Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
FCC Seeks to Enable State-of-the-Art Radar Sensors in the 60 GHz Band	)	ET Docket No. 21-264
	)	
	)	

COMMENTS OF ACCONEER AB

Laura Stefani
Mintz, Levin, Cohn, Ferris, Glovsky and Popeo, P.C.
555 12th Street, NW
Washington, DC 20004

Its Attorneys

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SUMMARY

Acconeer AB ("Acconeer") supports the Federal Communications Commission's ("FCC" or "Commission") proposal to align its rules for 60 GHz Field Disturbance Sensors ("FDS", also known as short-range radar) with the European standard, ETSI EN 305 550. Harmonization with the European standard, implemented today in more than 66 countries worldwide, is important to enable access to worldwide markets and to promote the development of numerous products that will benefit the American public.

Moreover, harmonization is the best means to achieve regulatory parity and simplicity for both types of FDS radar systems that operate in the band – pulse radar and frequency modulated continuous wave ("FMCW") radar. These two types of radar operate with different styles of transmission so that certain technical rules, such as duty cycle, if applied in the same manner would produce vastly different results in terms of the operational abilities of the devices. For this reason, the FCC must carefully consider the effect of its proposed rules and ensure that what it ultimately adopts is technically neutral and does not result in disparate operating conditions for some technologies. The ETSI standards were crafted to avoid this effect.

To this end, the FCC should ensure that the rules it adopts are fully consistent with EN 305 550 by, for example:

- providing for evaluation of the mean (*i.e.*, average) EIRP of a device over at least one full Equipment Under Test ("EUT") repetition cycle;
- specifying the transmitter conducted power limit as a mean, rather than peak, limit; and
- not adopting a duty cycle requirement, which is not part of the ETSI harmonized standard.

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Acconeer AB ("Acconeer") supports the Commission's efforts here to expand the operational flexibility of the 57-64 GHz ("60 GHz") band.[1/] Acconeer has developed an innovative radar sensor that operates on 57-64 GHz, providing for a wide-range of use cases serving a number of industry sectors. Acconeer recently received grant of a limited waiver from the Federal Communications Commission ("FCC" or "Commission") to market its sensor in the United States for certain vehicular use cases.[2/] Many customers, however, seek to market Acconeer's innovative pulse radar solution for a number of other functions in the U.S., including uses that require different and oftentimes broader technical specifications. Moreover, because these customers design and sell their products on a global basis, it is vital to adopt rules in the U.S. that would harmonize products with rules and standards already in use around the world. For these reasons, it would be in the public interest for the Commission to adopt new rules for 60

1/ *See FCC Seeks to Enable State-of-the-Art Radar Sensors in the 60 GHz Band*, Notice of Proposed Rulemaking, FCC-21-83 (rel. July 14, 2021) ("*60 GHz NPRM*" or "*NPRM*").

2/ *See* Letter from Ron T. Repasi, Acting Chief, Office of Engineering and Technology, Federal Communications Commission, to Laura Stefani, Mintz, Levin, Cohn, Ferris, Glovsky and Popeo, P.C., ET Docket No. 21-48, DA 21-814 (rel. July 9, 2021) ("Acconeer Waiver").

GHz Field Disturbance Sensors ("FDS", commonly referred to as "radar") consistent with the ETSI standard already in use throughout the world.[3/]

BACKGROUND

A. Introduction

Acconeer is a radar sensor development company located in Malmö, Sweden. Acconeer was formed in 2011 to develop innovative technologies based on research pioneered at Lund University and was listed on Nasdaq First North in 2017. Acconeer is a leader in developing small, power-efficient and cost-efficient radar systems that will enable a safer and more sustainable future.

Acconeer has developed an innovative 60 GHz pulsed coherent radar sensor which has the benefits of being produced in a compact form factor (*i.e.*, 5x5x0.8 mm) while consuming low amounts of power. Using the 60 GHz band allows Acconeer's radar sensor to detect extremely small variations in the local environment, such as the vital signs of a human being, while using small antennas that allow for the integration of the sensor into small form factors.

Acconeer's radar system can be used in a large variety of applications such as fixed systems that detect the presence of humans inside buildings and vehicles, and mobile, battery-operated devices such as cell phones, laptops, smart watches and robots. Due to its low power consumption, Acconeer's radar sensor is ideally suited to various Internet-of-Things ("IoT") applications requiring detection of the presence of objects or the distance to objects where cabling is not feasible and long battery life is important. Battery operation and low power

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[3/] *See e.g.*, Electronic Comm. Committee, *ERC Recommendation 70-03*, 44-48 (2021), https://docdb.cept.org/download/25c41779-cd6e/Rec7003e.pdf.

consumption are often the primary concerns of the customer and the public, including for the purpose of minimizing a system's environmental footprint.

B. Demand for Short Range Pulse Radar

During recent years, demand for new products operating in the 57-64 GHz band has grown tremendously. Acconeer supports removal of use case limitations from the rules so that U.S. consumers may have access to new technologies. Table 1 lists a selection of different identified use cases where Acconeer today is actively helping customers develop end products. The subsequent sections provide more details about their respective features.

Table 1 *Selection of use cases addressed by SRDs in 60 GHz*

ID	Use case	Feature
A	Vehicle passenger detection	Presence detection
B	Vehicle seat belt alarm and airbag suppression	Presence detection
C	Vehicle intruder alarm	Presence detection
D	Vehicle access control	Gesture control
E	Autonomous vehicle navigation	Obstacle detection
F	Autonomous vehicle perception	Object classification
G	Infrastructure alarm system	Presence detection
H	Parking space occupancy	Object classification
I	Inventory management	Level measurement
J	Dispense control	Flow rate measurement
K	Interactive sports and gaming	Speed measurement
L	Device control	Gesture control

1. Presence Detection

Radar sensors can be used for motion sensing in Smart Home devices (*e.g.*, thermostats, smoke detectors, smart speakers, etc.), Smart Lightning systems, industrial automation, security systems including IP cameras, automated door openers, and screen based devices (*e.g.*, TV, notebook, tablet etc.) where low power consumption is important. Delivering accurate detection at low power consumption is one of the key benefits of pulsed radar.

The distance resolution of the radar is an important property used to determine the presence of multiple persons within the radar's field-of-view. A bandwidth of 500 MHz, as is allowed today for fixed installations with higher output power, limits the distance resolution and therefore hinders the ability to distinguish between different people present (*e.g.*, an infant vs. an adult). Limited available bandwidth also will increase a system's false positive rate. The power levels allowed today in Section 15.255 for the 57-64 GHz band do not allow for the marketing of an acceptable radar system that could provide accurate detection.

Automotive passenger detection, intruder alarm, and seat belt reminders are several important use case that require the accurate detection of human presence. Over the past twenty years, almost 900 children have died due to pediatric vehicular heatstroke in the United States alone. All of these deaths could have been prevented with technology such as Acconeer's radar system which, when operating in 60 GHz, can detect the presence of a child left in a vehicle. Millimeter wave ("mmWave") radar systems have advantages over other types of sensing systems, including camera-based systems or in-seat occupant detection systems. Unlike cameras, mmWave radar provides depth perception and can "see" through soft materials, such as a blanket covering a child in a child restraint. Unlike in-seat sensors, mmWave systems can differentiate between a child and an object left on the seat, reducing the likelihood of false alarms. In addition,

mmWave radar can detect micro-movements like breathing patterns and heart rates, neither of which can be accurately captured by cameras or in-seat sensors alone.

Moreover, because passenger detection systems are active when a vehicle is stationary, it is critical that such systems engage in low power consumption to protect the vehicle's battery supply. Delivering accurate detection at low power consumption is one of the key merits of pulse radar technology.

Enhanced and persistent seatbelt reminders also can save lives. Pulse radar technology can detect breathing patterns and heart rates in a manner that permits discrimination between people and inanimate objects. From a safety perspective, when the sensor is used for seatbelt reminder function, it can more accurately detect the presence of a human in a seat than current pressure sensor technology. The same sensor also can be used to control a vehicle's passenger airbag suppression system, which is required to prevent injury to children in the event of an accident.

Pulse radar sensors also can enhance theft prevention systems by detecting a broken window or vehicle intrusion. While other sensors may be used for this purpose, mmWave radar is more efficient. For example, a camera-based sensor operates by taking multiple frames and comparing them, whereas radar takes a single scan and more accurately and efficiently acquires the same information. Thus, mmWave radar can increase the robustness of vehicle security systems. Furthermore, pulse radar in particular can significantly reduce the power consumption of an intruder alarm, prolonging the vehicle battery life. As already noted, low power consumption of systems within a vehicle while the vehicle is stationary is critical to the performance of a vehicle battery, and delivering accurate detection at low power consumption is one of the key merits of pulse radar technology.

2. Gesture Control

The desire for touchless intuitive interfaces to control devices is growing due to the COVID-19 pandemic, but also due to the desire to have a better way of interacting with devices that cannot have a touchscreen due to environment, size, or cost reasons. Examples of such uses include the activation of pedestrian crossing alerts, the control of in-ear headphones, and gesture-based vehicle entry/exit system – all of which require low power consumption enabled by pulse radar.

Gesture control for vehicle access promotes the public safety by allowing quick access to a vehicle in high-crime areas where it may be unsafe to loiter. Pulse radar can recognize a foot movement, for example, to open a car trunk or when opening or closing a sliding door when the vehicle is stationary. While other sensors may also be used for this purpose (such as capacitive systems), pulse radar can perform the function more robustly because of the millimeter accuracy provided by 60 GHz pulse radar, allowing for precise recognition of multiple gestures and the discrimination of false movements, while consuming small amounts of power. As noted, this low power consumption characteristic will greatly aid in prolonging a vehicle's battery life while parked. The gesture control detection system is only active when the vehicle is stationary, when low power consumption is critical. Again, delivering accurate detection at low power consumption is an important merit of pulse radar technology.

Another major benefit of pulse radar in the 57-64 GHz band is that the high bandwidth allows for the use of machine learning to identify gestures. This enables an accurate, low power non-intrusive way of controlling devices.

3. Obstacle Detection

The navigation systems used today by domestic robots such as vacuum cleaner robots, toy robots, or social robots rely on camera, infrared or ultrasonic based sensors. Pulse radar can accurately determine the location of transparent, soft, and dark materials, which can be a challenge with other technologies that may be sensitive to ambient lighting and sound conditions as well as dusty environments. In addition, radar does not have a lens or open aperture, which may become clogged and dirty, thereby losing the ability to perform. These factors – combined with the need for accurate detection of objects to avoid harm to humans or machines and the need for low power consumption for battery-powered devices – make pulse radar technology more suitable for use in these products requiring obstacle detection.

4. Object Classification

As discussed previously, the high bandwidth of pulse radar in the 57-64 GHz band enables the use of machine learning to solve complex use cases. For example, machine learning can perform object and material classification, allowing for cleaning and lawn mower robots to detect the surface on which they are operating. This permits cleaning robots to optimize their settings based on the surface and for lawn mower robots to stay within the lawn by detecting when they are entering a non-grassy surface.

Another use case for object classification is traffic and parking monitoring for Smart Cities. Parking space occupancy sensors can identify if a parking spot is vacant and reports this to a municipal Internet of Things ("IoT") network. Use of such systems helps to limit traffic and pollution in major cities by minimizing time spent looking for a parking space. A parking sensor that relies on pulse radar for detection can operate in ambient lighting and various sound conditions and in dirty environments. In addition, these systems need to be able to run on battery

for several years and need to be able to discriminate cars from other objects (*e.g.*, grocery carts) to avoid false detections. The pulse radar technology addresses these issues, delivering accurate detection at low power consumption.

High bandwidth is also needed for this use case, as the signal from a car is exposed to fading, *i.e.*, multiple reflections from the car arriving at the receiving antenna. These reflections can interfere constructively or destructively depending on their relative distances, meaning that in some cases the reflections from the car can interfere destructively with other reflections and the received signal will be reduced or disappear. The lower the bandwidth used, the higher the probability that this fading will occur. With a high bandwidth operation, the multi-path fading will be reduced. Hence, a bandwidth of 500 MHz, as is allowed today for fixed installations with higher output power, limits the distance resolution, reducing the ability of radar to perform object classification.

5. Level Measurement

Some industries, such as the process industry, agriculture, the petroleum industry, wastewater recycling, etc., need to determine the levels of liquids and solids in tanks for inventory and overflow protection. For these purposes, non-contact solutions are preferred, especially those which can be mounted outside the tank to measure through the container. In many cases, these devices are mounted without access to electrical installation and hence require radar systems with low power consumption.

Measuring levels within objects such as tanks creates similar concerns as a parked car that creates fading, *i.e.*, there can be multiple reflections from not only the surface of the liquid but also from the sides of the tank, the corners between the surface and tank walls, etc. These reflections, again, interfere constructively or destructively depending on their relative distances,

meaning that in some cases the reflections from the surface can interfere destructively with other reflections and the received signal will be reduced or disappear. The lower the allowable bandwidth for measurements, the higher the probability that this fading will occur. With a high bandwidth, multi-path fading will be reduced. This is especially true in harsh environments, such as in distance monitoring in outdoor environments for agricultural and railway operations.

6. Flow Rate Measurement

Other industries, such as agriculture, health care, and food manufacturing, require the measurement of the flow of items (*e.g.*, seeds, grains, pellets and other solids) through pipes to calibrate rates and to ensure that no blockage has occurred. Pulse radar operating in the 57-64 GHz band provides a robust solution for measuring these properties without having to install a flow meter inside of a pipe. This is especially useful for operations where there are high standards for hygiene and cleanliness. In addition, pulse radar provides a robust means of taking accurate measurements in harsh outdoor environments, such as for agricultural operations. Some of these applications require very low power consumption, as they are used in battery-powered products, making Acconeer's radar solution a sought-after choice

Additionally, radar-enabled flow rate measurements also require high bandwidth to enable accurate pulse radar using machine-learning solutions.

7. Speed Measurement

Finally, several markets need to measure an object's speed. Some examples of common use cases are driving ranges and baseball batting cases (i.e., swing measurements), interactive playground installations, and short-range traffic monitoring applications. There is a public interest for allowing for improved Smart City applications, as well as sports and gaming products

that can measure object speed. Several of these devices are battery-powered and therefore require technology that employs low power consumption.

C. Pulse Radar System Technological Overview

Acconeer believes that harmonization is the best means to achieve regulatory parity and simplicity for all types of FDS radar systems that operate in the 57-71 GHz band – pulse radar, FMCW radar, and radar relying on 802.11ad/ay protocol, as illustrated in **Figure 1**.

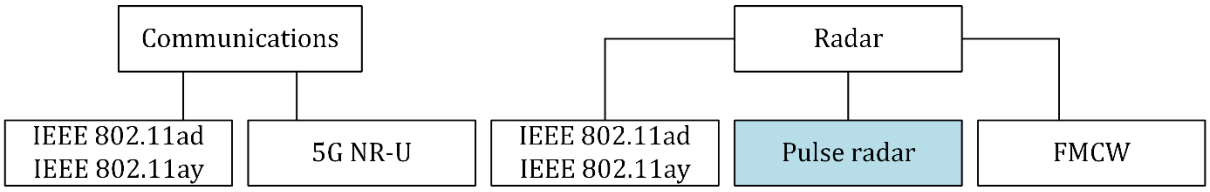

Figure 1 *Standards and technologies in the 57-71 GHz band*

These radars operate with different styles of transmissions so that certain technical rules, such as duty cycle, if applied in the same manner would produce vastly different results in terms of the operational abilities of the devices. For this reason, the FCC must carefully consider the effect of its proposed rules and ensure that the rules that it ultimately adopts do not result unfairly in operating constraints for some technologies but not others. The ETSI standards are crafted to avoid this effect.

Acconeer here provides a background on pulse radar to demonstrate the operational difference between FMCW and pulse radar. These differences affect the analysis of co-existence between each type of radar and 802.11ad/ay systems. Successful co-existence between pulse radar and 802.11ad/ay can be ensured by the ETSI standards, even under extreme conditions, as discussed further below.

Figure 2 shows a schematic view of a pulse radar transmission. Pulses emit in sweeps, where a sequence of consecutive pulses is used to sample a number of range bins.

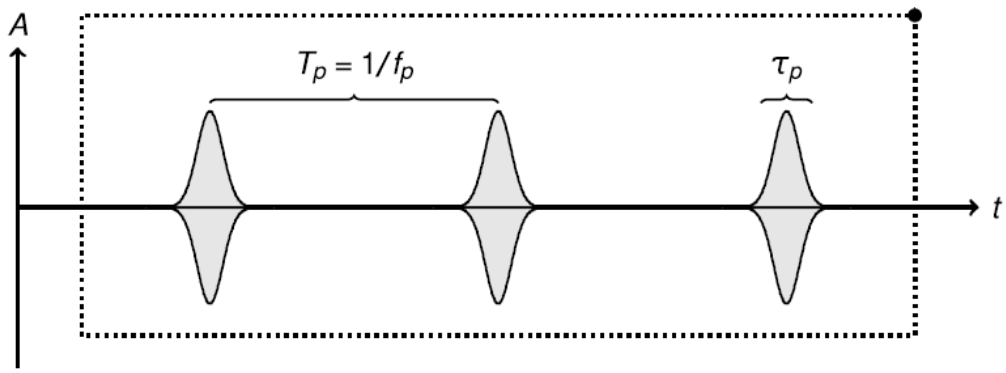

Figure 2 *Pulse radar system parameter definition*

The pulse length, τ_p, is the duration of the pulse, and the pulse repetition frequency, f_p, is the inverse of the time between start of two consecutive pulses, T_p. This makes it possible to define the duty cycle of pulse radar as $\tau_p * f_p$. Table 2 sets out the typical range of values for the defined parameters that are necessary to satisfy the requirements for the uses discussed above. These values are provided only to describe a pulse radar system and should not be construed as suggested parameters for new rules.

Table 2 *Parameter, symbol and range of typical value for pulse radar*

Parameter	**Symbol**	**Typical value**
Pulse length	τ_p	0.35-6 ns
Pulse repetition frequency	f_p	5-80 MHz

An illustration of the power spectral density of a pulse radar signal in Figure 2 is shown in Figure 3.

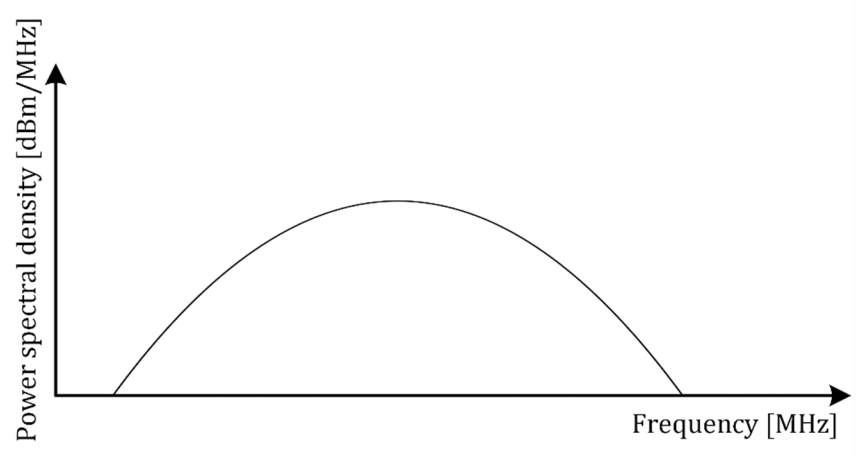

Figure 3 *Spectral density of pulse radar transmission*

Quantities related to power generated and emitted by pulse radar are:

- Peak EIRP in a pulse with duration τ_p
- Mean EIRP during a time that is greater than $1/f_p$
- Maximum peak power spectral density emitted in band during a time that is greater than $1/f_p$
- Maximum mean power spectral density emitted in band during a time that is greater than $1/f_p$

Although pulse radar and FMCW radar are in some instances used to solve similar use cases, there are some key differences related to their spectrum footprint and the ability to co-exist with other systems:

- Duration of continuous transmission

Pulse radar transmits in short ns-long pulses that can co-exist with 802.11ad/ay with low impact on throughput, as the error correction coding of the communication systems are able to cope with the pulse radar in the channel, even under extreme signal-to-interference ratio ("SIR"), as detailed below.[4/] As FMCW systems perform sweeps continuously during tens of µs to tens of

[4/] *See* Section D of the Discussion section.

ms, it is not possible for 802.11ad/ay systems to rely on error correction coding to maintain a high data rate during the slot occupied by the FMCW radar, given a high SIR.

- Mean EIRP

Pulse radar transmits short ns-long pulses at a duty cycle (defined as $\tau_p * f_p$) typically at or below 10%, which means that the mean EIRP is well below the peak EIRP. This is not the case for FMCW during transmission that would conform to the time scale of an 802.11ad/ay block duration. This means that on average 802.11.ad/ay systems experience less interference from pulse radar than from FMCW during the time that the radar performs a sweep.

- Peak power spectral density ("PSD")

Pulse radar transmits short ns-long pulses, which are instantaneously spread across a wide bandwidth. This means that the maximum peak power spectral density as measured over an 802.11ad/ay channel is significantly lower for pulse radar than for FMCW radar. This decreases potential interference to 802.11ad/ay and means that the probability of the listen before talk ("LBT") mechanism of the 802.11ad/ay system is less likely to be triggered.

DISCUSSION

The Notice of Proposed Rulemaking ("NPRM") seeks to develop new rules for Section 15.255[5/] to expand operations of Field Disturbance Sensor ("FDS") devices, generically referred to as short-range radars. Acconeer supports the Commission's main proposal to adopt rules consistent with the ETSI standard and does not support some suggested alternative spectrum management techniques that would either be ineffective or lack technical neutrality.

[5/] *See* 47 C.F.R. § 15.255.

A. Acconeer Supports the Commission's General Proposal to Align its Rules with ETSI

Acconeer welcomes the proposal from the FCC to align its new rules with the European standard.[6/] Acconeer is active in regulatory discussions and rulemaking proceedings worldwide regarding the 57-71 GHz band and has created a database of the current and proposed regulatory schemes for more than 127 countries. This information was gathered through direct contact with authorities and industry organizations and is continuously expanding. The FCC's revisions to Section 15.255 should harmonize with rules across the globe so that U.S. consumers are not impacted by regional regulatory differences that could limit their product choice and availability. Aligning the Commission's rules with ETSI EN 305 550 would accomplish this goal.

To date, more than 66 countries rely on the rules implemented by the European Commission[7/] and stipulated in the ETSI 305 550[8/] harmonized standard for the 57-64 GHz band, which has been in effect for more than six years. Information on the rules and released harmonized standard is provided in Table 3.

6/ *See NPRM* ¶ 24 ("We propose to allow FDS devices to operate at no more than 20 dBm average EIRP. This proposed EIRP limit is higher than the level requested in the multiple waivers that we received; however, it is consistent with ETSI EN 305 550.").

7/ Commission Implementing Decision (EU) 2019/1345 (Aug. 2, 2019).

8/ ETSI EN 305 550-1 V1.2.1 (2014-10), https://www.etsi.org/deliver/etsi_en/305500_305599/30555001/01.02.01_60/en_30555001v010201p.pdf

Table 3 *European regulation, in-band transmitter parameters*

Parameter	**COMMISSION IMPLEMENTING DECISION (EU) 2019/1345**	**Current released ETSI 305 550 harmonized standard (2014-10)**
Operating frequency range	f(Lowest) ≥ 57 GHz f(Highest) ≤ 64 GHz	f(Lowest) ≥ 57 GHz f(Highest) ≤ 64 GHz
Mean power	20 dBm EIRP	20 dBm EIRP
Mean transmitter conducted power	10 dBm	-
Mean power spectral density	-	13 dBm/MHz EIRP

B. The Commission Must Carefully Consider the Effect of its Proposed Rules on all Radar Technologies

The hallmark of contemporary FCC regulatory policy is technical neutrality, where the Commission's ever-present goal is to ensure that it does not adopt rules that benefit one particular technology over any others, whether intentionally or inadvertently.[9/] Thus, in this proceeding the Commission must carefully consider whether its proposals provide for the same levels of operation for both types of radar systems developed for use in the 60 GHz band. The general proposal to follow the ETSI standard achieves this, and for this reason among many Acconeer supports the proposal.

As Acconeer details above, there are numerous differences between pulse and FMCW radar operations that would undermine a goal of technological neutrality should the Commission adopt certain additional technical rules proposed here. The major differences include the duration

[9/] *See e.g.*, *In the Matter of Rural Digital Opportunity Fund*, Report and Order, 35 FCC Rcd 686, 702 ¶ 31 (2020) (explaining that the Commission follows a "consistent … policy of technological neutrality for voice and broadband services.").

of the continuous transmissions sent by each type of radar, with pulse radar sending much shorter bursts of information. As a result, measurements such as mean EIRP and peak PSD will vary greatly in their significance of each radar's effect on the spectral environment. For this reason, adding other technical requirements to the rule proposal, such as duty cycle, would require vastly different considerations for each radar type, requiring the Commission to carve out at least two different specialized rules. This risks the Commission implementing new rules that are specific to certain technologies, with the possible preclusion of other future technologies, in violation of its longstanding policy technological neutrality. The simpler approach, which is also in accord with regulators worldwide, is to implement the ETSI standards.

C. The Commission Should Modify its Proposal to Fully Align to the ETSI Harmonized Standard

1. The Commission Should Adopt a Mean EIRP Limit, Evaluated over at Least One Repetition Cycle of the Equipment Under Test

As stated, Acconeer believes that harmonization with the European standard is important to enable access to worldwide markets and to promote the deployment of products in the U.S. to benefit the American public. However, FCC makes the following comment, which appears to contradict its stated intention of being consistent with ETSI 305 550:

> If the limits are applied only during active transmission (i.e., only over the chirp or pulse duration), then the peak and the average signals will be equivalent. We further note that by specifying the limits only in terms of average power, potential measurement instrument desensitization phenomena can be avoided.[10/]

Although Acconeer welcomes a solution to address "potential measurement instrument desensitization phenomena," the requirement on evaluating the mean EIRP over the pulse duration makes the proposal in the NPRM sufficiently different from ETSI 305 550 so that the

[10/] *NPRM* at ¶ 29.

claimed consistency is lost. That is because ETSI 305 550 stipulates that the averaging time as "larger than one EUT cycle time." Further, EN 303 883-1 establishes three different methods to measure the mean EIRP over average time (specifically, larger than one EUT signal repetition time): the use of a spectrum analyzer with an RMS detector using a channel power function; a method with an RMS power meter; and a method with a peak power meter.[11/] Acconeer believes the Commission should apply similar methods to evaluate the mean EIRP limit proposed in the NPRM. Acconeer additionally proposes to keep the EIRP limit as mean power and to allow the evaluation to be done over at least one EUT repetition cycle to simplify testing and ensure consistency with the European regulation, which, as FCC takes note, "has been in existence since 2014, [and] thus these limits have been tested and deployed in other geographic regions with similar spectrum allocations."[12/]

2. A Duty Cycle Limit is Inappropriate

For the reasons already stated, Acconeer questions the need to add a duty cycle limitation to Section 15.255, given that it is not part of the ETSI 305 550 and cannot be done in a technologically neutral manner with a singular rule. Nonetheless, the Commission has sought comment on, and sets out in its proposed rule, a technical requirement that contains a 10% duty cycle for every 33 ms interval for all FDS devices.[13/] The Commission derives this proposal from a waiver granted several years ago that was negotiated for the purpose of marketing one particular type of device using FMCW radar. While the Commission then applied this same

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[11] EN 303 883-1 v1.2.0 (2020 07), https://www.etsi.org/deliver/etsi_en/303800_303899/30388301/01.02.00_20/en_30388301v010200a.pdf.

[12/] *NPRM* ¶ 12.

[13/] *See id.* ¶¶ 2, 15, 31.

condition for purposes of granting limited waivers (primarily for FMCW operations within vehicles), the Commission also recognizes that those waivers were not the "broad based relief" contemplated herein, and that other parties require longer transmission times.[14/] For these reasons, Acconeer does not believe that the 33 ms proposal should be the Commission's rule, or even its starting point.

The ultimate goal here is to create a sufficiently co-existent environment amongst several different types of unlicensed users. It is well established that Part 15 users accept interference from all other sources, which means that no one unlicensed user operating in the 60 GHz band may expect to operate in a quiet or interference-limited environment.[15/] While parties negotiated reduced forms of operations for purposes of entering the market under waivers that were limited in use cases and time, considerations differ now when contemplating the adoption of permanent rules that will apply to a wide range of use cases and technologies. The starting point in the development of rules here must be that all users must design their equipment robustly to operate around other potential interfering sources. The next consideration must be the likelihood of all unlicensed users operating to some degree of sufficiency.

The suggestion made by certain companies that the Commission impose a radar "off-time period" of less than 2 ms[16/] would have a severe impact on a pulse radar system, and the Commission must reject this proposal outright. The 2 ms idea comes from a concern that 802.11ad/ay technologies should be able to operate virtually interference free across the entire

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14/ *See id.* ¶¶ 14, 31.

15/ *See* 47 C.F.R. § 15.5 (stating that operation is subject to the condition that "interference must be accepted").

16/ *See id.*

band, and it was made without regard to the effect on pulse radar. Indeed, Acconeer's waiver contains very different technical conditions than the waivers granted for FMCW technologies.[17/] The 2 ms off period fails to consider that pulse radar systems transmit short pulses at low mean power spectral density, resulting in a low probability of triggering the LBT mechanism of 802.11.ad/ay. Acconeer demonstrates that the short τ_p, on the order of an 802.11ad/ay symbol length, of pulse radar gives a minimal impact on 802.11ad/ay throughput, as detailed below. This makes duty cycle an unsuitable parameter for the new Section 15.255 rules generally, and mean power within a defined bandwidth a better approach.

3. Peak Transmitter Conducted Power is an Inconsistent Requirement

The FCC notes that "the EIRP, transmitter conducted output power, and power density limits proposed here are consistent with those stipulated by the ETSI standard EN 305 550."[18/] However, the transmitter conducted power limit as suggested by FCC is a peak limit and not a mean limit and is hence not consistent with the European standard, summarized in **Table 3** above.

FCC also seeks comment on whether a transmitter conducted output limit is necessary.[19/] Acconeer believes that this requirement should be adopted only if necessary to evaluate a device when access to the antenna port is provided. Evaluating a transmitter conducted limit for a device where the antenna is integrated as part of the package or chip is not easy as the interface may not be well defined, and there would be no port impedance that allows for a separate determination of antenna gain. Hence, Acconeer proposes that transmitter conducted power should not be part

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17/ Acconeer Waiver at 5.

18/ *NPRM* ¶ 28.

19/ *See id*. ¶ 26.

of the new rule and if FCC still sees the need for this limit then it should be evaluated as mean EIRP to be consistent with the European regulation.

4. The Commission Should Consider Expanding the Allowable Operating Frequency Range and Adopting the UWB Measurement Method

The Commission also seeks comment on whether it should allow the proposed FDS operation across the entire 57-71 GHz band.[20/] Acconeer supports this proposal. A wider available bandwidth would provide for radar systems with higher depth resolution, enabling more advanced and precise functionality for use cases such as gesture control, vital sign monitoring, robot navigation, and any application benefiting from ability to resolve multipath reflections for characterizing the environment. Hence, Acconeer believes that FCC can take the leading role globally in additional development of the 60 GHz band by allowing for use of the full 14 GHz bandwidth by FDS under the proposed 20 dBm mean EIRP limit. This will promote innovation and inspire the rest of the world to follow in the path set by the FCC.

Further, the Commission asks whether the transmission bandwidth should be represented only by the chirp or pulse specifications, or expressed as a measured occupied bandwidth, 20-dB bandwidth, or some other representation.[21/] For wideband pulse systems measuring the 20 dB bandwidth is challenging, as the spectral density often is so low that the 20 dB occupied bandwidth lies below the noise floor of the measurement equipment. Any additional measurement requirement of -30 dBc margin to the noise floor would be even harder to fulfill.

20/ *See id*. ¶ 22.

21/ *See id*. ¶ 44.

For ultra wideband devices this issue has been addressed by the standards setting body,[22/] where instead the -10 dBc level is evaluated according to "[t]he frequency at which the maximum power level is measured with the peak detector is designated f_M" and "[t]he outermost 1 MHz segments above and below f_M, where the peak power falls by 10 dB relative to the level at f_M, are designated as f_H and f_L, respectively." Acconeer proposes that the same method established for evaluating the bandwidth of ultra-wideband devices in the 3.1-10.6 GHz band[23/] should be applied to ultra-wideband devices operating in the 57-71 GHz band.

D. Successful Co-Existence between Pulse Radar and 802.11ad/ay

Simulations and measurements demonstrate that successful co-existence is possible between 802.11ad/ay communications devices and pulse radar systems. In general, the potential risk of interference from pulse radar to 802.11ad/ay technologies is low for the following reasons:

- Short pulse transmissions allow for error correction coding of 802.11ad/ay functioning, even under extreme and unlikely signal to interference ratio ("SIR") conditions;
- The low mean power spectral density of pulse radar, with a low risk of triggering the LBT mechanism of 802.11.ad/ay; and
- The low mean EIRP compared to levels allowed for communication devices under Section 15.255.

22/ *See* Institute of Electrical Engineering, American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices C63 (2021), https://ieeexplore.ieee.org/document/9340083.

23/ *See* 47 C.F.R. §§ 15.501, *et. seq.*

There are numerous other reasons why 802.11ad/ay devices, including those designed for VR headsets requiring high throughput, can co-exist with pulse radar. These include the facts that 802.11ad/ay radios employ high beam forming gain, error correction coding, and short transmission distances. Indeed, only in extreme and unlikely conditions would there ever be perfect alignment between a pulse radar and an 802.11ad/ay receiver such that worse case scenarios would be likely. In that instance, the short bursts of interference from pulse radar would be mitigated by the 802.11ad inherent coding procedures. Of course, in worst-case conditions in any co-existence study, some decrease in throughput can be expected.

Given these factors, there exists an exceedingly low potential risk of interference. In addition, adoption of WiGig systems in this band have been low and no reports of interference issues have been reported,[24/] even in Europe where the ETSI 305 550 standard allows 20 dBm mean EIRP evaluated over at least one EUT cycle.

1. Analytical Modelling and Measurement Study

Acconeer has developed an analytical framework for evaluating the packet error rate ("PER") after decoding of an 802.11ad single carrier system that is under interference from a pulse radar. When evaluating the PER under such conditions, it is essential to consider that the interference affects only a certain fraction of the symbols in a WiGig packet. Hence, there will be a number of symbols unaffected by interference and some symbols affected by interference. The PER is then the result after joint decoding of the unaffected bits (typically having low bit error rates) and the affected bits (possibly having somewhat higher bit error rates due to interference).

[24/] *See* Letter from Megan Anne Stull, Senior Counsel, Google LLC, to Marlene H. Dortch, Secretary, FCC, ET Docket No. 21-48 (filed May 17, 2021) ("Google Ex Parte").

Acconeer has attached a report,[25/] demonstrating that in the studied additive white Gaussian noise ("AWGN") cases the coding of the 802.11ad system makes it very robust to pulse radar interference, as only a very limited amount of the bits in any packet are interfered. Even with a very high interference level, the decoder is able to correct for the errors caused by interference. For this reason, 802.11ad devices would experience only a minor loss in performance even in the face of very high interference levels from pulse radars.

Calculations of the PER were performed for two cases with some simplifying assumptions. Case 1 considers short pulses and very high interference levels, while Case 2 considers long pulses and medium interference levels. In Case 1, the pulse is short so that only a single symbol is affected by a single pulse and the interference level is assumed so strong that the bit error rate is almost 50% when subjected to interference. In Case 2, the radar signals and the 802.11ad signals are equally strong but with a pulse length so that 6-7 symbols are affected per pulse. Acconeer's modeling shows that the 802.11ad system should be robust to pulse radar (and similar) interference, and with realistic radar parameters, the influence on the 802.11ad system should be limited.[26/]

In addition, Acconeer has attached interference measurement studies that were performed to demonstrate the findings of the analytical modeling studies.[27/] The study was done using commercially available 802.11ad devices and pulse radar. The conclusion is that no significant degradation of throughput to the 802.11ad system was observed even under extreme SIR values.

25/ *See* Appendix A ("Analytic calculation of the packet error rate of 802.11ad with pulse radar interference.")

26/ *See id.*

27/ *See* Appendix B ("Pulse radar to 802.11ad interference measurement study.").

E. Channelization and LBT Techniques Should Not be Adopted

1. Channelization is Not an Appropriate Interference Management Tool for Spread Spectrum Radar

Acconeer does not support channelization requirements for radar operations in the 60 GHz band. Ultra-wideband technologies such as pulse radar are not well suited for this type of spectrum management, as access to the full bandwidth is necessary to provide an acceptable level of transmission required to enable the many use cases discussed above. Acconeer also has a concern that the channelization approach favors certain technologies (*e.g.*, devices capable of flexibly adjusting to specific channels) and does not sufficiently consider the impact these devices would have on other devices that use the full band. In addition, such a rule would be contrary to the goal of international harmonization, as more than 66 countries worldwide rely on the ETSI 305 550 standard, which does not include channelization.

From an interference point of view the opposite logic would apply, *i.e.*, wider bandwidth should allow higher EIRP. As the emitted power is spread over a wider bandwidth, the average power per defined channel that can cause interference decreases and the possibility for co-existence increases. Hence, spread spectrum devices such as pulse radar, when using larger bandwidth, should be allowed to use a higher EIRP.

2. Listen Before Talk is Not a Useful Co-existence Technique for mmWave Systems

Acconeer does not view LBT as a preferred co-existence technique for any technology operating in this band. As a regulatory baseline, LBT generally does not provide efficient co-existence among different systems in high millimeter Wave frequencies such as the 60 GHz band, where transmissions have high directivity. This has been shown in simulations and argued

in recent contributions[28/] to the ETSI Broadband Radio Access Networks ("BRAN") working group during the ongoing development of EN 303 753, which is the harmonized standard for access to radio spectrum (WDTS for Mobile and Fixed Equipment) in the 57-71 GHz band. These studies also showed that LBT might potentially be useful in certain standards where LBT receiver assistance is possible or when the directivity of the transmissions can be controlled. The 802.11ad/11ay standard, for example, specifies use of an omni-directional antenna configuration for the LBT Clear Channel Assessment ("CCA") procedure and use of virtual carrier sense, or Network Allocation Vector ("NAV"). Such functionality is not possible to implement for systems like radar since they require data transmission and reception, and an agreed protocol or advanced antenna array configuration possibilities. For this reason, LBT might be appropriate for certain technology standards, but it is not appropriate as a regulatory approach.

Moreover, Acconeer considers the inherent directivity of 60 GHz unlicensed devices, due to the use of directional antennas, would provide spatial isolation in many real use scenarios. For this reason, the potential interference levels will typically be much lower than the worst case scenarios suggest, rendering the use of additional spectrum management requirements such as LBT unnecessary.

[28/] *See* BRAN(21)109014r1 Adaptivity in 60 GHz band; BRAN(21)110012 Further 60 GHz co-existence simulations; BRAN(21)109006r1 LBT as a co-existence mechanism at 60 GHz.

CONCLUSION

For the foregoing reasons, the Commission should act promptly to establish new rules for FDS operations in the 60 GHz band, consistent with the comments above.

Respectfully submitted,
ACCONEER AB

By: */s/ Laura Stefani*
Laura Stefani
Mintz, Levin, Cohn, Ferris, Glovsky
and Popeo, P.C.
555 12th Street, NW
Washington, DC 20004
202-434-7300
Its Attorneys

September 20, 2021

APPENDIX A – ANALYTIC CALCULATION OF THE PACKET ERROR RATE OF 802.11AD SUBJECT TO PULSE RADAR INTERFERENCE

In this appendix, we use an analytical framework for evaluating the packet error rate ("PER") of an 802.11ad single carrier system, after decoding, under interference from a pulse radar operating in the 60 GHz band. When evaluating the PER under such conditions, it is essential to consider that the interference affects only a limited fraction of the symbols in a packet. Hence, there will be a number of symbols unaffected by interference and a number of symbols affected by interference. The PER after decoding is the result of the bit error rates of the unaffected bits and the bit error rates of the affected bits. To make the translation from the two bit error rates to PER we use an approach used in the EU project MiWEBA from 2014,[1] where the full description of the framework can be found.

The link performance prediction is based on determining the function which maps multiple physical signal to interference and noise ("SINR") observations to a single "wide-band" metric which then can be converted to PER by means of a second mapping function (usually an AWGN reference). The physical layer abstraction method is based on the Mean Mutual Information per coded Bit ("MMIB") metric[2] and includes two steps:

- Calculation of MMIB metric for the given post-processing SINR values corresponded to each of the N symbols in the packet, *i.e.*, based on the signal to noise ratio ("SNR") for unaffected bits and SINR for affected bits; and
- MMIB to PER mapping.

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[1] MiWEBA, Millimetre-Wave Evolution for Backhaul and Access, WP4: Radio Resource Management for mm-wave Overlay HetNets, D4.1: System Level Simulator Specification, Dec 2014.

[2] K. Sayana, J. Zhauang and K. Stewart, "Short term link performance modeling for ML receivers with mutual information per bit metrics," Proc. IEEE GLOBECOM 2008, Nov. 2008.

Given this analytical framework, the performance of a single carrier 802.11ad system under interference from a pulse radar now can be evaluated. The calculations are done under the assumption that the interference can be seen as additive white Gaussian noise, which will give a good indication of the system performance.

The ratio of 802.11ad symbols impacted by interference is given by

$$X_{interference} = f_p/R_{ad} * \max(1, \tau_p * f_p),$$

where R_{ad} is the symbol rate of 802.11ad, τ_p is the pulse length, and f_p is the pulse repetition frequency of the pulse radar. These symbols will experience an SINR that is worse than the SNR that the rest of the symbols will experience. The ratio of symbols in a packet not impacted by interference therefore is given by

$$X_{non\text{-}interference} = 1 - X_{interference} = 1 - f_p/R_{ad} * \max(1, \tau_p * f_p).$$

The MMIB is now calculated as a sum of $X_{interference}$*MMIB with SINR=Z and $X_{non\text{-}interference}$*MMIB with SNR=Y, and then the corresponding PER is derived.

A. Case 1, high interference, short pulses

In the following case study, we assume a signal to interference ratio ("SIR") of -30 dB, and vary the SNR and pulse repetition frequency. This scenario corresponds to a very high interference scenario so that the bit error rates for the symbols affected by interference is almost 50% and hence those symbols carry essentially no information.

Figure 1 shows the analytical packet error rate for the 12 different modulation and coding schemes ("MCS") in 802.11ad for a pulse repetition frequency of 13 MHz and SIR=-30 dB. The red curve shows the PER with interference, whereas the blue curve shows the PER without interference for comparison. As seen in the figure, the influence of the interference is marginal on the packet error rate under those settings.

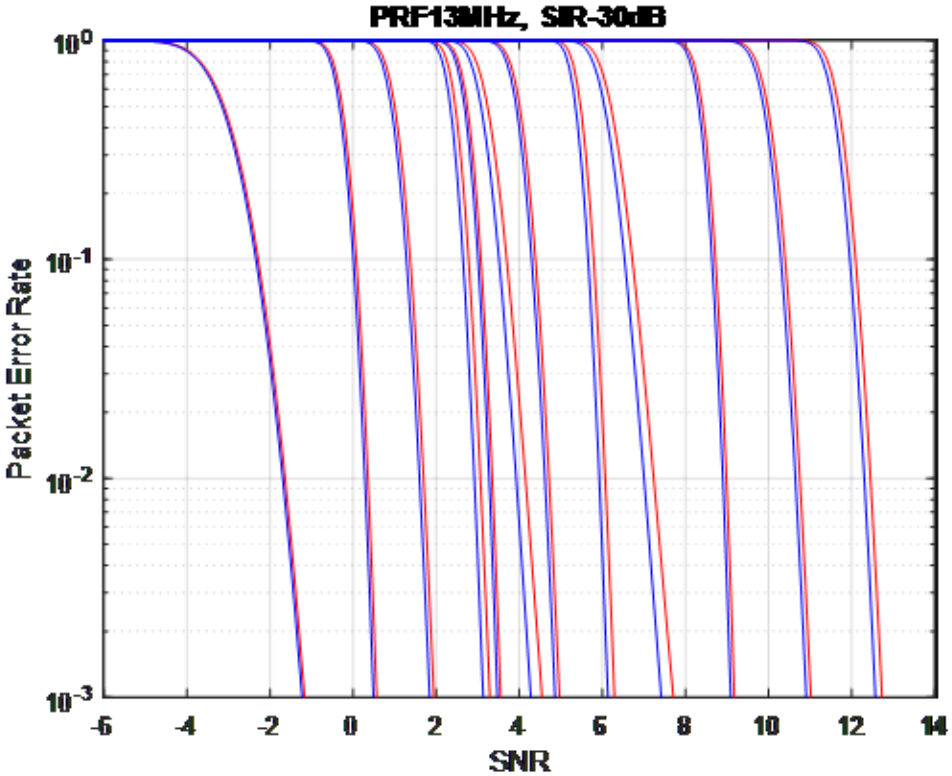


Figure 1 *Analytical packet error rate in an AWGN channel for the different MCS alternatives 1-12 for pulse repetition frequency 13 MHz and with a very high interference level, SIR=-30 dB. Red curve indicates the channel under interference, and the blue curve is without interference. Pulses are here 0.35 ns, hence shorter than the 802.11ad symbol time.*

B. Case 2, medium interference, longer pulses

In the following analysis, we assume a signal to interference ratio ("SIR") of 0 dB and use longer pulses, τ_p=3.6 ns. The longer pulses mean that on the average 6.3 of the 802.11ad symbols are affected by interference for every pulse, and with a pulse repetition frequency of 13 MHz, 4.7% of the 11ad symbols are affected by interference. Note that an SIR of 0 dB typically means that the radar is physically closer to the 802.11ad receiver than the 802.11ad transmitter due to the differences in antenna gains. If the radar is not aligned towards the 802.11ad receiver then the differences in distances can be rather large, with the radar even closer to the 802.11ad receiver.

Figure 2 shows the packet error rate, and indicates that the influence of the pulse radar is only marginal to the performance of the 802.11ad system. For lower SNR values, there is essentially no influence as the SNR already is somewhat limited. For high SNRs, there is a slight performance loss and when being close to the boundary the 802.11ad system will back off to the closest but somewhat more robust MCS.

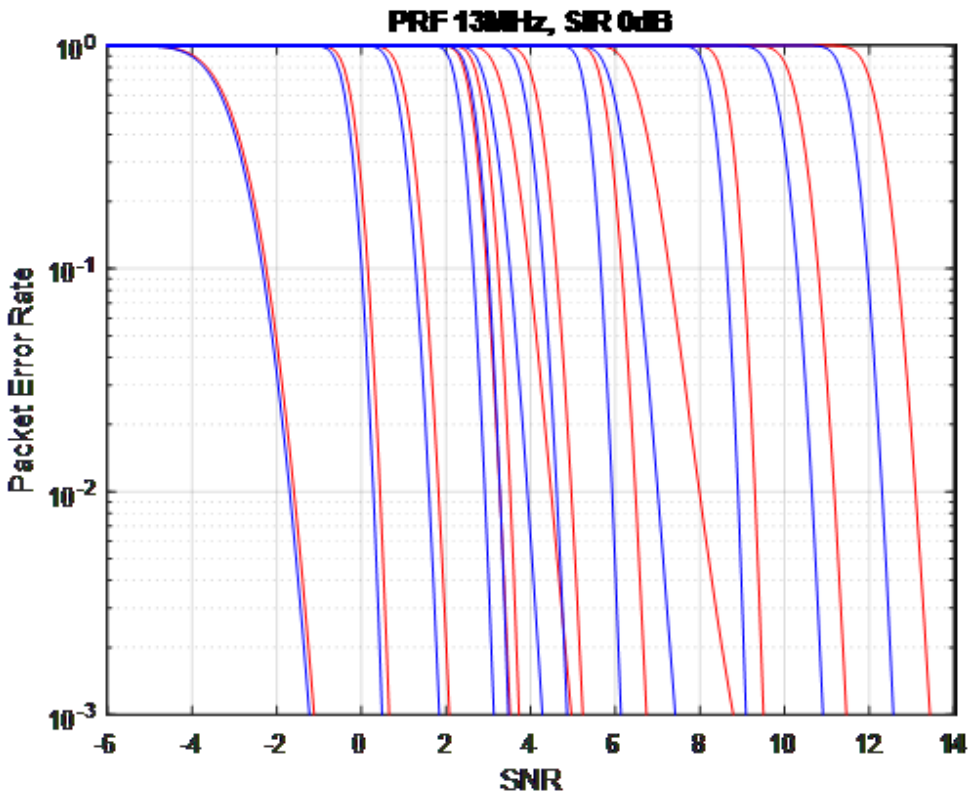


Figure 2 *Analytical packet error rate in an AWGN channel for the different MCS alternatives 1-12 for pulse repetition frequency 13 MHz and with a medium interference level, SIR=0 dB and longer pulses of 3.6 ns.*

C. Conclusions

In the studied AWGN cases here, the coding makes the 802.11ad system very robust to pulse interference as only a part of the bits in a packet are interfered. Even with a very high interference level, the decoder is able to correct for the errors caused by interference. There is only a minor loss in performance even for very high interference levels.

Calculations of the PER have been shown for two cases with some simplifying assumptions, but the framework is general and can been used with various settings. Case 1 is for short pulses and very high interference levels, case 2 is for longer pulses and medium interference levels. In case 1, the pulse is short so that only a single symbol is affected by a single pulse, though the assumed interference level is so strong that the bit error rate would be almost 50% when subjected to interference. In case 2, the radar

signals and the 802.11ad signals are equally strong but with a pulse length set so that 6-7 symbols are affected per pulse. Both of these evaluations demonstrate that an 802.11ad system should be robust to pulse-like interference and with realistic radar parameters the influence on the 802.11ad system should be limited.

***

I HEREBY CERTIFY THAT I AM THE TECHNICALLY QUALIFIED PERSON RESPONSIBLE FOR THE PREPARATION OF THIS ANALYSIS, AND THAT IT IS COMPLETE AND CORRECT TO THE BEST OF MY KNOWLEDGE AND BELIEF.

BY:

Fredrik Tufvesson, Ph.D
System Specialist
Acconeer AB
Västra Varvsgatan 19, 211 77 Malmö, Sweden
September 20, 2021

APPENDIX B – PULSE RADAR TO 802.11AD INTERFERENCE MEASUREMENT STUDY

This measurement study investigates the interference from pulse radar to 802.11ad. Commercially available devices are used and the measurement setup is described in **Figure 1**.

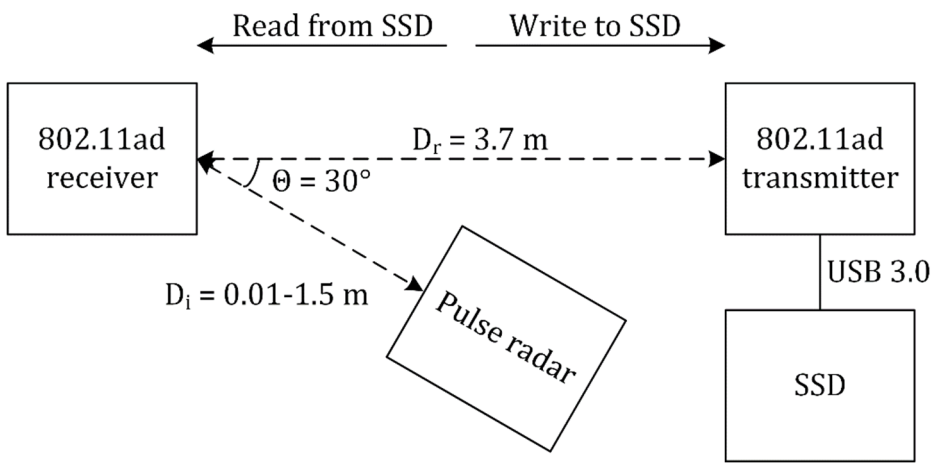


Figure 1 *Measurement setup*

The 802.11ad receiver is a Lenovo ThinkPad X270 PC with built-in WiGig Devices and the transmitter is a ThinkPad WiGig Docking station. The technical parameters of the 802.11ad equipment used is provided in **Table 1** and the technical parameters of the pulse radar equipment used is provided in **Table 2**.

Table 1 *Technical parameters of 802.11ad equipment used in interference measurement study*

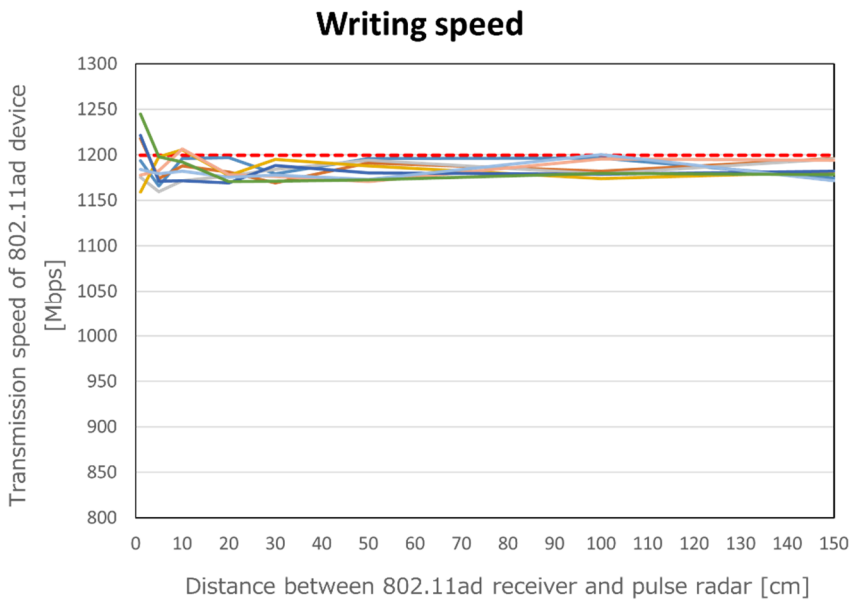
Center frequency	60.48 GHz
802.11ad channel	CH2（59.40-61.56GHz）
802.11ad transmitter EIRP	23 dBm （estimated from measurement）
TX/RX CH Bandwidth	2.16 GHz
Modulation	SC-BPSK/QPSK/16QAM (estimated from communication speed）

Table 2 *Technical parameters of pulse radar used in interference measurement study*

Center frequency	60.5 GHz
Pulse width	0.35, 0.8, 2.0, 3.6 ns
Peak EIRP	17 dBm
Calculated SIR at the 802.11ad receiver antenna according to setup in Figure 1, pulse radar at 0.05 m.	-31 dB + alignment factor due to the directional characteristics of the 802.11ad receive antenna

The result from the measurement study is shown in

Figure 2. No decrease in throughput is observed even when the pulse radar is as close as 5 cm to the 802.11ad receiver. When the pulse radar was placed 1 cm from the 802.11ad receiver, the reading speed decreased; however, the writing speed was not impacted. The decreased reading speed is attributed to the fact that the pulse radar shielded the 802.11ad signal. If considering the effect of the SIR caused by the pulse radar signal, the necessary separation distance between the 802.11ad receiver and the pulse radar to ensure low interference is shown to be less than 5 cm based on the setup used in this study.



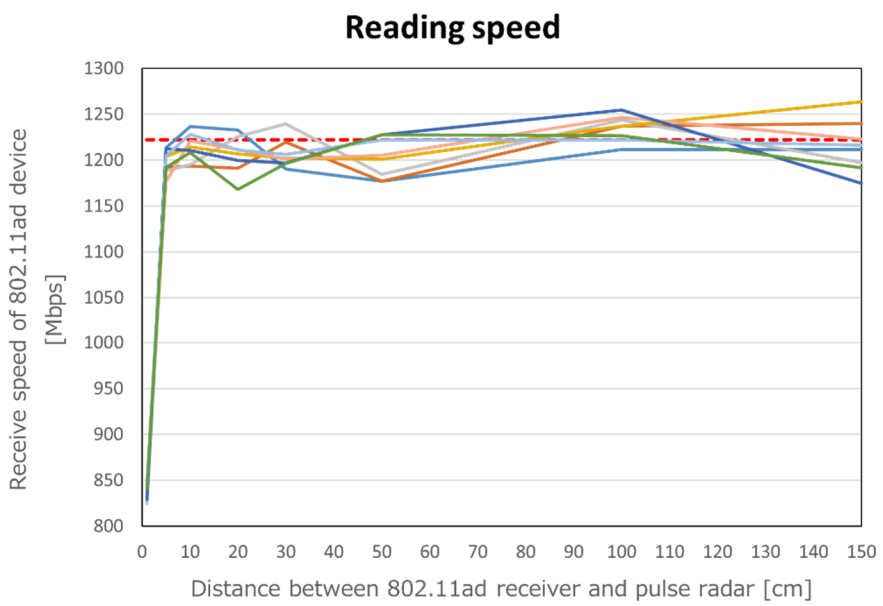


Figure 2 *Pulse radar to 802.11ad interference measurement study results. The calculated SIR at the 802.11ad receiver is -31 dB + alignment factor due to the directional characteristics of the 802.11ad receive antenna, when the pulse radar is positioned 5 cm from the 802.11ad receiver*

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I HEREBY CERTIFY THAT I AM THE TECHNICALLY QUALIFIED PERSON RESPONSIBLE FOR THE PREPARATION OF THIS ANALYSIS, AND THAT IT IS COMPLETE AND CORRECT TO THE BEST OF MY KNOWLEDGE AND BELIEF.

BY:

Mikael Egard, PhD
Chief Operating Officer
Acconeer AB
Västra Varvsgatan 19, 211 77 Malmö, Sweden
September 20, 2021