Report on the Radio Testing

For

Lacuna Space

on

LS300

Report no. TRA-058206-47-03C

2023-03-29

Report Number: TRA-058206-47-03C
Issue: C

REPORT ON THE RADIO TESTING OF A
Lacuna Space
LS300
WITH RESPECT TO SPECIFICATION
FCC 47CFR 15.247

TEST DATE: 2022-12-09 to 2022-12-20

Tested by:		Steven Garwell
Written by:		Steven Garwell Radio Test Engineer
Approved by:		John Charters Department Manager - Radio
Date:	2023-03-29	

1 Revision Record

Issue Number	*Issue Date*	*Revision History*
A	2022-12-06	Original
B	2022-12-09	Contact details changed
C	2023-03-15	Technical corrections throughout document

2 Summary

TEST REPORT NUMBER:	TRA-058206-47-03C
WORKS ORDER NUMBER:	TRA-058206-01
PURPOSE OF TEST:	Certification
TEST SPECIFICATION:	47CFR15.247
EQUIPMENT UNDER TEST (EUT):	LS300
FCC IDENTIFIER:	2A8AP-LS300
EUT SERIAL NUMBER:	0012 (conducted), 0009 (radiated)
MANUFACTURER/AGENT:	Lacuna Space
ADDRESS:	R104 Rutherford Appleton Laboratory Harwell Campus Didcot OX11 0QX United Kingdom
CLIENT CONTACT:	Rob Spurret ☎ +447827828624 ✉ regulatory@lacuna.space
ORDER NUMBER:	LN-PO-042-22
TEST DATE:	2022-12-09 to 2022-12-20
TESTED BY:	Steven Garwell Element

2.1 Test Summary

Test Method and Description		*Requirement Clause 47CFR15*	*Applicable to this equipment*	*Result / Note*
Radiated spurious emissions (restricted bands of operation and cabinet radiation)		15.247 (d)	☒	*PASS*
AC power line conducted emissions		15.207	☐	*Note 1*
Occupied bandwidth		15.247 (a) (2)	☒	*PASS*
Conducted carrier power	Peak	15.247 (b) (3)	☒	*PASS*
	Max.		☐	
Out of band emissions		15.247 (d)	☒	*PASS*
Power spectral density		15.247 (e)	☒	*PASS*
Calculation of duty correction		-	☐	*Client Declaration*

Specific Note:

1. The EUT is a battery powered device.

General Notes:

The results contained in this report relate only to the items tested, in the condition at time of test, and were obtained in the period between the date of initial receipt of samples and the date of issue of the report.

The apparatus was set up and exercised using the configurations, modes of operation and arrangements defined in this report only. Any modifications made are identified in Section 8 of this report.

Particular operating modes, apparatus monitoring methods and performance criteria required by the standards tested to have been performed except where identified in Section 5.2 of this test report (Deviations from Test Standards).

3 Contents

4 Introduction

This report TRA-058206-47-03C presents the results of the Radio testing on a Lacuna Space, LS300 to specification 47CFR15 Radio Frequency Devices.

The testing was carried out for Lacuna Space by Element, at the address detailed below.

☐ Element Hull
Unit E
South Orbital Trading Park
Hedon Road
Hull
HU9 1NJ
UK

☒ Element Skelmersdale
Unit 1
Pendle Place
Skemersdale
West Lancashire
WN8 9PN
UK

This report details the configuration of the equipment, the test methods used and any relevant modifications where appropriate.

All test and measurement equipment under the control of the laboratory and requiring calibration is subject to an established programme and procedures to control and maintain measurement standards. The quality management system meets the principles of ISO 9001, and has quality control procedures for monitoring the validity of tests undertaken. Records and sufficient detail are retained to establish an audit trail of calibration records relating to its test results for a defined period. Under control of the established calibration programme, key quantities or values of the test & measurement instrumentation are within specification and comply with the relevant traceable internationally recognised and appropriate standard specifications, which are UKAS calibrated as such where these properties have a significant effect on results. Participation in inter-laboratory comparisons and proficiency testing ensures satisfactory correlation of results conform to Elements own procedures, as well as statistical techniques for analysis of test data providing the appropriate confidence in measurements.

Throughout this report EUT denotes equipment under test.

FCC Site Listing:

The test laboratory is accredited for the above sites under the US-UK MRA,

Designation number(s):

Element Hull	UK2007
Element Skelmersdale	UK2020

IC Registration Numbers:

Element Hull	3483A
Element North West	3930B

The test site requirements of ANSI C63.4-2014 are met up to 1GHz.

The test site SVSWR requirements of CISPR 16-1-4:2010 are met over the frequency range 1 GHz to 18 GHz.

5 Test Specifications

5.1 Normative References

- FCC 47 CFR Ch. I – Part 15 – Radio Frequency Devices.
- ANSI C63.10-2013 – American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices.
- ANSI C63.4-2014 – American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.

5.2 Deviations from Test Standards

There were no deviations from the test standard.

6 Glossary of Terms

§	denotes a section reference from the standard, not this document
AC	Alternating Current
ANSI	American National Standards Institute
BW	bandwidth
C	Celsius
CFR	Code of Federal Regulations
CW	Continuous Wave
dB	decibel
dBm	dB relative to 1 milliwatt
DC	Direct Current
DSSS	Direct Sequence Spread Spectrum
EIRP	Equivalent Isotropically Radiated Power
ERP	Effective Radiated Power
EUT	Equipment under Test
FCC	Federal Communications Commission
FHSS	Frequency Hopping Spread Spectrum
Hz	hertz
IC	Industry Canada
ITU	International Telecommunication Union
LBT	Listen before Talk
m	metre
max	maximum
MIMO	Multiple Input and Multiple Output
min	minimum
MRA	Mutual Recognition Agreement
N/A	Not Applicable
PCB	Printed Circuit Board
PDF	Portable Document Format
Pt-mpt	Point-to-multipoint
Pt-pt	Point-to-point
RF	Radio Frequency
RH	Relative Humidity
RMS	Root Mean Square
Rx	receiver
s	second
SVSWR	Site Voltage Standing Wave Ratio
Tx	transmitter
UKAS	United Kingdom Accreditation Service
V	volt
W	watt
Ω	ohm

7 Equipment under Test

7.1 EUT Identification

- Name: LS300
- Serial Number: 0012 (conducted), 0009 (radiated)
- Model Number: LS300-915-A
- Software Revision: LSM Ver 0.10.0
- Build Level / Revision Number: Version 2.1

7.2 System Equipment

Equipment listed below forms part of the overall test setup and is required for equipment functionality and/or monitoring during testing. The compliance levels achieved in this report relate only to the EUT and not items given in the following list.

- *Laptop - Dell Inspiron P114G*

7.3 EUT Mode of Operation

The EUT was transmitting a modulated carrier on the required frequencies for the duration of the test, programming was performed using customer supplied test scripts.

7.4 EUT Radio Parameters

7.4.1 General

Frequencies of operation:	902 MHz – 928 MHz
Modulation type:	LoRa
Occupied channel bandwidth:	500 kHz
Declared output power(s):	≤ 23 dBm
Nominal Supply Voltage:	4.5 Vdc

7.4.2 Antennas

Type:	Integrated RHCP patch
Frequency range:	902 MHz to 908 MHz
Gain:	1.75 dBi Peak
Connector type:	Integrated

7.5 EUT Description

The EUT is a Wireless satellite terminal utilising a Lora modulation scheme the EUT has an integrated multi-band circularly polarized antenna system, See datasheet in appendix A.

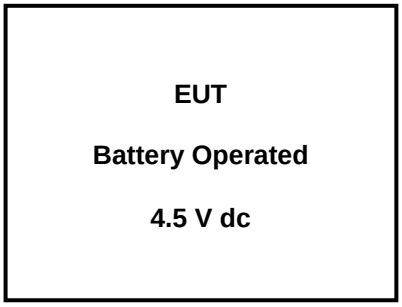
8 Modifications

No modifications were performed during this assessment.

9 EUT Test Setup

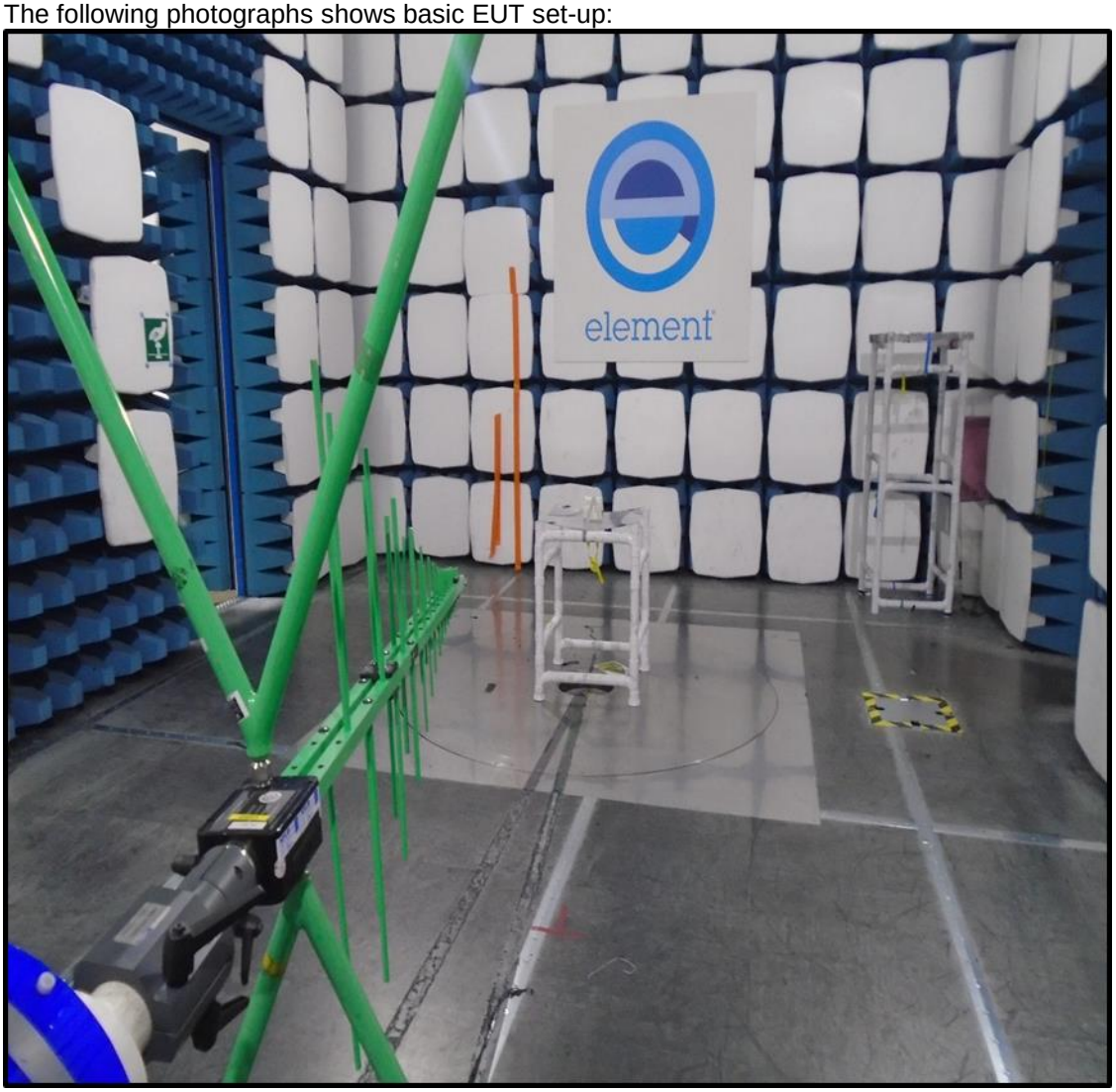
9.1 Block Diagram

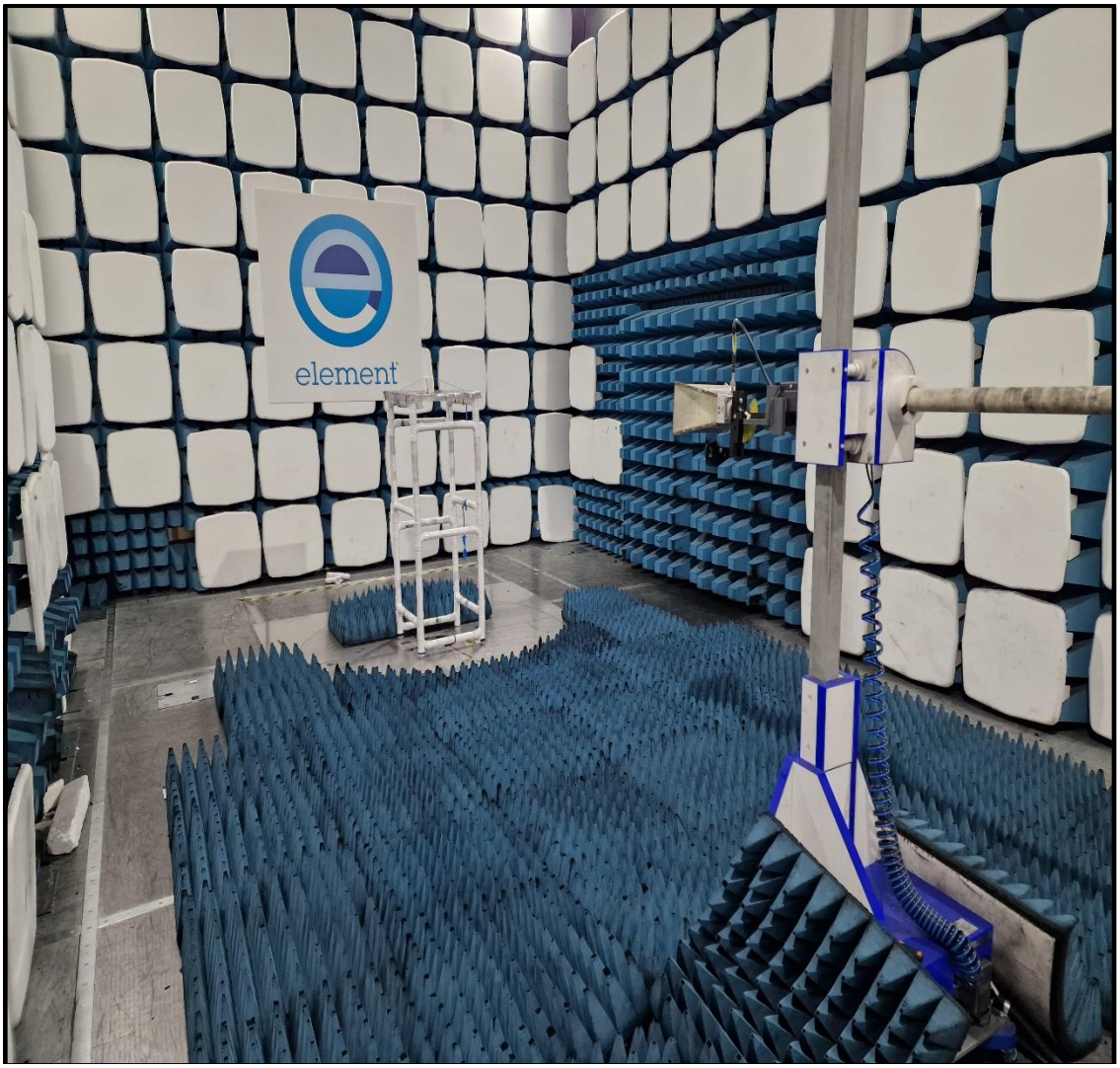
The following diagram shows basic EUT interconnections with cable type and cable lengths identified:



9.2 General Set-up Photograph

The following photographs shows basic EUT set-up:





9.3 Measurement software

Where applicable, the following software was used to perform measurements contained within this report.

Element Emissions R5
Element Transmitter Bench Test
ETS Lindgren EMPower V1.0.4.2

General Technical Parameters

9.4 Normal Conditions

The EUT was tested under the normal environmental conditions of the test laboratory, except where otherwise stated. The normal power source applied was 4.5 V dc from 3 AA Alkaline batteries.

9.5 Varying Test Conditions

There are no specific frequency stability requirements for the type of device. The results contained in this report demonstrate that the occupied bandwidth is contained within the authorised band and the manufacturer has declared sufficient frequency stability (refer to section 7.4).

Variation of supply voltage is required to ensure stability of the declared output power. During carrier power testing the following variations were made:

	Category	***Nominal***	***Variation***
☐	Mains	110 Vac +/-2 %	85 % and 115 %
☒	Battery	New battery	N/A

10 Radiated emissions

10.1 Definitions

Spurious emissions
Emissions on a frequency or frequencies, which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions.

Restricted bands
A frequency band in which intentional radiators are permitted to radiate only spurious emissions but not fundamental signals.

10.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	SK03 Radio Chamber / Chamber 1
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.5 and 6.6
EUT Frequencies Measured:	903 MHz, 915 MHz & 927 MHz
Deviations from Standard:	None
Measurement BW:	30 MHz to 1 GHz: 120 kHz; Above 1 GHz: 1 MHz
Measurement Detector:	Up to 1 GHz: quasi-peak; Above 1 GHz: RMS average and Peak

Environmental Conditions (Normal Environment)

Temperature: 19 °C	+15 ºC to +35 ºC (as declared)
Humidity: 60 % RH	20 % RH to 75 % RH (as declared)
Supply: 4.5 Vdc	4.5 Vdc (as declared)

10.3 Test Limit

Unwanted emissions that fall within the restricted frequency bands shall comply with the limits specified:

General Field Strength Limits for License-Exempt Transmitters at Frequencies above 30 MHz

Frequency (MHz)	*Field Strength (µV/m at 3 m)*	*Field Strength (dBµV/m at 3 m)*
30 to 88	100	40.0
88 to 216	150	43.5
216 to 960	200	46.0
Above 960	500	54.0

On frequencies below or equal to 1000 MHz, the limits shown are based on measuring equipment employing a CISPR quasi-peak detector function. On frequencies above 1000 MHz, the radiated emission limits are based on the use of measurement instrumentation employing an average detector function. The limit on peak radio frequency emissions is 20 dB above the maximum permitted average emission limit.

10.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure i, the emissions from the EUT were measured on a spectrum analyzer / EMI receiver.

Radiated electromagnetic emissions from the EUT are checked first by preview scans. Preview scans for all spectrum and modulation characteristics are checked, using a peak detector and where applicable worst-case determined for function, operation, orientation, etc. for both vertical and horizontal polarisations. Pre-scan plots are shown with a peak detector and 100 kHz RBW.

If the EUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in ANSI C63.10 are followed. Alternatively, a layout closest to normal use (as declared by the provider) is employed, (see EUT setup photographs for more detail).

Emissions between 30 MHz and 1 GHz are measured using calibrated broadband antennas. Emissions above 1 GHz are characterized using standard gain horn antennas. Pre-amplifiers and filters are used where required. Care is taken to ensure that test receiver resolution bandwidth, video bandwidth and detector type(s) meet the regulatory requirements.

For both horizontal and vertical polarizations, the EUT is then rotated through 360 degrees in azimuth until the highest emission is detected. At the previously determined azimuth the test antenna is raised and lowered from 1 to 4 m in height until a maximum emission level is detected, this maximum value is recorded.

Power values measured on the test receiver / analyzer are converted to field strength, FS, in dBµV/m at the regulatory distance, using:

$$FS = PR + CL + AF – PA + DC – CF$$

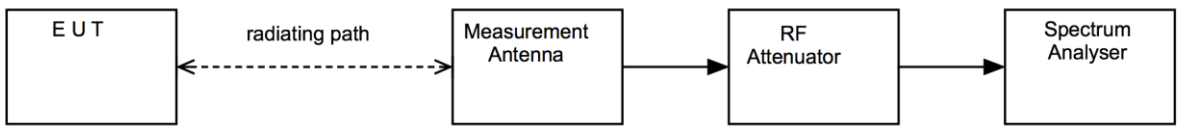
$$Factor = CL + AF - PA$$

Where,

PR is the power recorded on the receiver / spectrum analyzer in dBµV;
CL is the cable loss in dB;
AF is the test antenna factor in dB/m;
PA is the pre-amplifier gain in dB (where used);
DC is the duty correction factor in dB (where used, e.g. harmonics of pulsed fundamental);
CF is the distance factor in dB (where measurement distance different to limit distance);

This field strength value is then compared with the regulatory limit.

Figure i Test Setup

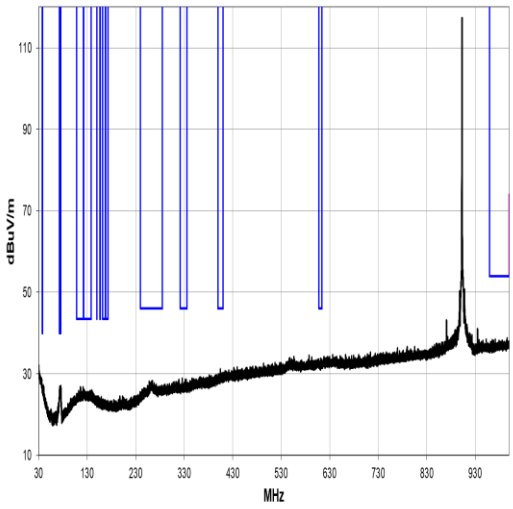


10.5 Test Equipment

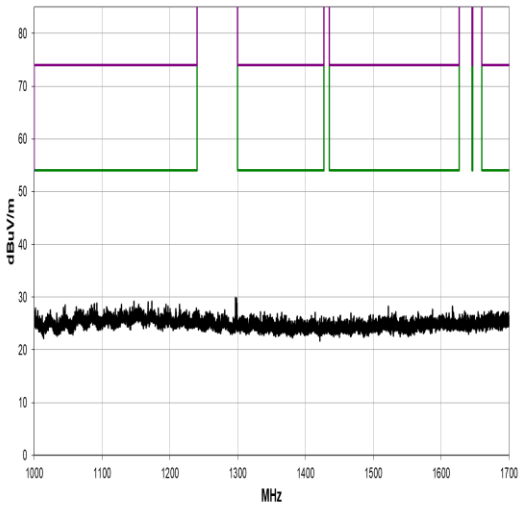
Equipment Type	*Manufacturer*	*Equipment Description*	*Element No*	*Due For Calibration*
Radio Chamber - PP	Rainford EMC	ATS	REF940	2023-11-06
Radiated Test Software	Element	Emissions R5	REF9000	Cal not required
Spectrum Analyser	R&S	ESR 7	U727	2023-04-27
Spectrum Analyser	R&S	FSU46	REF910	2022-12-22
Bilog	Chase	CBL611/A	L290	2023-03-24
PreAmp	Watkins Johnson	6201-69	U372	2023-03-01
1-18GHz Horn	EMCO	3115	L139	2024-07-01
Pre Amp	Agilent	8449B	U457	2023-01-22
High Pass Filter	MiniCircuits	VHF-1500+	U519	2023-02-03

10.6 Test Results

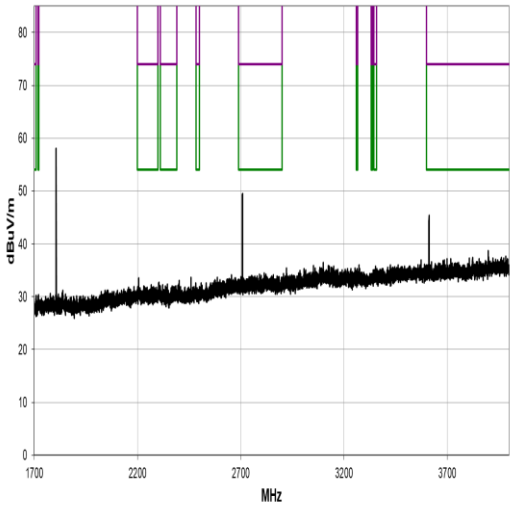
Frequency: 903.0 MHz; Bandwidth: 500 kHz



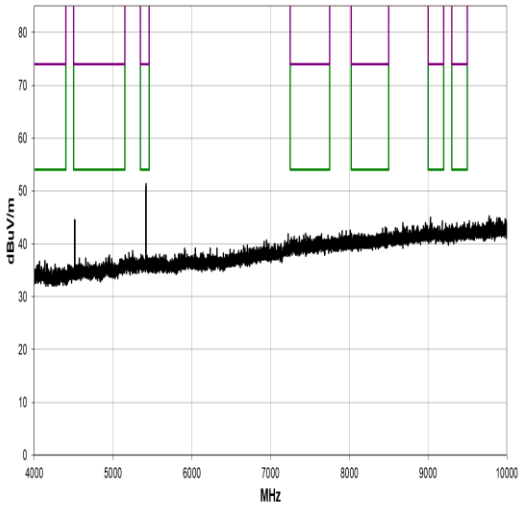
30 MHz to 1 GHz



1 GHz to 1.7 GHz



1.7 GHz to 4 GHz

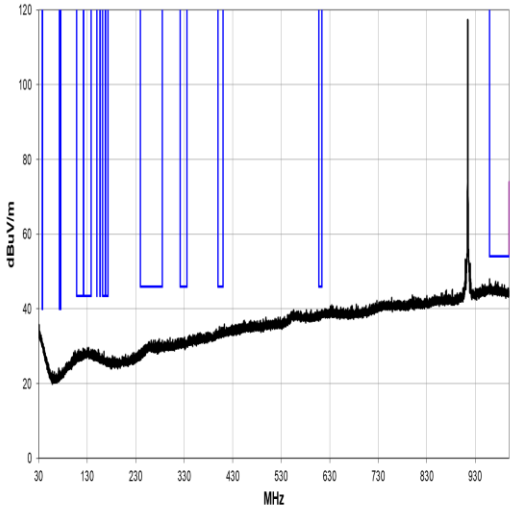


4 GHz to 10 GHz

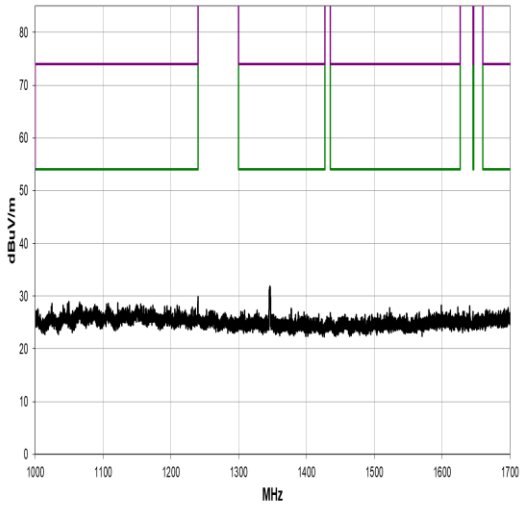
Freq (MHz)	Amplitude (dBuV)	Factor (dB/m)	Antenna Height (meters)	Azimuth (degrees)	Test Distance (meters)	External Attenuation (dB)	Polarity/ Transducer Type	Detector	Distance Adjustment (dB)	Adjusted (dBuV/m)	Spec. Limit (dBuV/m)	Compared to Spec. (dB)
2709.017	45.8	-0.7	1.52	131.9	3.0	0.0	Horz	AV	0.0	45.1	54.0	-8.9

Freq (MHz)	Amplitude (dBuV)	Factor (dB/m)	Antenna Height (meters)	Azimuth (degrees)	Test Distance (meters)	External Attenuation (dB)	Polarity/ Transducer Type	Detector	Distance Adjustment (dB)	Adjusted (dBuV/m)	Spec. Limit (dBuV/m)	Compared to Spec. (dB)
5418.092	41.7	4.9	1.11	234.1	3.0	0.0	Vert	AV	0.0	46.6	54.0	-7.4
5419.167	39.3	4.9	2.18	275.0	3.0	0.0	Horz	AV	0.0	44.2	54.0	-9.8
5419.392	53.0	4.9	1.11	234.1	3.0	0.0	Vert	PK	0.0	57.9	74.0	-16.1
5419.275	52.3	4.9	2.18	275.0	3.0	0.0	Horz	PK	0.0	57.2	74.0	-16.8
4515.767	34.2	2.9	1.32	314.8	3.0	0.0	Horz	AV	0.0	37.1	54.0	-16.9
4513.942	33.7	2.9	1.5	52.9	3.0	0.0	Vert	AV	0.0	36.6	54.0	-17.4

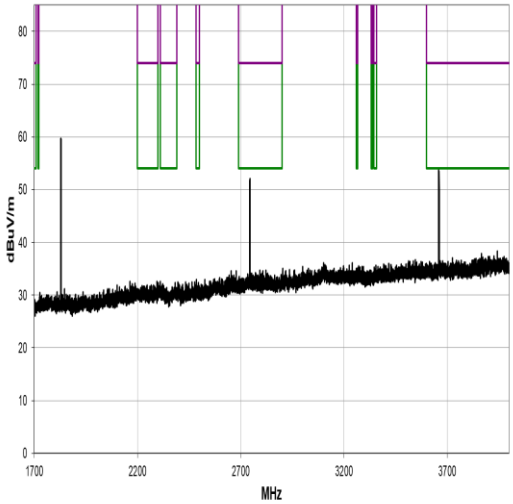
Frequency: 915.0 MHz; Bandwidth: 500 kHz



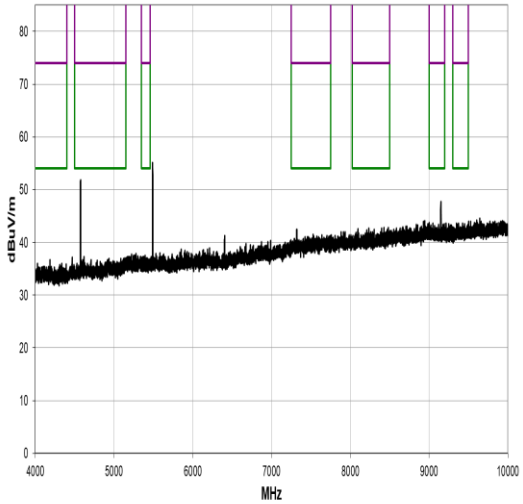
30 MHz to 1 GHz



1 GHz to 1.7 GHz



1.7 GHz to 4 GHz

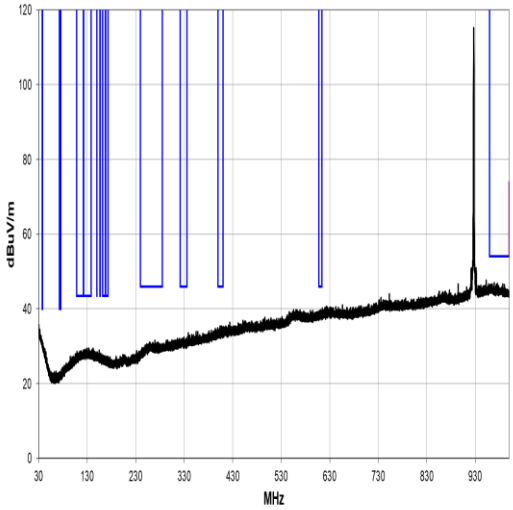


4 GHz to 10 GHz

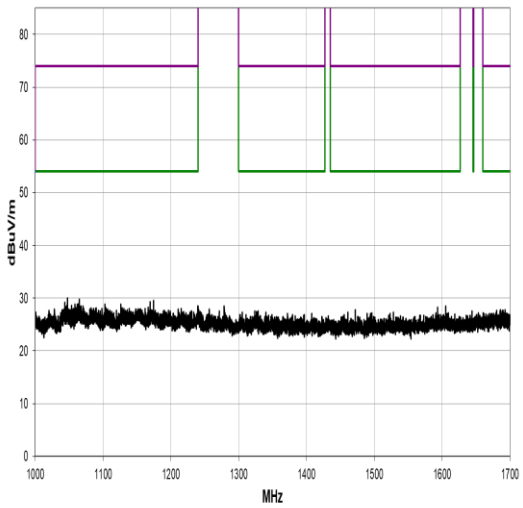
Freq (MHz)	Amplitude (dBuV)	Factor (dB/m)	Antenna Height (meters)	Azimuth (degrees)	Test Distance (meters)	External Attenuation (dB)	Polarity/ Transducer Type	Detector	Distance Adjustment (dB)	Adjusted (dBuV/m)	Spec. Limit (dBuV/m)	Compared to Spec. (dB)
2745.100	49.6	-0.5	1.12	287.9	3.0	0.0	Vert	AV	0.0	49.1	54.0	-4.9
3659.917	45.9	2.2	1.5	358.8	3.0	0.0	Horz	AV	0.0	48.1	54.0	-5.9
3660.708	44.0	2.2	1.14	234.0	3.0	0.0	Vert	AV	0.0	46.2	54.0	-7.8
2744.308	45.5	-0.5	1.31	14.9	3.0	0.0	Horz	AV	0.0	45.0	54.0	-9.0

Freq (MHz)	Amplitude (dBuV)	Factor (dB/m)	Antenna Height (meters)	Azimuth (degrees)	Test Distance (meters)	External Attenuation (dB)	Polarity/ Transducer Type	Detector	Distance Adjustment (dB)	Adjusted (dBuV/m)	Spec. Limit (dBuV/m)	Compared to Spec. (dB)
9152.042	32.9	9.6	1.81	189.0	3.0	0.0	Horz	AV	0.0	42.5	54.0	-11.5
9148.375	48.0	9.6	1.81	189.0	3.0	0.0	Horz	PK	0.0	57.6	74.0	-16.4

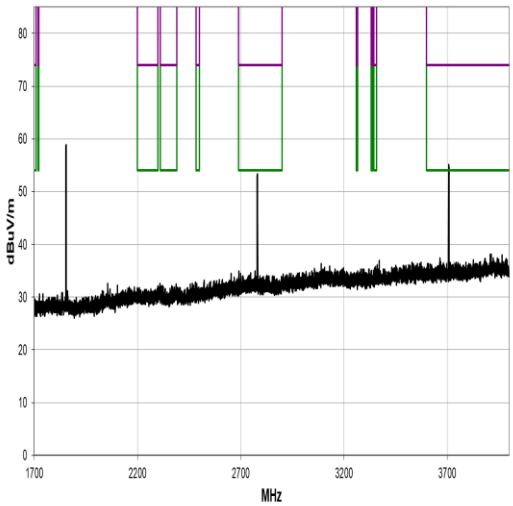
Frequency: 927.0 MHz; Bandwidth: 500 kHz



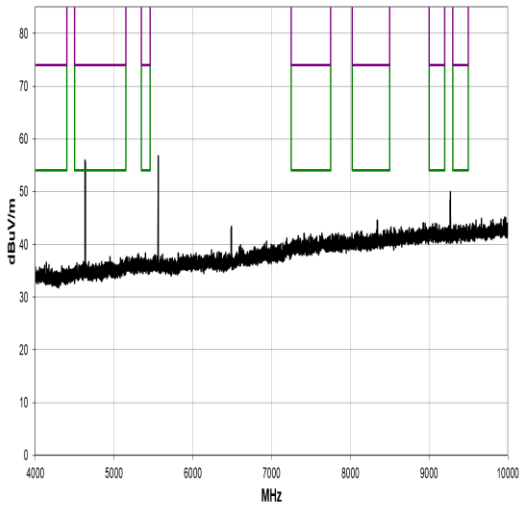
30 MHz to 1 GHz



1 GHz to 1.7 GHz



1.7 GHz to 4 GHz



4 GHz to 10 GHz

Freq (MHz)	Amplitude (dBuV)	Factor (dB/m)	Antenna Height (meters)	Azimuth (degrees)	Test Distance (meters)	External Attenuation (dB)	Polarity/ Transducer Type	Detector	Distance Adjustment (dB)	Adjusted (dBuV/m)	Spec. Limit (dBuV/m)	Compared to Spec. (dB)
2780.983	50.7	-0.4	1.08	296.0	3.0	0.0	Vert	AV	0.0	50.3	54.0	-3.7
3707.600	47.4	2.3	1.4	352.9	3.0	0.0	Horz	AV	0.0	49.7	54.0	-4.3
3708.708	46.7	2.3	1.02	290.8	3.0	0.0	Vert	AV	0.0	49.0	54.0	-5.0
2780.292	46.7	-0.4	1.12	36.2	3.0	0.0	Horz	AV	0.0	46.3	54.0	-7.7
3708.500	56.5	2.3	1.02	290.8	3.0	0.0	Vert	PK	0.0	58.8	74.0	-15.2
3708.183	55.8	2.3	1.4	352.9	3.0	0.0	Horz	PK	0.0	58.1	74.0	-15.9
2780.742	56.6	-0.4	1.12	36.2	3.0	0.0	Horz	PK	0.0	56.2	74.0	-17.8
2780.767	56.6	-0.4	1.08	296.0	3.0	0.0	Vert	PK	0.0	56.2	74.0	-17.8

Freq (MHz)	Amplitude (dBuV)	Factor (dB/m)	Antenna Height (meters)	Azimuth (degrees)	Test Distance (meters)	External Attenuation (dB)	Polarity/ Transducer Type	Detector	Distance Adjustment (dB)	Adjusted (dBuV/m)	Spec. Limit (dBuV/m)	Compared to Spec. (dB)
4635.175	45.7	3.3	1.14	316.0	3.0	0.0	Horz	AV	0.0	49.0	54.0	-5.0
4636.200	42.0	3.3	1.41	245.9	3.0	0.0	Vert	AV	0.0	45.3	54.0	-8.7
8343.117	31.2	8.9	1.03	289.0	3.0	0.0	Vert	AV	0.0	40.1	54.0	-13.9
8344.058	30.6	8.9	1.94	170.0	3.0	0.0	Horz	AV	0.0	39.5	54.0	-14.5
4635.350	55.8	3.3	1.41	245.9	3.0	0.0	Vert	PK	0.0	59.1	74.0	-14.9
4634.533	55.4	3.3	1.14	316.0	3.0	0.0	Horz	PK	0.0	58.7	74.0	-15.3
8344.850	46.6	8.9	1.03	289.0	3.0	0.0	Vert	PK	0.0	55.5	74.0	-18.5
8344.967	45.8	8.9	1.94	170.0	3.0	0.0	Horz	PK	0.0	54.7	74.0	-19.3

11 Occupied Bandwidth

11.1 Definition

The emission bandwidth (x dB) is defined as the frequency range between two points, one above and one below the carrier frequency, at which the spectral density of the emission is attenuated x dB below the maximum in-band spectral density of the modulated signal.

The 99% emission bandwidth is defined as the frequency range between two points, one above and the other below the carrier frequency, within which 99% of the total transmitted power of the fundamental transmitted emission is contained.

11.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.8
EUT Frequencies Measured:	903 MHz, 915 MHz, 927 MHz
EUT Channel Bandwidths:	500 kHz
EUT Test Modulations:	Internal pattern generation
Deviations From Standard:	None
Measurement BW:	100 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	300 kHz
Measurement Span: (requirement 2 to 5 times OBW)	1.5 MHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 46 % RH	20 % RH to 75 % RH (as declared)
Supply: 4.5 V dc	4.5 V dc (as declared)

11.3 Test Limit

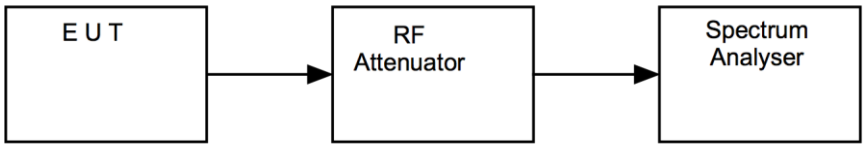
The minimum -6 dB bandwidth shall be at least 500 kHz.

11.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure iii, the bandwidth of the EUT was measured on a spectrum analyser.

The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst-case configuration in each bandwidth.

Figure iii Test Setup

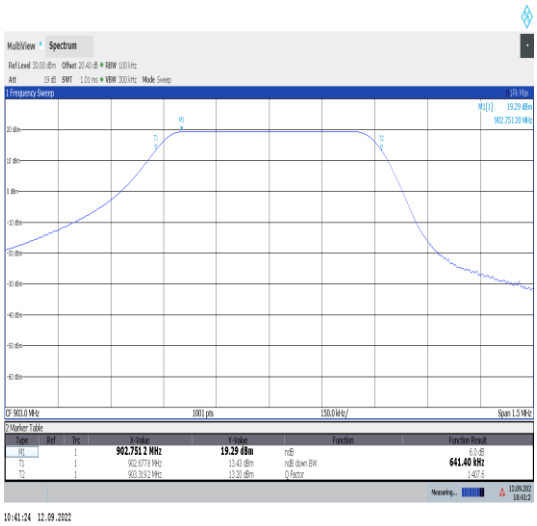


11.5 Test Equipment

Equipment Type	*Manufacturer*	*Equipment Description*	*Element No*	*Due For Calibration*
Spectrum Analyser	R&S	FSW 43	U728	2023-04-26
Attenuator	AtlanTecRF Microwave	20dB SMA Attenuator	U632	Cal in use

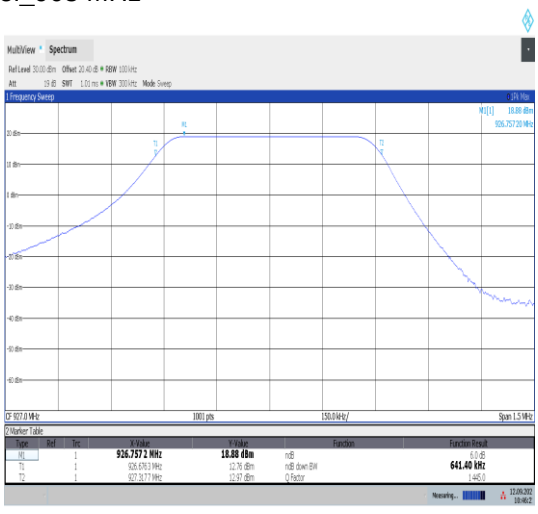
11.6 Test Results - 6 dB Bandwidth

Bandwidth Type: 6 dB; Modulation: d-m2_500; Power setting: 20				
Frequency (MHz)	***F_L (MHz)***	***F_H (MHz)***	***Bandwidth (kHz)***	***Result***
903	902.6778	903.3192	641.4	PASS
915	914.6778	915.3192	641.4	PASS
927	926.6763	927.3177	641.4	PASS



Bottom Channel_903 MHz

Middle Channel_ 915 MHz



Top Channel_927 MHz

12 Maximum conducted average output power

12.1 Definition

The maximum average conducted output power uses trace averaging with the EUT at full power throughout each sweep.

12.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.9.2.2.2
EUT Frequencies Measured:	903 MHz, 915 MHz, 927 MHz
EUT Channel Bandwidths:	500 kHz
Deviations From Standard:	None
Measurement BW:	10 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	30 kHz
Measurement Detector:	RMS Average
Voltage Extreme Environment Test Range:	Mains Power = 85 % and 115 % of Nominal (FCC only requirement); Battery Power = new battery.

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 46 % RH	20 % RH to 75 % RH (as declared)

12.3 Test Limit

FCC:

For systems employing digital modulation techniques operating in the bands 902 to 928 MHz, 2400 to 2483.5 MHz and 5725 to 5850 MHz, the maximum peak conducted output power shall not exceed 1 W.

ISED:

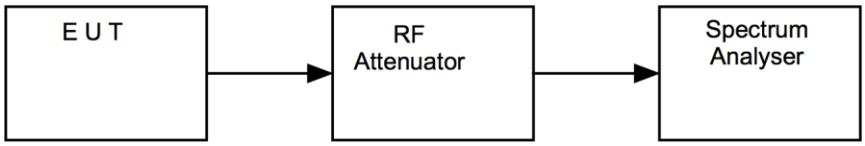
For systems employing digital modulation techniques operating in the bands 902 to 928 MHz, 2400 to 2483.5 MHz and 5725 to 5850 MHz, the maximum peak conducted output power shall not exceed 1 W. The EIRP shall not exceed 4 W.

12.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure iv, the carrier power was measured using the trace averaging method as described in ANSI C63 10 Clause 11.9.2.2.2 AVGSA-1.

The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst-case configuration in each bandwidth.

Figure iv Test Setup

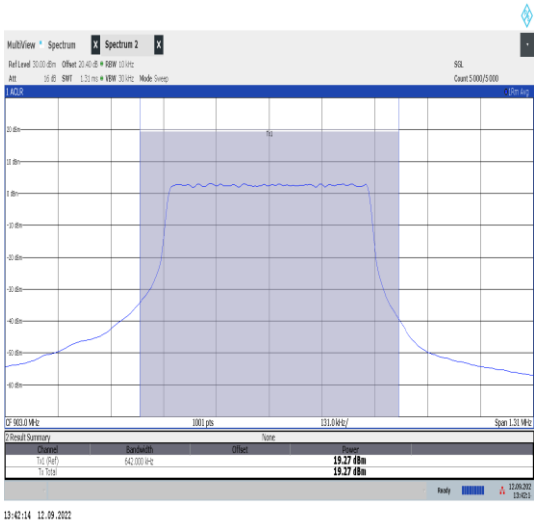


12.5 Test Equipment

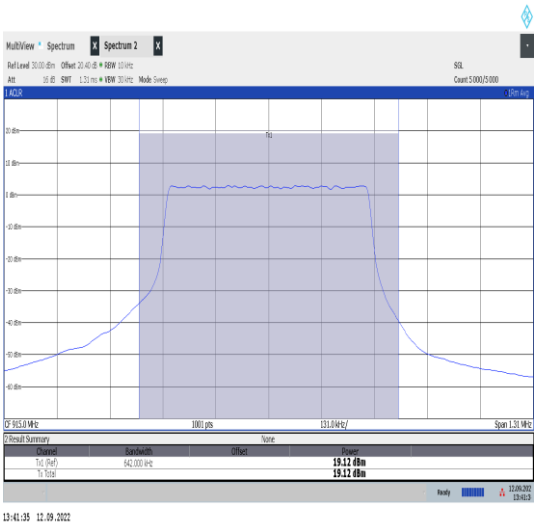
Equipment Type	*Manufacturer*	*Equipment Description*	*Element No*	*Due For Calibration*
Spectrum Analyser	R&S	FSW 43	U728	2023-04-26
Attenuator	AtlanTecRF Microwave	20dB SMA Attenuator	U632	Cal in use

12.6 Test Results

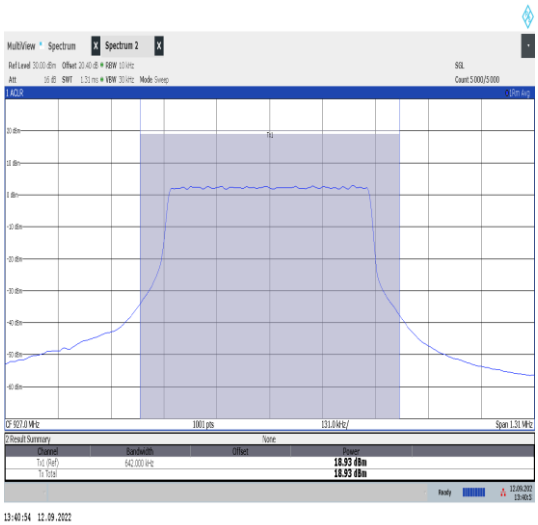
Modulation: d-m2_500; Power setting: 20					
Channel Frequency (MHz)	***Analyzer Level (dBm)***	***Maximum average conducted output power (W)***	***Antenna gain (dBi)***	***E.I.R.P. (W)***	***Result***
902	19.27	0.0845	1.75	0.1265	PASS
915	19.12	0.0817	1.75	0.1222	PASS
927	18.93	0.0782	1.75	0.1169	PASS



Bottom Channel



Middle Channel



Top Channel

Note: Measurement method used - AVGSA-1

13 Out-of-band and conducted spurious emissions

13.1 Definition

Out-of-band emission.
Emission on a frequency or frequencies immediately outside the necessary bandwidth that results from the modulation process but excluding spurious emissions.

Spurious emission.
Emission on a frequency or frequencies that are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products, and frequency conversion products, but exclude out-of-band emissions.

13.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.11
EUT Frequencies Measured:	903 MHz, 915 MHz, 927 MHz
EUT Channel Bandwidths:	500 kHz
Deviations From Standard:	None
Measurement BW:	100 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	300 kHz
Measurement Detector:	Peak
Measurement Range:	30 MHz to 10 GHz

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 46 % RH	20 % RH to 75 % RH (as declared)
Supply: 4.5 V dc	4.5 V dc (as declared)

13.3 Test Limit

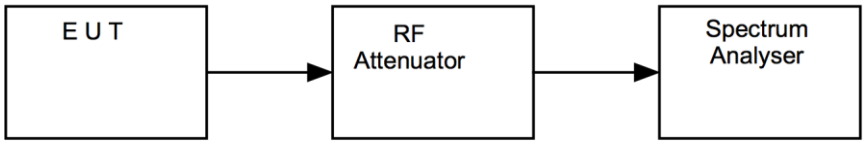
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in FCC 47CFR15.209(a) / RSS-Gen is not required.

13.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure v, the emissions from the EUT were measured on a spectrum analyser.

The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst case configuration in each bandwidth.

Figure v Test Setup

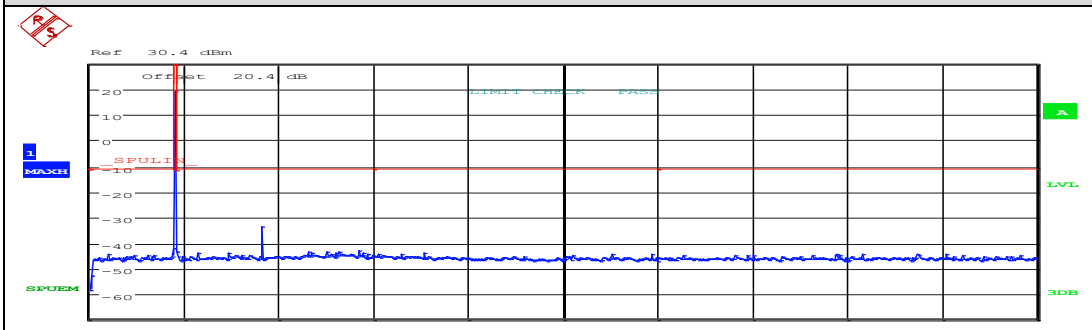


13.5 Test Equipment

Equipment Type	*Manufacturer*	*Equipment Description*	*Element No*	*Due For Calibration*
Spectrum Analyser	R&S	FSW 43	U728	2023-04-26
Attenuator	AtlanTecRF Microwave	20dB SMA Attenuator	U632	Cal in use

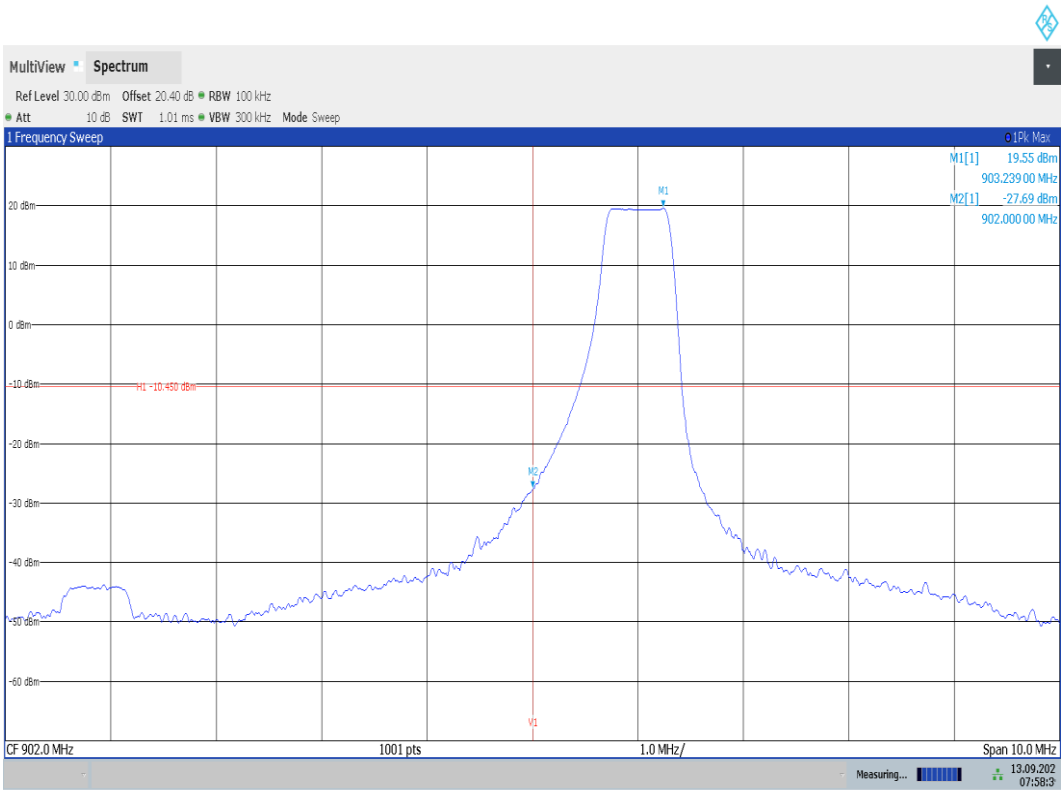
13.6 Test Results

Frequency: 902 MHz; Modulation: d-m2_500; Power Setting: 20



Start [Hz]	Stop [Hz]	RBW [Hz]	Freq [Hz]	PwrAbs [dBm]	Δ Limit [dB]
9.000 k	150.000 k	1.00 k	9.000000 k	-58.71	-48.06
150.000 k	30.000 M	10.00 k	176.865000 k	-52.93	-42.28
30.000 M	902.000 M	100.00 k	901.389600 M	-42.22	-31.57
902.000 M	928.000 M	100.00 k	902.813800 M	19.34	-10.66
928.000 M	3.000 G	100.00 k	1.805906 G	-33.90	-23.25
3.000 G	6.000 G	100.00 k	3.529200 G	-43.99	-33.34
6.000 G	10.000 G	100.00 k	7.883200 G	-44.57	-33.92

Date: 13.SEP.2022 08:58:49



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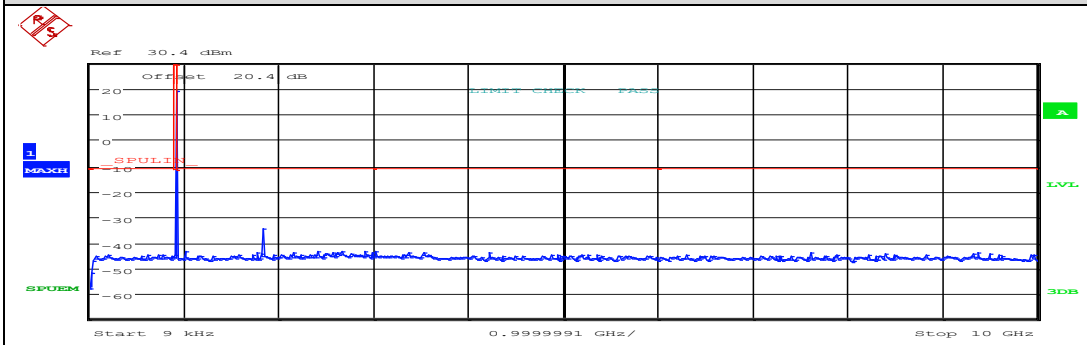
Lower conducted band edge

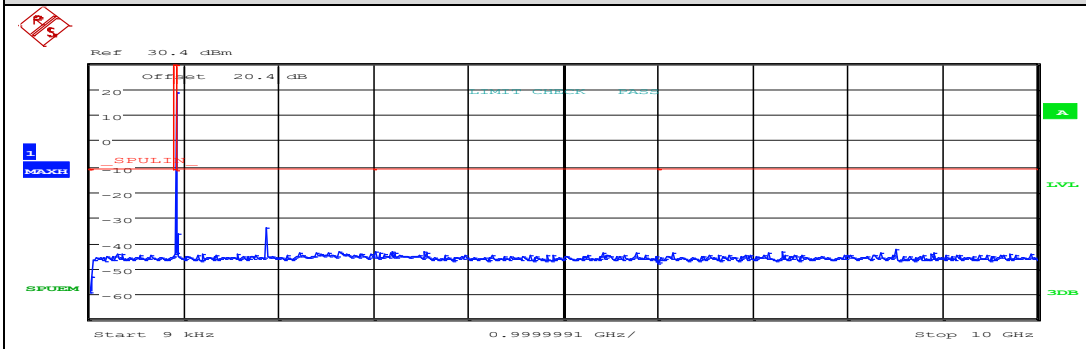
Frequency: 915 MHz; Modulation: d-m2_500; Power Setting: 20



Start [Hz]	Stop [Hz]	RBW [Hz]	Freq [Hz]	PwrAbs [dBm]	Δ Limit [dB]
9.000 k	150.000 k	1.00 k	9.903846 k	-57.91	-47.10
150.000 k	30.000 M	10.00 k	152.985000 k	-51.97	-41.16
30.000 M	902.000 M	100.00 k	772.508000 M	-44.72	-33.91
902.000 M	928.000 M	100.00 k	914.870000 M	19.15	-10.85
928.000 M	3.000 G	100.00 k	1.829734 G	-34.58	-23.77
3.000 G	6.000 G	100.00 k	3.008400 G	-43.57	-32.76
6.000 G	10.000 G	100.00 k	9.372400 G	-44.09	-33.28

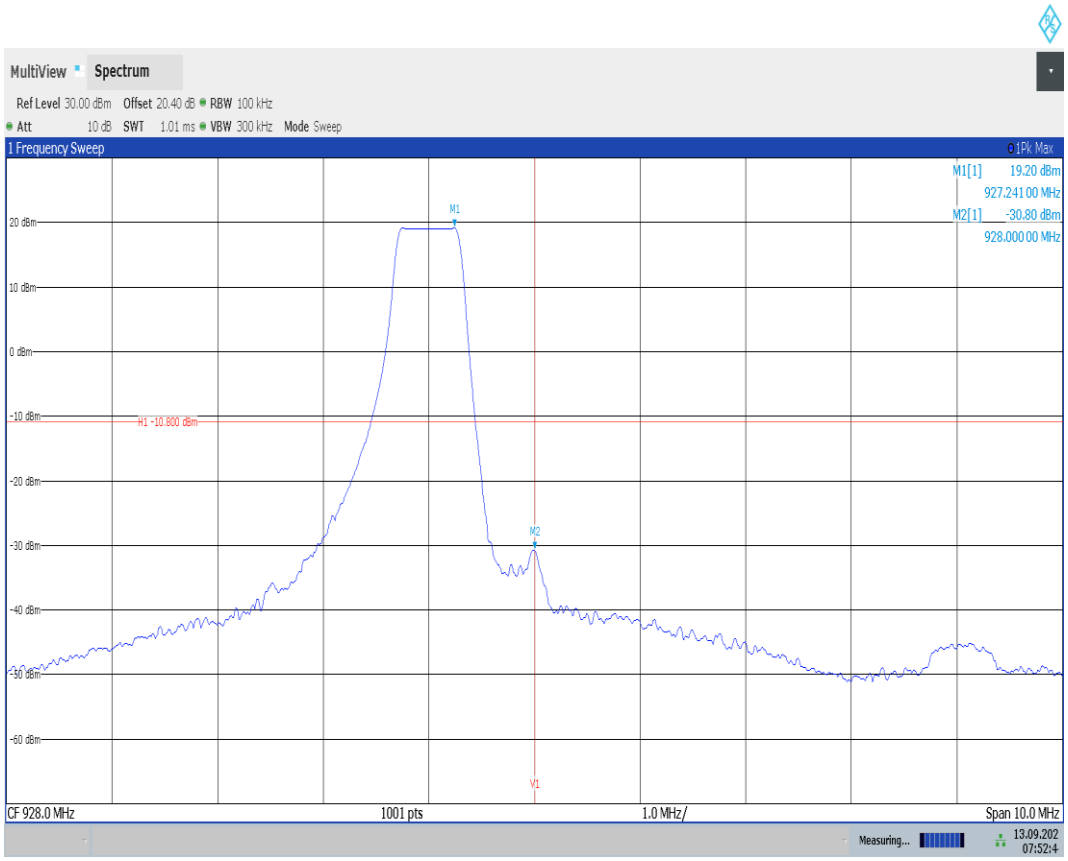
Date: 13.SEP.2022 08:56:40

Frequency: 927 MHz; Modulation: d-m2_500; Power Setting: 20



Start [Hz]	Stop [Hz]	RBW [Hz]	Freq [Hz]	PwrAbs [dBm]	Δ Limit [dB]
9.000 k	150.000 k	1.00 k	12.163462 k	-59.49	-48.46
150.000 k	30.000 M	10.00 k	182.835000 k	-53.17	-42.14
30.000 M	902.000 M	100.00 k	344.094400 M	-44.43	-33.40
902.000 M	928.000 M	100.00 k	927.181000 M	18.97	-11.03
928.000 M	3.000 G	100.00 k	1.854391 G	-34.19	-23.16
3.000 G	6.000 G	100.00 k	3.525000 G	-43.47	-32.44
6.000 G	10.000 G	100.00 k	8.510800 G	-42.74	-31.71

Date: 13.SEP.2022 09:00:40



07:52:45 13.09.2022

Upper conducted band edge

14 Power spectral density

14.1 Definition

The power per unit bandwidth.

14.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.10
EUT Frequencies Measured:	903 MHz, 915 MHz, 927 MHz
EUT Channel Bandwidths:	500 kHz
Deviations From Standard:	None
Measurement BW:	3 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	30 kHz
Measurement Span: (requirement 1.5 times Channel BW)	750 kHz
Measurement Detector:	RMS Average

Environmental Conditions (Normal Environment)

Temperature: 23 °C	+15 ºC to +35 ºC (as declared)
Humidity: 46 % RH	20 % RH to 75 % RH (as declared)
Supply: 4.5 V dc	4.5 V dc (as declared)

14.3 Test Limit

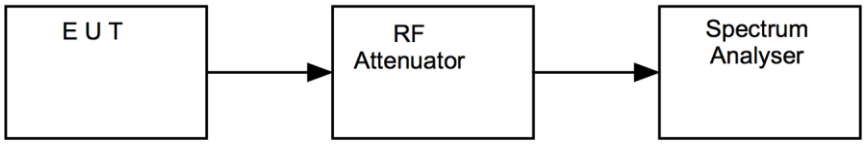
The transmitter power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

14.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure vi, the average emission of the EUT was measured on a spectrum analyser, with path losses taken into account.

The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst case configuration in each bandwidth.

Figure vi Test Setup

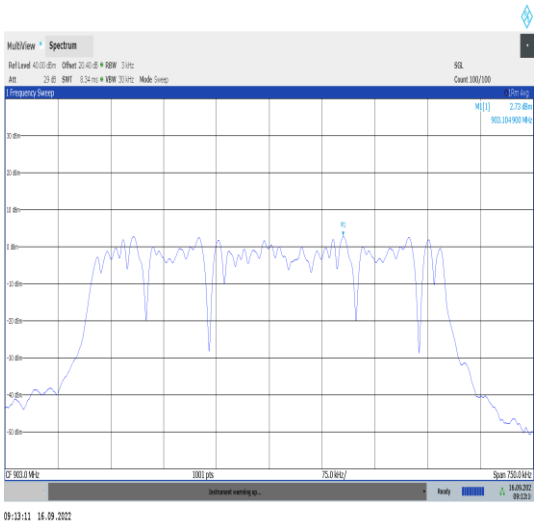


14.5 Test Equipment

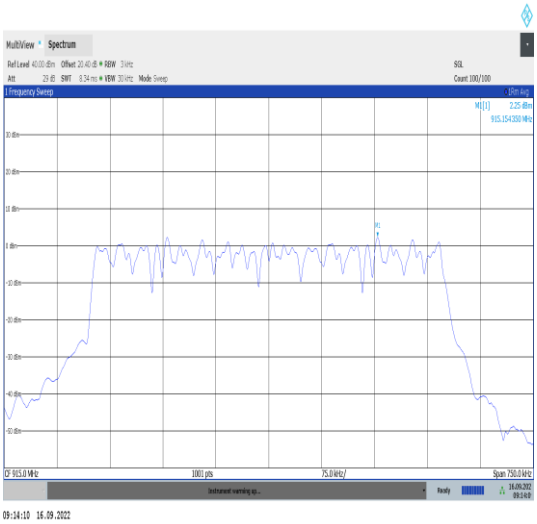
Equipment Type	*Manufacturer*	*Equipment Description*	*Element No*	*Due For Calibration*
Spectrum Analyser	R&S	FSW 43	U728	2023-04-26
Attenuator	AtlanTecRF Microwave	20dB SMA Attenuator	U632	Cal in use

14.6 Test Results

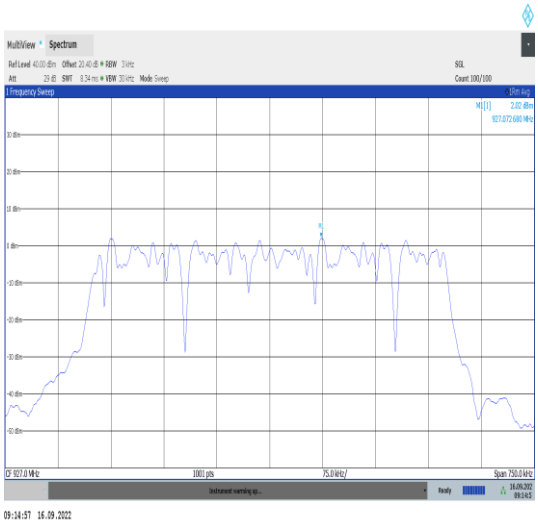
Modulation: d-m2_500; Power setting: 20				
Channel Frequency (MHz)	***Analyzer Level (dBm)***	***Cable loss (dB)***	***Power (dBm)***	***Result***
903	2.73	0	2.73	PASS
915	2.25	0	2.25	PASS
927	2.02	0	2.02	PASS



Bottom Channel



Middle Channel



Top Channel

Note: measurement method used - AVGPSD-1

15 Measurement Uncertainty

Radio Testing – General Uncertainty Schedule

All statements of uncertainty are expanded standard uncertainty using a coverage factor of 1.96 to give a 95 % confidence where no required test level exists.

Test/Measurement	Budget Number	MU
Conducted RF Power, Power Spectral Density, Adjacent Channel Power and Spurious emissions		
Absolute RF power (via antenna connecter) Dare RPR3006W Power Head	MU4001	**0.9 dB**
Carrier Power and PSD - Spectrum Analysers	MU4004	**0.9 dB**
Adjacent Channel Power	MU4002	**1.9 dB**
Transmitter conducted spurious emissions	MU4041	**0.9 dB**
Conducted power and spurious emissions 40 GHz to 50 GHz	MU4042	**2.4 dB**
Conducted power and spurious emissions 50 GHz to 75 GHz	MU4043	**2.5 dB**
Conducted power and spurious emissions 75 GHz to 110 GHz	MU4044	**2.4 dB**
Radiated RF Power and Spurious emissions ERP and EIRP		
Effective Radiated Power Reverb Chamber	MU4020	**3.7 dB**
Effective Radiated Power	MU4021	**4.7 dB**
TRP Emissions 30 MHz to 1 GHz using CBL6111 or CBL6112 Bilog Antenna	MU4046	**5.3 dB**
TRP Emissions 1 GHz to 18 GHz using HL050 Log Periodic Antenna	MU4047	**5.1 dB**
TRP Emissions 18 GHz to 26.5 GHz using Standard Gain Horn	MU4048	**2.7 dB**
TRP Emissions 26.5 GHz to 40 GHz using Standard Gain Horn	MU4049	**2.7 dB**
Spurious Emissions Electric and Magnetic Field		
Radiated Spurious Emissions 30 MHz to 1 GHz	MU4037	**4.7 dB**
Radiated Spurious Emissions 1-18 GHz	MU4032	**4.5 dB**
E Field Emissions 18GHz to 26 GHz	MU4024	**3.2 dB**
E Field Emissions 26GHz to 40 GHz	MU4025	**3.3 dB**
E Field Emissions 40GHz to 50 GHz	MU4026	**3.5 dB**
E Field Emissions 50GHz to 75 GHz	MU4027	**3.6 dB**
E Field Emissions 75GHz to 110 GHz	MU4028	**3.6 dB**
Radiated Magnetic Field Emissions	MU4031	**2.3 dB**
Frequency Measurements		
Frequency Deviation	MU4022	**0.316 kHz**
Frequency error using CMTA test set	MU4023	**113.441 Hz**
Frequency error using GPS locked frequency source	MU4045	**0.0413 ppm**
Bandwidth/Spectral Mask Measurements		
Channel Bandwidth	MU4005	**3.87 %**
Transmitter Mask Amplitude	MU4039	**1.3 dB**
Transmitter Mask Frequency	MU4040	**2.59 %**
Time Domain Measurements		
Transmission Time	MU4038	**4.40 %**
Dynamic Frequency Selection (DFS) Parameters)		
DFS Analyser - Measurement Time	MU4006	**679 µs**
DFS Generator - Frequency Error	MU4007	**92 Hz**
DFS Threshold Conducted	MU4008	**1.3 dB**
DFS Threshold Radiated	MU4009	**3.2 dB**

Test/Measurement	Budget Number	MU
Receiver Parameters		
EN300328 Receiver Blocking	MU4010	**1.1 dB**
EN301893 Receiver Blocking	MU4011	**1.1 dB**
EN303340 Adjacent Channel Selectivity	MU4012	**1.1 dB**
EN303340 Overloading	MU4013	**1.1 dB**
EN303340 Receiver Blocking	MU4014	**1.1 dB**
EN303340 Receiver Sensitivity	MU4015	**0.9 dB**
EN303372-1 Image Rejection	MU4016	**1.4 dB**
EN303372-1 Receiver Blocking	MU4017	**1.1 dB**
EN303372-2 Adjacent Channel Selectivity	MU4018	**1.1 dB**
EN303372-2 Dynamic Range	MU4019	**0.9 dB**
Receiver Blocking Talk Mode Conducted	MU4033	**1.2 dB**
Receiver Blocking Talk Mode- radiated	MU4034	**3.4 dB**
Rx Blocking, listen mode, blocking level	MU4035	**3.2 dB**
Rx Blocking, listen mode, radiated Threshold Measurement	MU4036	**3.4 dB**
Adjacent Sub Band Selectivity	MU4003	**4.2 dB**

16 RF Exposure

General SAR test reduction & exclusion guidance

KDB 447498

Section 4.3 General SAR test reduction and exclusion guidance

For Standalone SAR exclusion consideration, when SAR Exclusion Threshold requirement in KDB 447498 is satisfied, standalone SAR evaluation for general population exposure conditions by measurement or numerical simulation is not required.

The SAR Test Exclusion Threshold for frequencies in the range 100 MHz to 6 GHz, and for test separation distance of ≤ 50 mm, is determined as follows.

$$\text{SAR Exclusion Threshold (SARET)} = (NT \times TSD_A) / \sqrt{f_{GHz}}$$

Where,

NT = Numeric Threshold (3.0 for 1-g SAR and 7.5 for 10-g SAR)
TSD_A = Minimum Test separation distance or 50 mm (whichever is lower)
f_{GHz} = Transmit frequency in GHz

Channel Frequency (MHz)	*Maximum Conducted Power (mW)*	*SAR Exclusion Threshold at 27 mm (mW)*	*SAR Evaluation*
902	85.1	85.3	Not Required
915	81.3	84.7	Not Required
927	77.6	84.1	Not Required

Therefore standalone SAR evaluation for general population exposure conditions by measurement or numerical simulation is not required.

Note: Evaluation based on maximum conducted power.

MPE Calculation

Prediction of MPE limit at a given distance

For purposes of these requirements mobile devices are defined by the FCC as transmitters designed to be used in other than fixed locations and to generally be used in such a way that a separation distance of at least 20 centimeters is normally maintained between radiating structures and the body of the user or nearby persons. These devices are normally evaluated for exposure potential with relation to the MPE limits. As the 20 cm separation specified under FCC rules may not be achievable under normal operation of the EUT, an RF exposure calculation is needed to show the minimum distance required to be less than the power density limit, as required under FCC rules.

Equation from IEEE C95.1

$$S = \frac{EIRP}{4\pi R^2} \quad \text{re-arranged } R = \sqrt{\frac{EIRP}{S4\pi}}$$

Where:

S = power density
R = distance to the centre of radiation of the antenna
EIRP = EUT Maximum power

Result

Channel Frequency (MHz)	***EIRP (mW)***	***Power density limit (S) (mW/cm^2)***	***Distance (R) cm required to be less than the power density limit***
902	126.5	0.6	4.1
915	122.2	0.6	4.0
927	116.9	0.6	3.9

Note: Evaluation based on maximum conducted power.

17 Appendix A

17.1 Antenna Information

RF Parameter

Parameter	868/915 band*		GNSS	S-Band	
Frequency Range (MHz)	862-870	902-928	1500-1700	1950-2250	
Typical Frequency (MHz)	870	915	1575	2000 (up)	2180 (down)
Peak Total Gain (dBi)**	1.69	1.75	1.31	2.68	2.78
Peak RHCP Gain (dBic)**	1.49	1.62	0.99	2.51	1.53
Average Gain (dBi)**	-2.3	-2.2	-2.74	-1.77	-2.85
Total Efficiency	< 49%	< 50%	< 37%	< 46%	< 45%
Axial Ratio (dB)	< 6	< 6	< 6	< 6	< 6
Reflection coefficient (dB)	< -10	< -10	< -6	< -6	< -6
Peak EIRP (dBm)***	23.69	23.75	N/A	26.51	N/A

* Model variant 868: LS300-868-A, Model variant 915: LS300-915-A
** Values for "Typical Frequency"
*** Hardware maximum. Transmissions will be limited in software according to regional regulations.

Antenna Type

All antennas are integrated RHCP patch antennas. The antennas will be fixed, i.e. not replaceable by other antennas.