ETSI TR 102 079 V1.1.1 (2002-11)

Technical Report

Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document for HIPERMAN in the band 5,725 GHz to 5,875 GHz

Reference
DTR/ERM-RM-017

Keywords
access, FWA, HIPERMAN, MAN, radio, SHF, SRDOC

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

Contents

Intellectual Property Rights

IPRs essential or potentially essential to the present document may have been declared to ETSI. The information pertaining to these essential IPRs, if any, is publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (http://webapp.etsi.org/IPR/home.asp).

Pursuant to the ETSI IPR Policy, no investigation, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

1 Scope

The present document contains functional requirements for licence-exempt FWA in general and a basic sharing and interference assessment based on [1] to investigate feasibility of providing licence-exempt FWA in the band 5,725 GHz to 5,875 GHz. It also proposes terms to facilitate this sharing and describes expected market information and compatibility issues.

The present document defines those requirements for Licence Exempt Fixed Wireless Access (FWA), which can affect radio frequencies in the sense of the international Radio Regulations.

It includes necessary information to support the co-operation between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications administrations (CEPT), including:

- Detailed market information (annex A);
- Technical information (annex B);
- Expected compatibility issues (annex C).

2 References

For the purposes of this Technical Report (TR) the following references apply:

[1] ERC Report 72: "Compatibility studies related to the possible extension band for HIPERLAN at 5 GHz" (see http://www.ero.dk/doc98/Official/pdf/REP072.pdf).

[2] IEEE 802.11a: "Information technology; Telecommunications and information exchange between systems; Local and metropolitan area networks; Specific requirements; Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications; Amendment 1: High-speed Physical Layer in the 5 GHz band".

[3] ETSI TS 101 475 (V1.1.1): "Broadband Radio Access Networks (BRAN); HIPERLAN Type 2; Physical (PHY) layer".

[4] IEEE P802.16a/D5:"Draft IEEE Local and Metropolitan Area Networks; Part 16: Air Interface for fixed Broadband Wireless Access Systems; Medium Access Control Modifications and Additional Physical Layer Specifications for 2-11 GHz".

[5] ITU: "Radio Regulations", appendix S8, 1998 (see http://www.itu.int/itu-r/publications/rr/rr-98/index.html).

[6] Department for Environment, Food & Rural Affairs (DEFRA): "Digest of Environmental Statistics", (see http://www.defra.gov.uk/environment/statistics/des/index.htm).

[7] Radiocommunications Agency: "Recommendations on the Licensing of the 5 GHz (5 150-5 350, 5 470-5 725, 5 725-5 875 MHz) Frequency Bands", submission by the UK 5 GHz Advisory Group.

[8] ETSI EN 300 674 (V1.1.1): "ElectroMagnetic Compatibility and Radio Spectrum Matters (ERM); Road Transport and Traffic Telematics (RTTT); Technical characteristics and test methods for Dedicated Short Range Communication (DSRC) transmission equipment (500 kbit/s/250 kbit/s) operating in the 5,8 GHz Industrial, Scientific and Medical (ISM) band".

[9] EN 12253: "Road Transport and Traffic Telematics (RTTT); Dedicated Short Range Communication (DSRC); Physical Layer using Microwave at 5,8 GHz".

[10] ERC Report 15: "Market surveillance, radio equipment inspection, spectrum monitoring and the enforcement aspects of these activities".

[11] ERC/DEC(99)23: "ERC Decision of 29 November 1999 on the harmonized frequency bands to be designated for the introduction of High Performance Radio Local Area Networks (HIPERLANs)".

[12] ERC/REC 70-03: "Relating to the use of Short Range Devices (SRD)".

[13] ERC Report 25: "The European table of frequency allocations and utilizations covering the frequency range 9 kHz to 275 GHz".

[14] ETSI ETS 300 019-1: "Equipment Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; Part 1: Classification of environmental conditions".

[15] ETSI EN 301 489-1: "Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic compatibility (EMC) standard for radio equipment and services; Part 1: Common technical requirements".

[16] ETSI ETS 300 385: "Radio Equipment and Systems (RES); ElectroMagnetic Compatibility (EMC) standard for digital fixed radio links and ancillary equipment with data rates at around 2 Mbit/s and above".

[17] ETSI ETS 300 386-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Telecommunication network equipment; ElectroMagnetic Compatibility (EMC) requirements; Part 2: Product specific compliance criteria and operating conditions".

[18] ETSI EN 301 753: "Fixed Radio Systems; Point-to-Multipoint equipments and antennas; Generic harmonized standard for Point-to-Multipoint digital fixed radio systems and antennas covering the essential requirements under Article 3.2 of the Directive 1999/5/EC".

[19] ETSI EN 301 021: "Fixed Radio Systems; Point-to-multipoint equipment; Time Division Multiple Access (TDMA); Point-to-multipoint digital radio systems in frequency bands in the range 3 GHz to 11 GHz".

[20] ETSI EN 302 085 (V1.1.2): "Fixed Radio Systems; Point-to-Multipoint Antennas; Antennas for point-to-multipoint fixed radio systems in the 3 GHz to 11 GHz band".

[21] J Färber, S. Bodamer, J. Charzinski, "Statistical evaluation and modelling of Internet dial-up traffic", Proceedings of the Conference on Performance and Control of Network Systems III, SPIE's International Symposium on Voice, Video, and Data Communications, Boston, Sep. 1999, pp. 112-121
(see http://www.ind.uni-stuttgart.de/en/Content/Publications/).

[22] J. Färber, M. Frank, J. Charzinski, "The WWW-Service in the AMUSE Field Trials: Usage Evaluation and Traffic Modelling", Proceedings of the EXPERT ATM Traffic Symposium, Mykonos, Greece, September 1997
(see http://www.ind.uni-stuttgart.de/en/Content/Publications/).

[23] IEEE 802.16.c/D3: "Draft IEEE Local and Metropolitan Area Networks; Part 16: Air Interface for fixed Broadband Wireless Access Systems; Detailed System Profiles for 10-66 GHz".

[24] ERC/DEC(92)01: "ERC Decision of 22 October 1992 on the frequency bands to be designated for the coordinated introduction of the Terrestrial Flight Telecommunications System".

[25] ITU Yearbook of Statistics: "Telecommunication Services (Chronological time series 1991-2000)", 28th Edition 2001.

[26] Eurostat: "Enterprises in Europe, Sixth Report", Luxembourg 2001.

[27] ETSI EN 300 440-1 (V1.3.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short range devices; Radio equipment to be used in the 1 GHz to 40 GHz frequency range; Part 1: Technical characteristics and test methods".

[28] ETSI EN 300 440-2 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short range devices; Radio equipment to be used in the 1 GHz to 40 GHz frequency range; Part 2: Harmonized EN under article 3.2 of the R&TTE Directive".

[29] ETSI TS 101 136 (V1.3.1): "Satellite Earth Stations and Systems (SES); Guidance for general purpose earth stations transmitting in the 5,7 GHz to 30,0 GHz frequency bands towards geostationary satellites and not covered by other ETSI specifications or standards".

[30] ETSI EN 301 783-1: "ElectroMagnetic Compatibility and Radio Spectrum Matters (ERM); Land Mobile Service; Commercially available amateur radio equipment; Part 1: Technical characteristics and methods of measurement".

[31] ETSI EN 301 783-2: "Electromagnetic compatibility and Radio Spectrum Matters (ERM); Land Mobile Service; Commercially available amateur radio equipment; Part 2: Harmonized EN covering essential requirements under article 3.2 of the R&TTE Directive".

[32] ETSI ETS 300 385/A1: "Radio Equipment and Systems (RES); ElectroMagnetic Compatibility (EMC) standard for digital fixed radio links and ancillary equipment with data rates at around 2 Mbit/s and above".

[33] ETSI EG 201 212: "Electrical safety; Classification of interfaces for equipment to be connected to telecommunication networks".

[34] CEPT Recommendation 74-01: "Spurious emissions".

[35] ERC/DEC(92)02: "ERC Decision of 22 October 1992 on the frequency bands to be designated for the coordinated introduction of Road Transport Telematic Systems".

[36] ISO/IEC 8802-5: "Information technology; Telecommunications and information exchange between systems; Local and metropolitan area networks; Specific requirements; Part 5: Token ring access method and physical layer specifications".

[37] ETSI TR 101 177: "Broadband Radio Access Networks (BRAN); Requirements and architectures for broadband fixed radio access networks (HIPERACCESS)".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

Access Point (AP): network device with direct access to the core network, central hub in a PMP network

Base Station (BS): central hub in a point-to-multipoint network

Data Link Control (DLC): layer 2 of the ISO/OSI reference model

extended neighbourhood: joint set of neighbourhoods of each mesh device in the neighbourhood of a mesh device

Fixed Wireless Access (FWA): wireless access application in which subscriber stations are fixed in location during operation, which includes nomadic operation

local access: short range (< 100 m) wireless access to other, possibly wired, networks

mean EIRP: EIRP averaged over the transmission burst at the highest power control setting

NOTE: See [11].

mesh: Multipoint-To-Multipoint topology

mesh access point: mesh device with access to backhaul infrastructure

mesh cluster: network consisting of an mesh access point and all nodes routing traffic through it into the backhaul infrastructure

neighbourhood: set of mesh devices consisting of a mesh device and all mesh devices with which this device has direct links

node: system in a mesh network

Physical Layer (PHY): layer 1 of the ISO/OSI reference model

remote access: long range (< 10 km) wireless access to other, possibly wired, networks

NOTE: Remote access networks are also referred to as "local loop networks".

(radio) link: capability of multiple PHY's to exchange data

repeater: device consisting of at most a pair of systems, which solely consists for the purpose of retransmitting the received information

NOTE: A repeater lacks convergence layers and layers above. Two types of repeaters are recognized; One type, which with minimum delay, directly passes the signal from the RX chain to the TX chain in the PHY layer, and one type, which passes the received data through the DLC layer.

sector: APT in conjunction with an antenna with a 3 dB beamwidth less than 360 °

NOTE: Typically a number of sectors are co-located, and may share one controller to minimize self-interference. A co-located set of sectors is generally deployed as base-station.

subscriber: one connected via a HIPERMAN network

Subscriber Station (SS): customer premise equipment in a Point-To-Multipoint network

system: network independent PHY and DLC layer plus one or more core network specific Convergence sublayers

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AF	Assured Forwarding
AP	Access Point
APC	Adaptive Power Control
APMP	Any-Point-to-Multi-Point
AT	Access Terminal
BER	Bit Error Ratio
BRAN	Broadband Radio Access Networks
BS	Base Station
BST	Base Station Transceiver
BSU	Base Station Unit
CEPT	European Post and Telecommunications Consultative Committee
DFS	Dynamic Frequency Selection
DLC	Data Link Control (Layer)
EF	Expedited Forwarding
EMC	ElectroMagnetic Compatibility
FDD	Frequency Division Duplex
FDDI	Fiber Distributed Data Interface
FS	Fixed Service
FSS	Fixed Satellite Service
FWA	Fixed Wireless Access
HIPERLAN	High PErformance Radio Local Area Networks
HIPERMAN	High PErformance Radio Metropolitan Access Networks
HL/2	HIPERLAN type 2
IP	Internet Protocol
ISO	International Standards Organization
ITU	International Telecommunications Union
LAN	Local Area Network
LOS	Line Of Sight
MAP	Mesh Acces Point
MPEG4	Motion Picture Experts Group type 4
MPLS	Multi-Protocol Label Switching
NLOS	Non Line Of Sight
NMS	Network Management System
ODU	OutDoor Unit
OFDM	Orthogonal Frequency Division Multiplexing

OSI	Open System Interconnect
PAPR	Peak-to-Average Power Ratio
PHY	PHYsical (layer)
PMP	Point-to-Multipoint
PPP	Point-to-Point Protocol
QAM	Quadrature Amplitude Modulation
QoS	Quality of service
PER	Packet Error Ratio
RF	Radio Frequency
RLAN	Radio Local Area Network
RSSI	Received Signal Strength Indicator
RSVP	Resource ReSerVation Protocol
RTTT	Road Transport and Traffic Telematics
SLA	Service Level Agreement
SME	Small and Medium Enterprises
SNI	Service Node Interface
SOHO	Small Office/Home Office
SS	Subscriber Station
SU	Subscriber Unit
TDD	Time Division Duplex
UNI	User Network Interface
USB	Universal Serial Bus
xDSL	x (= generic) Digital Subscriber Line

4 Executive summary

The European Commission and the CEPT member administrations have been working towards strengthening competition in the telecommunications sector during the last decade by de-regulation, encouraging the use of harmonized standards and innovative technologies, in order to facilitate industrial growth and new and competitive service provision.

While broadband access is becoming available from a variety of service providers many potential subscribers still do not have access to broadband services or are limited to a single service provider. There is now a significant opportunity to introduce fixed wireless broadband as an alternative technology for providing broadband services to customers and works towards providing universal broadband access. The typical peak data rate to a customer would be in the order of several Mbps within an average deployment.

Technology alone is not sufficient to ensure new competitive options. Licensing policy is also a critical factor. The approach used in the US incorporating licence-exempt and minimum regulatory hurdles, facilitates competitive solutions and new opportunities to service providers which can attract investment capital and establish new complementing and competing networks rapidly and efficiently. As a result, more service options are available quickly and with competitive monthly charges ensuring that more of the region has access to a broadband connection to the internet. Market information is included in the report to discuss these details. It is worth to stress that wireless technology offers feasible and cost efficient broadband solutions in particular to rural areas.

The thrust of the present document is to allow the use of licence-exempt Fixed Wireless Access in the band 5,725 GHz to 5,875 GHz.

4.1 Status of the present document

The present document has been prepared by BRAN in July 2002, and reviewed by ERM RM in September 2002.

4.1.1 Position of Secrétariat d'Etat à l'Industrie

The Secrétariat d'Etat à l'Industrie expresses its concerns about the premature adoption of the present document for the following reasons:

- a permanent confusion about the exact purpose of the HIPERMAN system exist throughout the document. Indeed, this system is either presented as a competitor to the licensed FWA or as an innovative fixed HIPERLAN-like system, as this appears in the following extracts:

  - Scope, p. 7: the very first sentence indicates that this "SRDoc contains functional requirements for licence-exempt FWA" while the initial sharing studies are based on those carried out for HIPERLAN (ERC Report 72, reference [1] of the present document): and indeed, these studies provided in the Attachment show that the scenarios considered and technical characteristics proposed are very similar to those of HIPERLAN;

  - Clause 4 (Executive summary), p. 11: in the 3rd paragraph, it is clearly stated that the critical factor is the licensing policy and the last line does not leave doubt about the purpose of this SRDoc (opening the 5 725 MHz to 5 875 MHz band for licence-exempt Fixed Wireless Access);

  - Clause 4.2.1.1 (System description), p. 11, seems to propose a new system however the 1st paragraph of clause 4.2.1.4, Short market information, p. 13) comes back to a description which could be applied to the "classic" (and currently licensed) FWA since it is really close to that one of the last mile access. On the other hand, clause 4.2.1.2 precise that this system would be limited to IP application, strengthening its similarities with HIPERLAN;

  - Clause 4.2.1.5 (Market size, forecasts and timing), p. 13: again, the confusion is maintained since no distinction at all is proposed between licensed FWA and HIPERMAN, both being included in the forecasts for FWA;

  - On a more technical side, clause 4.2.2.1 (1st and 3rd paragraphs) closely relates this system to that one of the 5 470 MHz to 5 725 MHz band;

  - The conclusion in clause 5 does not clarify the situation, and on the contrary, provide more confusion about HIPERMAN being a competitor of licensed FWA.

The Secrétariat d'Etat à l'Industrie would have preferred to see this confusions clarified before the present document be sent to CEPT so that this organization be clearly aware of the proposed new use of the 5 725 MHz to 5 875 MHz band. In that respect, it should be clearly indicated if HIPERMAN is intended to compete licensed FWA or if it is an innovative proposal, aside from the licensed FWA market. In both cases, the operational characteristics and the applications should be clearly defined. In case the first solution has to be retained, more clarification should be given to the exact values of radio and packet data availability (see clause B.1.7.5.3) which should be high enough for HIPERMAN to be a sustainable competitor to licensed FWA. In case the second solution has to be retained, the effort should aimed at clearly distinguishing the difference between HIPERMAN and the systems allowed below 5 725 MHz. It is believed that once such clear distinction will be made, a review of the market forecast will be necessary.

- As indicated in its comment made the 6th of August 2002, the Secrétariat d'Etat à l'Industrie would have preferred that the studies carried out within EP BRAN be not attached to this SRDoc since sharing and compatibility issues remain under the responsibility of ECC.

4.1.2 Reservations made on behalf of TC SES chairman

1) Background

The proposed Fixed Wireless Access (FWA) system under consideration would require from 120 MHz to 150 MHz of spectrum to be allocated to Fixed Services (FS) in the frequency band 5,725 GHz to 5,875 GHz.

In ITU-R Region 1, the current primary allocation in the 5,725 GHz to 5,875 GHz frequency band is Fixed Satellite Services (FSS) and there are systems already on operation or planning to operate under this allocation. It is essential that all interested parties have the relevant information to assess the technical feasibility and viability of the proposed Fixed Wireless Access (FWA) system and its impact on existing systems if the current allocation is modified.

2) Reservations about the parameters of the proposed FWA system

Despite the lengthy discussions which took place during ERM RM #22 (2-5 Sept. 2002), it has not been possible to assess the impact of some characteristics of the proposed FWA system on the basis of the material provided by EP BRAN in the present document. This mainly concerns the following topics:

a) Service definition in terms of quality of service including availability and performance;

b) Radio link availability including link budget;

c) Definition of the mesh antenna characteristics;

d) Assumptions used so far to assess interference to satellite systems (bend-pipe, regenerative, GSO, Non-GSO);

It is felt that the actual study with 80 % of the subscriber terminals below a roof or behind a window, no antenna pointing towards the GSO arc may be too optimistic:

e) A worst case scenario have also to be proposed to actually assess the impact on satellite network systems presently under operation.

3) Synthesis

Without precluding the results of the sharing studies which will be carried out by the ECC's experts, TC SES considers that more technical evidence, for at least the aforementioned reservations, are required to assess the impact of proposed Fixed Wireless Access (FWA) system on satellite networks already in operation and planning to operate in the targeted frequency band.

4.2 Technical Issues

4.2.1 Short background information

4.2.1.1 System description

The system is an access network, primarily intended for the delivery of IP-based services ("Internet"). Three system architectures have been considered:

- PMP;
- APMP;
- Mesh.

4.2.1.2 Applications

The system is intended for access and bridging IP applications embracing voice and broadband data services to SMEs, SOHOs and residential customers. The system is intended to fill the demand for broadband "Internet" where wired (DSL and cable) solutions are unavailable or not cost-effective. It is specifically designed to overcome some of the problems that have slowed down the growth of the broadband access market, delivering coverage, capacity and scalability at sustainable cost.

4.2.1.3 Considered technologies

4.2.1.3.1 PMP

The PMP architecture is proven, as it has been widely deployed in licensed bands [18] as access network and cellular network. It has further been used in licence-exempt applications. The use of repeaters and relays in this type of network has also been implemented.

4.2.1.3.2 Any-Point to Multipoint

The Any-Point to Multipoint architecture is a hybrid network topology between PMP and Mesh. Like in the Mesh topology, any node can route traffic to its neighbours and can therefore serve as the Access Point for new nodes in the network. Like in the PMP topology, nodes attach to a specific Access Point in the network, chosen at installation time. This allows the new node to attach to the network using a directive antenna, with the inherent advantages of increasing range, reducing exposure to interference, and reducing the generation of interference.

Nodes in the APMP network contain two antenna ports, one used for the directive antenna to attach to the network, the second as a broadbeam antenna to provide access to new nodes. With any node having the capability to act as an AP, the dark areas encountered in a typical PMP topology become easily covered.

The new technology in this architecture lies on the combination of a frequency diversity scheme with the discrimination offered by the directional antennas that allows non-interfering unsynchronized transmissions from nodes in close proximity. Additionally, the MAC layer protocol provides a self-synchronization mechanism of the repeater nodes, which, together with the frequency diversity referred above, results in an air-time efficiency approaching that of a PMP network. Finally the MAC layer also provides an inherent knowledge of the traffic congestion in the network which is the basis for a flow control algorithms that allow node by node configuration of Quality of Service parameters.

4.2.1.3.3 Mesh

The Mesh architecture concept is not new either, though it has solely been used in military, mostly highly mobile applications to obtain highly redundant robust networks. Very recently, it has been introduced in licensed FWA systems above 11 GHz, using engineered point-to-point links. The application of mesh architectures to residential (licence-exempt) FWA, using ad-hoc and self-healing routing techniques is new.

In the mesh concept every node is able to route traffic to other nodes. Thus once a node is able to connect to any other node in the network, it automatically has access also to all the others. This enables better coverage with less power required and additionally in most cases, forms redundancy through availability of several routes. Also neighbours will be selected more on a LOS (if available at all) weight than on the location thus ensuring that obstacles are rather avoided by using routes around them than by using excessive power to punch through.

The new technology lies in protocols used to share the radio resources and route the traffic through the adhoc established network. The protocol takes care of fair allocation of the channels as well as the hidden terminal problem. As a consequence every node gets a reasonable understanding of its neighbours and their neighbours' situation. This knowledge is then used to determine the radio resource usage as well as aiding in the traffic routing. In the latter case, routing decisions can be based on avoidance of congested areas, shortest path, shortest delay, lowest power or any combination of these.

For the purpose of the present document, the PHY parameters are based either on HIPERMAN, HIPERLAN Type 2 [3], IEEE 802.11a [2] or those defined in the licence-exempt part of IEEE 802.16a (WirelessHUMAN) draft standard [4]. All these PHY's are based on OFDM(A).

4.2.1.4 Short market information

FWA systems are designed to provide broadband data and voice services to SMEs, SOHOs and residential users. With fixed broadband connections, users can take full advantage of all the services available over the internet including email, educational materials, entertainment and more. However, today's demand for broadband Internet access is growing faster than the wired infrastructure can keep up with in many areas. Cities and towns are demanding that carriers upgrade their facilities for broadband to avoid losing residents and businesses to other, better-connected areas and to avoid further creation of a "digital divide" in today's societies.

While today's wireless broadband networks make high performance Internet access possible where wired broadband infrastructure is impractical, they are often not designed for residential environments. In order for wireless broadband to be practical for residential and small business markets, the infrastructure must be low-cost, robust to changing environments, easy to deploy and scalable with market demand.

Traditional wireless broadband technology has not been practical for price-sensitive, residential markets because of a combination of spectrum costs, technological constraints and deployment costs. However, the combination of license exempt spectrum and low-cost wireless network equipment, made possible by RLAN technology, promises to change this.

4.2.1.5 Market size, forecasts and timing

Residential fixed broadband subscribers, already numbering more than 10 Million world-wide are expected to grow more than ten-fold by the end of 2005 according to Ovum. Fixed broadband data services can be delivered over twisted pair telephone wires (xDSL), cable TV wires (cable modem), satellite dishes and through fixed (terrestrial) wireless equipment. While fixed wireless deployments are in the early stages of deployment today, ARC Group is predicting that residential fixed wireless subscribers will number more than 7 million by the end of 2005 in Europe alone (see figure 1).

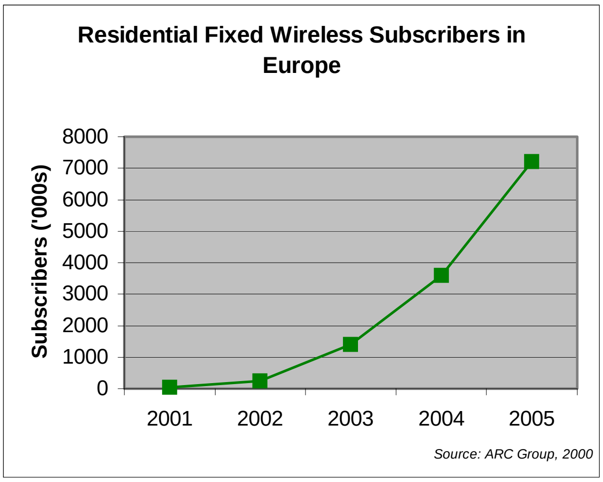

Figure 1: Residential FWA subscriber forecast for Europe

4.2.1.6 Spectrum requirement and justifications

The systems may use 5 MHz, 10 MHz or 20 MHz channelization, which is necessary to obtain sufficiently high data rates.

In single cell deployments, usually one or two channels suffice. In large area multi-cell deployments a common number of channels used per operator is 4. For backhaul an additional channel may be required. 15 MHz guard bands would leave 120 MHz in the 5,725 GHz to 5,875 GHz band for FWA deployments. This would allow up to 6 overlapping single-cell deployments utilizing 20 MHz of spectrum or at least 2 overlapping multi-cell deployments utilizing 10 MHz channels, allowing for at least 2 competing operators.

4.2.2 Spectrum parameters

4.2.2.1 Radiated power

The envisioned power is 1W mean EIRP, equal to the current regulation in 5,470 GHz to 5,725 GHz [11]. It is required to achieve sufficient link-budget margin in order to deploy PMP systems with economical cell-sizes and to initially deploy mesh system. For mesh systems, as the customer density increases, the EIRP value used will drop. For PMP systems, as microcells are deployed in high customer density areas, the used EIRP value will drop also. For APMP systems, in high customer density areas, the used EIRP value will drop also.

The use of FWA devices in license exempt spectrum, with a maximum of 17 dBm/MHz mean EIRP density (resulting in 1 W mean EIRP for 20 MHz channels, 0,5 W mean EIRP for 10 MHz channels and 0,25 W max EIRP for 5 MHz as illustrated in figure 2) is desirable both from a commercial, technical and service perspective. For highly directive antennas (for example 20 degrees), 20 dBm/MHz is suggested.

To allow for this separation in EIRP densities, it is assumed that the regulator will require a statement in the approval process, which specifies which antennas are used with the device, as well as a requirement of the antenna being either integrated or requiring a proprietary connector. Such requirements would be in line with the requirements currently in effect for the ISM, HL/2 and U-NII bands.

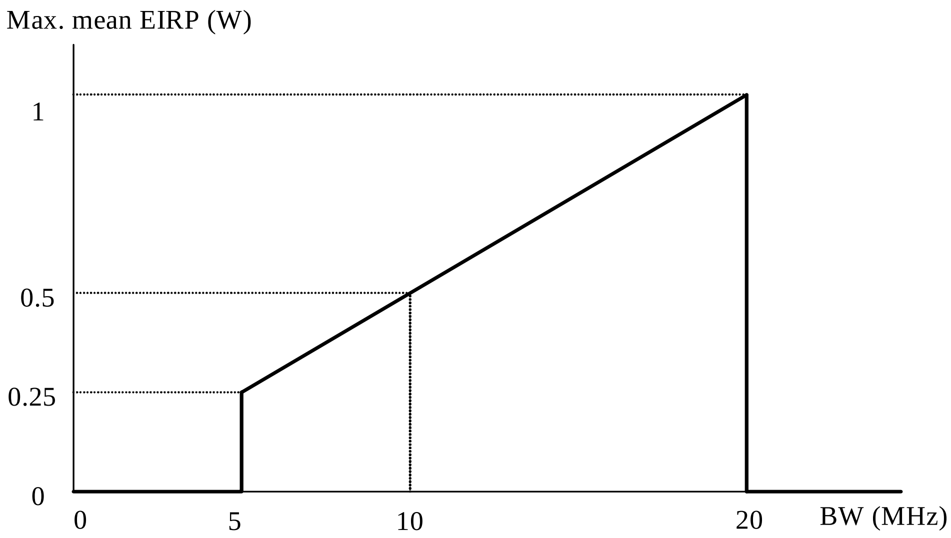

Figure 2: Suggested radiated power limit vs bandwidth (-3 dB BW)

4.2.2.2 Transmitted bandwidth

For the purpose of illustration, three channel bandwidths have been used in the present document: 5 MHz, 10 MHz and 20 MHz.

Using 20 MHz channelization, the -20 dBr transmitted bandwidth is 22 MHz or less. The -3 dB transmitted bandwidth is less than 19 MHz. Using 10 MHz channelization, the -20 dBr transmitted bandwidth is 11 MHz or less. The -3 dB transmitted bandwidth is less than 9,5 MHz. For a 5 MHz channelization, the -20 dB transmitted bandwidth is 5,5 MHz or less and the -3 dB transmitted bandwidth is 4,8 MHz or less.

4.2.2.3 Frequency considerations

This type of system requires transmission technology that is both low-cost, provides a reasonable range and a reasonable amount of spectrum to operate in to achieve the data-rates necessary to provide broadband services. Due to the high cost and low range of above 11 GHz RF technology, only sub-11 GHz spectrum is suitable. The choice for 5,725 GHz to 5,875 GHz spectrum is based both on the availability of cheap RLAN RF technology, the favourable propagation properties, as well as the suitable amount of low-cost spectrum.

4.2.2.4 Current regulations.

[12]:	5,725 GHz to 5,875 GHz:	SRD:	Maximum EIRP limited to 25 mW
[13], [29]:	5,725 GHz to 5,875 GHz:	FSS:	
[30], [31]:	5,650 GHz to 5,850 GHz:	Amateur:	

5 Main conclusions

FWA providing narrowband connections (< 256 kbps) is not economically viable in Western Europe with wired telecommunications infrastructure reaching the vast majority of the population. In some remote areas narrowband FWA could provide a reasonable alternative to wires but this market is very small and not really attractive for the FWA equipment manufacturers as can be seen from the fairly limited offering of WLL type of equipment.

The number of broadband connections is still in its infancy in Europe where less than 10 % of all connections are broadband. The EU Commission is advocating broadband to every home to maintain the economic competitiveness in the European region. Since migration from narrowband to broadband does not happen overnight and requires huge investments, there is an opportunity for new technologies to enter the market place.

FWA on licensed bands has not so far been able to compete with the wired alternatives mainly due to additional costs (some countries) or time (timing might be critical) needed in acquiring the license, unattractive coverage requirements (some countries), limited harmonization (on 3,5 GHz leading to limited product offerings), expensive technology (especially >11 GHz RF, low volumes) and not the least deployment issues like roof rights, providing LOS coverage and professional installation of end-user equipment.

Wireless broadband over radio requires spectrum allocations in the range of hundreds of MHz if shared or divided by several operators. It is in the interest of all that the spectrum is well utilized, which is not necessarily the case when license owners are backed up with poor business plans (due to above mentioned or other reasons). Enabling sharing of the spectrum in a license exempt manner would likely lead to a more effective spectrum usage.

Additionally FWA on licensed exempt bands could overcome some of the hurdles related to the licensing by allowing rapid roll-out, free selection of local or national roll-out depending on the business case (licenses restricts this) but also more competition. If the license exempt allocation would reside below 6 GHz (allowing some NLOS propagation) and additionally on a band allowing re-use of technology, the likelihood of success would be boosted further.

ETSI BRAN has identified the 5,725 GHz to 5,875 GHz band as a desirable candidate, which would meet the above considerations, and which would in addition result in desirable harmonization with current regional regulations in ITU Region 2. Some initial compatibility studies have been made by ETSI BRAN to determine whether FWA could possibly be sharing the band (see attachment). Based on the results CEPT is encouraged to conduct detailed sharing studies to determine the license-exempt FWA allocation in the band 5,725 GHz to 5,875 GHz or on another suitable band (subject to power limitation, mask requirements and other functional requirements).

Annex A: Detailed market information

A.1 Range of applications

A.1.1 Targeted applications

Licence-exempt FWA networks should support a wide range of IP applications and be extendable to support future services. The main user applications that can be foreseen today are as follows:

- Internet access, which includes:
  - Low to medium quality video and audio streaming (such as remote learning);
  - HTTP services;
  - Computer gaming.

A.1.2 Features

The main features that are expected in these systems are:

- User installable terminals.

On site visits to engineer SU installation pose an undue burden on service initialization. NLOS operation capability, which eases antenna installation, in combination with turnkey SU solutions, enables user installable terminals, which significantly cuts the deployment cost.

- Air interface.

The air interfaces should be based on standards to reduce co-existence issues.

- Very rapid scalable infrastructure deployment.

Time to market with new broadband services will be crucial for the success of new operators. Through deployment of an efficient new radio access system time-to-market for new services is reduced.

- Efficient spectrum usage.

New broadband radio technologies have a very efficient use of spectrum, which will allow the operator to offer services requiring high peak bit rates.

- Modular cost-effective growth.

Radio can offer the possibility of selective access, investments not relying on multi-connections. Further it can reach where other technologies cannot, where fiber is too expensive to deploy and where xDSL is not suitable. The system allows easy customer installation of SUs and is easily expanded. The radio systems are not subject to disturbance by civil works, which results in frequent interruption of services and in high on-going repair costs for a cabled network. Fiber is expensive to deploy. Copper is expensive to maintain. The main cost of radio access is in the equipment itself. This cost is quickly decreasing with the development of new technology in contrast to digging and maintenance costs. Using 5,725 GHz to 5,875 GHz band enables significantly less expensive RF solutions than are possible for licence-exempt bands above 11 GHz, less expenses due to lack of licence procurement, and less expensive solutions due to reuse of standardized technologies (RLAN, MAN, DVB).

On the system architecture level, the rescalability is the essential factor. The system should allow easy customer installation of SUs and it should be easily expand with high coverage probability.

- The system provides packet-based services with a certain level of QoS support and means to mitigate the unprotected nature of the band.

A.1.3 Target markets

Broadband fixed wireless access systems in licence-exempt bands are intended to cost-effectively compete with, and complement other broadband wired access systems, such as xDSL and cable modems. In this context "broadband" means peak rate "above 2 Mbit/s" to provide such services as data, voice and video.

The target markets to be addressed are residential (single family, as well as multitenant dwellings) and SOHO locations.

The critical parameters for serving these markets are the combination of cost, coverage and capacity factors. The cost factors are equipment costs, deployability, maintainability, costs associated with the SU installation, and the spectrum efficiency/reuse for economically serving the required number of customer locations with a minimum cost of infrastructure.

A.2 Market size and value

See clause B.1.9.

A.3 Traffic evaluation

For statistical traffic analysis, few public measurement studies of user behaviour exist. In [23], a proposal for a traffic model was made, which is however more suitable for system stress testing than for a common traffic evaluation. A more suitable model could possibly be taken from wired broadband studies, such as those performed within the ACTS AMUSE program [21]. This model provides both an inter-arrival-time model, as well as a packet-size distribution model. It does however lack a session duration model, which could possibly be adopted from another dial-up based study detailed in [21]. These three distributions would fully describe the user behaviour for data services.

In general, without going into the complexity of the above models, it can be asserted that the average transmission time per SS, even during the busy hour, will be far less than the 5 % used for simplicity in the attached co-existence study.

Annex B: Detailed Technical Description

B.1 Functional Requirements

B.1.1 Topologies and deployment Scenarios

This clause presents a high level description of a FWA system model.

The network may be either a PMP, APMP or a Mesh topology. In PMP systems, all data traffic goes directly through the base station, which serves as a radio resource supervisor. In mesh systems, all data traffic is routed from one system to the next, which avoids the need for adequate link budget to directly reach the backbone access point.

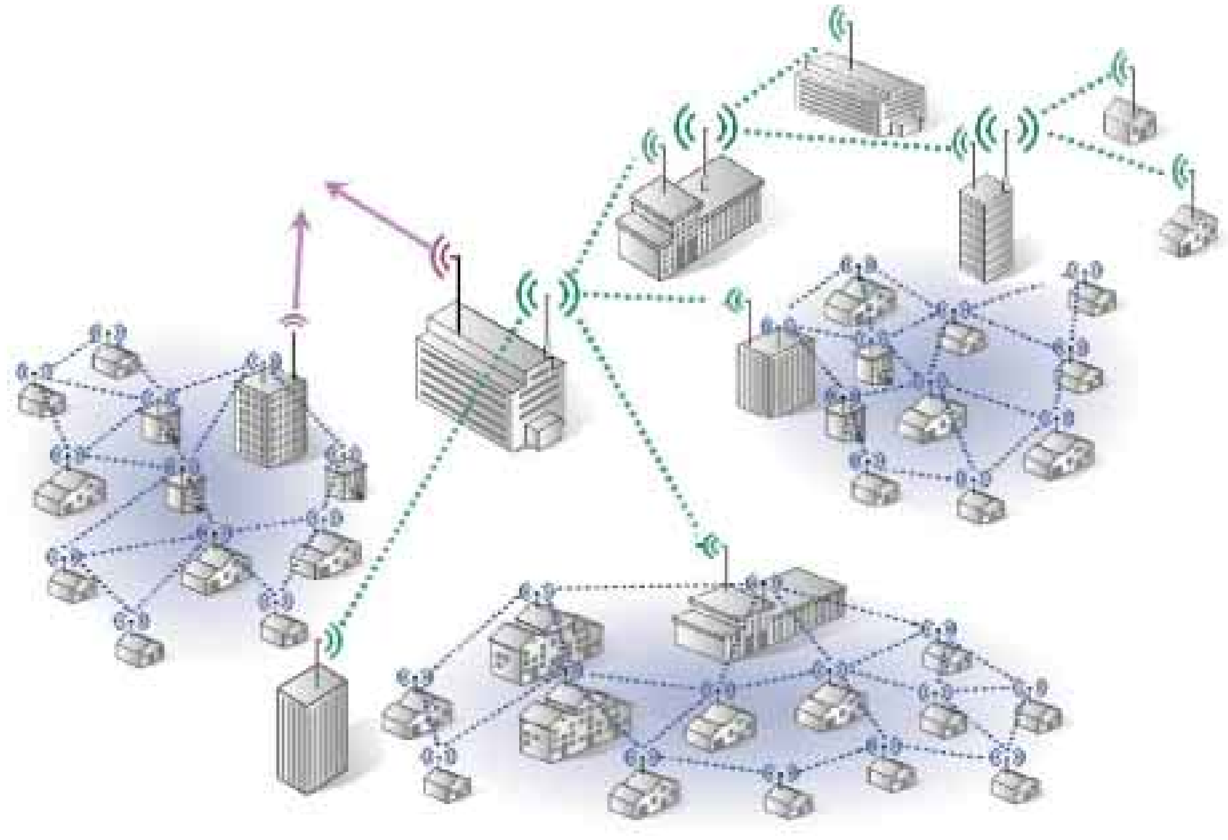

Figure B.1: Example network deployment configuration based on PMP, APMP and mesh configuration

Figure B.1 shows an example network configuration using both the PMP and Mesh architecture in a two layer configuration using a Point-to-Point backhaul link.

Figure B.1 shows an example network configuration using the APMP technology.

B.1.2 Large Scale Deployments and co-existence

To enable large scale deployments efficiently, PHY and DLC protocols must permit good frequency reuse factors, providing an aggregate peak data rate of at least 25 Mbit/s per channel or per Mesh Cluster. In order to reduce the interference level, the system must provide power control per subscriber on all links and permit real-time changing of modulation, coding and power levels, as function of propagation conditions, in order to use the minimum power needed for the target BER.

The network must support adequate techniques to facilitate co-existence. The application of DFS should be required.

B.1.3 Duplex Mode

In licence-exempt bands, only TDD should be allowed. FDD systems, especially those that use continuous transmit and hence have a 100 % activity factor, prevent effective sharing, as well as the effective usage of DFS. In TDD mode, the system should support dynamic variable duration for the up- and down-link according to the existing traffic to ensure effective spectrum usage.

B.1.4 Channelization

For the purpose of illustration, three channel bandwidths have been used in the present document: 5 MHz, 10 MHz and 20 MHz.

The channel slot should have 1 MHz granularity since effective sharing with for example SRD devices might require a reasonable granularity to choose the channel from. A granularity finer than 1 MHz is unnecessary, since the channels are already fairly broad. A granularity courser than 5 MHz is inadequate to allow effective sharing with other services.

B.1.5 Services

This clause contains technical service requirements, which are needed to support the applications discussed in clause A.1 and pose requirements on the PHY and DLC layers. The QoS parameters supporting the described services are provided in clause B.1.8.2.1.

B.1.5.1 Internet Protocol Services

The system should be optimized to transport variable length IP datagrams, supporting both IP versions 4 and 6. For efficient transport of IPv6, TCP/IP header compression over the air interface should be supported. Support the emerging IP-QoS efforts (e.g MPLS, Diffserv, RSVP) is recommended for adequate application support. The system should be able to facilitate unicast, multicast, as well as broadcast services.

B.1.6 External interfaces, and network management

B.1.6.1 Network Management

The network shall provide a network management interface based on existing open standard protocols (for example SNMP), which enables the following management aspects:

- Fault and Performance management.

The protocols must enable fault and performance monitoring, as well as provide means for local and remote testing. The management functionality must include reboot, reactivation and shutdown capabilities.

- Configuration and software upgrading management.

The protocols must enable both local and remote configuration including the updating of software in any device in the network without service interruption.

- Security.

The system shall enable centralized authentication and authorization services.

- Service management.

The protocols must permit operators to enforce service level agreements (SLAs) with subscribers by restricting access to the air link, discarding data, dynamically controlling bandwidth available to a user or other appropriate means. The protocols must permit the subscriber to monitor the performance at the SU.

- Interoperability.

The network management system shall enable provisioning and operation of a number of different SU's provided by several suppliers on a BS.

- Accounting and Auditing.

The system management framework, architecture, protocols, and managed objects must allow for operators to effectively administer accounting and auditing, by making available the relevant information to an external billing system. An operator must be able to account for time- and bandwidth utilization (i.e. throughput) and the various QoS parameters for each subscriber.

Any radio relay or repeater function shall be a managed element.

B.1.6.2 External Interfaces

B.1.6.2.1 User Network Interface (UNI)

A single SU may comprise several UNIs. The DLC convergence layer at the SU shall support IP. It may support other interfaces such as HomePNA, Ethernet and USB.

B.1.6.2.2 Service Node Interface (SNI)

The BS or Mesh Access Point may comprise several SNIs. The DLC convergence layer at the BS shall be packet-based. It may be IP over Ethernet, Gigabit Ethernet, PPP, FDDI (see ISO/IEC 8802-5 [36]), etc.

B.1.7 Transport requirements

Priority information given to the convergence layer shall be used for the QoS mechanism.

B.1.7.1 Service independence

A system shall provide services without requiring information on the type of application.

B.1.7.2 Service Support

B.1.7.2.1 Quality of Service

The system shall support QoS guarantees to provide the services that shall be transported. Thus, the protocol standards shall define interfaces and procedures that accommodate the requirements of the services with respect to allocation of prioritization of radio resources.

The system shall support different classes for service quality in terms of delay, jitter, packet error ratio and data rates. Jitter generated in the system should be taken into account in the design of the buffers. Jitter automatically impacts the total delay of the system and is therefore included in the Max. Delay.

Figure B.2 shows a variety of typical currently available applications and their required bandwidths and dependencies on QoS.

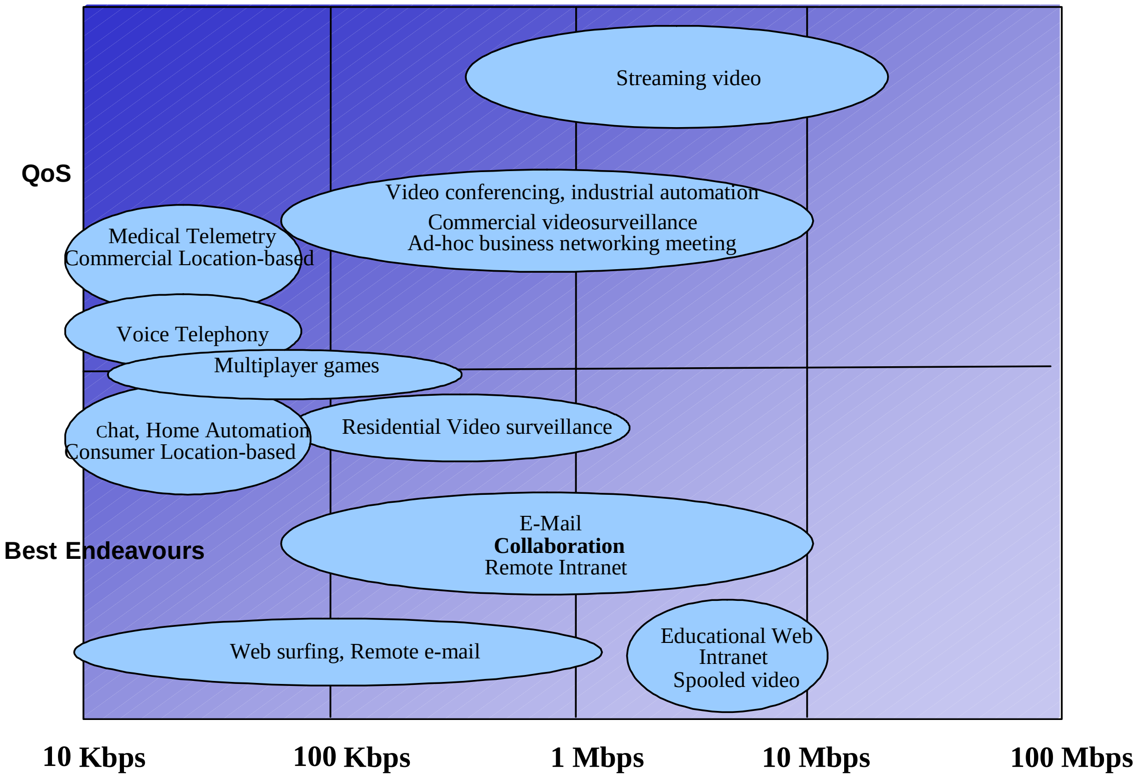

Figure B.2: Some currently available applications and their typical bandwidth and QoS requirements

Table B.1: Service QoS Requirements

Service	Max. Delay (ms) including jitter, for at least 95 % of packets (see note)	Max. Jitter (ms) for at least 95 % of packets (see note)	Packet Error Ratio (see note)	Data rates
VoIP	20	10	3 %	≤ 64 kbps
Time Critical Data	40	20	1 %	≤ 400 kbps
Streaming	100	50	1 %	≤ 768 kbps (Info: realaudio/mp3 < 96 kbps, MPEG4 Speech < 24 kbps Video: MPEG4 Visual, see http://www.m4if.org/resources/profiles/index.php, Table A.1 for details.
Non-Time Critical Data	N/A	N/A	N/A	typically 2 Mbps
NOTE: The QoS parameters are specified between two convergence layers on a single radio link.				

B.1.7.2.2 Service Classes

Three classes of service are recognized:

- Expedited Forwarding (EF): This class of service can have a varying bandwidth requirement over time, but tolerance of delay and jitter are limited

EXAMPLE: VoIP.

- Assured Forwarding (AF): Within this class of service, the bandwidth can vary over time within limits, but the tolerance of delay and jitter are higher than EF.

- Best Effort: The bandwidth in this class varies widely and is allowed to burst up to the link capacity not occupied by EF and AF traffic. Delay and jitter tolerance is high.

B.1.7.2.3 Service QoS Mappings

The basic mechanism available within the systems for supporting QoS/service class requirements shall be able to allocate various bandwidths to various services. The protocols shall include a mechanism that can support dynamically variable bandwidth channels and paths (such as those defined for IP environments).

Since customer units will contend for capacity to/from one or more base stations, the DLC protocol shall efficiently resolve contention and bandwidth allocation.

This mechanism shall be done as a negotiation between convergence layer and higher layer.

B.1.7.3 Channel Conditions

Due to the multipath inherent in the targeted frequency bands, the system should be capable of handling several μs of delay spread with limited performance degradation.

To accommodate changes in the channel characteristics, the PHY and DLC protocols shall specify functions and procedures to adjust parameters such as transmit power and modulation. Note that the function of the DLC layer and/or PHY layer can include error correction.

Link distances will vary strongly based on the environment, propagation conditions, antenna gain, etc. The system should be such that it supports typical link distances as listed in table B.2. Because large distances can be expected between terminal and base station in PMP network architectures, time delay compensation mechanisms should be provided.

Table B.2: Typical cell-sizes

	Typical link distances (km)		
	PMP	APMP	Mesh
NLOS urban	2	2	1
NLOS suburban	2,5	2,5	1,25
NLOS rural	4	4	2
LOS	10	10	4

B.1.7.4 Flexible Asymmetry

Over a short period of time (e.g. a few seconds) the traffic generated by and for any given user can be highly asymmetric in either way. The system shall efficiently support this type of asymmetric traffic. Over longer periods of time, a given user can need on average more bandwidth in one way than in the reverse way. The system shall therefore enable the operator to grant asymmetric traffic contracts.

The total traffic generated by and for all the users sharing the same radio resource may be instantaneously asymmetric or even asymmetric during a long period of time, depending on the type of users connected to the shared resource. This global asymmetry can be handled differently with TDD and FDD modes. In TDD mode, a global dynamic asymmetry in the range of 10 % upstream, 90 % downstream to 90 % upstream, 10 % downstream should be supported. In FDD mode, the modulation type and coding should be adjustable to maximize total sector capacity and near the capacity asymmetry to the traffic asymmetry.

B.1.7.5 Throughput requirements

B.1.7.5.1 Target Throughput

To be competitive with wired solutions, it is desirable for the system to support an aggregate peak data rate at the BST of 25 Mbit/s, which is the instantaneous aggregated bit rate (up- plus downstream) between the PHY and the DLC layer, and shall be shared among the users or shall be capable of being allocated to one user. The system shall accommodate different types of SUs with different maximum data rates. This for example allows optimization of the cost-performance ratio for specific markets/customers and operation with longer ranges.

B.1.7.5.2 Spectrum Requirements

The system may use 5 MHz, 10 MHz or 20 MHz channelization, which is necessary to obtain sufficiently high data rates. A minimum re-use factor of 3 applies. Provision for at least 2 competing providers in the same area requires hence a minimum of 120 MHz of spectrum. 150 MHz in 5,725 GHz to 5,875 GHz would allow for the necessary 15 MHz guard bands. A larger number of providers or higher reuse factors can be provided with 5 MHz or 10 MHz channelization.

B.1.7.5.3 Radio Link Availability

Unlike in licensed bands, radio link availability cannot be guaranteed due to potential interference. It is expected that the system can operate with a packet failure ratio of approximately 10 % caused by radio interference into the FWA system. Therefore, the system can cope with this without any substantial detoriation of the QoS parameters.

[When installing the system, a targeted availability is at least 98,5 % (also a typical value of fixed subscriber lines).]

The system should permit radio links to be engineered for different link availabilities, based on the preference of the system operator.

B.1.7.5.4 Scalability

The protocols should allow for different capacities and performance for the system instances. The system should support features to maximize the scalability of a deployment.

B.1.8 Radio specific security requirements

The system shall provide secure means of authentication, authorization and adequate means of encryption to ensure privacy.

B.1.8.1 Authentication

There are two levels of authentication for the system. The first level of authentication is when the subscriber unit authenticates itself to the access network. This initial authentication shall be strong in order to prevent "enemy" subscriber unit from entering the network or an "enemy" base station from emulating a real base station. Once the initial authentication at this level is complete, subsequent authentication at this level can be a little more relaxed. The DLC layer shall support this level of authentication.

The second level of authentication, between the user and the NMS, should be handled by higher layer protocols.

An additional level of authentication can exist between the two levels above. This additional layer is the authentication of the user with the subscriber unit. This is also beyond the scope of the system. The authentication mechanisms shall be secure so that an "enemy" subscriber unit is not able to gain access to a system, or to the core network. Passwords and secrets shall NOT be passed "in the clear" through the air interface.

B.1.8.2 Authorization

Authorization is a security process that determines which services an authenticated user is permitted to invoke. Each user has a set of credentials that describe what the user is "allowed" to do. The standard shall identify a standard set of credentials and allow for vendors to extend the defined credentials with non-standard credentials. Some possible credentials are:

- Permission to access the system;
- Permission to request up to a defined QoS profile (bandwidth, delay, etc.);
- Permission to operate certain services (IP, Remote Bridging, Digital Audio/Video, etc.).

User authorization requests and responses shall be transacted securely.

B.1.8.3 Privacy

Privacy is a security concept that protects transmitted data from being intercepted and understood by third parties (e.g. an "enemy" subscriber unit, base station or passively "listening" radio).

The system should allow a cryptographic algorithm to be employed that is internationally applicable. Facilities shall also be defined in the protocol for the use of alternate cryptographic algorithms that can be supported.

B.1.9 Operational requirements

B.1.9.1 User density and market penetration

B.1.9.1.1 Residential market

Caution has to be taken with figures for "average" household density, as local peaks can be much larger than the average for a large area. Table B.3 gives figures for typical household densities in a square kilometre in Europe and the likely range of variations on a smaller scale.

Table B.3: Typical household densities in Europe (Households per square km)

Environment:	Rural	Suburban	Urban	City centre
Average household density		1 000	3 000	
Household density range	5 to 500	500 to 3 000	1 000 to 8 000	8 000 to 30 000
NOTE: Source: TR 101 177 [37].				

Systems may be installed both in regions of relatively low household densities (rural areas) and regions with very high household densities (urban areas including city centres). At least in the early rollout stages of a network, only a small fraction of the potential user base within the coverage area may subscribe, which will result in a low-to-medium user density in densely populated areas.

Licence exempt FWA systems therefore need to allow economic deployment in areas with fairly low user density, but have adequate growth potential to maintain a good grade of service as the user density increases. In rural areas, systems should target clustered households, such as villages, and not isolated houses.

B.1.9.1.2 SOHO market

In a business a number of employees can use broadband services simultaneously through a single company subscription (probably sharing the access transceiver through an internal network). Little data seems to be available on the actual *density* of businesses. However, data is available on the proportions of businesses across economies. Table B.4 gives data for five EU countries.

From the table it is clear that in each market:

- Approximately 2/3 to 3/4 of all telephone connections are to residences; and
- 80 % of all businesses employ less than 10 employees.

Table B.4: Market statistics for Europe

Country	Households 000s	Res. lines 000s	Total lines 000s	Enterprises - % - with # of employees: 1 to 9	10 to 49	50 to 249	250 +	Number of enterprises
France	23 900	22 400	34 114	86,0	11,6	2,0	0,4	1 147 000
Germany	38 140	36 400	50 220	81,1	16,2	2,1	0,6	2 180 000
Italy	21 176	20 300	27 153	90,1	8,8	0,9	0,2	1 804 000
Spain	12 503	12 500	17 102	88,1	10,3	1,4	0,2	1 064 000
UK	25 085	23 300	35 177	85,1	12,5	1,9	0,5	1 232 000
NOTE: Sources: ITU [25], Eurostat [26].								

These figures show that the predominant potential market for access will be for residential and SOHO premises, with the majority of business premises housing less than 10 employees. It is assumed that all businesses will also have telecommunications service.

The system should be designed on the assumption that, in each type of region (suburban, urban, city centre) it should support the same penetration of the SOHO customer base as the residential customer base. The density of SOHO is assumed to be in proportion to the household density. The number of users per subscription (i.e. per customer) will be distributed according to the distribution of enterprise size. However, it is assumed that only half the employees in each enterprise will have access to broadband services (i.e. on average this is the proportion of employees who use communications in their daily work).

B.1.10 Installation aspects

Environmental concerns mean that an ODU (if the SU includes an ODU) including antenna on customer premises MUST be small.

End-User installation shall be supported. The system should allow a design to include any functionality necessary to enable the economical installation of subscriber equipment. For example, to make available Received Signal Strength Indicator (RSSI)/Bit Error Ratio (BER) indications for proper antenna alignment. Easy installation with a minimum of manual configuration should be the goal. Flexibility and an installation that is as automated as possible are highly desirable.

B.1.11 Capacity

The system capacity requirement is a function of the number of users, their bandwidth requirements and traffic characteristics (contracted service levels with users). This can for example be optimized by radio resources reservation schemes.

In a given system instance, capacity has to be planned to ensure that the user's quality of service guarantees are met.

The time-variant impairments (e.g. interference profiles) are expected to be the most significant contributor to channel impairments and complexity in cell capacity planning.

B.1.12 Maintaining QoS

A number of problems can arise during the operation of a network which affect the quality of the service delivered to the SU:

- The radio path may become obstructed, either temporarily or permanently.
- Sporadic co- and adjacent channel interference can arise from within the system or from other systems.
- As the network grows new BSs or Mesh Access Points may be added to increase capacity or extend or "fill-in" coverage.

The system shall incorporate system features to monitor and if possible maintain the QoS in the face of these effects.

B.1.13 Environmental conditions

The system is intended to operate with in- and outdoor equipment. The equipment shall meet appropriate classes defined in ETS 300 019-1 [14] and should meet other relevant regional standards.

B.1.14 ElectroMagnetic Compatibility (EMC) and safety

The system shall conform to the EMC standards EN 301 489-1 [15], ETS 300 385/A1 [32] and ETS 300 386-2 [17]. The emerging EMC standard EN 301 753 [18] should be taken into consideration. The system shall also conform to the applicable parts of electrical safety document EG 201 212 [33] (Electrical safety; Classification of interfaces for equipment to be connected to telecommunication networks). The present document has not taken into account radiation safety aspects.

B.1.15 Example detailed technical description

B.1.15.1 FWA system using PMP architecture

B.1.15.1.1 PMP applications

It is assumed that the PMP FWA system [18] will be used for broadband voice, video and data access for the small and medium enterprises as well as residential customers. In addition the PMP FWA system is suitable for backhaul of wireless LAN traffic to a central hub.

B.1.15.1.2 PMP architecture

A FWA PMP network consists of several systems arranged in a cellular pattern. Each cell system includes a Base Station Unit (BSU), configured with several sectors (usually four or six) and multiple Subscriber Units (SUs). The available channels are distributed between all sectors, where they are shared between all SUs.

B.1.15.1.3 PMP benefits

1) coverage and capacity

PMP systems support large area coverage (typically 10 km radius in LOS) with a minimal initial investment (one base station). The capacity of modern PMP broadband wireless access systems allow these cells to support thousands of subscriber units while allowing peak rates in excess of 20 Mb/s. This means that PMP system offer an ideal compromise between initial investment and capacity and performance. Furthermore modern PMP FBWA are not limited to Line of Sight conditions, which means that installation cost can be reduced down to zero in the case of self installations.

2) scalability and service flexibility

The latest generation of FWA systems are also highly scalable: capacity and coverage can be extended by adding more base stations as the service provider's business grows. PMP FWA system hubbed architecture also enable the efficient management of the total bandwidth available, making it possible for the operator to offer a differentiated and layered service offering. This is critical in order to effectively address all clauses of the market, from residential to enterprise, as well as to offer many types of applications such as voice, data and video.

3) Scheduling and MAC efficiency

Since the base station can schedule all traffic in a centralized manner, the radio resource is optimally used, unlike other configurations which results in higher efficiency

4) Summary

PMP FWA therefore is a suitable technology for service providers using the 5 GHz license exempt spectrum band. It forms a suitable complement to a Wireless LAN solution such as HIPERLAN (II) which will always require a cost efficient and complementary backhaul solution.

As detailed above PMP FWA systems offer an efficient and broadband wireless access system to a wide range of users and applications. The low cost of ownership of a PMP FWA system (low equipment cost, centralized Base Station and low cost of installation) associated with exemption from getting a license make these systems ideal for emerging service providers seeking short term profitability and unlimited growth for their businesses.

PMP FWA systems have been deployed in several parts of the World to support various types of services. This is therefore a proven technology supporting the needs for QoS powered last mile connectivity to either business, residential or Wireless LAN backhaul applications.

B.1.15.2 FWA system using Mesh architecture

B.1.15.2.1 Concept

A mesh network consists of subscriber nodes and Mesh Access Points (MAP). There are two distinct differences between the two. A Mesh Access Point has a wired interface into a core-network access device (which may be as simple as a wire into a gateway, or as complex as a multi-tier wireless backbone network), whereas the subscriber node's wired interface connects to a LAN or individual computer. The second difference is, that a few Mesh Access Points may be co-located and using sector antennas, in order to aggregate more traffic into a single point, whereas subscriber nodes are individual installations typically with omni-directional antennas. In all other aspects their functionality is entirely the same. The definition of whether a node constitutes an Mesh Access Point or a subscriber node hence entirely depends on what type of device is connected to its network interface.

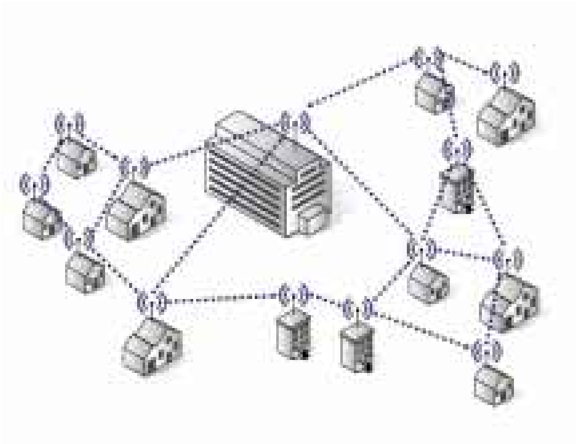

Figure B.3: Mesh network example

In terms of functionality, a node consists of an standardized PHY, a mesh optimized DLC and a router. Example antenna specifications (as also used in the interference analysis) are shown in table .

B.1.15.2.2 Coverage

One of the crucial factors in providing residential broadband wireless access, is to achieve sufficient coverage at low cost.

A mesh architecture does not rely on attempts to overcome NLOS. Instead, it avoids NLOS problems by routing around obstacles and by keeping transmission links short. The principal is explained in figure B.4 and figure B.5, which are the result of a TSS geographical information system using a digital elevation model map, an aerial photograph, and a suitable propagation model, correlated and verified with empirical data.

In figure B.4, the coverage achieved by a single Mesh Access Point (displayed as red dot) is displayed in purple. Coverage is defined as the ability to locate a node at that spot at rooftop level with sufficient link budget margin to ensure reliable operation. Since the Mesh Access Point is located on a hill-side, and the terrain rolls down to the left of the figure, the coverage is less than homogeneous. Trees and the homes in this residential area add to the coverage reduction.

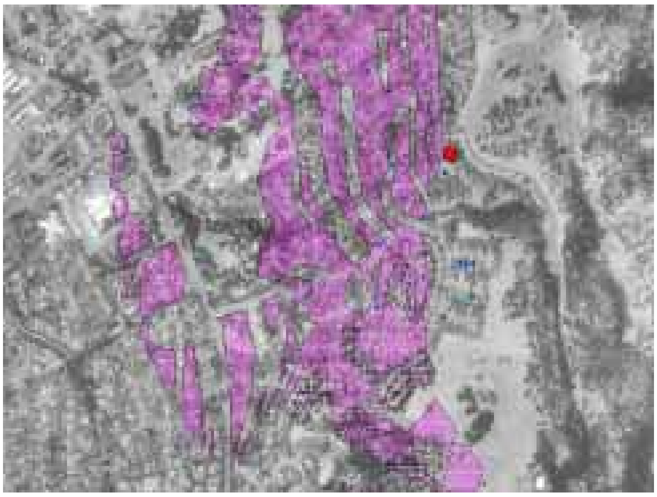

Figure B.4: Mesh Access Point node coverage

In figure B.5, the coverage of the system is shown after only 5 customers have signed up. Comparing the figures, four of the nodes are in areas with direct coverage by the Mesh Access Point. The fifth (top-left) resides in an area not covered by the Mesh Access Point, and hence has an indirect link through another node to the Mesh Access Point. Even at this low level of customer density, it can clearly be seen that coverage is near homogeneous, without any increase in infrastructure cost.

Figure B.5: Mesh Access Point node with 5 subscriber nodes coverage

B.1.15.2.3 Scalability

One of the major problems of deploying a wireless access network is determining its actual size.

Mesh systems do not suffer from scalability problems. In the initial deployment, a provider merely needs to seed the target area with a number of nodes to achieve a certain level of coverage. This can easily and cheaply be obtained by installing a few Mesh Access Points on regular size buildings (BSs require high buildings, the rights to which tend to be exponential with their height) and providing some strategic first customers with rebates.

Once capacity has been reached in this system, expanding capacity is as simply as providing a node with a backhaul link to turn it into a new Mesh Access Point. Due to the automatic power control, which lowers power when too many neighbouring nodes are present, Mesh Cluster sizes will shrink automatically.

B.1.15.2.4 Provisioning Cost

The provisioning cost of rolling out network infrastructure consist of three aspects. In each aspect, a mesh architecture has distinct advantages. The result of the trade-off between hardware cost, right-of-way cost and installation cost for various topologies, makes it very cost-effective to bring a multitude of distributed Mesh Access Points to where the demand is. Of course these distributed Mesh Access Points then need to be connected to the backbone network, which can effectively and cost-efficiently be done with a multi-tiered network structure. Figure B.6 shows an example of such a network, in which residential access is merged with access for corporate customers.

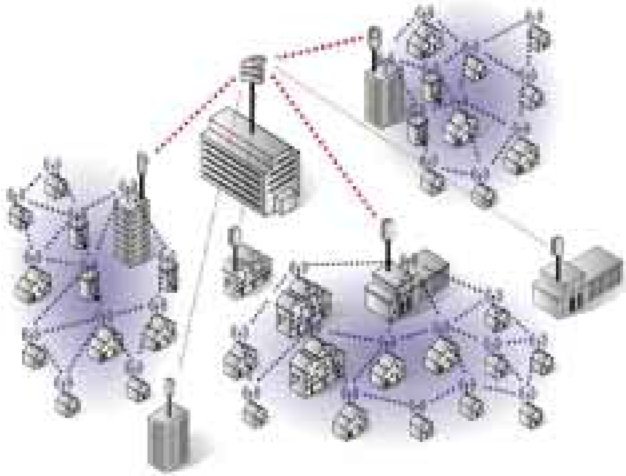

Figure B.6: Multi-tiered access network example

On the subscriber side, the cost of hardware is approximately the same, while the right-of-way cost is zero. However, due to the use of omni-directional antennas and the rooftop height mounting, the installation cost for mesh devices is limited.

B.1.15.2.5 Capacity

As a mesh network inherently forwards traffic, and hence transmits the same data from successive nodes, care must be taken to avoid reducing the Mesh Access Points capacity, as the Mesh Access Point, just like a BS, forms the capacity bottleneck in the system. This is achieved by setting the Mesh Access Point's neighborhood to a different data channel one that all other nodes in the Mesh Cluster, while all nodes use the same control channel. Doing so allows the Mesh Access Point to transmit and receive data with a similar capacity as a BS using the same transmission technology and bandwidth.

Using another data channel does however not require additional channels nor lowers the spectral efficiency. Since the Mesh Access Points energy need only be receivable in a fraction the cell, as other nodes forward traffic to the edges of the Mesh Cluster, the interference level generated by the Mesh Access Point outside its Mesh Cluster is extremely low due the following two facts:

1) Propagation: Mesh systems are located at residential roof-height. Propagation properties, resulting from properties small Fresnell zones, are significantly less favorably, resulting in a very rapid drop-off of excess energy beyond the Mesh Clusters edges.

2) Radiated Power Since the link-distances between mesh devices in a typical deployment are comparatively short to those in PMP systems, and the need for penetrating obstacles to overcome NLOS does not exist, the average EIRP will be much lower than in a PMP system.

As a result of this, it is possible to use the data channel of an Mesh Access Point's neighborhood as the data channel of the nodes in an adjacent Mesh Cluster, which results in an overall same spectral re-use factor and spectral efficiency as a typical sectorized PMP deployment.

B.1.15.3 Any-Point to MultiPoint (APMP)

B.1.15.3.1 Introduction

The APMP architecture is an extension of PMP where any node can take the role of Access Point (AP), Access Terminal (AT) or both. As the network is deployed, it forms a natural tree as shown in figure B.7. Depending on its position in the tree, nodes can take the following roles:

- Root: Only one node in the APMP network acts as the root, it is the AP for all its one-hop children.

- Branch: Nodes that communicate with an upstream AP node (parent), but also assume the AP role to communicate with nodes downstream (children).

- Leaf: Nodes that only communicate upstream with an AP.

The root and the leaf nodes act in a similar fashion as the AP and AT in PMP. Branch nodes, however, are equipped with two antenna ports, A and B. Antenna A is a high gain directional antenna pointing at the node's parent. Antenna B is for communications with the node's children and would typically be a sectored antenna. A branch node alternates between acting as a slave to its parent (on antenna A), and a master to its children (on antenna B). The MAC protocol controls the timing of this switching, which is key to the efficient operation of the APMP network.

Typically, all radios in the APMP would be similar and equipped with the two antenna ports. A leaf node can be promoted to a branch with a simple configuration change, and possibly the installation of the sectored antenna B, if that was not done at the time of the original installation. As beam forming antennas become more economical, they may replace the two-antenna approach described here.

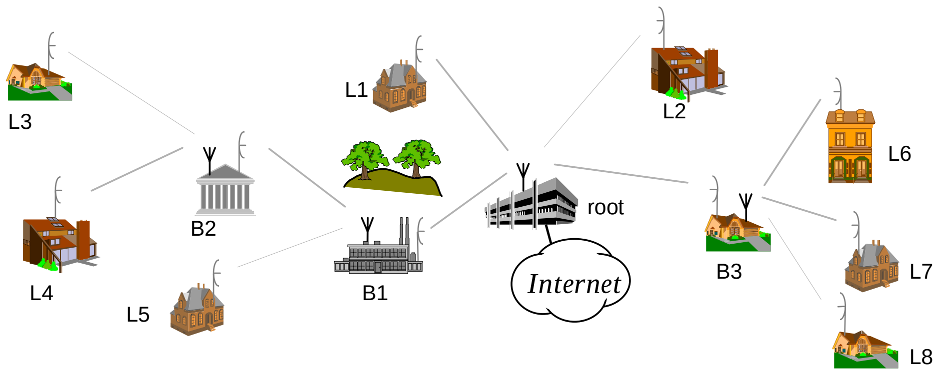

Figure B.7: APMP network topology

B.1.15.3.2 Coverage

PMP networks typically require line of sight between the AP and all the ATs within each cell. More recent developments in technology allow PMP systems to overcome some level of obstructions, taking advantage of multipath effects to recover weak or distorted signals. However, as link distances increase, or the obstructions are too severe, a cell based PMP approach will encounter coverage limitations.

With the APMP extension, any node in the network is a potential AP for other ATs. Hard to reach locations have a much higher probability of being covered through multiple hops. Otherwise, a hard to reach location would require the installation of a new cell with the associated backhaul connection.

B.1.15.3.3 Scalability

The PMP cell based approach requires a backhaul network connecting all the cells from the day that the system is installed. This backhaul network is typically provisioned for the eventual maximum capacity of the system.

The APMP allows a gradual and economical deployment since the APMP network itself provides the initial "backhaul network". While the total traffic does not exceed the capacity of the root radio, a large geographic area can be covered through multiple hops without recurring to an external backhaul link. Once the traffic reaches the capacity of the root radio, the following two approaches can be used to scale up the network:

1) Multiple root radios can be co-located, each feeding a different sector antenna.

2) Branch nodes can be promoted to the roots of their own independent APMP networks. These locations would now need to have a backhaul connection (wired or wireless) to their previous parent. This is the beginning of a backbone that gradually replaces the initial APMP. As traffic demand increases and more branches get promoted to roots, the network evolves to resemble a PMP cell based network. However, the investment in the backbone is gradual and only required once a large number of subscribers are signed up.

B.2 Technical justifications for spectrum

B.2.1 Power

B.2.1.1 PMP Network Architecture

APC is used in a PMP system to lower the transmitted power and hence the overall interference.

B.2.1.2 APMP Network Architecture

APC is used in an APMP system to select the lowest possible power required for reliable communication between nodes. Power control is also used to control range/cell size in a network by reducing transmit power between any two nodes in a branch or cell. The closer the nodes are within a network the lower the transmit power needs to be. The farther away the nodes are within a network the higher the transmit power needs to be. Thus static and dynamic power controls combine to ensure reliable links and minimize interference within a network.

For branch nodes, downstream and upstream links can be at different power levels that are determined by the needs of the system. A branch node, therefore, has the ability to set and control transmit power levels for its upstream and downstream links independently.

APMP systems, due to their architecture, are able to route RF links around obstacles and typically will not require large panel antennas or antenna masts.

B.2.1.3 Mesh Network Architecture

APC is used in a mesh FWA system to select the lowest possible power required for communication to the receiving node (the neighbour used to bypass the packet). Power control is also used to restrict the number of neighbours in a dense network by reducing the power for broadcasted control packets to a level where only the intended receivers can receive the message. Thus the denser a network becomes, the lower transmit powers will be used.

Since it is impractical to seed the network as dense as the target customer density, transmit power in a newly established network need generally be higher to provide coverage of the targeted area. Over time, as customers are added, the transmit power will drop. A mean EIRP limit of 30 dBm is assumed in the proceeding to achieve reasonable initial link ranges of 0,5 km with sufficient margin.

In selected rural cases a 0,5 km link range might not be enough to connect all customers. Compared to the more urban case, the used powers will hardly decrease over time, but on the other hand, the deployment density would be around 1-4 nodes per km^2 and not rise until new settlements are built.

Mesh systems, due to their ability to route around obstacles, do not require masts or big panel antennas, are therefore unobtrusive, and aesthetically suitable to residential deployment.

B.2.2 Frequency

The 5 GHz frequency band provides almost global availability. The global availability will enable larger quantities and thus lower equipment cost due to the economics of scale.

5 GHz is very good also from a propagation perspective. Reasonable link distances can be obtained with EIRP powers up to 30 dBm. The available bandwidth in 5 GHz frequency band is also sufficient to mesh last mile access operation.

The licence exempt status of 5 GHz is also compelling since it lowers the deployment barrier considerably compared to licensed spectrum and allows also set-up of community or private networks without owning the spectrum rights.

B.2.3 Bandwidth and other radio parameters

Transmission mask

The transmission mask being considered is the worst-case combination of the PHYs of HL/2 and the current HIPERMAN/IEEE 802.16a draft standards, which falls within the TM4 TDMA mask requirements [19].

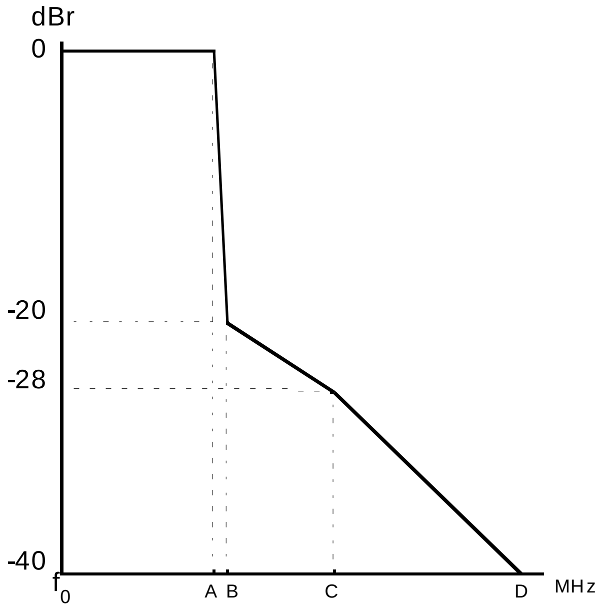

Figure B.8: Transmit spectral power mask

Table B.5: Numeric values for figure B.8

Channelization (MHz)	A	B	C	D
20	9,5	11	20	30
10	4,75	5,5	11	15
5	2,375	2,75	5,5	7,5

Reception mask

The reception mask being considered is the worst-case combination of relatively loose implementations the PHYs of HL/2 and the current HIPERMAN/IEEE 802.16a draft standards.

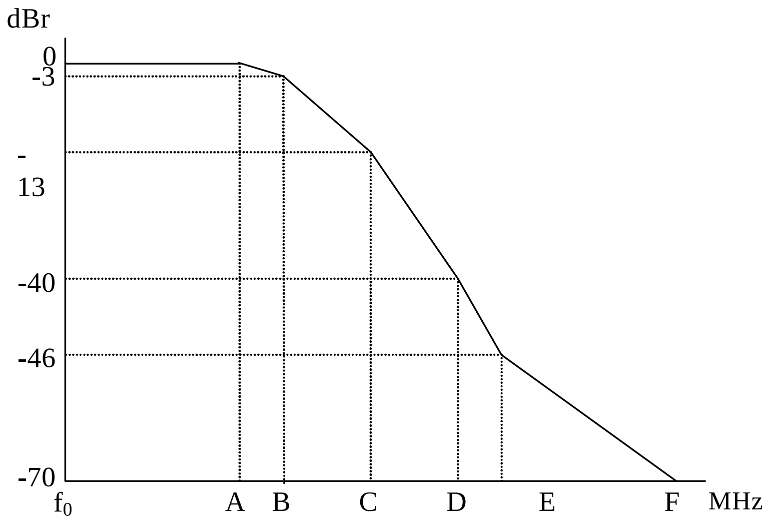

Figure B.9: Reception mask

Table B.6: Numeric values for figure B.9

Channelization (MHz)	A	B	C	D	E	F
20	9	9,5	10,5	11,5	12,0	14,0
10	4,5	4,75	5,25	5,75	6,0	7,0
5	2,25	2,375	2,625	2,875	3,0	3,5

Spurious emissions

The requirements are compliant with CEPT Recommendation 74-01 [34].

Spectrum Power Density

The mean spectrum power density should be less than -13 dBW/MHz. This allows channelization of 20 MHz with the full envisioned 1 W mean EIRP.

B.3 Information on current version of relevant ETSI standard

Physical layers which are envisioned to be permitted are TS 101 475 [3], which is published and the ETSI BRAN HIPERMAN, which is being drafted.

Devices must be compliant with ETS 300 386-2 [17], which is published.

Annex C: Expected Compatibility Issues

C.1 Coexistence studies (if any)

The following areas have been identified for study by CEPT:

- The Fixed Satellite Service (FSS).
- Road Transport & Traffic Telematics (RTTT).
- Radiolocation (radar).
- Short Range Devices (SRDs).
- Amateur Service.
- Amateur Satellite Service.
- Between uncoordinated FWA.

Attachment 1 contains details of a preliminary compatibility study conducted by ETSI BRAN.

Rest of appendix C moved to a new annex at the end of the present document.

C.2 Current ITU allocations

Table C.1 has been duplicated from [13]. Note that this table precedes the HL/2 allocation [11] in 5 470 MHz to 5 725 MHz.

Table C.1: Frequency utilization [13]

Frequency Band	RR Region 1 allocation and relevant footnotes	European Common Allocation	Major Utilization	Notes
5 470 MHz to 5 650 MHz	MARITIME RADIONAVIGATION Radiolocation S5.450 S5.451 S5.452	MARITIME RADIONAVIGATIO N Radiolocation S5.452	Weapon system radars Shipborne and VTS Radar Ground based and airborne weather radar Tactical Radar Position Fixing	EU 22
5 650 MHz to 5 725 MHz	RADIOLOCATION Amateur Space Research (deep space) S5.282 S5.451 S5.453 S5.454 S5.455	RADIOLOCATION Amateur S5.282	Weapon system radars Shipborne and VTS Radar Ground based and airborne weather radar Tactical Radar Position Fixing	EU22, EU17,23 Amateur Satellite Service (Earth to space), 5 650 MHz to 5 670 MHz from RR S5.282
5 725 MHz to 5 830 MHz	FIXED-SATELLITE (Earth-to-space) RADIOLOCATION Amateur S5.150 S5.451 S5.453 S5.455 S5.456	FIXED-SATELLITE (Earth-to-space) RADIOLOCATION Amateur Mobile S5.150	Non civil radiolocation Ground based and airborne weather radar ISM 5 725 MHz to 5 875 MHz 5 795 MHz to 5 805 MHz RTTT SRDs in 5 725 MHz to 5 875 MHz	EU 22, EU23 ERC/DEC(92)02 [35] CEPT/ERC/REC 70-03 [12] Amateur Satellite Service (space to Earth), 5 830 MHz to 5 850 MHz from RR S5.282 RTTT in 5 805 MHz to 5 815 MHz on a rational basis
5 830 MHz to 5 850 MHz	FIXED-SATELLITE (Earth-to-space) RADIOLOCATION Amateur Amateur-Satellite (space-to-Earth) S5.150 S5.451 S5.453 S5.455 S5.456			
5 850 MHz to 5 925 MHz	FIXED FIXED-SATELLITE (Earth-to-space) MOBILE S5.150	FIXED FIXED-SATELLITE (Earth-to-space) MOBILE S5.150	Telecommunications satellites from coordinated Earth stations. Priority for civil networks. ISM 5 725 MHz to 5 875 MHz 5 795 MHz to 5 805 MHz RTTT SRDs in 5 725 MHz to 5 875 MHz	ERC Recommendation CEPT/ERC/REC 70-03

Table C.2: European frequency allocations and utilizations [13]

RR Region 1 Allocation and RR footnotes relevant to CEPT and frequency band	European Common Allocation	Utilization	EU footnote	ECC/ERC document	Standard	Note
5 725 MHz to 5 830 MHz FIXED-SATELLITE (E/S) RADIOLOCATION Amateur 5.150 5.451 5.455 5.456	FIXED-SATELLITE (E/S) RADIOLOCATION Amateur Mobile 5.150 EU22	Amateur applications ISM Non civil radiolocation Non specific SRD Road Transport and Traffic Telematic Systems (RTTT) Weather radars		ERC DEC (01)06 ERC REC 70-03 ERC DEC (92)02 ERC REC 70-03	EN 301 783 EN 300 440 EN 300 674	Within the band 5 725 MHz to 5 875 MHz Within the band 5 725 MHz to 5 875 MHz Within the band 5 795 MHz to 5 805 MHz RTTT in the band 5 805 MHz to 5 815 MHz Ground based and airborne
5 830 MHz to 5 850 MHz FIXED-SATELLITE (E/S) RADIOLOCATION Amateur Amateur-Satellite (S/E) 5.150 5.451 5.455	FIXED-SATELLITE (E/S) RADIOLOCATION Amateur Amateur-Satellite (S/E) Mobile 5.150 EU22	Amateur Satellite applications (S/E) ISM Non civil radiolocation Non specific SRD Weather radars	EU23	ERC DEC (01)06 ERC REC 70-03	EN 301 783 EN 300 440	Within the band 5 830 MHz to 5 850 MHz Within the band 5 725 MHz to 5 875 MHz Within the band 5 725 MHz to 5 875 MHz Ground based and airborne
5 850 MHz to 5 925 MHz FIXED FIXED-SATELLITE (E/S) MOBILE 5.150	FIXED FIXED-SATELLITE (E/S) MOBILE 5.150	Coordinated earth stations in FSS ISM Non specific SRD		ERC DEC (01)06 ERC REC 70-03	EN 301 443 EN 300 440	Priority for civil networks Within the band 5 725 MHz to 5 875 MHz Within the band 5 725 MHz to 5 875 MHz

Table C.3: Frequency allocations [12]

SRD APPLICATIONS IN BANDS ABOVE 2 400 MHz

This spreadsheet is intended to give a rough guide to the frequencies generally available for Short Range Devices.
It should not be taken as a definitive statement of availability and the appropriate annexes should be referred to for the fine detail.
It should also be noted that not all the frequencies listed are available in all CEPT countries and therefore information on free circulation is only indicative.

	Frequency Bands																				Power Levels	Transmitter Antenna Source			Channel Spacing	Licensing Require-ment		Marking and free circulation. For administrations which have not implemented the R+TTE Directive				Duty cycle			
	2 400 MHz to 2 483,5 MHz	2 446 MHz to 2 454 MHz	5 150 MHz to 5 250 MHz	5 250 MHz to 5 350 MHz	5 470 MHz to 5 725 MHz	5 725 MHz to 5 875 MHz	5 795 MHz to 5 805 MHz	5 805 MHz to 5 815 MHz	9 200 MHz to 9 500 MHz	9 500 MHz to 9 975 MHz	10,5 GHz to 10,6 GHz	13,4 GHz to 14,0 GHz	17,1 GHz to 17,3 GHz	24,00 GHz to 24,25 GHz	24.05 GHz to 24.25 GHz	61,0 GHz to 61,5 GHz	63 GHz to 64 GHz	76 GHz to 77 GHz	122 GHz to 123 GHz	244 GHz to 246 GHz	Maximum Power Level	Integral	Dedicated	External	Permitted Channel	Individual Licence	No Individual Licence	Rxxxx SRD Aa	CEPT SRD Aa Y	National Approval	Free Circulation	Very low, < 0.1%	Low, < 1%	High, < 10%	Very High, up to 100%
Non-specific Short Range Devices Annex 1																					See Annex	Y	Y	No	All	-	Y	Y	-	-	Y	-	-	-	-
	Y																				10 mW	Y	Y	No	All	-	Y	Y	-	-	Y	-	-	-	-
						Y															25 mW	Y	Y	No	All	-	Y	Y	-	-	Y	-	-	-	-
														Y							100 mW	Y	Y	No	All	-	Y	Y	-	-	Y	-	-	-	-
																Y			Y	Y	100 mW	Y	Y	No	All	-	Y	-	-	Y	No	-	-	-	-
RLANs, Annex 3	Y																				100 mW	Y	Y	No	250 kbit/s	-	Y	Y	-	-	Y	-	-	-	-
5 GHz HIPERLANs			Y	Y																	200 mW	-	Y	No	All	-	Y	Y	-	-	Y	-	-	-	-
5 GHz HIPERLANs					Y																1 W	-	Y	No	All	-	Y	-	-	Y	No	-	-	-	-
17 GHz HIPERLANs													Y								100 mW	-	Y	No	All	-	Y	-	-	Y	No	-	-	-	-
Railway																																			
Applications, Annex 4 AVI for Railways		Y																			500 mW	Y	Y	No	Annex 4	-	Y	Y	Y	-	Y	-	-	-	-

SRD APPLICATIONS IN BANDS ABOVE 2 400 MHz

This spreadsheet is intended to give a rough guide to the frequencies generally available for Short Range Devices.
It should not be taken as a definitive statement of availability and the appropriate annexes should be referred to for the fine detail.
It should also be noted that not all the frequencies listed are available in all CEPT countries and therefore information on free circulation is only indicative.

	Frequency Bands																				**Power Levels**	**Transmitter Antenna Source**			**Channel Spacing**	**Licensing Require- ment**		**Marking and free circulation. For administrations which have not implemented the R+TTE Directive**				**Duty cycle**			
Road Transport & Traffic Telematics, Annex 5							Y														2 W or 8 W	Y	Y	No	See Annex	-	Y	Y	Y	-	Y	-	-	-	-
								Y													2 W or 8 W	Y	Y	No	See Annex	Y	-	-	Y	Y	No	-	-	-	-
																	Y				t.b.d.	-	Y	No	All	-	Y	Y	Y	-	Y	-	-	-	-
																		Y			See Annex	-	Y	No	All	-	Y	Y	Y	-	Y	-	-	-	-
Movement detection, Annex 6										Y		Y									25 mW	Y	Y	No	All	-	Y	Y	Y	-	Y	-	-	-	-
	Y								Y												25 mW	Y	Y	No	All	-	Y	-	Y	Y	No	-	-	-	-
															Y						100 mW	Y	Y	No	All	-	Y	Y	Y	-	Y	-	-	-	-
											Y										500 mW	Y	Y	No	All	Y	-	-	Y	Y	No	-	-	-	-
RFIDs (under development)																																			
Wireless Audio, Annex 13																																			

Annex D: Initial assessment of compatibility issues by ETSI BRAN for the information of CEPT

This annex contains information on a preliminary analysis of sharing issues.

D.1 Assumptions on FWA systems

In this clause a short description of the FWA systems and services proposed for operation in the band 5,725 GHz to 5,875 GHz is given together with the necessary parameters for the subsequent interference analysis.

D.1.1 FWA PMP system

D.1.1.1 PMP system parameters

The Point to Multi-Point system shall be assumed to have the characteristics as shown below:

Parameter	Value	Unit	Remarks
Considered channel bandwidth	5 and 10	MHz	Narrower channels are preferable to minimize probability of interference. Also, support for frequency re-use in cellular deployments as well as concurrent service providers in same area make these channel bandwidth optimal.
Number of channels in band	12 (10 MHz) 24 (5 MHz)	Channels	150 MHz available between 5 725 MHz to 5 875 MHz. Two 15 MHz guard bands are recommended, leaving 120 MHz available
Access scheme	TDD/TDMA		Band is not paired, therefore FDD is not appropriate in this band
Max Tx peak EIRP (5 MHz)	30	dBm	Consistent with assumptions in ERC report 72
Max power spectral density	-70 (10 MHz) -67 (5 MHz)	dBW/Hz	
Average number of SUs per channels	200	Units	Based on a 6 MHz channel
Per SU Tx duty ratio	3	%	
Per BSU duty ratio	60	%	
BSU antenna gain	15	dBi	Assuming 60 ° and 90 ° antennas
SU antenna gain	18	dBi	
SU antenna beamwidth	20	Degrees	
% rooftop SUs	20	%	Modern FWA systems are required to be "easy to install". This means that customers will be able to install their antennas near an easy to reach location
Rooftop penetration loss	0	dB	
% eaves-mounted SUs	50	%	
Eaves-mount penetration loss	-10	dB	
% indoor mounted SUs	30	%	
Indoor penetration loss	-15	dB	
Number of channel in reuse pattern	6		Based on hex scheme with 4 or 6 sectors
Receiver sensitivity (BSU) (avg. for all modulations)	-88	dBm	
Receiver sensitivity (SU) (avg. for all modulations)	-85	dBm	

D.1.2 FWA APMP system

APMP systems are conceptually a hybrid between PMP and Mesh networks, and the architecture allows a high degree of flexibility in deploying the network to address local concerns. For the purpose of modelling compatibility, the following parameters are assumed.

Deployment model: Exclusive APMP deployment

Node types and distribution:

a) root node
- Incidence: 0,3 %
- Typical antenna: 60 ° or 90 ° sector with 15 dBi gain, 3 ° to 5 ° degree elevation beam width
- Tx activity: 50 % duty cycle

b) branch node
- Incidence: 5 %
- Typical antenna: 24 dBi antenna towards root and 10 dBi OMNI antenna
- Tx activity: 10 % duty cycle

c) leaf node, rooftop mounted
- Incidence: 19,7 %
- Typical antenna: 24 dBi towards root or repeater
- Tx activity: 0,75 % duty cycle

d) leaf node, eave mounted
- Incidence: 25 %
- Typical antenna: 18 dBi towards root or repeater, 10 dB eave loss
- Tx activity: 0,75 % duty cycle

e) leaf node, indoor/window mounted
- Incidence: 50 %
- Typical antenna: window mounted 12 dBi antenna towards root or repeater, 15 dB window penetration loss
- Tx activity: 0,75 % duty cycle

Other radio parameters:

Table D.1: APMP radio parameter assumptions

Parameter	Value	
Channel Bandwidth	10	MHz
Number of channels	12	
Access scheme	TDD	
Max mean Tx EIRP	30	dBm

Table D.2: APMP radio parameters II

Modulation	Coding Rate	Rx Sensitivity (dBm @ 3% PER)	C/I (dB @ 3% PER)
QPSK	1/2	-83	9
	3/4	-81	14
16 QAM	1/2	-76	16
	3/4	-74	20
64 QAM	1/2	-69	25
	3/4	-68	30

Table D.3: Antenna and topology related parameters

	Root	Branch		SU			
		upstream	downstream	roof	eave	indoor	
Avg. APC EIRP reduction	-8	-10		-10			dB
Antenna gain, mainlobe	15	24	15	24	18	12	dBi
Antenna gain, sidelobe	-25	-30	-25	-30	-30	-20	dBi
TX duty cycle	50	4	5	0,75			%

D.1.3 FWA mesh system

The FWA mesh deployment scenario is abstracted into a regular hexagonal shape as shown in figure D.1. At the center of each hexagon, one mesh node is located. By parameterizing the distance between a set of neighboring nodes, different mesh deployment density scenario's can relatively easily be analyzed.

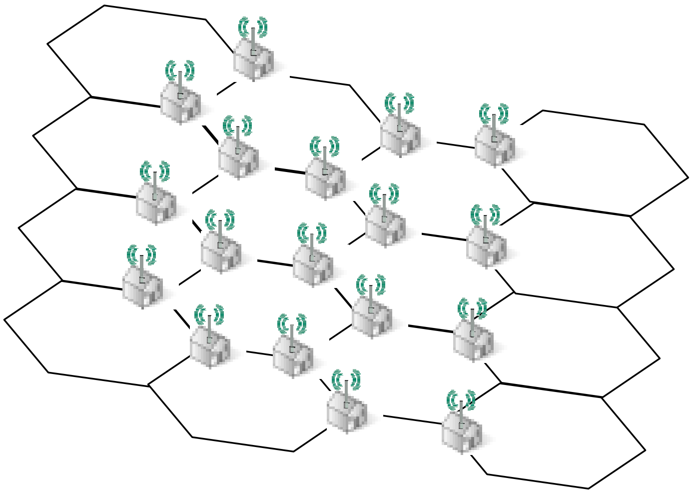

Figure D.1: FWA mesh deployment model

If the distance between two nodes is denoted *r*, then from each node, we have 3 neighbours at distance *r*, 6 nodes at distance $2r\sqrt{3}/2$, 3 nodes at distance $2r$, 6 nodes at distance $3r\sqrt{3}/2$, 6 nodes at distance $3r$, 12 nodes at distance $\sim 4r\sqrt{3}/2$, 3 nodes at distance $4r$, 12 nodes at distance $\sim 5r\sqrt{3}/2$ etc.

Mesh devices that are close to each other cannot transmit at the same time on the same channel. This is normally defined in terms of extended neighbourhoods, which comprises all nodes within two hops from the transmitting node. For modelling purposes, it is assumed that if a node is transmitting, all other nodes on the three hexagons that intersect on that node are silent. This translates into all nodes within a distance of *2r* being silent, which is a low value compared to real deployment scenario's (this is based on Nokia's Neighbourhood Established Transmission Scheduling).

In table D.4, the topology and traffic assumptions are shown. The Tx activity of a node depends heavily on its position in the network, i.e. on how much traffic must be forwarded from/to other nodes, and how active neighbouring nodes are. To keep the analysis simple, an average of 5% is assumed (This based on the current average household internet usage of 30 minutes per day, as well as the activity probability during this on-time).

Table D.4: Topology and traffic parameters

Typical Hops/packet	2
Outdoor nodes	100 %
Total Tx activity/node	5 %
NOTE: The number of hops is the number of nodes a packet has to be transmitted from to reach its destination and an average of the percentage of nodes that have a direct link to the backhaul node (1 hop) and the percentages of nodes with multiple hops to the backhaul node. This number obviously varies from deployment to deployment.	

Though it is possible to install mesh nodes indoors, provided that outdoor nodes provide sufficient coverage, the co-existence study worst case assumes that all nodes are rooftop mounted.

Based on this model, the background interference at any node can be computed, which can be added to the interference from the node in question, resulting in the overall system interference.

D.1.3.1 Antenna parameters

The mesh device is assumed to be using omni-directional antennas at all times, which is a worst-case assumption, as non-broadcast communications between nodes could be performed with smart antennas to reduce overall interference.

It is extremely important to notice that the mesh device is by necessity a roof-mounted device, as it must extend coverage in all directions. In contrast to PMP Subscriber Units (SUs), which are typically installed under the eves, the amount of vertical scattering, which is harmful to both ground-based RLAN devices and satellites, is significantly less despite the lack of directivity. This is due to the relatively good probability of clear line-of-sight of the nodes to each other due to their individual mounting location as well as the significantly shorter distances to each other than a PMP SU typically enjoys to its BS. On top of this, the variation in heights of the nodes' antennas is negligible, whereas a PMP BS typically is installed at much greater height than its SUs, the result of which is that SUs are generally installed with some vertical tilt, which worsens their illumination of satellites.

For these reasons, no extra scattering in the vertical direction is assumed for this evaluation besides the antenna pattern.

As shown in table D.5, the antenna is an 10 dBi gain omni-directional antenna with a -25 dBi vertical gain and worst-case -15 dBi between 30 and 50° from vertical.

The antenna characteristics should include the vertical beamwidth covering 0 ° to 70 ° and 90 °.

Table D.5: FWA Mesh Antenna Parameters

Mounting	Outdoors/rooftop
Gain (Horizontal omni-directional)	10 dBi @ 90° -25 dBi @ 0 - 30° -15 dBi @ 30 - 50°
Polarization	vertical

D.1.3.2 Radio parameters

Based on the co-existence concerns with the IEEE 802.11a [2] and HiperLAN/2 [3] PHY standards and the FWA standardization efforts currently underway for the U-NII band in IEEE 802.16a [4], only OFDM based radios are considered. Although 10 MHz channelization is also being standardized in IEEE 802.16a, the focus here is on the default 20 MHz channelization, which gives the worst case scenarios.

In radio's employing OFDM, a Peak-to-Average Power Ratio (PAPR) of more than 6 dBs (depending on the modulation employed) is used. In order to describe a worst case scenario, a PAPR of 6 dB is used in the analyzed scenarios.

Table D.6: FWA Mesh Radio Parameters- I

Transmit Power	26 dBm (i.e. 1W (30 dBm) mean EIRP, 36 dBm peak EIRP) with dynamic power control
20 dB bandwidth	22 MHz
Peak-to-Average Power	6 dB
Radio Access	TDD/TDMA

Table D.7: FWA Mesh Radio parameters - II

Modulation/Coding Rate		Rx Sensitivity (dBm @ 3% PER)	C/I (dB @ 3% PER)
BPSK	1/2	-82	6
	3/4	-81	11
QPSK	1/2	-79	9
	3/4	-77	14
16QAM	1/2	-74	16
	3/4	-70	20
64QAM	1/2	-66	25
	3/4	-65	30

For the purpose of analytical full network interference analysis, the receiver sensitivity of the mesh system is chosen to be -78 dBm, an average of the modulation and coding mode sensitivities up to rate 1/2, 16-QAM, which will be the most likely used in practical deployments.

D.2 Assumptions on Systems in use

D.2.1 Fixed Satellite Service (FSS)

The characteristics of Fixed Satellite Service satellites have been derived from [1].

The maximum allowable interference power spectral density tolerated by FSS satellites is given by

$$p = -42 - (G/T) - \gamma \text{ dBW/Hz},$$

in which G is the gain of the satellite antenna, T the noise temperature (G/T is termed the merit factor), and γ the link gain. FSS satellites are geo-stationary and hence located at 36 000 km, resulting in 199 dB pathloss. In the case of the Telecom 3 network, which is used as example, 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. G/T then becomes 4,6 dB.

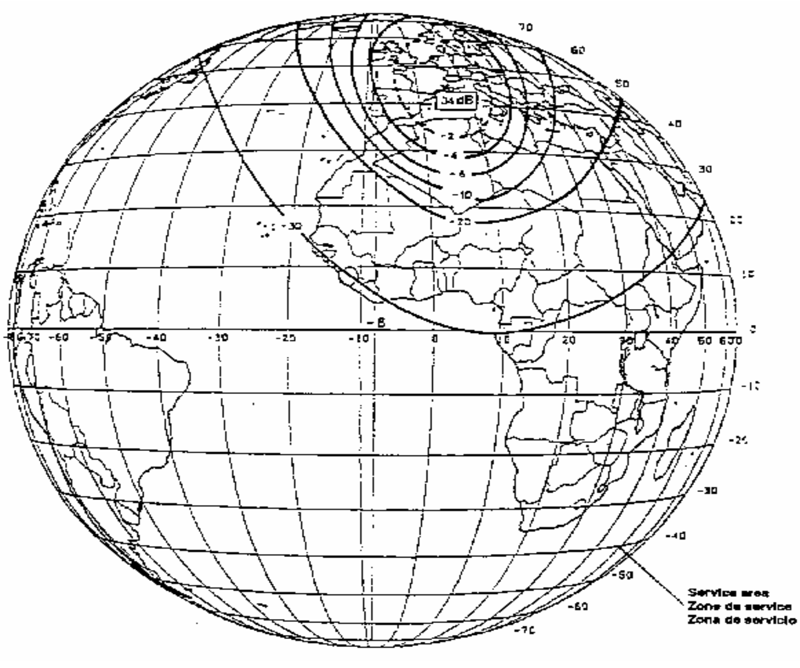

Figure D.2: Telecom 3 FSS Satellite Service Region [1]

D.2.2 Road Transport & Traffic Telematics (RTTT)

RTTT devices [8] are allocated in the band 5 795 MHz to 5 805 MHz (2×5 or 1×10), with an extension band 5 805 MHz to 5 815 MHz (2×5 or 1×10), which may be used on a national basis at multi-lane road junctions. These devices are split into the Road Side Unit (RSU) and the onboard unit (OBU), the parameters for which are shown in tables D.8 and D.9.

Table D.8: RTTT RSU Parameters

Tx Power (max EIRP)	3 dBW
Rx sensitivity	-105 to -130 dBW
Antenna gain	20 dB
C/I: 2/4/8 - PSK	11/14/14 dB
polarization	circular
NOTE: This range is merely informative. The device must merely meet the manufacturer's claim.	

Table D.9: RTTT OBU Parameters (-35° to +35°)

Class	A,B,C,D	F	E
Re-radiated subcarrier power (max EIRP)	-54 dBW	-54 dBW	-44 dBW
Antenna gain	1 dB		
Rx sensitivity	-73 dBW	-87 dBW	-70 dBW
C/I: 2/4/8 - PSK	12/12/14 dB		
polarization	circular		

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: $L = P_t - \max\left\{10\log\left(\frac{B_i}{B_{Rx}}\right), 0\right\} - I_{Rx}$

Where:

P_t = transmitter power

B_{Rx} = receiver bandwidth (MHz)

B_i = interferer bandwidth (MHz)

I_{Rx} = tolerable interference at receiver (dBW)

Required separation distance: $d = \frac{\lambda}{4\pi} 10^{pathloss/23}$ where *pathloss = L + Antenna and feeder gains and losses.*

D.2.3 Radar

The radar parameters used in the radar analysis are taken from [1] and [10]. Only systems B, C and D are relevant for the considered band. System 'F', as mentioned in [1], has been omitted as some essential parameters appeared to be lacking, making analysis impossible. In the analysis, the MCL technique described in clause C.1.1.4 will be used, with the exception that for the airborne radar (radar type B), a propagation exponent 2.0 instead of 2.3 is used.

Table D.10: Relevant Radar parameters

Radar type	A	B	C	D	E	
Peak EIRP	98,6	26	60	93	97	dBW
BW_{radar}	3	15	30	14	3	MHz
Antenna gain	40	0	46	43	43	dBi
Tuning range	5,30 to 5,60	5,70 to 5,80	5,40 to 5,82	5,25 to 5,85	5,60 to 5,65	GHz
Use	Transportable long range	Airborne	Fixed long range	Transportable multi-function	Fixed long range	

D.2.4 Generic Short Range Devices (SRDs)

These are devices regulated by annex 1 of [12].

The maximum e.i.r.p. for such devices in the 5,8 GHz frequency band in [12] is 25 mW. Receiver Performance specification can be found in [27] and [28]. RTTT devices are discussed separately in clause D.2.2.

D.3 Interference Study

D.3.1 FWA Interference to/from FSS

D.3.1.1 FWA PMP Interference to FSS satellite

This clause examines co-existence between PMP FWA systems and Fixed Satellite Service (FSS) operating in the 5 725 MHz to 5 875 MHz band. The band from 5 725 MHz to 5 850 MHz has been allocated for the uplink of FSS (Earth to Space) in Region 1.

The methodology used consists in determining the maximum number of transmitters (including base station and CPEs) that can be deployed in the region considered, based on the parameters determined above and deployment statistics. The method used to determine the maximum allowable aggregate interference power seen by the satellite from the FWA transmitters is based on Appendix S8 of the ITU radio regulations (also detailed in Report 72 of the CEPT).

The following table details the calculation used to determine the total amount of transmitter that can be used in the given area (Region 1).

Table D.11: Maximum interference to FSS by a PMP FWA system

	BSU	SU	
Max. mean EIRP	0	0	dBW
mean EIRP with APC	-5	-5	dBW
Mean antenna sidelobe	-25	-30	dB
Mean EIRP in sidelobe	-30	-35	dBW
Permitted total EIRP in direction of FSS [1]	20,4	20,4	dBW
distribute EIRP over BSU and SU	-3	-3	dB
total power ratio	47,4	52,4	dB
Max. nr of active sources	54954,087	173780,083	
channels	4	4	
Total allowed number of sources	366360,58	34756016,6	Units

A total of more than 240 000 cells and more than 69 million Subscriber Units can be deployed in region 1 (assuming 6 sectors per cell, and two channels used in the cell).

NOTE 1: Directional antennas typically do not point towards satellite geo-stationary arc. The mean sidelobe value should be considered in a statistical analysis (as opposed to the maximum sidelobe value).

NOTE 2: Subscriber installations assume a 80 % deployment under the roof or behind a window.

D.3.1.2 FWA APMP Interference to FSS satellite

The configuration of leaf nodes is essentially similar to the SS in a PMP system. The configuration of root nodes is essentially similar to BS in a PMP system. The configuration of branch nodes in the worst case is essentially similar to an BS co-located with a roof-mounted SS in the PMP system.

Throughout the deployment area, the line of sight to GEO satellites is outside of the antenna beam, even for south facing directional antennas with a moderate up tilt. 18 dBi antennas have a typical beam width of 20 ° to 25 °. Sector antennas used for root or branch nodes have a typical elevation beam width of 3 ° to 6 °. At the polar circle, the elevation angle for a GEO satellite is about 10,5 °. Only an insignificant fraction of the deployment will be at latitudes approaching this. By 60 ° latitude (Oslo/Stockholm/Helsinki) the GEO elevation angle is 22 °, well outside any antenna pattern under consideration.

Table D.12 shows the model for noise affecting the FSS uplink for a network as described under assumptions.

Table D.12: APMP to FSS Interference

Node type	(unit)	Root	Branch, upstream	Branch, down-stream	SU roof	SU eave	SU indoor
Max Tx power, EIRP	dBm	30	30	30	30	30	30
APC pwr reduction, avg	dB	-8	-10	-10	-10	-10	-10
Antenna gain, mainbeam	dBi	15	24	15	24	18	12
Mean antenna sidelobe	dBi	-25	-30	-25	-30	-30	-20
Roof penetration loss	dB	0	0	0	0	-10	-15
Tx duty cycle	%	50,0%	4,00%	5,00%	0,75%	0,75%	0,75%
Duty-cycle derating	dB	-3	-14	-13	-21	-21	-21
Time-avg power in sidelobe	dBm	-6	-24	-18	-31	-41	-36
Noise power contribution	mW	0,25059	0,00400	0,01581	0,00075	0,00007	0,00024
Incidence	%	0,30%	5%	5%	19,7%	25%	50%
Incidence per 1000 nodes		3	50	50	197	250	500
Power contribution per 1000 nodes	mW	0,7518	0,2000	0,7906	0,1478	0,0188	0,1186

Total noise per 1 000 nodes (972 subscribers) is 2,0274 mW.

Allowable nodes within 20,4 dBW limit (110 W) is 54,1 million nodes (52,6 million subscribers).

Compared to the point-to-multipoint model, the repeaters allow a higher power reduction (because a repeater will be available nearer to the subscriber than a PMP base station) and more nodes can be installed with an indoor antenna.

D.3.1.3 FWA mesh interference to FSS satellite

The bandwidth of the FWA mesh device is 22 MHz (73,4 dBHz).

The maximum allowable interference power spectral density tolerated by the Telecom 3 network (see clause D.2.1) then becomes 27 dBW/Hz.

Appendix S8 of the ITU Radio Regulations [5] 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 FWA mesh devices into a satellite receiver, we have to consider all the mesh devices under the satellite footprint as a single source. This means that the source is not specifically located, and only the direct top lobe of the mesh antenna is taken into account.

Table D.13: Tolerable FWA mesh nodes for FSS satellite operation

Tx EIRP	-6	0	3	6	dBW
Tx antenna gain (main lobe)	10	10	10	8	dBi
Tx antenna gain (top lobe)	-20	-20	-20	-20	dBi
Peak-to-Average reduction	6	6	6	6	dB
shielding effect	0	0	0	0	dB
acceptible interference	27	27	27	27	dBW
Active users	501,19	125,89	63,10	19,95	K nodes
Average Tx ratio	5%	5%	5%	5%	
Tolerable nodes	60,14	15,11	7,57	2,39	nodes (millions)

From table D.13, it shows that even using 4 W (6 dBW) EIRP, an enormous amount of FWA Mesh nodes can be in operation within the FSS footprint.

D.3.1.4 FSS Interference to FWA

The candidate frequency band for FWA (5,725 GHz to 5,875 GHz) is currently allocated on primary basis to FSS in Region 1, therefor the impact on the FWA deployment in the vicinity of the Satellite Earth Stations operating in that band has to be studied. The following cases are for further study:

- FSS interference to FWA PMP.
- FSS interference to FWA APMP.
- FSS interference to FWA Mesh.

The TS 101 136 [29] will be used during these studies.

D.3.2 FWA Interference to RTTT

It is understood that either interference mitigation techniques (e.g. DFS or other frequency agile solutions) or even the exclusion of the RTTT frequency range (where necessary) could apply in order to minimize or avoid interference.

D.3.2.1 FWA PMP interference to RTTT

Co-existence between PMP FWA systems and RTTT devices can be handled in two ways:

- Reserve the 5,795 GHz to 5,805 GHz as well as 5,805 GHz to 5,815 GHz for RTTT wherever those are deployed.
- Define co-existence rule for these bands.

The first method is straightforward and will not be detailed in the present document. Note that in the case of a PMP FWA system where directional antennas are the norm at the CPE, the probability of interference from the SU to a RTTT device is very low.

D.3.2.2 FWA APMP interference to RTTT

Co-existence considerations are identical to PMP case.

D.3.2.3 FWA Mesh interference to RTTT

In accordance with [1] and [9], the cross-polarization is assumed to be 10-15 dB to the RSU and 6-10 dB to the OBU (table D.14 uses the lower numbers).

Table D.14: Needed separation distance FWA mesh to RSU and OBU

P_t	6		dBW
B_{Rx}	10	5	MHz
B_i	22		MHz
$I_{Rx} = Rx_{sens}$ - C/I_{8PSK}	-119		dB
L	121,6	118,6	dBW
cross-polarization	10		dB
Antenna&feeder gain	8		dB
RSU Separation distance	651	481	m
P_t	6		dBW
B_{Rx}	10		MHz
B_i	22		MHz
I_{Rx}	-106		dB
L	108,6		dBW
cross-polarization	6		dB
Antenna&feeder gain	8		dB
OBU Separation distance	264		m

It should be noted that in the above calculations, the duty-cycle of the FWA mesh devices, which significantly reduces the interference scenario, has not been taken into consideration.

Especially for the RSU case, where the separation distance is fairly significant, it can be shown that the interference to the FWA mesh device is significantly larger than the other way around. Since RTTT devices normally have a fairly high duty-cycle, a close FWA mesh device would not be able to operate properly in this channel and would need to use the DFS mechanisms to switch to another channel. Therefore, for RSUs, proper operation is virtually guaranteed by virtue of its own interference potential.

D.3.3 FWA interference to Radar

D.3.3.1 FWA PMP interference to Radar

Only radars that transmit or received in the 5,725 MHz to 5,875 MHz bands need to be considered in this study. This includes type B, C and D as identified in report 72.

D.3.3.1.1 Interference to radar

Table D.15: FWA PMP interference to radar - from BSU

Radar Types		B	C	D	
Radar Ant Gain	dBi	0	46	43	
Occ BW radar	MHz	15	30	14	
Rx BW radar		15	30	14	
Rx NF radar		5	5	5	
Min I/N		-6	-6	-6	
On tune rejection		-1,9	0	-2,2	
Max Intf	dBW	-131,3	-130,2	-131,3	
MCL		115	117	115	
Hi elevation FWA beam loss	dB	-30	0	0	
Propagation Loss		100	178	173	
Free Space Intf range	km	0,4	3 496	1 921	at 5 562,5 MHz
Obscured path Intf range	km	0,0	0,5	0,4	range ^3.5

Table D.16: FWA PMP interference to radars - from SU

Radar Types		B	C	D
Radar Ant Gain	dBi	0	46	43
Occ BW radar	MHz	15	30	14
Rx BW radar		15	30	14
Rx NF radar		5	5	5
Min I/N		-6	-6	-6
On tune rejection		-1,9	0	-2,2
Max Intf	dBW	-131,3	-130,2	-131,3
MCL		112	114	112
Hi elevation FWA beam loss		-30	0	0
Propagation Loss		100	178	173
Free Space Intf range	km	0,4	3 496	1 921
Obscured path Intf range	km	0,0	0,5	0,4

As can be seen in this study, interference from FWA into radar is unlikely to be a problem.

In addition Dynamic Frequency Selection (DFS) may provide an additional means of reducing the probability of interference into radar.

D.3.3.2 Radar interference to FWA PMP

Table D.17: Radar interference to FWA PMP BSUs

Radar Type		**B**	**C**	**D**	**Notes**
PeakEIRP	dBW	26	60	93	
BW	MHz	15	30	14	
PRF					
Pulse Width	us	0,5 - 1	0,25 - 1	0,25	
AntGain	dBi	0	46	43	
Tune Range	MHz	5 700-5 800	5 400-5 820	5 250-5 850	
Use		Airborne	Fix Lg Rnge	Transportable	
For interference into BU		**B**	**C**	**D**	
MCL	dB	155	140	179	
Hi elevation FWA beam loss	dB	-30	0	0	
Propagation Loss	dB	140	155	194	
PL less shielding	dB	140	155	194	outdoor use
Distance (5.6GHz)	km	43	240	22 168	Assumes r^2
Radio horizon	km	346,6	51,4	51,4	
Separation distance	km	43	51	51	
If loss to radar is assumed to be Range ^3.5 rarther than LoS then					
Distance (5.6GHz)	km	0,04	0,11	1,52	Assumes r^3.5
Loss to radio Horizon	dB	172	143	143	Assumes r^3.5

Table D.18: Radar interference to FWA PMP SUs

FWA PMP		**BU**	**SU**	**Notes**	
Parameter					
MaxEIRP	dBW	-5	-5	Av with TPC	
AntGain	dBi	15	18		
Ch BW	MHz	6	6		
Max Intf	dBW	-133	-133		
Reqd C/I	dB	18	18		
Rx Threshold	dBm	-85	-85		
Shielding Loss	dB	0			
Interference into SU		**B**	**C**	**D**	
MCL	dB	155	140	179	
Hi elevation FWA beam loss		-30	0	0	
Propagation Loss	dB	143	158	197	
PL less shielding	dB	143	158	197	
Distance (5.6 GHz)	km	60	339	31 314	Assumes r^2
Radio horizon	km	346,6	51,4	51,4	
Separation distance	km	60	51	51	
Distance (5.6 GHz)	km	0,05	0,14	1,85	Assumes r^3.5

It should be noted that in addition to these physical layer parameters, several interference mitigation techniques can be used. For example ARQ, link optimization and Dynamic Frequency Selection (DFS) may provide additional means of managing radar interference into FWA systems.

As a summary, it can be seen in this study, interference from radar into an FWA system is unlikely to be a problem.

D.3.3.3 FWA APMP interference to Radar

This analysis follows the methodology from [1]. Only radars of type B, C and D are considered since all others operate outside the band being considered.

D.3.3.3.1 APMP Interference to radar

Table D.19: APMP Interference to radar

Radar Type		**B**	**C**	**D**
Rx Ant. Gain	dBi	0,00	46,00	43,00
Rx BW (radar)	MHz	15,00	30,00	14,00
Rx NF (radar)	dB	5,00	5,00	5,00
Noise (dBW)	dBW	-124,20	-124,20	-124,20
Minimum I/N	dB	-6,00	-6,00	-6,00
On-Tune rejection	dB	-1,90	0,00	-2,20
Max Interference	dBW	-128,30	-130,20	-128,00
Min Coupling Loss (MCL)	dB	106,06	110,97	105,46
Prop. Loss	dB	130,06	180,97	172,46
Distance free space	Km	13,11	4 603,03	1 728,01

D.3.3.4 Radar Interference to APMP

For this analysis we assumed the most robust modulation and code rate scheme.

Table D.20: Radar Interference to APMP

Radar Type		**B**	**C**	**D**
Peak EIRP	dBW	26,00	60,00	93,00
Antenna Gain	dBi	0,00	46,00	43,00
Transmit Power	dBW	26,00	14,00	50,00
Bandwidth	MHz	15,00	30,00	14,00
Min Coupling Loss (MCL)	dB	146,24	131,23	170,54
Prop. Loss	dB	170,24	201,23	237,54
Shielding	dB	0,00	0,00	0,00
Distance (free space)	Km	1337,94	47415,77	3100411,79
Distance to radio horizon	Km	346,60	51,40	51,40

For all radar types the interference from radar to FWA is considerably stronger than the reverse. Other than the radar type B in table D.20, the separation distance between the two systems becomes the distance to radio horizon.

D.3.3.5 FWA Mesh interference to Radar

For radars, a somewhat similar situation exists as with RTTT RSUs. To show this, the interference distance from radars into FWA mesh devices is derived, followed by the derivation of the interference distance from FWA mesh devices into radars. As is shown below, the first is much larger than the second, necessitating the use of the FWA mesh's DFS algorithm to switch to another channel to survive, eliminating the interference potential to the radar.

For analysis of the minimum distance at which an FWA mesh device still operates, shown in table D.21, the most robust modulation and coding mode is used.

Table D.21: Minimum Separation distance for Radar to FWA Mesh

Radar type	B	C	D	
Peak EIRP	26	60	93	dBW
Antenna gain	0	46	43	dBi
P_t	26	14	50	dBW
BW_{radar}	15	30	14	MHz
$I_{mesh}=Rx_{sens}-C/I_{BPSK\ 1/2}$	-116	-116	-116	dBW
L	142,0	131,3	166,0	dB
gain + feeder loss	10	56	53	dB
propagation loss	152	187,34699	219	dB
distance @ 5.5GHz	173	607	14431	km
radio horizon	346,6	51,4	51,4	km(see[10])
Separation distance	172,8	51,4	51,4	km

In table D.22, the thermal noise level has been assumed -204 dB/Hz, whereas the Rx noise factor is assumed 5 dB. The maximum I/N is -6 dB as specified by NATO (see [1] and [10]).

Table D.22: Minimum Separation distance for FWA Mesh to Radar

Radar type	B	C	D	
P_t (FWA Mesh)	-2	-2	-2	dBW
BW_{radar}	15	30	14	MHz
Noise (dBW)	-127,2	-124,2	-127,5	dBW
On-tune rejection	-1,9	0,0	-2,2	dB (see[1])
Maximum Interference	-131,3	-130,2	-131,3	dBW
L	129,3	129,6	129,3	dB
gain + feeder loss	10,0	56,0	53,0	dB
propagation loss	147,3	193,6	190,3	dB
distance @ 5.5GHz	99,9	1119,4	809,6	km

Comparing the result of table D.21 (line 10) and table D.22 (line 10), we see that in all cases, the separation distance is larger for the FWA system, forcing it effectively out of the channel used by the radar. In all cases, the separation distance is effectively limited by the radio horizon.

In the case of Radar type B, which is airborne, depending on the exact location of the radar, the gain+feeder loss will reduce from +8 to -22 dB, significantly reducing the necessary separation distance. Since the angle of detection (if any) is not known, this factor has not been used in the above tables. For the other types, the distance is limited by the radio horizon, but in practice likely much lower due to obstructions and clutter.

From the above tables, similar conclusions to the RLAN analysis in [1] can be drawn. Sharing with maritime radars (which are not likely operating anywhere near residential areas) and S5.452 meteorological radars in 5,470 GHz to 5,725 GHz and radiolocation radars in both 5,470 GHz to 5,725 GHz and C is feasible when an effective DFS mechanism is employed by the FWA Mesh system operating in the 5, 725 GHz to 5,875 GHz and the radar density is not too high.

D.3.4 FWA Interference to/from SRDs

D.3.4.1 FWA PMP interference to SRDs

Co-existence considerations for FWA PMP interference to SRDs have not yet been considered.

D.3.4.2 FWA APMP interference to SRDs

Co-existence considerations are similar to Mesh case for outdoor SRDs and to PMP for indoor SRDs.

D.3.4.3 FWA Mesh interference to SRDs

For purpose of evaluation, a non-specific SRD device is studied, the nature & characteristics of which are not exactly known. The assumptions made are duplicated from [1]. SRD applications can be categorized in indoor and outdoor devices. RTTT devices and WLAN's, which are sometimes also categorized as SRD devices, are evaluated separately in this study, and hence not included here.

From the analyses as shown below, it can generally be concluded that the ranges in which interference occurs are generally quite short (less than 50 m theoretical worst case). For practical situations, the required distance will be substantially lower.

D.3.4.4 Mesh interference to indoor SRD device

It is assumed that a generic SRD device has 0 dB antenna gain. The isolation due to indoor/outdoor separation is assumed to be limited to one wall, without any other obstructions in the LOS path. The SRD device is assumed to operate randomly and sporadically (like door-opener), as continuously used SRD device would cause the FWA DFS to react and change to a free channel. The separation distance is computed with a loss exponent of 2,5, which is an extremely conservative value (typical values range between 3 and 5).

Table D.23: Minimum separation distance for indoor SRD device to FWA mesh

Item	value	unit	Comment
Mesh max. mean EIRP	30	dBm	
Bandwidth ratio	-13	dB	[1]
Wall isolation	-15	dB	[1]
Net effect	2	dBm	
SRD RF power	14	dBm	25mW EIRP
SRD link budget	82	dB	[1]
SRD minimum wanted signal	-68	dBm	[1]
C/N required for SRD operation	10	dB	[1]
Allowed Mesh power	-78	dBm	in SRD antenna port
Required Mesh free space loss	80	dB	
Required Mesh distance to SRD	6,5	m	assuming r^2.5 pathloss

If the SRD's maximum input level can be higher than -68 dBm and it is sufficient that the application works with shorter range, the required separation distance becomes even smaller. Typically, SRD applications such as RF ID equipment and security sensors function within 0 m to 30 m range, so maximum input level is not supposed to be a problem. In the case of for example 6,5 m range, the SRD receiver level would be -50 dBm, resulting in a required separation distance of only 1,24 m.

At the short distances as calculated above, the angle of radiation at the roofmounted mesh device would for most SRD applications be such, that the EIRP in the direction of the SRD would be substantially lower than the one assumed in [1], further reducing the interference potential.

D.3.4.5 Indoor SRD interference to Mesh

Under the same assumptions and the reverse interference analysis, the interference from SRD's into mesh devices is analyzed.

Table D.24: Minimum separation distance for mesh to indoor SRD

Item	value	Unit	comment
SRD RF power	14	dBm	mean EIRP
Bandwidth ratio	0	dB	
Wall isolation	-15	dB	
Net effect	-1	dBm	
Mesh wanted signal	-82	dBm	
C/N required for Mesh operation	6	dB	
Allowed SRD power	-88	dBm	in Mesh antenna port
Required SRD free space loss	87	dB	
Required SRD distance to Mesh	12,4	m	assuming r^2.5 pathloss

Compared to the reverse direction, the mesh device is more sensitive to inference from the SRD, though the same angle of arrival consideration holds. However, the link-quality measurements performed by the FWA device would be capable of detecting the SRD when very active, and likely activate its DFS.

D.3.4.6 Mesh interference to outdoor SRD device

The analysis for outdoor SRD's is similar to that of indoor SRD's, with the exception that the wall-isolation assumption has been discarded. The assumptions are otherwise the same.

Table D.25: Minimum separation distance for outdoor SRD device to FWA mesh

Item	**value**	**unit**	**Comment**
Mesh max. mean EIRP	30	dBm	
Bandwidth ratio	-13	dB	[1]
Wall isolation	0	dB	
Net effect	17	dBm	
SRD RF power	14	dBm	25mW EIRP
SRD link budget	82	dB	[1]
SRD minimum wanted signal	-68	dBm	[1]
C/N required for SRD operation	10	dB	[1]
Allowed Mesh power	-78	dBm	in SRD antenna port
Required Mesh free space loss	95	dB	
Required Mesh distance to SRD	26,0	m	assuming r^2.5 pathloss

If the SRD desired signal is -50 dBm at 6,5 m as before, the separation distance reduces to 5 m.

D.3.4.7 Outdoor SRD interference to Mesh

Table D.26: Minimum separation distance for mesh to outdoor SRD

Item	value	Unit	comment
SRD RF power	14	dBm	mean EIRP
Bandwidth ratio	0	dB	
Wall isolation	0	dB	
Net effect	14	dBm	
Mesh wanted signal	-82	dBm	
C/N required for Mesh operation	6	dB	
Allowed SRD power	-88	dBm	in Mesh antenna port
Required SRD free space loss	102	dB	
Required SRD distance to Mesh	49,5	m	assuming r^2.5 pathloss

Note that the above calculations assume an isotropic SRD antenna, or an antenna aimed directly at the mesh device on the roof. For practical situations, the required distance will be substantially lower.

D.4 Conclusions by EP BRAN

License exempt bands, which allow for rapid rollout, facilitate making FWA services a viable business case.

- Sharing with satellite services
  - Based on realistic deployment and system considerations, the use of FWA technology was generically shown not to exceed the interference limits for various satellite services in the 5,725 GHz to 5,875 GHz band.
- Sharing with Short-Range Devices
  - From the analyses performed, it can generally be concluded that the ranges in which interference occurs are generally relatively short. Taking into account the relatively low probability of a nearby FWA device operating on the same frequency as the SRD device will ensure excellent sharing conditions.
- Sharing with maritime radars
  - Sharing with maritime radars and radiolocation radars in band C as well as sharing with RTTT devices was found to be feasible when an effective DFS mechanism is employed by the FWA system and the radar density is not too high, as these devices cause significantly more interference to the FWA devices than the other way around.

In general, it is hence concluded that the use of FWA devices in band C of the 5 GHz license exempt spectrum, with a maximum of 17 dBm/MHz mean EIRP density (resulting in 1 W mean EIRP for 20 MHz channels, 0,5 W mean EIRP for 10 MHz channels and 0,25 W max EIRP for 5 MHz) seems feasible from an interference/spectrum sharing with other services perspective. For highly directive antennas (for example 20 °), 20 dBm/MHz is suggested. It is proposed that the use of licence exempt FWA in band C is considered in Europe (subject to power limitation, mask requirements and other functional requirements).

History

Document history		
V1.1.1	November 2002	Publication