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Report on Measurement Campaigns for Total Radiated Power of one UltraWideBand (UWB) device to support EU RF spectrum regulation

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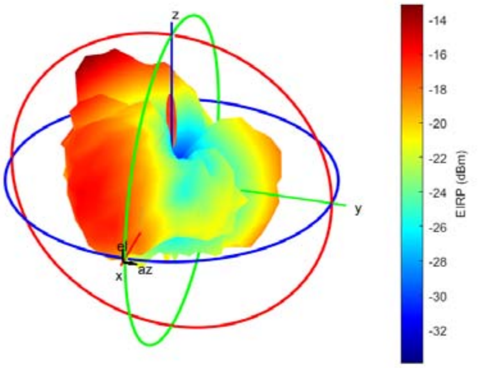
2023



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Abstract

Ultra-Wideband (UWB) is a communications technology that employs a wide bandwidth (typically defined as greater than 20% of the centre frequency or 500MHz). The transmission centre frequency varies with the identifier of the communication channel (e.g., 6.4896 GHz). Because of such large radio frequency spectrum occupancy, spectrum regulations have to be carefully defined to avoid the risk of interference with other wireless services coexisting in the same bands.

The next update cycle of the UWB regulation in the European Union will be started based on the System Reference Document (SRD) SRDoc (TR 103 750) from the European Telecommunication Standardization Institute (ETSI) asking for a band extension of some applications (mainly location tracking and sensor applications) up to 10.6 GHz. The focus of the new investigations in SE24 will be the band 8.5 GHz to 10.6 GHz using a set of mitigation techniques and mechanisms to protect the incumbent services in the band (e.g., X-band radio navigation and radiolocation systems).

One of the mitigation factors to be considered is the Total Radiated Power (TRP) spectral density (SD) TRP_{SD}. The TRP_{SD} parameter is not new in the UWB regulation and has been used in the sensor regulation of UWB since several years. Nevertheless, systematic measurements of the value using typical UWB devices for other application have never been performed. In order to be able to use realistic values in the Conférence européenne des administrations des postes et des télécommunications (CEPT), a study was conducted in the JRC on one UWB device to support a realistic evaluation of the interference effects of UWB into other systems and services.

Acknowledgements

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1 Introduction

1.1 Background information

Ultra-wideband (UWB) wireless communication is a technology for transmitting large amounts of digital data over a wide frequency spectrum using different modulation schemes including short-pulse, low-powered radio signals or an aggregate of at least 500 MHz of a narrow-band carrier with orthogonal frequency-division multiplexing (OFDM).

Then, UWB commonly refers to a signal or system that either has a large relative bandwidth (BW) that exceeds 20% or a large absolute bandwidth of more than 500 MHz.

UWB technology has a number of applications including non-cooperative radar imaging, wireless communications and positioning.

Due to its large spectrum occupancy, a UWB radio system is particularly robust against multi-path effects. For example, in positioning, UWB can be used to determine the "time of flight" of the transmission at various frequencies. This helps overcome multipath propagation, since some of the frequencies have a line-of-sight trajectory, while other indirect paths have longer delays.

This study is focused on the application of UWB technology to wireless communication and positioning. In both applications, the potential risk of UWB technology is to create interference to other wireless services occupying the same band, taking in consideration not only the large bandwidth of the UWB signal but also that spectrum regulations around the world allow the use of UWB technology in a large portion of the RF spectrum, where other services are also granted the permission to transmit. To mitigate the risk of wireless interference, the emission power of UWB devices is limited through “emissions masks” or other techniques are used including the detection of the presence of wireless service in the space in a specific RF spectrum band. In case of positive detection of a primary wireless service, the UWB device change the transmit band to another band where no wireless service was detected.

Radio Frequency spectrum regulations around the world set precise rules for the UWB wireless devices to operate.

In the European Union, the European UWB regulation is being driven by a permanent mandate of the European commission to CEPT. Under this permanent mandate all spectrum requests by industry via ETSI SRDocs in the domain of UWB are handled. The last update of the CEPT regulation have been published in 2022 as amendment of the ECC decision (06)04. The corresponding EC regulation will be updated in the run of 2023 based on a CEPT report under finalization in CEPT WGFM.

The next update cycle of the UWB regulation will be started based on the SRDoc (TR 103 750) from ETSI asking for a band extension of some applications (mainly location tracking and sensor applications) up to 10.6 GHz. The focus of the new investigations in SE24 will be the band 8.5 GHz to 10.6 GHz using a set of mitigation techniques and mechanisms to protect the incumbent services in the band.

One of the mitigation factors to be considered in the evaluation of the coexistence between UWB and incumbent services in the band is the total radiated power spectral density (TRP_{SD}). This value is a measure for the average of the emitted interference power in all directions in contrast to the Effective Isotropic Radiated Power (EIRP) value, which give the worst-case highest emission level into one single direction. Especially for small and body worn devices the TRP_{SD} is typically significantly lower than the EIRP value. The TRP_{SD} parameter is not new in the UWB regulation and it has been used in the sensor regulation of UWB for several years. Nevertheless, systematic measurements of the value using typical UWB devices for other applications were never performed.

In order to be able to use realistic values in the CEPT investigations, it is important to execute measurements of total radiated power from UWB devices in a controlled environment as the European Commission (EC) Joint Research Centre (JRC) Radio Frequency (RF) laboratory. These measurements would be an important element for the realistic evaluation of the interference effects of UWB into other systems and services.

Then, the purpose of this report is to describe the Radio Frequency (RF) measurements conducted in the JRC on a sample of UWB transmitter used for positioning applications.

1.2 Scope of the report

The aim of the measurements performed on this UWB module is to assess a test setup for the measurement of TRP_{SD} as proposed in Annex A of the System Reference document (SRdoc) ETSI TR 103 750 [2]. This initial implementation applies only to the category of small form factor devices whose weight and size are compatible with our facility.

This report does not assess the compliance of the tested device and uses the referenced standard and technical report only as a guide for the implementation of the tests.

1.3 Structure of the report

The structure of this report is following:

- Section 2 describes the test bed and materials including a description of the shielded chamber used for the tests, the test equipment and the reference framework (e.g., angles and position).
- Section 3 describes the methodology to perform the measurements, the calibration process and provides some considerations on the uncertainties during the measurement phase.
- Section 4 provides the results of the measurements and an analysis.
- Section 5 provides the conclusions of the report.

2 Test bed and materials

2.1 Test bed anechoic chamber

Experiments were carried out in the JRC's Shielded Anechoic Chamber (SAC) of the DG JRC of the European Commission, located in Ispra, Italy.

The device under test (DUT) was a UWB module development kit, Qorvo DWM3001CDK (described more in detail in sub-section 2.3.2), placed in the quiet zone of the chamber on a two-axis positioner as shown on the picture of Figure 1. On the left in the foreground, appears a double-ridged horn antenna used as probe antenna to measure the radiation emitted by the DUT.

A schematic of the measurement setup is shown in Figure 2. The DUT was placed on a two-axis system consisting of a compact table providing rotation around the vertical axis and a turn unit for the rotation around the horizontal axis. The aperture of the probe antenna was placed at a distance d from the centre of the DUT antenna. Measurements were performed at two different distances, i.e. d=1 m and d=3 m. Absorbers were removed from the floor for the measurements at d=1 m because there was not enough space between the compact table and the probe antenna tripod whereas twelve pieces of absorbers were presents for the measurements at d=3 m in the full anechoic configuration of the chamber.

A low noise amplifier (LNA) was connected to the probe antenna, followed by a series of coaxial cables linked to a spectrum analyser situated in the laboratory below the chamber. A computer was used to acquire the spectrum trace and to control the axes.

Figure 1: Over The Air (OTA) measurement set up in the Shielded Anechoic Chamber (SAC) in full anechoic configuration.

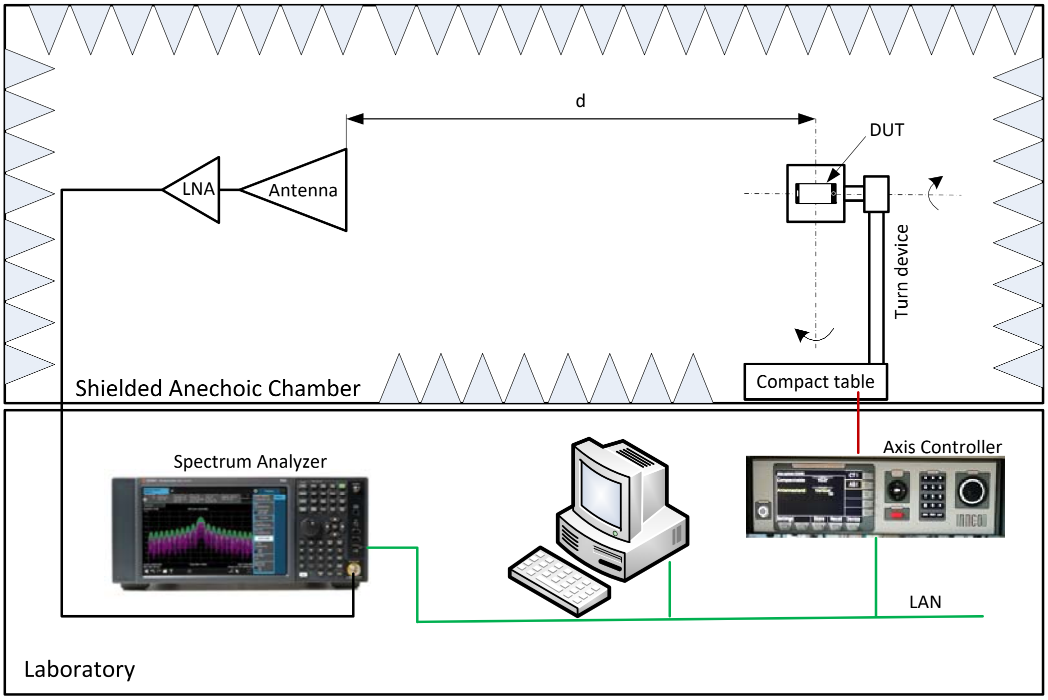

Figure 2: Measurement setup

2.2 Referential for reporting the test results

The terminology and coordinate system are taken from the CTIA Test Plan for Wireless Devise Over-the-Air Performance [3]. A spherical coordinate system is linked to the DUT as shown in Figure 3. The phi (ϕ) axis is defined as being along the Z-axis. As the phi axis rotates, the orientation of the theta axis varies with respect to the DUT. The green arrow identifies the direction of the probe antenna (Horn antenna).

The two polarizations of the measured electric field are defined in terms of the two rotation axes:

- ϕ-polarization is along the direction of motion when the phi axis rotates
- Θ-polarization is along the direction of motion when the theta axis rotates

In the same manner as the combined-axes system shown in Appendix A of the CTIA test plan and reproduced in Figure 4, our Z-axis is in fact the horizontal axis. Therefore, the phi polarisation is measured when the polarisation of horn antenna is orientated vertically. The horn antenna was rotated by 90° to measure the theta (Θ) polarisation.

This referential differs from the one described in clause 5.6 of EN 303 883 [1] where θ is the elevation angle and is independent of phi. In the present report, phi and theta are combined axes.

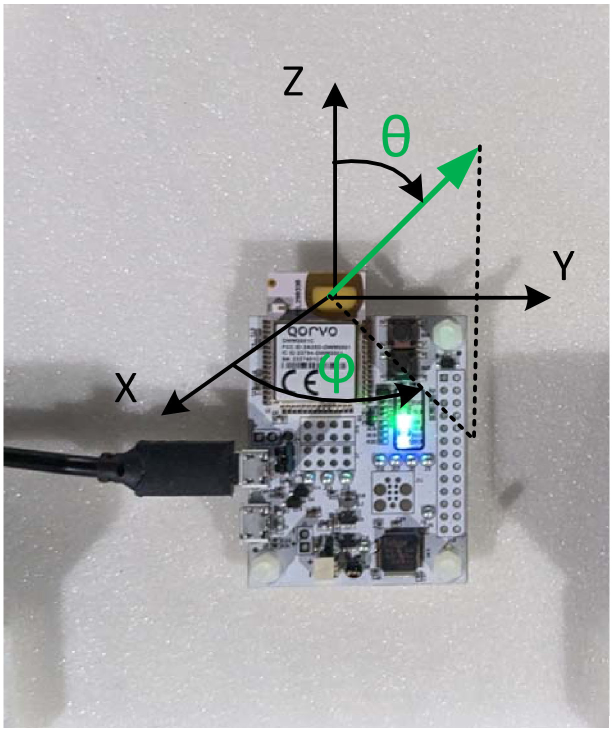

Figure 3: Coordinate system associated with the DUT

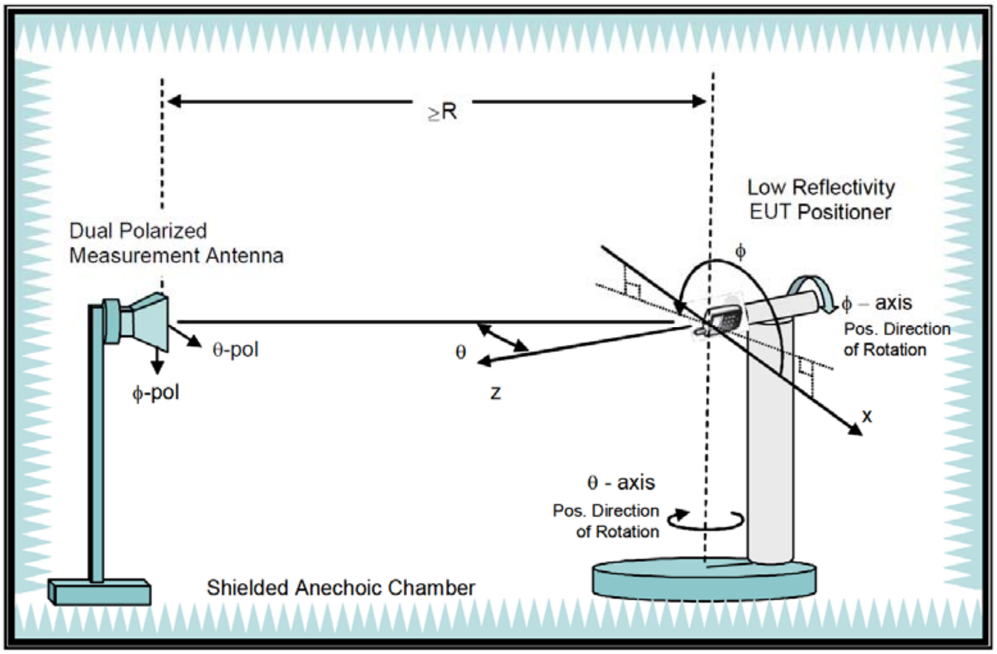

Figure 4: Typical setup for a combined-axes system as shown in Appendix A of the CTIA test plan [4].

The compact table was rotated around the vertical axis (theta axis) from 5° to 175° in steps of 10°. For each theta angle, the turn unit, holding the DUT, was rotated from 0° to 360° in steps of 10°. In total, radiation patterns were measured for 18 values of theta and 37 values of phi.

2.3 Materials

2.3.1 Description of the test equipment

The test equipment and tools used for the test are listed in Table 1.

Table 1: List of equipment used for the test.

Description	Manufacturer	Model	Notes
Shielded Anechoic Chamber	Global EMC	dimensions 7m x 3.5m x 3m	
Compact table	INNCO Systems	CT1000	
Turnable unit	INNCO Systems	DE3700-RH	Rotating platform where the UWB device is deployed
Standard Horn Antenna	Schwarzbeck	BBHA 9120D	This horn antenna was selected because its frequency operating range is suitable for the UWB transmissions
Low Noise Amplifier	B&Z Technologies	BZ-04000800-071040-152020	
Spectrum analyser	Keysight	N9030B	
Signal generator	Rohde & Schwarz	SMM100A	The signal generator was used for calibration.
Power meter	Rohde & Schwarz	NRP50SN	

2.3.2 Device Under Test (DUT) description and configuration

The device under test (DUT) was a UWB module development kit module development kit, Qorvo DWM3001CDK.

Qorvo's DWM3001CDK has been developed as a design kit for the DWM3001C fully integrated (UWB) module based on the Qorvo DW3110 IC. This kit can be used to evaluate hardware performance as a Time Direction of Arrival (TDoA) Tag and build an evaluation real time location system (RTLS) for indoor positioning[1].

Two micro Universal Serial Bus (USB) ports connect to the J-Link and DWM3001C USB interface. Two micro USB ports connect to the J-Link and DWM3001C USB interface. The board can be powered from either of these USB ports, a Raspberry Pi interface, a battery or an external power supply

The DUT was operated using the CLI interface. The frame configuration was the default one as seen after the command 'uwbcfg' on the terminal screen. The command 'uwbcfg' was used only to change the UWB channel

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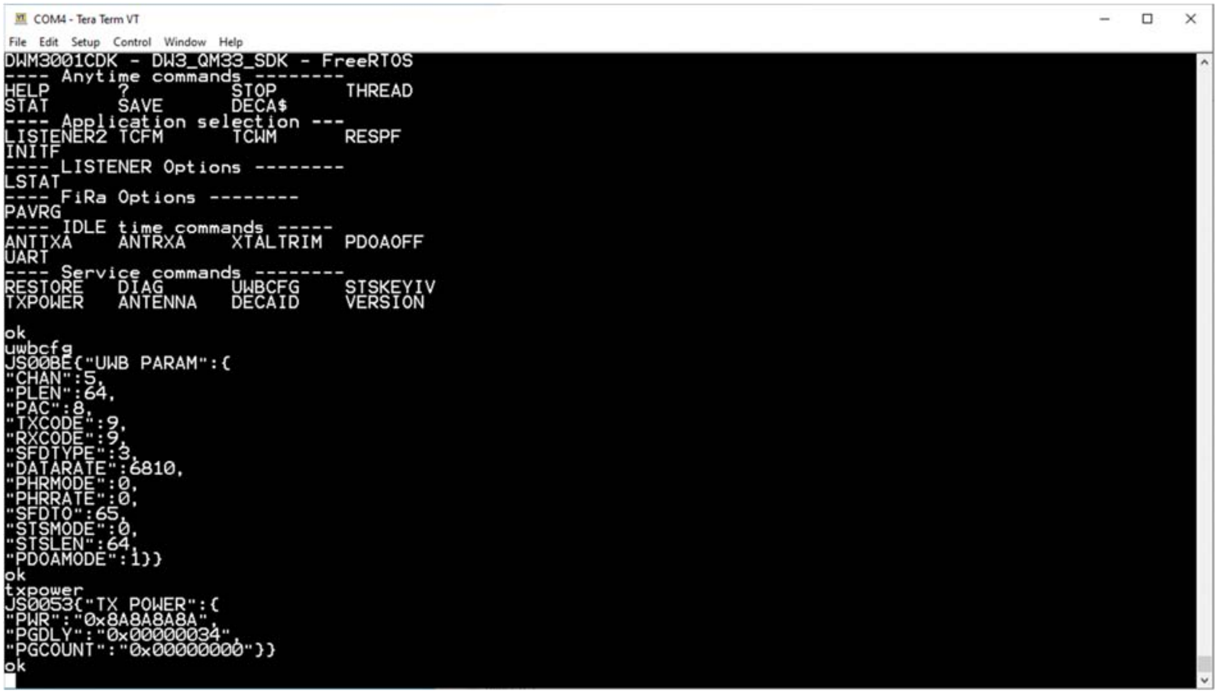
[1] Text extracted from https://www.qorvo.com/products/p/DWM3001CDK.

from 5 to 9. The default Tx power parameters were kept unchanged as seen after the command ‘txpower’. Finally, the application command ‘tcfm’ was used to force the DUT to transmit frames with a repetition time of 1 ms.

The device was set to transmit in UWB channel 5 and 9 whose centre frequencies are respectively 6489.6 MHz and 7987.2 MHz.



```
DWM3001CDK - DW3_QM33_SDK - FreeRTOS
---- Anytime commands --------
HELP      ?         STOP      THREAD
STAT      SAVE      DECA$
---- Application selection ---
LISTENER2 TCFM      TCWM      RESPF
INITF
---- LISTENER Options --------
LSTAT
---- FiRa Options --------
PAVRG
---- IDLE time commands -----
ANTTXA    ANTRXA    XTALTRIM  PDOAOFF
UART
---- Service commands --------
RESTORE   DIAG      UWBCFG    STSKEYIV
TXPOWER   ANTENNA   DECAID    VERSION

ok
uwbcfg
JS00BE{"UWB PARAM":{
"CHAN":5,
"PLEN":64,
"PAC":8,
"TXCODE":9,
"RXCODE":9,
"SFDTYPE":3,
"DATARATE":6810,
"PHRMODE":0,
"PHRRATE":0,
"SFDTO":65,
"STSMODE":0,
"STSLEN":64,
"PDOAMODE":1}}
ok
txpower
JS0053{"TX POWER":{
"PWR":"0x8A8A8A8A",
"PGDLY":"0x00000034",
"PGCOUNT":"0x00000000"}}
ok
```

Figure 5: Screen shot of the terminal interface.

The transmitted signal was captured during 2.5 ms at a sampling rate of 600 MHz using the IQ Analyzer function of the spectrum analyser. The time trace shown in Figure 6 confirms the repetition time of 1 ms. The duration of the burst is 121 µs leading a duty cycle of 12.1%.

Three different waveforms can be identified when zooming on a single frame (Figure 7). The initial waveform of lower peak amplitude may correspond to the Synchronization field SYNC. The second waveform could be the Start of Frame delimiter SFD and the third one a combination of the Physical layer Header (PHR) and Payload Field. Further zoom on the SYNC field shows that the signal consists of pulses whose duration is about 2 ns (Figure 8).

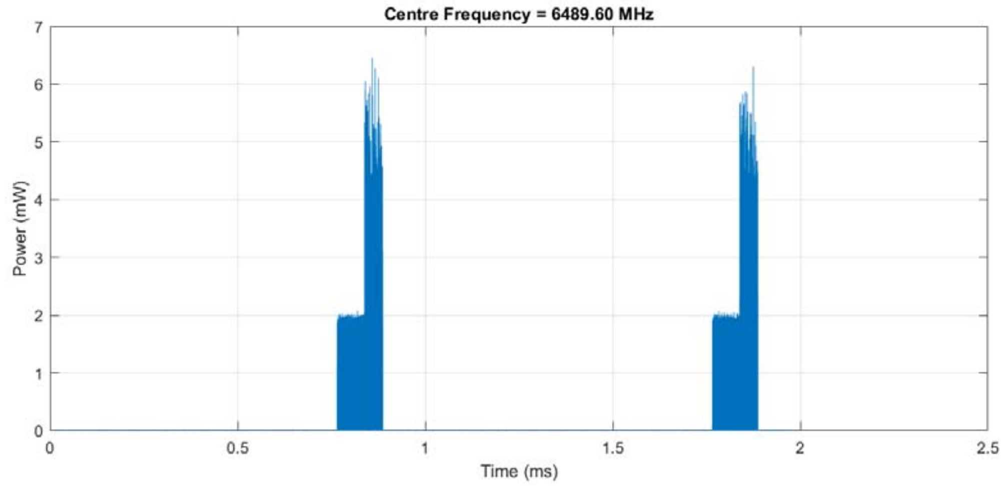


Figure 6: Amplitude of UWB signal versus time.

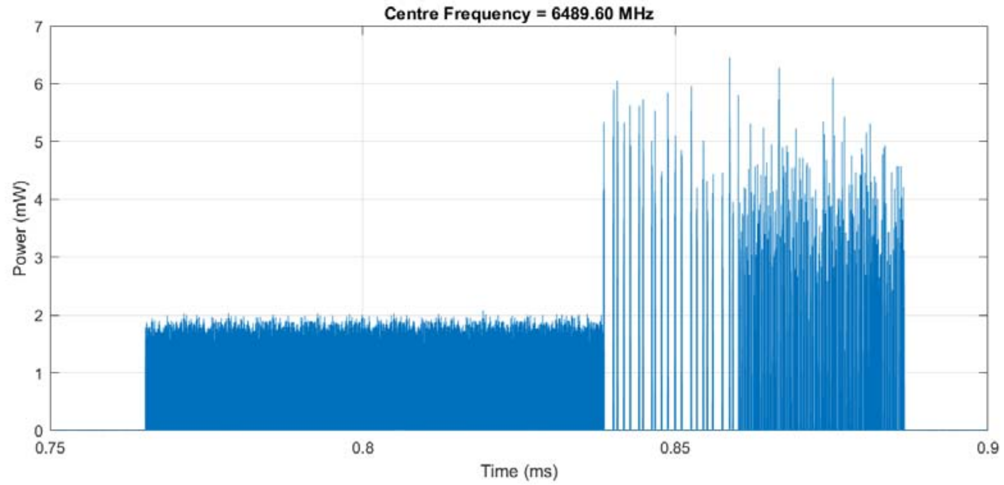


Figure 7: Amplitude of UWB signal during one frame.

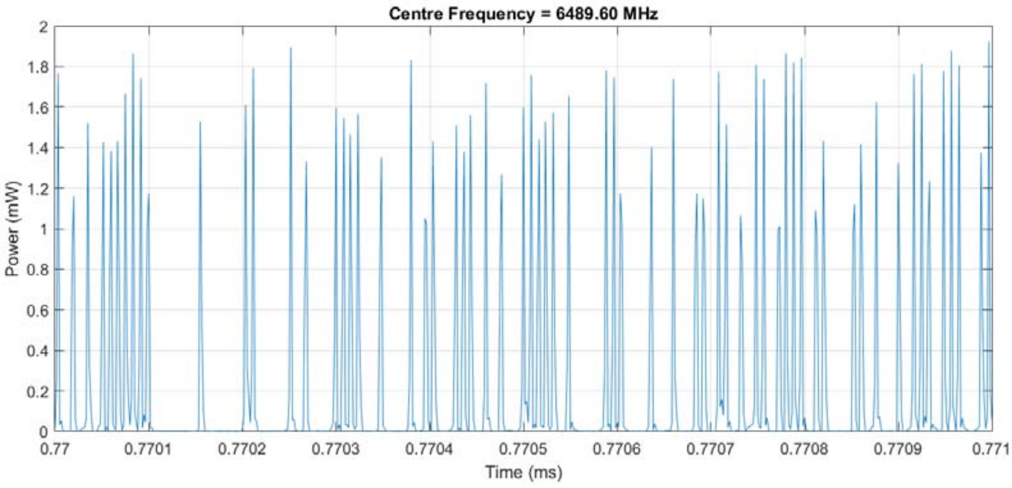


Figure 8 Amplitude of preamble pulses.

3 Methodology for calibration and measurements collection

3.1 Calibration and parameter calculation

Power spectral density Effective Isotropic Radiated Power (EIRP) values are calculated, for each polarisation (θ-polarisation and ϕ-polarisation), theta and phi angles, and measured frequency in the following way:

$EIRP\_SD_{\theta}(\theta,\phi,f) = P_{\theta}(\theta,\phi,f) + FSPL - G_{A} - CF$ and $EIRP\_SD_{\phi}(\theta,\phi,f) = P_{\phi}(\theta,\phi,f) + FSPL - G_{A} - CF$ where:

- P_{θ} is a sample of the spectrum trace in dBm for the θ-polarisation.
- P_{ϕ} is a sample of the spectrum trace in dBm for the ϕ-polarisation.
- FSPL is the Free Space Path Loss in dB.
- G_{A} is the probe antenna gain in dBi, calibrated by the manufacturer at the very same measuring distances d=1m and d=3m.
- CF is a calibration factor that incorporates the Low Noise Amplifier (LNA) gain and cable losses. It was measured by replacing the probe antenna with a signal generator transmitting a continuous wave at the centre frequencies of UWB channels 5 and 9.
- $EIRP\_SD_{\theta}$ is the power spectral density in dBm for the θ-polarisation.
- $EIRP\_SD_{\phi}$ is the power spectral density in dBm for the ϕ -polarisation.

The calibration parameters are summarised in Table 2.

Table 2: Calibration parameters

Distance (m)	1	1	3	3
Frequency (MHz)	6489.6 (channel 5)	7987.2 (channel 9)	6489.6 (channel 5)	7987.2 (channel 9)
FSPL (dB)	48.69	50.50	58.24	60.04
Antenna gain (dBi)	10.42	10.83	11.46	11.35
Calibration factor CF (dB)	36.6	36.6	36.1	36.1

The resulting mean EIRP Spectral Density *eirp_sd*, in mW, is the linear sum of the two polarisation components:

$$eirp\_sd(\theta,\varphi,f) = eirp\_sd_{\theta}(\theta,\varphi,f) + eirp\_sd_{\varphi}(\theta,\varphi,f)$$

with $eirp\_sd_{\theta} = 10^{\frac{EIRP_{SD\theta}}{10}}$ $and\ eirp\_sd_{\varphi} = 10^{\frac{EIRP\_SD_{\varphi}}{10}}$

the mean EIRP is calculated is the following way:

$$eirp = \frac{B_s}{B_r}\frac{1}{n}\sum_{i=i_l}^{i=i_h} eirp\_sd(\theta,\varphi,f)$$

With:

B_s the specified bandwidth

B_r the resolution bandwidth

n the number of data points in the summation

i_l the index of the lower frequency

i_h index of the higher frequency

The total radiation power is calculated as follows:

$$TRP = \frac{\pi}{2NM} \sum_{i=1}^{N} \sum_{j=1}^{M-1} eirp(\theta_i, \varphi_j) \sin(\theta)$$

Similarly, the total radiation power spectral density is:

$$TRPSD = \frac{\pi}{2NM} \sum_{i=1}^{N} \sum_{j=1}^{M-1} eirp\_sd(\theta_i, \varphi_j) \sin(\theta)$$

Where N is the number of measured theta points (18 points from 5° to 175°) and M the number of phi points (37 points from 0° to 360°). Note that j goes from 1 to M-1 because there are 36 intervals from 0° and 360° in 10° steps.

3.2 Consistency check of channel power calculation

Instead of using the Channel Power function of the spectrum analyser as specified in clause 5.3.1.3 of EN 303 883 [1], the Channel Power was calculated from the spectrum trace, recorded for each orientation of the DUT. This deviation from the standard allows to calculate the channel power in different bandwidths and to estimate the TRP_{SD} for each measured frequency point. The correctness of the post processing in assessed in the following.

The channel power is calculated, in a specified bandwidth, by linear summation of samples of the spectrum trace as follows:

$$P_{ch} = 10\, Log_{10}\left(\frac{B_s}{B_r}\frac{1}{n} \sum_{i=i1}^{i=i2} 10^{\left(\frac{P_i}{10}\right)}\right)$$

with P_{ch} the channel power in dBm

B_s the specified bandwidth

B_r the resolution bandwidth

n the number of data points in the summation

$i1$ index of the lower frequency

$i2$ index of the higher frequency

P_i a sample of the spectrum trace in dBm

The parameters of the spectrum analyser are given in Table 3:

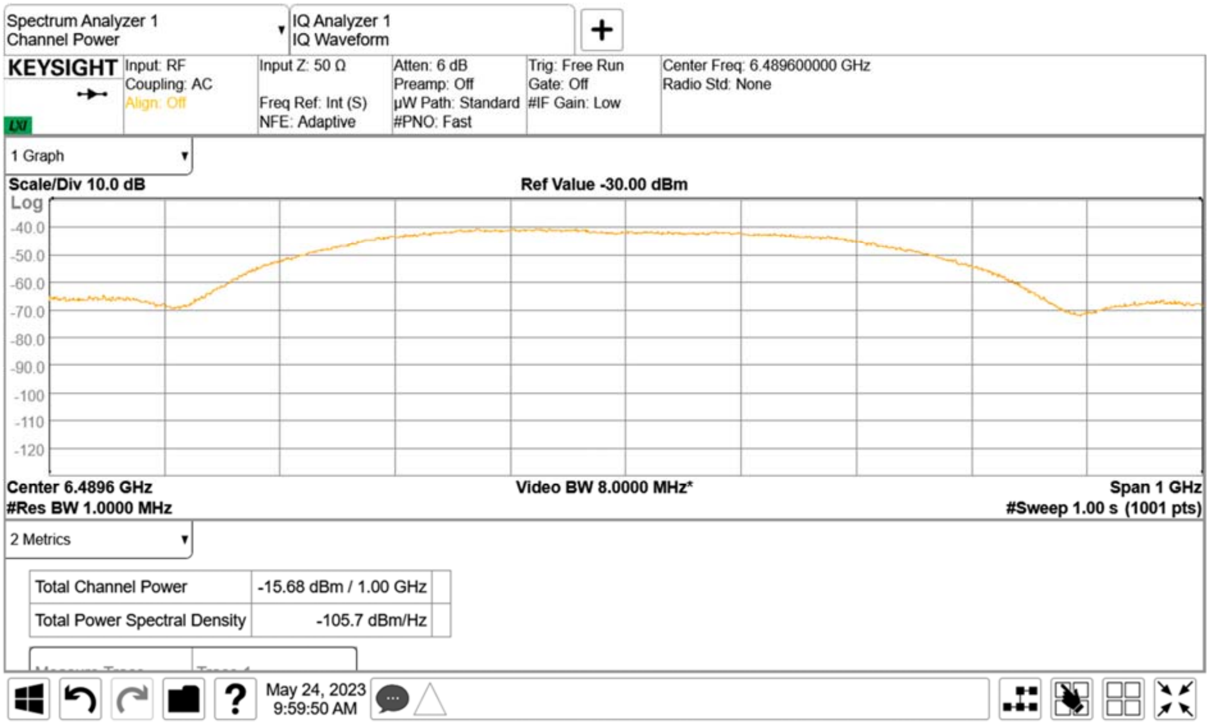
Table 3: Spectrum analyser parameter

Parameter	Value
Centre frequency	6.4896 GHz
Span	1 GHz
RBW	1 MHz

Resolution filter type	Gaussian
Detector	Average
Sweep time	1 s
Sweep points	1001
Trace	Clear write

Sweep points and sweep time are chosen such that the power is averaged on exactly one period of the UWB signal, i.e. 1 ms. There is therefore no need to accumulate traces using the Max Hold mode. The value of 1001 for the number of sweep points allows having exactly 1 MHz between two points.

Figure 9 is a screen shot of the spectrum analyser showing the spectrum trace in yellow and the result of Channel Power measurement. The trace samples are imported in a computer for post-processing.



Input: RF
Coupling: AC
Align: Off
Input Z: 50 Ω
Freq Ref: Int (S)
NFE: Adaptive
Atten: 6 dB
Preamp: Off
µW Path: Standard
#PNO: Fast
Trig: Free Run
Gate: Off
#IF Gain: Low
Center Freq: 6.489600000 GHz
Radio Std: None

Scale/Div 10.0 dB
Ref Value -30.00 dBm
Center 6.4896 GHz
#Res BW 1.0000 MHz
Video BW 8.0000 MHz*
Span 1 GHz
#Sweep 1.00 s (1001 pts)

Total Channel Power	-15.68 dBm / 1.00 GHz
Total Power Spectral Density	-105.7 dBm/Hz

May 24, 2023
9:59:50 AM

Figure 9: Spectrum analyser screen shot showing spectrum trace and result of Total Channel Power calculation.

The calculated channel power is compared to the total power measured with a power meter Rohde&Schwarz NRP50SN, the mean power of an IQ waveform acquired in a 510 MHz bandwidth and the channel power calculated by the instrument.

The results are summarized in Table 4.

Table 4: Results of the comparison

Method	Measured power

Sum of spectrum trace	-15.43 dBm / 1 GHz
Power meter	-15.4 dBm
Sum of spectrum trace	-15.60 dBm / 510 MHz
Mean power of IQ waveform	-15.64 dBm / 510 MHz
Instrument channel power	-15.68 dBm / 1 GHz

There is a good agreement between the power measured with the power meter and the channel power calculated as the sum of the spectrum trace over 1 GHz. There is also a good agreement between the channel power calculated over the central 510 MHz bandwidth and the mean power of the IQ waveform acquired in a 510 MHz analysis bandwidth.

However, the channel power calculated by the instrument is 0.25 dB lower than the one calculated as the sum of the spectrum trace. This difference is because the spectrum analyser uses the noise equivalent bandwidth as resolution bandwidth B_r instead of the 3dB bandwidth of the resolution filter RWB. In fact, the spectrum analyser subtracts 0.24 dB to take into account the noise equivalent bandwidth of a Gaussian filter as explained in the Keysight application note 5966-4008 “Spectrum and Signal Analyser Measurements and Noise” [4].

The first observation is that the correction factor of 0.24 dB applied by the Channel Power function of the spectrum analyser is not needed in the case of the tested UWB signal.

The second observation is that although the UWB consists of very short pulses there is no negative effect due the impulse response of the resolution filter.

Therefore, the method used for the measurement of the Channel Power and Power Spectral Density is validated.

3.3 Effect of Device Under Test (DUT) orientation

There are measurements points of the radiation pattern where the structure supporting the turn unit happen to be situated between the DUT and the probe antenna. Although the structure is made of low dielectric constant materials, it is necessary to check that it does not affect significantly wave propagation.

Measurements have been performed with two different orientations of the DUT on the turn unit: the normal orientation and the reverse orientation as shown in Figure 10 and Figure 11.

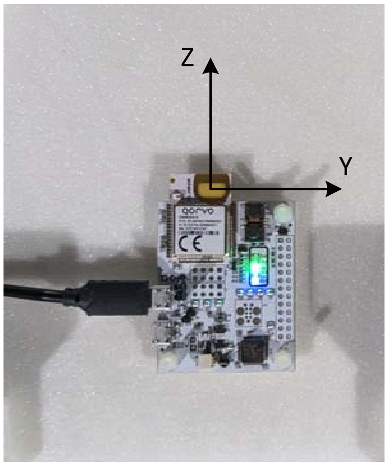


Figure 10: Normal orientation

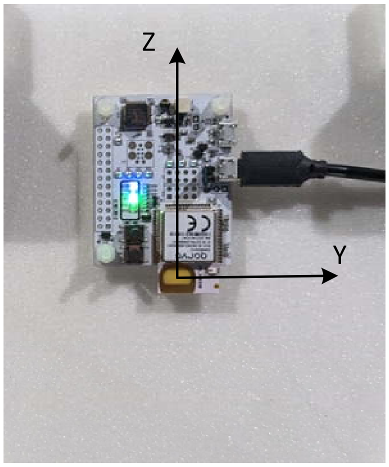


Figure 11: Reverse orientation

The following tables compare the results obtained with the two DUT's orientations when transmitting in UWB channels 5 and 9 and for the two distances between DUT and probe antenna.

Differences of ±0.5 dB for TRP and ±1 dB for EIRP are within the ±2 dB measurement uncertainty. This result is also illustrated in the vertical cut of the radiation pattern of Figure 12 that displays the EIRP in function of theta at phi=0°. The blue and red traces correspond to the Normal and Reverse orientations respectively.

Therefore, there is no need to split the measurement in two "half" spheres as noted in clause 5.6.2.2 of EN 303 883 [1]. The full sphere can be measured without repositioning the DUT.

Table 5: Effect of the orientation of the DUT transmitting in channel 5 and measured at 1m.

Metric	Normal orientation	Reverse orientation	Difference (dB)
EIRP (dBm)	-13.15	-14.20	1.05
TRP (dBm)	-20.16	-20.04	-0.12
EIRP PSD (dBm/MHz)	-38.25	-39.35	1.1
TRP PSD (dBm/MHz)	-45.57	-45.48	-0.09

Table 6: Effect of the orientation of the DUT transmitting in channel 9 and measured at 1m

Metric	Normal orientation	Reverse orientation	Difference (dB)
EIRP (dBm)	-13.30	-13.86	0.56
TRP (dBm)	-19.72	-19.67	-0.05
EIRP PSD (dBm/MHz)	-38.11	-38.96	0.85
TRP PSD (dBm/MHz)	-45.28	-45.22	-0.06

Table 7: Effect of orientation DUT transmitting in channel 5 and measured at 3m

Metric	Normal orientation	Reverse orientation	Difference (dB)
EIRP (dBm)	-13.14	-13.28	0.72
TRP (dBm)	-20.27	-19.78	-0.49
EIRP PSD (dBm/MHz)	-38.30	-38.14	-0.16
TRP PSD (dBm/MHz)	-45.69	-45.13	-0.56

Table 8: Effect of orientation DUT transmitting in channel 9 and measured at 3m

Metric	Normal orientation	Reverse orientation	Difference (dB)
EIRP (dBm)	-12.96	-11.83	-1.13
TRP (dBm)	-18.96	-19.26	0.3
EIRP PSD (dBm/MHz)	-37.63	-36.60	-1.03
TRP PSD (dBm/MHz)	-44.56	-44.95	0.39

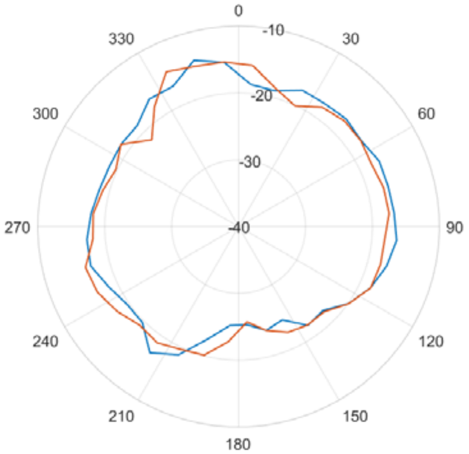


Figure 12: Comparison of radiation patterns with Normal (blue) and Reverse (red) orientations.

4 Results

4.1 Radiation patterns

An example of radiation pattern when the DUT was transmitting in channel 5 is given in the following figures. Figure 13 is a 3D representation of the radiation pattern whereas Figure 14 consists in eighteen polar plots of EIRP versus phi angle, one for each theta angle. Each plot shows the θ-polarisation component, the ϕ-polarisation component and the sum of them. A maximum EIRP of -13.2 dBm is found at theta=45° and phi=250°.

Figure 15 shows the result of calculation of TRP_{SD} versus frequency. The maximum TRP_{SD} is found to be -45.6 dBm/MHz at the frequency of 6392.6 MHz. It is important to note that the frequency at which TRP_{SD} is maximum is not necessarily the centre frequency of the UWB channel. Therefore, it would be necessary to specify that the measurement of TRP_{SD} shall be performed for all 1 MHz intervals within the operating frequency range and the maximum shall be retained as value of TRP_{SD}.

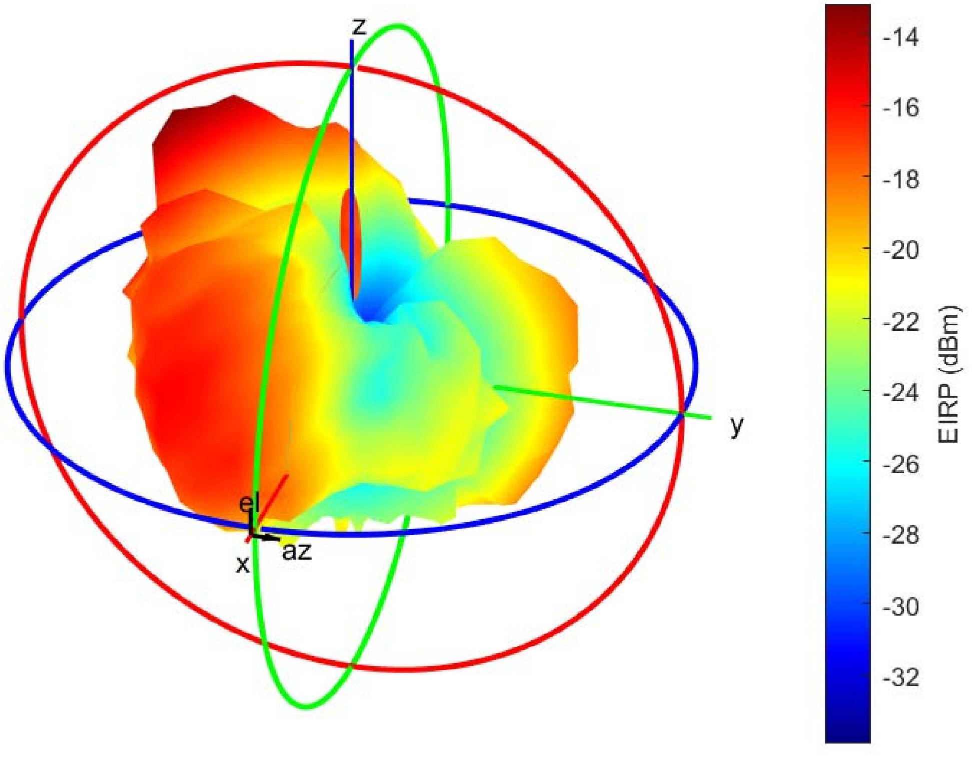


Figure 13: Example of 3D radiation pattern

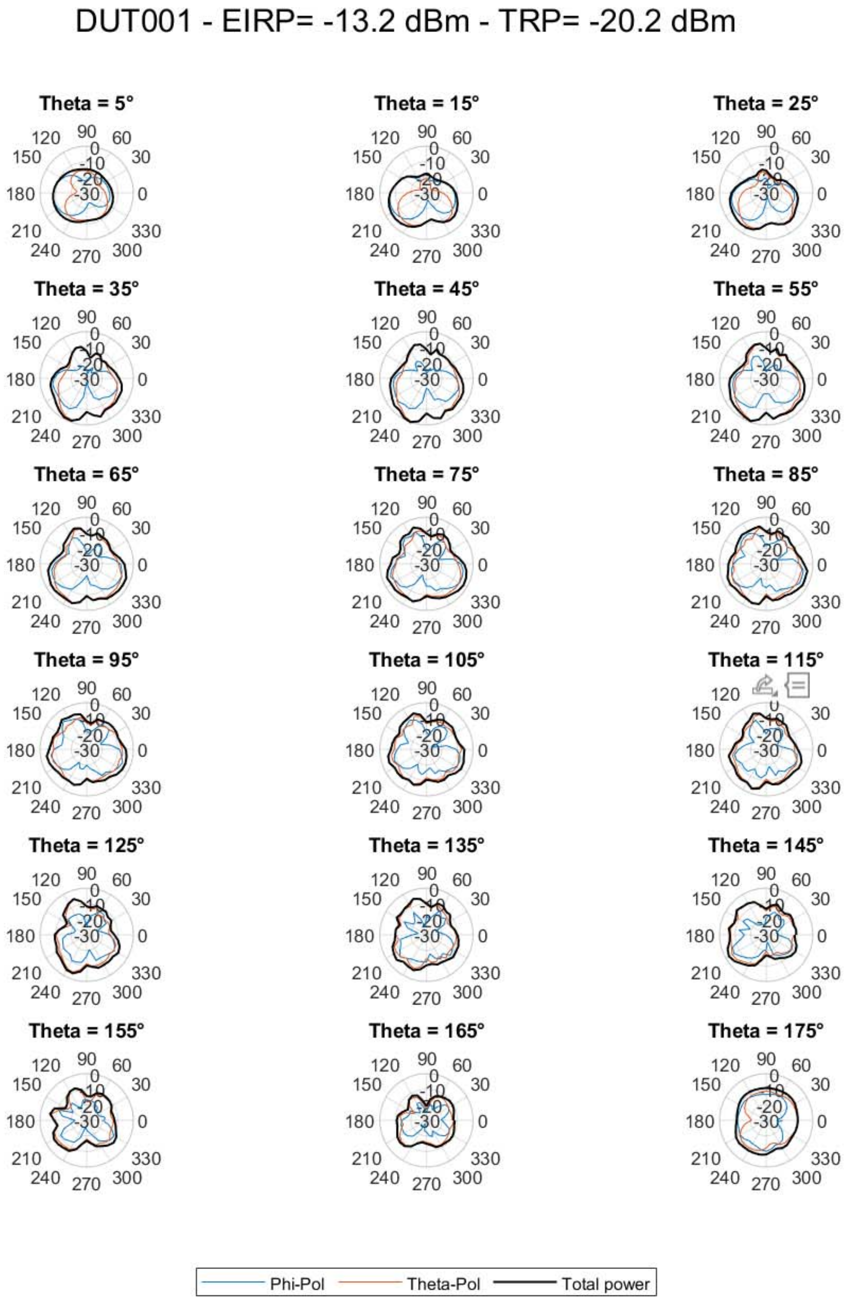


Figure 14: Example of measured radiation pattern

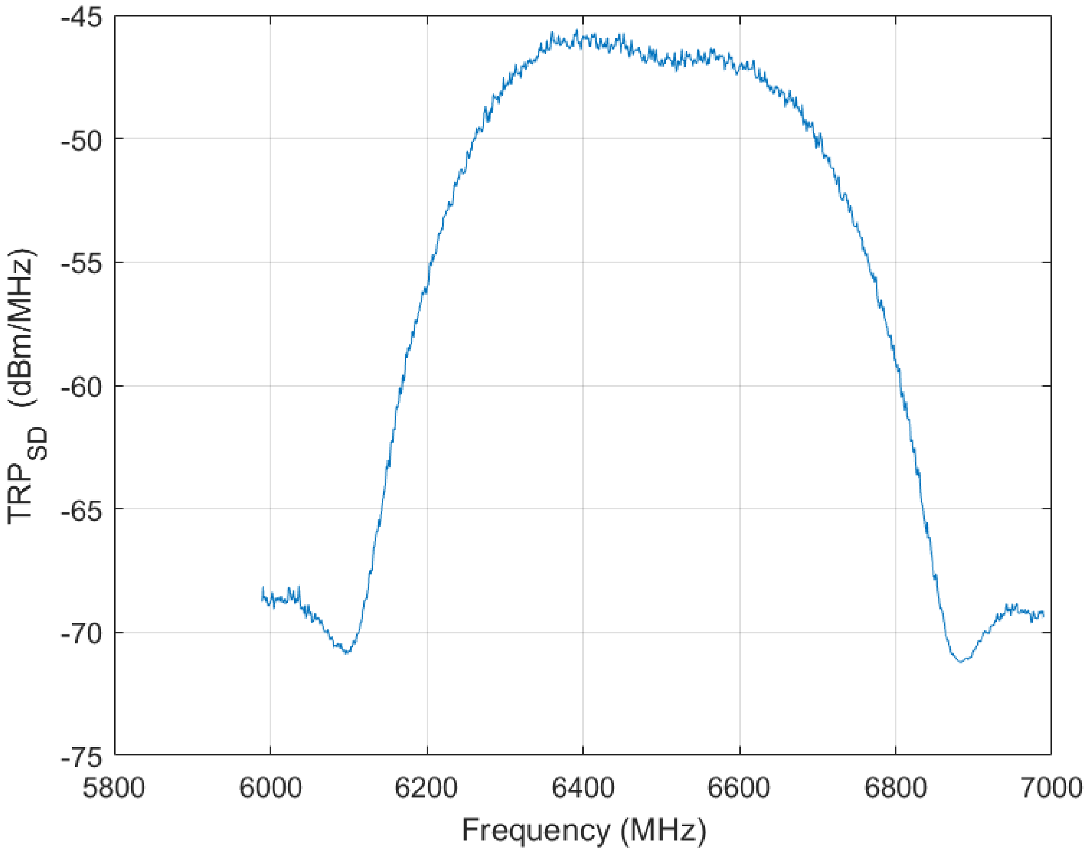


Figure 15: Result of TRP_{SD} measurement versus frequency

4.2 Result summary

Measurement results are reported in Table 9 and are represented graphically in Figure 16. Maximum values of EIRP and $EIRP_{SD}$ do not vary significantly with channel number and measuring distance. The maximum mean $EIRP_{SD}$ (-37.6 dBm/MHz) exceeds the limit of -41.3 dBm/MHz because the device was forced to transmit with higher duty cycle. The fact that TRP and TRP_{SD} values are more spread at 3 m measurement distance can be explained because their calculation includes points with low signal to noise ratio. Finally, it is found that the TRP_{SD} of this DUT is about 7 dB lower than its mean $EIRP_{SD}$.

This result shows that the radiation pattern is far from being isotropic because the mean $EIRP_{SD}$, which is the emitted power spectral density in the direction of the maximum level is 7 dB higher than the TRP_{SD}, which is the emitted power spectral density averaged over all directions.

Table 9: Measurement results

UWB channel	Distance (m)	EIRP (dBm)	$EIRP_{SD}$ (dBm/MHz)	TRP (dBm)	TRP_{SD} (dBm/MHz)
5	1	-13.15	-38.25	-20.16	-45.57
9	1	-13.3	-38.11	-19.72	-45.28

5	3	-12.93	-37.95	-19.9	-45.2
9	3	-13.3	-38.25	-19.01	-44.7
9	3	-12.96	-37.63	-18.96	-44.56
5	3	-13.14	-38.3	-20.27	-45.69

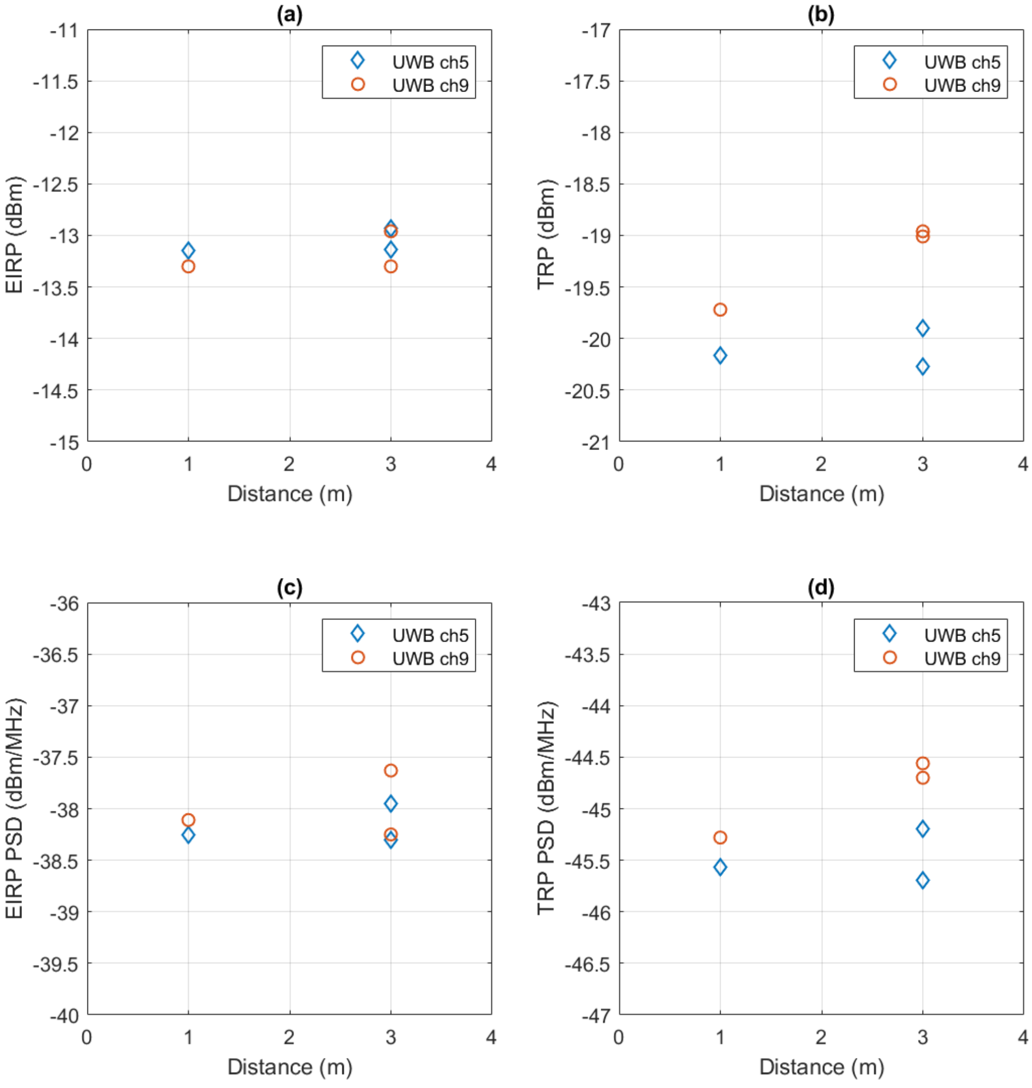


Figure 16: Graphical results of the measurements of EIRP (a), TRP (b), EIRP$_{SD}$ (c) and TRP$_{SD}$ (d)

4.3 Discussion on the results

Initial measurements of radiated power transmitted by a UWB development kit module has been carried out in JRC's Shielded Anechoic Chamber (SAC) to assess a test setup and a methodology for measuring the TRP_{SD}.

The following observations were made:

- It is necessary that the DUT is operated in a testing mode such that it transmits continuously at high repetition rate (e.g. 1 ms repetition time).
- The correction that the Channel Power function of spectrum analysers apply to take into account the noise equivalent bandwidth of the resolution filter does not seem to be appropriate to UWB signals.
- The impulse response of the resolution filter does not affect negatively the measurement.
- There is no need to split the measurement in two "half" spheres as noted in clause 5.6.2.2 of EN 303 883 [1]. The full sphere can be measured without repositioning the DUT.
- For the tested device, the frequency at which TRP_{SD} is maximum is not the centre frequency of the UWB channel.
- There are no significant differences between the results obtained at a measuring distance of 1 meter and 3 meters. A measurement distance of 1 meter could be chosen at the condition that the far field requirement be met.
- This result shows that the radiation pattern is far from being isotropic because the mean $EIRP_{SD}$, which is the emitted power spectral density in the direction of the maximum level is 7 dB higher than the TRP_{SD}, which is the emitted power spectral density averaged over all directions.

5 Conclusions

This report describes the measurement campaign conducted in the JRC facilities on one Ultra Wide Band (UWB) device to measure the Total Radiated Power Spectral Density (TRP_{SD}). Some observations were made on the results on the measurements including the consideration that the correction that the Channel Power function of spectrum analysers apply to take into account the noise equivalent bandwidth of the resolution filter does not seem to be appropriate to UWB signals. In addition, there is no need to split the measurement in two “half” spheres as noted in clause 5.6.2.2 of EN 303 883 [1]. The authors also noted a large variability in the radiation pattern, which is far from being isotropic. Finally, the full sphere can be measured without repositioning the Device Under Test (DUT).

The results of this measurement campaign can be used to support the regulatory activities in the European Union (EU) regarding UWB technology CEPT System Engineering SE24.

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List of abbreviations and definitions

Abbreviation	Definition
BW	Band Width
CF	Calibration Factor
CEPT	Conférence européenne des administrations des postes et des télécommunications
dB	deciBel
dBm	deciBel milliwatt
DUT	Device Under Test
EIRP	Effective Isotropic Radiated Power
EIRP_{SD}	Effective Isotropic Radiated Power Spectral Density
ETSI	European Telecommunications Standards Institute
EU	European Union
FSPL	Free Space Path Loss
IQ	in-phase (I) and quadrature (Q) components
LNA	Low Noise Amplifier
OFDM	Orthogonal Frequency Division Multiplex
OTA	Over The Air
PF	Payload Field
PHL	Physical layer Header
PHR	Physical layer Header
PSD	Power Spectral Density
RTLS	Real Time Location System
SAC	Shielded Anechoic Chamber
SD	Spectral Density
SE	System Engineering
SFD	Start of Frame Delimiter
SRD	Short Range Devices
SRdoc	System Reference document

TDOA	Time Direction Of Arrival
TRP	Total Radiated Power
TRPSD or TRP_{SD}	Total Radiated Power Spectral Density
Universal Serial Bus	USB
UWB	Ultra Wide Band

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