Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
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Abstract	This contribution consists of clauses re-organizing and extending the preliminary interference study in Annex A.2 The main extention comes in the form of a description of other services in the 5GHz bands an analysis of the mesh mode of 802.16b air interface standard in 5 GHz. The text is structured around a separation between the PMP and mesh analysis as these different network topologies have significantly different properties. As there is no seperate task group working on a interference and co-existence document for license-exempt, it is important to study the interference and co-existence issues surrounding this standard and maintain it as an annex to the draft standard, because it adds weight to the arguments and efforts to get this standard accepted world-wide. This document is not a standalone document but should be used in parallel with the related comments giving definite instructions.
Purpose	Adopt the text proposed to the 802.16ab-01/01 draft to expand the interference analysis.
Notice	
Release	
Patent Policy and Procedures	

Absurdly late contribution: Appendix A.2 rewrite

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Comment 1 related text follows:

A.2 License-exempt

A.2.1 Interference mitigation and sharing mechanisms

In this clause a number of license exempt interference mitigation and sharing mechanisms is identified. Two categories are considered: mechanisms that fall within the scope of the IEEE 802.16b standard and methods that fall outside that scope.

Within the scope of the IEEE 802.16 standard, three methods are identified: dynamic frequency selection (DFS), which is not mandated by the standard, but mandated by some regulatory bodies such as ERC [B54]; transmit power control, which is mandated by the standard [REF????] and by some regulatory regions such as ERC [B54]; and ephemeris transmit interruption, which is mandated by neither.

Outside the scope of the IEEE 802.16 standard, two methods are identified: antenna directivity and antenna polarization.

A.2.1.1 Dynamic frequency selection

As frequency planning is not practical in licensed-exempt bands, DFS can be used to avoid assigning a channel to a channel occupied by another system. DFS is generally based on comparison of a C/I threshold against idle time RSSI measurements. DFS is predominantly effective to combat interference from and to ground based systems, such as WLANS, RTTT, radar and other IEEE 802.16b compliant systems. It is generally ineffective to combat interference from and to airborne systems, such as airborne radars and satellites.

A.2.1.2 Transmit power control

With power control, the transmitter EIRP is reduced according to the link margin. Shorter link ranges hence result in lower transmitted power levels. For PMP systems, the average EIRP will hence typically be several dB’s below the legal limit assuming that SSs are spread throughout the coverage area. For mesh systems, this means that EIRP values decrease rapidly as customer deployment density increases. Therefore, an estimate of total interference within the footprint could be as much as 'n' dB below the reference value. As power control is also influenced by C/I levels, the use of TPC with DFS, where possible, tends to result in the most effective interference mitigation.

A.2.1.3 Ephemeris transmit interruption

Earth Resources Satellites operate at very precise orbits, therefore, the Ephemeris (orbital position correlated to time) of the satellites can be calculated with great accuracy. If an Ephemeris calculator is included in the basestations, and/or in the networks, the stations could be muted during the satellite pass. This would amount to a muting time of approximately 15 seconds per satellite pass-typically 5-10 days per pass. Coupled with antenna directivity, this feature would allow virtually any number of stations to operate within the satellite footprint.

A.2.1.4 Antenna directivity

Antenna directivity, in horizontal but especially in vertical direction can significantly reduce an FWA's interference potential and resilience. Vertical directivity especially reduces the interference caused to satellite systems, which are designated primary users of part of the addressed bands. It also can significantly help reduce interference to and from indoor WLAN systems. Horizontal directivity significantly reduces the probability of interference to other systems (assuming interference is mainly caused in the main lobe), but tends to increase the severity of the interference, as the energy in the main lobe is generally higher.

A.2.1.5 Antenna polarization

Antenna cross-polarization in the 5GHz band can achieve an isolation of up to 15 dB in LOS, but reduces significantly in near-LOS and NLOS environments. Most deployments use both horizontal and vertical polarization (circular polarization is not as common in currently known systems) to maximize spectral re-use. Polarization hence has the potential to provide some isolation between differently polarized systems, especially in LOS, but given the operational needs and implementation of most systems in the targeted spectrum, the effectiveness will be mostly marginal.

A.2.2 Services in the 5 GHz band

In this section a short description of the systems and services in the 5GHz bands is given together with the necessary parameters for the subsequent interference analysis. This includes assumptions on parameters of IEEE 802.16b compliant systems that are beyond the scope of this standard.

It is important to note that, throughout this study, the use of 6 dBW max. EIRP is assumed for all parts of the spectrum with a backoff of only 3 dB for WLAN type devices. In a practical OFDM system, the backoff is in the order of at least 6 dB minimum, whereas the rules commonly specify at most 0 dBW maximum mean EIRP [B55] or 6dBW maximum peak EIRP [B19] for fractions of the band. It should hence be understood that this study errs on the side of caution in how much interference can be tolerated.

A.2.2.1 IEEE 802.16b PMP system

TBD

A.2.2.2 IEEE 802.16b mesh system

The Mesh deployment scenario is abstracted into a regular hexagonal shape as shown in Figure 1. On each corner 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.

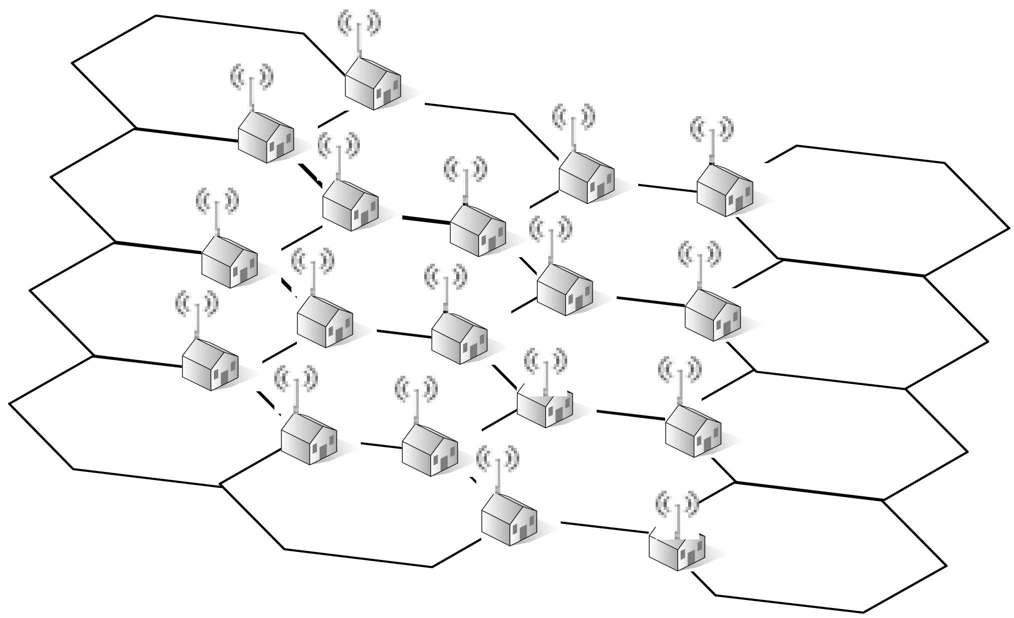


Figure 1—IEEE 802.16b mesh deployment model

If the distance between two nodes is denoted *r*, then from each node, we have 3 neighbors 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 neighborhoods, which comprises all nodes within two hops from the transmitting node. For modeling 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.

In Table 1, 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 neighboring 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 1—Tx activity parameters

Parameter	Value
Typical hops/packet	2
Total Tx activity	5%

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.

A.2.2.2.1 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 System (SSs), which are typically installed under the eves, the amount of vertical scattering, which is harmful to both ground-based WLAN devices and satellites, is significantly less despite the lack of horizontal 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 SS 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 SSs 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.

Table 2—Antenna parameters

Parameter	Value
Mounting	Outdoors/rooftop
Gain (Horizontal omni-directional)	8 dBi @ 90° -22 dBi @ 0 - 30° -15 dBi @ 30 - 50°
Polarization	vertical

As shown in Table 2, the antenna is an 8dBi gain omni-directional antenna with a -22 dBi vertical gain and worst-case -15 dBi between 30 and 50° from vertical.

A.2.2.2.2 Mandatory mode Radio parameters

Although 5 and 10 MHz channelization are also defined, the focus here is on the mandatory 20 MHz channelization, which gives the worst case scenarios.

It is important to note that the use of 6 dBW max. EIRP is assumed for all parts of the spectrum with a backoff of only 3 dB. In a practical OFDM system, the backoff is in the order of at least 6 dB minimum, whereas the rules commonly specify at most 0 dBW maximum mean EIRP [B55] or 6dBW maximum peak EIRP [B19] for fractions of the band. It should hence be understood that the analyses err (by 3 to 10 dB) on the side of caution in how much interference can be tolerated.

Table 3—Relevant Radio parameters I

Parameter	Value
Transmit Power	28 dBm (i.e. 36 dBm max EIRP) with dynamic power control
20 dB bandwidth	21 MHz
Peak-to-Average Power ratio	3 dB

The Rx Sensitivity and C/I parameters for the code rates defined in Table 175 and Table 195 are temporarily, as they are currently not yet defined in the IEEE 802.16b standard.

They are estimated using the formula:

$$Rx_{sens}(dBm) = K \cdot T_0(dBm) + 10\log(BW_{-26dB}) + NF(dB) + SNR_{avg} + margin$$

The thermal noise is $K \cdot T_0 = -174dBm$ and the noise figure is chosen to be $NF = 7dB$. The margin is assumed to be 5dB, consistent with [B47]. This leaves us with $Rx_{sens}(dBm) = SNR_{avg} - 88.5$. SNR's are guesstimated from several preliminary studies

Table 4—Relevant Radio parameters II

Modulation	Coding Rate	SNR_{avg} (dB @ 0.1%PER)	Rx Sensitivity (dBm @ 0.1% PER)
BPSK	1/2	7	-82
	3/4	13	-76
QPSK	1/2	10	-79
	3/4	17	-72
16QAM	1/2	19	-70
	3/4	25	-64
64QAM	2/3	30	-59
	3/4	40	-49

For the purpose of analytical full network interference analysis, the receiver sensitivity of the mesh system is chosen to be -75 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.

A.2.2.3 EESS and FSS

Two types of satellite services are deployed in the 5 GHz; fixed satellite service (FSS) and earth exploratory satellite systems (EESS) services, EESS services are provided by two distinct types of satellite: Altimeter satellites and SAR satellites.

A.2.2.3.1 Altimeter satellites

The characteristics of altimeter satellites have been derived from [B46].

Table 5—Altimeter satellite characteristics

Parameter	Value
Bandwidth	320 MHz
Rx sensitivity	-88 dBm
On-axis Antenna gain	32.5 dBi
Off-axis Antenna gain	$10^{3.25}(\mathrm{Sin}(\varphi)/\varphi)^2$ [a]
Antenna size	1.2 m
height	1344 km
Input loss = Output loss	1 dB
coverage	$\varphi \in [-60°, 60°]$
Bandwidth	320 MHz

a. φ is the angle between the vertical and the direction of the ground-based device

A.2.2.3.2 SAR satellites

The characteristics of SAR-1 through SAR-4 satellites have been derived from [B46].

Table 6—Typical Spaceborne Imaging Radar Characteristics

Parameter	Value			
	SAR1	**SAR2**	**SAR3**	**SAR4**
Orbital Altitude	426 km (circular)	600 km (circular)	400 km (circular)	400 km (circular)
Orbital Inclination	57 deg	57 deg	57 deg	57 deg
RF Centre Frequency	5305 MHz	5305 MHz	5305 MHz	5300 MHz
Peak Radiated power	4.8 Watts	4800 Watts	1700 Watts	1700 Watts
Polarization	Horizontal (HH)	Horizontal & Vertical (HH,HV,VH,VV)	Horizontal & Vertical (HH,HV,VH,VV)	Horizontal & Vertical (HH,HV,VH,VV)
Pulse Modulation	Linear FM chirp	Linear FM chirp	Linear FM chirp	Linear FM chirp
Pulse Bandwidth	8.5 MHz	310 MHz	310 MHz	40 MHz
Pulse Duration	100 µs	31 µs	33 µs	33 µs
Pulse Repetition Rate	650 pps	4492 pps	1395 pps	1395 pps
Duty Cycle	6.5%	13.9%	5.9%	5.9%
Range Compression Ratio	850	9610	10230	1320
Antenna Type	Planar phased array 0.5m x 16.0m	Planar phased array 1.8m x 3.8m	Planar phased array 0.7m x 12.0m	Planar phased array 0.7m x 12.0m
Antenna Peak Gain	42.2 dBi	42.9 dBi	42.7/38 dBi (full focus/beam-spoiling)	42.7/38 dBi (full focus/beam-spoiling)
Antenna Median Sidelobe Gain	-5 dBi	-5 dBi	-5 dBi	-5 dBi
Antenna Orientation	30 deg from nadir	20-38 deg from nadir	20-55 deg from nadir	20-55 deg from nadir
Antenna Half-power Beamwidth	8.5 deg (El), 0.25 deg (Az)	1.7 deg (El), 0.78 deg (Az)	4.9/18.0 deg (El), 0.25 deg (Az)	4.9/18.0 deg (El), 0.25 deg (Az)
Antenna Polarization	Linear horizontal/ vertical	Linear horizontal/ vertical	Linear horizontal/ vertical	Linear horizontal/ vertical
System Noise Temperature	550 K	550 K	550 K	550 K
Image swath width	50 km	20 km	16 km/ 320 km	16 km/ 320 km

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

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

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

Table 7—Typical Spaceborne Imaging Radar Characteristics

Parameter	Value			
Noise (dBW)	-129.5	-113.8	-113.8	-122.7
Minimum Desired Signal (dBW)	-189.7	-198.6	-187.1	-187.0
Maximum Acceptable Interfering signal (dBW)	-135.5	-119.8	-119.8	-128.7
Receiver Bandwidth (MHz)	9.8	356.5	356.5	46
Maximum Acceptable Interfering spectral power density (dBW/Hz)	-205.4	-205.4	-205.4	-205.4
Antenna Polarization	Linear horizontal/ vertical	Linear horizontal/ vertical	Linear horizontal/ vertical	Linear horizontal/ vertical
System Noise Temperature	550 K	550 K	550 K	550 K
Receiver front end 1 dB compression point ref to receiver input	-62 dBW input	-62 dBW input	-62 dBW input	-62 dBW input
Ground Illumination Area	93 km (elevation), 2.2 km (azimuth)	At 20° from nadir: 20 km (elevation), 8.7 km (azimuth)	At 20° from nadir: 40 km (elevation) 2 km (azimuth)	At 20° from nadir: 40 km (elevation) 2 km (azimuth)

A.2.2.3.3 FSS satellites

The characteristics of Fixed Satellite Service satellites have been derived from [B46].

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

$$p = -42 + (G/T) - \gamma \qquad dBW/Hz$$

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 36000 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.

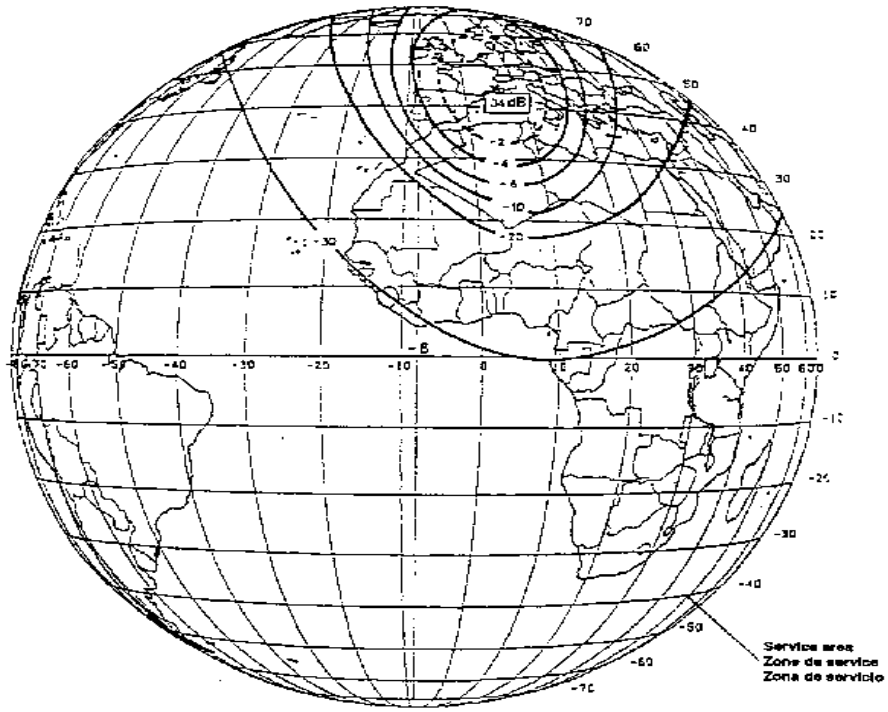


Figure 2—Telecom 3 FSS Satellite Service Region [B46]

A.2.2.4 WLANs

The WLAN deployments considered here are the ETSI BRAN HIPERLAN/2 [B48] and IEEE 802.11a devices. Only indoor deployments are considered in detail. It is clear that outdoor WLAN devices can generally not co-exist in the same channel with FWA devices in the same geographical area. However, the use of DFS, as well as the fact that the hotspot locations envisioned for outdoor WLAN deployments (such as airports and school campuses) do generally not coincide with the residential areas Mesh devices are targeted towards, easily resolve this type of WLAN deployments.

Table 8—WLAN Parameters I

Parameter	Value
Antenna type	Isotropical
Tx probability WLAN device	5%
Tx Power	30 dBm max EIRP with dynamic power control
Radio Access	TDD/TDMA

Table 9—WLAN parameters II[a]

Modulation	Coding Rate	Rx Sensitivity (dBm @ 10% PER)	C/I (dB @ 10% 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

a.Copied from [B47], Table 91

A.2.2.5 RTTT

Road transport & traffic telematics (RTTT) devices[B51] are allocated in the band 5795-5805 MHz (2×5 or 1×10), with an extension band 5805-5815 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 Table 10 and Table 11.

Table 10—RTTT RSU Parameters

Parameter	Value
Tx Power (max EIRP)	3 dBW
Rx sensitivity	-105 to -130 dBW[a]
Antenna gain	20 dB
C/I: 2 / 4 / 8 - PSK	6 / 9 /12 dB
polarization	circular

a. This range is merely informative. The device must merely meet the manufacturer's claim.

Table 11—RTTT OBU Parameters (-35° to +35°)

Parameter	Value	
Class	A,B,C,D	E
Re-radiated subcarrier power (max EIRP)	-54 dBW	-44 dBW
Antenna gain	1 dB	
Rx sensitivity	-73 dBW	-70 dBW
C/I: 2 / 4 / 8 - PSK	6 / 9 /12 dB	C/I: 2 / 4 / 8 - PSK
polarization	circular	polarization

In analyzing 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 $pathloss = L + Antenna\ and\ feeder\ gains\ and\ losses$

A.2.2.6 Radar

The radar parameters used in the radar analysis are taken from [B46],[B53]. In the analysis, the MCL technique described in clause A.2.2.5 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 12—Relevant radar parameters

Parameter	Value				
Radar type	A	B	C	D	E
Peak EIRP (dBW)	98.6	26	60	93	97
BW_{radar} (MHz)	3	15	30	14	3
Antenna gain (dBi)	40	0	46	43	43
Tuning range (GHz)	5.30-5.60	5.70-5.80	5.40-5.82	5.25-5.85	5.60-5.65
Use	Transportable long range	Airborne	Fixed long range	Transportable multi-function	Fixed long range

A.2.3 IEEE 802.16b PMP interference analyses

A.2.3.1 Coexistence with SAR satellites in middle UNII

The Wireless HUMAN Standard-based systems that will operate in the middle U-NII band (5.25-5.35 GHz) will have to share this band with a number of other systems (e.g., Earth Exploratory Satellite (active) Service (EESS) Synthetic Aperture Radars (SARs), Wireless HUMAN Standard-based systems, non-standard point-to-multipoint Broadband Fixed Wireless Access (BFWA) systems, terrestrial Radars, and IEEE 802.11a, 802.15 and HIPERLAN/2 Wireless LANs). As this is a License-Exempt (LE) band these diverse systems will often be operated in the same geographical area by different operators. Moreover besides having to meet local Regulatory requirements (e.g., in the USA the FCC Subpart E Requirements) the Wireless HUMAN Standard-based systems will also be called to meet global agreements; e.g., from the World Radiocommunications Conference (WRC).

What follows gives an indication of the interference that Wireless HUMAN based BFWA systems can cause to SARs operating in Middle U-NII band. In particular it has been shown by published results of ITU-R studies that BFWA antenna directivity is effective in minimizing interference to SAR-4, (e.g., USA ITU-R WP7C/24 Contribution). Table 13 shows that use of 6dB antenna directivity can decrease the SAR-4 interference by 4dB.

Note: The value of antenna directivity that should be specified requires trade-off studies with the other mechanism. SAR-4 is used because the SAR-4 system is more interference sensitive than SAR-3 and SAR-4, and the SAR-4 center frequency is 5.3GHz.

The SAR-4 Synthetic Aperture Radar scans a path from 20^{o} to 55^{o} from Nadir. This corresponds to Earth incident angles of 21^{o} and 60^{o}-which can be translated to angles of 69^{o} and 30^{o} with respect to the horizon. That is, any radiation from U-NII devices within that angular range could cause/contribute to satellite interference.

An approach that can be used in analyzing the interference potential from Middle U-NII BFWA systems into spaceborne SAR-4 receiver is to determine the worst case signal power received from a single BFWA transmitter at the spaceborne SAR. Then, the single interferer margin can be calculated by comparing the single BFWA interferer level with the SAR-4 interference threshold. Knowing the SAR-4 footprint, the allowable density of active BFWA transmitters can then be calculated, if a positive margin results from a single BFWA interferer.

Table 13—Single U-NII BFWA to SAR-4 Interference

Parameter	System	Value	dB
Transmitted Power (W)	BFWA1	0.25	-6.02
	BFWA2	0.25	-6.05
Building Loss (dB)	-	0	0
Antenna High Elevation TX Gain (dB)	BFWA1	0	0
	BFWA2	-4	-4
Antenna Gain, RX (dB)	-	44.52	44.52
Polarization Loss (dB)	-	3	-3
Wavelength (m)		0.0565	24.96
$(4\pi)^2$		0.00633	-21.98
Distance (km)		425.67	-112.58
Power RX (dBW)	BFWA1	-	-124.03
	BFWA2	-	-128.03
Noise Figure (dB)	-	4.62	4.62
kT	-	$4 \cdot 10^{-21}$	-203.98
RX Bandwidth (MHz)	-	46	76.63
Noise Power (dBW)	-	-	-122.73
SAR-4 Interference Threshold (I/N=-6dB)	-	-	128.71
Margin (dB)	BFWA1	-	-4.71
	BFWA2	-	-0.71

Table 13 shows the signal power at the SAR-4 receiver from a transmitter with power output of -6 dBW (24 dBm) and an isotropic radiator with unity gain at all look angles. The space loss at angles of 21^o and 60^o, receive antenna gain, polarization loss, scattering gain and satellite interference threshold are derived from ITU-R reports. The reference margin is the difference between the Signal Power at the Satellite Receiver and the Satellite Interference Threshold. The negative margin numbers indicate that radiating an EIRP of 24 dBm toward the satellite will exceed the interference threshold. Fortunately, real-world antennas do not exhibit unity gain at high elevation look angles, and this feature can be used to mitigate interference

A conclusion that can be drawn is that antenna directivity, if properly utilized, will provide interference margin for multiple transmitters. However, it should be noted that the satellite footprint is large (53 sq. km at 20^o from Nadir and 208 sq. km at 55^o from Nadir). Therefore, given the potential variables associated with the design, installation and maintenance of the various unlicensed transmitters, antenna directivity alone may not be sufficient to assure non-interference.

The margin calculation in Table 13 includes 3 dB polarization loss. The fact that most P-MP systems rely on polarization for maximizing channelization, as many as half of the U-NII transmitters in a given area could be transmitting on each polarization. If so, the 3 dB polarization loss may not be fully realizable.

If the satellite were restricted to one linear polarization and the U-NII transmitters were restricted to the other linear polarization, greater polarization isolation could be achieved. Given the operational needs of both services, this is unlikely to happen.

A.2.4 IEEE 802.16b mesh interference analyses

A.2.4.1 Interference to EESS and FSS

A.2.4.1.1 Altimeter satellites

The interference from one mesh node into the boresight of the SAR can be described by (see [B46])

$$P_r = \frac{P_m G_m G_a \lambda^2}{(4\pi)^2 R^2} L$$

in which $P_m G_m = 6dBm$ (28 dBm Output power - 22 dBi top lobe) is the EIRP of the mesh antenna in the vertical direction, $G_a = 32.5dBi$ the gain of the altimeter antenna, $\lambda = 5.66cm$ the wavelength, $L = -1dB$ the input loss of the altimeter, and $R = 1344km$ the lowest orbit.

From this we obtain a value for $P_r = -132dBm$

The altimeter interference threshold is - 88 dBm; we can thus deduce that the altimeter can withstand the operation of huge numbers of mesh devices simultaneously, since we have a 44 dB margin. Furthermore, the altimeter is built to provide measurements mainly over oceans and is not able to provide accurate data when a significant amount of land is in view of its antenna beam. From this analysis, it is clear that the altimeter will not suffer from the operation of Mesh networks. However, for completeness, the number of mesh devices per square kilometer tolerable by the altimeter can be calculated.

The distance between the satellite and a mesh node under angle φ is R tan(φ) km. Only freespace attenuation, which ignores atmospheric properties (which further attenuate the signal, especially when φ>>0) has been considered.

For simplicity, the 3 mesh nodes that on average exist in one hexagon are assumed to all be in the centre point of the hexagon. The hexagon grid then reduces to a square grid with 3 nodes every 2 times the distance of a single set of nodes.

We then have:

$$P_r = \sum_{r_1}\sum_{r_2} \frac{3P_m G_m G_a \lambda^2}{(4\pi)^2 R^2} L\left(1 + 4A\sum_{r_1}\sum_{r_2} \operatorname{sinc}^2[2\varphi(r_1,r_2)]\right) \qquad \forall \sqrt{r_1^2 + r_2^2} < \frac{R\sqrt{3}}{2} \qquad \varphi = arc\tan\left[\frac{2\sqrt{r_1^2 + r_2^2}}{R}\right]$$

in which r_1 and r_2 enumerate over the square grid, and A is the activity factor. This derivation is easily computed numerically. According to [B50], significantly less than 15%[1] of land is used for residential areas and normally a significant fraction of the footprint covers water as well. Hence a Residential fraction of 0.05 is introduced, to simulate

1. Figure includes land used for urban and other purposes, e.g. transport and recreation, and non-agricultural, semi-natural environments, e.g. sand dunes, grouse moors and non agricultural grasslands, and inland waters.

clusters of nodes spread out over the whole satellite footprint. The receiver sensitivity is, as discussed in clause A.2.2.2.2, chosen to be -75 dBm.

```
%Satellite specifications
Ga = 32.5;              % dBi   Antenna gain
lambda = 0.0566;        % m     Wavelength
L = -1;                 % dB    Insertion Loss
R = 1344;               % km    Height
Int_limit = 88;         % dBm Interference limit
%Mesh specifications
Rbase = 0.5;            % km    Distance between two mesh nodes
AntGain  = 8            % dBi   Mesh antenna gain (max)
AntTop   = -22          % dBi   Mesh antenna gain (top-lobe)
RxSens      =-105       % dBW Rx sensitivity Mesh
Pout        = 28;       % dBm Max. output power Mesh
Backoff   = 3;          % dB   Average Backoff
Activity    = 0.05;
pi = 3.1415;
pathloss = -20*log10(3E8/(4*pi*5.3E9))+2.3*10*log10(Rbase*1000);
PmGm = (pathloss - AntGain + FadingMargin + RxSens) + (AntTop-AntGain) -Backoff+ 30; % dBm
Residential = 0.15;     % fraction residential landuse
Pr1 = 0;nodes =0;
for r1 = Rbase : Rbase/sqrt(Residential): R*sqrt(3)/2
    for r2 = Rbase : Rbase/sqrt(Residential): R*sqrt(3)/2
        if( sqrt(r1*r1+r2*r2) < R*sqrt(3)/2)
            nodes = nodes+3;
            phi = atan( 2*sqrt(r1*r1+r2*r2)/R );
            Pr1 = Pr1 + sinc(2*phi/pi)*sinc(2*phi/pi);
        end;
    end;
end;
Pr2=10*log10(3*lambda*lambda*(1+4*Pr1*Activity)*10^((Ga+PmGm+L)/10)/...
        ((4*pi)*(4*pi)*R*R*1E6) );
sprintf('Distance between nodes: %d m\n',Rbase*1E3)
sprintf('Interference margin to altimeter: %d dB\n',Int_limit + Pr2)
```

Figure 3—mesh interference code sample

The result of the simulation, as shown above, is that over 30 million nodes can be supported under the footprint, with 6 dB in interference margin. In many cases shorter distances between the nodes will result in lower used power due to power control. Hence in practice many more nodes could be supported without violating the interference limit.

A.2.4.1.2 SAR satellites

In analogy with [B46], only the case for SAR-1 satellites is examined, since this provides the worst case analysis. However, contrary to this report, it will show that using mesh technology, an increase in network density actually reduces the interference into the SAR satellite, since the dynamic power-control reduces the power for shorter links. The receiver sensitivity is, as discussed in clause A.2.2.2.2, chosen to be -75 dBm.

As can be seen from Table 14, a mesh networks has limitations both on the maximum distance and maximum density of the network. The maximum distance that can be achieved by the mesh network using 4 Watts EIRP is about 1 km, which retains a margin of 10 dB to the interference threshold.

Deployments with distances between nodes of one km are however exceedingly sparse and not practical except in the very early stages of service rollout (i.e. when seeding the service area).

Reducing the distance increases the number of nodes, but reduces the necessary power levels, hence reducing the overall interference into the satellite. Increasing the density, and hence the number of nodes to very high levels, up to about one device per 92 m would still obtain tolerable interference levels. Deployment densities of this nature, especially in the areas of major interest to the satellite community (which to our understanding are mostly oceanic and agrarian), are however extremely unlikely.

PMP systems do not enjoy the same advantage, as increased capacity needs are mostly met by increasing the number of sectors on the base-station, keeping the EIRP on each SU constant. Interference in that case increases linearly with the number of sectors deployed, and hence in practice linearly with the number of SUs installed on each basestation. The limitations on the SU density are hence much sooner violated.

To allow an easier comparison with the WLAN results in [B46], Table 14 computes the number of Mesh devices that can be situated in the SAR footprint without exceeding the interference limit.

Table 14—IEEE 802.16b mesh devices in the SAR footprint

Parameter	Value				
Node distance	1	0.5	0.25	0.1	km
Tx antenna gain	8				dBi
Rx sensitivity	-105				dBW
path loss	115.93	109.00	10.08	92.93	dB
P_{out} required (EIRP)	2.93	-4.00	-10.92	-20.07	dBW
P_{out} required (conducted)	-5.07	-12.00	-18.92	-28.07	dBW
freespace distance	-160.8				dB
building attenuation	0				dB
Tx antenna gain (top lobe)	-22				dBi
Polarization loss	-3				dB
Peak-to-Average ratio	-3				dB
Rx antenna gain (main lobe)	42.4				dBi
Rx Power	-224.90	-231.82	-238.74	-247.90	dBW/Hz
SAR threshold	-205				dBW/Hz
margin	19.54	26.46	33.38	42.54	dB/Hz
SAR footprint	22.59				dB
Tx activity	-13.01				dB
Permissible density/km^2/ch	9.91	498.78	240.22	1976.39	nodes
nodes within SAR footprint (CEPT region)	**26967**	**132804**	**654001**	**5380723**	**nodes**

In Table 14, it is assumed that all Mesh devices are located in the boresight of the SAR satellite, which provides the worst case scenario.

A.2.4.1.3 FSS satellites

The bandwidth of the Mesh device is 21 MHz (73.2 dBHz). The maximum allowable interference power spectral density tolerated by the Telecom 3 network (see clause A.2.2.3.3) then becomes 27 dBW/Hz.

Appendix S8 of the ITU Radio Regulations [B49] 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 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 15—Tolerable mesh nodes for FSS operation

Parameter	Value				
Tx EIRP	-6	0	3	6	dBW
Tx antenna gain (main lobe)	8				dBi
Tx antenna gain (top lobe)	-22				dBi
Peak-to-Average Ratio	3				dB
Shielding effect	0				dB
Acceptable interference	27				dBW
Active users	1000	251	126	63	nodes (thousands)
Average Tx ratio	5				%
Tolerable nodes	300	75.4	37.8	18.9	nodes (millions)

From Table 15, it shows that even using 4 W (6 dBW) EIRP, an enormous amount of Mesh nodes can be in operation within the FSS footprint.

A.2.4.2 Interference to WLANs

A.2.4.2.1 Immediate neighborhood analysis

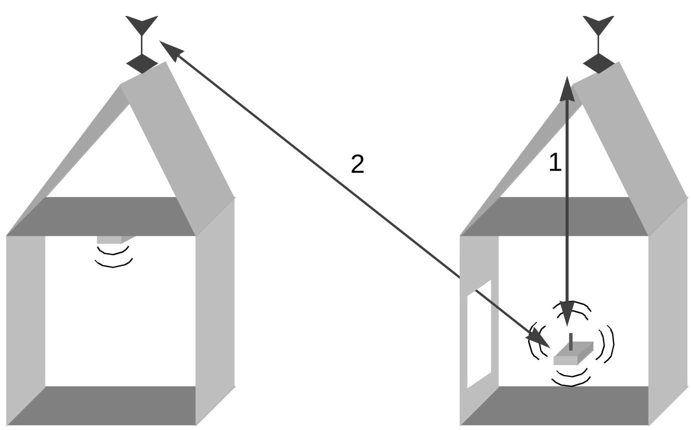


Figure 4—Immediate neighbourhood scenario

A.2.4.2.1.1 ‘Same building' analysis (1)

In the immediate neighborhood scenario, the interference from a Mesh node to a WLAN device in the same building is analyzed (link 1 in Figure 4).

It is assumed for this scenario, that the distance between the Mesh node and the WLAN device in the same building is 5 m. The structural isolation plus attenuation due to multipath/scattering is assumed to be 25 dB over that distance, based to Annex 2 of [B46]. Note that this is not the same as the average 13.4 dB assumed in [B46], since we consider only placement of Mesh devices on the roof, and not placement outside in general as in the outside WLAN case. This is likely to be a very modest value for a typical home with concrete ceiling and stone tile roofing. The total attenuation is then $25 + 20*\log10(4*\pi*d*f_0/c) = 86$ dB. Given the radiation pattern of a Mesh node transmitting at full 28 dBm (i.e. 36 dBm EIRP), the interference level at the WLAN = 28-22-86= -80 dBm. Taking into account the backoff, 3 dB, and the effect of the Mesh activity factor, an additional 13 dB, brings the average interference level, -97 dBm, far below receiver sensitivity values. Operation of a mesh device on the roof, while running an WLAN network inside is hence feasible, even in the same channel.

In this scenario, to operate the WLAN at its highest modulation and coding rate (64 QAM, 3/4 coding) while the Mesh device is transmitting, would require the separation to be at least 20 meters. (instead of the 5 meters used). For (16 QAM, 1/2 coding), the separation would be 10 meters.

A.2.4.2.1.2 'Across the street' analysis (2)

Another critical consideration is the analysis of illumination of indoor WLANs in adjacent buildings. This is due to the fact that despite the larger distance, normally only one isolating building layer (which may also be a window) is situated in-between, and the Mesh antenna gain increases with the angle from the vertical axis.

It is assumed for this scenario that the street is 10 m wide, which gives an antenna gain of -15dBi and an outdoor distance of $\sqrt{125}=11.2$m. The structural isolation plus attenuation due to multipath/scattering is assumed to be 10 dB (window plus some indoor scattering). The total attenuation is then $10+20*\log10(4*\pi*d*f_0/c) = 78$ dB. Taking into account the antenna gain, the backoff and the mesh activity factor of the mesh node reduces the average level at the WLAN to -78 dBm.

Of course, the numbers in the above analysis fluctuate by a number of dB's for individual deployments. The average structural attenuation was quoted to be 13.4 dB in [B46], but there may be variations in building height or terrain sloping which increase the antenna gain in the direction of the WLAN by a few dBs. Typically however, the above results are broadly applicable as conservative estimates to a wide range of deployment scenarios.

Power-control and DFS can assist in further reducing these interference levels. Note that the transmit probability of the WLAN device, (13 dB), has not been taken into consideration.

A.2.4.2.2 Outdoor WLAN analysis

An argument often used against the use of FWA devices in the 5GHz bands is that it will interfere with outdoor deployments of WLAN devices. It is quite obvious that co-location of these two types of devices on a roof (or neighboring roofs) will cause severe interference when operating in the same channel. However, it should be realized that exactly the same issue exists with two WLAN APs on a roof (or neighboring roofs) are competing for the same channel. (To be specific, this is mostly the case for HIPERLAN/2, which is schedule based. IEEE 802.11a uses CSMA/CD attempting to avoid this type of interference, which works well for low duty-cycles.) In both cases, the requirement for a DFS mechanism can gracefully resolves the problem.

In addition, outdoor WLAN deployments are predominantly used for hot-spot coverage and bridging, which implies the use of down-tilted antennas and oftentimes geographical isolation for hot-spot coverage and very directive antennas for bridging, each of which reduces the interference potential. In the cases where WLANs are currently used for access provisioning, IEEE 802.16 compliant systems will likely not be deployed or be used as more efficient substitutes.

FWA deployments require broad coverage and hence reasonable frequency re-use numbers to maintain sufficient Signal-to-Noise Ratio plus limited DFS flexibility to avoid local interference sources. The likelihood of roof-mounted WLAN devices not finding a sufficiently noise-free channel for proper operation are therefor rather small.

A.2.4.2.3 Network analysis

To illustrate the interference analysis further, an example typical scenario, consisting of a 4 node indoor WLAN network and a nearby 4 node Mesh network, is examined.

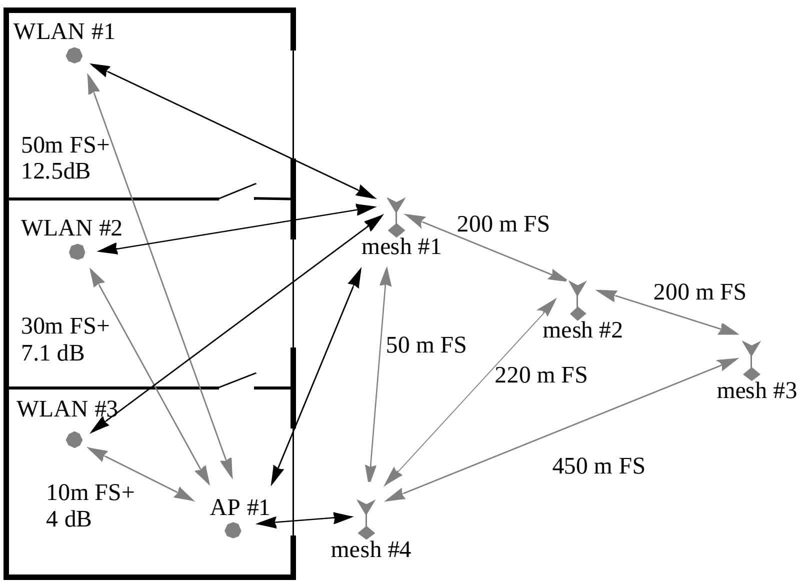
From Annex 2 of [B46], we extract that the typical indoor attenuation on top of free-space attenuation at 5 m is 4 dB for a mixture of line-of-sight through non-line-of-sight scenarios. The additional attenuation through 1 wall is 7.1 dB and the additional attenuation through 2 walls is 12.5 dB (the walls in these cases were breeze blocks and the rooms contained both wooden and metal furniture). The attenuation through a double-glazed window was found to be 7 dB.

In the case under study, a SU is assumed from each of these cases in a Small Office setting. The SU in the same room is assumed at 10 m, The SU in the adjacent room at 30 m and the SU behind two walls at 50 m.

The Small Office is assumed to be a single-floor building with a flat roof. The attenuation through the roof is 22 dB. 19 dB is a typical indoor cross-floor attenuation according to Annex two of [B46], so this is probably a fairly pessimistic value. The Mesh #4 node is situated on the roof directly atop AP #1 and provides the 'Internet access' for the WLAN service within the building. This makes sense, as the cabling distance between the data gathering point, the AP, and the access service, Mesh #4 node, is shortest. The distance between AP #1 and Mesh #4 is assumed to be 5m.

The nearest neighboring node, Mesh #1, is 50 m away on an adjacent building. The building attenuation is 10 dB (a window plus indoor scattering, as in clause A.2.4.2.1.2. It is assumed that this building is lower than the building with the WLANs, resulting in an antenna gain of -10 dBi in the direction of the WLANs, rather than the -15 dBi specified in Table 2). Two other nodes are each 200m away as shown in Figure 5. All mesh nodes are on the roof and hence only have free-space (FS) attenuation to each other. Mesh #3 is assumed to have an additional 15 dB obstruction to the WLANs in the form of a building (basically the building on which Mesh #2 is located).

Note that in the Path Losses in Figure 5, the antenna gain of the Mesh nodes (see Table 2) in the direction of the WLANs has been included.



Path	Path Loss
mesh#1 - AP#1	50m FS + 28dB
mesh#1 - WLAN#1	60m FS + 28dB
mesh#1 - WLAN#2	70m FS + 28dB
mesh#1 - WLAN#3	80m FS + 28dB
mesh#2 - AP#1	250m FS + 33dB
mesh#2 - WLAN#1	250m FS + 33dB
mesh#2 - WLAN#2	260m FS + 33dB
mesh#2 - WLAN#3	270m FS + 33dB
mesh#3 - AP#1	450m FS + 48dB
mesh#3 - WLAN#1	450m FS + 48dB
mesh#3 - WLAN#2	460m FS + 48dB
mesh#3 - WLAN#3	470m FS + 48dB
mesh#4 - AP#1	5m FS + 52dB
mesh#4 - WLAN#1	52m FS + 48dB
mesh#4 - WLAN#2	32m FS + 48dB
mesh#4 - WLAN#3	12m FS + 52dB

Figure 5—Example network scenario

In Table 16, the ranges and corresponding total link attenuations, which are assumed to be symmetrical, are gathered. In general, it can be observed that only nodes that are really close or in line of sight through little attenuation (particularly windows) result in significant interference.

Table 16—Link attenuations and ranges

	Link attenuation / Range							
	Mesh #1	Mesh #2	Mesh #3	Mesh #4	AP #1	WLAN #1	WLAN #2	WLAN #3
Mesh #1	------------	200 m	400 m	50 m	50 m	60 m	60 m	60 m
Mesh #2	94 dB	------------	200 m	220 m	220 m	230 m	230 m	230 m
Mesh #3	100 dB	94 dB	------------	450 m	450 m	460 m	460 m	460 m
Mesh #4	82 dB	94 dB	101 dB	------------	5 m	52 m	32 m	12 m
AP #1	110 dB	127 dB	149 dB	106 dB	------------	50 m	30 m	10 m
WLAN #1	111 dB	128 dB	149 dB	130 dB	94 dB	------------	50 m	20 m
WLAN #2	111 dB	128 dB	149 dB	126 dB	84 dB	132 dB	------------	30 m
WLAN #3	111 dB	128 dB	149 dB	121 dB	72 dB	94 dB	107 dB	------------

In Table 17, the maximum power and EIRP values for each of the devices is shown. For the WLAN devices and their AP, values are chosen which reflect implementations as are currently available in the market.

Table 17— Tx Power, conducted and EIRP (regulatory limited)

	AP	**WLAN**	**mesh**
Tx Power (mW)	200	200	500
Antenna (dBi)	2	0	8
EIRP (dBm)	25	23	35

In Table 18, the resulting received signal strengths are shown assuming transmission with EIRP values as shown in Table 17. Note that especially between the mesh nodes, the Rx values are extremely high, which would automatically be reduced by the AGC. For simplicity of computation, this is however ignored. This table is not symmetric since different antenna gains at each end can affect the perceived signal level.

Table 18—Received Signal Levels (dBm)

	Mesh #1	Mesh #2	Mesh #3	Mesh #4	AP #1	WLAN #1	WLAN #2	WLAN #3
Mesh #1	------------	-54	-60	-42	-80	-83	-83	-83
Mesh #2	-54	------------	-54	-54	-97	-100	-100	-100
Mesh #3	-60	-54	------------	-61	-119	-121	-121	-121
Mesh #4	-42	-54	-61	------------	-84	-102	-98	-93
AP #1	-76	-93	-115	-80	------------	-72	-62	-50
WLAN #1	-79	-96	-117	-98	-72	------------	-112	-74
WLAN #2	-79	-96	-117	-94	-62	-112	------------	-87
WLAN #3	-79	-96	-117	-89	-50	-74	-87	------------

Table 19 below shows the results. The top row in each box shows the actual communication direction, the used modulation and the Noise threshold. The four next rows illustrate the effect of interference from each source (using maximum allowed EIRP). If the modulation differs from the top box, then switch to a more robust modulation scheme was mandatory to maintain 3% PER. The last column defines the interference margin. A positive value means the threshold has been exceeded and is shown in bold.

Table 19—Sustainable modulation during interference

WLAN#1 =>AP#1	3/4 QPSK	-90	WLAN#2 =>AP#1	2/3 64QAM	-95	WLAN#3 =>AP#1	3/4 64QAM	-95
mesh #1	**PER>3%**	**4**	mesh #1	1/2 QPSK	-5	mesh #1	1/2 QPSK	-5
mesh #2	3/4 QPSK	-13	mesh #2	2/3 64QAM	-22	mesh #2	2/3 64QAM	-22
mesh #3	3/4 QPSK	-35	mesh #3	2/3 64QAM	-44	mesh #3	3/4 64QAM	-44
mesh #4	**PER>3%**	**0**	mesh #4	3/4 QPSK	-9	mesh #4	3/4 QPSK	-9
AP#1 => WLAN#1	3/4 QPSK	-90	AP#1 => WLAN#2	2/3 64QAM	-95	AP#1 => WLAN#3	3/4 64QAM	-95
mesh #1	**PER>3%**	**1**	mesh #1	3/4 QPSK	-8	mesh #1	3/4 QPSK	-8
mesh #2	3/4 QPSK	-16	mesh #2	3/4 64QAM	-25	mesh #2	3/4 64QAM	-25
mesh #3	3/4 QPSK	-37	mesh #3	3/4 64QAM	-46	mesh #3	3/4 64QAM	-46
mesh #4	3/4 QPSK	-18	mesh #4	2/3 64QAM	-23	mesh #4	3/4 16QAM	-18

From Table 19, two observations can be generalized. The first is that in certain scenarios interference in unavoidable if DFS is not used. The second is that interference only occurs when nodes are really close (such as mesh #4) or have relatively good line of sight properties (such as mesh #1, which only has a window in-between and a reduced height antenna) to the WLAN network. The later generalization means that very few nodes in a mesh network will cause degradation of a WLAN network. Realizing that the interference excess is relatively low, and the mesh network further uses power-control to reduce the EIRP where possible, interference from a transmitting mesh device will be very limited. Combined with the activity factors for both devices (on average 13 dB each) and DFS mechanisms, the likelihood of interference becomes so small that it is easily handled with Automatic Request (ARQ) causing minimal degradation of performance.

A.2.4.2.4 Adjacent channel issues

A nice feature of the OFDM technology used in both WLANs and Mesh technology at 5GHz, is that the adjacent channel rejection is very high, at least 35 dB (compare clause 8.3.6.4.2.4.2). Since the interference levels between WLANs and Mesh devices are relatively low compared to this (see previous sections), it is reasonable to assume that adjacent channels using WLAN and Mesh technology will not cause any noticeable interference to each other. Therefor, this is not further considered here.

A.2.4.3 Interference to RTTT

In accordance with [B46], [B52], the cross-polarization is assumed to be 10-15 dB to the RSU and 6-10 dB to the OBU (Table 20 uses the lower numbers).

Table 20—Needed separation distance mesh to RSU and OBU

Parameter	RSU		OBU	
P_t	6		6	dBW
B_{Rx}	10	5	10	MHz
B_i	22		22	MHz
$I_{Rx}=Rx_{sens}-C/I_{8PSK}$	-117		-90	dB
L	119.6	116.6	92.6	dBW
cross-polarization	10		6	dB
Antenna & feeder gain	8		8	dB
Separation distance	**553**	**394**	**53**	**m**

It should be noted that in the above calculations, the duty-cycle of the 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 Mesh device is significantly larger than the other way around. Since RTTT devices normally have a fairly high duty-cycle, a close 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. Therefor, for RSUs, proper operation is virtually guaranteed by virtue of its own interference potential.

A.2.4.4 Interference to Radar

For radars, a somewhat similar situation exists as with RTTT RSUs. To show this, the interference distance from radars into Mesh devices is derived, followed by the derivation of the interference distance from Mesh devices into radars. As is shown below, the first is much larger than the second, necessitating the use of the 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 Mesh device still operates, shown in Table 21, the most robust modulation and coding mode is used.

Table 21—Minimum separation distance of radar to mesh

Radar type	A	B	C	D	E	
Peak EIRP	98.6	26	60	93	97	dBW
Antenna gain	40	0	46	43	43	dBi
P_t	58.6	26	14	50	54	dBW
BW_{radar}	3	15	30	14	3	MHz
$I_{mesh}=Rx_{sens}-C/I_{BPSK1/2}$	-116					dBW
L	174.6	142.0	131.3	166.0	170.0	dB
gain + feeder loss	48	8	54	51	51	dB
propagation loss	222.6	150	185.3	217	221	dB
distance @ 5.5GHz	20693	137	497	11813	17630	km
radio horizon	51.4	346.6	51.4	51.4	51.4	km (see [B53])
separation distance	**51.4**	**137**	**51.4**	**51.4**	**51.4**	**km**

In Table 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 [B46], [B53]).

Table 22—Minimum separation distance of mesh to radar

Radar type	A	B	C	D	E	
P_t mesh	-2					dBW
BW_{radar}	3	15	30	14	3	MHz
Noise (dBW)	-134.2	-127.2	-124.2	-127.5	-134.2	dBW
On-tune rejection	-8.9	-1.9	0.0	-2.2	-8.9	dB (see [B46])
Max. Interference	-131.3	-131.3	-130.2	-131.3	-131.3	dBW
L	129.3					dB
gain + feeder loss	48	8	54	51	51	dB
propagation loss	177.3	145.3	191.6	188.3	188.3	dB
distance @ 5.5GHz	**220.1**	**79.4**	**916.3**	**662.7**	**662.0**	**km**

Comparing the result of Table 21 (line 10) and Table 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 WLAN analysis in [B46] can be drawn. Sharing with maritime radars (which are not likely operating anywhere near residential areas) and S5.452 meteorological radars in band B and radiolocation radars in both band B and C is feasible when an effective DFS mechanism is employed by the Mesh system and the radar density isn't too high.

A.2.5 Channel and interference simulation model

Continue here with the text of A.2.2 Channel and interference model in 80216ab-01_01r1.

13. Bibliography

Add the following references as used in Appendix A.2

[B46] ERC *Report 72: Compatibility Studies Related to the possible Extension Band for HIPERLAN at 5 GHz*, http://www.ero.dk/doc98/Official/pdf/REP072.pdf

[B47] IEEE 802.11a: *Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High Speed Physical Layer in the 5 GHz Band*, http://standards.ieee.org/reading/ieee/std/lanman/802.11a-1999.pdf

[B48] ETSI TS 101 475 v1.1.1 (2000-4) *BRAN HIPERLAN Type 2; Physical Layer*

[B49] ITU, *ITU Radio Regulations*, appendix S8, 1998 edition

[B50] U.K. Dept. of the Environment, Transport and the Regions, *Digest of environmental Statistics*, 15/3/2001, http://www.environment.detr.gov.uk/des

[B51] ETSI EN 300 674 v1.1.1 (1999-2) ERM 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*

[B52] CEN/TC 278 prEN 12253: *Road Transport and Traffic Telematics (RTTT) - Dedicated Short Range Communication (DSRC) - Physical Layer using Microwave at 5.8 GHz*

[B53] ERC *Report 15:Compatibility Studies Between Radar and WLANs Operating at Frequencies Around 5.5 GHz*, http://www.ero.dk/doc98/Official/pdf/REP015.pdf

[B54] ERC/DEC/(99)23 *ERC Decision on the harmonised frequency bands to be designated for the introduction of HIPERLANS, 29-11-1999*, http://www.ero.dk/doc98/official/pdf/DEC9923E.PDF

[B55] CEPT/ERC/REC 70-03 Relating to the use of short range devices (SRD), http://www.ero.dk/doc98/official/pdf/REC7003E.PDF