networks, and

$$\Delta T_{link}/T_{link} < 6\ \%, \qquad (6.4)$$

in the case of transparent satellite networks.

Where

ΔT_{sat} apparent increase in the receiving system noise temperature of the satellite, caused by an interfering emission

T_{sat} the receiving system noise temperature of the space station

ΔT_{link} apparent increase in the equivalent satellite link noise temperature due to the interfering emission

T_{link} the equivalent satellite link noise temperature

Because Telecom 3 is a transparent satellite network, the equation (6.4) applies. So from the equation (6.4) the maximum allowable increase in the total link noise temperature for avoiding interference without co-ordination can be derived as follows:

$$\Delta T_{link} = T_{link} * 0.06 \quad (6.5)$$

For transparent satellites, the following equation applies:

$$\Delta T_{link} = \Delta Tsat * \gamma + \Delta T_{earth} \quad (6.6)$$

Where,

γ transmission gain of the link,

ΔT_{earth} the apparent increase in the noise temperature of the earth station antenna; in this case this parameter is 0 because HIPERLANs interfere with the satellite at the uplink, but they have no effect on the downlink of the satellite network (no increase in the noise at the earth station).

Appendix S8 also gives the following formula for $\Delta Tsat$:

$$\Delta Tsat = p * G/(k*l) \quad (6.7)$$

Where,

p the power spectral density in W/Hz (the gain of the interferer is taken into account in the mean EIRP of HIPERLANs, see next section)

G satellite antenna gain

k Bolzman constant (1.38e-23 J/K)

l free space path loss

So combining the previous equations we obtain the following formula for maximum allowable interference power spectral density that could be produced by all HIPERLANs:

$$p = 0.06 * (G/T)^{-1} * k * l / \gamma \text{ W/Hz}$$

or in dB

$$p = -12.2 - (G/T) - 228.6 + 20(\log f_{5750\text{ MHz}} + \log d_{36000\text{ km}}) + 32.45 - \gamma$$
$$= -42 - (G/T) - \gamma \text{ dBW/Hz} \quad (6.8)$$

All the satellites in this band are geostationary, so the distance to be used for the calculation for free space path loss is 36000 km in equation 6.8. The frequency used in the calculation for free space path loss is 5750 MHz in equation 6.8.

The nominated bandwidth of HIPERLAN is 23.5 MHz (74 dBHz), so that the total maximum allowable interference power produced by all HIPERLANs within one HIPERLAN channel is:

$$P = 32 - (G/T) - \gamma \text{ dBW} \quad (6.9)$$

Appendix S8 gives the method to calculate the maximum interference power produced by an earth station to a satellite receiver. When calculating the maximum interference power from HIPERLAN devices into a satellite receiver, we have to consider all the HIPERLAN devices under the satellite footprint as a single source. This means that the source is not specifically located and thus some considerations on the mean pointing direction of HIPERLAN antennas are needed. These are included in the next section when dealing with mean EIRP.

Appendix S8 is the only method that has been used for the calculation. This appendix describes a procedure to decide if a co-ordination is necessary between two GSO-FSS networks. The problem is that in the case of HIPERLAN no specific co-ordination is possible due to the licence exempt nature of this service.

Calculating the maximum number of HIPERLAN devices that can be deployed

Knowing the maximum allowable aggregate interference power from the HIPERLAN devices seen by the satellite, we can calculate the maximum number of HIPERLAN devices under the satellite footprint. Taking into account the building attenuation and the percentage of outdoor use, one can calculate the shielding effect L_{se} and the total maximum allowable interference power:

$$P = 32 - (G/T) - \gamma + L_{se} \text{ dBW} \qquad (6.10)$$

Finally, dividing the total maximum interference power (6.10)) by the mean EIRP in the direction of the satellite of one HIPERLAN device we can get the maximum number of HIPERLAN devices that can be active at the same time, without affecting the FSS network. This number can be multiplied by the inverse of the transmit/silent ratio, in order to estimate the maximum allowable number of HIPERLAN devices that can be deployed within the coverage area of the satellite.

When calculating the maximum number of HIPERLAN devices the relevant parameters are the merit factor G/T of the satellite, the transmit/silent ratio of HIPERLANs, the shielding effect and EIRP of HIPERLAN devices. **Table 6.9** below gives the total allowable number of HIPERLANs in the case of the 'Metropole' spot of the French Telecom 3 network with two different figures for the shielding effect and with three different mean EIRP levels for HIPERLAN devices in the direction of HIPERLAN devices.

In the case of Telecom 3 network γ is 0 dB, the total link equivalent noise temperature is 870 K, the gain for the 'Metropole' spot is 34 dBi and the coverage area of this spot is all of Europe.

The mean transmit/silent ratio used in the table is 5%. The building attenuation takes into account the effect due to the shielding of outside buildings, the additional multipath effect and elevation integration. For the shielding factor, including the building attenuation and the percentage of outdoor usage, two cases have been considered:

case i: 20 dB Building attenuation;
case ii: 10 dB Building attenuation;
with a range of outdoor use from 1 to 15%.

The number of HIPERLANs channels is hypothetical and as it is not known at the time of writing this report the use of 14 channels has been chosen for the purposes of this study. It is noted that the limit to be considered for drawing a conclusion at this stage can only be the tolerable number of HIPERLANs per channel.

Because of the statistical nature of the deployment of HIPERLANs, it is difficult to estimate precisely the mean EIRP on a continent of the different types of HIPERLANs taking into account all the factors like gain in the direction of the satellite, effect of power control, percentages of each class of HIPERLAN type 1 and the increase in power spectrum density due to Low Bit Rate transmission mode. Therefore for the purpose of this study three representative figures have been used (100, 250 and 1000 mW). These power levels represent an average EIRP, provided the indoor and outdoor averages are the same in each case.

The following table summarises the results:

	HIP EIRP 100 mW	HIP EIRP 250 mW	HIP EIRP 1 W
Frequency [MHz]	5750	5750	5750
Free-space path loss [dB]	199	199	199
P [dBW/Hz]+G/T[dB/K]	-42.1	-42.1	-42.1
HIPERLAN bandwith [MHz]	23.5	23.5	23.5
P[dBW]+G/T[dB/K]	31.7	31.7	31.7
G/T [dB]	4.6	4.6	4.6
P acceptable [dBW]	27.1	27.1	27.1
NB: Results below are shown as ranges corresponding to 1-15% outdoor use			
Shielding effect [dB] Case i	17.0-8.0	17.0-8.0	17.0-8.0
Shielding effect [dB] Case ii	9.6-6.3	9.6-6.3	9.6-6.3
Aggregate P acceptable [W] Case i	25500-3200	25500-3200	25500-3200
Aggregate P acceptable [W] Case ii	4700-2200	4700-2200	4700-2200
Number of active users Case i	255400-32100	102200-12800	25500-3200
Number of active users Case ii	46600-21600	18700-8700	4700-2200
Transmit/silent ratio [%]	0.05	0.05	0.05
Max number of tolerable HIPERLANs per channel in Europe (i)	**5 108 k-641 k**	**2 043 k-257 k**	**511 k-64 k**
Max number of tolerable HIPERLANs per channel in Europe (ii)	**932 k-433 k**	**373 k-173 k**	**93 k-43 k**
Hypothetical number of channel	14	14	14
Max number of tolerable HIPERLANs for the hypothetical bandwidth in Europe (i)	71.5 M-9.0 M	28.6 M-3.6 M	7.1 M-0.9 M
Max number of tolerable HIPERLANs for the hypothetical bandwidth in Europe (ii)	13.1 M-6.1 M	5.2 M-2.4 M	1.3 M-0.6 M

case i : 20 dB Building attenuation.
case ii : 10 dB Building attenuation.

Table 6.10: Results of the interference calculations between HIPERLANs and FSS

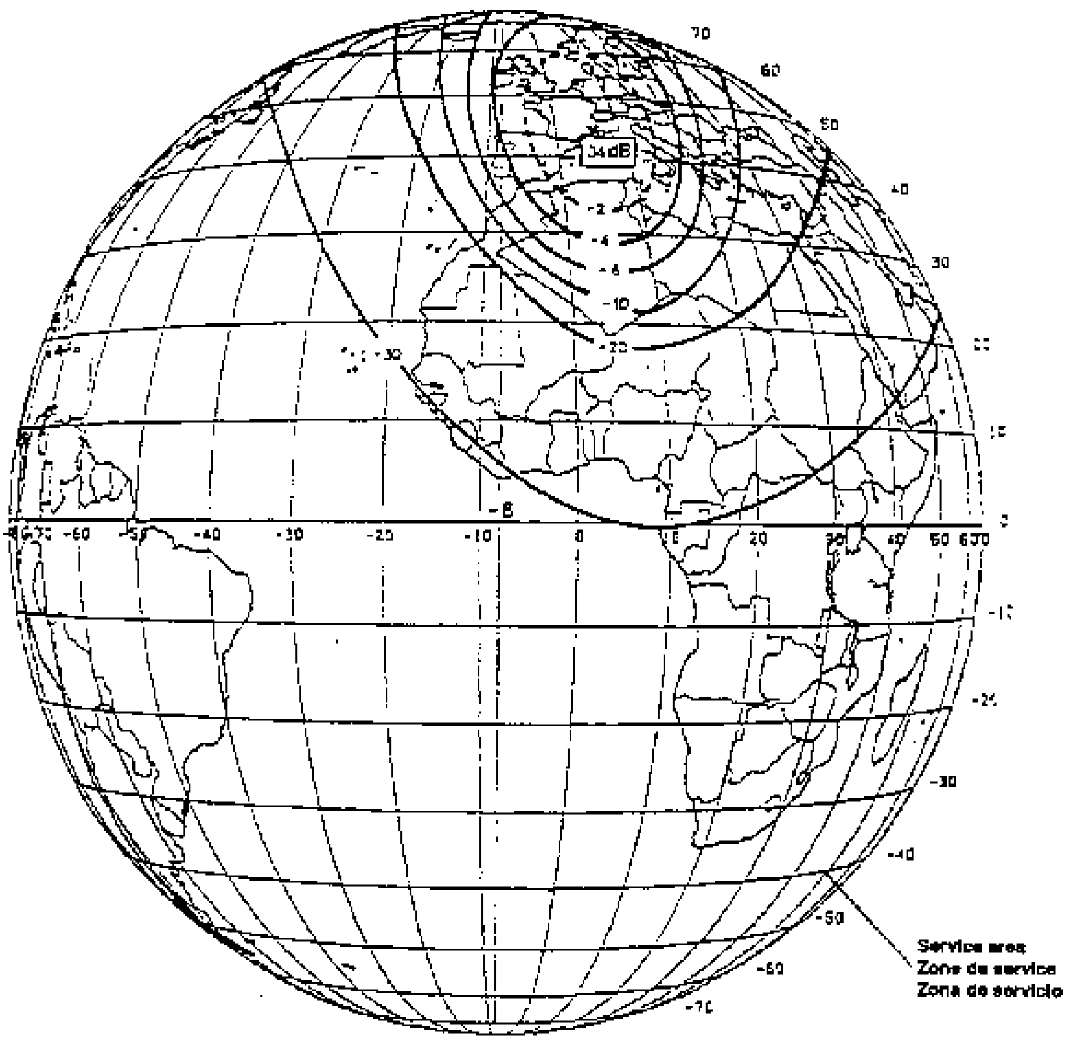

Figure 6.1: Spot Metropole

Conclusion

The results of this part of the study give information on the total allowable number of HIPERLAN devices per HIPERLAN channel over all of Europe which could share with FSS networks.

In the most favourable case studied here corresponding to an average EIRP of 100mW and a percentage of outdoor usage of 1%, a range of 1-5 million devices per channel would be acceptable.

SE24H proposes limiting HIPERLANs to indoor use with an EIRP[3] of 200 mW, taking account of the additional mitigation assuming:

- Transmitter power control shall be defined in the ETSI standard to ensure a mitigation factor of at least 3 dB on the average output power of the devices under the coverage area of a satellite.
- Dynamic Frequency Selection is to be used.

The above calculations have been produced for one FSS network. It is very likely that Telecom 3 is not the only network with such stringent characteristics, and it is possible that other networks could require better protection. Telecom 3 operates also in the band below 5850 MHz (5725-6725 MHz), as do other networks declared mainly by the Russian Federation and by Intelsat. Telecom 3 spot beams covering Region 2 are limited in frequency to the band 5850-6725 MHz because of the differences in the allocation table in Region 1 and 2. This difference is also the reason why in the USA the FCC has allocated the band 5725-5825 MHz to U-NII devices.

6.6 Fixed Services and ENG/OB

Background

Within the frequency range of interest, 5250 MHz to 5875 MHz, there is a primary frequency allocation to the fixed service in the ITU-R Radio Regulations, Article S5 for Region 1 and in the ERC Report 25 Table of European Common Allocations. In both cases the allocation starts at 5850 MHz and extends up to 8500 MHz. However, the majority of fixed service usage is in the range above 5925 MHz, in accordance with the major utilisation as shown in ERC Report 25. A recent survey[4] by the ERO for a study on trends in the fixed service post-1998 supported this view and also identified the following seven Administrations with fixed links operating below 5925 MHz: Austria, Czech Republic, Germany, Ireland, Latvia, Lithuania and Turkey. Of those, only 3 administrations, the Czech Republic, Lithuania and Turkey extend below 5850 MHz. Fixed service channel plans employed are either ITU-R Recommendation F.383 or ERC Recommendation CEPT/ERC/REC 14-01 (with the lower band edge at 5925 MHz). The types of systems deployed include digital systems with capacities in the range 2 to 155 Mbit/s or analogue systems with various channel bandwidths (typically between 20 and 40 MHz).

Key parameters of fixed service systems for use in studies on frequency sharing with other services are contained in ERC Report 40.

Although ENG/OB is now treated by CEPT as being part of the mobile service, for convenience it is considered here. ERC Recommendation CEPT/ERC/REC 25-10 recommends tuning ranges for ENG/OB equipment for use at events in other CEPT countries. It also includes, in Annex 1, limited information on national frequency usage. In the range of interest Austria uses a channel at 5850 MHz, the Netherlands uses 7 channels in the range 5725-5850 MHz, Switzerland uses a channel centred on 5856.25 MHz and the United Kingdom uses frequencies in the range 5472-5815 MHz. Channel bandwidths in use in these countries range between 14 and 20 MHz. When considering compatibility between ENG/OB and HIPERLANs it can be assumed that the majority of ENG/OB transmissions are unidirectional, i.e. from the mobile unit to a central point and the highest probability is that the significant interference problem will be the ENG/OB unit interfering with a HIPERLAN station. On the basis of the available information, use of ENG/OB in the frequency range of interest appears to be fairly limited and this potential interference situation could be alleviated if dynamic channel selection technology is used by HIPERLANs.

Conclusion

Compatibility between HIPERLANs and fixed services or ENG/OB has not been studied in detail. It has been assumed in this report that an allocation to HIPERLANs is unlikely to extend above the upper limit of the ISM allocation, i.e., 5875

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[3] The power here refers to the EIRP averaged over the transmission burst at the highest power control setting
[4] ERO Report "Fixed service trends post 1998", published May 1998

MHz. For fixed service systems based on ITU-R Recommendation F.383 or CEPT/ERC/REC 14-01 the centre frequency of the lowest channel is 5945.2 MHz with the occupied spectrum resulting in an effective guard band of 5.375 MHz above 5925 MHz. Consequently, there is unlikely to be any interference between HIPERLANs and the fixed service.

In the case of co-frequency sharing between ENG/OB and HIPERLANs the use of dynamic channel selection by the latter system should facilitate sharing in the few limited cases likely to arise.

6.7 General (non-specific) short range devices

Background

CEPT Recommendation ERC/REC/70-03 designates the band 5275-5875 MHz to general short range devices with a maximum power output of 25 mW.

Conclusion

A study presented to SE24H shows that there may be compatibility problems between HIPERLANs and SRDs when operated in close proximity, i.e. in the same room, a copy of this study is attached at Annex 4.

It is noted that the HIPERLAN DFS mechanism will improve the compatibility.

Because of the general nature of the SRD designation it is not practical to reach definitive conclusions on the compatibiliy of these devices as it is impossible to predict the nature of future SRD applications.

7 CONCLUSIONS

PT SE24H carried out compatibility studies in the band 5250 – 5875 MHz in order to find a suitable extension band for HIPERLANs. The study contains the verification of the spectrum need for HIPERLANs based on the data rate requirement estimation from the ETSI BRAN project. Some parameters of HIPERLAN could not be unequivocally determined, in these cases several values of the relevant parameter were used. The study shows that HIPERLANs need 330 MHz from the 5 GHz frequency band. The current designation is 100 MHz and a further 50 MHz on a national basis. A summary of the results of the studies can be seen in **Annex 1**. **Table 7.1** is an extract from **Annex 1**.

In order to facilitate uncoordinated band sharing it is proposed that HIPERLANs should be designated additional spectrum beyond the requirement for 330 MHz; such additional spectrum in combination with dynamic frequency selection (DFS) allows HIPERLANs to avoid co-channel operation with incumbent services (e.g. radars, RTTT) without the need for frequency coordination. The additional spectrum provides additional mitigation of interference due to the lower densities of HIPERLANs per channel, this is particularly beneficial in the case of sharing with the satellite services. The DFS process would need to follow some algorithm, which would spread uniformally the loading over all the available channels, it could even be tailored to reduce loading in some more critical areas, if needed. The conclusion on sharing between HIPERLAN and terrestrial services will only be valid provided DFS has been carefully specified, tested and proved efficient.

When developing this report the HIPERLAN industry proposed to distinguish between the mobile terminals and the access points when proposing the different power limits for the different bands. The reason for this being the different nature of these two devices. Access Points will usually be mounted high up on walls or on ceilings, whereas mobile terminals can be located anywhere, e.g. close to a window and in view of a satellite. In particular it was suggested that a certain antenna gain should be allowed (in addition to the proposed power limits), but only on the fixed mounted Access Point. This extra gain would be beneficial for both the uplink and the downlink Hiperlan link budget. And in case power control in the uplink were to become a requirement this allowance could also be beneficial for the incumbent services. The reason being that the mobile terminals could take benefit of the receiver antenna gain in the AP and thus reduce their output power. It was, however, agreed not to adopt this distinction between mobile terminals and Access Points, mainly due to the fact that this proposal was entered into the discussions at a very late stage. This mitigating factor is thus not considered in this report.

Sharing between the EESS and HIPERLANs is considered feasible only with technical and regulatory restrictions to HIPERLAN output power and outdoor use. Sharing is feasible between radar altimeters and HIPERLANs because radar altimeters are used mainly above the sea. The critical application is SAR/scatterometers which can be used anywhere and the SAR/scatterometer data is today used for many scientific and economic purposes. SE24H proposes an EIRP limit of 200 mW, taking account of the additional mitigation provided by the use of power control and assuming an even distribution of HIPERLANs across the whole available spectrum noting the fact that it is only proposed to introduce HIPERLANs in a proportion of the total EESS bandwidth.

Sharing between radars and HIPERLANs is generally feasible, provided that a dynamic frequency selection facility is implemented which ensures that HIPERLANs will detect the presence of a radar system and move to a clear channel. Due to the high powers used radars create an exclusion zone around them which means that the main direction of interference is from radars to HIPERLANs. HIPERLANs can be operated beyond the radio horizon of the radars. Aeronautical radionavigation bands should be avoided due to the large radio horizon distance. Any decision to allow HIPERLANs into the bands used for meteorological radars should take account of the future use of these systems in Europe.

Sharing with the FSS is feasible with HIPERLANs limited to an EIRP of 200 mW and indoor use only. The power limitation is derived from the 100 mW case in the sharing study with a 3 dB increase due to the additional mitigation provided by the use of power control and assuming an even distribution of HIPERLANs across the whole available spectrum.
Sharing with RTTT is possible provided that a dynamic frequency selection facility is implemented which ensures that HIPERLANs will detect the presence of an RTTT system and move to a clear channel.

Compatibility with short range devices were not studied in detail due to the difficulty to predict the possible applications which could be developed in future, However problems are only expected where these devices are operated in close proximity.

The amateur service, which operates on a secondary basis, was not studied.

Frequency band (MHz)	CEPT allocation	Requirements for possible HIPERLAN use
5250 – 5255	RADIOLOCATION EESS (active) SPACE RESEARCH	Sharing is feasible with restrictions – see Note 1
5255 – 5350	RADIOLOCATION EESS (active) SPACE RESEARCH (active)	
5350 – 5450	AERONAUTICAL RADIONAVIGATION EESS (active)	Sharing is not feasible
5450 – 5460	AERONAUTICAL RADIONAVIGATION EESS (active)	
5460 – 5470	RADIONAVIGATION S5.449 AERONAUTICAL: (Annex 1)	
5470 – 5650 5600 – 5650	MARITIME RADIONAVIGATION S5.452 METEROLOGICAL RADARS	1 W EIRP Indoor and Outdoor use Dynamic Frequency Selection
5650 – 5725	RADIOLOCATION	
5725 – 5850 5795 – 5805	FSS (E-to-S) RADIOLOCATION RTTT	Sharing is feasible with restrictions – see Note 1
5850 – 5875	FIXED FSS (E-to-S) MOBILE	

Table 7.1: Summary of the results

Note 1: As far as the satellite services (EESS in the band 5250-5350 MHz and FSS in the band 5725-5875 MHz) are concerned, the sharing feasibility depends on the number of channels which can be identified for HIPERLANs (the higher the number of channels the easier is the sharing). If the total required amount of spectrum (i.e. 330 MHz) can be identified, sharing between HIPERLAN and satellite services is feasible under the following conditions:

- HIPERLANs are limited to **indoor use;**
- The power is limited to an **EIRP of 200 mW** (The power here refers to the EIRP averaged over the transmission burst at the highest power control setting);
- **Transmitter power control** shall be defined in the ETSI standard to ensure a mitigation factor of at least 3 dB on the average output power of the devices under the coverage area of a satellite.
- **Dynamic Frequency Selection** is to be used.

These conditions are sufficient provided that the DFS process is capable to ensure the uniform spreading of the loading over all the available channels. If this cannot be ensured, more spectrum or a reduction in power is needed.

ANNEX 1: SUMMARY TABLE OF FREQUENCY ALLOCATIONS FOR FREQUENCY BAND 5250 - 5875 MHz

Freq. (MHz)	ITU (Radio Regulations, Region 1)	CEPT (European common allocation)	Major Utilisation	National services	Feasibility of sharing
5250 - 5255	EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION SPACE RESEARCH *S5.448: Add. alloc. RADIONAVIGATION, countries list A*	EARTH EXPLORATON-SATELLITE (active) RADIOLOCATION SPACE RESEARCH Mobile (HIPERLAN extension band on national basis) *S5.447D* *S5.448A*	Weapon system radars Shipborne and VTS Radar Ground based and airbourne weather radar Tactical Radar Position Fixing Active Sensors	GER, HUN: 5250 - 5255 civil radars GER, HUN: 5255 - 5350 military radars GER, HUN: Space research	YES 200 mW EIRP indoor HIPERLANs with Dynamic Frequency Selection (DFS) and Power control
5255 - 5350	EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION SPACE RESEARCH (active) *S5.448: Add. alloc. RADIONAVIGATION, countries in list A*	EARTH EXPLORATON-SATELLITE (active) RADIOLOCATION SPACE RESEARCH Mobile (HIPERLAN extension band on national basis) *S5.448A*	Weapon system radars Shipborne and VTS Radar Ground based and airbourne weather radar Tactical Radar Position Fixing Active Sensors		YES 200 mW EIRP indoor HIPERLANs with DFS and power control
5350 - 5460	EARTH EXPLORATION-SATELLITE (active) AERONAUTICAL RADIONAVIGATION S5.449: aeron. to airbone radars and ass. beacons Radiolocation S5.448B	EARTH EXPLORATON-SATELLITE (active) AERONAUTICAL RADIONAVIGATION S5.449 Fixed Radiolocation S5.448B	Weapon system radars Shipborne and VTS Radar Ground based and airbourne weather radar Tactical Radar Position Fixing Active Sensors	GER, HUN: RADIOLOCATION (military)	NO
5450-5460		AERONAUTICAL RADIONAVIGATION S5.449 EARTH EXPLORATON-SATELLITE (active) Radiolocation S5.448B	Weapon system radars Shipborne and VTS Radar Ground based and airbourne weather radar Tactical Radar Position Fixing Active Sensors		NO
5460 - 5470	RADIONAVIGATION S5.449: aeron. to airbone radars and ass. beacons Radiolocation	RADIONAVIGATION S5.449 Radiolocation	Weapon system radars Shipborne and VTS Radar Ground based and airbourne weather radar Tactical Radar Position Fixing Active Sensors	GER, HUN: RADIOLOCATION (military)	NO
5470 - 5650	MARITIME RADIONAVIGATION Radiolocation *S5.450: Ad. alloc. AERONAUTICAL RADIONAVIGATION, countries in list B* *S5.451: Add. alloc. Land mobile service (UK)* *S5.452: METEOROLOGICAL RADARS (equality with maritime radionavigation)*	MARITIME RADIONAVIGATION Radiolocation *S5.452*	Weapon system radars Shipborne and VTS Radar Ground based and airbourne weather radar Tactical Radar	GER: Radioastronomy station UK: 5470 - 5815 ENG/OB links No use of Maritime Radionavigation in Germany	YES, 1 Watt EIRP indoor and outdoor use. DFS and power control Sharing with Met. Radars dependant on the future deployment/density of these systems

Freq. (MHz)	ITU (Radio Regulations, Region 1)	CEPT (European common allocation)		National services	Feasibility of sharing
5650 - 5725	**RADIOLOCATION** Amateur Space Research (deep space) *S5.282: Amateur satellite service (non-interference)* *S5.451: Add. alloc. Land mobile service (UK)* *S5.453: Add. alloc. FIXED and MOBILE (not in CEPT countr.)* *S5.454: SPACE RESEARCH, countries in list C* *S5.455: Add. alloc. FIXED, countries in list D*	RADIOLOCATION Amateur S5.282	Weapon system radars Shipborne and VTS Radar Ground based and airbourne weather radar Tactical Radar Position Fixing Active Sensors	HUN: FIXED SERVICE (military) UK: 5470 - 5815 ENG/OB links	Yes, 1 Watt EIRP indoor and outdoor use. DFS and power control amateur and mobile not studied
5725 - 5830	FIXED SATELLITE (Earth-to-space) RADIOLOCATION Amateur *S5.150: ISM* *S5.451: Add. alloc. Land mobile service (UK)* *S5.453: Add. alloc. FIXED and MOBILE (not in CEPT countr.)* *S5.455: Add. alloc. FIXED, countries in list D* *S5.456: Add. alloc. FIXED (GER, CAM)*	FIXED SATELLITE (Earth-to-space) RADIOLOCATION Amateur Mobile *S5.150*	Non-civil radiolocation Ground based and airbourne weather radar ISM 5725-5875 5795-5805 Road Transport and Traffic Telematic Systems (RTTT) SRDs in 5725-5875 MHz	GER, HUN: 5725 - 5755 military radars GER, HUN: 5755 - 5850 FIXED SERVICE (civil) UK: 5470 - 5815 ENG/OB links	YES 200 mW EIRP indoor HIPERLANs with DFS and power control amateur and mobile not studied
5830 - 5850 *5725 - 5875* *5470 - 5850* *5650 - 5850* *5670 - 5850* *5755 - 5850*	FIXED SATELLITE (Earth-to-space) RADIOLOCATION Amateur Amateur-Satellite (space-to-Earth) *S5.150: ISM* *S5.451: Add. alloc. Land mobile service (UK)* *S5.453: Add. alloc. FIXED and MOBILE (not in CEPT countr.)* *S5.455: Add. alloc. FIXED, countries in list D* *S5.456: Add. alloc. FIXED (GER, CAM)*				
5850 - 5925 *5725 - 5875*	FIXED FIXED SATELLITE (Earth-to-space) MOBILE *S5.150: ISM*	FIXED FIXED SATELLITE (Earth-to-space) MOBILE *S5.150*	Telecommunications satellites from coordinated Earth stations. Priority for civil networks ISM 5725-5875 SRDs in 5725-5875 MHz		YES 200 mW indooor HIPERLANs with DFS and power control fixed and mobile not studied

List A: Austria, Azerbaijan, Bulgaria, Libya, Mongolia, Kyrgyzstan, Slovakia, the Czech Republic, Romania, Turkmenistan, Ukraine

List B: Austria, Azerbaijan, Bulgaria, the Islamic Republic of Iran, Mongolia, Kyrgyzstan, Slovakia, the Czech Republic, Romania, Turkmenistan, Ukraine

List C: Armenia, Azerbaijan, Belarus, Bulgaria, Georgia, Kazakstan, Moldova, Mongolia, Uzbekistan, Kyrgyzstan, Russia, Tajikistan, Turkmenistan, Ukraine

List D: Armenia, Azerbaijan, Belarus, Bulgaria, Cuba, Hungary, Kazakstan, Latvia, Moldova, Mongolia, Uzbekistan, Poland, Kyrgyzstan, Slovakia, Russia, Tajikistan, Turkmenistan, Ukraine

ANNEX 2 SUMMARY OF INDOOR PROPAGATION MEASUREMENTS AT 5GHz

This paper builds on the work presented in the summary report on Building Shielding Loss at 5GHz which was prepared by the Radio Technology and Compatibility Group of the Radiocommunications Agency (Reference 11). The Building Shielding Loss at 5GHz document analysed a number of existing, published papers which provided details of radio propagation measurements made at around 5GHz (both in Europe and USA) - further details of all the reference documents are provided in section 4. This paper includes the results from one further reference document. Section 1 provides the values for the penetration losses through different building materials; section 2 provides a summary of the indoor pathloss results in a uniform format and gives pathloss figures with respect to the free-space propagation values and section 3 suggests typical values for the building shielding loss in different environments and an average building shielding loss figure.

1.) External Building Wall Losses

Reference 2 gives values for the transmission coefficients and penetration losses of a number of different building materials for measurements made at 5.8GHz. Results are given below for some typical interior and exterior materials.

Building material	**Material description (where available)**	**Parallel polarisation**	**Perpendicular polarisation**
Typical interior wall materials			
PVC plate		0.4 dB	0.6 dB
Gypsum plate		0.8 dB	0.7 dB
Plywood	0.4 cm	0.9 dB	0.9 dB
Gypsum wall	13.5 cm - plastered gypsum wall with 1mm maximum thickness of plaster	1.2 dB	3.0 dB
Rough chipboard	1.5 cm	1.3 dB	1.0 dB
Veneer board		2.2 dB	2.0 dB
Glass plate		3.2 dB	2.5 dB
Sound proof door	6.2 cm - multi-layered material, consisting of two layers of veneer containing a layer of sand	3.4 dB	3.6 dB
Typical exterior wall materials			
Double-glazed window	2.0 cm - two standard insulating glass plates with a 12mm air layer	6.9 dB	11.7 dB
Concrete block wall	30.2 cm - reinforced concrete block	11.7 dB	9.9 dB

Using the results above, an average penetration loss of 10 dB would be typical for the exterior walls of buildings with double-glazed windows (assuming a facade with 50% window area and 50% wall material).

For buildings with single-glazed windows, a figure of 5 dB would be typical for the average penetration loss through the exterior wall (again assuming a facade with 50% window area and 50% wall material).

2.) Interior Path Losses

Reference with brief description of measurement environment	Exponential delay index, n *[1]	Additional loss constant, A_r (in dB) *[1]	Typical indoor path loss for 5m separation distance with respect to path loss for 1m separation (in dB) *[2]	Typical indoor path loss in excess of free-space path loss for 5m separation (in dB) *[3]
Ref 3: Delay spread and pathloss measurements made at 5GHz. The building used is of steel framed reinforced concrete construction with exterior curtain walling, breeze block interior walls and concrete floors. Interior furniture included desks, wooden and metal bookshelves and metal filing cabinets.	2.09 (With direct path obstructed by single internal wall.) 4.29 (With direct path obstructed by two internal walls.)	6.5 dB -3.5 dB	21.1 dB 26.5 dB	7.1 dB 12.5 dB
Ref 4: Delay spread and pathloss measurements made at 5GHz. The building used has breeze block interior walls and concrete floors. Interior furniture included desks, wooden and metal bookshelves and metal filing cabinets.	2.50 (For obstructed path measurements, where up to 2 walls separated the transmitter from the receiver. However, most of the measurements were taken in positions where the obstruction was caused by furniture alone.)	3.5 dB	21.0 dB	7.0 dB
Ref 5: Delay spread and pathloss measurements made at 5.2GHz. The buildings used are of brick construction with interior walls of brick or modern plasterboard. The furniture included wooden chairs and tables.	2.9 (For a mixture of line of sight and obstructed path measurements.)	0 dB	20.2 dB	6.3 dB
Ref 8: Delay spread and pathloss measurements made at 5.8GHz. The building used is of masonry construction with some large glass windows and reinforced concrete floors. Much of the interior is effectively open plan and the furniture included booths, cubicles and large amounts of electronic equipment.	2.99 (For a mixture of line of sight and obstructed path measurements with approx. 4 - 10m separation distances.) 3.65 (For a mixture of line of sight and obstructed path measurements with approx. 10 - 20m separation distances.)	-2.9 dB -9.5 dB	18.0 dB	4.0 dB
Ref 9: Delay spread and pathloss measurements made at 4.75GHz. The building used is constructed of brick and stone with plasterboard or brick internal walls and concrete floors. The furniture included desks and other office furniture.	3.75 (For obstructed direct path measurements.)	-6.5 dB	19.7 dB	5.7 dB
Ref 10: Delay spread and pathloss measurements made at 5GHz. Measurements are made within an office building - no detail is provided on the building's construction type.	2.92 (For non line of sight measurements.) 3.55 (For cross-floor measurements.)	-0.1 dB 8.2 dB	20.3 dB 33.0 dB	6.3 dB 19 dB

Table 2

(N.B. None of the experimental results given in **Table 2** include the effects which the presence of people may have on the pathloss measurements.)

*1 The simple power law path loss equation given below can be used to model the attenuation of average received power with distance:

Path loss (in dB) = A + 10n log d

Where:
A = loss constant
n = path loss exponent (decay index)
d = separation distance (in metres) - i.e. distance between transmitter and receiver.

The value of the loss constant is dependent on the source power level and measurement systems losses and may include a component which is due to wall and floor penetration losses (for measurements which involve transmission through walls and floors).

The loss constant A can be considered to be composed of two parts, A_0 and A_r : A_0 is the value which would be obtained from measurements of the direct line of sight signals alone and is therefore only dependent on the measurement parameters (e.g. transmitted power levels, cable losses, measurement system gains, etc.). A_r is the additional constant component which is the difference between the direct line-of sight value and the measured obstructed path value at the same separation distance once the different path loss exponents have been taken into account. This additional component may be due to attenuation by walls, floors and furniture. The values of A_r and n have been calculated from graphs of pathloss or received power against log d given in the references; in most of the references the required minimum mean square error lines are already plotted and in the remaining cases a 'best fit' line has been applied to the graphs.

*2 The values for indoor path loss at 5m separation distance with respect to the path loss at 1m separation are calculated using the following equation:

Indoor path loss at 5m = $10\ n \log 5 + A_r$

*3 The values for excess indoor path loss at 5m separation with respect to the free-space path loss at 5m are calculated using the following equation:

Excess indoor path loss = $10\ n \log 5 + A_r - 20 \log 5$

The results given in **Table 2** suggest that a value of 6dBr (relative to 1m distance) is typical for the additional path loss, with respect to free-space path loss.

If the path is obstructed by more than 2 internal walls or involves a cross-floor junction, then an additional path loss figure of about 16 dBr is typical.

3.) Conclusions

The two path loss component figures from sections 1 and 2 must be added to give an overall value for the building shielding loss. The level of shielding loss experienced will depend on the specific building materials and the position of devices within a building. Examples of calculated building shielding loss figures for different environments are given below:

Environment and position of transmitter	Building shielding loss
Single glazed building with transmitter adjacent to window	5 dB
Double glazed building with transmitter adjacent to window	10 dB
Single glazed building with transmitter a few metres from window	11 dB
Double glazed building with transmitter a few metres from window	16 dB
Single glazed building with transmitter several metres from window (e.g. in inner office or corridor)	21 dB
Double glazed building with transmitter several metres from window (e.g. in inner office or corridor)	26 dB

Table 3

Given this range of typical values, an average value for the building shielding loss can be calculated:

Average building shielding loss = 13.4 dB

(Assuming:

1) 67% double glazed buildings and 33% single glazed buildings = 7.6 dB penetration loss

2) Distribution of transmitters within buildings: 5% immediately adjacent to window; 85% within a few metres of a window; 10% several metres from a window = 5.8 dB interior path loss)

4.) References

Ref 1: Gerhard Kadel (Deutsche Telecom AG): “Wideband chanel characteristics at 5 GHz in outdoor environments and resulting requirements for HIPERLAN 2”; ETSI EP BRAN WG3 TD18, 30 June 1997.

Ref 2: Pei Hou: “Investigation of the Propagation Characteristics of Indoor Radio Channels in GHz Wavebands”; published by Cuvillier Verlag, Goettingen, 1997.

Ref 3: P Nobles and F Halsall: “Radiowave Propagation Measurements Within a Building at 2 GHz, 5 GHz and 17 GHz”; Wireless ‘97 Conference paper, Calgary, July 1997.

Ref 4: P Nobles, D Ashworth and F Halsall: “Indoor Radiowave Propagation Measurements at Frequencies up to 20 GHz”; IEEE Vehicular Technology Conference, Sweden, 8-10th June 1994.

Ref 5: John Airs: “Comparative Indoor RF Channel Soundings at 2, 5 and 17 GHz”; Wireless Personal Communications, 1996.

Ref 6: Simon Black, Dr T A Wilkinson and Prof S K Barton: “Personal Communications Research Programme, Wireless Local Area Networks”; DTI/SERC LINK Report, March 1993.

Ref 7: D A Hawbaker and T S Rappaport of Virginia Polytechnic Institute and State University, USA: “Indoor Wideband Radiowave Propagation Measurements at 1.3 GHz and 4.0 GHz”; Electronics Letters, 11th October 1990.

Ref 8: D M J Devasirvatham, C Banerjee, R R Murray and D A Rappaport: “Four-Frequency Radiowave Propagation Measurements of the Indoor Environment in a Large Metropolitan Building”; IEEE 1991.

Ref 9: Gerard J M Janssen, Patrick A Stigter and Ramjee Prasad: “Wideband Indoor Channel Measurements and BER Analysis of Frequency Selective Multipath Channels at 2.4, 4.75 and 11.5 GHz”; IEEE Transactions on Communications, October 1996.

Ref 10: C Bergljung, P Karlsson and F Malmstrom (Telia Research): “Indoor Propagation Characteristics in the 5 GHz Band”; ETSI EP BRAN, 3TRS072A, 30 January 1998.

Ref 11: UK Radiocommunications Agency, Radio Technology and Compatibility Group: “Building Shielding Loss at 5 GHz”; October 1997.

Ref 12: (N.B. This reference has been included here for information , but it was not available in time for data from it to be included in the analysis in this paper).
G Durgin, T S Rappaport and H Xu, all of Virginia Polytechnic Institute and State University: “5.85 GHz Radio Path Loss and Penetration Loss Measurements In and Around Homes and Trees”; IEEE Communications Letters, Vol.2, No. 3, March 1998. - The reference estimates an average path loss exponent of n = 3.4 for indoor locations and it also includes results for the additional path loss arising from external shielding effects, such as building and foliage shadowing.

ANNEX 3 COMPATIBILITY BETWEEN HIPERLANS AND ROAD TRANSPORT & TRAFFIC TELEMATICS

1 Introduction

Spectrum for High Performance Radio Local Area Networks (HIPERLANs) has been designated by CEPT in the band 5150-5250 MHz[1]. With the development of multimedia applications and supporting technologies (e.g., ATM) the potential spectrum requirements for HIPERLANs have increased significantly beyond what could be supported by the current spectrum allocation. Consequently ETSI has requested CEPT/ERC to consider making additional spectrum available, contiguous with or close to the 5200 MHz band allocation.

One of the bands considered by WGSE Project Team 24 was 5725-5875 MHz. The band is designated for ISM applications on a global basis[2]. This band is also of interest as a potential HIPERLANs extension band because the United States FCC designated the band for use by SUPERNet type devices which are similar in application to HIPERLANs. Harmonising the US and European allocation in this case could be beneficial to industry and users in both regions.

In 1992 CEPT designated spectrum in the band 5795-5805 MHz for use by Road Transport and Traffic Telematics (RTTT)[3] systems for initial road to vehicle systems. An extension band 5805-5815 MHz may be used on a national basis at multi-lane road junctions. ETSI has developed associated standards, specifically EN 300 674 defining the technical characteristics of RTTT equipment.

As both systems are considered to be significant European harmonisation measures (i.e. ERC Decisions have been implemented in CEPT) it is necessary to determine the level of compatibility between the two systems if they are to share the same spectrum.

2 Compatibility Analysis

2.2 Technical Parameters of HIPERLAN and RTTT systems

The following technical parameters for HIPERLANs and RTTT systems have been assumed:

For convenience of calculation all power levels have been converted into dBW.

HIPERLAN Type	1[4]			2	3
Class	A	B	C		
eirp (dBW)	-20	-10	0	0[5]	0
RX sensitivity[6] (dBW) for BER 10[7]	-100	-100	-100	-100	-100
Bandwidth (MHz)	23.5	23.5	23.5	~25	~25
Interference Margin (C/(I+N)) for BER 10^{-5} (dB)	20	20	20	20	20
Building Attenuation (dB)	13.4[8]				

Table 1. HIPERLAN system parameters

[1] CEPT ERC Decision ERC/DEC/(96)03)
[2] ITU Radio Regulations RR S5.150
[3] CEPT ERC Decision ERC/DEC/(92)02.
[4] ETS 300 652
[5] Dynamic transmitter power management (see Doc. SE24(97)170
[6] Doc. SE24 (97)113 and SE24 (97)148 rev. 2
[7] The Power here refers to the EIRP averaged over the transmission burst at the hightst power control setting
[8] Doc. SE24(98)52; Summary of Indoor Propagation Measurements at 5 GHz, RA UK

Frequency Band = 5795-5805 MHz (and 5805-5815 MHz*)
Transmit Frequencies: For 5 MHz channel spacing:
5800 -2.5 MHz
5800+2.5 MHz
5810-2.5 MHZ *
5810+2.5MHz *
Transmit Frequencies: For 10 MHz channel spacing:
5800 MHz
5810 MHz *
* at multi-lane junctions (national options)

Roadside Unit (RSU)	
eirp (dBW):	
Class I (standard)	3
Class II (optional)	9
Receiver sensitivity at antenna connector (dBW)	-105 to -130
RSU Antenna gain (dB)	20
Co-channel C/I (dB):	
for 2-PSK	6
for 4-PSK	9
for 8-PSK	12

Table 2a. RTTT system parameters[9]

On Board Unit					
Transmitter spectrum class	A	B	C	D	E
Transponder conversion gain					
high gain in boresight	+1dB				
+/-35 degrees	+1dB				
low gain in boresight	0dB				
+/-35 degrees	-5dB				
Maximum re-radiated subcarrier eirp[10] (dBW)	-54	-54	-54	-54	-44
Sensitivity limit in boresight					
+/- 35 degrees (dBW)	-73	-73	-73	-73	-70
Maximum allowed interference level (dBW)	-90	-90	-90	-90	-90

Table 2b. RTTT system parameters (on board unit)

2.2 RTTT Transmission spectrum classes

The classes of transmission spectrum are defined in EN 300 674 as follows on the basis of reuse distances and data rates:

A Data rates up to 500 kbit/s; frequency reuse distance 7 to 37 metres*
B Data rates up to 500 kbit/s; frequency reuse distance 7 to 48 metres*
C Data rates up to 500 kbit/s; frequency reuse distance negligible*
D Data rates up to 31.5kbit/s
E Data rates between 500 kbit/s and 1 Mbit/s
* Reuse distance between multiple RSUs is determined by the spectrum mask attenuation. Distances derived from ISO TC204 WG15 DSRC: the ranges reflect the different interference situations e.g., Class 1 to Class 1, Class 2 to Class 1, etc.

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[9] EN 300 674
[10] This is the maximum permitted re-radiated subcarrier eirp from the OBU irrespective of the incident signal level. Ref: EN 300 674.

On-board units may be either transponders or transceivers. The eirp limits apply in either case.
The maximum re-radiated sub-carrier eirp is measured[11] with the OBU transponder orientation angle set to 0°, i.e., face–on to the test antenna and with the same polarisation as the test antenna.

2.3 Minimum Coupling Loss Calculations

In analysing the compatibility between HIPERLANs and RTTT the basic approach taken is to use the Minimum Coupling Loss (MCL) technique to determine the necessary separation distances between the two systems.

Minimum Coupling Loss, $MCL = P_t + 10log(B_{Rx}/B_i) - I_{Rx}$
Where P_t = transmitter power
B_{Rx} = receiver bandwidth (MHz)
B_i = interferer bandwidth (MHz)
I_{Rx} = tolerable interference at receiver (dBW)
(if B_{Rx} is greater than B_i and all of the interferer power falls within the receiver bandwidth then $10log\,(B_{Rx}/B_i) = 0$)

Required separation distance, $d = \lambda/4\pi \times 10^{(propagation\ loss/20)}$
where *propagation loss = MCL + Antenna and feeder gains and losses*

In general, worse case parameters have been assumed e.g., HIPERLANs Type 1, Class C, against RTTT Roadside Unit Class II with co-channel operation of both systems. Antenna gains and feeder losses are considered to be insignificant (i.e. transmit and receive gains and losses effectively cancel out). Calculations are based on an idealised environment, i.e., free space path loss is assumed and factors such as clutter due to buildings, foreground obstacles, etc., have been ignored.

a) HIPERLAN to RTTT Roadside Unit				Separation Distance (metres)
P_t (dBW)	0			
B_{Rx} (MHz)	10	(5)		
Bi (MHz)	23.5			
I_{Rx} (dBW)	-117[12]			
MCL (dB)	113.29	(110.28)		1901 (1344)
Building attenuation:	13.4dB		Revised distance	406 (287)
b) HIPERLAN to RTTT On Board Unit				
P_t (dBW)	0			
B_{Rx} (MHz)	10			
B_I (MHz)	23.5			
I_{Rx} (dBW)	-90			
MCL (dB)	86.29			85

Figures in parentheses show case for RTTT receive bandwidth 5MHz

Table 3 (a) and (b) HIPERLAN interfering with RTTT

c) RTTT Roadside Unit (Class II) to HIPERLAN			Separation Distance (metres)
P_t (dBW)	9		
B_{Rx} (MHz)	23.5		
Bi (MHz)	10		
I_{Rx} (dBW)	-120[13]		
MCL (dB)	129		11601
Building attenuation:	13.4dB	Revised distance	2480

Table 3 (c) RTTT interfering with HIPERLAN

[11] Full details of the test conditions are in EN 300 674.
[12] For 8 PSK case: RX sensitivity -105dBW; required C/I 12dB)
[13] RX sensitivity –100dBW; C/(I+N) 20dB

d) RTTT Roadside Unit (Class I) to HIPERLAN			Separation Distance (metres)
P_t (dBW)	3		
B_{Rx} (MHz)	23.5		
Bi (MHz)	10		
I_{Rx} (dBW)	-120		
MCL (dB)	123		5814
Building attennuation:	13.4 dB	Revised distance	1243

Table 3 (d) RTTT interfering with HIPERLAN

e) RTTT On Board Unit to HIPERLAN				Separation Distance (metres)
Pt (dBW)	-44			
B_{Rx} (MHz)	23.5			
Bi (MHz)	10			
I_{Rx} (dBW)	-120			
MCL (dB)	76			26

Table 3 (e) RTTT interfering with HIPERLAN

On the basis of the simple assumptions made above it can be seen that a potential compatibility problem could arise between a HIPERLANs station and the RTTT Roadside unit with separation distances of 1.9km and between 5.8 to11.6km respectively required depending on which system is the interferer and the relative power levels (Tables 3(a-e)). The inclusion of an additional 13.4dB for building attenuation can improve the sharing situation considerably but the required distances (406 metres and 1.2 to 2.5 kilometres) are still significant enough to cause concern over the possibility of extending HIPERLANs into the RTTT band. Note that in the case of an RTTT system employing a 5 MHz bandwidth the required separations are reduced from 1.9km and 406 metres to 1344 and 287 metres respectively (Table 3(a and b)).

3 Other Factors

Other factors, which should be considered in determining the level of compatibility between HIPERLANs and RTTT, are:

- the density of the HIPERLANs population has been ignored on the assumption that HIPERLANs will switch to a channel outside of the RTTT band if the presence of an RTTT transmission is detected;
- the bursty nature of HIPERLANs transmissions. Whilst it is recognised that this cannot easily be taken into account in the compatibility calculations, it is nevertheless a factor which influences the interference scenario;
- if HIPERLANs use transmitter power control then, in practice, eirps could be lower than the values assumed above;
- robust coding protocols employed in RTTT which are designed to withstand interference. According to EN 300 674[14], the RTTT on-board unit *"shall be designed to respond to appropriately modulated signals only and shall not respond to wrong codes or to any simple carrier frequency"*. However, draft CEN European PreStandard prENV 12253 on RTTT recommends that the band 5795-5805 MHz be designated for exclusive use by RTTT systems to avoid problems with interference from other systems;
- the low frequency re-use distances specified for RTTT indicate that the system is very robust in a shared spectrum environment;
- additional losses due to building clutter, intervening terrain, etc., would further reduce separation distances;
- RTTT unit antennas will be circularly polarised thus providing further protection against linearly polarised signals or those with an opposite polarisation to the wanted signal. Figures for cross-polar discrimination of between 10-15 dB or better within 3dB of boresight for the Roadside Unit and 6-10 dB for the On-Board Unit are quoted[15]. However, due to the unpolarised nature of HIPERLAN signals, the level of cross-polar discrimination will not exceed 3 dB in practice, and will typically be around 1-2 dB;
- depending on the frequencies selected for HIPERLANs and the bandwidths used for RTTT there may be some gain due to frequency offset;

[14] EN 300 674; clause 9.2.1
[15] Draft CEN European PreStandard prENV 12253

- it is also feasible that due to the relatively small band designated to RTTT (i.e., 10 MHz compared to 150 MHz being considered for HIPERLANs) that HIPERLANs could be required to avoid the band if they detect interference. Five nominal carrier frequencies[16] are identified for HIPERLANs in the 5150-5300 MHz band. Translating these into the band 5725-5875 MHz, assuming the same channel raster is applied, indicates that at most two HIPERLAN channels[17] (the middle channel and channel immediately above it) would be likely to affect RTTT operations.

For comparison the following table shows how some of the above factors could impact on the MCL separation distance

Factor	Effect	Impact on sharing
Transmitter power control on HIPERLANs	Reduced eirp from HIPERLAN transmitter.	Reduction in required separation distances, e.g., 3dB reduction in eirp would reduce separation distances by about 30%.
HIPERLAN Type 1 has a low bit rate mode transmitting short bursts in 1.4MHz bandwidth centred on the channel frequencies	Increases overall interference from HIPERLAN to RTTT by 2.5dB[18].	Increases required separation distances by factor of approximately 1.33.
RTTT coding protocols	OBU should not respond to DM-4' test signals[19]; OBU should not respond to an interference field at 5.8 GHz of 15 V/m[20].	Improves sharing possibilities by reducing required separation distances. Exact reduction has not been determined.
Antenna cross-polar discrimination	10-15 dB available for RTTT RSU within 3 dB of boresight and 6-10 dB for the OBU. With the unpolarised HIPERLAN signals, cross polar discrimination of about 1-2 dB would be expected.	Separation distances reduced by about 20%.

4 Conclusions

This analysis has shown that there may be a potential interference problem between HIPERLANs and RTTT systems if the former were to be deployed in the 5.8 GHz band.

However, as the above interference analysis shows, the MCL distance is greater for interference to HIPERLANs than in the other direction. Therefore, of the two systems, the HIPERLAN should be more sensitive to the presence of an RTTT system and hence could avoid using the affected channel(s).

Nevertheless, it may be possible for the two systems to share the same band through a combination of techniques:

- HIPERLANs should be required to avoid using the RTTT band (5795-5805 MHz) if they detect the presence of an RTTT transmission;
- Sharing would be facilitated if portable HIPERLANs were required to exercise transmitter power control.

The impact of channel avoidance techniques on HIPERLAN capacity should also be noted, e.g., in the vicinity of a busy road junction with all RTTT frequencies in use a nearby HIPERLAN system could be deprived of 40% of its capacity.

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[16] ETS 300 652
[17] Carrier frequencies at approximately 5798.528 and 5822.058 MHz
[18] Doc. SE24(97) 170
[19] D-M4' consists of incorrectly coded signals.
[20] EN 300 674

ANNEX 4 SHARING WITH SHORT RANGE DEVICES

SRDs operate at 25 mW eirp. The applications are broad and unspecified. The bandwidth needed for SRDs is likely to be in the order of 1 MHz – fast data transfers are better done with HIPERLANs. Further, SRD receivers are assumed to be simple devices that need a C/N of 10 dB

The simplest interference scenario is where both HIPERLAN and SRD are co-located in the same space/room. This scenario typically requires a decision on the part of the user to use both systems or to allow the use of both systems. From a regulatory point of view this is not a relevant case.

The more relevant case is where HIPERLAN and SRD are operated in different spaces by different users who do not co-ordinate their actions.

HIPERLAN (H) > SRD (S) interference assessment:

H RF power	23 dBm
Bandwidth ratio: 20/1 =	- 13 dB
Wall isolation factor =	- 15 dB
The net effect =	-5 dBm
At 8 m distance	- 75 dBm
C/N	10 dB
Wanted signal	- 68 dBm
S RF power	14 dBm
S link budget	82 dB
S range:	> 24 m (1 m loss is 47 dB – 30 dB ~ 4 octaves at 6 dB,rest at 10 dB/octave)

The resulting operating range is assumed to be practical for the majority of uses.
H RF power 23 dBm

SRD > HIPERLAN interference assessment:

S RF power	14 dBm
Bandwidth ratio: 1 =	0 dB
Wall isolation factor =	- 15 dB
The net effect =	- 1 dBm
At 8 m distance	- 71 dBm
C/N	23 dB
Wanted signal	- 49 dBm
H RF power	23 dBm
H link budget	72 dB
H operating range	8 m (1 m loss is47 dB – 25 dB ~ 4 octaves at 6 dB)

The 8 m figure is a pessimistic one: any interferer that does not block a HIPERLAN receiver and that occupies less than 4 MHz will not affect the HIPERLAN throughput. The reason for this is that the OFDM modulation of HIPERLAN is resistant to the loss of up to 20% of its carriers.

In addition, a HIPERLAN system that suffers strong interference will, by means of its DFS function, attempt to find another channel that is free from interference.

Conclusion:

Provided that HIPERLAN and S are operated in separated spaces, the sharing of the same spectrum between HIPERLAN and S is considered feasible.