Project	**IEEE 802.18 Radio Regulatory Technical Advisory Group**
Title	Estimate of Potential Interference from a Single UWB LAN /PAN Device into an IEEE 802.11 device
Date Submitted	18 July 2003
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Re:	This contribution is submitted to highlight some concerns that Nortel Networks has regarding the potential impact of emissions from UWB PAN/LAN devices into IEEE 802.11 devices
Abstract	The contribution provides an analysis of possible impact from emissions from a single UWB LAN / PAN Device into an IEEE 802.11 receiver and indicates potential interference at distances of 3 – 6 m separation between the devices.
Purpose	It is proposed that IEEE 802.18 consider where current FCC rules on emissions from UWB LAN / PAN equipment are sufficient to avoid impacting other services, specifically RLANs at 2.4 GHz and 5 GHz, or whether modifications to the UWB Rules should be proposed.
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Estimate of Potential Interference from a Single UWB LAN /PAN Device into an IEEE 802.11 device

Mike Lynch, Nortel Networks

1 Introduction

If LAN / PAN devices based on UltraWideband Technology (UWB) become ubiquitously deployed, then, especially in homes, public places, meeting rooms and offices, it is likely that some emissions from a **single** active UWB device will fall inband of any nearby IEEE 802.11 systems and may impact their communications. This contribution provides quantification of this possibility and assesses the impact.

This analysis does NOT include any interference from emissions that occur outside the receiver's intended band i.e. assumes that the 802.11 device has a perfect receiver bandpass filter of 18 MHz bandwidth to block other off-frequency emissions.

This analysis does NOT include the combined effects from multiple UWB devices in the same area.

The following analysis is applicable to 802.11a, 802.11b and 802.11g devices, if the correct operational band is selected.

2 Analysis

2.1 IEEE 802.11 Receiver (Victim)

From basic theory, the thermal noise (kTB) expected at the input to an 802.11 receiver is:

$$N_0 = kTB = -101.4 \text{ dBm}$$

Where k = Boltzmann constant = $1.38 * 10^{-23}$ J/°K/Hz
T = ambient temperature = 20 °C = 293 °K
B = bandwidth of receiver = 18 MHz

The front-end of a nominally compliant 802.11 device has a Noise Figure of 10 dB and an implementation margin of 5 dB (data from 802.11a specification section 17.3.10.1) causing an effective input noise power of -86.4 dBm (-98.9 dBm/MHz). A more typical device may be 5 dB better i.e. -91.4 dBm effective input noise (-103.9 dBm/MHz).

If emissions received from the UWB device are 6 dB below this effective input noise power then the combination of the real thermal noise and the UWB noise will cause a 1 dB increase in the effective noise seen in the receiver and thus cause a 1 dB increase in desired receive power needed to maintain normal operation of the 802.11 device. Any higher UWB power at the receiver input will clearly degrade the 802.11 device more severely.

Thus the highest "tolerable" spectral density is nominally -92.4 dBm (-104.9 dBm/MHz) or typically -97.4 dBm (-109.9 dBm/MHz).

802.11a devices operate on channels in sub-bands within 5150-5850 MHz – possible UWB impacts at both these upper and lower limits will be estimated (assuming the 802.11a device is 12.5 MHz within the band-edge). 802.11b and 802.11g devices operate on channels within 2400-2490 MHz – possible UWB impacts at both these upper and lower limits will be estimated (assuming the 802.11b and 802.11g devices are 12.5MHz within the band-edge).

2.2 UWB LAN/PAN Transmitter

In 2002, the FCC issued rules for the operation of UWB devices, which specify emission mask limits on various types of UWB devices and the emission mask relevant for handheld[1] LAN/PAN devices (e.g. in a laptop or PDA) and indoor[2] LAN/PAN devices (e.g., LAN card in a desktop PC or a LAN server node) is specified[3] in Table 1.

Table 1 UWB Emission Mask

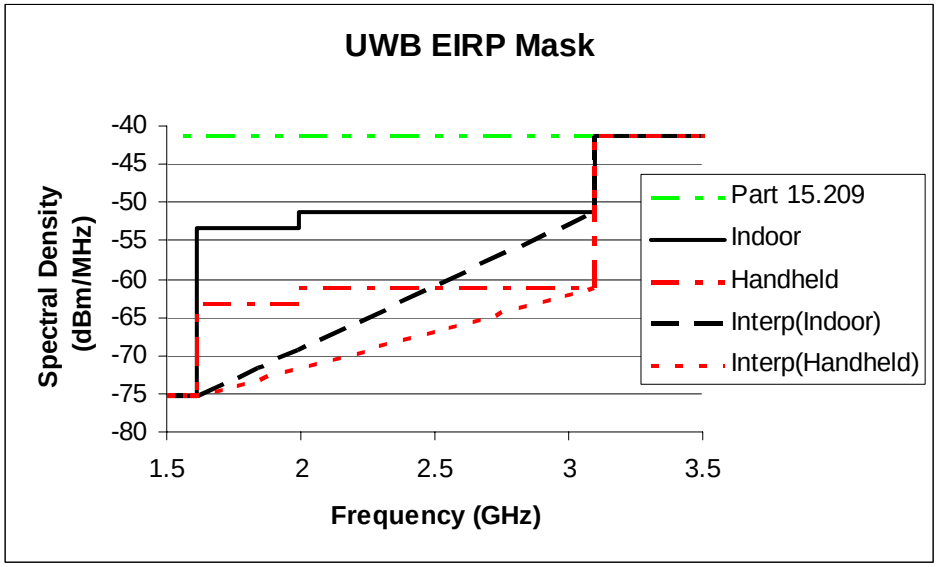
Frequency (MHz)	Average EIRP (dBm/MHz) (handheld)	Average EIRP (dBm/MHz) (indoor)
960 – 1 610	-75.3	-75.3
1 610 – 1 990	-63.3	-53.3
1 990 – 3 100	-61.3	-51.3
3 100 – 10 600	-41.3	-41.3
Above 10 600	-61.3	-51.3

The 10 dB emission bandwidth of the UWB device must be within the range 3 100-10 600 MHz.

802.11a devices at 5GHz will clearly experience the impact of co-frequency emissions with a spectral density of -41.3 dBm/MHz. Whereas 802.11b and 802.11g devices at 2.4GHz will experience UWB emissions approximately 10-20 dB lower, if the UWB transmitter just complies with the FCC specification.

This mask is shown graphically in the following Figure 1 – lines "Indoor" and "Handheld".

Figure 1 UWB Emission Mask



[1] The FCC state that handheld devices "are relatively small devices that are primarily hand held while being operated and do not employ a fixed infrastructure" and "may operate indoors or outdoors".

[2] The FCC state that indoor devices are "employed solely for indoor operation" and "be capable of operation only indoors …. e.g., … must be connected to the AC power lines"

[3] FCC 02-48, "Revision of Part 15 of the Commission's Rules regarding Ultra Wideband Transmission Systems" First Report an Order, Part 15.519 "Technical Requirements for Handheld UWB Systems", subsection (c) and Part 15.517 "Technical Requirements for Indoor UWB Systems" and Erratum DA 02-1289

It is unlikely that a physical emitter would exactly follow the stepped "Indoor" or "Handheld" function of the mask specified in Table 1, so in this analysis the assumed transmit spectral density will be calculated based on linear interpolation between the "internal knees" of the mask, e.g., this interpolation provides the following average interference spectral density power at the specified frequencies (Table 2) and in Figure 1 ("Interp(Indoor)" and "Interp(Handheld)" lines).

Table 2 Linear Interpolation between Knees at 1610 MHz and 3100 MHz

	Average EIRP (dBm/MHz)	
Freq (MHz)	Knees: -61.3 dBm@3 100 MHz and -75.3 dBm@1 610 MHz	Knees: -51.3 dBm@3 100 MHz and -75.3 dBm@1 610 MHz
2 412.5	-67.8	-62.4
2 477.5	-67.1	-61.3

As this interpolation is falling relatively slowly across an 18 MHz bandwidth, only the value at the carrier center frequency of the victim will be used in this study.

In the FCC rules, the peak spectral density is permitted to be 0 dBm in 50 MHz. Thus in an 18 MHz 802.11 receiver bandwidth, the potential peak power is -4.4 dBm (-17.0 dBm/MHz) giving a peak/average ratio of 24.3 dB (relative to the average -41.3 dBm/MHz specification).

The repetition period of pulse train (0.001 - 0.1 µS) from a UWB device will typically be much more rapid than the symbol period (0.5 – 100 µS) of the victim system, so the maximum peak / average ratio (e.g. +24.3 dB) may not be applicable, but as the waveform is clearly irregular, the peakedness will impact the receiver and some peakedness should be assumed. This study assumed a conservative +6 dB peak/average ratio – a higher value would increase the separation distance calculated below (e.g. +12 dB would double the required separation, if $1/R^2$ propagation).

2.3 Methodology

From the interference spectral density, calculated in section 2.2 and the victim interference threshold (e.g. -104.9 dBm/MHz nominal or -109.9 dBm/MHz typical) in section 2.1, the minimum separation distance needed to avoid excess impact from interference can be calculated. Simple propagation ($1/R^2$ for first 2 m, then $1/R^4$ for greater, partly-obscured, separation distances) may be assumed between the interferer and victim as they are likely to be relatively close together.

3 Results

The following Table 3 provides the analysis assuming the interference is from a single Handheld UWB device. Table 4 provides the corresponding result for Indoor UWB devices. Note should be taken of the numbers in the bottom right of the tables "Interference Distance", which indicate the distance at which interference will occur and thus indicate the Minimum Separation distance between UWB interferer and the 802.11 receiver to avoid significant interference.

Table 3 Required Separation Distance from a Single Handheld UWB Device

					Interpolated FCCspec					
				Band-Edge (MHz)	2400	2490	5150	5850	5150	5850
				frequency (MHz)	**2412.5**	**2477.5**	**5162.5**	**5837.5**	**5162.5**	**5837.5**
				wavelength (m)	0.124	0.121	0.058	0.051	0.058	0.051
				2m Knee pathloss	-46.118	-46.349	-52.726	-53.793	-52.726	-53.793
				Interference (dBm/MH	-67.76	-67.15	-61.30	-61.30	-41.30	-41.30
				Peak/Avg factor(dB)	6.0	6.0	6.0	6.0	6.0	6.0
802.11 a, b, g	Amb Noise	N Backoff	Bandwidth	Interferenc	**Interference Distance (m)**					
Nominal spec	-86.4	6.0	18	-104.9	1.4	1.5	1.4	1.2	5.3	5.0
Typical spec	-91.4	6.0	18	-109.9	2.3	2.3	2.2	2.1	7.1	6.6

Table 4 Required Separation Distance from a Single Indoor UWB Device

					Interpolated FCCspec					
				Band-Edge (MHz)	2400	2490	5150	5850	5150	5850
				frequency (MHz)	**2412.5**	**2477.5**	**5162.5**	**5837.5**	**5162.5**	**5837.5**
				wavelength (m)	0.124	0.121	0.058	0.051	0.058	0.051
				2m Knee pathloss	-46.118	-46.349	-52.726	-53.793	-52.726	-53.793
				Interference (dBm/MH	-62.37	-61.33	-51.30	-51.30	-41.30	-41.30
				Peak/Avg factor(dB)	6.0	6.0	6.0	6.0	6.0	6.0
802.11 a, b, g	Amb Noise	N Backoff	Bandwidth	Interferenc	**Interference Distance (m)**					
Nominal spec	-86.4	6.0	18	-104.9	2.3	2.4	3.0	2.8	5.3	5.0
Typical spec	-91.4	6.0	18	-109.9	3.1	3.2	4.0	3.7	7.1	6.6

From the results, "typical" 802.11b and 802.11g will experience interference at ranges (columns 1 & 2 in "Interference Distance" sub-table) less than 3.1 m separation from a single indoor UWB device and separation of 2.3m for a handheld UWB device. These distances are consistent with the assumed "$1/R^2$ then $1/R^{4"}$ propagation. For 802.11 b and 802.11g devices meeting nominal specs, the separation can decrease to 2.3 m and 1.4 m respectively.

"Typical" 802.11a devices will need a separation of 6.6 m (over 21 feet) (columns 5 & 6 in "Interference Distance" sub-table) from a single indoor or handheld UWB device (same UWB emission at 5GHz). For 802.11a devices meeting nominal specs, the separation can decrease by 1.6 m. If the UWB device is on an adjacent frequency near 5GHz (NOT co-frequency), so that the interference spectral density is -51.3 or -61.3 dBm/MHz rather than -41.3 dBm/MHz, then the results (columns 3 & 4 in "Interference Distance" sub-table) show a performance similar to the 2.4 GHz results.

4 Conclusion

The calculations indicate that 802.11b and 802.11g victim receivers will need a separation of approx 3 m from a **single** active UWB handheld LAN/PAN, whereas 802.11a devices need over 6 m separation. Clearly the impact of multiple UWB devices operating in a LAN/PAN environment could be much worse.

There could be multiple impacted 802.11 devices within the separation distance of a single UWB LAN/PAN device. From this study, it is clear that an interference problem exists any time that both devices are active. In a modern meeting room or office, it is likely that multiple UWB LAN/PAN devices could be deployed within 3 m of each other and thus the problem could easily permeate across the whole room affecting the performance of many of the 802.11 devices.

5 Proposal

Nortel Networks believes that 802.11a, 802.11b and 802.11g devices will experience significant interference from UWB LAN/PAN devices. It is proposed that IEEE 802.18 consider where current FCC rules on emissions from UWB LAN / PAN equipment are sufficient to avoid impacting other services, specifically RLANs at 2.4 GHz and 5 GHz, or whether modifications to the UWB Rules should be proposed.