Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [UWB Interference Comparison]
Date Submitted: [13 November, 2003]
Source: [Gadi Shor] Company [Wisair]

Address [24 Raul Wallenberg, Tel-Aviv, Israel]
Voice:[+972-3-7676605], FAX: [+972-3-6477608], E-Mail:[gadi.shor@wisair.com]

Abstract: [Contribution on UWB interference comparison]

Purpose: [For discussion by IEEE 802.15 TG3a]

Notice: This document has been prepared to assist the IEEE P802.15. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.

Release: The contributor acknowledges and accepts that this contribution becomes the property of IEEE and may be made publicly available by P802.15.
Outline

• UWB interference comparison

• Analysis, simulations and measurements

• Measurement set-up and calibration procedure

• Conclusions
UWB interference comparison

- MBOA members performed analysis, simulations and measurements

- Measurements, analysis and simulation results match each other

- Results show difference of up to 1.5 dB for realistic operating scenarios of C-Band victim receivers
Operating conditions for C-Band receivers

- The operating condition (I/N) is related to the allowed isolation between the UWB device and the C-Band receiver (e.g. distance, side-lobe attenuation, etc.)

- C-Band receivers have 1.5-2 dB link margin above the sensitivity level
  - Expected fading due to rain is about 1 dB
  - Leftover margin for total interference from other sources is 0.5-1 dB

- This means that \( I_{\text{uwb}}/(N+I_{\text{sat}}) \leq -6 \text{ dB} \)
Operating conditions for C-Band

- NTIA in their analysis of the UWB systems assumed an $I/(N+Isat)$ of $-13.5$ dB

- XSI in their FCC petition filing in September, 2003 proposed an $I/(N+Isat)$ of $-9.5$ dB

- FCC has studied cases of $I/(N+Isat) < -3.5$ dB

- Remark: $Isat = \text{adjacent satellite interference of about 1 dB above the thermal noise}$

- Demonstration by Motorola/XSI was done at an unacceptable operating condition of $I/(N+Isat)$ greater than zero in which the interference from the UWB device is even stronger than the other noise sources
Operating conditions for C-Band

To justify the proposed I/N = -9.5 dB XSI in their FCC petition filing in September, 2003 states the following:

"The vanishingly low probability of harmful interference depends on the joint probability that a handheld UWB device is actively transmitting, is close enough to a low-elevation earth station, is in the susceptible azimuth region, has its antenna oriented in the worst case direction, has the antenna aligned with a linearly polarized earth station antenna, lies along the bore site azimuth of the earth station antenna, has no other intervening people, fences, berms or foliage, and all at a moment when the earth station is suffering a fade deep enough to eat away its margin. The actual probability of all this occurring is essentially zero."
Analysis based on APD

• It has been suggested that the Amplitude Probability Distribution (APD) is a way to analyze the effect of a non Gaussian noise on a victim receiver

• It has been argued that the APD for MB-OFDM is not compliant with the FCC regulations [IEEE 802.15-03/334r5].

• We show that
  – APD for the MB-OFDM is similar to the APD of pulsed systems already allowed by FCC.
  – APD for the noise plus interference as seen by the C-Band receiver in realistic operating conditions is very close to AWGN (up to 1.5 dB of difference)
  – APD for narrow band receivers is almost identical to AWGN regardless of the operating conditions
MB-OFDM and Pulsed UWB APD

- MB-OFDM APD is similar to pulsed UWB systems already allowed by FCC even with 50 MHz resolution bandwidth.
**APD for MB-OFDM with different I/(N+I_{sat})**

- The APD of MB-OFDM with $I/(N+I_{sat}) = -3.5, -9.5, -13.5$ is less than 1.5 dB from AWGN.
APDs for narrow band receivers

- MB-OFDM APD is similar to AWGN with a 1 MHz resolution bandwidth.

![Amplitude probability distribution, 1 MHz BW, 1 msec. observation time](chart)

MB-OFDM is similar to AWGN
Link simulations for C-Band receivers

• C band DVB-S system parameters
  – 30 Msps
  – convolutional code (133,171) rate 3/4, outer RS code (204,188)
  – convolutional interleaver between inner and outer codes
  – no channel interleaving before Viterbi decoder

• We show that the difference between interference from DS-CDMA and MB-OFDM to C-Band receivers is very small (below 1.5 dB) for realistic operating conditions
Signal of 0.5 dB above sensitivity
Equivalent to \( I/(N+I_{\text{sat}}) = -8.5 \text{ dB} \)

MB-OFDM I =
\( f_1 \ f_2 \ f_3 \ f_1 \ f_2 \ f_3 \)

MB-OFDM II =
\( f_1 \ f_1 \ f_2 \ f_2 \ f_3 \ f_3 \)

Remarks: Ber represent Ber at the Viterbi output. Threshold is set according to RS decoder threshold
Signal of 1 dB above sensitivity
Equivalent to $I/(N+I_{sat}) = -5.5$ dB

Remarks: Ber represent Ber at the Viterbi output. Threshold is set according to RS decoder threshold
Measurements

- Measurements were taken with a digital C-Band victim receiver in a carefully calibrated laboratory environment
- Performed preliminary testing with 2.5 Msps and 30 Msps including combinations of convolutional and RS encoders
- Initial measurement results match simulation results when considering measurement accuracy and implementation degradation
  - Less than 1.5 dB difference between MB-OFDM and DS-CDMA for 30 Msps receivers under realistic operating conditions similar to simulation and analysis results
  - No difference between MB-OFDM and DS-CDMA for 2.5 Msps receivers
Digital Test Setup (1)

*LNB sets the initial noise level. Interference is added on top.
Digital Test Setup (2)
Digital Test Setup (3)
Digital Test Setup (3)
Calibration

- Calibration is a very critical part of the measurement procedure
- For each data point, N, C+N, I+N and C+I+N were measured using a spectrum analyzer with a RMS channel power measurement capability in a 40 MHz bandwidth
- Accurately calculated C, N and I
- Compared results to attenuators readings
- Performed all measurements relative to actual sensitivity level of the C-Band receiver
- Repeated tests and were able to duplicate results to within several tenths of a dB
Conclusions

• Analysis based on APD, bit error rate simulations and measurement results match each other
  => this gives us confidence in our results

• For realistic operation conditions (with interference below the noise and not above it) difference between MB-OFDM and DS-CDMA is smaller than 1.5 dB

• This difference does not apply for more narrowband receivers

• Analysis, simulation and measurement activities will continue

• We believe Motorola/XSI findings are flawed and are willing to work with them to find the measurement error here in ABQ.