AN0002 - Wi-Fi Interference with CSS Transmission

1.0

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Contents

1. Introduction

The CSS spreading method used on Nanotron nanoLOC chips and *swarm* bee LE modules spreads the transmitted signal over the whole 2.4 GHz ISM band. The whole 80 MHz band from 2.4 GHz to 2.48 GHz is used by CSS. Wi-Fi can also operate in 2.4 GHz ISM band, but the band is divided into 20 MHz channels (non-overlapping or overlapping). The degree of occupation of the 2.4 GHz spectrum depends on how many Wi-Fi channels are used simultaneously.

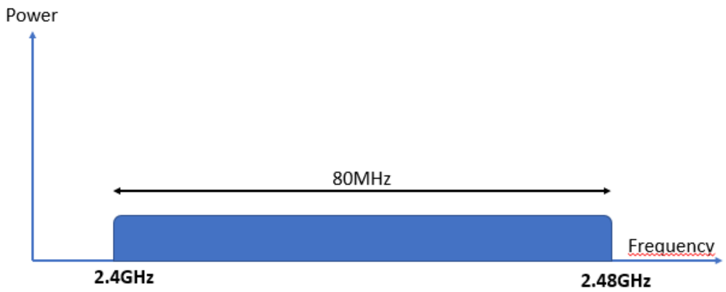

Figure 1 CSS Signal Spectrum

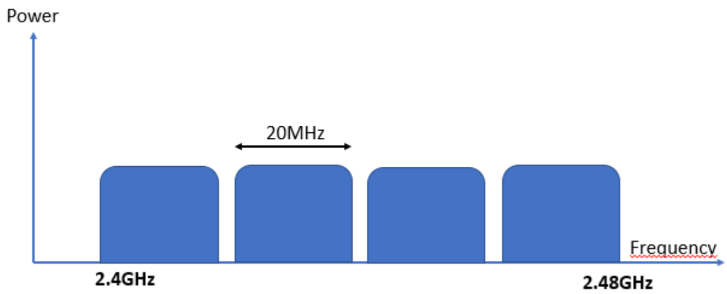

Figure 2 Wi-Fi Signal Spectrum

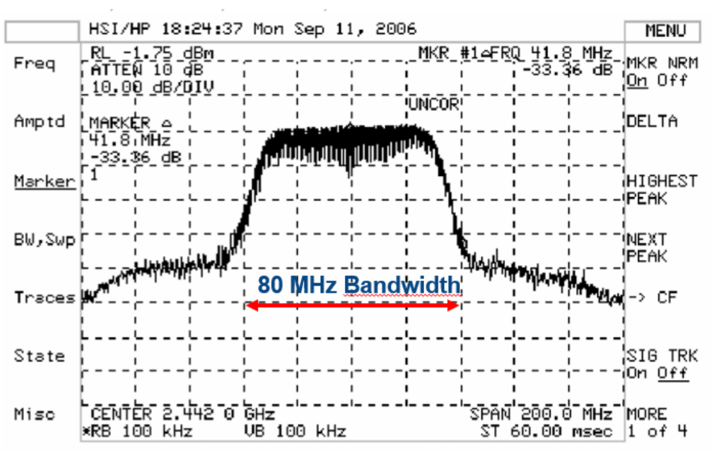

Figure 3 Measured CSS (80 MHz) Signal Spectrum

The fact that both the Nanotron CSS and Wi-Fi share the same 2.4 GHz ISM band is the reason for interference. The much wider spreading of the CSS is the reason why the CSS effect on Wi-Fi is minimal. However, the Wi-Fi affects the CSS more significantly due to higher power density in narrower channels (20 MHz) , especially when a few channels are occupied at the same time.

2. The main factors influencing the Wi-Fi interference with CSS transmission

2.1. Wi-Fi vs CSS signal power

In general the bigger the Wi-Fi to CSS signal power the more the CSS transmission is affected. If the CSS signal is not powerful enough in relation to the Wi-Fi signal there will be a significant amount of transmission packet (blink) losses. Both the ranging and RTLS system performance if affected.

2.2. Medium access mechanism – CSMA

When both Wi-Fi and CSS systems operate in the same area there will be collisions of their packets in the air. Therefore, a medium access mechanism is needed to provide seamless access of CSS and Wi-Fi to the shared RF medium. A CSS tag simply listens if there is a Wi-Fi transmission by detecting the RF energy in the band (Please refer to the API UG [1]). If it is not there, it sends a packet in the air after a random waiting time. Figure 4 shows the effect of the CSMA mechanism on the blink loss (significant improvement for CSMA ON).

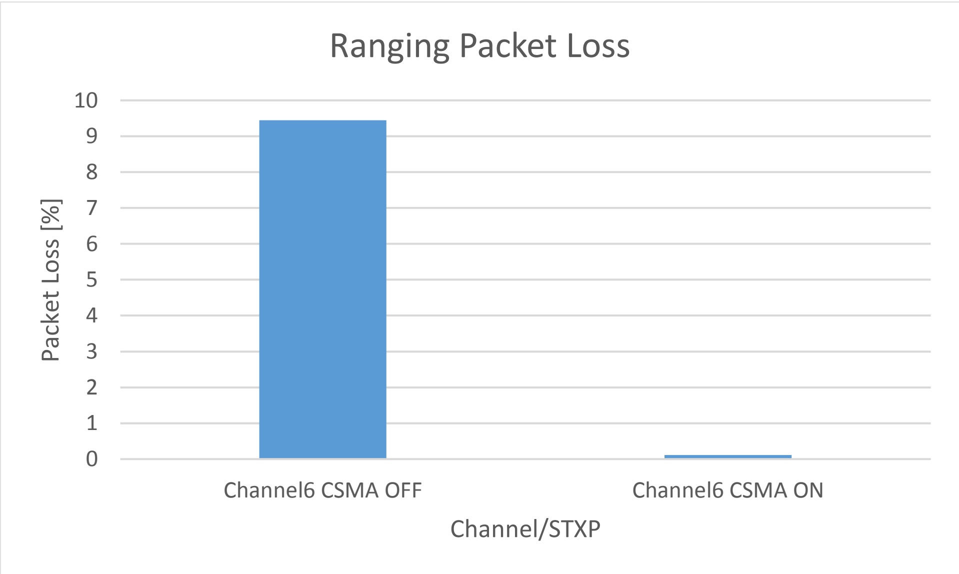

Figure 4 Ranging packet (blink) loss - channel 6 (AP: -30dBm, *swarm* bee: -45dBm, 1 Mbit/s Wi-Fi data rate, (CSMA:3,5,20))

It is crucail to use CSMA when the ISM band is occupied by many users particularly when the CSS to Wi-Fi power level ratio is small.

2.3. The selection of wi-fi channels

As it was mentioned before, the CSS uses the whole 2.4 GHz ISM band. When it comes to Wi-Fi, there is freedom in picking one of the 13 20 MHz overlapping channels. The goal here is to use as few as possible Wi-Fi channels in the case of the coexistance with a CSS system. The more Wi-Fi channels are used the more significant the effect on the CSS transmission quality will be (increased level of blink losses).
Figure 5 shows the ranging packet (blink) loss for Wi-Fi operating at combined channels 1,6,11 vs DK+ LE power level. There is also the effect of one Wi-Fi channel (channel 6) added for comparison.

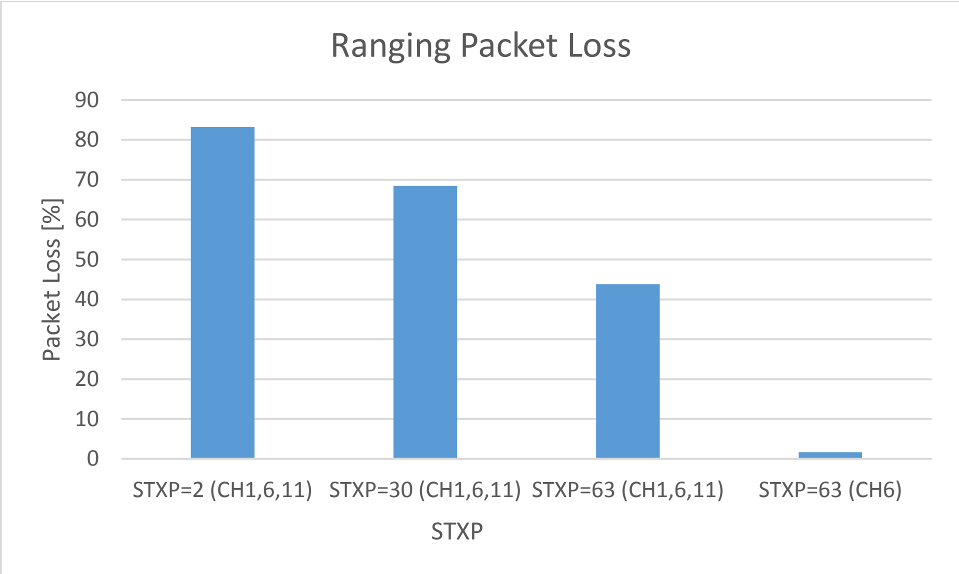

Figure 5 Packet loss vs STXP (transmit power) for Wi-Fi interference on combined channels 1, 6 and 11 and channel 6 only

Figure 6 Wi-Fi Spectrum - combined channels 1, 6 and 11

2.4. Wi-Fi Data rate

The data rate of a Wi-Fi channel has also infuence on the CSS transmission. In general, the higher the data rate of the Wi-Fi stream the higher the ranging packet (blink) loss. Figure 7 shows that at 40Mbit/s the packet loss goes up to almost 30% compared to 10% at 5Mbit/s.

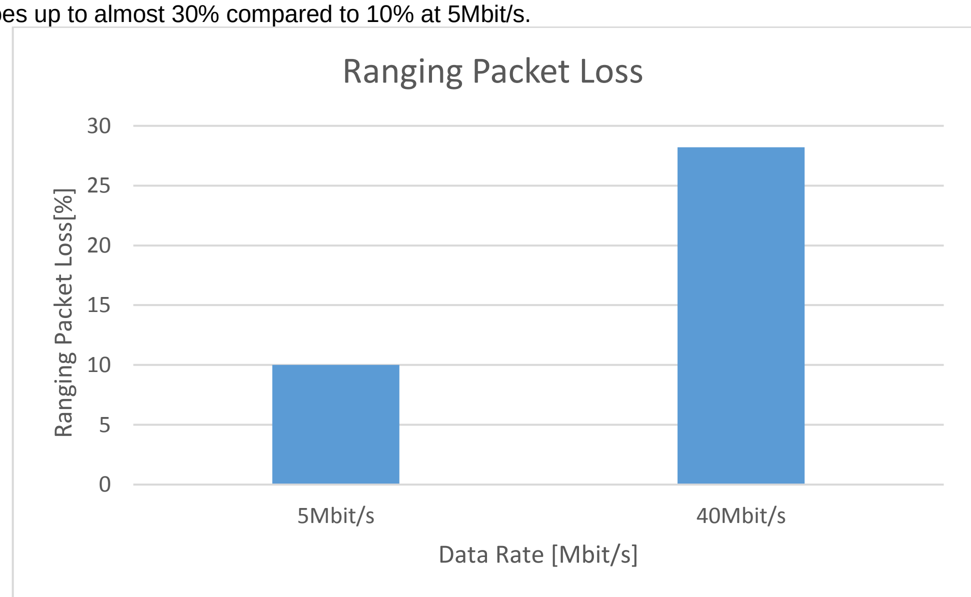

Figure 7 Ranging Packet Loss vs data rate in a Wi-Fi interference environment

2.5. Other settings (FEC, CSS transmission mode)

FEC doesn't have much influence on mitigating the effect of Wi-Fi interference. in Figure 8 shows this fact.

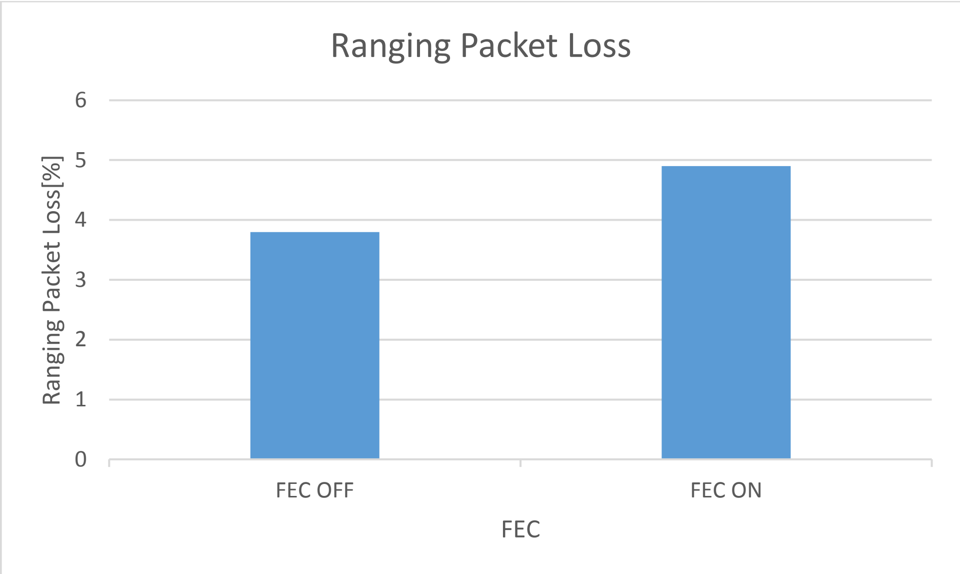

Figure 8 Ranging Packet Loss vs FEC in a Wi-Fi interference environment

Data mode (80/1 vs 80/4) affects the influence on Wi-Fi interference on packet (blink) loss as it is shown in Figure 9.

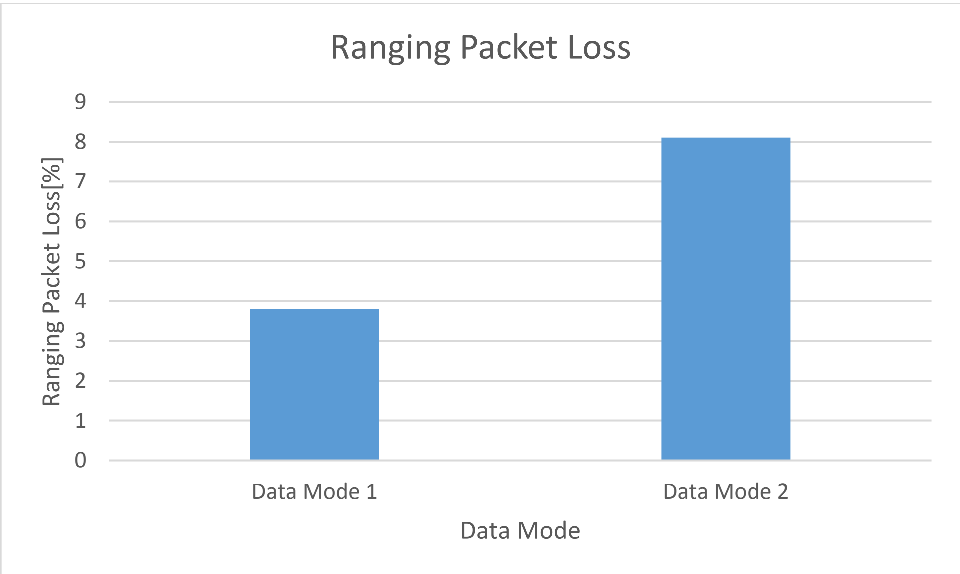

Figure 9 Ranging Packet Loss vs Data Mode in a Wi-Fi interference environment

- Data Mode 1: 1us chirp symbol duration
- Data Mode 2: 4us chirp symbol duration

For data mode 2 the ranging packet (blink) loss in a Wi-Fi interference environmanet is higher due to a longer duration of a symbol and thus higher probability of collsion with Wi-Fi packets.

2.6. Antennas

A proper selection of antennas has a significant effect on the quality of the radio link. The parameters like antenna gain, directivity, radiation pattern and polarity need to be taken into account. The optimal antenna should provide a strong and stable enough CSS signal at the receiver to mitigate the Wi-Fi interference effect.

3. Wi-Fi interference effect on the CSS ranging

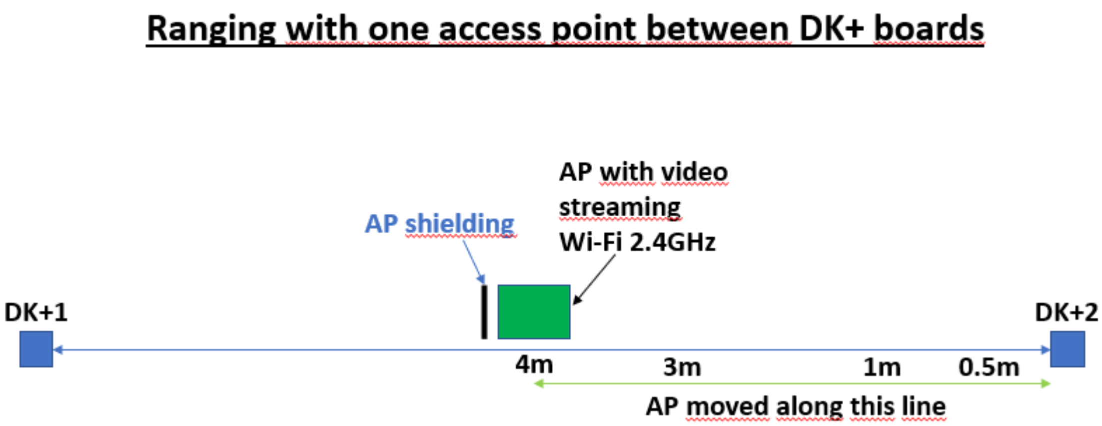

Figure 10 Wi-Fi interference in a ranging system – AP (access point) power effect

Ranging parameters affected by Wi-Fi interference:

- Ranging Packet Loss
- Ranging Accuracy
- Ranging Cycle Duration

swarm bee (on DK+ board) settings and setup: STXP=24, CSMA ON (CSMA:3,5,20), FEC OFF, Data Mode=1, DK+ RSSI = -55 dBm, data rate = 1Mbit/s, access point channel = 6

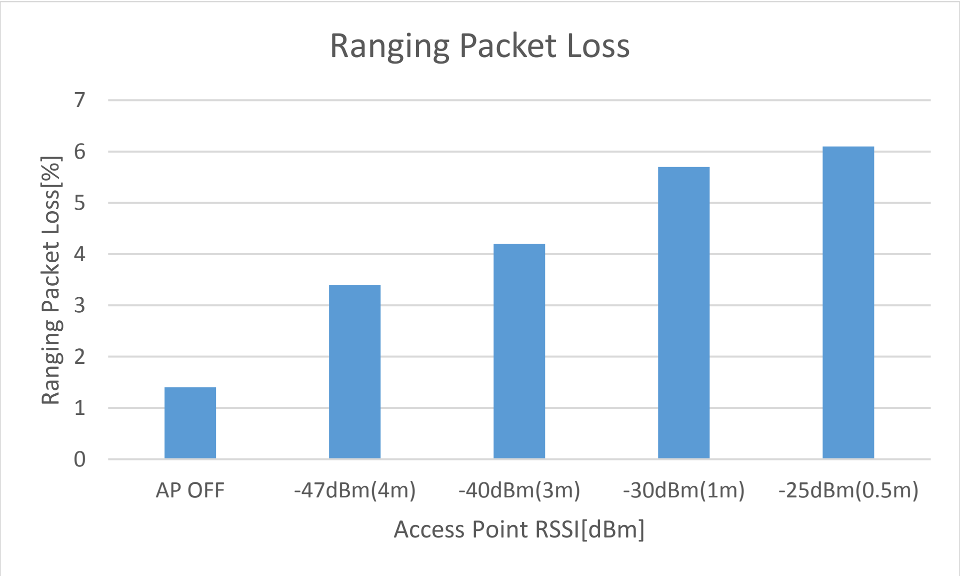

Figure 11 Ranging Packet Loss vs AP power

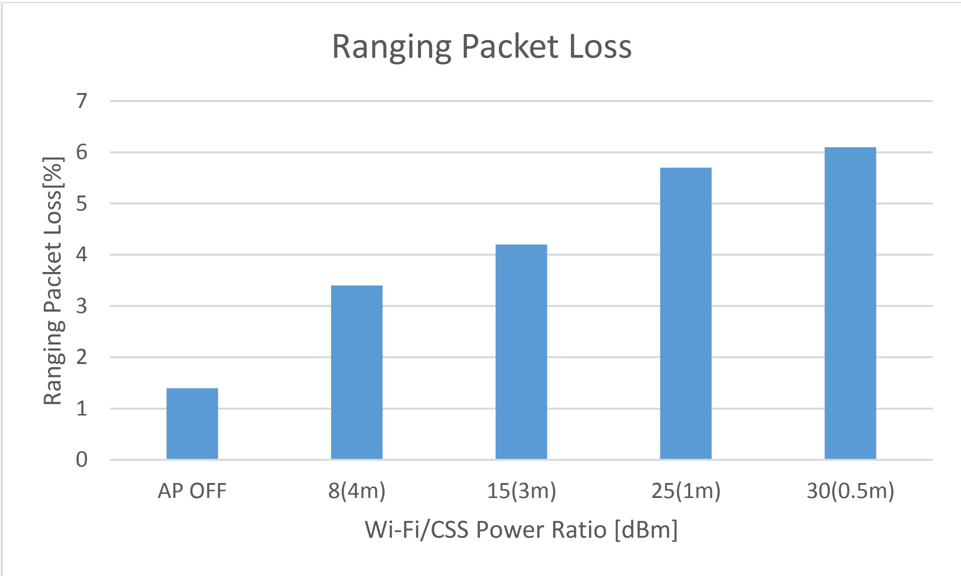

Figure 12 Ranging Packet Loss vs Wi-Fi/CSS Power Ratio

Blink loss (packet loss) increases with the increasing Wi-Fi power/CSS power ratio. In order to minimize it the power of the Wi-Fi signal should be lowerd and the power of the CSS tag/anchor should be increased.

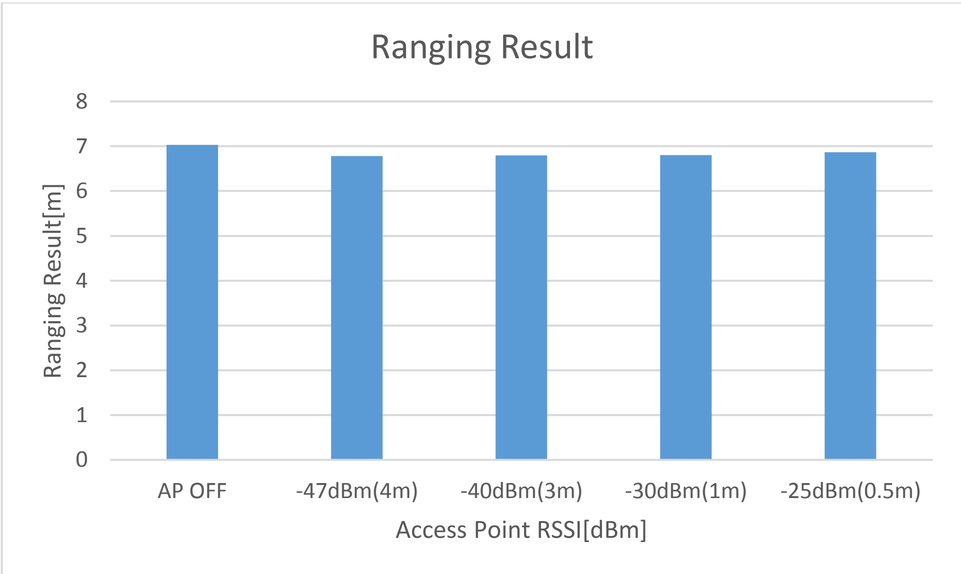

Figure 13 Ranging Accuracy Variations

Ranging accuracy does not significantly decrease in the presence of the Wi-Fi interference. Up to 2m variations are natural for CSS signal in indoor environment.

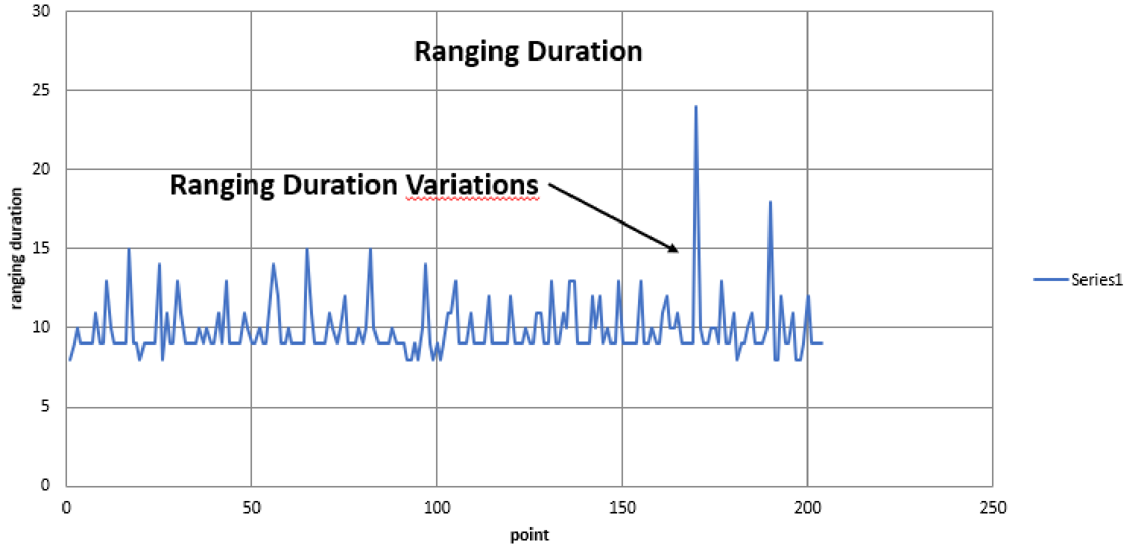

Figure 14 Ranging Duration: Blink Interval: STXP=24, CSMA ON, DK+ 4m away from AP

Ranging duration does not significantly rise in the presence of the Wi-Fi interference. Ocassional 5-10ms variations are natural for a CSS signal in indoor environemnts and are caused by multipath propagation. They can be easily filtered out.

4. Wi-Fi interference effect on the CSS RTLS system

Table 1 Wi-Fi Interferer Worst Case Scenarios

Wi-Fi Interferer close to CSS tag	Wi-Fi Interferer close to CSS anchor
	

RTLS parameters affected by Wi-Fi interference:

- Positioning Success Rate (blink loss)
- Positioning Accuracy

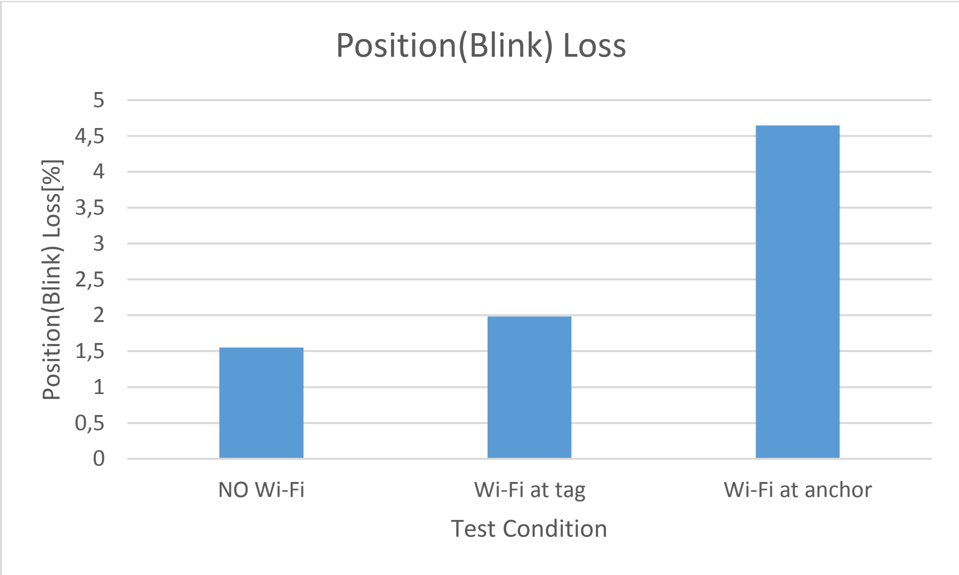

Figure 15 Blink loss as positioning quality metrics (with Wi-Fi interference), STXP=63, channles 6, CSMA OFF, AP: -25dBm, 1Mbit/s

There is no significant blink loss increase in the presence of Wi-Fi interference provided that the *swarm* bee operates with enough of RF power vs Wi-Fi power (CSMA on is stil recommended).

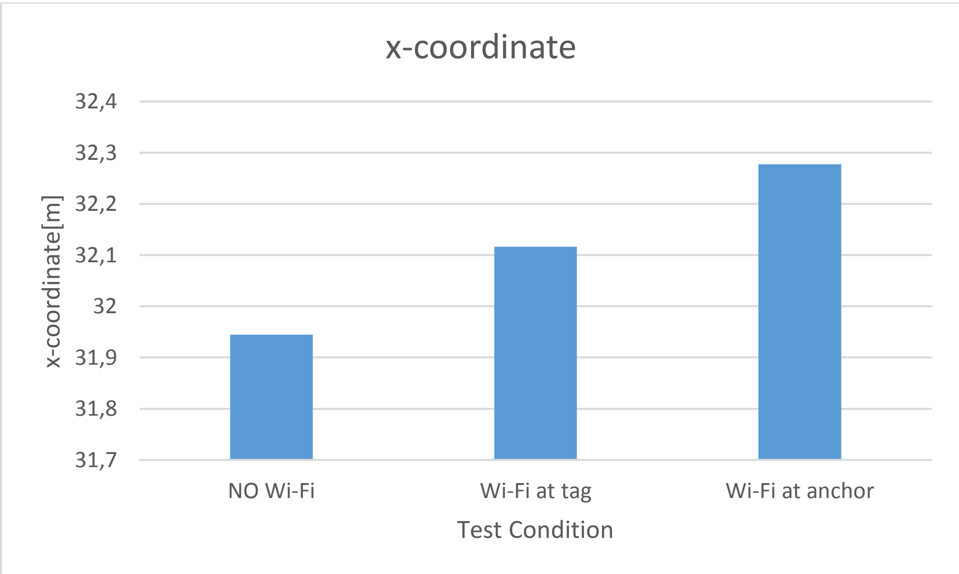

Figure 16 Tag's positioning accuracy - x coordinate, STXP=63, channles 6, CSMA OFF, AP: -25dBm, 1Mbit/s

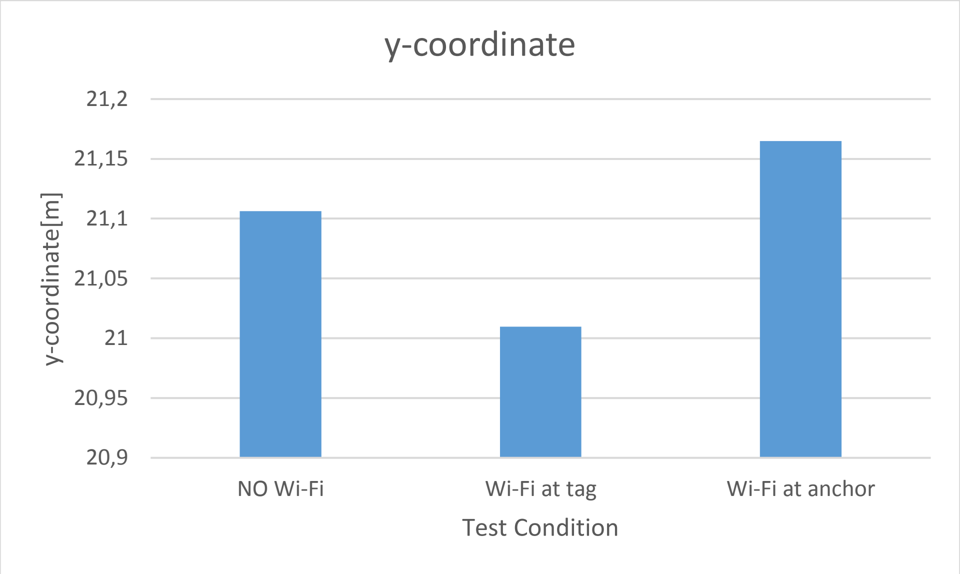

Figure 17 Tag's positioning accuracy - y coordinate, STXP=63, channles 6, CSMA OFF, AP: -25dBm, 1Mbit/s

There is no significant deterioration in the positioning accuracy in the presence of Wi-Fi interference provided that the *swarm* bee operates with enough of RF power vs Wi-Fi power (CSMA on is stil recommended).

5. Best practices to minimize the Wi-Fi effect on the CSS transmission

- The 2.4 GHz spectrum should be scanned by a Wi-Fi scanner/analyzer software.

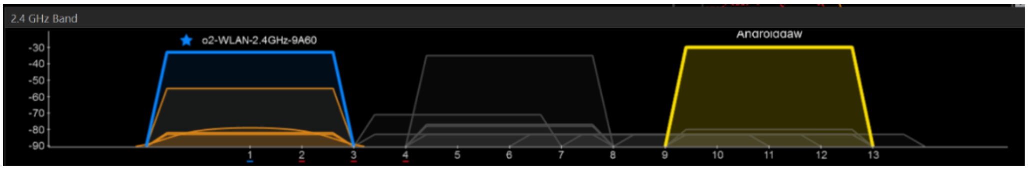

Figure 18 Wi-Fi (2.4 GHz) spectrum scanned by a Wi-Fi analyzer software

- The less Wi-Fi channels are used the less CSS is affected.
- The Wi-Fi channels should be set far apart if possible.
- The case of occupying the whole Wi-Fi spectrum (all channels used by Wi-Fi) should be avoided.
- The higher the CSS to Wi-Fi signal power ratio the less the CSS transmission is affected.
- The lower the Wi-Fi data rate the less the CSS transmission is affected.
- Data Mode 1 (1us chirp symbol duration) is recommended in the presence of Wi-Fi interference due to shorter duration of chirp pulses.
- Medium access control mechahnism should be used – CSMA ON.
- Wi-Fi interferers should be kept away from tags and anchors.

6. Summary

In general CSS system can coexist with Wi-Fi without being much affected. However, a few things need to be taken into account and optimized/avoided. The less Wi-Fi channels are occupied, the lower the Wi-Fi to CSS power ratio the better the quality of the CSS transmission. It is also necessary to use CSMA as a medium access mechanism to reduce the number of collisions between CSS and Wi-Fi packets in the air. Lower Wi-Fi data rates as well as using CSS data mode 1 (1us chirp pulse duration) also helps in minimizing the effect of Wi-Fi interference.

7. References

[1] Reference 1 *swarm* API 3.0 Doc. Id. NA-13-0267-0003

Document History

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