Research and Technical Services

Core-Transport Technology

CTT-0033 Core-TT tag model 'PLT004' RF emissions measurements

Final Deliverable Report

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Revision history

Date	Version	Notes
28 Jun 23	1.0	Initial release

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Executive summary

This report presents RF emissions measurements of a Core-TT PLT004 Tag. During the measurements the RTCA/DO-160G [1] methodology and test set up conditions were followed where possible.

The EUT is a battery-operated Bluetooth Low Energy (IEEE 802.15.1) (BLE) device. It will autonomously emit short BLE messages at an average rate of approximately 6 transmissions per minute.

RTCA/DO-160G requirements only concern *unintended* RF emissions. It explicitly excludes *intentional* transmissions.

Measurement methodology, setup and results are presented and compared to RTCA/DO-160G section 21 Category H maximum allowed emission levels.

The RF emissions of the EUT, a Core-TT tag model ‘PLT004’, are entirely below DO-160G section 21 Category H levels.

AC 91.21-1D [2] in section 10.3.2 states that “the device may use low-power wireless communication during flight… . The low-power emission limit is 100 mW EIRP… . Wireless communication standards which are limited to this level do not need to be analyzed for backdoor coupling. This includes Bluetooth (IEEE 802.15.1)”. As the Core-TT PLT004 uses Bluetooth Low Energy (IEEE 802.15.1) it complies with AC91.21-1D for use during flight for backdoor coupling.

1 Project and report details

1.1 Project Name

Core-TT purchase order 4500038629 2023-05-22 Callaghan PLT004 DO160G, job number J07027.

1.2 Project Manager

Marco Meijer.

1.3 Deliverable

This report is the deliverable report for Core-TT purchase order 4500038629 2023-05-22 Callaghan PLT004 DO160G.

2 Introduction

Core-TT has designed an asset tracking system using readers and tags based on Bluetooth Low Energy (BLE) (IEEE 802.15.1). The equipment under test (EUT) (PLT004) tag will autonomously emit short BLE transmissions at an average rate of approximately 10 transmissions per minute.

The RTCA/DO-160 standard [1] sets out a procedure for measuring the unintended RF emissions of a device. Core-TT has contracted Callaghan Innovation to measure the RF emissions from their PLT004 tag.

[1] states in section 21.3: “Do not measure radiation emanating from antennas or, in the case of transmitters, any radiation on the selected frequency +/-50% of the band of frequencies between adjacent channels while the transmitter is keyed and supplying RF to the load.” As the Core-TT PLT004 tag is a BLE device that transmits on frequencies between 2.400 GHz and 2.4385 GHz, the emissions in that band were not measured.

AC 91.21-1D [2] in section 10.3.2 states that “the device may use low-power wireless communication during flight… . The low-power emission limit is 100 mW EIRP… . Wireless communication standards which are limited to this level do not need to be analyzed for backdoor coupling. This includes Bluetooth (IEEE 802.15.1)”. As the Core-TT PLT004 uses Bluetooth Low Energy (IEEE 802.15.1) it complies with AC91.21-1D for use during flight for backdoor coupling.

Section 3 describes the Equipment under Test, followed by section 4 which presents the methodology and section 5 describes the test setup. Sections 6 and 7 present the results and conclusions respectively. Where possible the DO-160 methodology and test set up conditions have been followed.

Appendix A and B contain the antenna calibration data, Appendix C the cable loss and Appendix D contains the equations used to calculuate the EUT RF radiated electric field strength.

3 Equipment under Test (EUT) description

The EUT is a small (approximately 11x2x1 cm) battery-operated device with no connectors or cables in a plastic enclosure (Figure 1). The device is also called ‘PLT004’. In the remainder of this document, we will refer to it as ‘tag’ or ‘EUT’.

The tag (EUT) acts as a Bluetooth Low Energy (BLE) beacon; the tag emits short BLE transmissions at an average rate of approximately 6 transmissions per minute.

BLE transmissions are between 2400 and 2483.5 MHz using a frequency hopping scheme.

Figure 1 Photograph of the EUT, a Core-TT PLT004 tag.

4 Methodology

All measurements were done in an RF anechoic chamber with measurement antennas and a spectrum analyser.

To determine the RF emissions, the EUT was placed on the wooden pedestal.

The EUT was verified to be transmitting by monitoring the frequency spectrum between 2.4 and 2.5 GHz using the spectrum analyser set to peak hold (while the EUT was in a closed RF anechoic chamber) and observing that RF emissions occurred at the three Bluetooth advertising channels.

5 Measurement setup

5.1 Equipment setup

Figure 2 shows the equipment setup for the measurements. The EUT and antenna were placed in an RF anechoic chamber. The spectrum analyser is placed outside the room and is connected to the measurement antenna through a cable.

The EUT is a battery-operated device and has no connectors. It operates autonomously; hence, no connections are needed from the EUT.

The antenna is placed so that its phase centre is 1 metre from the EUT. The EUT is placed upon a wooden pedestal. The antenna is placed on a wooden tripod and levelled[1]. The antenna height and orientation are adjusted so that it is pointing at the centre of the EUT.

For the measurements, a Rohde & Schwarz FSW-13 spectrum analyser and two measurement antennas were used:

- Rohde & Schwarz HL223 Log periodic dipole antenna which is calibrated from 200 MHz to 1.3 GHz
- EMCO 3115 Double Ridged waveguide horn which is calibrated from 1 GHz to 18 GHz.

[1] This setup differs from [1] where a $2m^2$ ground plane is prescribed.

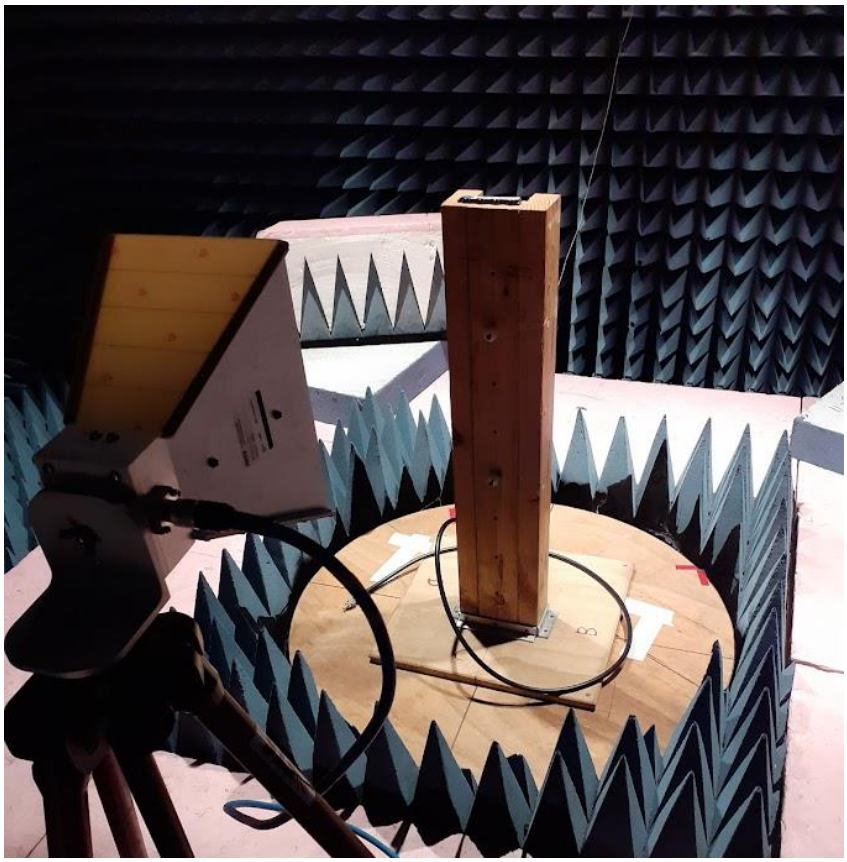

Figure 2 Photograph illustrating the measurement setup. The EUT is placed on top of the wooden pedestal. The EMCO 3115 measurement antenna can be seen in the foreground.

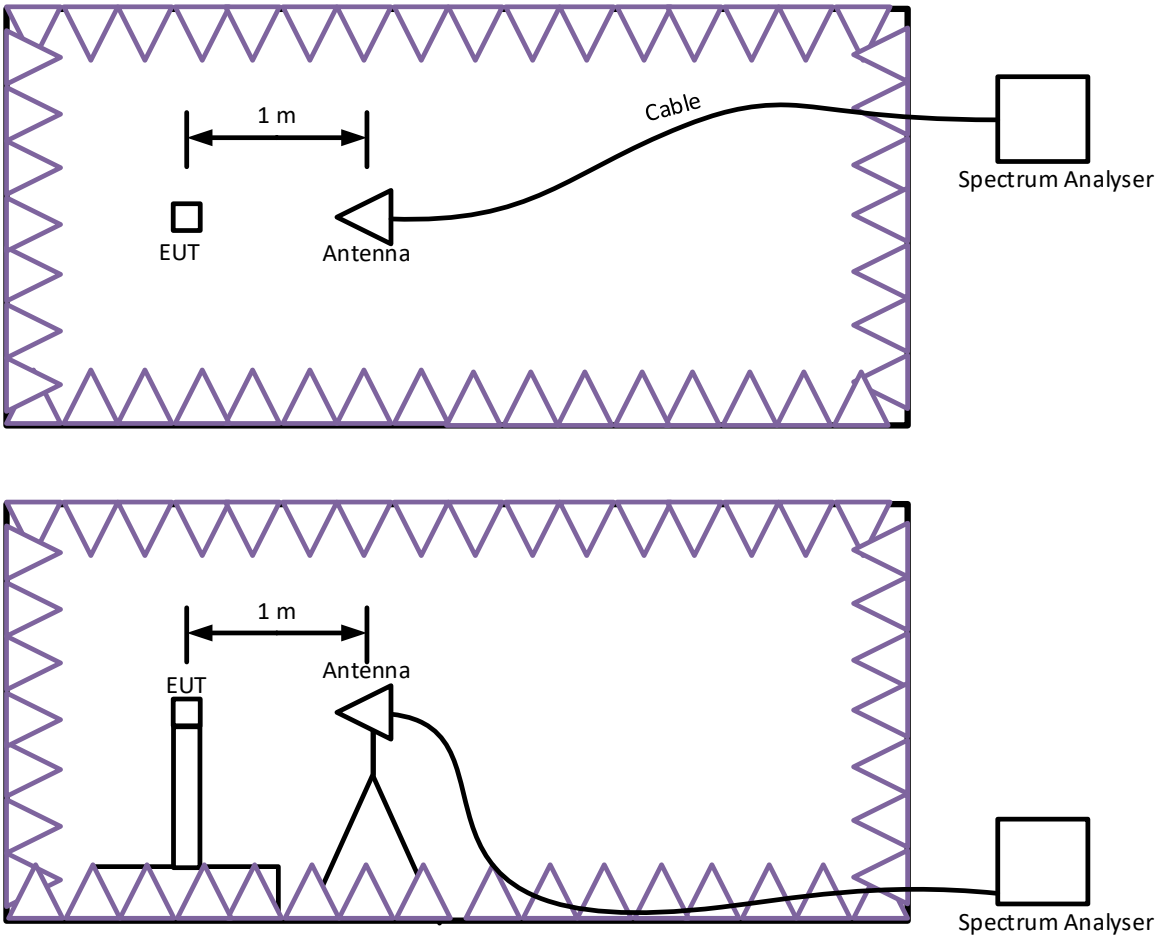

Figure 3 Test setup. Top diagram shows top view and the bottom diagram shows side view.

5.2 Measurements

For the measurements [1] was followed where possible.

No conducted RF emissions ([1], section 21.4) were measured as there are no cables connected to the EUT.

Radiated RF emissions ([1], section 21.5) were measured from 100 MHz to 6,000 MHz for the following situations:

- No EUT in the room: this establishes a background RF measurement.
- The EUT in the room: the EUT periodically transmits Bluetooth Low Energy (BLE) advertisements. The emissions between 2.400 GHz and 2.4835 GHz (the BLE frequency band) have not been measured as per RTCA/DO160G [1] section 21.3.

Radiated RF emissions were measured using the two antennas described above, for the appropriate frequency ranges:

- HL223 was used for the frequency range 100 MHz 1000 MHz[2]
- EMCO 3115 was used for the frequency range 960 MHz to 6 GHz[3]

All measurements were done for both horizontal and vertical polarisation.

Cable attenuation was measured (see also Appendix C) and VSWR of cable with antenna was verified.

[2] The HL223 is calibrated from 200 MHz to 1.3 GHz
[3] The 3115 is calibrated from 1 GHz to 18 GHz

5.3 Spectrum analyser settings

[1] section 21.3 was followed to determine the FSW-13 Spectrum Analyser (SA) settings. The settings are summarised in the table below.

Table 1 Requirements and actual SA settings

	Frequency band			
	100 to 400 MHz	400 to 960 MHz	0.960 to 1 GHz	0.96 to 6 GHz
[1] parameters				
6 dB bandwidth	10 kHz	100 kHz	1 MHz	1 MHz
Minimum dwell time	0.015 s	0.015 s	0.015 s	0.015 s
Freq step	0.5 BW	0.5 BW	0.5 BW	0.5 BW
SA settings				
RBW	10 kHz	100 kHz	1 MHz	1 MHz
VBW	10 kHz (auto)	100 kHz (auto)	1 MHz (auto)	1 MHz (auto)
Detector	Autopeak	Autopeak	Autopeak	Autopeak
Trace setting	Maxhold	Maxhold	Maxhold	Maxhold
Total band width	300 MHz	560 MHz	40 MHz	5.04 GHz
Num of points per sweep[4]	60,000	60,000	60,000	60,000
Num sweeps[5]	3,000	4,500	10,000	10,000
Preamp	30 dB	30 dB	30 dB	30 dB
Attenuator	0 dB	0 dB	0 dB	0 dB
Vertical unit	dBµV	dBµV	dBµV	dBµV
Start Freq	100 MHz	400 MHz	960 MHz	0.96 GHz
Stop Freq	400 MHz	960 MHz	1 GHz	6 GHz
Antenna used	HL223	HL223	HL223	EMCO 3115

[4] Total bandwidth divided by 0.5 times the resolution bandwidth. The number of points was calculated once for the worst case and kept constant during all measurements.

[5] Using the required dwell time and the number of points per sweep the required total sweep time becomes 900 seconds. The number of sweeps was calculated to achieve the minimum required total sweep time. The number of sweeps was increased to ensure that sporadic emissions of the EUT are captured.

6 Results

The following figures (Figure 4 and Figure 5) show the results for the measurements described above. The measurements were corrected for cable loss and antenna factor as described in Appendix D using the antenna factors from Appendices A and B and the cable loss of Appendix C. The measurements were not corrected for background emissions.

Only measurement data for which the antennas were calibrated are shown, i.e., no data is shown for the frequencies between 100-200 MHz. As per RTCA/DO160G [1] section 21.3, the RF emissions between 2.400 GHz and 2.4835 GHz (the BLE frequency range) are not shown for that interval.

In both figures a spike in emissions is shown with a peak near 2,399.95 MHz. In both cases the spikes are below the Cat H spectrum mask. The spikes appear because the spectrum analyser takes measurements at approximately every 84 kHz with a 6 dB resolution bandwidth (RBW) of 1 MHz. When the spectrum analyser centre frequency is set to 2,399.95 MHz, the upper 6 dB corner frequency the RBW is 2,400.45 MHz which is inside the BLE frequency band. So, even though the spectrum analyser centre frequency is outside the BLE frequency band, it still measures some of the energy from the BLE band even though the energy is not transmitted outside of this band.

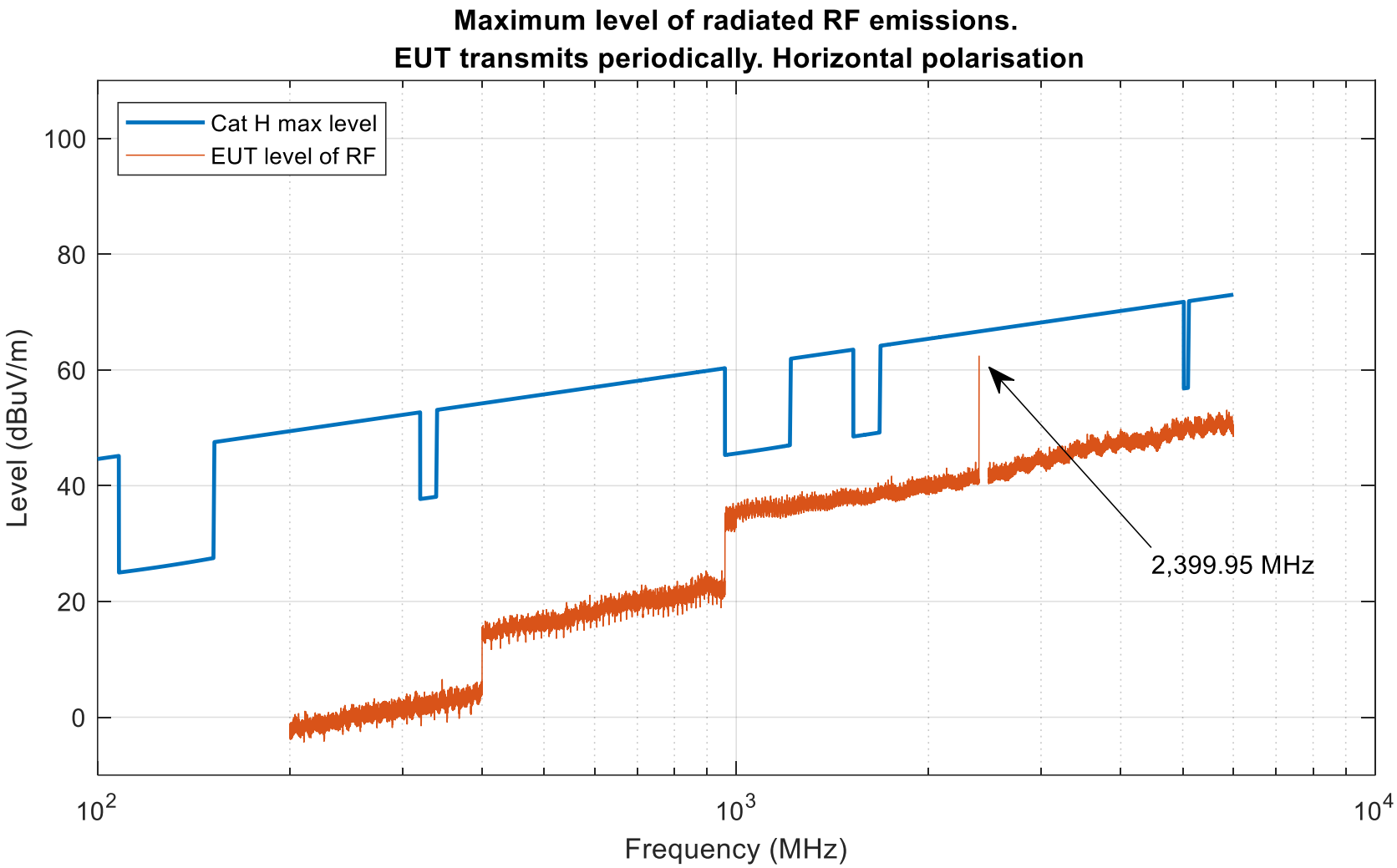

Figure 4 Measured radiated RF emissions of EUT. Horizontal polarisation. Also shown is the DO-160 Section 21 Cat H mask.

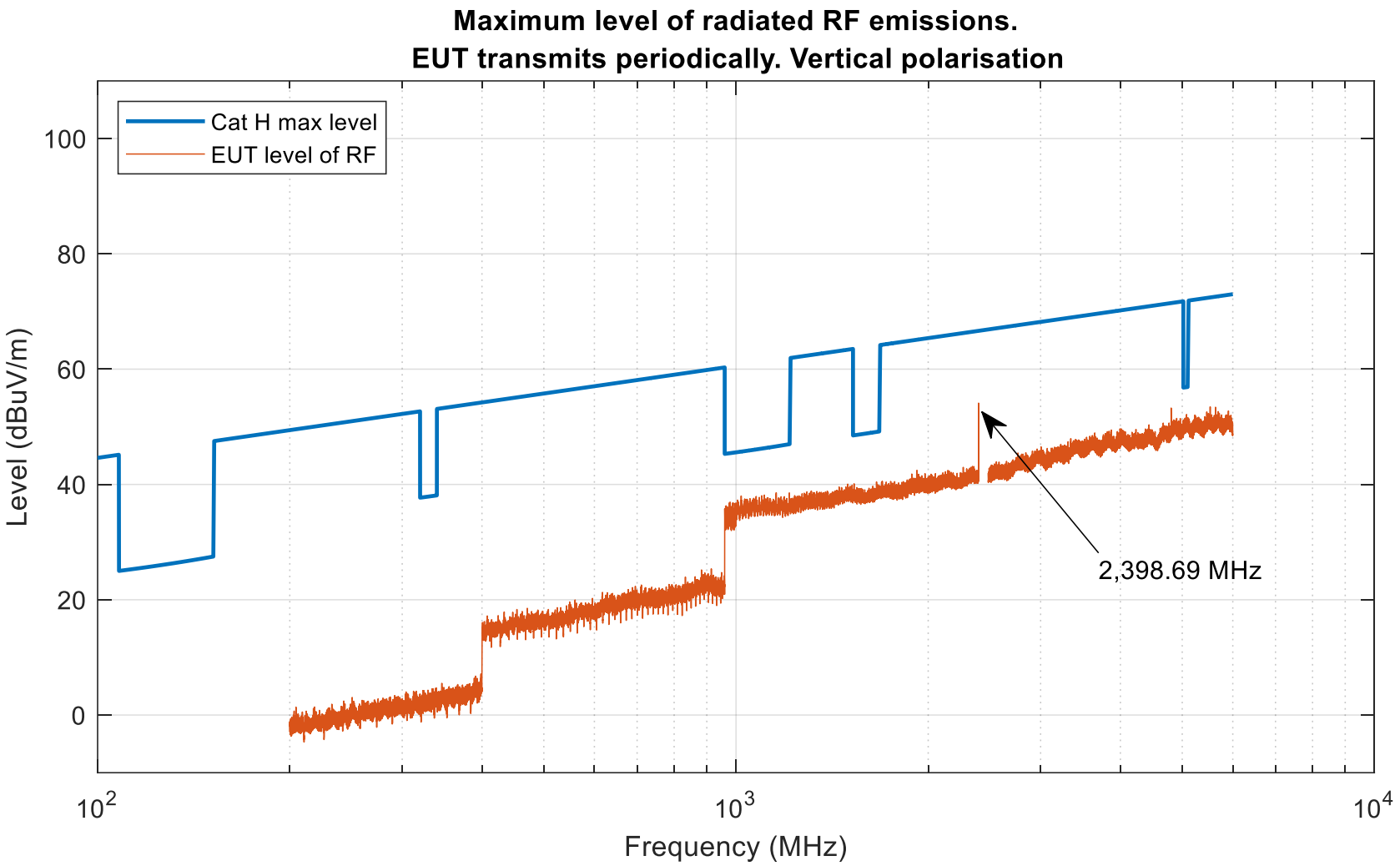

Figure 5 Measured radiated RF emissions of EUT. Vertical polarisation. Also shown is the DO-160 Section 21 Cat H mask.

7 Conclusions

The RF emissions of the EUT, a Core-TT tag model ‘PLT004’, are entirely below DO-160G section 21 Category H levels.

AC 91.21-1D [2] in section 10.3.2 states that “the device may use low-power wireless communication during flight… . The low-power emission limit is 100 mW EIRP… . Wireless communication standards which are limited to this level do not need to be analyzed for backdoor coupling. This includes Bluetooth (IEEE 802.15.1)”. As the Core-TT PLT004 uses Bluetooth Low Energy (IEEE 802.15.1) it complies with AC91.21-1D for use during flight for backdoor coupling.

8 References

[1] "Environmental Conditions and Test Procedures for Airborne Equipment," *RTCA/DO-160G*. RTCA Special Committee SC-35, 2010.

[2] "Advisory Circular No: 91.21-1D. Use of Portable Electronic Devices Aboard Aircraft." U.S. Department of Transportation Federal Aviation Administration, 2017.

Appendix A Log-Periodic Dipole Antenna HL223 calibration data

The HL223 is a Rohde & Schwarz linearly polarised Log-Periodic Dipole Antenna designed for general broadband transmitting and receiving application in the frequency range 200 to 1300 MHz.

The antenna was calibrated according to DIN 45003 on 21 June 1993. The calibrated antenna factor data were copied from the calibration report and are shown below in tabular and graphical form below. The calibration is within +/- 1 dB.

The SWR is smaller than 1.8 over the frequency range. The polarization decoupling is > 20 dB. The front to back ratio > 15 dB and > 20 dB from 400 MHz upward. The gain > 6 dBi.

Table 1 HL223 sn 832727/003 calibrated antenna factor

Frequency (MHz)	Antenna Factor (dB)
200	9.7
225	10.3
250	11.5
275	12.3
300	12.8
325	13.3
350	14.2
375	14.6
400	15.7
425	16.2
450	16.8
475	16.9
500	17.3
525	17.5
550	18.0
575	18.9
600	18.7
625	19.9
650	19.7
675	20.4
700	20.5
725	21.0
750	20.8
775	21.0
800	21.5
825	21.2
850	21.8
875	22.5
900	23.1
925	22.5
950	22.2
975	22.9
1000	22.6
1025	23.3
1050	23.6
1075	24.6
1100	25.5
1125	24.5
1150	23.5
1175	24.0
1200	24.3
1225	25.4
1250	26.4
1275	25.5
1300	25.0

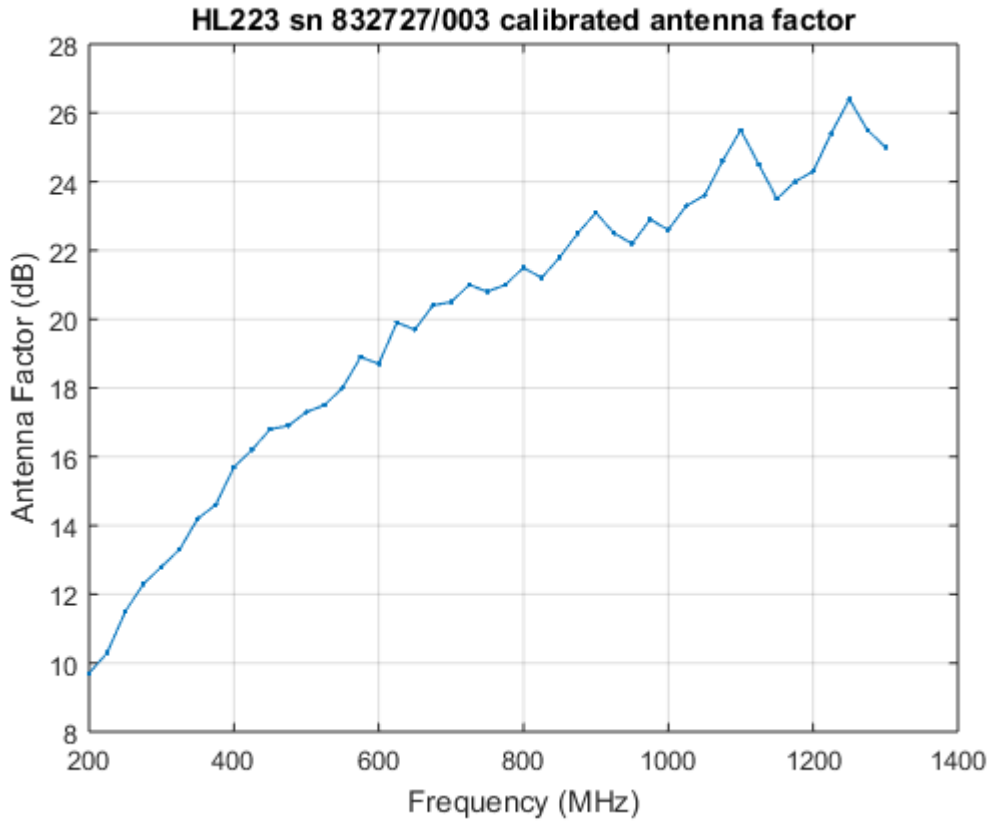

Figure 6 HL223 sn 832727/003 calibrated antenna factor

Appendix B Double Ridged Waveguide Horn 3115 calibration data

The 3115 is an EMCO double-ridged waveguide antenna designed for EMI measurements and specification compliance testing in the frequency range 1 to 18 GHz.

The antenna was calibrated according to SAE, ARP-958 – 1997 on 1 June 2001. The calibrated antenna factor data were copied from the calibration report and are shown below in tabular and graphical form. The calibration is within +/- 0.3 dB.

The VSWR is less than 3:1 over the frequency range and less than 2:1 from 2 GHz to 17 GHz. The polarization decoupling is > 20 dB.

Table 2 3115 sn 6454 calibrated antenna factor

1000	24.2
1500	25.6
2000	27.8
2500	28.6
3000	30.4
3500	31.7
4000	32.8
4500	32.7
5000	34.1
5500	34.4
6000	34.8
6500	35.1
7000	36.3
7500	37.4
8000	37.4
8500	37.8
9000	38.0
9500	37.9
10000	38.3
10500	38.3
11000	38.4
11500	39.1
12000	38.8
12500	38.5
13000	39.7
13500	40.4
14000	41.0
14500	40.5
15000	39.2
15500	37.8
16000	37.7
16500	39.4
17000	41.8
17500	45.4
18000	47.9

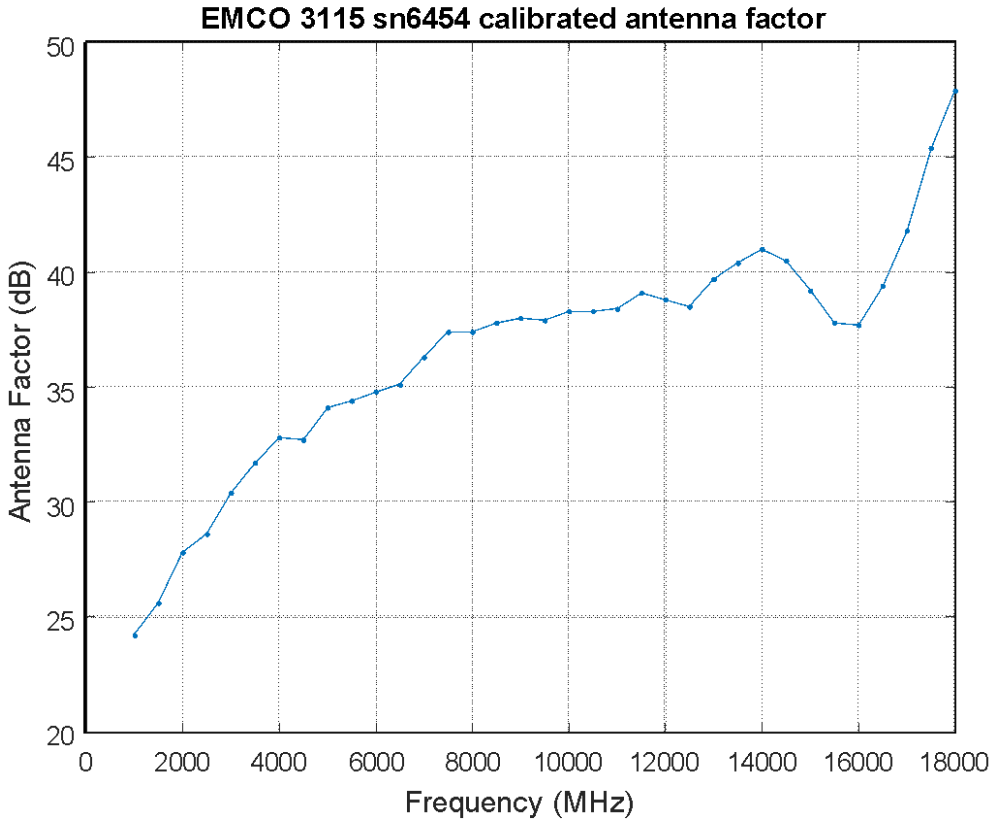

Figure 7 EMCO 3115 sn 6454 calibrated antenna factor

Appendix C Cable loss

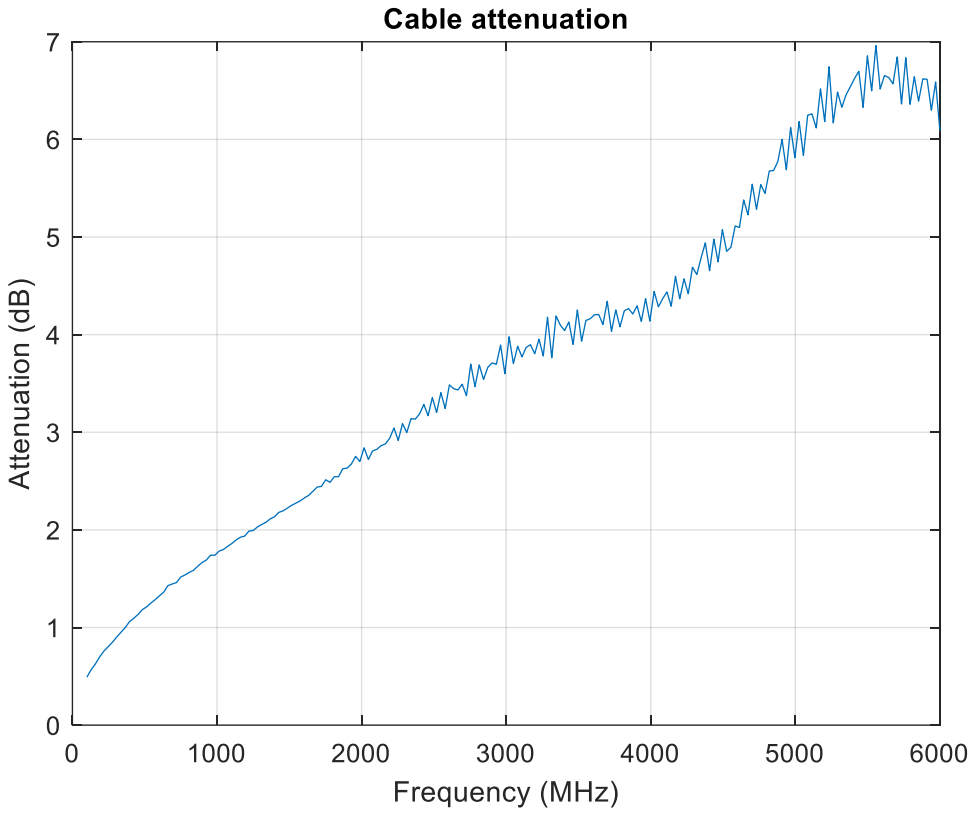

Figure 8 Cable attenuation (loss)

Appendix D Calculations

The EUT RF emissions produce an electric field at the measurement antenna which in turn produces a voltage at the input of the spectrum analyser. (The background RF emissions and spectrum analyser produce additional noise power at the spectrum analyser input which we assume to be much lower.) Hence, the voltage caused by the EUT emissions at the spectrum analyser is:

$$V_{SA} = V_{EUTatSA}$$

where the units are Volt.

As indicated above, the field strength at the antenna E_{Ant} $(\frac{V}{m})$ is converted into a voltage at the output terminals of the antenna. The conversion factor is the antenna factor of the antenna[6].

$$E_{Ant} = V_{Ant} \cdot AF$$

where V_{Ant} is the antenna voltage in V and AF is the antenna factor in $\frac{1}{m}$.

Expressed in logarithmic form:

$$E_{AntdB} = V_{AntdB} + AF_{dB}$$

with

$$E_{dB} = 20 \cdot log_{10}(E)$$

Note that if the antenna is at a distance from the EUT other than 1 metre, the field strength at 1 metre can be calculated as follows[7]:

$$E_{EUT} = E_{EUT_{Ant}} \cdot r$$

The voltage measured at the spectrum analyser is the antenna voltage attenuated by the cable.

$$V_{SAdB} = V_{AntdB} - L_{cabledB}$$

Combining the above we arrive at:

$$V_{EUTatSA} = V_{SA}$$

$$E_{EUTatAntdB} = V_{EUTatSAdB} + L_{cabledB} + AF_{dB}$$

$$E_{EUTdB} = E_{EUTAntdB} + 20 \cdot log_{10}(r)$$

[6] The antenna factor takes into account the loading of the antenna by 50 Ohm.

[7] Using spherical expansion, the field strength decreases inversely proportionally with distance; a doubling in distance will cause the field strength to halve.