

Report on the Radio Testing

For

Lacuna Space

on

LS200

Report no. TRA-060214-47-00C

19 April 2023

Report Number: TRA-060214-47-00C
Issue: C

REPORT ON THE RADIO TESTING OF A
Lacuna Space
LS200
WITH RESPECT TO SPECIFICATION
Customer Test Plan Version 1.0 2022_11_17

TEST DATE: 2022-11-18

Tested by:



Steven Garwell
Radio Test Engineer

Written by:



Steven Garwell
Radio Test Engineer

Approved by:

John Charters
Department Manager - Radio

Date:

19 April 2023

Disclaimers:

- [1] THIS DOCUMENT MAY BE REPRODUCED ONLY IN ITS ENTIRETY AND WITHOUT CHANGE
[2] THE RESULTS CONTAINED IN THIS DOCUMENT RELATE ONLY TO THE ITEM(S) TESTED

1 Revision Record

<i>Issue Number</i>	<i>Issue Date</i>	<i>Revision History</i>
A	2022-12-01	Original
B	2022-12-09	Contact details amended
C	2023-04-18	Amended test limits in section 11.6 to FCC 47CFR 15.247

2 Summary

TEST REPORT NUMBER:	TRA-060214-47-00C
WORKS ORDER NUMBER:	TRA-058206-00
PURPOSE OF TEST:	Disconnected S-band radio in LS200 satellite Radio
TEST SPECIFICATION:	Customer Test Plan Version 1.0 2022_11_17 this test report references test limits from FCC 47CFR 15.247
EQUIPMENT UNDER TEST (EUT):	LS200
EUT SERIAL NUMBER:	0009
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-048-22
TEST DATE:	03 Oct 2022 - 20 Oct 2022
TESTED BY:	Steven Garwell Element

2.1 Test Summary

<i>Test Method and Description</i>	<i>Requirement</i>	<i>Applicable to this equipment</i>	<i>Result / Note</i>
Disconnected S Band Radio	Customer Test Plan Version 1.0 2022_11_17	☒	PASS

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

1	Revision Record.....	3
2	Summary.....	4
2.1	Test Summary.....	5
3	Contents.....	6
4	Introduction	7
5	Test Specifications	8
5.1	Normative References	8
6	Glossary of Terms.....	9
7	Equipment under Test.....	10
7.1	EUT Identification.....	10
7.2	System Equipment	10
7.3	EUT Mode of Operation	10
7.4	EUT Radio Parameters	11
7.4.1	General	11
7.4.2	Antennas	11
7.5	EUT Description	11
8	Modifications	12
9	EUT Test Setup	13
9.1	Block Diagram.....	13
9.2	General Set-up Photograph	13
9.3	Measurement software.....	14
10	General Technical Parameters.....	15
10.1	Normal Conditions.....	15
10.2	Varying Test Conditions	15
11	Disconnected S Band Radio	16
11.1	Definitions	16
11.2	Test Parameters.....	16
11.3	Test Limit.....	16
11.4	Test Method	17
11.5	Test Equipment.....	18
11.6	Test Results	19
12	Measurement Uncertainty	22

4 Introduction

This report TRA-060214-47-00C presents the results of the Radio testing on a Lacuna Space, LS200 to Customer Test Plan Version 1.0 2022_11_17.

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 Skelmersdale 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

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

- Customer Test Plan Version 1.0 2022_11_17 this test report references test limits from FCC 47CFR 15.247

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: LS200
- Serial Number: 0009
- Model Number: LS200-868-A
- Software Revision: LSM 0.9.13
- Build Level / Revision Number: Pre-Production

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 Computer*

7.3 EUT Mode of Operation

The EUT is set to test mode which transmit in a designated channel and power. It is exercised by sending command to the EUT with serial port and any kind of serial communication software (e.g. Terraterm Client).

7.4 EUT Radio Parameters

7.4.1 General

Radio Type:	900 MHz	Disabled S band
Frequency of operation:	902 MHz – 928 MHz	2010MHz – 2010MHz
Modulation type(s):	LoRa	LR-FHSS
Nominal Supply Voltage:	4.5 Vdc	

7.4.2 Antennas

Radio Type:	900 MHz FHSS	Disabled S band
Type:	Integrated RHCP patch	Integrated RHCP patch antennas
Frequency range:	902 MHz to 908 MHz	1980MHz – 2010 MHz (uplink) 2170MHz – 2200 MHz (downlink)
Gain:	2.1 dBic Peak	2.65dBic
Mounting:	Integrated	Fixed – Non replaceable

7.5 EUT Description

The LS200 is a battery powered sensor for operation using LoRa in the sub GHz band only.

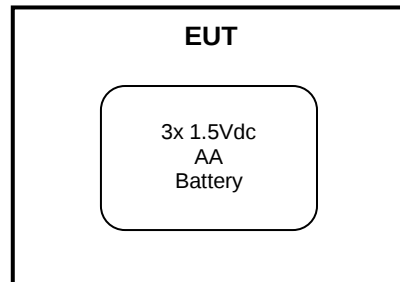
8 Modifications

No modifications were performed during this assessment.

9 EUT Test Setup

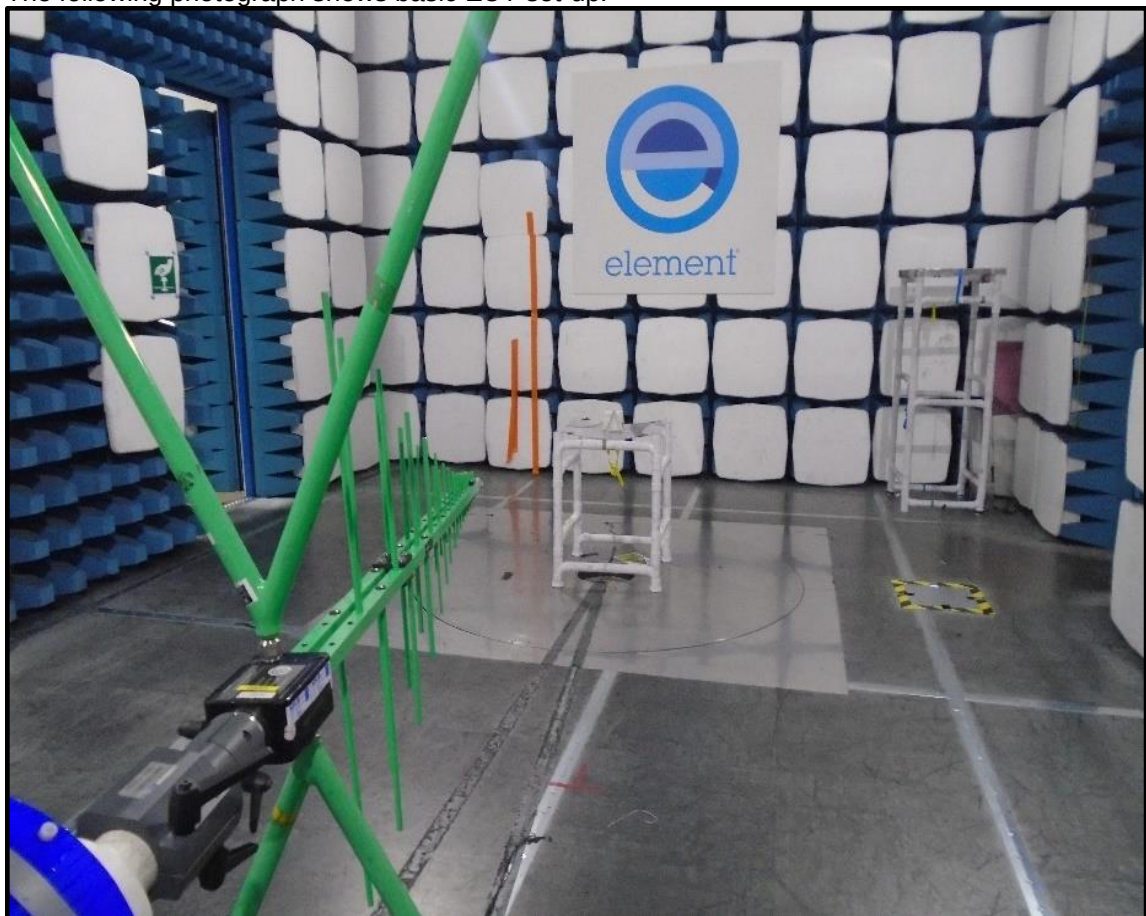
9.1 Block Diagram

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



9.2 General Set-up Photograph

The following photograph 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 – 2022.07.06.0
ETS Lindgren EMPower V1.0.4.2

10 General Technical Parameters

10.1 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 Vdc from 3 x AA alkaline batteries.

10.2 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.

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	-

11 Disconnected S Band Radio

11.1 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.

11.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Chamber 1
EUT Frequencies Measured:	2000.2 MHz, 2009.8MHz
Test Standard and Clause:	N/A
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: 16 °C	+15 °C to +35 °C (as declared)
Humidity: 63 % RH	20 % RH to 75 % RH (as declared)
Supply: 4.5 Vdc	4.5 Vdc (as declared)

11.3 Test Limit

No transmissions in the S band.

11.4 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:

$$FS = PR + CL + AF - PA + DC - CF$$

$$\text{Factor} = CL + AF - PA$$

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;

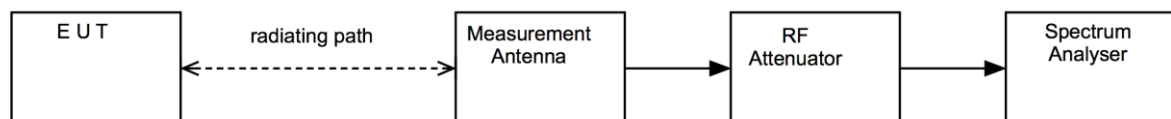
PA is the pre-amplifier gain in dB (where used);

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.

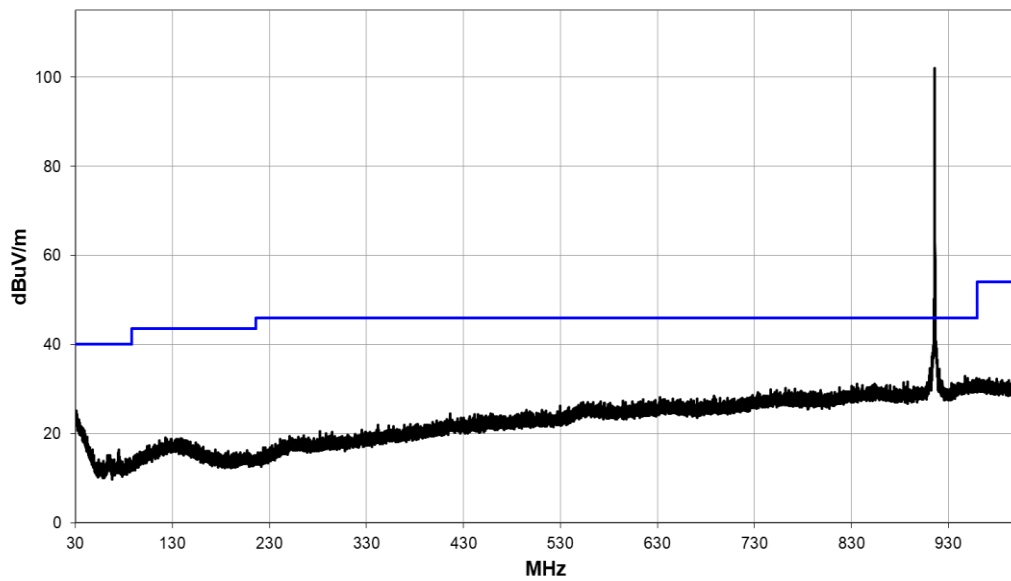
Figure i Test Setup



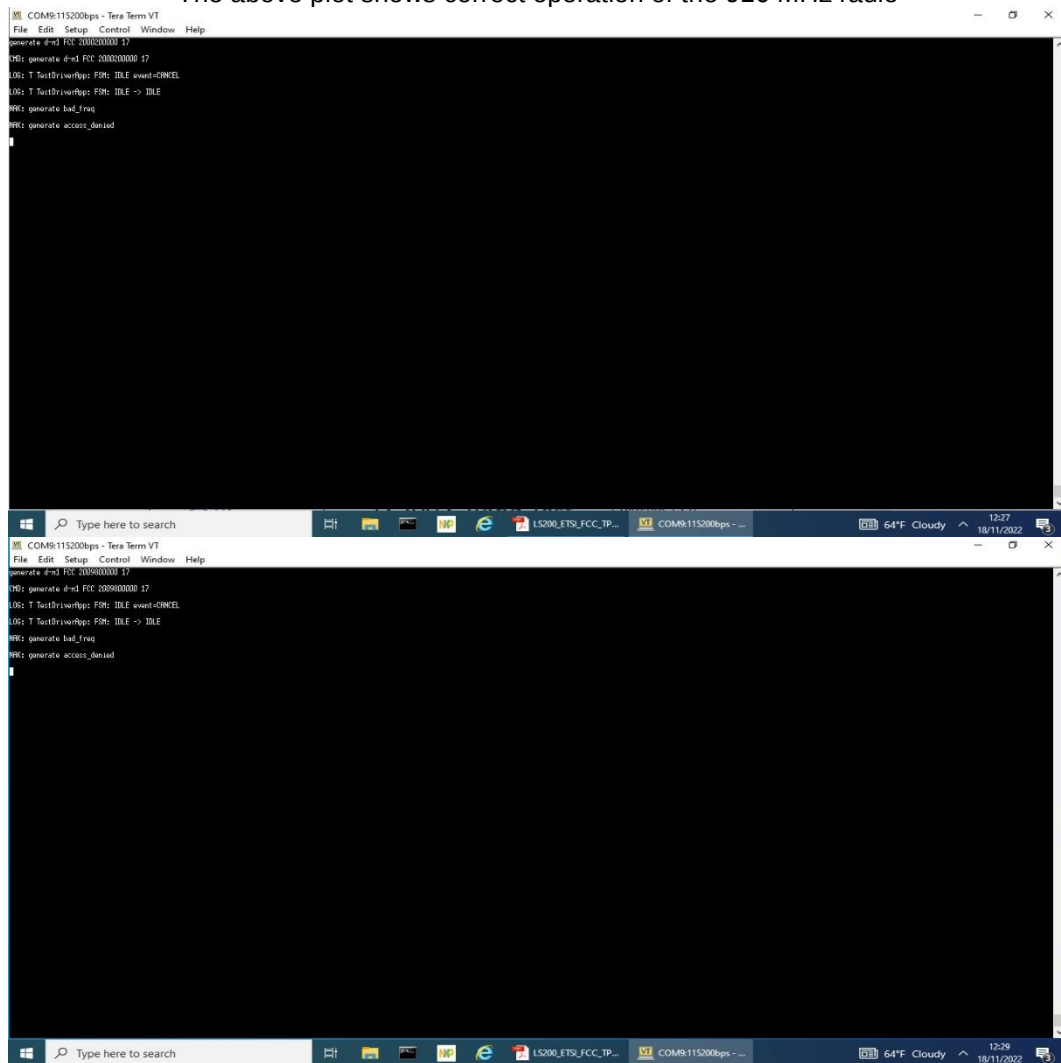
11.5 Test Equipment

<i>Equipment Type</i>	<i>Manufacturer</i>	<i>Equipment Description</i>	<i>Element No</i>	<i>Due For Calibration</i>
Radio Chamber - PP	Rainford EMC	ATS	REF940	2023-11-06
Radiated Test Software	Element	Emissions R5	REF900 0	Cal not required
Horn Antenna	EMCO	3115	L138	2024-05-23
Pre Amp	Agilent	8449B	U457	2023-01-22
Bilog	Chase	CBL611/B	U573	2023-01-28
Pre Amp	AMETEK	LNA6901	U711	2023-03-14

11.6 Test Results

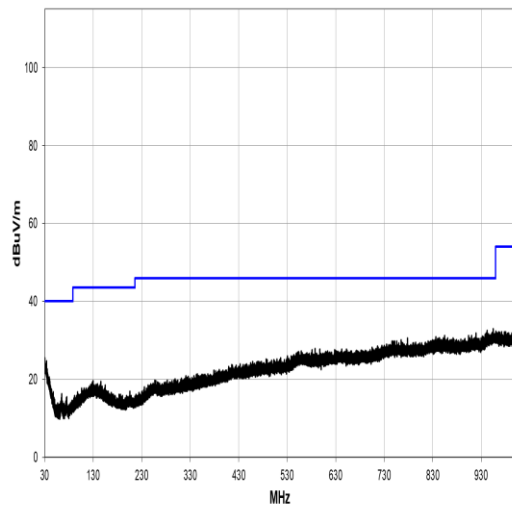


The above plot shows correct operation of the 916 MHz radio

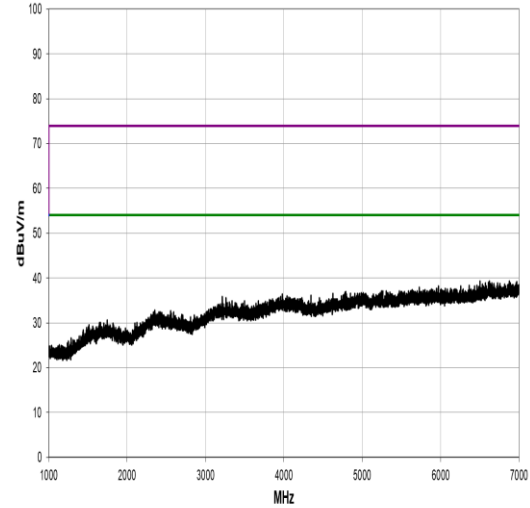


The above plots show the Terraterm output window

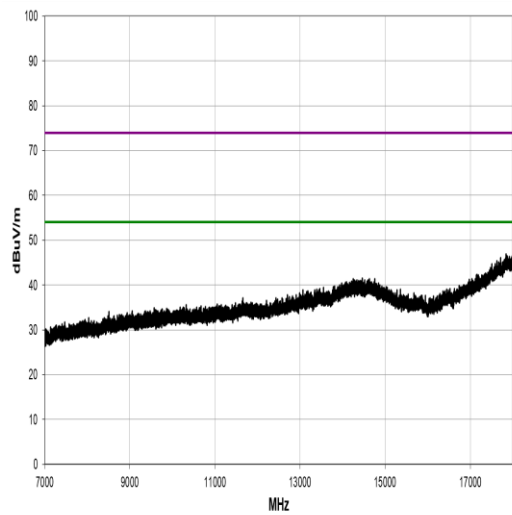
Frequency: 2000.2 MHz; Test Command: generate d-m1 FCC 2000200000 17



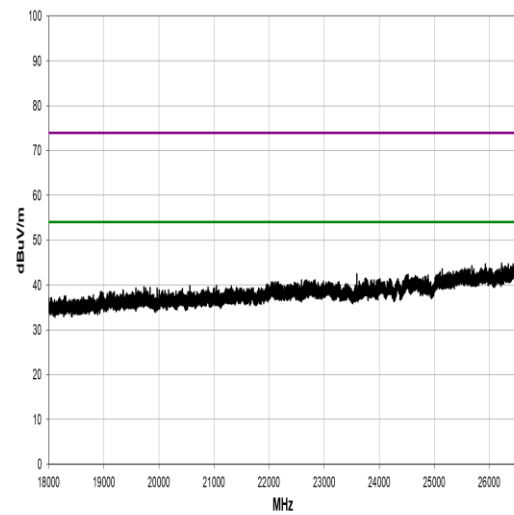
30 MHz to 1 GHz



1 GHz to 7 GHz



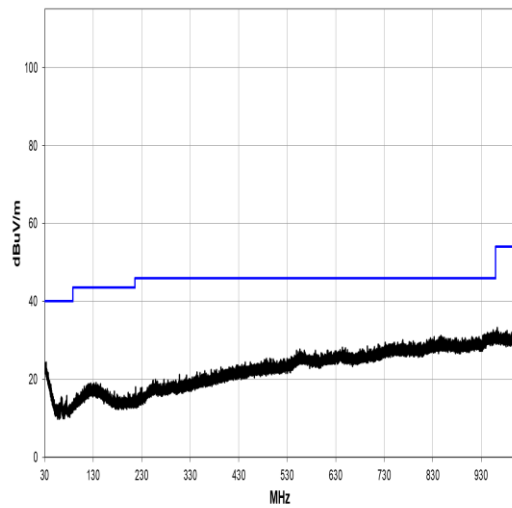
7 GHz to 18 GHz



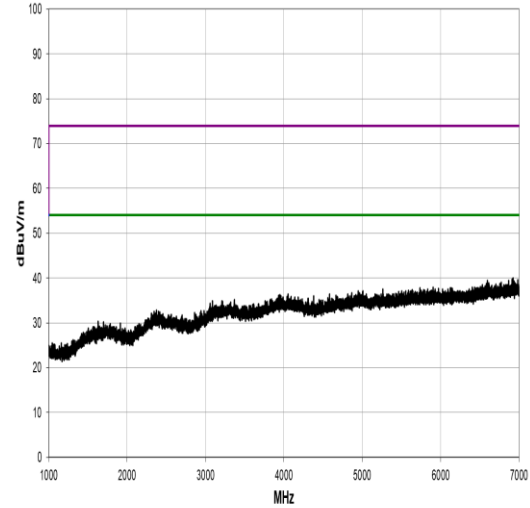
18 GHz to 26.5 GHz

Note: No transmissions in the S band

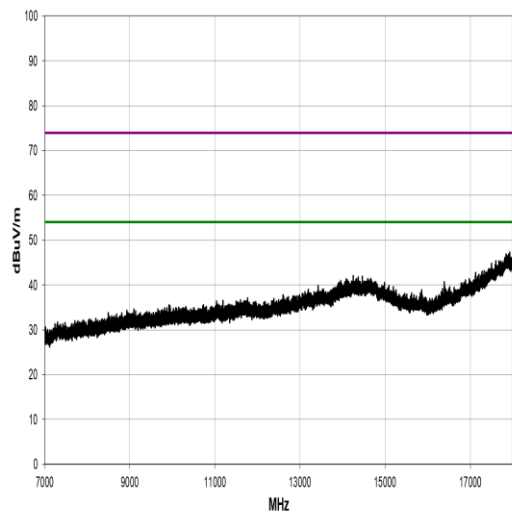
Frequency: 2009.8 MHz; Test Command: generate d-m1 FCC 2009800000 17



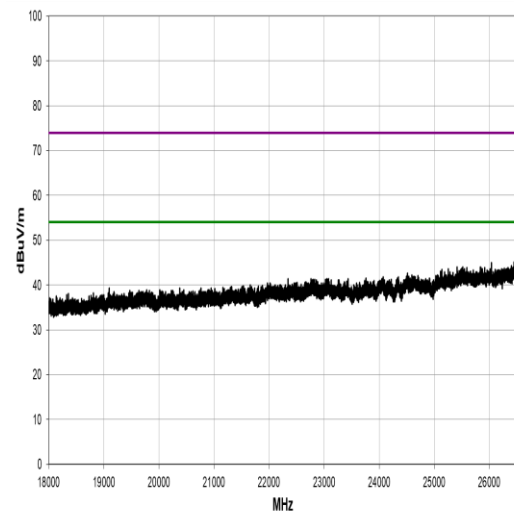
30 MHz to 1 GHz



1 GHz to 7 GHz



7 GHz to 18 GHz



18 GHz to 26.5 GHz

Note: No transmissions in the S band

12 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 connector) 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 μ s
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