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TECHNICAL REPORT

Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference document (SRdoc); Technical characteristics and spectrum requirements of wideband SRDs with advanced spectrum sharing capability for operation in the UHF 870 - 876 MHz and 915 - 921 MHz frequency bands

Reference

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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

The present document includes necessary information to support the co-operation under the MoU between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Postal and Telecommunications Administrations (CEPT).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**may not**", "**need**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

Wideband SRDs are a subset of the broader SRD family that can enable further market growth for divers applications including Internet of Things, Machine-to-Machine communications, smart home/building automation and 'wearables'. This can be achieved in particular through advanced characteristics of these devices such as higher data rates, improved power usage, and efficient spectrum utilization. Therefore, Wideband SRD's are expected to grow rapidly over the foreseeable future for mass market applications. Based on these expected growth rates and currently limited available frequency bands, there is an essential need for additional spectrum for Wideband SRDs to accommodate the anticipated market growth. The present document requests modifications to the regulatory rules of the UHF 870 - 876 MHz and 915 - 921 MHz frequency bands to enable the operation of Wideband SRDs with advanced spectrum sharing capabilities in these bands.

1 Scope

The present document applies to the potential future usage of Wideband SRDs with advanced spectrum sharing capabilities in the UHF 870 - 876 MHz and 915 - 921 MHz frequency bands. In particular, it:

- Gives an SRD market overview and explains the development and emergence of new Wideband SRD technologies.
- Describes technical characteristics of Wideband SRDs, including advanced spectrum sharing capabilities, as they relate to the usage of the UHF 870 - 876 MHz and 915 - 921 MHz spectrum.
- Details the requested regulatory changes to allow for efficient use of Wideband SRDs.

The present document is intended to include all necessary information required by the Electronic Communications Committee (ECC) under the MoU between ETSI and the ECC.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] CEPT ECC ERC Recommendation 70-03: "Relating to the Use of Short Range Devices (SRD)", 07 February 2014.

[i.2] ABI Research, "Short Range Wireless and Cellular ICs Enabling the Connected World of Tomorrow", July 2013 (PT-1027).

[i.3] ABI Research Report "Home Automation Systems", May 5, 2014 (MD-HAS-1047).

[i.4] IHS, "Wearable Technology - World", October 2013.

[i.5] IEEE P802.11ah / Draft 2.0 June 2014. "Part II: Wireless LAN Medium Access Control (MAC) and Physical (PHY) Layer Specifications. Amendment 6: Sub 1 GHz License Exempt Operation".

[i.6] ETSI EN 300 220-1 (V2.4.1) (2012-01): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment to be used in the 25 MHz to 1 000 MHz frequency range with power levels ranging up to 500 mW; Part 1: Technical characteristics and test methods".

[i.7] ETSI EN 300 328 (V1.8.1) (2012-04): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Wideband transmission systems; Data transmission equipment operating in the 2,4 GHz ISM band and using wide band modulation techniques; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.8] ETSI EN 303 204 (V1.1.0): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Network Based Short Range Devices (SRD); Radio equipment to be used in the 870 MHz to 876 MHz frequency range with power levels ranging up to 500 mW".

[i.9] CEPT ECC Report 200: "Co-existence studies for proposed SRD and RFID applications in the frequency band 870-876 MHz and 915-921 MHz", September 2013.

[i.10] CEPT ECC Report 189: "Future Spectrum Demand for Short Range Devices in the UHF Frequency Bands".

[i.11] CEPT ECC Report 181: "Improving Spectrum Efficiency in the SRD Bands", September 2012.

[i.12] ETSI TR 103 055 (V1.1.1) (2011-09): "Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference document (SRdoc): Spectrum Requirements for Short Range Device, Metropolitan Mesh Machine Networks (M3N) and Smart Metering (SM) applications".

[i.13] ETSI TR 102 649-2 (V1.3.1) (2012-08): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Technical characteristics of Short Range Devices (SRD) and RFID in the UHF Band; System Reference Document for Radio Frequency Identification (RFID) and SRD equipment; Part 2: Additional spectrum requirements for UHF RFID, non-specific SRDs and specific SRDs".

[i.14] IEEE 802.11: "IEEE Standard for Information technology --Telecommunications and information exchange between systems Local and metropolitan area networks--Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications".

[i.15] IEEE 802.11n: "IEEE Standard for Information technology -- Local and metropolitan area networks -- Specific requirements -- Part 11: Wireless LAN Medium Access Control (MAC)and Physical Layer (PHY) Specifications Amendment 5: Enhancements for Higher Throughput".

[i.16] IEEE 802.11ac: "IEEE Standard for Information technology -- Telecommunications and information exchange between systems - Local and metropolitan area networks -- Specific requirements -- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications -- Amendment 4: Enhancements for Very High Throughput for Operation in Bands below 6 GHz".

[i.17] ABI Research Report "Commercial Building Automation", March 19, 2013. (MD-CBA-102).

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

channel: small frequency sub-band within the operating frequency band into which a Radio Signal fits

duty cycle: for the purposes of the ERC Recommendation 70-03 [i.1], the duty cycle is defined as the ratio, expressed as a percentage, of the maximum transmitter "on" time on one carrier frequency, relative to a one hour period

NOTE: For frequency agile devices the duty cycle limit applies to the total transmission.

Listen Before Talk (LBT): action taken by a device to detect an unoccupied channel prior to transmitting

frequency agility: ability of a device to selectively change its frequency sub-band of operation within the larger operating frequency band

Non-specific Short Range Devices (SRDs): SRDs that do not necessarily fit under the specific applications outlined in ERC/REC 70-03 [i.1], Annexes 2 to 13

Short Range Devices (SRDs): radio devices which provide either unidirectional or bi-directional communication and which have low capability of causing interference to other radio equipment

NOTE: SRDs use either integral, dedicated or external antennas and all modes of modulation can be permitted subject to relevant standards. SRDs are normally "license exempt".

Specific Short Range Devices (SRDs): SRDs that are used in specific applications (e.g. Applications of ERC/REC 70-03 [i.1], Annexes 2 to 13)

Wideband SRDs: SRD devices that use wideband modulation techniques with channel bandwidths larger than 600 kHz (which current regulations for UHF 870 - 876 MHz and 915 - 921 MHz already specify) and up to 1 MHz

NOTE: This definition is for the purpose of notational simplicity and clarity in the context of drafting the present document and does not claim a consensus on global definition for Wideband SRDs.

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AC	Access Category
ACK	Acknowledgement
AFA	Adaptive Frequency Agility/Autonomous Frequency Assignment
AP	Acces-Point
BPSK	Binary Phase Shift Keying
BSS	Basic Service Set
CA	Collision Avoidance
CAGR	Compound Annual Growth Rate
CCA	Clear Channel Assessment
CEPT	Commission Européenne des Postes et Télécommunications
CSMA	Carrier Sense Multiple Access
CW	Contention Window
DCF	Distributed Coordination Function
DIFS	DCF Interframe Spacing
DSSS	Direct Sequence Spread Spectrum
e.r.p/e.i.r.p.	effective radiated power/effective isotropic radiated power
ECC	Electronic Communications Committee of the CEPT
EDCA	Enhanced Distributed Channel Access
ER-GSM	Extended Railways GSM
FFT	Fast Fourier Transform
FHSS	Frequency Hopping Spread Spectrum
GSM-R	Global System for Mobile communication for Railway application
HVAC	Heating, Ventilation and Air Conditioning
IoT	Internet of Things
IP	Internet Protocol
ISM	Industrial Scientific and Medical
LBT	Listen-Before-Talk
M2M	Machine-to-Machine communication
MAC	Medium Access Layer
OBSS	Other Basic Service Set
OFDM	Orthogonal Frequency Division Multiplexing
PER	Packet Error Rate
PHY	Physical Layer
PSD	Power Spectral Density
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RAW	Restricted Access Window
RFID	Radio Frequency Identification
SIFS	Short Interframe Spacing
SRD	Short-Range Device

SST	Sub-band Selective Transmission
STA	Station
TWT	Target Wake Time
TXOP	Transmit Opportunity
UHF	Ultra-High Frequency

4 Comments on the System Reference Document

The statements in clause 4.1 have been recorded.

4.1 Statements by ETSI Members

BWMi statement concerning the utilization in Germany of the UHF frequency bands 870 - 876 MHz and 915 - 921 MHz.

In Germany a designation of the frequency bands 870 - 876 MHz and 915 - 921 MHz for wideband SRD applications as described in this SRdoc is not foreseen due to incumbent German military and GSM-R usage.

5 Executive summary

The present document proposes modifications to the regulatory rules of the SRDs [i.1] in Sub-1 GHz frequency ranges, to be considered with the aim of helping market introduction and proliferation of Wideband SRDs in the overall context of ongoing strategic re-alignment of SRD uses and allowing new bands and applications, e.g. in 870 - 876 MHz and 915 - 921 MHz frequency bands. Current usage rules [i.1] governing maximum allowable transmit bandwidth and duty cycle will not allow even basic SRD Wideband deployments and therefore these parameters need to be reviewed by taking into account the information given in the present document. In return, Wideband SRDs will implement advanced spectrum sharing techniques such as more sophisticated LBT and AFA procedures to ensure coexistence and balance the changes to spectrum usage. These changes will ultimately lead to SRD systems that are capable of more data rates to support the needs of various SRD applications and allow more efficient and fair utilization of the spectrum.

The present document first presents market data and predictions for the growth of the "Internet of Things" (IoT) and in a broader sense Machine-to-Machine (M2M) communications market in Europe and worldwide. The technologies for IoT are also evolving to address the ever emerging market needs and use cases and one direction is towards Wideband SRD systems such as (but not limited to) those based on IEEE 802.11ah [i.5]. Based on expected growth rates and currently limited available frequency bands, there is an essential need for new spectrum designations for these types of Wideband SRDs to support IoT deployments.

The IEEE 802.11ah [i.5] is an example technology for Wideband SRDs that allows for a wide-range of data rates through the use of OFDM modulation and has built-in mechanisms for efficient spectrum sharing. The present document describes its salient technical characteristics and features such as LBT based on CSMA-CA and AFA using Sub-channel Selective Transmissions.

Based on the market data and the technical requirements for deployment of IEEE 802.11ah [i.5] (and other Wideband SRD-type systems), spectrum designation is being requested. For Wideband SRDs to be efficiently deployed in the UHF 870 - 876 MHz and 915 - 921 MHz frequency bands and to specifically support more sensor-type network use cases, the following changes to spectrum regulations need to be considered:

- Creation of sub-band definitions between 870 - 875,8 MHz and 915,2 - 920,80 MHz for Wideband SRDs.
- Increase of Maximum Transmission Bandwidth from 600 kHz to 1 MHz.
- Inclusion of IEEE 802.11 [i.14] CSMA-CA as a compliant method of LBT within 870 - 876 MHz and 915 - 921 MHz, with the minimum CCA interval times and timing parameters defined to align with IEEE 802.11ah [i.5] values.
- Relaxation of Maximum Duty Cycle for AP-type devices implementing LBT+AFA from 1 % to 10 %, and for non-AP devices using LBT+AFA from 1 % to 2,8 %.

6 Market information

Markets that stand to benefit from Wideband SRD's are expected to grow rapidly over the foreseeable future. For example ABI Research is projecting that globally installed base of wirelessly connected devices will grow from over 10 billion units in 2013 to over 30 billion units in 2020 [i.2]. The market for smart home/building automation, IoT/M2M, and "Wearables" is expected to grow at a very rapid pace. For example, according to ABI Research [i.3], the market for new installs of Home Automation systems in Europe is expected to grow by 40 % (CAGR) between 2014 and 2019 to 7,3 million in 2019. The market for wirelessly enabled building automation devices installed in Europe is expected to grow at a rate of 19 % (CAGR) between 2014 and 2018 to 6,9 million new installs in 2018 [i.17]. The unit shipment volume market for the emerging market of "Wearable" technology in Europe is projected to be around 70 million units in 2018 according to IHS [i.4]. This market (e.g. for smartwatches, fitness trackers, etc.) is projected to have a high wireless connectivity attach rate (over 60 %).

Additional relevant market data is given in annex A of the present document. Wideband SRDs are expected to become the key enablers for new deployments and applications in the above sectors. Examples of benefits of Wideband SRD enabled devices include increased energy efficiency in homes/buildings, medical/fitness applications to help reduce medical expenses, remote elderly care, security/surveillance cameras, etc.

Another example of the market momentum towards the adoption of Wideband SRD technology is that the Wi-Fi Alliance (a global, non-profit industry association of more than 600 leading companies devoted to seamless interoperability) is working on the development of an industry interoperability program for devices that implement the IEEE 802.11ah [i.5] standard under development.

The key advantages of using Wideband SRDs for wireless connectivity are:

- Provide higher data rates for IoT and similar data-rich applications.
- Enable IP networking for security and scalability.
- Open up new use cases for low power, battery operated, wireless sensors.
- Enables the use of one network in a home or building with enough capacity and features to support a variety of integrated sensor type services and applications.

The expected high growth in the number of deployed Wideband SRDs drives the need for an increase in overall network capacity. It is expected that the exiting 7 MHz of spectrum available for SRDs in the 863 - 870 MHz band will be quickly exhausted. A complicating factor here is that usage of the 863 - 870 MHz spectrum is constrained by the 3 % duty cycle limitation for all devices using this spectrum even with advanced spectrum sharing techniques like LBT/AFA.

Additional spectrum for Wideband SRDs in the 870 - 876 MHz and 915 - 921 MHz bands will be required to accommodate the anticipated market growth for IoE, M2M and "Wearable" devices. Applications and devices in these high growth markets increasingly require higher data rates than SRDs that have been historically deployed in these spectrum bands. For example Wideband SRDs are needed to support IP networking, to offer more robust security and to enable more sophisticated IP based applications (like for smartgrid networking). In order to enable networks, which could scale up to meet the anticipated demand, more advanced spectrum sharing techniques and the ability to use wider channel bandwidths will be needed for these bands.

One additional consideration, which may apply, is that the IoE market will likely serve as an engine for technology innovation and economic growth in the foreseeable future. The availability of larger amounts of Sub-1 GHz spectrum with fewer spectrum usage limitations in key markets like the USA, South Korea, Japan, Australia and possibly China may put the competitive advantage of EU member countries at risk.

7 Technical characteristics

This clause will describe the technical details of Wideband SRDs and specifically cover the future IEEE 802.11ah system (currently in drafting process, expected completion of standard specification by early 2015 [i.5]), focusing on the PHY/MAC characteristics and notably its advanced spectrum sharing capabilities, which are relevant to operation and coexistence in the UHF 870 - 876 MHz and 915 - 921 MHz bands.

The term Wideband SRD is used to describe devices using technologies and protocols that have larger operation bandwidths (e.g. ≥ 1 MHz) than most current SRDs on the market. These Wideband SRDs will also generally have higher supported data rates as a consequence of the wider operation bandwidths.

7.1 Description of IEEE 802.11ah as an Example Technology for Wideband SRDs

Like other IEEE 802.11-based systems, the IEEE 802.11ah [i.5] system is based on a network topology consisting of Access Points (APs) and stations (STAs). The APs act as nodes that the STAs are associated with, and APs can generally be expected to serve large numbers of STAs in IEEE 802.11ah [i.5]. An AP and the STA(s) associated to it comprise a Basic Service Set (BSS) and BSSs are set up with an operating channel bandwidth around a carrier frequency from a set of valid carrier frequencies, which are determined by regulations in the region of operation. An overall network can consist of multiple BSSs of different coverage radiuses spread over a geographical area, with individual BSSs overlapping or partially overlapping the frequencies and channel(s) of other BSSs (OBSS), see Figure 1 for an illustrative example.

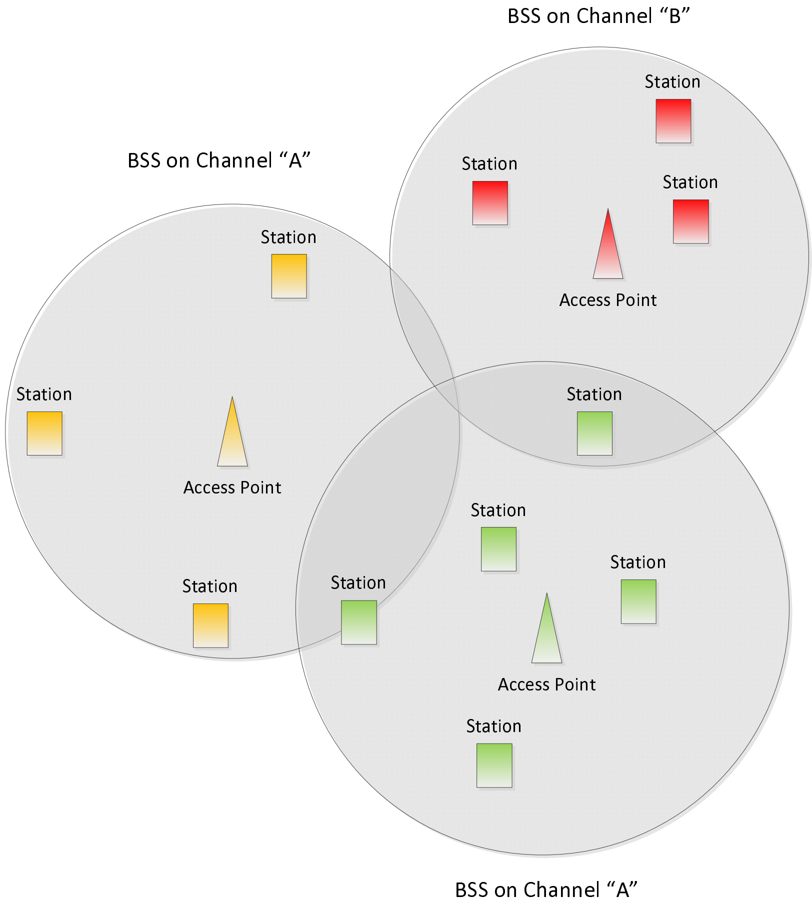

Figure 1: An illustrative example of a IEEE 802.11ah [i.5] network consisting of multiple BSSs

An AP is responsible for broadcasting management frames (e.g. beacon frames) to be received by the STAs in its BSS. These management frames contain operational parameters and information necessary for the STAs to operate and remain synchronized within the BSS.

Similar to other IEEE 802.11-based systems [i.14], APs are responsible for setting up associations with STAs entering the BSS, and additionally serve data traffic to STAs on the downlink and respond with ACKs for incoming uplink traffic. Because of the APs role in the BSS, they will generally need to transmit more frequently than an individual STA would.

The IEEE 802.11ah [i.5] system is designed with rules for channel access but does not have specific limitations on transmit duty cycles for individual devices. Because the system was defined to work globally across regions with differing limitations, APs and STAs will adhere to the regulatory rules within the region of its operation. Regulatory rules for the operation of Wideband SRDs (including IEEE 802.11ah [i.5] systems) in the UHF 870 - 876 MHz and 915 - 921 MHz spectrum are addressed in clause 9. Such rules will have to be established based on the findings of co-existence studies to be performed within CEPT, i.e. an extension and evolution of the scenarios and analysis considered in ECC Report 200.

7.1.1 IEEE 802.11ah PHY

The IEEE 802.11ah [i.5] system has an OFDM-based PHY designed for operation at sub-1 GHz carrier frequencies. The primary design goals included multiple interoperable operation bandwidth modes, and support for a wide range of data rates.

The supported operation bandwidths in the overall IEEE 802.11ah [i.5] system are 1, 2, 4, 8, and 16 MHz and the OFDM tone spacing across the different bandwidth modes is a constant 31,25 kHz. OFDM symbols for 1, 2, 4, 8 and 16 MHz transmissions are based on 32, 64, 128, 256, and 512-pt FFTs, respectively. OFDM symbols will have a guard interval duration (i.e. cyclic prefix) of 8 us or 4 us, and a single OFDM symbol will have a duration of 40 us or 36 us, depending on the guard interval duration used. In IEEE 802.11ah [i.5], transmissions are frame-based, with each frame consisting of multiple OFDM symbols.

However during the design, the system was specifically optimized in the lower bandwidth modes to support lower data rates and longer ranges that would be useful for power limited (e.g. battery operated sensors) SRDs operating in sub-1 GHz bands. Standalone operation of the lowest bandwidth mode (of 1 MHz) is envisaged for IEEE 802.11ah [i.5] within the UHF 870 - 876 MHz and 915 - 921 MHz bands, and is the focus of the remainder of the technical characteristics description.

The maximum duration of a single IEEE 802.11ah [i.5] frame on the medium is determined by the maximum payload capable of being signalled in the control field of the preamble. For example, in 1 MHz operation the longest possible single frame can be 27,92 ms. The duration of a total transmission can be longer however if MAC protocols for aggregated PHY frame transmissions are used. These transmissions fit within Transmit Opportunity (TXOP) duration allocated for that device, which is determined at channel access. Channel access in IEEE 802.11ah [i.5] is controlled by the procedure described in clause 7.1.3.

In practice however, the maximum duration of a transmission or of a TXOP is regulated by the Listen-Before-Talk (LBT) rules defined for the spectrum in the region of operation. Specifically, the LBT rules define parameters such as the maximum "on-time" that will set the limits on the allowable TXOP durations in IEEE 802.11ah [i.5]. The LBT rules for the UHF 870 - 876 MHz and 915 - 921 MHz bands will be discussed in clause 9.

7.1.2 IEEE 802.11ah MAC

The IEEE 802.11ah [i.5] MAC layer was designed by inheriting many of the protocols from existing IEEE 802.11 systems (i.e. IEEE 802.11n [i.15] and IEEE 802.11ac [i.16]) and then augmenting or modifying aspects to specifically address long-range and sensor-network use cases. Some of the other design goals included low-power usage and support for large numbers of users across multiple overlapping networks.

One such new feature in IEEE 802.11ah [i.5] is Sub-band Selective Transmission (SST), which is a type of Adaptive Frequency Agility (AFA) scheme that allows devices to rapidly select and switch to the channels on which they transmit, between transmissions. From the perspective of the transmitting device, this scheme allows for coordination between it and the intended receiver to select the most favourable channel amongst a larger set on which to transmit. The "best" channel here can be determined based on measurement to take into consideration short-term fading conditions and/or interference levels from other sources.

For example, a single AP may be serving many sensor-type devices using 1 MHz operation bandwidth. If there is a total of 8 MHz of spectrum available, the sensor-type STA devices can select the most favourable 1 MHz sub-channel contained in the wider 8 MHz to transmit and receive. From the perspective of the sensor device, it can potentially improve its link conditions from taking advantage of the available fading diversity over the wider bandwidth and therefore ultimately improve its throughput and power usage. The overall system impact within a network is that transmissions can potentially be more evenly distributed across the available spectrum, and that channel occupancy time for individual channels can be reduced.

Another feature in IEEE 802.11ah [i.5] which is of particular interest to sensor device networks is support for defining Restricted Access Windows (RAW). The AP can set up a RAW in which during certain intervals of time, specific classes of devices (e.g. sensors) in the BSS are given exclusive access to the medium. This allows for some degree of coordination and improvement of medium usage efficiency for coexisting traffic types within a BSS, such as between sensor devices with lower data rates and other devices with higher data rate needs. Oftentimes RAW usage is paired with the Target-Wake-Time feature of IEEE 802.11ah [i.5], which was designed to specifically coordinate power-save and sleep modes across battery-operated sensor devices. Both the set-up and usage of RAW and TWT are coordinated through beacon management frames from the APs to the STAs in their BSSs.

7.1.3 Transmitter and Receiver Specifications

The transmitter and receiver specifications and requirements for the IEEE 802.11ah system are defined in the IEEE 802.11ah specification document [i.5]. In addition to the requirements described in Sections 24.3.16 S1G (sub-1 GHz) transmit specification and 24.3.17 S1G receiver specification, any IEEE 802.11ah device also meets the regulatory requirements (e.g. transmit spectrum masks, max e.r.p.) of the regulatory region in which it operates. For the reader's convenience, the transmitter and receiver specifications for Transmit Spectrum Mask, Receiver Minimum Sensitivity, and Adjacent/Non-Adjacent channel rejection from that document are summarized in this subsection, as they will be of relevance during future compatibility analysis for Wideband SRDs.

7.1.3.1 Transmit power levels

The maximum transmit power levels for STA and AP are based upon regulations established by regional and national regulatory administrations. Annex D of the IEEE 802.11ah specification [i.5] summarizes these parameters for 802.11ah operation as they stand currently in various defined regulatory domains, and will change to reflect any evolution of existing regulations. As is also stated in the IEEE 802.11ah specification [i.5], operation in countries within the defined regulatory domains may be subject to additional or alternative national regulations, some of which may supersede those described in the specification. The proposed maximum transmit power levels for the 870 - 876 MHz and 915 - 921 MHz bands within CEPT countries are described in the table of clause 9.3.1.

7.1.3.2 Transmit Spectrum Mask

For 1 MHz transmissions in IEEE 802.11ah [i.5], the transmit spectral mask will have a 0dBr (dB relative to the maximum spectral density of the signal) bandwidth of 0,9 MHz, or in other words from -0,45 to +0,45 MHz around the transmission's center frequency. At further offsets from the center frequency, the requirements are: -20 dBr at ±0,6 MHz offsets, -28 dBr at ±1 MHz offsets, and -40 dBr at ±1,5 MHz offsets and greater. For the regions in between the ±0,45, ±0,6, ±1, and ±1,5 MHz offsets, the spectrum mask is defined to be a linear interpolation (in dB domain) of the defined values at those offsets.

Additionally, the transmit spectrum does not exceed the maximum of the transmit spectrum mask and -40 dBm/MHz at any frequency offset. An illustration of the described transmit spectrum mask, when the -40 dBr spectrum level is greater than -40 dBm/MHz, is shown in Figure 2.

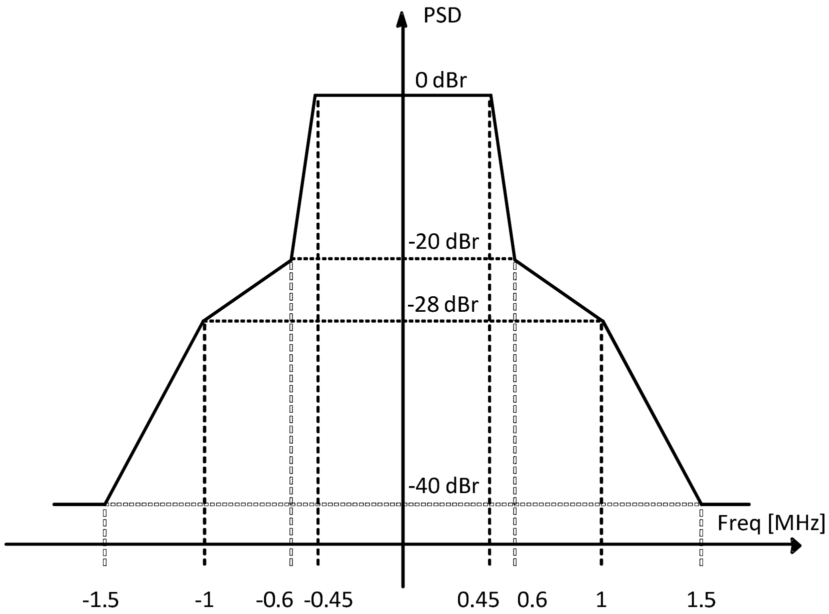

Figure 2: IEEE 802.11ah [i.5] 1 MHz Transmit Spectrum Mask

7.1.3.3 Receiver Minimum Input Sensitivity

In the IEEE 802.11ah specification [i.5], the Receiver Minimum Input Sensitivity is defined as the input power level (measured at a single receive antenna) where the device successfully receive a packet with greater than 90 % reliability (i.e. packet error rate less than 10 %). The sensitivity level is defined for 256-byte packets and is rate-dependent and bandwidth mode dependent.

For 1 MHz mode of operation, and for the lowest defined rate (150 kbps), the minimum sensitivity is -98 dBm. Table 1 lists the defined minimum sensitivity levels for each of the available data rates in 1 MHz mode of operation for IEEE 802.11ah [i.5].

Table 1: Receiver Minimum Input Level Sensitivity

Modulation	Code Rate	Data Rate (Kbps)	Minimum Sensitivity, 1 MHz frame, 256 bytes (dBm)
BPSK	1/4 (1/2 with 2x rep.)	150,0	-98
BPSK	1/2	300,0	-95
QPSK	1/2	600,0	-92
QPSK	3/4	900,0	-90
16-QAM	1/2	1 200,0	-87
16-QAM	3/4	1 800,0	-83
64-QAM	2/3	2 400,0	-79
64-QAM	3/4	2 700,0	-78
64-QAM	5/6	3 000,0	-77
256-QAM	3/4	3 600,0	-72
256-QAM	5/6	4 000,0	-70

7.1.3.4 Adjacent and Nonadjacent channel rejection

The adjacent and nonadjacent channel rejection requirements in the IEEE 802.11ah specification [i.5] define how resistant a receiver should be to blocker signals in nearby bands. For the 1 MHz case in IEEE 802.11ah [i.5], the Adjacent channel rejection requirement is tested by placing a 1 MHz blocker signal adjacent to the 1 MHz desired signal being tested (where the center frequency of the blocker signal is 1 MHz away from the center frequency of the desired signal being tested). The signal being tested is sent at each of its available rates (256 byte payload) and is set such that its received power is 3 dB above the minimum input sensitivity for that rate (e.g. -95 dBm for the lowest rate in 1 MHz). The blocker signal's power is varied until a > 10 % PER is observed for the signal of interest. The adjacent channel rejection requirement is the relative amount (in dB) the blocker signal that exceeds the desired signal's power before the PER threshold is crossed.

The nonadjacent channel rejection test follows the same procedure except the blocker signals are now placed at center frequencies of 2 MHz and greater away from the center frequency of the desired signal being tested. The criteria for satisfying the requirement are the same as that for the adjacent channel rejection test.

The test states that the blocker signal is to be an OFDM signal that is unsynchronized to the desired signal within the 1 MHz band being tested. The minimum required adjacent and nonadjacent channel rejection levels are listed in Table 2.

Table 2: Minimum Required Adjacent and Nonadjacent Channel Rejection Levels

Modulation	Code Rate	Data Rate (Kbps)	Adjacent Channel Rejection (dB)	Non-Adjacent Channel Rejection (dB)
BPSK	1/4 (1/2 with 2x rep.)	150,0	19	35
BPSK	1/2	300,0	16	32
QPSK	1/2	600,0	13	29
QPSK	3/4	900,0	11	27
16-QAM	1/2	1 200,0	8	24
16-QAM	3/4	1 800,0	4	20
64-QAM	2/3	2 400,0	0	16
64-QAM	3/4	2 700,0	-1	15
64-QAM	5/6	3 000,0	-2	14
256-QAM	3/4	3 600,0	-7	9
256-QAM	5/6	4 000,0	-9	7

7.2 Advanced Spectrum Sharing Capabilities

The IEEE 802.11ah [i.5] system employs a Distributed Coordination Function (DCF) for enabling spectrum sharing and allowing for contending devices to fairly contend for and transmit on the medium. The procedure, which is inherited from prior IEEE 802.11 systems, is based on a Carrier Sense Multiple Access protocol with collision avoidance (CSMA-CA) that all devices are required to follow prior to transmitting. This procedure allows for a distributed control of channel access across devices and across BSSs that aims to reduce collisions between transmissions while allowing for fairness in transmit opportunities. Additionally, the CSMA-CA protocol accounts for coexistence and spectrum sharing with non-IEEE 802.11ah [i.5] technologies through the use of Energy Detection-based deferral. This procedure detects for all transmissions on the medium independent of transmission pattern, modulation type, etc., based on measured received energy.

The IEEE 802.11ah [i.5] CSMA-CA is based on a slotted timeline, where the PHY provides channel "busy" or "idle" indications to the MAC once every 52 us (definition of a slot in IEEE 802.11ah [i.5]) based on a Clear Channel Assessment (CCA) procedure. The MAC layer will use these indications from the PHY to drive its countdown/backoff procedure, which is also operating in units of slots. A device is permitted to transmit only once the MAC countdown/backoff procedure is completed. The duration for which the device is granted channel access is termed a Transmit Opportunity, or TXOP.

In principle, CSMA-CA is a sophisticated and dynamic Listen-Before-Talk procedure that before transmitting detects if the medium "busy" and only attempts transmissions after the medium has been "idle" for a set amount of time. Like any other LBT-type protocol, the issue of Hidden Node problem might need to be considered for CSMA-CA during CEPT coexistence studies.

7.2.1 PHY Layer CCA

As part of the CSMA-CA process, the PHY layer is responsible for performing the CCA: monitoring the contended channel of interest for ongoing traffic or interference and declaring to the MAC whether the channel (i.e. medium) can be considered "busy" or "idle". The conditions for declaring "busy" and "idle" are dependent on checking for both intra-technology (i.e. IEEE 802.11ah [i.5]) and inter-technology (signals of other types) traffic on the medium.

For intra-technology coexistence, to prevent devices from transmitting over ongoing IEEE 802.11ah [i.5] traffic and causing collisions, the PHY layer detects for valid IEEE 802.11ah [i.5] frames in the channel being monitored. The required sensitivities and depend on the bandwidth of the channel being monitored and the measurement intervals depend the type of detection being performed. When signals are detected according to this criteria, the channel is declared "busy", otherwise the channel is "idle".

For inter-technology coexistence, all IEEE 802.11ah [i.5] devices perform a mandatory energy detection of the channels it wishes to access and transmit on. The energy detection sensitivity for the 1 MHz operation bandwidth is -75 dBm / 1 MHz, with the signal energy level measured at each receiving antenna. The observation duration is 40 us, meaning that if any signal is detected above the detection sensitivity threshold, and continues to exceed the threshold for at least 40 us, the PHY layer declares that the channel is "busy". The -75 dBm / 1 MHz level should be checked for compatibility with other systems.

For the channel to be declared idle, none of the intra-technology and inter-technology conditions being checked for should be present (i.e. triggered). An example illustration of the PHY CCA is depicted in Figure 3.

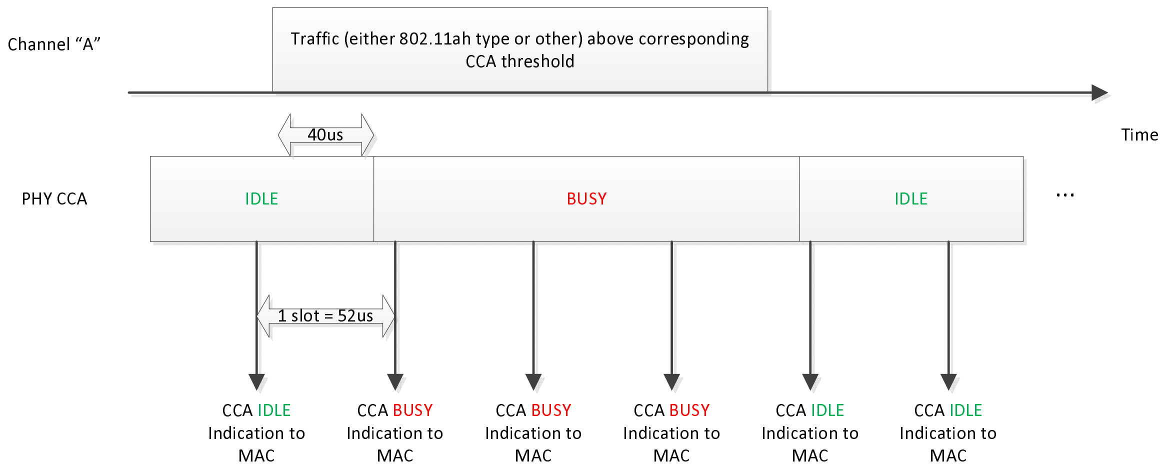

Figure 3: Illustrative example timeline of the PHY Clear Channel Assessment procedure

7.2.2 MAC Layer EDCA

The MAC layer performs Enhanced Distributed Channel Access (EDCA, or more descriptively, CSMA/CA with an exponential random backoff/countdown) based on the "busy" or "idle" indications generated by the PHY for the channel of interest. Once the channel has been considered idle for an accumulated duration of time, the device is given access to the channel and may transmit.

When a device wants to access the channel to transmit, it will start the EDCA procedure in the MAC. The first step is waiting for the channel to be idle: if the channel is busy with other traffic or interference (as indicated by the PHY), it should wait until the CCA indication transitions to "idle".

Once the channel is idle, the device will monitor the channel for an additional DIFS (DCF Interframe Spacing) duration, defined in IEEE 802.11ah [i.5] to be 264 us. If the channel remains idle continuously for at least a full DIFS duration, it can then start the binary exponential random backoff process. The device will randomly choose a backoff countdown value between [0, CW] where CW is the initial Contention Window size parameter. The units of the countdown value is in slots. The CW is initially started at the minimum value, which can be dependent on the device's assigned Access Category (AC) within the BSS. As will be described shortly, the CW value can also increase (after transmission failures) up to an eventual maximum value, also dependent on the device's AC. As an example, for best effort traffic (a reasonable assumption for battery-powered sensors), the CW can range between 31 and 2 023 slots.

During the backoff, the countdown value is decremented at every slot if the CCA indication from the PHY for that slot shows idle. If the counter is successfully decremented to 0 without interruption, the device will gain access to the channel to transmit. This basic procedure is illustrated in Figure 4.

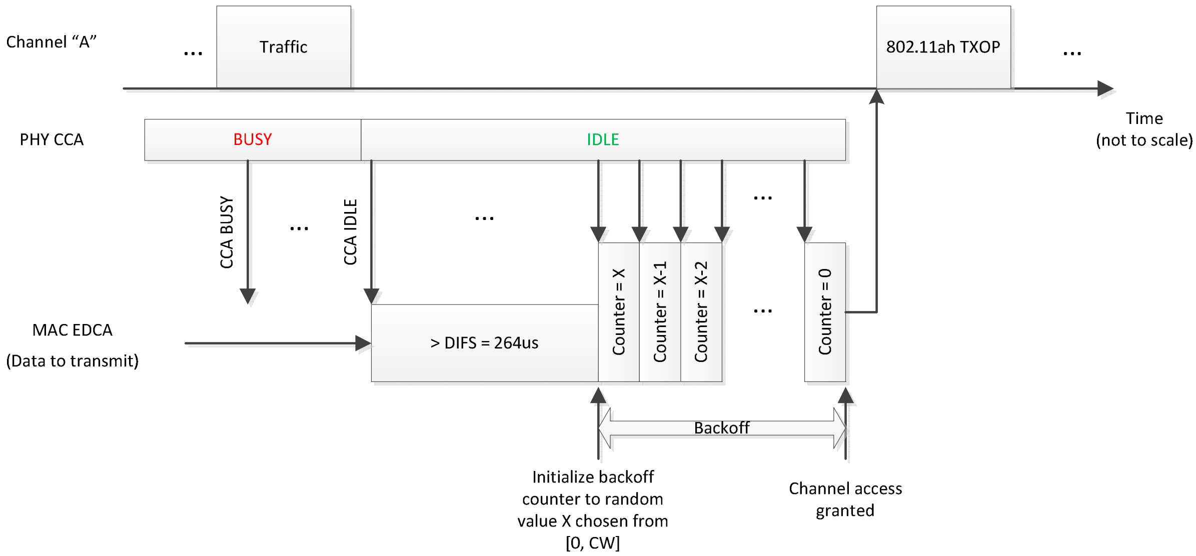

Figure 4: Example of timeline for backoff procedure used for gaining access to the channel (no interruptions)

However if at any point during the countdown procedure, the MAC receives a CCA indication of "busy" from the PHY, the countdown is temporarily halted. The device will then wait for the ongoing traffic to clear and for the CCA indication from the PHY to return to "idle". Once the CCA indication is "idle", the device will again need to observe that the channel remains idle for an additional continuous DIFS duration. After this is satisfied, the device will resume the countdown procedure, picking up the counter value where it left off previously. This process is illustrated in Figure 5.

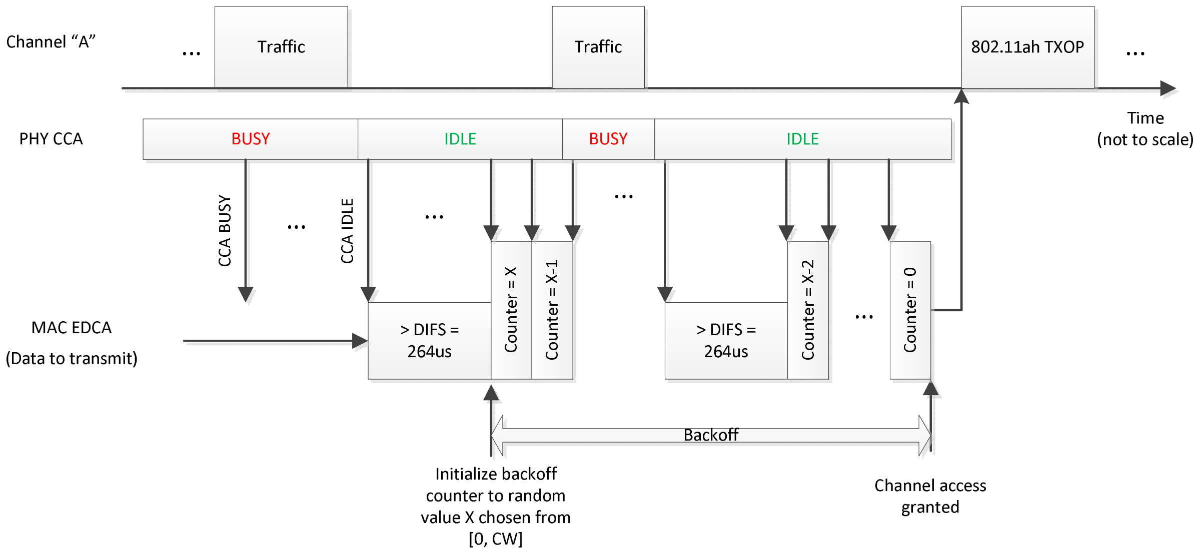

Figure 5: Example of timeline for backoff procedure used for gaining access to the channel (with interruptions)

After the device is given access to the channel and transmits its data, it will wait for an acknowledgement (i.e. ACK response) indicating successful reception of the packet at the other end. In IEEE 802.11ah [i.5], the receiver of any packet is required to generate an ACK response within a Short Interframe Spacing (SIFS) duration, which is 160 us. The receiving device does not need to repeat the LBT procedure for transmitting the ACK response. If a negative acknowledgement or no response is received, and the device wishes to retransmit the data, the same EDCA procedure will be repeated again for access to the channel. However in this instance the randomly chosen backoff counter value will be taken from a larger set (e.g. [0, CW_init × 2^failed attempts - 1], such that the initial contention window range increases exponentially with every subsequent packet failure/retransmission). The maximum size of this set is determined by the CWmax, defined according to the AC of the device.

One note is that for any transmission, either the AP or the STA will initiate the EDCA procedure for the TXOP period. In the example scenario where TWT is used, the AP can perform EDCA to obtain the TXOP for STAs such that a power-saving STA can wake up and safely transmit without performing EDCA again, once receiving the wake-up trigger from the AP.

8 Justification of Spectrum Request

The main purpose of the present document is to present consideration for Wideband SRDs usage in the UHF 870 - 876 MHz and 915 - 921 MHz frequency bands. The target outcome is to request changes to the regulations outlined in ERC Recommendation 70-03 [i.1], pending the results of coexistence and compatibility studies and analysis, to make the spectrum amenable for the deployment of Wideband SRDs.

As outlined in clause 6 and annex A of the present document, the SRD industry has grown over recent years to cover many different types of use cases. Wideband SRDs are a useful subset of the broader SRD family that can enable further growth of IoT and M2M markets through their higher data rates, improved power usage characteristics, and efficient spectrum utilization. Clause 7 briefly outlined technical characteristics of the future IEEE 802.11ah [i.5] system, which has built-in features for advanced spectrum sharing based on LBT and AFA, as an example of such Wideband SRDs. Systems that are capable of more efficient sharing through means such as LBT will more and more become the norm in the future as spectrum usage is shared among more types of SRDs and data rate and network capacity requirements increase.

ECC Report 189 [i.10] took into consideration System Reference Documents such as ETSI TR 102 649-2 [i.13] and ETSI TR 103 055 [i.12], and the outcomes of the coexistence analysis done in ECC Report 200 [i.9] to outline and propose modifications to ERC Recommendation 70-03. It additionally gave justification for the changes based on analysis of future spectrum demand based on SRD use cases. ERC Recommendation 70-03 [i.1] was successfully updated in February 2014 to incorporate the proposals for UHF 870 - 876 MHz and 915 MHz. The general principle followed throughout (including the analysis for ECC Report 200 [i.9]) was that generic (i.e. non-specific) SRDs should be allowed to operate in bands of countries where they are unlikely to cause harmful interference to existing radiocommunications, and that the technical parameters be determined to allow for intra-SRD compatibility and coexistence.

The same rationale and criteria hold when evaluating spectrum requests for Wideband SRDs, which were not part of the set of System Reference Documents considered for ECC Report 200 [i.9] and ECC Report 189 [i.10]. The latest updates to Annex 1 of ERC Recommendation 70-03 should therefore not be considered a judgement on the technical parameters for Wideband SRDs, as these should get their own dedicated compatibility analysis with respect to primary radio services (e.g. ER-GSM, but varying by country) and other SRD technologies.

The UHF spectrum in consideration here has been opened in many other regions of the world for classes of Wideband SRDs such as IEEE 802.11ah [i.5]. Having unified bands for Wideband SRDs usage in as many regions as possible can lead to benefits of global operation compatibility for devices, and economies of scale in the design and production. Additionally, the adjacency to the 863 - 870 MHz SRD bands is beneficial from hardware design and cost perspectives. As outlined in other previous reports [i.10], these bands are prime locations for generic SRD usage due to its favorable radio propagation characteristics.

The next clause details and provides further justification for the requested changes to the current regulations for the UHF 870 - 876 MHz and 915 - 921 MHz bands that are necessary for efficient operation of Wideband SRDs. These changes along with the opening of the spectrum can provide much economic benefit by providing room for Wideband SRD growth and proliferation of these devices.

9 Regulations

9.1 Overview of Current UHF 870 - 876 MHz and 915 - 921 MHz Spectrum Regulations

The regulatory rules for the operation of SRDs in the UHF 870 - 876 MHz and 915 - 921 MHz spectrum are covered in detail in ERC Recommendation 70-03 [i.1]. The rules were determined based on the proposed and requested technical parameters of various SRD-specific System Reference Documents considered in ECC Report 200 [i.9] and on the outcomes of the coexistence studies of that report. In the ECC Report 200 [i.9], there was no specific consideration for the type of Wideband SRDs described in the present document.

Under current regulations, Wideband SRDs most closely align with the category and listed characteristics of "Non-Specific SRDs", and its behaviour would be governed by its corresponding regulatory parameters. The regulatory parameters (as defined in ERC Recommendation 70-03 [i.1]) for Non-Specific SRDs operating in the 870 - 876 MHz and 915 - 921 MHz bands are separated into frequency sub-bands (G2, G2.1, G3, G3.1) and are reproduced in Table 3.

Table 3: ERC Recommendation 70-03 Regulations for Non-Specific SRDs operating in 870 - 876 MHz and 915 - 921 MHz

Frequency Band		Power / Magnetic Field	Spectrum access and mitigation requirements	Modulation/ Maximum occupied bandwidth
G2	870 - 876 MHz	≤ 25 mW e.r.p.	≤ 0,1 % duty cycle For ER-GSM protection (873 - 876 MHz), the duty cycle is limited to ≤ 0,01 % and a maximum single transmitter on-time of 5 ms / 1 s.	≤ 200 kHz
G2.1	870,0 - 875,8 MHz	≤ 25 mW e.r.p.	≤ 1 % duty cycle For ER-GSM protection (873 - 875,8 MHz), the duty cycle is limited to ≤ 0,01 % and a maximum single transmitter on time of 5 ms / 1 s.	≤ 600 kHz
G3	915,000 - 921,000 MHz	≤ 25 mW e.r.p.	≤ 0,1 % duty cycle For ER-GSM protection (918 - 921 MHz), the duty cycle is limited to ≤ 0,01 % and a maximum single transmitter on-time of 5 ms / 1 s.	≤ 200 kHz
G3.1	915,200 - 920,8 MHz	≤ 25 mW e.r.p. except for the 4 channels at 916,3 MHz, 917,5 MHz, 918,7 MHz, and 919,9 MHz where ≤ 100 mW e.r.p. applies	≤ 1 % duty cycle For ER-GSM protection (918 - 920,8 MHz), the duty cycle is limited to ≤ 0,01 % and a maximum single transmitter on-time of 5 ms / 1 s.	≤ 600 kHz except for the 4 channels at 916,3 MHz, 917,5 MHz, 918,7 MHz, and 919,9 MHz where ≤ 400 kHz applies

In both the 870 - 876 MHz and 915 - 921 MHz regions, the maximum channel bandwidth (determined by the channel spacing) is either 200 kHz or 600 kHz, and in special cases 400 kHz.

For the subbands G2, G2.1, G3, G3.1 defined above, the spectrum access conditions limit the transmit duty cycles of any operating device to either 0,1 % or 1 %, regardless whether Listen-before-talk (LBT) or Adaptive Frequency Agility (AFA) techniques are used to mitigate contention with other transmissions on the medium.

9.1.1 Regulations for SRD-designated sub-bands in 863 - 870 MHz

The adjacent 863 - 870 MHz bands, which are also classified for SRD usage, have different spectrum access conditions in that non-specific SRD devices can implement LBT and AFA mechanisms and in return not be restricted to the listed duty cycle limits. The LBT rules for 863 - 870 MHz are defined in the Harmonized Standard ETSI EN 300 220-1 [i.6].

The regulatory rules as it relates to the usage of Wideband SRDs in this band are taken from ERC Recommendation 70-03 [i.1] and summarized in Table 4.

Table 4: ERC Recommendation 70-03 Regulations for Non-Specific SRDs operating in 863 - 870 MHz

Frequency Band		Power / Magnetic Field	Spectrum access and mitigation requirements	Modulation/ Maximum occupied bandwidth	Notes
G1	863 - 870 MHz	≤ 25 mW e.r.p. Power density: -4,5 dBm / 100 kHz	≤ 0,1 % duty cycle or LBT+AFA	No spacing requirements	DSSS and other wideband techniques other than FHSS

The rules for the 863 - 870 MHz band are such that it is suited for the deployment of Wideband SRD technologies such as IEEE 802.11ah [i.5] and other digitally modulated systems with wider minimum bandwidth operations.

9.1.2 Spectrum Access Techniques for SRDs

The rules for Spectrum Access (and consequently the LBT rules) for SRDs operating in bands between 25 MHz and 1 GHz are defined in the Harmonized Standard ETSI EN 300 220-1 [i.6]. The document defines the following limits for the parameters related to generalized and compliant LBT procedures:

- **Minimum Transmitter off-time:** The amount of time a transmitter remains off after a transmission or communication dialogue should be greater than 100 ms.
- **LBT Minimum Listening Time (Fixed and Pseudorandom):** The amount of time a transmitter should monitor the channel for ongoing transmissions above the LBT threshold is a fixed 5 ms. If the channel is free, it can start transmitting immediately (or within the Dead Time). However if busy, the transmitter restarts the Listening Time after the channel becomes free again and listen for the fixed 5 ms and additionally a Pseudorandom duration ranging between 0 and 5 ms (value chosen randomly within the range at equal 0,5 ms steps).
- **Dead Time:** The maximum amount of time allowed to pass between the end of the listening time and the start of the transmission is not to exceed 5 ms.
- **ACK Transmissions:** Acknowledgment transmissions do not need an additional LBT procedure to be performed but should happen within 5 ms.
- **Maximum transmitter on-time:** To prevent a transmitter from occupying a channel for an extensive period of time, the limits for:
    - A single transmission is 1 s.
    - Multiple transmissions and acknowledgments for a communication dialogue or polling sequence given that the channel is free is 4 s, after which the Minimum Transmitter off-time applies before additional transmissions are allowed.
    - Accumulated transmissions within 1 hour of any fixed 200 kHz of spectrum is 100 s, which effectively translates to an implicit duty cycle limitation of 2,8 %.

At the time of publication of the latest version of ETSI EN 300 220-1 [i.6], the UHF 870 - 876 MHz and 915 - 921 MHz bands were not yet designated for the use of SRDs and hence the spectrum access rules were also unspecified. However, since the publication of that document, various System Reference Documents (e.g. ETSI TR 102 649-2 [i.13], ETSI TR 103 055 [i.12]) requested that these bands be made available for the use of SRDs.

There is currently ongoing work on the drafting of Harmonized Standard ETSI EN 303 204 [i.8], specific to Network-Based SRDs operating in the 870 - 876 MHz bands. The present document gives certain types of Network SRDs operating in the 870 - 876 MHz bands the option of performing LBT+AFA in exchange for a relaxed duty cycle limitation. Additionally it makes modifications to the more generalized LBT rules of ETSI EN 300 220-1 [i.6] (which covers all SRDs in 25 - 1 000 MHz), primarily in the time durations of the required LBT steps.

The draft text states [i.8]:

"Before transmitting, a device implementing LBT senses the channel for at least the clear channel assessment interval to determine if it is free. If the channel is found free the device proceeds with the transmission. If a signal above the signal threshold is detected, the LBT device defers its transmission to a later time. The equipment shall not attempt re-transmission on the same channel until a random interval has expired. Alternatively, the equipment may select another channel and again start the listen time before transmission."

The main LBT parameter defined is CCA Interval, which is set to 160 us and this is equivalent to the LBT Minimum Listening time in ETSI EN 300 220-1 [i.6]. The other intervals, such as deferral period and dead time are derived from this value. By reducing the time scale of the listening times, the LBT is made more flexible especially for the use cases where shorter duration transmissions are concerned.

9.2 Limitations of Spectrum Regulations for Wideband SRDs

The current regulatory rules for usage of the UHF 870 - 876 MHz and 915 - 921 MHz spectrum severely limit the operation of many types of Wideband SRDs and would additionally prohibit the operation of technologies with wider minimum operation bandwidths (such as IEEE 802.11ah [i.5]) in those bands. The following is a list and description of the 2 current regulatory issues:

- **Maximum Transmit Bandwidth:** In ERC Recommendation 70-03 [i.1], the maximum transmit bandwidth for non-specific SRDs (i.e. SRDs not already covered by the other categories) is defined to be either 200 kHz, 400 kHz, or 600 kHz for the UHF 870 - 876 MHz and 915 - 921 MHz bands, with the maximum transmit powers of 25 mW for 200 kHz and 600 kHz channels and 100 mW for the select 400 kHz channels. These restrictions would limit the types of Wideband SRD technologies that can operate in these bands. The IEEE 802.11ah [i.5] technology described in the previous section has a minimum operation bandwidth of 1 MHz and would therefore be prohibited from being deployed in this spectrum.

  For Wideband SRDs to effectively service the IoT and M2M use cases, it is that expected future devices will include natural IP support. A requirement for this is more robust choices of data rates, and especially the need for higher minimum data rates. It is expected that SRDs in the UHF spectrum will function to serve a large range of device types of varying use cases and data rate needs. A single interconnected network would bring large gains to efficiency and spectrum usage which is important as these devices proliferate, and wider operation bandwidths are essential for supporting these types of heterogeneous deployments.

- **Spectrum Access/Mitigation Requirements:** Within the UHF 870 - 876 MHz and 915 - 921 MHz bands, the current regulations from ERC Recommendation 70-03 [i.1] limit the amount of time any device can actively transmit within a defined time interval. The duty cycle limitation for the sub-band G2 is 1 % for 600 kHz channels and 0,1 % for 200 kHz channels. For sub-band G3, the same limitations apply. It should be noted that there are safe-haven bands with 0,1 % duty cycle limits within both 870 - 876 MHz and 915 - 921 MHz to provide ensured reliable service to low-duty cycle, low data rate devices.

  A duty cycle limitation of 1 % would be restrictive for many types of SRD applications. Such a restrictive limit would be especially harmful for AP-type devices, which may be expected to serve large numbers of distributed sensor-type devices within its managed network. In the IEEE 802.11ah [i.5] BSS example, APs are responsible for broadcasting periodic management frames and individual response frames to all incoming sensor node traffic. In BSSs with potentially thousands of sensor node devices, a 1 % duty cycle would effectively limit the size of supportable networks and hence reduce the efficiency of IoT deployments.

Unlike the neighbouring 863 - 870 MHz SRD bands [i.6], within 870 - 876 MHz and 915 - 921 MHz the current regulations do not stipulate any scenarios in which LBT and AFA can be used in return for relaxed duty cycle limitations. Coexistence is currently managed through ensuring a certain level of sparseness of transmissions to probabilistically limit collisions. Strictly relying on duty-cycling for coexistence across the entire 870 - 876 MHz and 915 - 921 MHz bands is inefficient use of valuable spectrum and limits achievable throughput due to its inflexibility to loading conditions or usage patterns of the spectrum.

Load based and adaptive LBT and AFA procedures lead to more flexible and efficient usage of the medium because rather than relying on duty cycle limitations (which is by nature uncoordinated) to mitigate the long-term impact of collisions, LBT channel sensing allows for collision avoidance and does not unnecessarily limit transmission when the medium is otherwise unoccupied.

Wideband SRDs are expected to implement LBT and AFA techniques as they ultimately lead to better individual performance and network performance. As evidenced by the progress of the drafting of ETSI EN 303 204 [i.8] and also predicted in ECC Report 181 [i.11],the overall direction of the SRD-space is towards greater coordination and polite spectrum access between devices to better share the limited spectrum in an efficient manner.

9.3 Proposed Changes and Benefits

Based on the described limitations to Wideband SRDs of the current regulations, the present document requests that the following modifications to the regulatory rules outlined in ERC Recommendation 70-03 [i.1] for the UHF 870 - 876 MHz and 915 - 921 MHz bands be considered:

- Creation of a new frequency sub-band between 870 - 875,8 MHz and 915,2 - 920,8 MHz:
    - Accommodates Wideband SRDs while respecting existing safe-haven bands in those regions.
- Increase of the Maximum Transmission Bandwidth to 1 MHz:
    - Wider bandwidth operation allows for higher achievable data rates and enables IP support.
    - Will lead to more power efficient operation via higher data rates and shorter transmission durations, which complements power save-sleep modes.
    - No increases in the expected PSD of transmissions.
- Extension of generalized LBT+AFA and Duty Cycle requirements for 863 - 870 MHz (as defined in ETSI EN 300 220-1 [i.6]) to UHF 870 - 875,8 MHz and 915,2 - 920,8 MHz bands:
    - Allows for devices across different technologies to coexist through the use of energy detection-based deferral, while allowing for fair access to the medium.
    - Broadly defined LBT requirements allow for low-complexity devices to implement variety of simple LBT protocols.
    - As mentioned in previous System Reference Documents (e.g. ETSI TR 102 649-2 [i.13]), predictable spectrum sharing environments are desired by all future systems in SRD spectrum, and the introduction of LBT is essential for achieving that efficiently.
- Inclusion of IEEE 802.11-style CSMA-CA as an optional mode of LBT compliance, with CCA minimum listening time, CCA parameter values matched with IEEE 802.11ah [i.5]:
    - Similar in concept to existing LBT procedure in ETSI EN 300 220-1 [i.6], but has exponential random backoff procedure to minimize future collisions and increase fairness:
        - Range for Pseudorandom backoff time can adaptively grown or shrink based on traffic conditions and contention issues.
        - Key feature that Pseudorandom backoff time does not reset each time the Listening interval is interrupted by CCA-busy indication, which tends towards priority for devices that have been contending longer.
    - As described in the Harmonized Standard for devices in the 2,4 GHz ISM bands, a similar approach is used to allow devices to use IEEE 802.11 CSMA-CA to satisfy Load-Based LBT requirements [i.7].

- Will allow Wideband SRDs to implement and follow more sophisticated LBT procedure that has better spectrum usage efficiency and can adapt to traffic and channel occupancy:
    - For example, under lighter loading scenarios, LBT based on CSMA-CA can increase power efficiency of low-power devices wishing to access medium by shortening listening times.
    - In higher loading scenarios, exponential random backoff procedure can minimize collisions while still allowing for fair access to medium.
- CCA parameter values defined for IEEE 802.11ah [i.5] are shorter (and similar in time scale with values used for Network SRDs), which is more appropriate for Wideband SRD data rates and traffic patterns.

- For non-AP type devices (e.g. sensors) implementing LBT+AFA, a relaxation of the maximum duty cycle limit to 2,8 % (determined by Maximum Transmitter On-Time parameter of LBT protocol) to align with requirements stated in ETSI EN 300 220-1 [i.6]:
    - Duty cycle limitation of 2,8 % would correspond to Maximum Transmitter On-time of 100 s per hour, per LBT parameters specified in ETSI EN 300 220-1 [i.6].
    - With LBT+AFA, no longer need to rely on strict duty-cycling to (probabilistically) avoid collisions with other ongoing transmissions.
- Relaxation of Maximum Duty Cycle for AP-type devices implementing LBT+AFA to 10 %:
    - Allows AP-type devices to effectively service larger numbers of sensor nodes.
    - AFA techniques can mitigate individual channel occupancy and distribute usage across available channels.
    - Comparable to allowable duty cycle for Network SRD access points (Annex 2 of ERC Recommendation 70-03 [i.1]), but with lower maximum output power (500 mW vs. 25 mW max e.i.r.p. limit for Wideband SRDs).

9.3.1 Detailed Changes to Regulatory Text

It is suggested that the proposed changes be incorporated as a new sub-band designation (G2.2 and G3.2) into the regulatory text of Annex 1: Non-specific Short Ranges Devices in ERC Recommendation 70-03 [i.1] as indicated in Table 5 (pending outcomes of coexistence and compatibility analysis).

Table 5: Proposed Regulations for Non-Specific SRDs operating in 870 - 876 MHz and 915 - 921 MHz

Frequency Band		Power / Magnetic Field	Spectrum access and mitigation requirements	Modulation/ Maximum occupied bandwidth
G2	870 - 876 MHz	≤ 25 mW e.r.p.	≤ 0,1 % duty cycle For ER-GSM protection (873 - 876 MHz), the duty cycle is limited to ≤ 0,01 % and a maximum single transmitter on-time of 5 ms / 1 s.	≤ 200 kHz
G2.1	870,0 - 875,8 MHz	≤ 25 mW e.r.p.	≤ 1 % duty cycle For ER-GSM protection (873 - 875,8 MHz), the duty cycle is limited to ≤ 0,01 % and a maximum single transmitter on time of 5 ms / 1 s.	≤ 600 kHz
G2.2	870,0 - 875,8 MHz	≤ 25 mW e.r.p.	≤ 0,1 % duty cycle for devices not implementing both LBT and AFA. ≤ 2,8 % duty cycle for non-Access Point devices implementing LBT and AFA. ≤ 10 % duty cycle for Access Point devices implementing LBT and AFA. (See notes)	≤ 1 MHz
G3	915,000 - 921,000 MHz	≤ 25 mW e.r.p.	≤ 0,1 % duty cycle For ER-GSM protection (918 - 921 MHz), the duty cycle is limited to ≤ 0,01 % and a maximum single transmitter on-time of 5 ms / 1 s.	≤ 200 kHz
G3.1	915,200 - 920,8 MHz	≤ 25 mW e.r.p. except for the 4 channels at 916,3 MHz, 917,5 MHz, 918,7 MHz, and 919,9 MHz where ≤ 100 mW e.r.p. applies	≤ 1 % duty cycle (note 9) For ER-GSM protection (918 - 920,8 MHz), the duty cycle is limited to ≤ 0,01 % and a maximum single transmitter on-time of 5 ms / 1 s.	≤ 600 kHz except for the 4 channels at 916,3 MHz, 917,5 MHz, 918,7 MHz, and 919,9 MHz where ≤ 400 kHz applies
G3.2	915,2 - 920,8 MHz	≤ 25 mW e.r.p.	≤ 0,1 % duty cycle for devices not implementing both LBT and AFA. ≤ 2,8 % duty cycle for non-Access Point devices implementing LBT and AFA. ≤ 10 % duty cycle for Access Point devices implementing LBT and AFA. (See notes)	≤ 1 MHz
NOTE: For Sub-bands G2.2 and G3.2: Devices implementing LBT and AFA may use a relaxed duty cycle limitation: - LBT procedures defined for general SRD devices in Harmonized Standard ETSI EN 300 220-1 [i.6] can be carried over and deemed compliant. - Additionally, IEEE 802.11 CSMA-CA (according to the procedures and parameters described in the IEEE P802.11ah specification [i.5]) may be used as an alternative method of LBT compliance. - In those countries that the band is allocated to ER-GSM, duty cycle and any other related parameter should be limited to values that guarantee ER-GSM protection.				

It is also proposed that the above Note be merged with the existing Notes and Additional Information text at the end of Annex 1.9.4 Technology Coexistence and Spectrum Sharing Considerations.

Like the previous System Reference Documents mentioned in ECC Report 189 [i.10] and evaluated in coexistence studies carried out as part of ECC Report 200 [i.9], the proposed modifications to regulations proposed in the present document should be considered in light of the coexistence potential of Wideband SRDs to the other radio technologies and SRD technologies within 870 - 876 MHz and 915 - 921 MHz.

Prior coexistence studies based on the previous System Reference Documents were carried out without specific consideration for Wideband SRD-type devices as there were no such technologies available at the time. In light of the development of such future systems like IEEE 802.11ah [i.5], the present document requests additional consideration of the specific requests outlined in this section along with the typical system characteristics (such as expected LBT techniques, operation bandwidths, deployments scenarios) described in prior sections.

ECC Report 181 [i.11], published in September 2012, explored improvements to spectrum efficiency in the SRD bands at the time and did analysis of spectrum access mechanisms with respect to intra-technology coexistence. One of the conclusions in the report is the importance of spectrum sharing in the SRD bands for improving spectrum occupancy and throughput. The report states that more advanced sharing mechanisms may need to be introduced in the future to improve overall spectrum efficiency while balancing fairness in spectrum access with less efficient devices relying on duty cycling.

With market needs pushing spectrum requirements in the direction of spectrum efficiency and higher throughputs for given amounts of spectrum, thorough technical analysis should be performed on the viability of advanced spectrum techniques. As suggested in ECC Report 181, techniques such as CSMA-CA available in systems such as IEEE 802.11ah [i.5] and described in the present document could offer improvements over existing LBT procedures in balancing the needs between spectrum efficiency and accommodating for legacy SRD devices.

Wideband SRD systems as described in the present document will have mechanisms to facilitate coexistence with other radio systems and other SRDs, independent of transmission characteristics or technology, based on procedures such as Energy Detection CCA. However, quantifiable impacts to performance and whether spectrum usage fairness is achieved will require system level simulations. Decisions on spectrum sub-band designation and technical parameters for spectrum access within 870 - 876 MHz and 915 - 921 MHz should therefore be based on the outcomes of coexistence analysis and the parameters may be adjusted if unresolvable coexistence issues arise.

10 Conclusions

The present document presents data on the expected evolution of the SRD market and highlights the need for additional spectrum designations in the UHF 870 - 876 MHz and 915 - 921 MHz bands to support future growth, particularly of SRDs that support higher data rates. The IEEE 802.11ah [i.5] system is described in the present document as an exemplary Wideband SRD system which aligns with this criteria, and which implements sophisticated LBT and AFA for improved spectrum efficiency and sharing.

Current spectrum regulations for the UHF 870 - 876 MHz and 915 - 921 MHz are too restrictive to make deployments in these bands feasible, however, based on the expected technical characteristics of Wideband SRDs. Therefore the present document proposes the modifications to the regulations outlined in ERC Recommendation 70-03 [i.1]:

- Creation of sub-bands definitions between 870 - 875,8 MHz and 915,2 - 920,8 MHz for Wideband SRDs.
- Increase of Maximum Transmission Bandwidth from 600 kHz to 1 MHz.
- Inclusion of IEEE 802.11 CSMA-CA as a compliant method of LBT within 870 - 876 MHz and 915 - 921 MHz, with the minimum CCA interval times and timing parameters defined to align with IEEE 802.11ah [i.5] values.
- Relaxation of Maximum Duty Cycle for AP-type devices implementing LBT+AFA from 1 % to 10 %, and for non-AP devices using LBT+AFA from 1 % to 2,8 %.

Benefits of these changes include higher spectrum efficiency and fairer approaches to spectrum access/utilization. Coexistence with other SRDs and interference to other radio systems in the spectrum are always concerns when new spectrum designations are considered, hence those impacts should be analysed and quantified during compatibility studies based on system parameter inputs from this System Reference Document.

Annex A:
Detailed Market Information

A.1 Overall Connected Devices Market

According to ABI Research, the overall global installed base of wirelessly connected devices is expected to grow from over 10 billion units in 2013 to over 30 billion units in 2020.

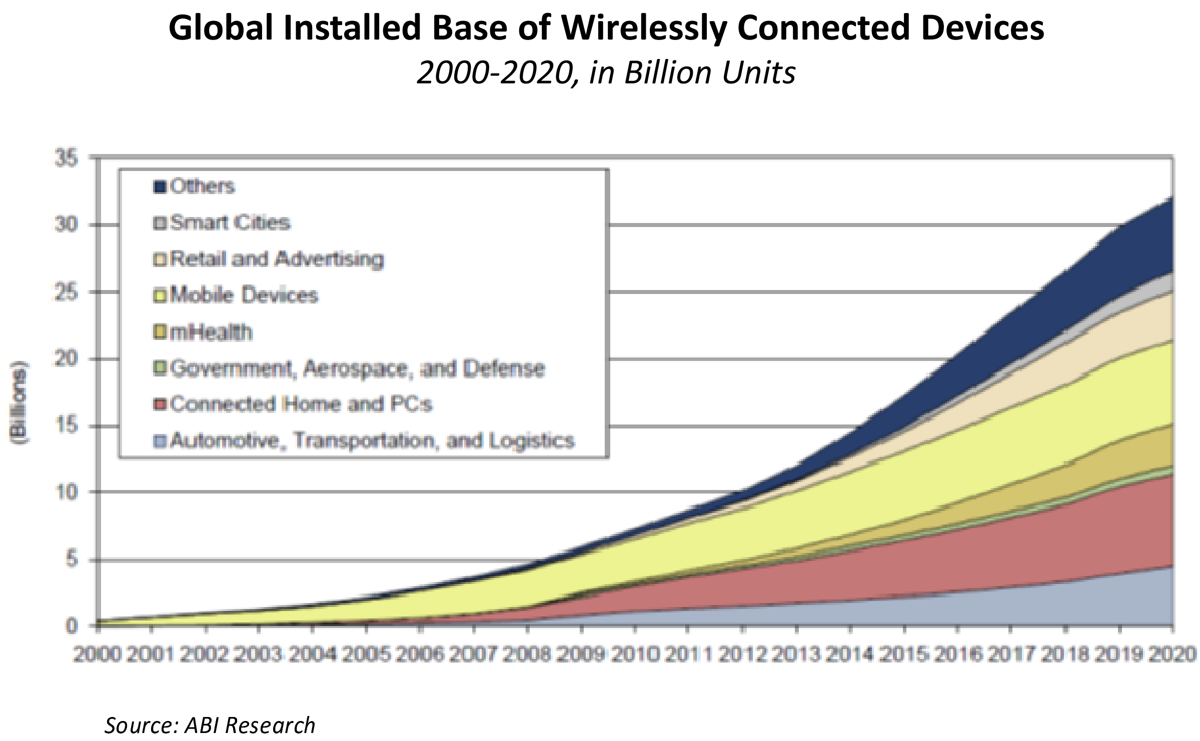

Figure A.1

According to ABI Research: *"The emergence of standardized ultra-low power wireless technologies is one of the main enablers of the IoE with semiconductor vendors and standard bodies at the forefront of the market push, helping to bring the IoE into reality"*.

A.2 European Home and Building Automation Market

ABI Research forecasts that the number of homes that will receive new installations of Home Automation systems in Western Europe will grow from 1,1 million in 2014 to 5,7 million in 2019.

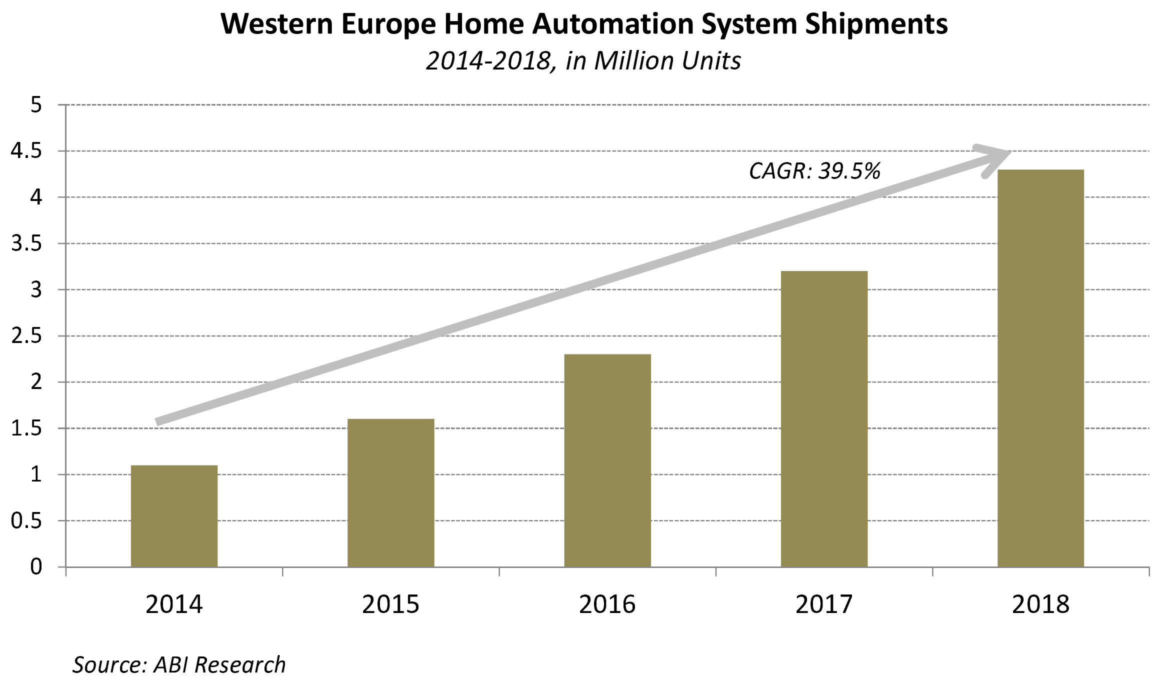

Figure A.2

Furthermore, ABI Research forecasts that the number of new wireless building automation field equipment devices shipped in Europe will grow from 2,9 million in 2014 to 6,9 million in 2018. Application areas for the wireless building automation field equipment shipments are categorize into: 'HVAC', 'Fire/Life safety', 'Lighting', 'Access' and 'Other category'.

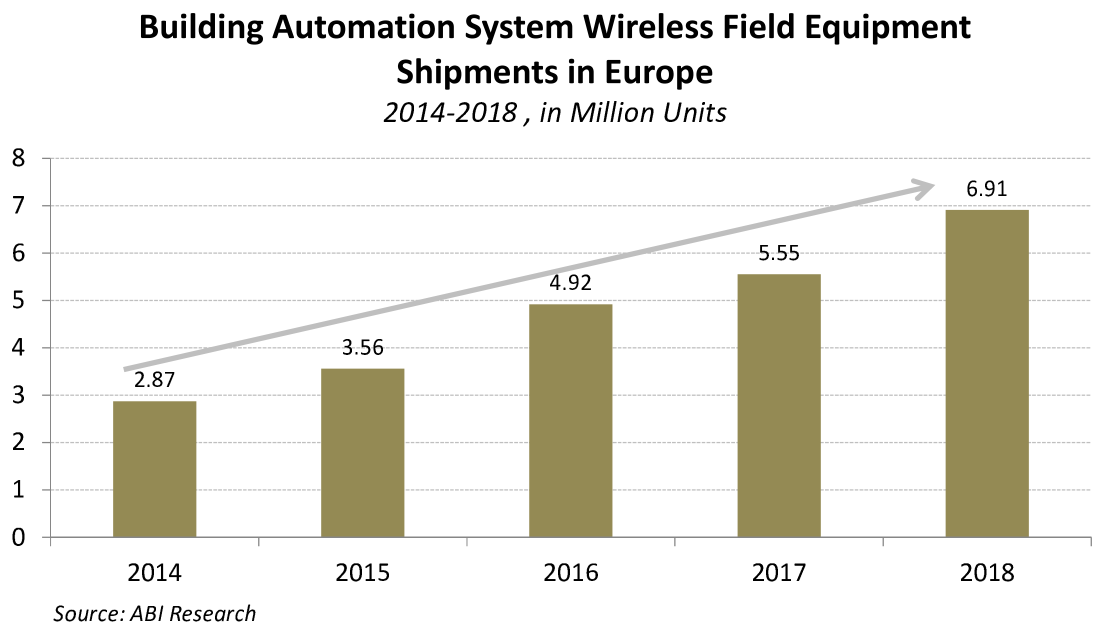

Figure A.3

A.3 Wearable Technologies Market

Another area where Wideband SRD's are likely to play an important role is the wearable technology sector. According to Juniper Research (see Press Release at http://www.juniperresearch.com/viewpressrelease.php?pr=405), mobile smart wearable device market is set to reach $19 billion by 2018 and it is going to experience a 10X growth from 2013 to 2018. Today's short range devices lack the IP connectivity required to connect these IoE devices in a scalable manner. IP connectivity requires wider bandwidth compared to the narrow bandwidth of existing SRDs that connect in a point-to-point manner.

Wearables can range from smart glasses and smart watches to health and fitness trackers, and even get embedded into smart clothing. There is a high rate of attach of wearables with wireless connectivity. Low power Wideband SRDs such as IEEE 802.11ah [i.5] can extend the range and reduce power consumption of the connectivity of wearable devices which typically run on small coin-cell type batteries, and require long battery life. Some data heavy wearable categories such as smart glasses, etc. require higher data rates at low power, which can only be addressed by Wideband SRDs.

Figure A.4

IHS forecasts that the unit volume shipment of wearable devices in Europe will be around 70 million in 2018.

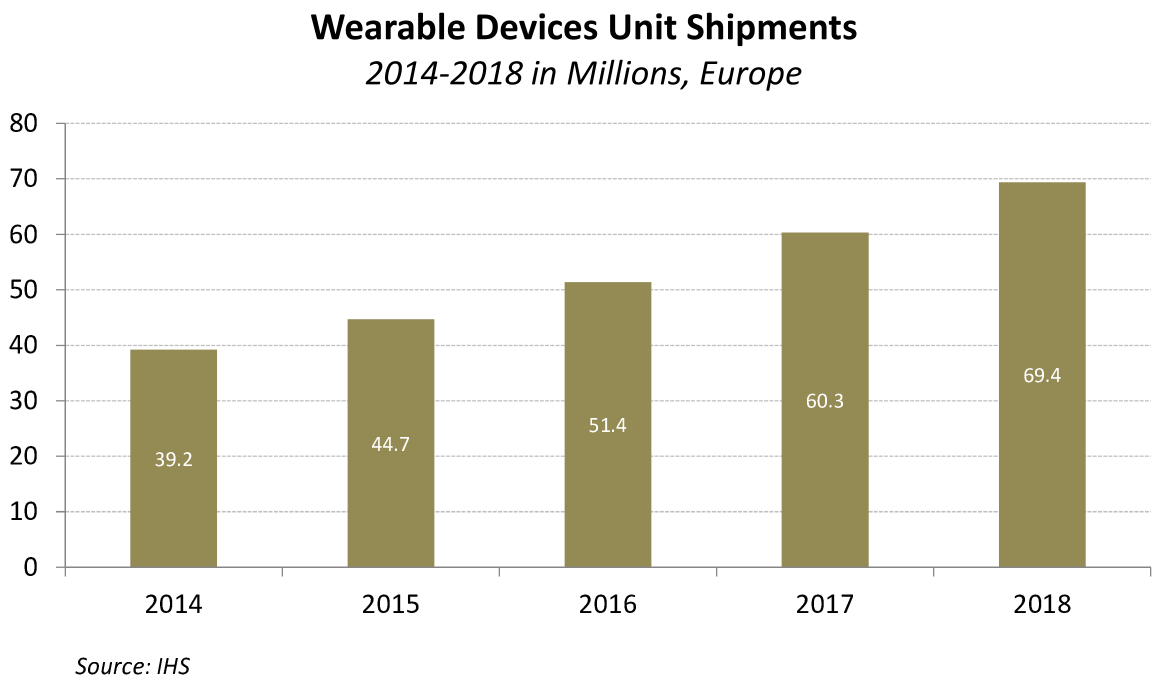

Figure A.5

The breakdown of the global shipment forecast for wearables indicates that the 'Infotainment' and 'Fitness and Wellness' are projected to be the largest application areas in terms of unit volume.

History

Document history		
V1.1.1	November 2014	Publication