Ultra Wideband Signal Impact on IEEE802.11b Network Performance

Matti Hämäläinen[1], Jani Saloranta[1], Juha-Pekka Mäkelä[1],
Tero Patana[2], Ian Oppermann[1]

[1]Centre for Wireless Communications (CWC), University of Oulu, P.O.Box 4500,
FIN-90014 University of Oulu, FINLAND
email: matti.hamalainen@ee.oulu.fi

[2]PJ Microwave Ltd., Tutkijantie 9, FIN-90570 Oulu, FINLAND
(currently with Elektrobit Ltd.)

ABSTRACT

This paper presents the results of a co-existence study investigating the impact of ultra wideband (UWB) interference on an IEEE802.11b network. Results are based on the experimental test measurements made at the University of Oulu, Finland using simple non-FCC compatible, high power UWB transmitters as interference sources.

Preliminary results showed that the IEEE802.11b network suffered slightly in the presence of very significant UWB interference. In our study, many high power UWB transmitters have been used in close proximity to the victim system. The cumulative effect of the UWB interference generated in the study corresponds to the interference caused by several hundred of FCC compliant UWB devices. The measured signal-to-noise ratio reported by the victim system showed a degradation of 5.5 dB and 1.5 dB when 20 or 10 UWB transmitters were active, respectively.

I. INTRODUCTION

At present, 10's of millions of IEEE802.11b enabled WLAN devices have been installed worldwide representing a huge investment in a popular wireless technology. Due to the extremely large bandwidth of the UWB devices they have been seen as a threat for those other existing systems. In this paper, the performance of an IEEE802.11b network is studied when intentional UWB interference is present. Several UWB transmitters are used to disturb the short range WLAN link and several functional parameters from the network are recorded.

The structure of the paper is as follows. Section II presents the hardware configuration used, section III describes the measurement scenarios, section IV presents the results from the experimental tests and section V gives conclusions.

II. HARDWARE DESCRIPTION

A. Ultra Wideband Transmitters

The UWB transmitters used in the study were designed and built by PJ Microwave Ltd.[1], Oulu, Finland. These signal sources are simple short pulse generators without data transmission capabilities. The pulse generation is based on the technique introduced in [1]. The transmitters generate a train of short pulses, referred to as monocycles using a fixed pulse rate. The UWB devices used in the study are presented in Figure 1.

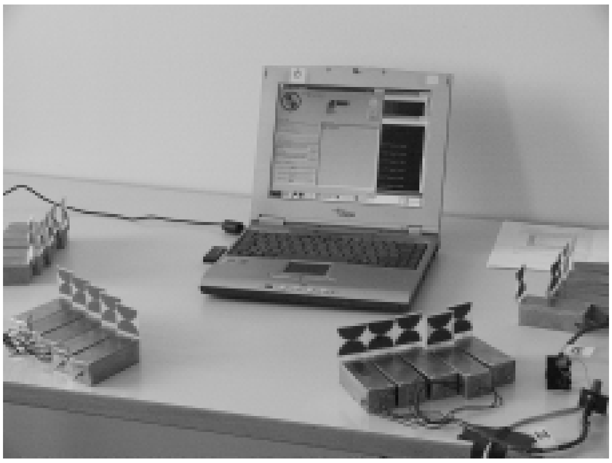

Figure 1. UWB transmitters and the example of the measurement setup.

The UWB transmitters are encapsulated in metal boxes to reduce the unintentional radiation so all the radiated signal power comes through the antenna. The pulse generator is built on a single sided circuit board alongside an oscillator which is used to trigger the step recovery diode that generates the short pulse.

[1] http://www.pjmicrowave.fi

In the time domain, the generated pulses have a width of T_p = 500 ps. The pulse repetition frequency in the first prototype UWB transmitters is fixed at 87 MHz due to the voltage controlled oscillator structure. The characteristics of the UWB signal have been measured using a digital sampling oscilloscope with the same antenna type as used at the transmitter. Stand-alone WLAN antennas were not available. The generated and received pulse waveforms are presented in Figure 2. The nominal centre frequencies of the generated and received UWB signals are around 2 GHz (Figure 3). The Fourier transform of the pulse train measured from the printed circuit board has been used to obtain the frequency domain representation.

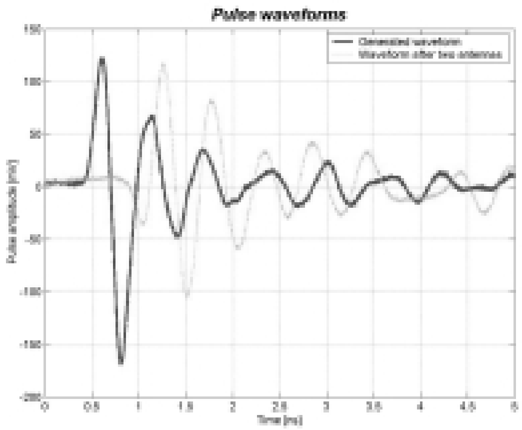

Figure 2. Generated and received pulse waveforms.

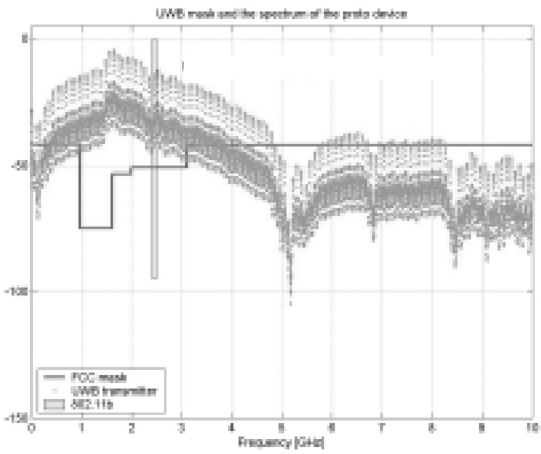

Figure 3. UWB spectrum with the FCC radiation mask. WLAN band is also highlighted.

Due to the narrower bandwidth of the WLAN antenna, the pulse waveform seen by the WLAN card is different to that presented in Figure 2.

The peak-to-peak voltage of the pulse measured from the output port of the printed circuit board is approximately 300 mV. The circuit boards are driven using a 9 volt DC power source. The total power consumption is less than 300 mW. The maximum number of UWB transmitters available at present is 20.

The antennas have an omni directional horizontal radiation pattern and are manufactured using a standard PCB process. EIRP power is frequency dependent, however is approximately -2...+3 dBm. The first UWB prototype transmitters built are not compatible with the FCC regulations, and they could be called as "**high power UWB devices**" as can be seen from Figure 3.

B. WLAN Test Network

The victim network examined is based on the IEEE802.11b WLAN standard. These preliminary studies have been made using two laptops with WLAN network cards. The network bit rates supported are 11 Mbps, 5.5 Mbps, 2 Mbps, and 1 Mbps depending on the available link quality. Connections between the two laptops were established in peer-to-peer mode. The distance between the communicating devices was set at the limit of the network performance to more readily see the impact of the UWB devices on WLAN. The UWB transmitters are located in the vicinity of the victim receiver as can be seen from Figure 1. The distance between the WLAN cards was set to allow a maximum data rate of 2 Mbps. Higher data rates were not supported due to the low SNR values.

The WLAN network cards allow measurement of signal-to-noise ratio, signal quality, and the number of successfully received packets of the local and remote device both in managed and peer-to-peer modes. In order to measure higher layer performance, additional network traffic analyzing tools are required. The following parameters can be measured using the network cards described above:

- Ping: Round-trip times and variable length packet loss statistics are computed [2]
- TTCP: TCP throughput and loss rate [3]
- MGEN: UDP throughput, delivery latency, loss rate [4].

III. MEASUREMENT SCENARIOS

Initially, there were two network topologies examined as shown in Figure 4 and Figure 5. The scenario in Figure 4, random placement of the UWB devices between WLAN devices, was rejected because as the UWB devices did not result in noticeable degradation of the WLAN network performance. Figure 6 represents the layout for the first experimental tests. Through-wall measurements are used to reduce the received WLAN signal power allowing greater impact of the UWB interferers on the victim system.
During the measurements, the WLAN network was operating in peer-to-peer mode. The access-point based WLAN setup was also examined however no results are available at the moment.

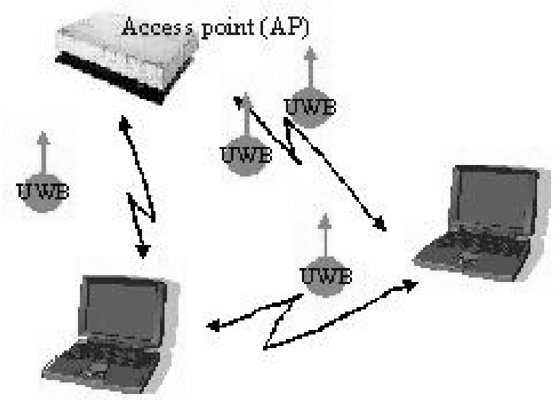

Figure 4. Measurement scenario #1.

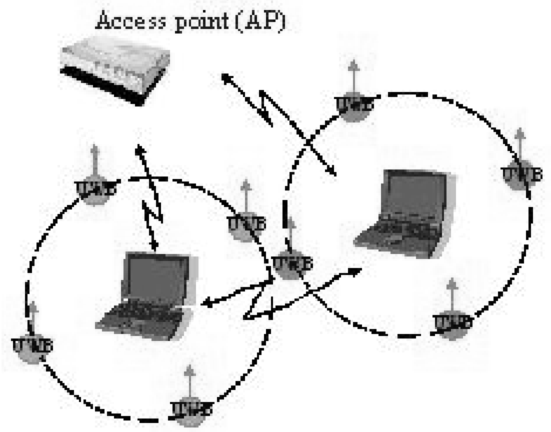

Figure 5. Measurement scenario #2.

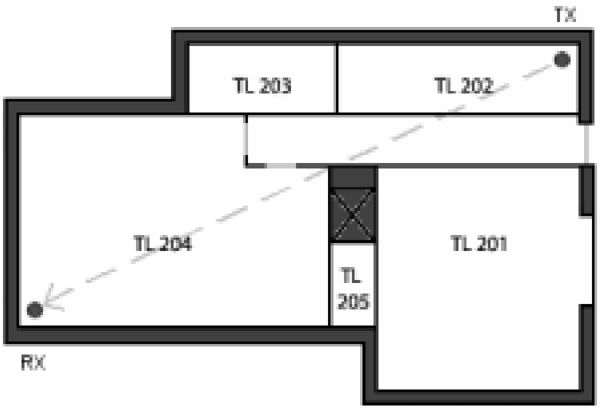

Figure 6. Measurement layout. TX and RX represent the locations of the laptops having the WLAN cards.

During the measurements the UWB interferers were evenly distributed in a circle around the WLAN receiver (Figure 1).

IV. MEASUREMENT RESULTS

This section presents the preliminary results based on the first experimental tests made at CWC using the 2 Mbps data rate in a regular office environment during office hours. The radio interference coming from the other radio systems cannot be rejected which means that the WLAN network is also suffering from non-UWB interference sources. During the post-processing of the results it was found that several UWB devices were generating much higher power than the others. At the moment these UWB transmitters are being tested in more detail.

A. Signal-to-Noise Ratio

In the first measurements, all the 20 UWB transmitters are switched between active and inactive modes in turn. In Figure 7, the instantaneous signal-to-noise ratio of the IEEE802.11b network, as reported by the network card, is presented as a function of time. Between minutes 0 and 6, all 20 UWB transmitters are active. Between 6 and 12 minutes only 10 UWB transmitters are active. The measurement period for consecutive active and inactive stages was 1 min. Timing for the measurement is presented in

Table 1 in more detail. The distance between the UWB transmitters and the victim laptop was 25 cm to 50 cm (see Figure 1).

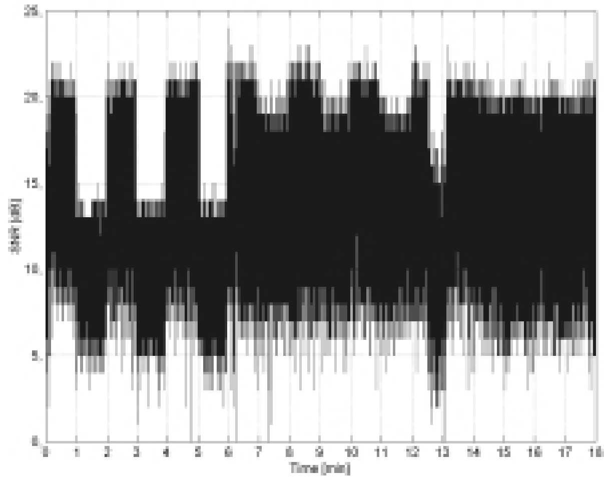

Figure 7. IEEE 802.11b network signal-to-noise ratio as a function of time. UWB transmitters are switched between active and inactive modes every minute.

Figure 8 gives the averaged values from the results presented in Figure 7. The average SNR shows 5.5 dB and 1.5 dB degradations when 20 or 10 UWB sources are active, respectively. As can be seen from the figure, the reported SNR shows substantial variation even without the intentional UWB interference. This indicates the WLAN system suffers substantially from other sources of interference.

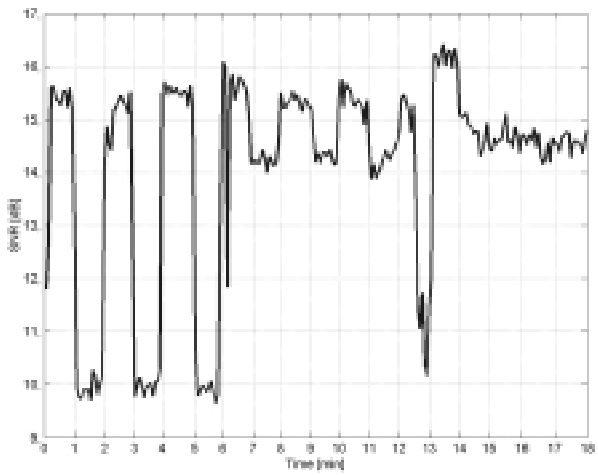

Figure 8. Averaged SNR from the results of Figure 7.

During the 14 – 20 min period, a 9 V DC source was used to drive a parallel resistor network causing unintentional radiation of two parallel switched 120 Ω resistors. The aim of this activity was to determine the effect of the power source on the victim network. As can be seen from Figure 8 the impact if the DC-power source (either when ON or OFF) is insignificant for the WLAN network performance. However, during this period, the reported SNR shows similar degradation as reported for 10 active UWB devices. This implies that the UWB devices themselves (metal boxes) are a source of signal attenuation or interference as seen by the WLAN card. For the period around 13, the line of sight between the communicating PC's was blocked by the operator. That blocking causes deep degradation to the reported SNR, and could easily be seen from the results.

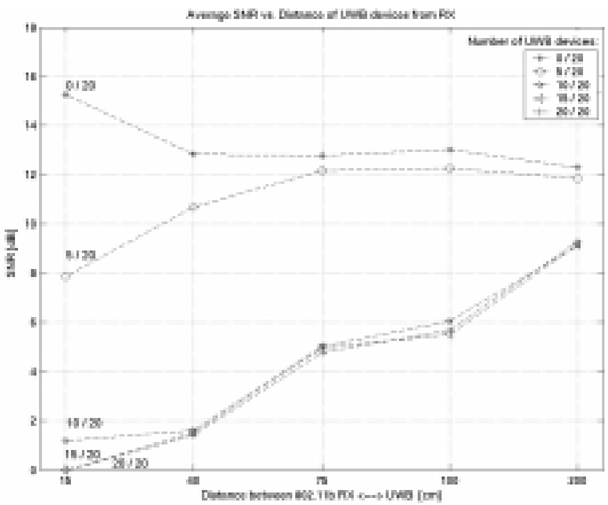

Figure 9. Average SNR as a function of active UWB devices and distance.

One should note that all of these measurements have been performed during normal office hours when other signal sources (interferers) of the typical office environment were present.

Table 1. Periods for the measurements presented in Figure 7 and Figure 8.

20/20 UWB devices	
1 min UWB OFF	0-1
1 min UWB ON	1-2
1 min UWB OFF	2-3
1 min UWB ON	3-4
1 min UWB OFF	4-5
1 min UWB ON	5-6
10/20 UWB devices	
1 min UWB OFF	6-7
1 min UWB ON	7-8
1 min UWB OFF	8-9
1 min UWB ON	9-10
1 min UWB OFF	10-11
1 min UWB ON	11-12
0/20 UWB devices, resistor network	
1 min Resistor ON	14-15
1 min Resistor OFF	15-16
1 min Resistor ON	16-17
1 min Resistor OFF	17-18
1 min Resistor ON	18-19
1 min Resistor OFF	19-20

B. Throughput

This section presents the corresponding results in the network from the throughput point-of-view. The network throughput was studied in a measurement over one night. Two sessions were performed. The first one gave a reference result without UWB interference. During the second measurement all 20 UWB transmitters were active.

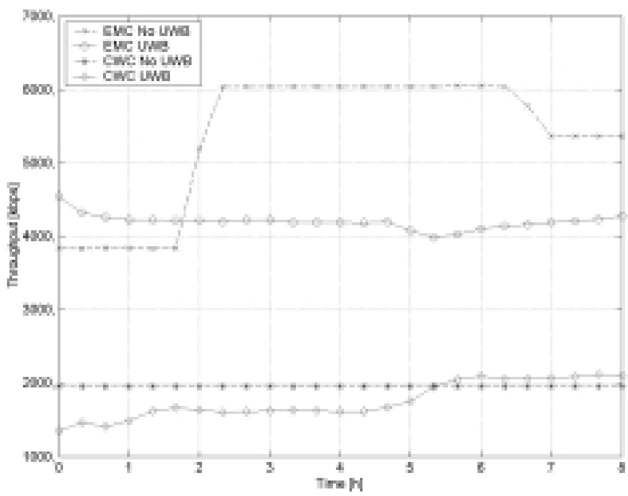

Figure 10. Throughput of the 8 hours measurement.

In Figure 10 the reported throughput of overnight measurements in both the office environment and an anechoic chamber are been presented. The WLAN network was set to operate at 2 Mbps and 5.5 Mbps in the office and anechoic chamber, respectively.

The reference curve gives the throughput when the UWB interference is not active, and the other curve gives the corresponding result when all UWB transmitters were active. For measurements made in the office environment, the UWB transmitters are powered by battery. The effect of the weakening battery can be seen over time from the figure as an increasing WLAN throughput after 4 hours recordings. The UWB transmitter was modified before the anechoic chamber measurement to use an external power source allowing consistent interference levels over time.

Throughput measurements made in the anechoic chamber show the nature of the testing software used (MGEN). MGEN attempts to keep the throughput constant over time. The average throughput increased by 2 Mbps during the recording period in the anechoic chamber when no UWB interference was present. The throughput of the WLAN network is reduced when the high power UWB interference is introduced in the vicinity of the WLAN receiver.
The throughput of the measurements from Figure 7 and Figure 8 is presented in Figure 11.

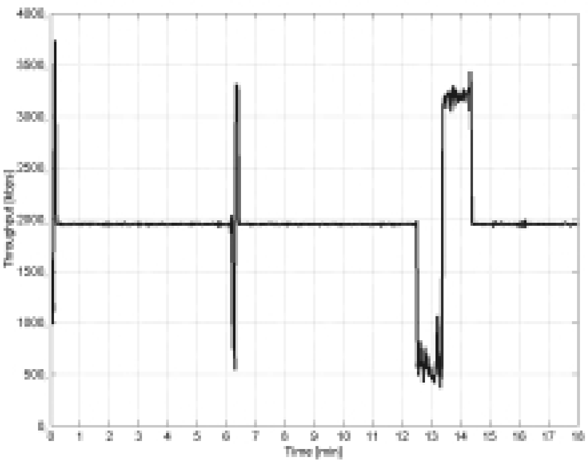

Figure 11. Throughput from the measurement corresponding the results of Figure 7 and Figure 8.

The spikes that can be seen at minutes 6 and 13 are based on the operator movement inside the room. As can be seen from the curve, MGEN keeps the average throughput fixed. A better tool to measure the throughput is TTCP which will be used it the future measurements.

V. CONCLUSION

At present, 10’s of millions of IEEE802.11b enabled devices have been installed worldwide representing a huge investment in a popular technology. This study shows some initial insights into the impact of inexpensive UWB devices on 802.11b systems. The non-FCC compliant devices correspond to hundreds of FCC compatible UWB devices.

Instantaneous signal-to-noise ratio and throughput values have been monitored from the WLAN network in the presence of high power, UWB interference. The preliminary results showed that there is a slight impact caused by high power UWB signal on IEEE802.11b network. The degradation of the received SNR in the office measurements was approximately 5.5 dB and 1.5 dB when 20 or 10 UWB sources were active, respectively. The preliminary tests also showed slight degradation in network throughput in this extreme interference scenario.

In the subsequent implementation of the UWB transmitters, several parameters will be adjustable including the pulse repetition frequency. The transmitters are also planned to have a centre frequency corresponding to that used by IEEE802.11a.

VI. ACKNOWLEDGEMENTS

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[2] http://www.ping127001.com/pingpage.htm (page available at April 16, 2003)

[3] http://www.pcausa.com/Utilities/pcattcp.htm (page available at April 16, 2003)

[4] http://mgen.pf.itd.nrl.navy.mil/ (page available at April 16, 2003)