Ultra-Wideband (UWB) Aggregation and Co-existence of Wi-Fi 6E Operating in the Presence of UWB

April 11, 2023

About the UWB Alliance

The Ultra Wide Band (UWB) Alliance is a global not-for-profit organization that works to collectively establish ultra-wideband (UWB) technology as an open-standards industry. A coalition made up of vendors that either design, manufacture, or sell products that use ultra-wideband technology, the UWB Alliance aims to promote and protect the current allocation of bandwidth as well as promote the continuing globalization of the technology. As part of our mission, we advocate UWB technology and use cases to promote verticals showing the value of UWB for IoT and Industry 4.0 and to build a global ecosystem across the complete UWB value chain, from the silicon to the service. In addition, the Alliance is promoting and assuring interoperability through its work with Standards Development Organizations such as the IEEE and ETSI and then working with members to define upper layers and testing to assure compliance. For more information, please visit us at www.UWBAlliance.org.

Executive Summary

This study examines how several wireless technologies operating in an increasingly dense wireless environment interact with each other and themselves. The study shows empirical results of RF and link performance measurements of numerous 802.11ax and Ultra-Wideband (UWB) devices operating in a typical urban office.

Over-the-air performance of several 802.11ax links were tested, including performance in the presence of multiple UWB devices. Numerous variables had measurable impact on the 802.11ax data communication rate and range including the quantity of Wi-Fi 6E devices operating in the area, the presence of people near the APs, as well as the positioning of the people throughout the room. **It should be noted however that the presence of UWB did not have any measurable impact on 802.11ax performance.**

The scope also included determining the ability to detect UWB activity using commercially available spectrum monitoring equipment. While UWB transmissions were easily identified, the quantity of transmitters could not be determined. RF measurements were made to characterize the aggregation effect of multiple UWB transmitters operating in close proximity to each other. **Contrary to conventional expectations, UWB power did not aggregate linearly with the number of devices, even when operated at high transmission rates.**

Background and Purpose

Ultra-Wideband wireless technology device adoption is growing rapidly due to its suitability in many important applications. These applications include, but are not restricted to, secure keyless entry, high dynamic voice transmission, proximity and direction identification for broadband transmission initiation, personal and industrial asset tracking, sports tracking, and radar.

Impulse Radio UWB (IR-UWB) has several unique properties that enable or enhance these applications such as precise ranging and low latency communication. Additionally, due to the extremely low transmit power and sparse, short pulses, the self-interference is extremely low, enabling very high density of devices to coexist in any given area.

The ability to instantaneously provide precise centimeter ranging accuracy and resolution is being widely applied for localization and secure entry applications. These properties make UWB a good complement to other wireless technologies by extending available performance capabilities. For example, UWB is being used to improve the locating abilities of BLE. It is also being used to initiate the transmission of Wi-Fi over personal area VPN links. Increasingly, UWB is also being used for low to moderate rate low latency communications such as high-performance audio. The signal properties of UWB also enable precise sensing such as presence detection which is gaining popularity in uses such as detecting the presence of a child inside a car, as well as other sensing such as heartbeat and respiration detection.

As these applications are becoming ubiquitous, concerns have grown as to the potential for harmful interference to sensitive receivers and systems utilizing RF communication. Among these concerns are aggregation of RF noise from the transmissions from large quantities of UWB consumer devices, and their effect of UWB on high QAM OFDM communications.

The primary goal of these tests was to determine whether the aggregation of signals should be a concern to other users of weak signal, high sensitivity radio equipment. Specifically, to determine if high QAM signals used in Wi-Fi that are spread over 160 GHz would be victims of harmful interference.

Conversely, entities that monitor communications for security reasons have concerns that they may not be able to detect the presence of UWB. Given that the power spectral density is limited to "at or below" unintentional emissions limits and the "noise like" characteristics of a UWB signal this is a reasonable concern. A secondary goal of this study was to determine if the presence of a UWB transmitter would be detectable using conventional, readily available detection equipment.

Methods

General methods

The environment chosen is representative *of a typical* urban office setting. A large open area was selected in which normal workday operations were in progress. Within this environment were multiple non-coordinated RF sources in various bands. The urban office setting was in Washington, D.C. during a normal workday. The large open area was being used for normal workday activities. The total number of people and associated devices (laptops, phones, etc.) varied throughout the day. Numerous other RF sources were observed in or near the 6 GHz test band, including what appeared to be some utility systems and perhaps building automation. Additionally, unintentional emissions from both unintentional radiators and what may have been out-of-band emissions from other RF transmitters were observed. The environment was typical of what will be encountered in the real world.

Test devices included 3 different Wi-Fi 6E access points and *multiple* Wi-Fi 6E client devices. The access points (AP) were configured to operate in the 6 GHz band as low power indoor (LPI) APs. The UWB test devices were configured to operate in the same band. Two types of UWB devices were used*;* one set was configured to perform ranging operations and another set was configured to stream data.

Test equipment included spectrum analyzers with instrumentation antennas to perform RF measurements, and an AirCheck G3 Wireless Analyzer to monitor performance of the Wi-Fi 6E devices. iPerf software was used for generating signals and determining Wi-Fi bandwidth performance. The APs were connected via 100 Gbit/sec Ethernet to computers that served as source and collector of traffic for testing. This assured that the wireless performance was not affected by backhaul limitations.

The spectrum analyzers were configured with appropriate instrumentation antenna and signal processing to make ambient measurements of the environment. Antenna placement and height were adjusted to empirically find the optimal placement. Once set, their position remained constant through the test cycle.

Baseline performance was established without any transmissions from the UWB devices. Wi-Fi 6E clients were added incrementally to the maximum available noting any changes in performance. A long-term characterization of the ambient baseline was not possible due to logistics. The focus of this portion of the test was to monitor the Wi-Fi 6E performance to detect influence from the UWB transmissions.

Equipment for tests

Test equipment:

For RF measurements, a Signal Hound 200C standard temperature version spectrum analyzer operating with computer interface software “Spike” from Signal Hound was used. An AS-48461 Series Dual-polarized quad-ridged horn antenna was connected to the spectrum analyzer. A portable spectrum analyzer was used to verify the measurements and confirm operation of test devices.

For Wi-Fi 6E performance testing, NetAlly computer software and handheld analyzer were used, with iPerf for traffic generation and performance monitoring. The AirCheck G3 handheld tester was used to monitor over-the-air performance, which provided greater visibility into the 802.11ax operating mode such as on-air data rate and retransmissions. The NetAlly Link-Live Collaboration, Reporting, and Analysis Platform was used to collect and analyze performance data.

A notebook PC running Windows 11 OS was used as the iPerf server. It was connected to a NETGEAR Nighthawk Wi-Fi 6e client to serve as host to the AirCheck G3 tester which provided over-the-air observations as shown in Figure 1.

Figure 1

Wi-Fi 6E equipment:

Three models of Access Points (AP) were used:

- ASUS AXE6600 tri-band mesh Wi-Fi 6e system
- Linksys MX8500 Wi-Fi 6e tri-band
- TP-link AXE7800 tri-band 8-stream Wi-Fi 6e router

NETGEAR Nighthawk Wi-Fi 6e client device was used with laptop computers as iPerf client.

UWB Equipment:

Two types of UWB devices were used:

- Qorvo DW3000 Development Kits: 10 devices (5 pairs)
- Spark Microsystems SR1000 Series evaluation kits (5 kits, total 10 devices)

The DW3000 were used with the Qorvo ranging and tracking application software, configured to transmit at a rate of one ranging exchange per second. The Spark SR1000 evaluation kit devices were configured to transmit a continuous stream of data.

Overview of tests

After environment characterization, the baseline performance of the Wi-Fi 6E links was established. Initially a single client was used. Additional client devices were added incrementally, and variations of Wi-Fi performance were recorded. The distances between the RLAN devices were kept constant throughout the test.

The nominal separation distance of the Wi-Fi 6E AP and client was 8 ft. The APs' bandwidth was autoconfigured and thus they would attempt maximum throughput and back off as needed to optimize the wireless performance.

After capturing the baseline performance of the RLAN network and clients, UWB devices were introduced incrementally. Performance measurements were taken at each increment. Initially, the UWB devices were tested within 1m and .5m of each RLAN access point. After observing no changes in Wi-Fi performance, the UWB devices were placed immediately adjacent to (within 5 in.) the RLAN APs' and the tests were repeated.

The test scenario was repeated for each of the Wi-Fi 6E access points.

Ambient environment baseline

Prior to turning on any of the test devices, Aircheck3 was used to examine the ambient RF environment. The device recorded 305 RF devices operating in the 2.4, 5, and 6GHz bands at our location.

Testing multiple UWB devices

Following baseline performance capture, UWB devices were introduced incrementally. Both increasing and decreasing sequences of adding UWB devices were used. Increasing sequence begins with a single device and then adds devices; the decreasing sequence begins with the maximum number of devices and then decreases to a single transmitter. This allowed immediate repeat measurements for the purpose of comparing the validity and stability of the performance result observed with each incremented value.

RF measurements were made during each test and observed results were recorded in the companion LinkLive software on the AirCheck G3 Pro system.

Results

UWB impact on Wi-Fi 6E performance

The addition of UWB devices had no measurable impact on Wi-Fi 6E performance. We observed that many other variables had measurable impact, including the number of Wi-Fi 6E devices operating in the area, as well as the presence of people near the APs. The addition of UWB devices in either the increasing or decreasing sequence had no measurable impact.

The absence of interference to the Wi-Fi throughput is shown in Figure 2 which shows zero UWB devices versus 3 UWB devices. This was true at the 1m or .5m separation distance. The AS-48461 Series Dual-polarized quad-ridged horn antenna was focused on the UWB transmitters to minimize reception from the Wi-Fi Access Points.

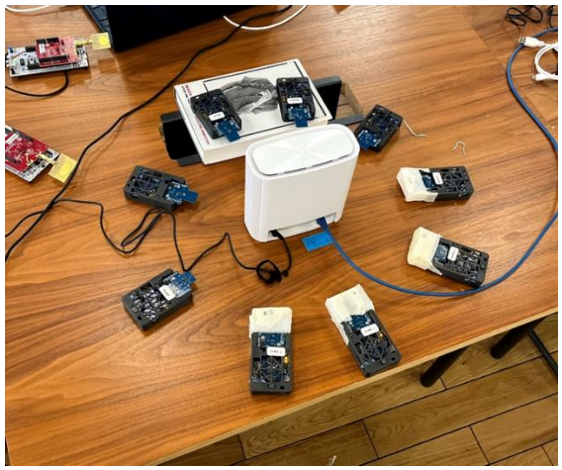
Figure 2

Wi-Fi Throughput with no UWB

Wi-fi throughput with 3 UWB devices

To find a “worse than worst case” configuration, 8 Spark UWB devices were arranged with a separation distance of approximately 4 in. (10cm) from the AP and set to transmit as shown in Figure 3. Even in this configuration, no measurable impact on the Wi-Fi 6E performance was observed.

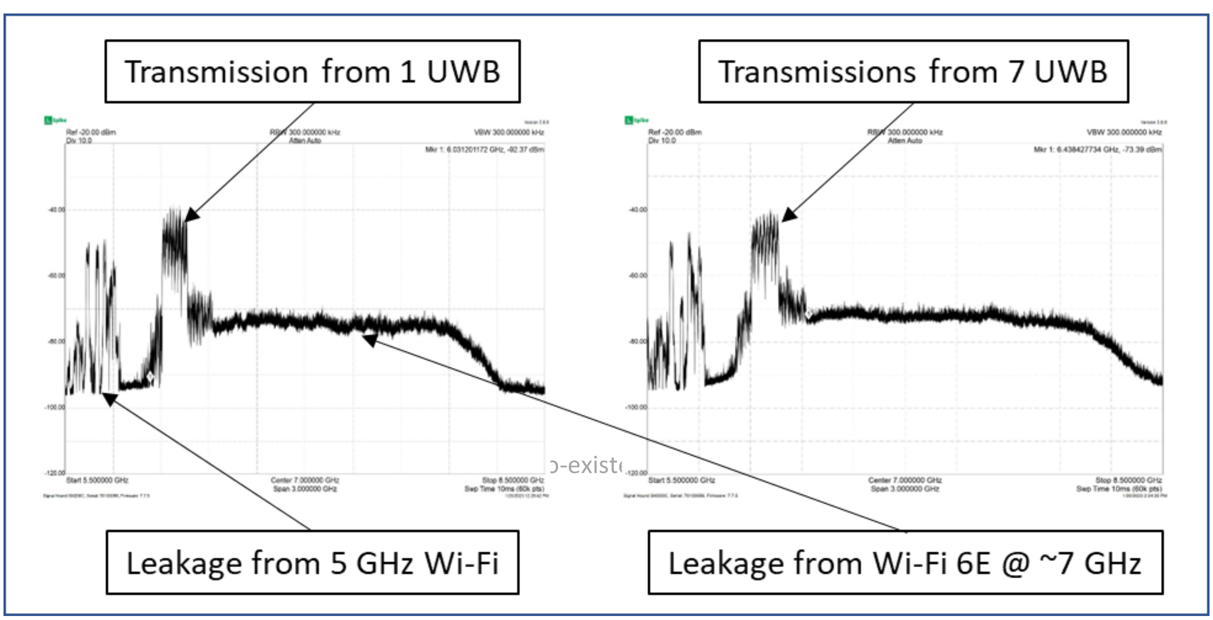
Figure 3



Detecting UWB and aggregation of UWB

RF measurements showed that the presence of a UWB transmitter was clearly observable on the spectrum analyzer. However, aggregation of UWB devices did not increase the measured energy in the channel. The difference between a single UWB transmitter and multiple transmitters in aggregate could not be determined for the RF measurements. Figure 4 shows a comparison of 1 UWB device versus 7 devices transmitting simultaneously. The figure is a snapshot in time that shows frequency across the X-axis. As shown, there is no difference in the observed power level.

Figure 4



Discussion

It is possible to show via simulation a potential for UWB to impact the performance of the 802.11ax link at separation distances of 1m to 3m when the 802.11ax link is simulated at the highest MCS and thus lowest receiver sensitivity. In this practical testing, we observed that the 802.11ax automatically chooses a lower MCS, hence no impact was observed.

Table 1 summarizes the performance of 802.11ax in the absence of UWB. This shows the standard deviation of multiple baseline 802.11ax performance and the impact of one or two additional APs with no UWB. Table 2 summarizes the performance of the 802.11ax links in the presence of one to 4 UWB transmitters.

Table 1: Baseline Performance, one to 3 APs, no UWB

	PHY Rate Mbps	Avg Down Throughput Mbps	Avg UP Throughput Mbps	Signal Level dBm	Retry Rate %
Standard deviation all AP perf data w/o UWB*	245.08	43.89	90.12	5.64	2%
TP-Link	1921.6	462	583.6	-44.00	1%
with ASUS	1729.4	456.4	488.3	-43.00	3%
with Linksys	1921.6	459.2	574.2	-44.00	3%
with ASUS and Linksys	2161.8	448.1	568.1	-41.00	5%

Table 2: Baseline vs with UWB

	PHY Rate Mbps	Avg Down Throughput Mbps	Avg UP Throughput Mbps	Signal Level dBm	Retry Rate %
All APs Average Performance - baseline	2087.07	439.57	538.79	-47.67	1.78%
All APs Average Performance - 1 UWB	2104.15	440.94	547.73	-55.30	1.40%
All APs Average Performance - 2 UWB	2185.82	438.87	534.68	-54.90	2.20%
All APs Average Performance - 3 UWB	2128.17	431.21	515.03	-54.30	1.10%
All APs Average Performance - 4 UWB	2209.83	441.40	534.12	-53.83	0.67%

The observation of iPerf data and the visibility into the Physical Layer (PHY) data rate showed that to maintain operation, the 802.11ax APs and clients were “down shifted” to a stronger modulation and coding scheme (MCS) in the baseline (no UWB) and there was no change in MCS with UWB present. In the real-world environment there are many potential interference sources and channel impairment variations. We observed that many factors other than UWB affected the 802.11ax performance. This can be observed via the standard deviation of the baseline measurements. Operating multiple 802.11ax networks (multiple APs) simultaneously had the greatest effect, as seen by retry rate.

The other key goal of the session was to determine detectability of one and multiple UWB devices and whether there was standard aggregation as seen from devices modulating in the frequency domain. The noise-like characteristics of the signal and extremely low power raised concerns by security agencies that a UWB transmitter may be difficult to detect. Determining methods by which UWB signals could be detected was part of this goal. What was observed is that the presence of a UWB transmitter was readily seen with the spectrum analyzer, but multiple transmitters made no difference. We can explain this due to the sparse nature of UWB pulses, which are unlikely to align. This is a well-known characteristic that enables multiple UWB transmitters to occupy the channel at the same time without interfering with each other. This may be a key factor in the actual aggregation observations.

Conclusions and Follow-up plans

High-rate Wi-Fi 6E devices operating in the 6 GHz band are subject to multiple sources of interference. However, UWB devices operating at standard power levels are not one of those factors, even when operating in close proximity to Wi-Fi transmitters and receivers.

UWB transmissions do not aggregate the same as transmissions from standard modulation methodologies.

As a follow-up study, UWB Alliance is planning to perform larger scale aggregation testing with a minimum of 100 UWB devices with a research agency in Europe. The details of this study are under development. Additionally, we are considering updated simulation studies, updating the simulation assumptions based on what has been empirically observed.