UWB Impact on IEEE802.11b Wireless Local Area Network

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Abstract

In this paper the impact of ultra wideband (UWB) interference on IEEE802.11b WLAN performance is studied through experimental tests. **Extremely high** power UWB transmitters, that are not FCC compliant, were used in the tests to simulate the impact of very high UWB device concentration. The measurement setup was organized to allow the UWB transmitters to generate as much interference to the WLAN network as possible. Configurations were examined with various distances between the UWB transmitters and WLAN receiver. Peer-to-peer connection and link via access point were studied in office environment during the regular office hours.

The results showed that the UWB population corresponding thousands of FCC compatible devices will decrease the network performance if the interference sources were near the device to be interfered. However, if the interference distance is longer than 50 cm significant decrease in the throughput cannot be seen. In real life, this high UWB population is absurd. Taking into account the reasonable amount of simultaneous UWB devices in a certain area these experiments do not show any significant harm to WLAN network throughput.

Keywords

Co-existence, IEEE802.11b, throughput, ultra wideband, WLAN

1. Introduction

Ultra wideband technology is a very promising option for future short-range indoor high data communication applications. The Federal Communications Commission (FCC) defines a radio system to be an UWB system if the fractional bandwidth Bf or the -10 dB bandwidth of the signal is greater than 20% or greater than 500 MHz, respectively [1]. For indoor applications the unlicensed frequency band from 3.1 GHz to 10.6 GHz has been allocated for that use by the FCC. At the moment, these regulations are valid only in the USA.

For mass deployment of UWB technology, co-existence will become of significant importance. In this paper, the impact of extremely high power impulse radio UWB transmitters on IEEE802.11b network is studied by experimental tests.

2. UWB transmitters

At present, 20 UWB transmitters are available for test purposes. These interference sources and the antennas used are designed and built by PJ Microwave Ltd., Oulu. The first prototypes are simple narrowband pulse transmitters with the following parameters:

The centre frequencies are approximately 1.84 GHz and -10 dB bandwidth is approximately 1 GHz. A significant proportion of the radiated power can be seen in the 2.45 GHz ISM band where the victim system is located. The generated UWB pulse train has a fixed 87 MHz pulse repetition frequency and the pulse duration is approximately 500 ps. Figure 1 shows that substantial ringing is present in the UWB pulse.

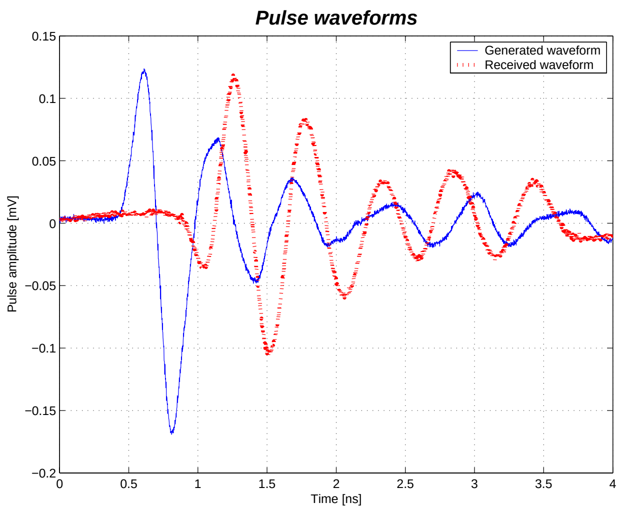

Figure 1. Generated and received pulse waveforms.

In Figure 2, the spectrum of the transmitted pulse train is depicted together with the FCC radiation mask and the bandwidth of the victim system. The line spectral components are based on the fixed pulse repetition frequency of the UWB transmitter.

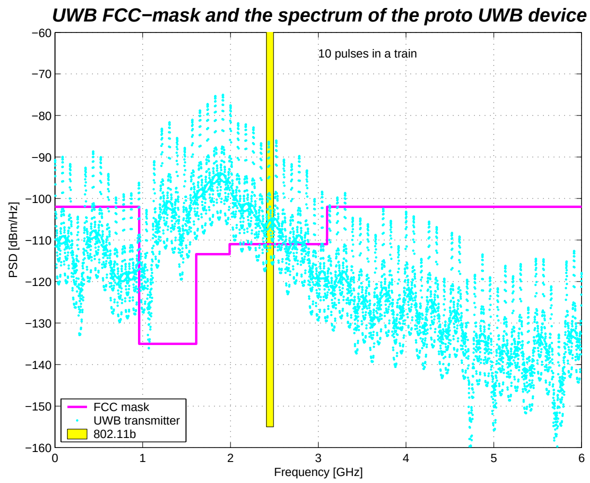

Figure 2. Spectra of the systems under study.

Pulses are generated using a step recovery diode controlled by a free running oscillator. The transmitted waveform is a monocycle derived from two differentially delayed pulses of the form presented in [2]. The measured peak-to-peak voltage for the pulse from the output port of the circuit board is approximately 300 mV. EIRP power is approximately -2...+3 dBm. The UWB devices are all independent and there is no synchronization between the devices. The UWB signal is radiated through the modified bow-tie antenna manufactured using the standard PCB process.

Due to the high power level of the used UWB devices, the real effect of these 20 transmitters corresponds to thousands of FCC compatible devices, and so the effect of very high UWB population can be demonstrated.

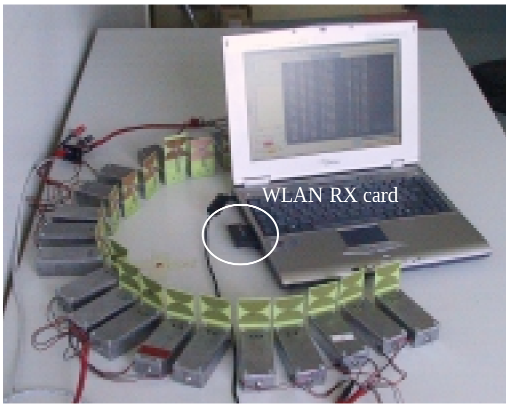

Figure 3. WLAN receiver encircled by the UWB transmitters.

The UWB transmitters used in the study are presented in Figure 3 in a typical placement with the WLAN receiver. The radius of the arc is one of the parameters to be changed during the measurements. The location of the WLAN card is also marked with a circle.

3. Victim network and measurement procedures

The victim network is based on the commercial-off-the-self PCMCIA IEEE802.11b-cards installed into the laptop computers. The reported signal-to-noise ratio (SNR) and throughput of the network were monitored from the peer-to-peer link (p2p, one-hop) and a link through an access point (AP, two-hop). The reports of the link quality are given by the network cards. Measurements were performed in a regular office environment during the office hours. The laptop operating as an access point includes two similar WLAN cards than is used in the other ends of the link (TX and RX).

In Figure 4, the measurement layout is presented. WLAN devices are marked with dots, and the typical outline of the UWB device setting is marked with stars. In peer-to-peer link measurements, the access point in room TL202 in Figure 4 was replaced with a WLAN transmitter. When measuring through the AP, the up- and downlink channels used were different to prevent crosstalk between the devices. WLAN channels 1 and 13 were used in our study. The AP measurements were performed so that the transmitting and receiving devices were in the same room (TX2 and RX were in the room TL204 in Figure 3 and the AP in room TL202) or in two rooms as marked into the figure (TX1-AP-RX).

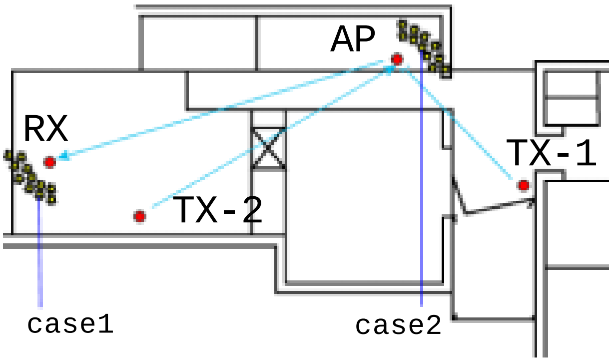

Figure 4. Measurement layout for the office environment.

The UWB interference sources were located in a semi arc at the opposite side of the laptop than the WLAN signal is coming. This setting rejects the WLAN signal to be blocked by the UWB devices. During the study, interference near both the WLAN receiver and the access point were examined. The former study is called as 'Case1' and the later one as 'Case2' (refer to Figure 4). The link distances in the p2p office tests were 10 m (LOS) and 25 m (NLOS). When signalling via AP, the first hop (TX-AP) was 15 m and the second hop (AP-RX) 20 m.

By using quite long hops, the WLAN was operated near the limit of performance to enhance the impact of the UWB interference. The WLAN cards used have a maximum data rate of 11 Mbps but even in a short distance no-interference link this rate was never achieved.

The measurement procedure was as follows: the UWB transmitters located on the arc where switched ON in a group of five devices (0-5-10-15-20). A reference measurement was performed when the UWB transmitters were all OFF but still located in the arc. The arc radii used were between 10 cm and 100 cm.

The network performance was studied using TTCP software [3] which is a command-line sockets-based benchmarking tool for measuring TCP and UDP performances between two systems. In our study, TCP was considered. Using TTCP SNR and throughput of the network can be measured. TTCP does not consider the quality of the link so there were no packet retransmissions if a data packet is lost. The achieved throughput can be calculated by comparing the amount of the transmitted and received packets in data post processing.

During the measurements, there was no movement inside the measurement room. The only intentional interference was caused by the UWB transmitters. However, a link quality measurement without UWB interference (but in the presence of movement) was made. There were no possibilities to control the RF radiation coming from the outside of the office. The effect of this unintentional interference was determined by the reference measurement with zero active UWB transmitters.

The difference between the results of this paper and [4] is that now the UWB transmitters did not block the signal path as was the case in [4]. This blocking effect can be noticed with increased SNR values in the results of this paper. However, there is a consistency between the general results of these two papers.

4. Results

In this section, the results of the measurements are presented. Measurements were performed in an office using peer-to-peer and access point links. Throughout the study, the reference measurements were performed without any UWB interference. The intentional interference was then introduced as described before.

4. 1. Peer-to-peer network

The throughput of the network utilizing peer-to-peer connection was measured at the office environment. To obtain more general results, links with both good and poor link qualities were examined (without UWB interference) as references. These results are presented in Figure 5. In the case of good link quality, e.g. high WLAN SNR at the link distance of 10 m, the impact of high UWB population on WLAN was insignificant. However, if the link distance was long, e.g. having a poor SNR, the throughput of the network decreased with the decreasing interference distance. If the distance between the WLAN RX and UWB interference sources were more than 50 cm the impact was insignificant.

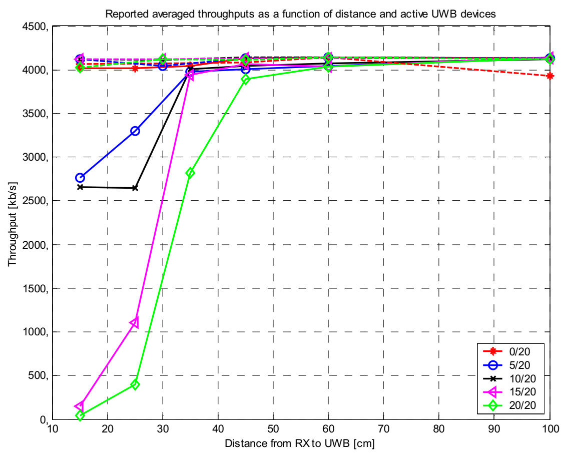

Figure 5. Throughput of the peer-to-peer link at the office.

4.2. Network via access point

In a two-hop connection, the WLAN network experienced interference through the receiver or access point. In both cases the network throughput was measured at the access point and receiver.

In Figure 6 the results for Case1, e.g. UWB devices are surrounding the WLAN RX, are presented. The solid lines and dashed lines represent the throughput of the access point and WLAN receiver, respectively. The different markers present the distance between the interference sources and a victim. The WLAN transmitter and receiver were located in the same room.

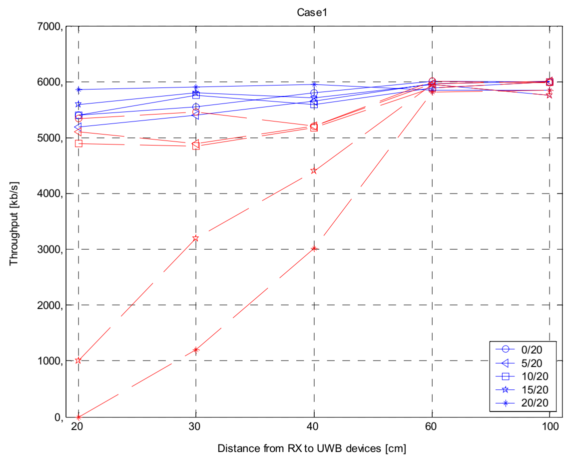

Figure 6. Throughput of the network when WLAN RX is interfered. Solid and dashed lines represent the throughput of the access point and receiver, respectively.

The SNR reported by the WLAN network decreased when as the interference sources came closer. Consequently, the throughput of the RX will also decrease. When all 20 high power UWB transmitters were approximately 20 cm from the WLAN-RX, the throughput dropped to zero. Compared to the undisturbed case, interference was noticeable when the UWB devices were at a distance of 50 cm or less. When only 10 active UWB devices are present, the performance drop was only 500 Mbps at the same distance. The throughput of the access point is insensitive to the interference near the WLAN-RX as the tool used, TTCP, does not measure the network performance, so there are no packet retransmission when packets are lost. The maximum data rate provided by the network was approximately 6 Mbps when UWB signal was absent. As can be seen from the results, the network performance e.g. the throughput, is not stable even in the no interference case. Corresponding measurements were done by interfering the access point, and the results can be seen from Figure 7.

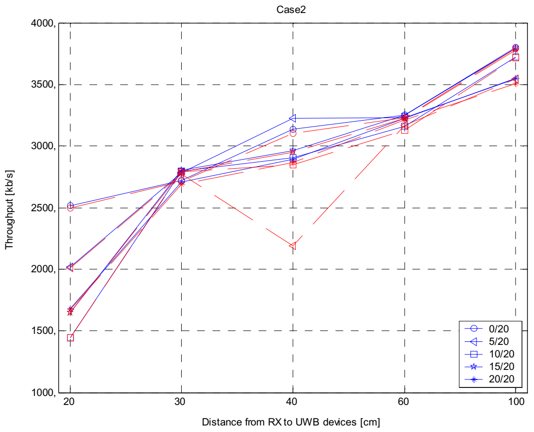

Figure 7. Throughput of the network when the access point was interfered.

Here there is no difference between the throughputs of access point and WLAN RX. All the packets passed through the access point were received at the WLAN destination. The worst case throughput is approximately 1500 kbps even in the case when all the UWB devices were active and the radius was 20 cm.

In Figure 8, the throughput of a two-hop link established between TX1 and RX (cf. Figure 4) are presented. The WLAN RX was encircled by the interference sources.

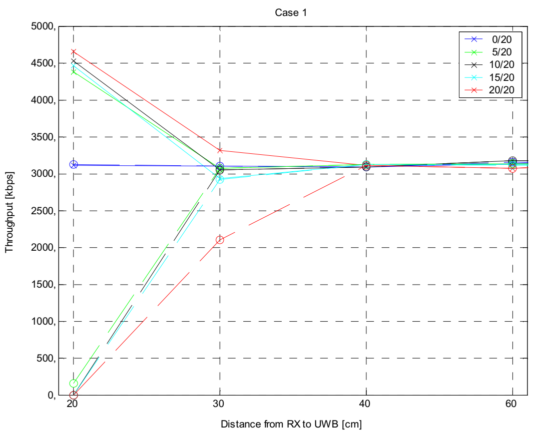

Figure 8. Throughput of the link TX1-AP-RX, WLAN RX was interfered.

During the measurements, the link quality varies significantly as can be seen from the results. The throughput without UWB interference was approximately 3.1 Mbps independent of the radius of the arc where the devices were located. However, the throughput of WLAN RX dropped almost totally when the UWB devices were active and near the receiver. At the same time the throughput of the access point increases. When the distance between the WLAN RX and interference sources was increased the constant throughput was achieved in both WLAN devices. Now, the distance where the effect of the interference can be seen is 40 cm in the worst case situation. One should again remember that the SNR of the WLAN link is relatively low due to the NLOS connection within both hops.

As a comparison, the p2p link performance was measured without UWB interference but having movement near the WLAN devices. The results from these measurements can be found from Figure 9. In the legend, the first and the second parameter defines the device which throughput was considered and which one was the WLAN device walked around, respectively.

As can be seen from the results, movement near the WLAN access point causes the whole network performance to drop. No difference between the throughput of the access point and WLAN RX can be seen. If the movement were near the WLAN RX the throughput of the RX changes a lot. No impact to AP performance can be seen. The average results are comparable with the interference caused by 20 high power UWB transmitters at the distance of 25 cm.

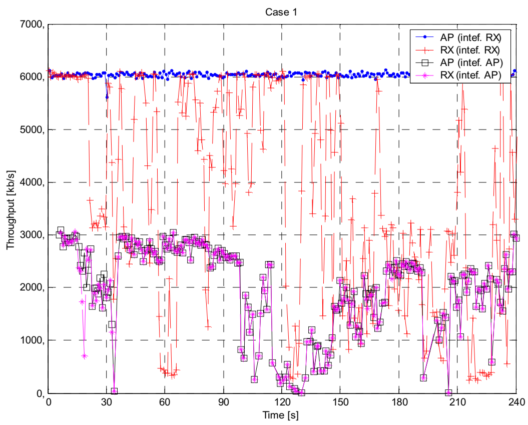

Figure 9. Throughput of the network when interference is based on the movement in a room. No UWB interference.

5. Conclusion

At present, millions of wireless local area networks based on IEEE802.11b have been installed worldwide. This study highlights the level of impact of simple UWB devices on existing IEEE802.11b connections. The results presented in this paper are based on SNR and throughput levels reported by the network cards.

The high power UWB devices used in the study correspond to thousands of FCC compatible UWB devices. Consequently, the effect of extremely large UWB population is demonstrated. Preliminary results showed that under the extremely high UWB interference, the throughput of IEEE802.11b network is decreasing if the distance between the interference sources and victim receiver is quite small.

The result showed that both in the peer-to-peer link and the connection through the access point the impact of the high UWB power on the network throughput can be seen only if the interfering distance is less than 40-50 cm. However, demonstrating the reasonable number of simultaneous UWB devices the distance is even smaller. As a comparison to the intentional RF interference, the impact of movement on WLAN was examined. The results showed that the movement corresponds to the worst case UWB interference at a distance of approximately 25 cm from the victim receiver.

The impact of the UWB interference on the WLAN performance depends on the SNR of the WLAN network. If the network is operating in the high SNR range, which means small distance between the devices and line-of-sight, the impact of the high power UWB interference on the network is negligible.

6. Acknowledgements

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