Application Note

Certification of SPARK UWB devices

Version 1.1.3
SPARK Microsystems
December 02, 2024

www.sparkmicro.com

Contents

Figures

Tables

1. Purpose

This document can be used as a guide for customers wishing to achieve UWB Regulatory Certification. The process described in this note has been executed by SPARK Microsystems to achieve certifiable RF Power levels using the SPARK SR1020 transceiver.

2. Introduction

The SR10x0 PHYs are UWB wireless transceivers operating in the license-free UWB spectrum from 3.1 to 5.8 GHz (SR1010) and 6 to 9.3 GHz (SR1020) bandwidths. They can achieve robust communications using short impulses and a dynamic shaping of the output spectrum for interference mitigation. This document primarily focuses on UWB as a communication technology.

Although this report covers certification requirements for both the SR1010 and SR1020, the certification process description will use the SR1020 as an example.

For more information about Global compliance, please refer to "SR10x0_Global_Regulations.pdf" available on SPARK website Products | High-performance UWB Transceivers | Spark UWB SPARK microsystems.

3. Certification Bodies and Regional Specifications

The main regions covered in this application note include the USA, Europe, Japan, China, and Taiwan. These countries and their main regulatory bodies are shown in Table 1. Many other countries follow regulations set forth by these regions. For example, South Korea's spectral mask and test methods are very similar to that of Japan.

Table 1: National Wireless Emissions Regulatory Bodies

Country/Region	Regulatory Body
United States of America	Federal Communications Commission (FCC)
European Union	European Telecommunications Standards Institute (ETSI)
Japan	Association of Radio Industries and Businesses (ARIB)
China	Ministry of Industry and Information Technology (MIIT)
Taiwan	National Communications Commission (NCC)

The wireless emissions regulations in the USA are governed by the Federal Communications Commission (FCC), and the full UWB regulations can be found in the Code of Federal Regulations (CFR) 47 Part 15 Subpart F. The most relevant sections of this document are:

- Section 15.517 technical requirements for indoor UWB systems (47 CFR 15.519 (up to date as of 5/25/2023))
- Section 15.519 technical requirements for handheld UWB systems (47 CFR 15.517 (up to date as of 5/25/2023))

• Section 15.521 technical requirements applicable to all UWB devices (47 CFR 15.521)

In regions regulated by the FCC:

• The SPARK SR1010 enables 2.65 GHz of unlicensed spectrum usage (3.1 - 5.8 GHz).

• The SPARK SR1020 enables 3.25 GHz of unlicensed spectrum usage (6 - 9.3 GHz).

In Europe, states retain authority over the spectrum use in their country. Coordination happens at CEPT ECC. ECC Decision (06)04 governs the use of most UWB applications. Moreover, the European Commission has the authority to mandate single market member states to implement harmonised legislation. The Commission Implementing Decisions (EU) 2024/1467 contains the harmonised radio spectrum regulations for equipment using UWB. Compliance with the regulations is shown by using Harmonised Standards. For SPARK based UWB products, the EN 302 065 family of Harmonised Standards published by ETSI applies. Communication application should comply with ETSI EN 302 065-1 V2.1.1 (2016-11) for Generic UWB Devices.

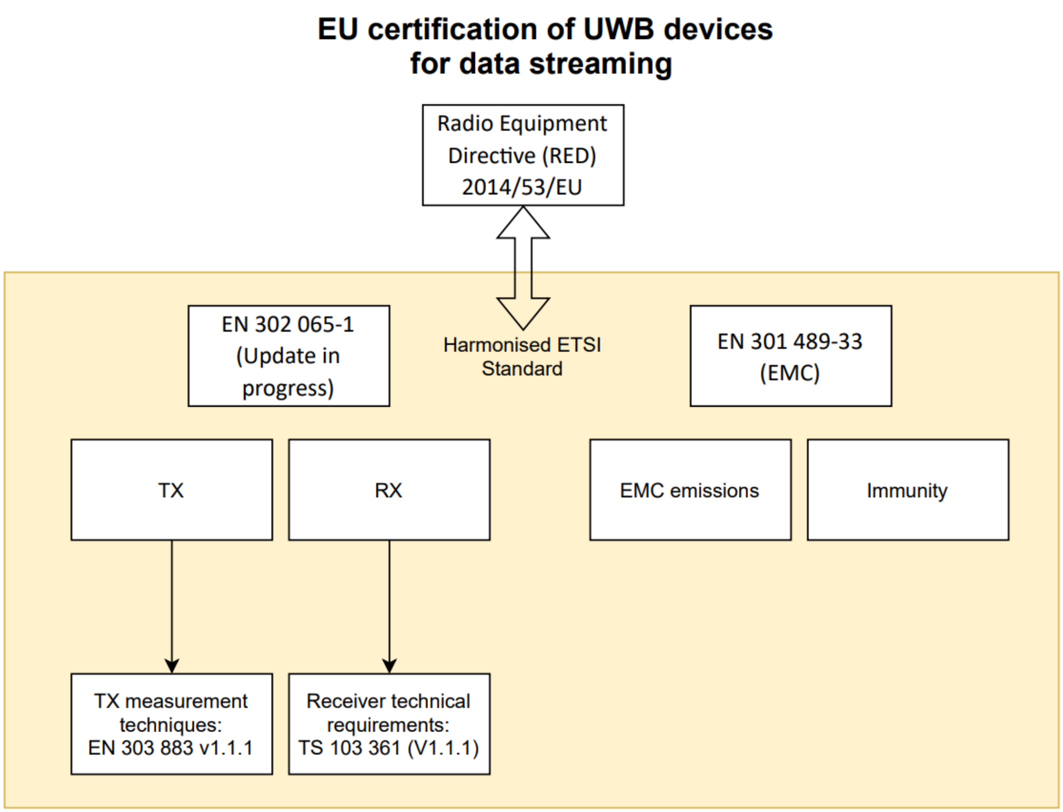
In regions following ETSI standards:

• The SPARK SR1010 enables 1.4 GHz of unlicensed spectrum usage with Low Duty Cycle (LDC) mitigation techniques (3.4 -4.8 GHz) [1]

• The SPARK SR1020 enables 2.5 GHz of unlicensed spectrum usage (6 - 8.5 GHz).

The chart below explains the relevant ETSI standards for UWB devices and their respective technical documents to satisfy the directives of the Radio Equipment Directives (RED).

Table 2- ETSI Regulations For UWB Devices And Their Respective Standard Tests



[1]Currently, Europe does not allow any fixed outdoors UWB infrastructure unless it is running below 4.8GHz in which case low data rate applications with the SR1010 can be done outdoors using Low Duty Cycle (LDC) mitigation technique.

In Japan, the (Association of Radio Industries and Businesses) ARIB Standards (STD-T91) defines the technical requirements for UWB radio systems to ensure compatibility, quality, and to avoid interference with other radio systems. The standard applies to radio equipment used for data transmission over wide bandwidths, primarily intended for indoor use. In this region the SPARK SR1020 radio is allowed to be used within 7.25 GHz to 9.3 GHz spectrum which provides about 2GHz of bandwidth. More details will be provided in the next section.

In China, the Ministry of Industry and Information Technology (MIIT) is responsible for regulating the frequency spectrum allocation. This entity currently follows the ETSI mask limits but has recently updated its directives on UWB frequency allocation defining the 7.163 to 8.812 GHz bandwidth as the operating frequency limits (taking effect in August 2025). This will provide about 1.7 GHz bandwidth for the SR1020 radio (MIIT No [2024] No. 77).

Finally, in Taiwan, the regulatory body is the National Communications Commission (NCC). For UWB communication, section 5.12 of the Low Power 0002 (LP0002) document outlines the relative emission mask which limits the UWB operation to 6336 – 8976 GHz providing about 2.6 GHz of bandwidth.

4. Conformance Requirements Summary (FCC-ETSI)

4.1 Operating Bandwidth

The operating bandwidth is defined as the -10 dB bandwidth of the transmitted UWB signal. FCC, NCC, and MIIT require a minimum of 500 MHz bandwidth, while ETSI requires a minimum of 50 MHz bandwidth and ARIB 450 MHz.

SPARK devices transmit over a very large, but customizable bandwidth. Within one millisecond, all frequencies defined in the pulse configuration are occupied by the SPARK transmitter. Certification firmware should use the same configuration as the final device. The certification lab will measure the total UWB emission and calculate the fundamental frequency as the center frequency of the observed emission bandwidth.

4.2 Average Power

4.2.1 FCC

The average EIRP is measured with an RMS detector, 1 MHz RBW and 1 ms averaging time.

The required spectral mask by the FCC is presented in Figure 1. As can be observed, both the SR1010 and the SR1020 can use this spectrum.

The maximum average power is limited to –41.3 dBm/MHz in the region defined by the mask.

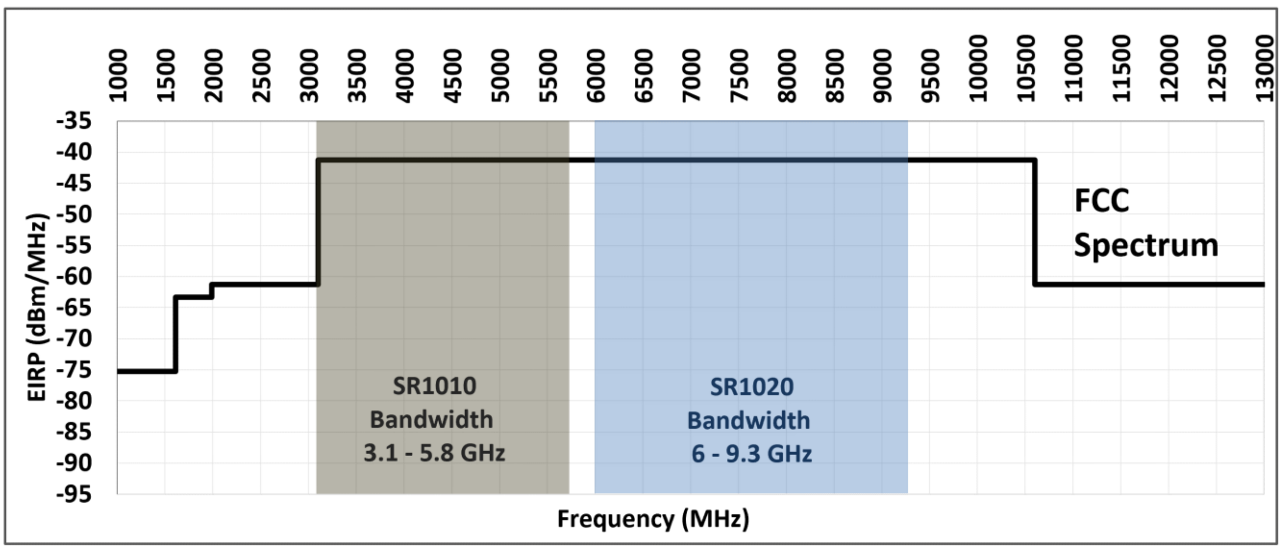


Figure 1: Maximum Mean Mission Levels for Handheld UWB Devices by FCC

In addition to the radiated emission limits specified above, to protect GPS devices, UWB transmitters shall not exceed the following average limits when measured using a resolution bandwidth of no less than 1 kHz:

Table 3- Mask Limits for The GPS Band

Frequency (MHz)	EIRP (dBm)
1164 - 1240	-85.3
1559 - 1610	-85.3

4.2.2 ETSI

ETSI has divided the UWB measurements into two parts. The UWB emissions only need to be measured in the operating bandwidth of the device, as explained in clause 4.2 of the EN 302 065 series and defined in section 4.1.

The repetition time of Spark pulses are less than 1ms therefore the following spectrum analyzer settings should be used according to ETSI EN 303 883 V1.1.1 (2016-09):

RBW=1 MHz, VBW= 3 MHz, Max. Hold,

Average time: 1ms (see clause 5.3.2.3 for more detail).

The emissions outside the operating frequency range are measured as other emissions and should follow the limits presented in document ETSI EN 302 065-1 V2.1.1 (2016-11) (Table 4). Therefore, the out of band emissions are subjected to the -30 dBm / 1 MHz limit from clause 4.3.6.3.

The ETSI spectral mask for the UWB signal is demonstrated in Figure 2 from 1 GHz to 13 GHz. The SR1020 can utilize most of the allowable spectrum, while the SR1010 must use LDC mitigation techniques.

It must be noted that a new draft is being worked on based on the ECC decision (06)04 (November 2022) and it is expected to take effect in 2025. Based on the new regulations, certain indoor applications with a duty cycle below 5% will be able to transmit up to –31.3 dBm/MHz between 6.0 and 8.5 GHz.

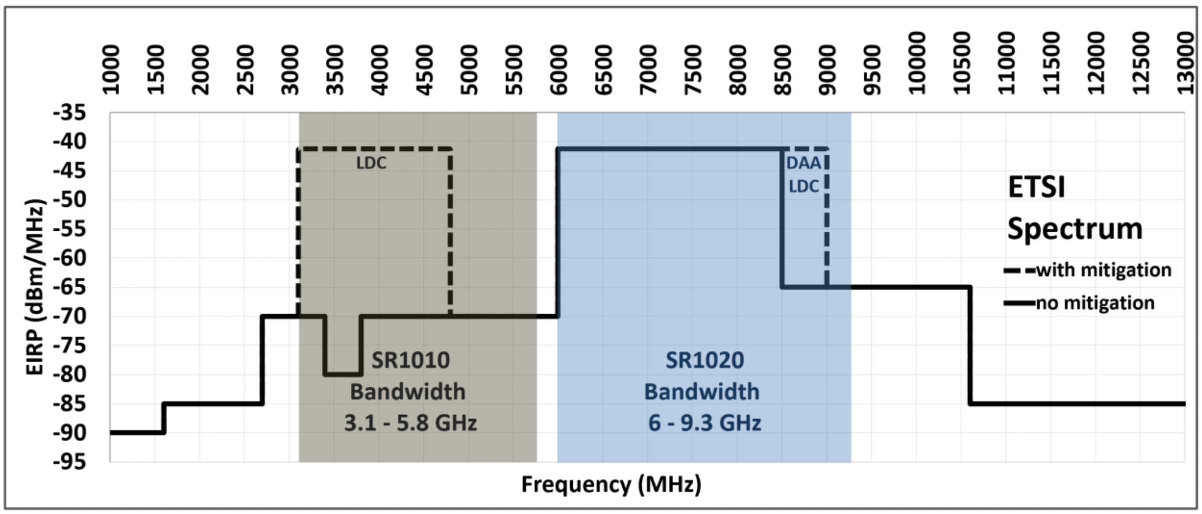


Figure 2: Maximum Mean Emission Levels for UWB Communications Devices by ETSI

4.3 Peak Power

Peak EIRP is measured with the peak detector and a RBW of 50 MHz. Both FCC and European regulations require that the peak power in 50 MHz of bandwidth, centered on the frequency with the highest emission does not exceed 0 dBm. To accurately measure the peak power, the certification lab must be equipped with a spectrum analyzer with 50MHz resolution bandwidth. Using other methods of measurement will lead to the overestimation of the measured value. More details on the measurement techniques can be found on the section 7.4.4.2 of ETSI EN 303 883 V1.1.1 (2016-09).

4.4 ETSI requirements on the receiver side

Simply put, the receiver has three sets of tests for ETSI certification.

- The receiver's spurious emissions;
- The receiver's transmitted ACK signals;
- Receiver's sensitivity.

For the spurious emissions testing, the receiver can be placed inside the anechoic chamber without any transmitter. In this case, it will be in receive only mode which is suitable for spurious emissions testing.

If a receiver sends ACKs, from a regulatory point of view, it becomes a transmitter. Therefore, a special FW needs to be developed to put the device in TX mode with the same pulse configuration that is used for transmitting the ACK packets. Then this module should comply with the transmit mask.

To test the baseline RX sensitivity, an OTA link needs to be established between TX and RX (with pulse configurations that passed the TX emission tests). The distance between the two is then increased and the distance at which the PER falls below 90% is noted. Next, this value will be transformed to path loss value using the free space path loss formula. This process is done according to ETSI TS 103 361 V1.1.1 (2016-03). (See section 6.1 for SPARK implementation.)

4.5 Operation of UWB devices on an airplane

According to the FCC standard, as well as ARIB and ETSI, UWB is not authorized onboard an aircraft, a ship, or a satellite as well as for the operation of toys.

4.6 FCC requirement of ceasing transmission after 10 seconds

If a device is categorized as a handheld device that can be used outside, the 47 CFR 15.519 (up to date as of 5/25/2023) would apply. A UWB device operating under the provisions of this section shall transmit only when it is sending information to an associated receiver. The UWB intentional radiator shall cease transmission within 10 seconds unless it receives an acknowledgement from the associated receiver that its transmission is being received. An acknowledgment of reception must continue to be received by the UWB intentional radiator at least every 10 seconds or the UWB device must cease transmitting. The TX can still start transmission to re-establish the link. The same rule applies in Canada if the device is intended to be used outdoors.

For indoor devices, the FCC regulation to follow for most SPARK applications is the 47 CFR 15.517 (up to date as of 5/25/2023) (Technical requirements for indoor UWB systems). According to this document, the 10 second rule does not apply to SPARK radio devices if they are intended to be used indoor only. To ensure that, the manufacturer needs to add a label stating that the device is meant for indoor use only.

5. Conformance Requirements Summary (ARIB-MIIT-NCC)

5.1 Summary of ARIB regulations

For the operating frequency band between 7.25 GHz and 10.25 GHz, the average power per 1 MHz bandwidth should not exceed -41.3 dBm. Additionally, the peak power per 50 MHz within this frequency band should be no greater than 0 dBm. The frequency bandwidth between the upper and lower frequencies for the radiation power points, which are 10 dB below the maximum radiation power level, must be at least 450 MHz.

The Japanese regulatory authority has imposed further restrictions on the operation of UWB devices used **outdoors**. Devices operating within the 7.25 GHz to 9 GHz range must incorporate a mechanism to cease transmission when in proximity to airports, satellite services, or radar systems. These devices are required to include a function that stops radio wave emissions. The specific method for halting radio wave emissions varies by device type, but generally involves either powering off the wireless device or enabling airplane mode on smartphones.

Devices operating between 7.587 GHz and 8.4 GHz are exempt from these restrictions.

Limits for **unwanted emission** intensity from the transmitter, specified as average power per 1 MHz bandwidth and peak power per 1 MHz bandwidth are presented in Table 4:

Table 4- Emission Mask Limits for UWB In Japan

Frequency (MHz)	Average EIRP (dBm)	Peak EIRP (dBm)
Below 1,600 MHz: Average	-90 dBm, Average	-84 dBm, Peak
1,600 MHz to below 2,700 MHz:	-85 dBm, Average	-79 dBm, Peak
2,700 MHz to below 10.6 GHz:	-70 dBm, Average	-64 dBm, Peak
10.6 GHz to below 10.7 GHz:	-85 dBm, Average	-79 dBm¸ Peak
10.7 GHz to below 11.7 GHz:	-70 dBm, Average	-64 dBm, Peak
11.7 GHz to below 12.75 GHz:	-85 dBm, Average	-79 dBm, Peak
12.75 GHz and above	-70 dBm, Average	-64 dBm, Peak

The required ARIB tests for the peak and average powers as well as spurious emissions will be done with a **conducted setup** where the output of the radio will be connected to an SMA connector which is then connected to the spectrum analyzer via cable. Then the antenna gain (simulated or measured are usually accepted by the labs) will be added to the measurement for the final pass/fail result.

Note: If the UWB module is placed as a separate module inside a product, the peak realized gain of the module only without the main board and components needs to be provided to the lab.

5.2 Summary of MIIT Chinese new upcoming regulations

According to the new MIIT regulations coming into effect from **1st August 2025**, the operating frequency range of UWB devices will be limited to 7163-8812 MHz providing about 1.7 GHz of total available bandwidth for the SR1020 radio. The minimum transmission signal bandwidth (-10dB Bandwidth) is 500 MHz with the maximum EIRP of -41 dBm/MHz.

The out-of-band emission limits are as follows:

Table 5- Out of band emission limits for UWB In China

Frequency (MHz)	EIRP (dBm) RMS detection
5.925-7.125 GHz	-70 dBm/MHz
7.125-7.163 GHz	-51 dBm/MHz
8.812-9 GHz	-51 dBm/MHz
9-10.6 GHz	-65 dBm/MHz

The general spurious emission limits are depicted as:

- Transmitter at maximum power:
  - 30 MHz-1 GHz: -36 dBm (100 kHz bandwidth, RMS detection)
  - 1 GHz-12.75 GHz: -30 dBm (1 MHz bandwidth)
- Transmitter in standby or idle state:
  - 30 MHz-1 GHz: -57 dBm (100 kHz bandwidth, RMS detection)
  - 1 GHz-12.75 GHz: -47 dBm (1 MHz bandwidth)

Note: The testing method for the above limits is not defined yet as of June 2024. They are to be published separately in a technical requirements document.

Note: The new regulation will come into effect on August 01, 2025, and the old regulation will be abolished at that time. From August 01, 2025, the national radio regulatory agency will no longer accept and approve ultra-wideband (UWB) radio transmission equipment that does not meet the technical requirements listed in the new regulation. However, Ultra-wideband (UWB) devices that have obtained an approval certificate can continue to be sold and used until they are scrapped.

5.3 Summary of Taiwan NCC regulations

The general rules in Taiwan follow the FCC and ETSI rules. This means that the measurement will be done over the air for radiated power. Devices are divided into **Handheld** and **Indoor** devices like the FCC rules. Spark devices can mostly be categorized as indoor devices.

Handheld device: A handheld device is a portable device, such as a laptop computer or a smart phone.

5.3.1 Handheld devices:

5.3.1.1 Radiated Emission Limits:

The radiated emissions at or below 960 MHz from a device must meet the emission levels specified in Section 3.6 of the regulatory document Low Power 0002 (LP0002).

The radiated emissions above 960 MHz must follow the requirements of the section 4.12 of Low Power 0002 (LP0002). UWB frequency bands are defined as: 4.224 GHz~4.752 GHz, 6.336 GHz~7.920 GHz, 7.392 GHz~8.976 GHz. The radiated emission from a device must not exceed the following average limits presented in Table 6 when measured using a resolution bandwidth of 1 MHz:

Table 6- Emission Mask Limits for Handheld UWB Devices In Taiwan

Frequency (MHz)	EIRP (dBm)
960 - 1610	-75.3
1610 - 1990	-63.3
1990 - 4224	-61.3
4224 - 4752	-41.3
4752 - 6336	-61.3
6336 - 8976	-41.3
Above 8976	-61.3

In addition to the limits specified above, UWB transmitters operating in the GPS band must not exceed the following average limits when measured using a resolution bandwidth of 1 kHz:

Table 7- Mask Limits for The GPS Band

Frequency (MHz)	EIRP (dBm)
1164 - 1240	-85.3
1559 - 1610	-85.3

Peak radiated emission limit: Within a 50 MHz bandwidth (to be measured with a spectrum analyser with 50 MHz resolution bandwidth), the peak emission limit is 0 dBm EIRP.

5.3.1.2 Other Requirements:

UWB devices must be handheld, meaning they are relatively small, primarily hand-held during operation, and do not employ fixed infrastructure.

A UWB device must transmit only when sending information to an associated receiver. It must cease transmission within 10 seconds unless it receives an acknowledgment from the associated receiver that its transmission is being received.

5.3.2 Indoor devices:

5.3.2.1 Radiated Emission Limits:

Below 960 MHz: Radiated emissions at or below 960 MHz must conform to the emission levels specified in Section 3.6.

Above 960 MHz: Radiated emissions above 960 MHz must not exceed the following average limits when measured using a resolution bandwidth of 1 MHz:

Table 8- Emission Mask Limits for Indoor UWB Devices In Taiwan

Frequency (MHz)	EIRP (dBm)
960 - 1610	-75.3
1610 - 1990	-53.3
1990 - 4224	-51.3
4224 - 4752	-41.3
4752 - 6336	-51.3
6336 - 8976	-41.3
Above 8976	-51.3

Peak Radiated Emission Limit: Within a 50 MHz bandwidth, the peak emission limit is 0 dBm EIRP. Alternative resolution bandwidths and corresponding peak emission limits can be used as described in Section 5.12.4.6 of Low Power 0002 (LP0002).

5.3.2.2 Other Requirements:

Devices are restricted to indoor use. Emissions should not be intentionally directed outside the building where the equipment is located (e.g., through a window or doorway for external detection functions).

The use of outdoor mounted antennas (e.g., on the outside of a building or a telephone pole) is prohibited.

Sensors installed inside metal or underground storage tanks are considered to operate indoors if emissions are directed toward the ground.

Systems should transmit only when sending information to an associated receiver.

UWB systems must label devices with the description “this device used for indoor only” at an obvious place on the device or in the operation manual.

5.4 Global Coverage

An overview of regulated UWB frequencies per country and applicable SPARK radios as is shown below.

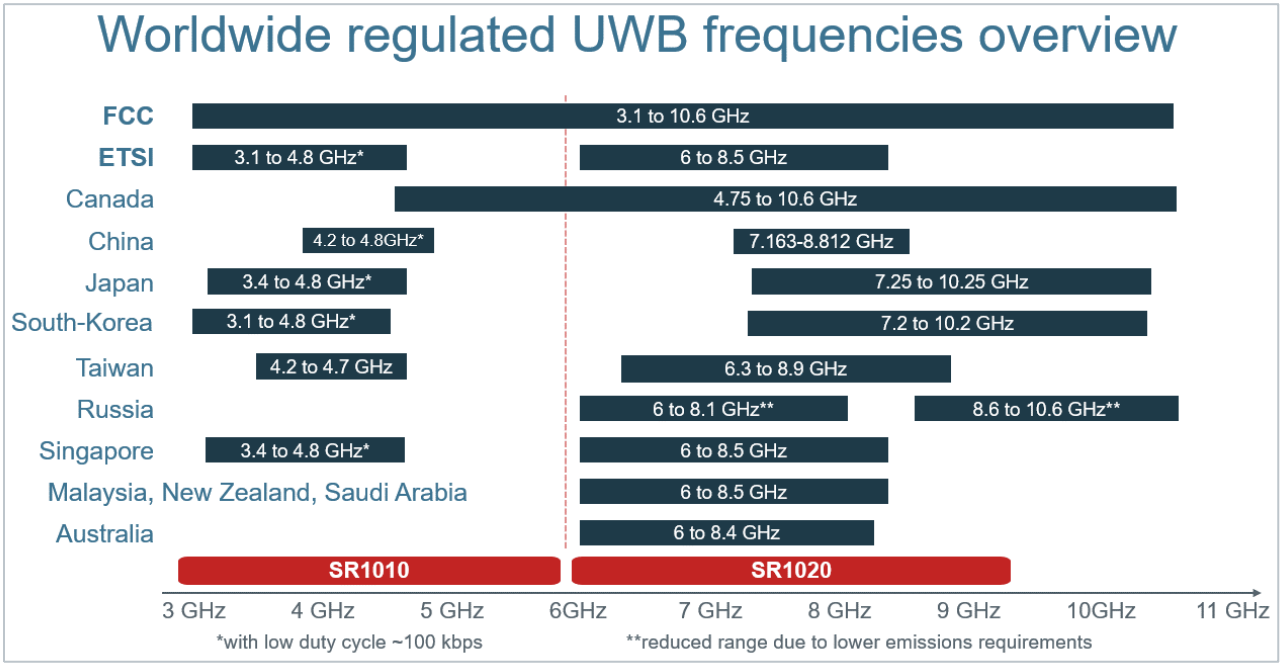


Figure 3- Overview of UWB frequency limits around the world as of ***July 2024***

6. SPARK Implementation

In this section, we discuss the SPARK radio implementation and how it relates to compliance testing.

6.1 SPARK Receiver Sensitivity Test (ETSI)

In the SPARK radio firmware, it is possible to activate the link statistics (i.e. PER) on the receiver side. Once activated, the percentage of successfully received packets are shown which is the ratio of successfully received packets over the number of timeslots. Therefore, a transmitted packet should be in every timeslot. If the timeslot is empty (i.e. the TX doesn't send anything) then it will be counted as an unsuccessful packet.

```
<<< Data RX Connection >>>
RX Timeslot Occurrence:                 1461
  Packet Successfully Received:         1435 (98.22%)
  No Packet Reception:                    26 (01.78%)
Packet Duplicated:                         1
Packet Rejected:                          14
Packet Overrun:                            0
```

Figure 4- Receiver statistics

To get transmission in all timeslots, on the node in the receive connection set the following:

```
.timeslot_count = ARRAY_SIZE(rx_timeslots),
.ack_enabled = false,   // true
.arq_enabled = false,    // true
.arq_settings.try_count = 0,
.arq_settings.time_deadline = 0,
.cca_enabled = false,
```

Figure 5- Receiver node settings for PDR calculation

To have a more stable data, it is recommended to modify the “stats_timer_init” parameter to 3000ms and reset stats after each USB print.

6.2 SPARK Transmit Power

The SPARK radio’s transmit output power is controlled by 3 settings:

1. Pulse Count
2. Pulse Width
3. Pulse Amplitude (also referred to as “Transmit Gain” or “Power Amplifier Backoff”)
    a. Note: the setting for pulse amplitude is an attenuation factor with higher values resulting in lower output power.

The combination of settings allows for a wide range of EIRP levels. From an applications point of view, we should expect output power to scale down with increasing data rate as the average power is limited.

6.3 SPARK Transmission Protocol

In most modes of operation, the SPARK radio will transmit a frame and then wait for an acknowledgement from the receiver. If no acknowledgement is received, the transmitter will attempt to retransmit the same frame a certain number of times before the frame is dropped.

Retransmissions are essential to maximize the robustness of an RF link between two devices. When we design the link, we must consider a certain retransmission margin. The retransmission margin consists of normally unused timeslots that can be used for retransmissions when the link starts to degrade. By accounting for a retransmission margin in the wireless schedule, we are in fact designing a link which allows for a higher throughput than what the application requires.

6.4 Worst Case Conditions

When testing for certification, we must emulate worst-case conditions thereby transmitting at the maximum throughput. An over-the-air test pattern with a balanced number of 0s and 1s should be implemented.

6.5 Zero Pulse Transmission Mode

For out-of-band emissions testing, a specific test mode should be implemented where the Equipment Under Test (EUT) is in transmit mode, but no pulses are transmitted through the antenna. This mode is essential for determining whether any unidentified out-of-band emissions originate from the UWB radio or digital circuitry. If emissions persist when this mode is activated, it confirms that the UWB radio is not the source of these emissions.

7. Power Adjustment Process

Testing at a certification lab can be time-consuming and expensive, especially if the lab is far from the office and travel expenses are considered. There is a risk of having to repeat the process multiple times if your device fails, and you are not prepared to make the necessary adjustments in the field.

We will now discuss how to adjust the power settings during certification testing when failures occur. Customers can request that the certification lab do emissions tests only, where results are shared on an informal basis. This would be a lighter way of getting power level results before engaging with the full certification process, which is more costly. Once the power levels are within the regulatory limits, then the full certification process can be initiated.

7.1 Power Setting and Adjustment

The process for setting and adjusting the UWB RF power levels is summarized below.

1. Use SPARK Link Calculator to estimate the RF power settings and determine the TDMA Schedule for the Equipment Under Test (EUT)
2. Implement settings, schedule, and transmit mode in firmware;
    a. Compile and load the binary into the EUT to start the test;
3. Compliance lab will measure the RF power and compare to regulatory mask limits;
    a. Repeat with slightly different power settings if mask failures occur;

This process is shown graphically in the following flow chart.

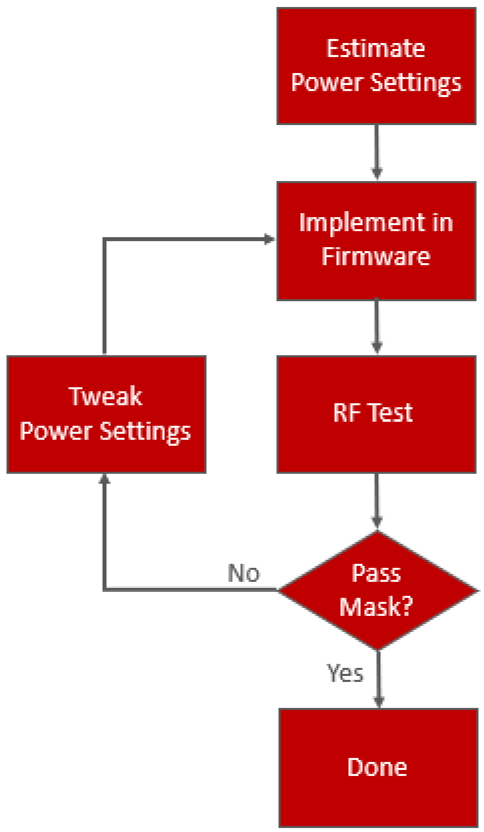


Figure 6: Power Setting and Adjustment Process

The process steps are described in more detail in the sections that follows.

7.2 Step 1 – Estimate Power Settings

The SPARK Link Calculator is used to estimate the power settings for a given application. Each application will be unique. In the following tables, we provide values for an example audio application.

7.2.1 Utility Calculators

Utility Calculators are available to help determine certain values for the Link Calculator. For example, you can use the Audio Utility Calculator to determine the application “Data Rate” and “Data Size per Frame” parameters for the Link Calculator.

Utility Calculator inputs are shown below:

Input	Value
Sampling Rate (kHz)	48
Bit Depth (bits)	16
Number of Channels	2
Required Latency (msec)	5

Table 9: Utility Calculator Inputs

Utility Calculator outputs are shown below:

Output	Value
Data Rate (kbps)	1536
Data Size per Frame (bytes)	52
Achievable Retransmission Margin	26.15%

Table 10: Utility Calculator Outputs

The Utility Calculator outputs are used as inputs to the Link Calculator.

7.2.2 Link Calculator

The Link Calculator is used to estimate the power settings and frequency band usage which yield maximum average power for a given application.

Link Calculator (Global) inputs are shown below:

Input	Example Value
SPARK Chip Type	SR1020
Region of deployment	Europe
Antenna gain with losses (dB)	4.0

Table 11: Link Calculator Global Inputs

Link Calculator (Wireless Link) inputs are shown below:

Input	Example Value
Application Data Rate (kbps)	1536
Retransmission Margin	26.15%
Modulation	2bPPM
FEC Level	1
Data Size per Frame (bytes)	52
Application Header (bytes)	2
WPS Header (bytes)	2
Ack Enable	enabled

Ack (bytes)	0
Required Latency (msec)	5

Table 12: Link Calculator Wireless Link Inputs

The Link Calculator outputs are shown below:

Output	Example Value (Data)	Example Value (ACK)
System Rate	5000 frames/s	
Frequency Hopping Bands	163, 170, 177, 184, 191	
Time Slot (µs)	200	
Number of pulses	1	3
Pulse Width	4	6
PA Back-Off	0	0

Table 13: Link Calculator Outputs

7.3 Step 2 – Prepare and Run the Test

For certification, the EUT firmware must be customized to emulate worst-case transmission conditions for the application being certified. We can call such configuration the Power-Level Test Mode. The Power-Level Test Mode must meet the following conditions:

1. Transmitter must consume the entire application transmission bandwidth
2. It must use the same pulse settings and schedule as the target application
3. It must generate a balanced number of 0s and 1s over the air (use test pattern word=0x0A6F)
4. It must continue to transmit despite the absence of an ACK from a receiver

Conditions can be satisfied by changing the setting ".certification_mode_enabled = true" in the application's "swc_cfg_t" instance (SDK v1.3.0 or greater):

```
swc_cfg_t core_cfg = {
    .timeslot_sequence = chosen_schedule,
    .timeslot_sequence_length = local_schedule_length,
    .fast_sync_enabled = false,
    .random_channel_sequence_enabled = true,
    .memory_pool = swc_memory_pool,
    .memory_pool_size = SWC_MEM_POOL_SIZE,
    .rdo_enabled = false,
    .ddcm_enabled = true,
    .certification_mode_enabled = true,
};
```

Figure 7: Certification Mode Setting

7.3.1 Application Firmware

The target application is customized such that the EUT enters Power-Level Test Mode upon power up. The firmware is compiled into a binary that is loaded into the EUT for certification testing.

7.3.2 Power Settings

The RF power settings are specified as follows for each channel:

Parameter	Description	Value
Freq	Center frequency specified as a multiple of 40.96 MHz (e.g. 163 = 6.7 GHz)	Obtained from calculator, example: 163
pulseCount	number of pulses per symbol	Obtained from calculator, example: 1
pulseWidth	width of each pulse	Obtained from calculator, example: 4
txGain	Attenuation factor, referred to as “PA Backoff” in calculator	Obtained from calculator, example: 0

Table 14: RF Power Settings

7.4 Step 3 – Power Tweaking

When performing the certification tests, you might find that the applied settings are exceeding the mask or are too far below the mask.

If that is the case, you can use the table below to increase or decrease the average/peak power. There is a difference of approximately 0.5 dB between settings.

Setting	Pulse Count	Pulse Width	Power Amplifier Backoff
21 (max)	3	7	0
20	3	6	0
19	3	5	0
18	2	7	0
17	2	6	0
16	2	5	0
15	2	4	0
14	2	3	0
13	1	7	0
12	1	6	0
11	1	5	0
10	1	4	0
9	1	3	0

Setting	Pulse Count	Pulse Width	Power Amplifier Backoff
8	1	2	0
7	1	1	0
6	1	1	1
5	1	1	2
4	1	0	0
3	1	0	1
2	1	0	2
1 (min)	1	0	3

Table 15: Power Tweaking

For example, if you are using Setting = 10 and the RF Power measurement indicates that the average power level is too high, you should apply a lower setting (e.g. use Setting = 9) and re-test.

Binaries with different power settings can be generated in advance or sent electronically upon request. A member of your staff can also be onsite to generate new binaries as required.

8. Certification Process

The certification process is summarized below.

1. Select an external certification lab: There are certification labs in different world regions and most of them are capable of doing UWB tests. For example, the following labs, not affiliated with SPARK microsystems, have experience with SPARK radio devices:
    - Compliance Worldwide Inc. in USA
    - Phoenix Testlab in Europe
    - MRT Technology China

*Note 1: **A fully anechoic chamber is needed** to ensure no ripple occurs in the measured power spectrum. If a semi-anechoic chamber is used for these tests, the reflections of emitted waves are not completely attenuated and might be picked up by the standard receiver antenna. This creates standing waves in the chamber and creates ripples in the power spectral density plot. In this case, the maximum recorded value might be over-estimated due to the bouncing of EM waves in the room and not the UWB device.

Note 2: Accurate measurement of the device's peak power requires a **spectrum analyzer with a 50 MHz resolution bandwidth. Utilizing alternative methods, such as employing a narrower resolution bandwidth and subsequently upconverting the measurement, may lead to an overestimation of the peak power.

2. Engage with the selected certification lab: It is recommended to have a direct line of communication with the lab during the test if you cannot be present.
3. Ship boards to selected certification lab with the following items:
    - EUT Board with UWB Antenna (Contact the certification lab for instructions)
    - Physical connection to EUT Board for firmware download
    - Instructions on how to download firmware
    - Many pre-compiled binaries with different power settings
4. Certification lab executes the tests and provides results: The lab may need to load multiple binaries before finding one that passes the mask
5. Use the settings that pass the mask in the final implementation. Once the certification has been approved, those settings must be the ones used in production.

SPARK Microsystems FAEs will provide support in different stages of certification.

9. Measurement Orientation

The certification lab will use a standard measurement method to determine the antenna peak gain orientation. For example, FCC will implement the process defined by ANSI-C63.10 (section 10). Certification testing is performed at the orientation which yields the maximum gain.

In our specific implementation, the maximum gain was determined with the unit standing upright, referred to as the Y Axis position, as shown in Figure 8.

Figure 8: Unit standing upright

10. Measurement Results

This section is used to illustrate the various tests that are performed during UWB certification.

10.1 In Band Tests

10.1.1 Average power

We try to get as close to the mask limit as possible, without violating the mask. Some margin can be beneficial to accommodate device and antenna variations.

A Spectrum Analyzer result for Average Power is shown below. A resolution bandwidth (RBW) of 1 MHz is used for this measurement.

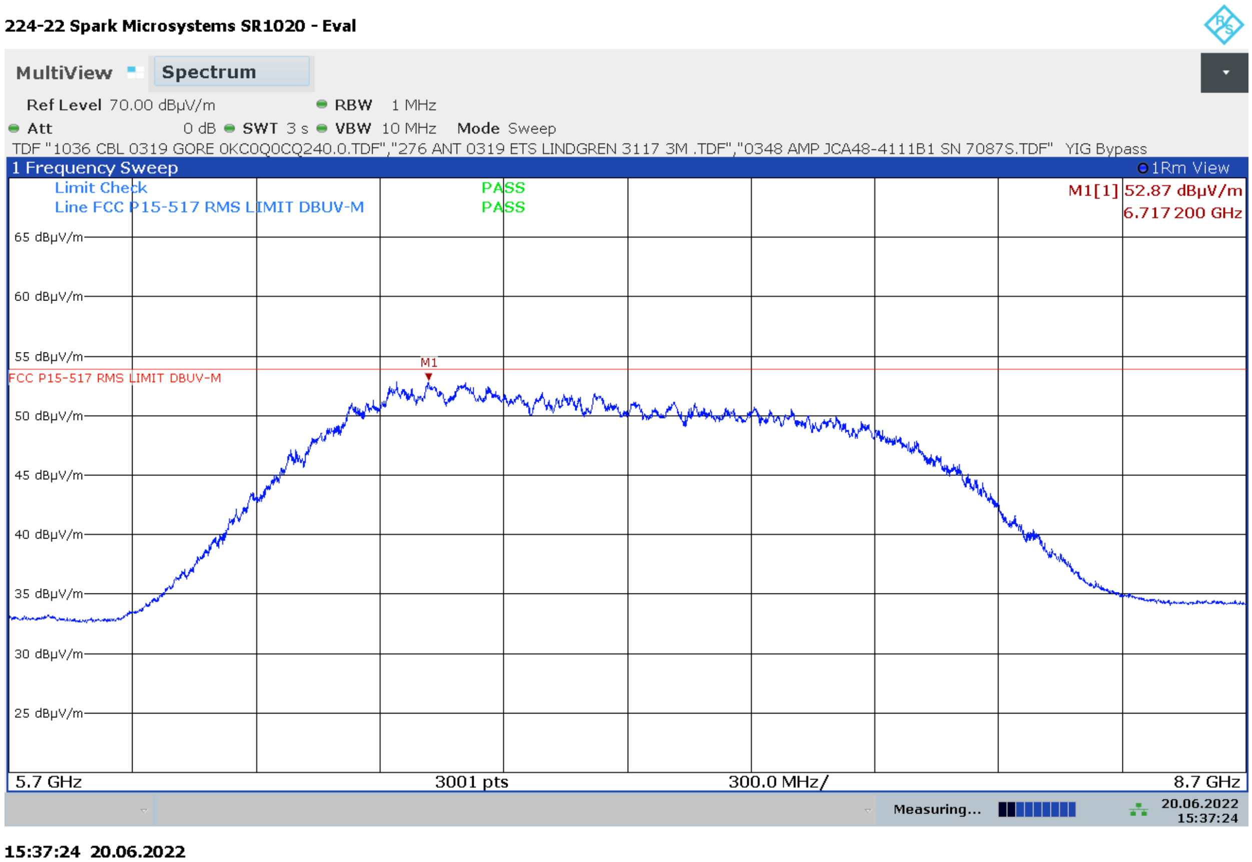


Figure 9: Average Power Measurement Result

The waveform captured by the spectrum analyzer uses dBµV/m as the measurement unit. This is easily converted into Effective Isotropic Radiated Power (EIRP) in dBm using the formula below:

$$\mathbf{P(dBm) = E(dB\mu V/m) - 95.2}$$

The measurement result is plotted with a dBm scale on the Y-axis:

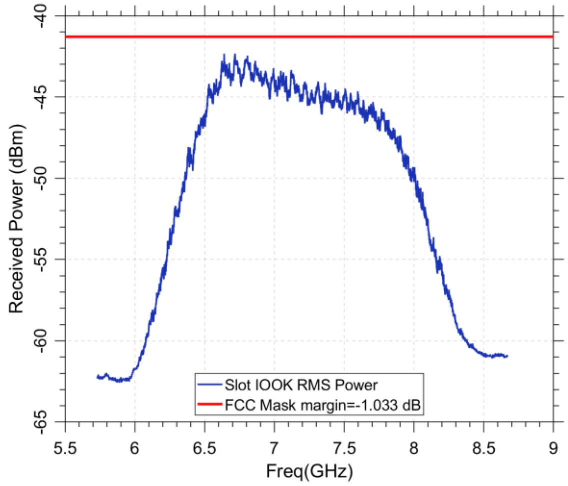


Figure 10: Average Power measurement with 1dB mask margin

10.1.2 Peak power

Peak power levels will vary with data rate as the average power of -41.3 dBm/MHz must be maintained. At higher data rates, the peak power levels must be reduced to stay within the Average Power limits.

A Spectrum Analyzer result for Average Power is shown below. A resolution bandwidth of **50 MHz** must be used for this measurement. Using a spectrum analyzer with lower resolution bandwidth than 50 MHz and applying a correction factor to calculate the peak power is not recommended. This will result in an over estimation of the peak power.

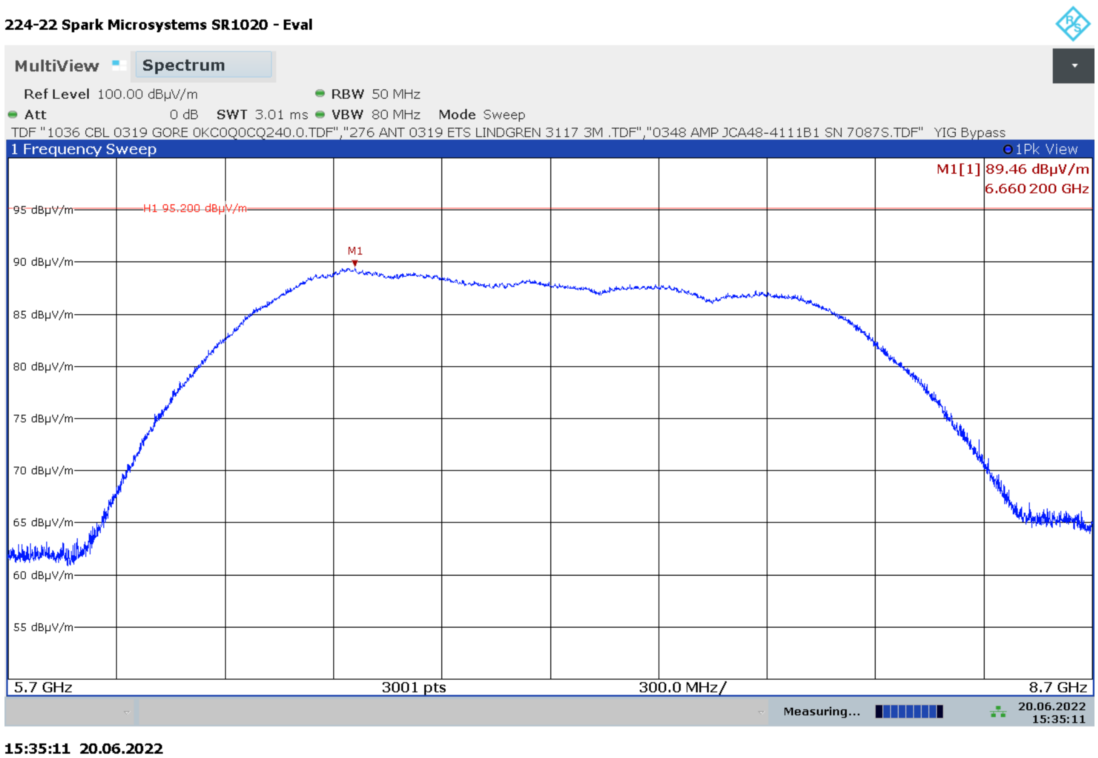


Figure 11: Peak Power Measurement Result

The measurement result is plotted with a dBm scale on the Y-axis:

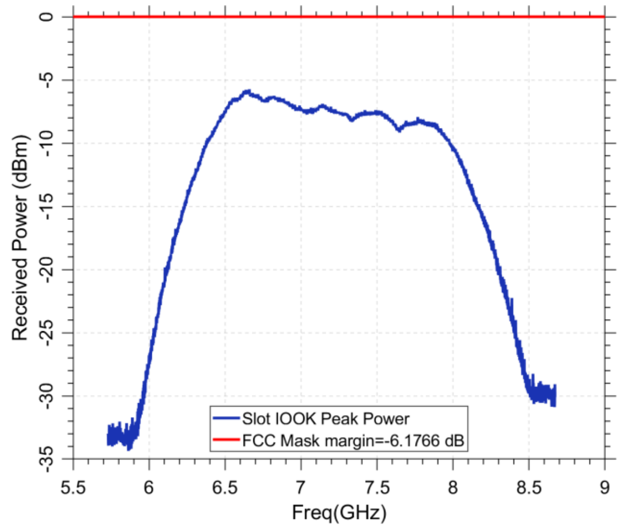


Figure 12: Peak Power measurement showing 6dB mask margin

10.2 Out of Band Tests

In this section, we present some results for out of band testing.

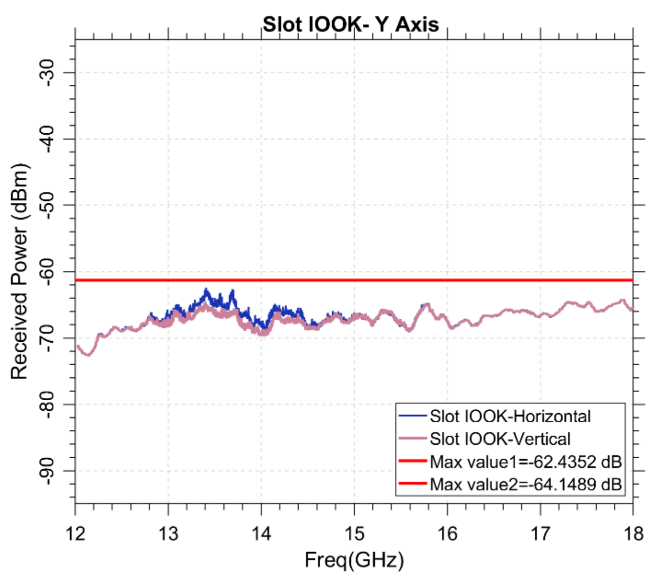


Figure 13: Second Harmonic 12-18 GHz

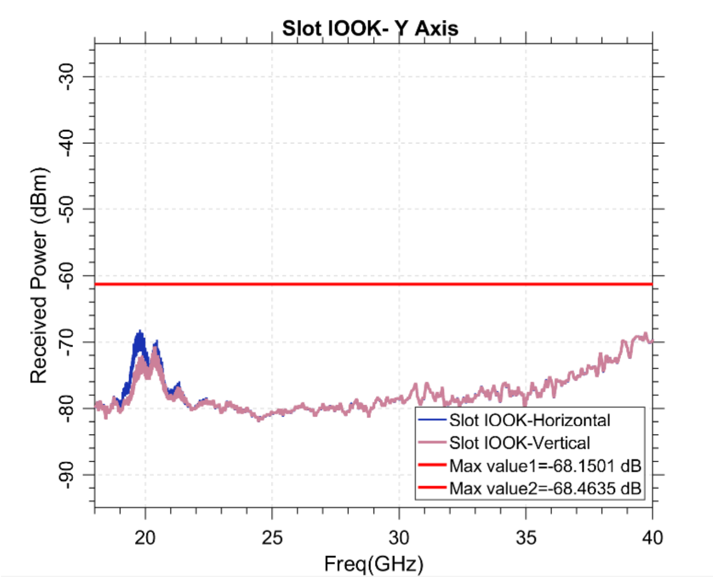


Figure 14: Third Harmonic 18-40GHz

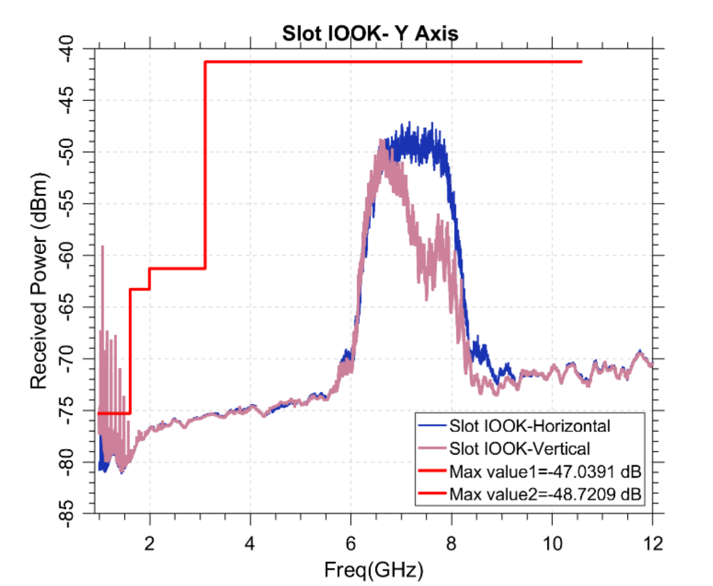


Figure 15: Frequency Range: 960 MHz to 12 GHz

In Figure 15, the power levels above 2 GHz are well under the mask. Some mask violations can be observed at relatively low frequency (between 960 MHz and 2 GHz), which required further investigation.

A special test mode where the EUT behaves normally, but with no pulse energy sent on the antenna was implemented in the EUT. In this mode, the violations were still present, therefore it was concluded that the violations were coming from digital circuitry used to enable the operation of the UWB transmitter (not the antenna).

Emissions from digital circuitry used to enable the operation of the UWB transmitter shall comply with more general radiation emission requirements. Special attention must be given to those circuits to pass certification. In this specific case, it would have been beneficial to configure the SPI interface with slower edge rates to reduce or eliminate these unwanted emissions.

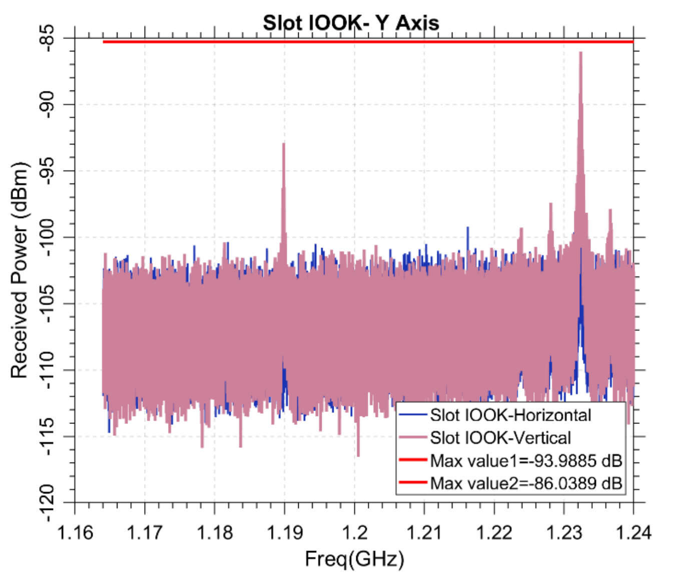


Figure 16: GPS Band 1: 1164 to 1240 MHz

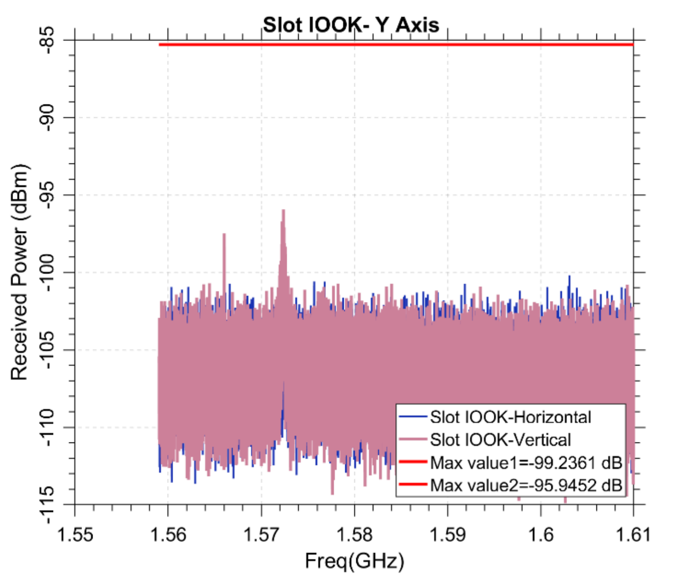


Figure 17: GPS Band 2: 1559-1610 MHz

11. Conclusion

This application note demonstrates how to achieve UWB power level certification using a SPARK UWB transceiver. In summary, A SPARK utility is used to estimate initial power settings and a custom firmware is used to setup the EUT into worst-case transmit conditions. Power settings are tweaked until all tests pass the regulatory masks.

12. References

12.1 FCC

47 CFR 15.517 (up to date as of 5/25/2023)

47 CFR 15.519 (up to date as of 5/25/2023)

47 CFR 15.521

12.2 ETSI

ETSI EN 302 065-1 V2.1.1 (2016-11)

ETSI EN 301 489-3 V2.3.2 (2023-01)

ETSI EN 303 883 V1.1.1 (2016-09)

ETSI TS 103 361 V1.1.1 (2016-03)

12.3 Japan

ARIB Standards (STD-T91)

12.4 China

MIIT No [2024] No. 77

12.5 Taiwan

Low Power 0002 (LP0002)

Revision History

Revision	Date	Description
1.0	Sept 20, 2022	Document creation
1.01	Dec 21, 2022	Minor updates, clarifications
1.02	Aug 23, 2023	Certification mode setting addition
1.1	July 12th 2024	General Major update- Added Japan-China-Taiwan-Added receiver sensitivity test for ETSI-Added more details on ETSI certification-Added references with hyperlinks for different standard documents
1.1.1	July 24, 2024	Corrected Japan mask power levels, corrected typos
1.1.2	August 29, 2024	Added frequency bands for NCC, corrected typos
1.1.3	December 2, 2024	Fixed ARIB PEAK and Average Power limits

SPARK MICROSYSTEMS

SPARK HQ
3300-1751 rue Richardson
Montréal, QC
Canada H3K 1G6

Tel: +1 (438) 375-3990

Support: support@sparkmicro.com

www.sparkmicro.com

Sales contacts

APAC: APAC_sales@sparkmicro.com
EMEA: EMEA_sales@sparkmicro.com
North America: NA_sales@sparkmicro.com