Coexistence Niche of Ultra-Wideband and Wi-Fi: Suspected Spurious Signal Reception in Channel 5

Radovan Juran[1], Jari Nurmi[2], Aleksandr Ometov[2]

[1]Department of Telecommunications, Brno University of Technology, Brno, Czech Republic
[2]Unit of Electrical Engineering, Tampere University, Finland
✉Contact author's e-mail: radovan.juran@vut.cz

***Abstract*—Introducing Wi-Fi 6E and the emerging Wi-Fi 7 has raised significant questions about the coexistence of Ultra-Wideband (UWB) systems operating in the 6 GHz frequency band. The research in this field has mainly focused on the impact of Wi-Fi on UWB communication and the range of their simultaneous operation. Prior studies have highlighted the destructive effects of Wi-Fi on UWB communication in this band, including the false detection of UWB frames while ongoing UWB transmission. However, to our knowledge, no studies have focused exclusively on the impact of Wi-Fi signals solely on UWB receivers' behavior in isolation. This paper addresses this gap by presenting results obtained under controlled conditions in an anechoic chamber, where external interference is eliminated. Using a setup with only a DW1000 UWB receiver (DWM1001-DEV) and a Wi-Fi 6E access point (Netgear RAXE500) transmitting standard beacon frames and then traffic emulated by iperf tool it was observed that UWB reception can be influenced even without ongoing active UWB transmissions. On top of that, some of these dropped UWB packets (false negatives) showed signs of good CRC checks (false positives). These findings provide a foundation for further exploration, particularly with both legacy and newer UWB chips to confirm or disprove the implications hereby presented.**

***Index Terms*—Ultra-Wideband, interference, coexistence, DW1000, reception, spurious signal**

I. Introduction

Ultra-Wideband (UWB) is gaining a lot of attention in the tech world for its ability to transfer data, precisely measure distances, and enables location tracking. UWB is being adopted widely across the market, thanks to progress in standardization, like the IEEE 802.15.4z standard and the upcoming UWB Next Generation (UWB-NG) IEEE 802.15.4ab [1], [2]. In Industrial Internet of Things (IIoT) applications, UWB is becoming a key technology for automating manufacturing and logistics by enabling precise real-time location and tracking. The European Telecommunications Standards Institute (ETSI) points out that tracking locations indoors has always been challenging, especially in industrial environments where signals can get blocked, reflected, or face interference. The UWB has proven to be much more effective in these situations compared to traditional radio systems. Thus, ETSI also supports the key role of UWB in positioning services [3].

Even though most UWB applications now use specific channels like CH3 and CH9 (as recommended by omlox [4] and required by the FiRa Consortium [5]), UWB can still operate in some overlapping unlicensed frequency bands and for various applications [6]–[8]. This is important for older UWB deployments and early experiments, many of which used CH5 (6489.6 MHz). Because of this, CH5 still plays a significant role and should not be overlooked.

The extended IEEE 802.11ax standard, known as Wi-Fi 6E, allows Wi-Fi devices to operate in the 6 GHz band [9]. Previous research has shown that Wi-Fi signals in the 6 GHz band can interfere with UWB signals, causing issues where the UWB receiver mistakenly tries to decode the Wi-Fi signal [10]. The goal of this study is to investigate this interference in detail and isolate it under controlled lab conditions.

Contribution: While the impact of 6 GHz Wi-Fi on UWB has been studied, most of the focus has been on destructive interference when both systems communicate simultaneously. This paper, however, examines how even a Wi-Fi signal alone can affect a UWB receiver, even when no UWB transmission is active between the receiver an UWB transmitter exchanging actual UWB data packets. The results were obtained from tests in an anechoic chamber, where external interference was completely suppressed. This study shows that even basic Wi-Fi Beacon frames, which are the minimum signals Wi-Fi devices send periodically, can cause issues for UWB reception. This is important because existing UWB hardware in the field could experience similar problems.

These findings raise new questions for further research, especially regarding different UWB chipsets beyond the legacy DW1000, which may also be affected. With Wi-Fi 7 devices (IEEE 802.11be) expected by the end of 2024, featuring new modulations and expanded spectrum use, more research is needed to understand how these changes might impact UWB [5], [10].

The rest of the paper is organized as follows. First, Section II provides the background information of spectrum the utilization and technology co-existence. Next, Section III outlines the experimental setup. Section IV delves into numerical results. The last two sections focus on the discussion and provide conclusions.

II. Background and Prior Research

This section summarizes the current use of frequencies in the 6 GHz target spectrum, the resulting coexistence problems, and existing research on them, highlighting the research gap in spurious reception.

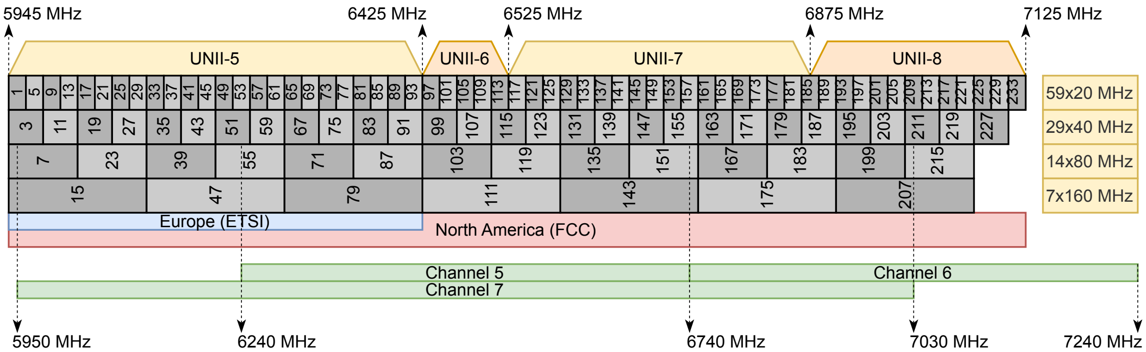

Fig. 1: Channels of UWB (CH) and Wi-Fi (Ch) [11].

A. The 6 GHz Spectrum Utilization

The Ultra-Wideband (UWB) is a radio technology that operates across a wide range of frequencies from 3.1 GHz to 10.6 GHz, yet as the Figure 1 shows, it also overlaps with some Wi-Fi 6E channels.

Briefly summarized, the state of standardization of the UWB is currently forged by the Task Group 4ab (TG4ab), which is focused on development of an amendment to the today's IEEE 802.15.4z [11] (802.15.4-2020) – the IEEE 802.15.4ab, also dubbed UWB Next Generation [1].

As for the Wi-Fi, the IEEE 802.11ax known as Wi-Fi 6 was extended, hence the "E" in Wi-Fi 6E, allowing Wi-Fi devices to operate in 6 GHz spectrum [9]. This was a fundamental step forward and a preliminary stage for the IEEE 802.11be or Wi-Fi 7 to operate [12].

B. Coexistence

The topic of Wi-Fi 6E and UWB coexistence is not new and has caught the attention of both researchers and industrial practitioners, as the increasing deployment of these technologies necessitates a better understanding of their interaction and the potential for interference in shared frequency bands. It has been concluded, that the UWB transmissions do not have measurable impact on IEEE 802.11ax performance [13], [14].

However, the first published experimental study analyzing the impact of Wi-Fi 6E traffic on co-located UWB systems, authored by Brunner et al. [10], shows, that there is a significant destructive interference to UWB transmissions caused by Wi-Fi 6E traffic specifically using the DW1000 radio. It was then followed by two studies of the same affiliation, comparing DW1000 to DW3000 and their performance [15], [16].

With precision of surgical pathology, the investigators offer an in-depth analysis of the signal reception and values of related registers of the DW1000 chip. The analysis brings two key takeaways:

1) UWB performance rapidly deteriorates under Wi-Fi 6E,
2) The errors over 100% indicate false packet detection.

III. Experimental Setup

The significance of utilizin the anechoic chamber lays in removing any external interference. The experimental setup is depicted in the Figure 2, showing host laptop, Wi-Fi 6E access point (AP) Netgear RAXE500, client PC with Wi-Fi 6E enabled Intel AX210, and a nearby listening receiver UWB DW1000 on a DWM1001-DEV kit. Control variables are follows: 5 m distance between AP and UWB receiver, default transmission power settings, UWB in CH5, 6.8 Mbps, CRC filter on, standard frame delimiter. Meanwhile Wi-Fi was set closest to UWB CH5 center frequency of 6489 MHz – narrowband channel 109 (center frequency 6495 MHz and 20 MHz bandwidth) as opposed to broadband channel 111 (center frequency 6495 MHz and 160 MHz bandwidth) [10].

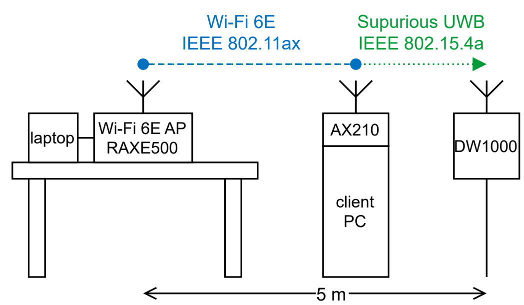

Fig. 2: Experimental setup.

The Wi-Fi signal was introduced in two scenarios:

1) beacons of the idle AP,
2) iperf traffic laptop-PC.

Wi-Fi beacons are typically transmitted with a default period of 100 milliseconds, which corresponds to a beacon interval of 10 time units (TUs), where each TU is 1024 microseconds.

The iperf traffic was generated by the iperf client (laptop), transmitting to the iperf server (PC) via Wi-Fi 6E, with the laptop connected to the AP via Ethernet and four processes on separate ports (5001-5004) were running as follows:

```
iperf3.exe -c 192.168.225.3 -p 5001 &
iperf3.exe -c 192.168.225.3 -p 5002 &
iperf3.exe -c 192.168.225.3 -p 5003 &
iperf3.exe -c 192.168.225.3 -p 5004
```

The terminology further used for description:

- **False Negative**: This can be described as a missed detection or failed packet reception, where the UWB receiver fails to recognize a valid UWB signal because it was overshadowed or interfered with by the WiFi signal.
- **False Positive**: This could be referred to as a spurious packet detection or erroneous reception, where the UWB receiver mistakenly interprets a WiFi signal as a valid UWB packet, even though it was not intended for it.

In both cases, these errors are often due to coexistence issues where the UWB receiver incorrectly processes non-UWB signals or misses genuine UWB packets due to interference.

IV. Results

This section summarizes all the empirical and systematial findings of Wi-Fi 6E impact on UWB receiver without any active ongoing UWB transmissions.

A. Common Office Background Noise

To understand any possible self-induced errors or noise interference on the configured DWM1001-DEV kit, the easiest way was simply leaving the receiver alone for a longer period of time in a standard office environment without any WI-Fi 6E present, but otherwise radiofrequency background with common services of legacy Wi-Fi, Bluetooth, digital audio broadcast (DAB) radio, and other energy normally present in the spectrum in a standard urban area presentable as noise to the UWB receiver or even out of its frequency range. The observation results are in Table I.

TABLE I: The UWB receiver on an office table, no Wi-Fi 6E present. Timestamps correspond to the time of day.

Parameters	10:47	10:56	11:51	12:24	12:46
Good CRC	0	0	0	0	0
Bad CRC	0	0	0	0	0
Header Errors	0	0	3	3	3
Frame sync loss events	0	0	0	0	0
SFD Timeouts	0	2	8	10	14

Time stamps were a random pick to check the state of the receiver in total of 5 samples. There are slight changes in counters, but this behavior is intentional and documented in DW1000 User Manual under sections discussing receiver sensitivity and detection thresholds [17]. This is an intentional trade-off to improve sensitivity and the receiver is tuned this way. As a consequence, the receiver can show occasional misclassifications and SFD timeout or detect preamble from noise and then trigger SFD TO as no SFD is present.

B. Beacons in the Chamber

The impact of beacon frames on UWB receiver in isolation is plotted in Figure 3.

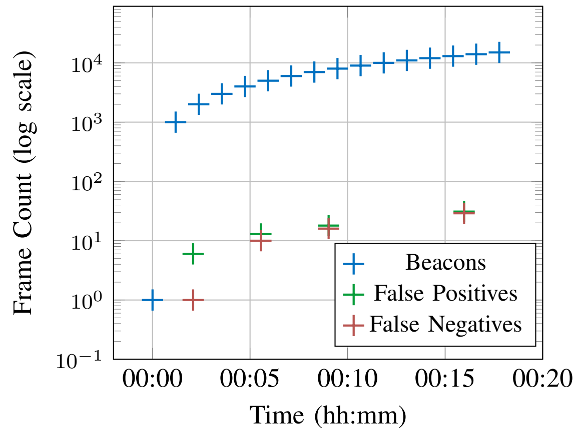

Fig. 3: Spurious reception of beacon frames.

As observed, the falsely classified packets are in linear relationship with the beacon frames. This is due to periodicity of beacons. However, a disturbing observation is that not only false negatives are rising, but also false positives. After short period of time the false negatives outnumber the false positives, which is more visible during a longer time period and under heavier load in the following setup with Wi-Fi traffic.

C. Traffic in the Chamber

As observed with the beacon frames in previous sub-chapter, the false negatives outnumber the false positives considerably after a short period of time. The Beacon frame count curve is left in the graph for comparison, even though the Wi-Fi signal presence is now denser due to iperf traffic as observable in Figure 4.

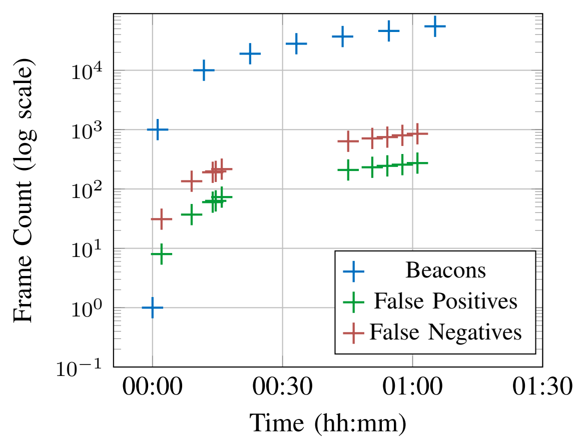

Fig. 4: Spurious reception under iperf traffic.

However, plots use a logarithmic scale on the vertical axis, as the number of spurious packets misclassified by the DW1000 is merely visible on linear scale when compared just to the count of the Wi-Fi beacons. The overall number of packets suspiciously passing the CRC check is always lesser.

Figure 5 shows a clear comparison of the number of frames and the related SFD and TO errors. For periodic beacon signal there is larger gap between total start of fram timeouts and header errors, indicating more successful tricking of the receiver into reception attempts, while with random iperf traffic the numbers are almost close to the order of magnitude.

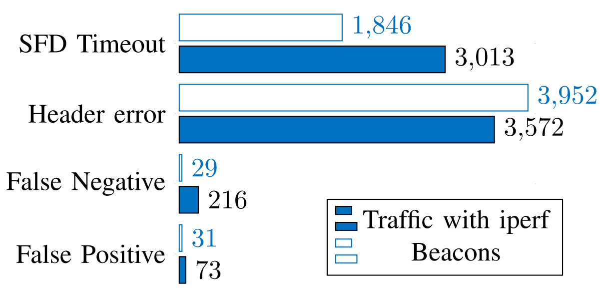

Fig. 5: Key metrics compared for both scenarios.

V. Discussion

Previously published studies conclude, that during simultaneous communication of Wi-Fi 6E and UWB the number of reported receptions exceeds the number of actually transmitted packets, clearly indicating spurious reception of Wi-Fi 6E signal by the UWB receiver [10], [15]. However, these erroneous receptions were observed as part of the overall reception statistics. Even though the authors discuss the impact on UWB receiver of a non-overlapping Wi-Fi 6E traffic in the eponymous chapter 4.3 in their work [10], they have investigated this event again only immersed into the ongoing UWB transmissions. Nonetheless, the key takeaways are:

1) The reception misclassification occurs,
2) Wi-Fi 6E signal effectively tricks UWB receiver,
3) There is a correlation with gain and sensitivity.

Errors in classification were observed even without direct interference of Wi-Fi 6E packets with UWB; they occurred just in the mere presence of Wi-Fi 6E signals.

The reception mechanism specifics likely originates from the DW1000 chip's design, which mistakenly identifies a Wi-Fi signal as a UWB preamble. This leads to a Synchronization Frame Delimiter (SFD) timeout, causing the UWB packet to be missed. Normally however, an invalid SFD sequence should trigger a Physical Header (PHR) error, preventing the frame from being decoded.

The DW1000 chip features Automatic Gain Control (AGC), which adjusts the receiver's gain based on the signal strength it detects. However, the power levels of Wi-Fi 6E are incomparable to the UWB, causing the AGC to reduce gain and sensitivity. The authors noted a direct link between the AGC settings and reception errors. Therefore, the described problem may be related to the sensitivity of the DW1000 receiver, as discussed in subsection IV-A.

However, more in-depth investigation into this phenomenon is necessary. The results also suggest a probability of a systematic error in data acquisition.

Conclusion

The coexistence of Wi-Fi 6E and UWB has been studied in detail in previous research. Standardization helps ensure that UWB applications run smoothly and without interference. Past studies agree that Wi-Fi 6E can interfere with UWB, even when there are no active UWB transmissions. This study provides insights into reception errors in the 6 GHz spectrum, revealing previously unobserved behavior in the receiver—specifically, the reception of incorrect frames. However, the exact causes of these issues are still uncertain. They could be due to a human factor, such as a firmware error, or because the power levels of Wi-Fi 6E are higher than what the chip was designed to handle, potentially causing saturation in the receiver. This phenomenon requires further investigation and encourages more research on additional chip types, including those in mobile phones. It would be valuable to disprove these findings or uncover their deeper causes.

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