Report on the Radio Testing

For

EkkoSense Ltd

on

EkkoSensor

Report no. TRA-047000-45-01B

8th October 2019

Report Number: TRA-047000-45-01B
Issue: B

REPORT ON THE RADIO TESTING OF A
EkkoSense Ltd
EkkoSensor
WITH RESPECT TO SPECIFICATION
FCC 47CFR 15.247

TEST DATE: 10th September 2019 - 12th September 2019

Written by: David Garvey
Radio Test Engineer

Approved by: John Charters
Department Manager -Radio

Digitally signed by John Charters
DN: cn=John Charters, o, ou=Element Materials Technology Ltd., email=john.charters@element.com, c=GB
Reason: I am the author of this document
Date: 2019.10.10 10:51:23 +01'00'

Date: 8th October 2019

1 Revision Record

Issue Number	*Issue Date*	*Revision History*
A	18th September 2019	Original
B	8th October 2019	Update

2 Summary

TEST REPORT NUMBER:	TRA-047000-45-01B
WORKS ORDER NUMBER:	TRA-047000-02
PURPOSE OF TEST:	USA: Testing of radio frequency equipment per the relevant authorization procedure of chapter 47 of CFR (code of federal regulations) Part 2, subpart J.
TEST SPECIFICATION(S):	47CFR15.247
EQUIPMENT UNDER TEST (EUT):	EkkoSensor
FCC IDENTIFIER:	2AP4G-FS-SNS-03
EUT SERIAL NUMBER:	0001:MC, 0001:HZ, 0001:GD
MANUFACTURER/AGENT:	EkkoSense Ltd
ADDRESS:	Sir Colin Campbell Building University of Nottingham Innovation Park Triumph Road Nottingham NG7 2TU United Kingdom
CLIENT CONTACT:	David Corder ☎ 01158 232 664 ✉ david.corder@ekkosense.co.uk
ORDER NUMBER:	PO-00001412
TEST DATE:	10th September 2019 - 12th September 2019
TESTED BY:	David Garvey Element

2.1 Test Summary

Test Method and Description		*Requirement Clause*		*Applicable to this equipment*	*Result / Note*
		RSS	*47CFR15*		
Radiated spurious emissions (restricted bands of operation and cabinet radiation)		Gen, 8.10	15.205	☒	*PASS*
AC power line conducted emissions		Gen, 8.8	15.207	☐	*Note 1*
Occupied bandwidth		247, 5.2 (1)	15.247(a)(2)	☒	*PASS*
Conducted carrier power	Peak	247, 5.4 (4)	15.247(b)(3)	☒	*PASS*
	Max.			☐	
Conducted / radiated RF power out-of-band		247, 5.5	15.247(d)	☒	*PASS*
Power spectral density, conducted		247, 5.2 (2)	15.247(e)	☒	*PASS*
Calculation of duty correction		-	15.35(c)	☐	*Note 2*

Notes:

1. The EUT is a battery powered device.
2. Duty Cycle is not required to be taken into account for any requirements to be met.

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-047000-45-01B presents the results of the Radio testing on a EkkoSense Ltd, EkkoSensor to specification 47CFR15 Radio Frequency Devices.

The testing was carried out for EkkoSense Ltd 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:
Element is accredited for the above sites under the US-EU MRA, Designation number UK0009.

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: EkkoSensor
- Serial Number: 0001:MC, 0001:HZ, 0001:GD
- Model Number: FS-TDX-03 , FS-THX-03, FS-TSX-03
- Software Revision: Not Applicable
- Build Level / Revision Number: Not Applicable

Except as indicated in the results sections of this report, testing has only been carried out on the FS-TDX-03 model.

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.

Not applicable – No support/monitoring equipment required.

7.3 EUT Mode of Operation

The mode of operation for TX tests was the EUT transmitting a modulated carrier as required.

No receive tests were performed during this assessment.

7.4 EUT Radio Parameters

7.4.1 General

Frequency of operation:	923 MHz
Modulation type(s):	GFSK
Occupied channel bandwidth(s):	Wideband
Channel spacing:	Single Channel
ITU emission designator(s):	625KF1D
Declared output power(s):	10 dBm
Nominal Supply Voltage:	3.6 V dc
Duty cycle:	100 % for test

7.4.2 Antennas

Type:	Ethertronics M620720
Frequency range:	ISM 868/915
Impedance:	50 Ohms
Gain:	2.6 dBi gain
Polarisation:	Linear
Beam width:	Omni
Connector type:	PCB Mounted
Length:	6mm
Weight:	0.1 k/g
Environmental limits:	Not Stated
Mounting:	Solder

7.4.3 Product specific declarations

Multiple antenna configuration(s), e.g. MIMO:	Single Antenna
Fixed pt-pt operations (yes/no):	No
Installation manual advice on pt-pt operational restrictions (yes/no):	Not Applicable
Fixed pt-mpt operations (yes/no):	No
Simultaneous tx (yes/no):	No

7.5 EUT Description

The EUT is a range of wireless sensors with options for temperature and/or humidity sensing, all containing 923 MHz Radio.

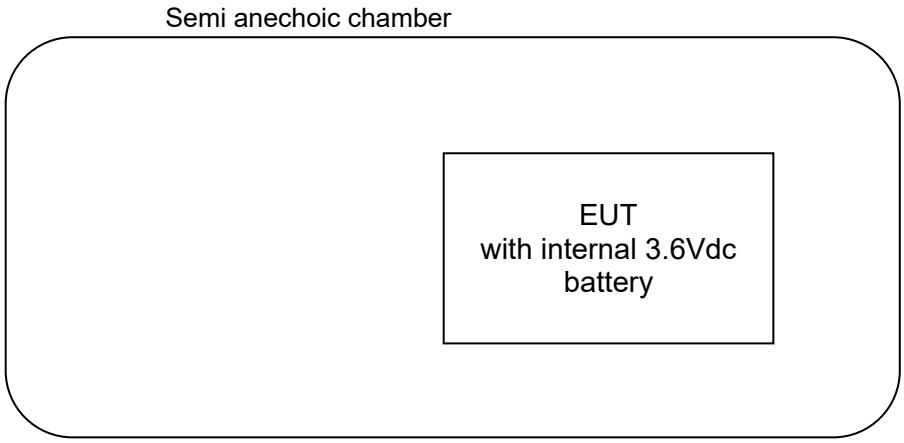
8 Modifications

No modifications were performed during this assessment.

9 EUT Test Setup

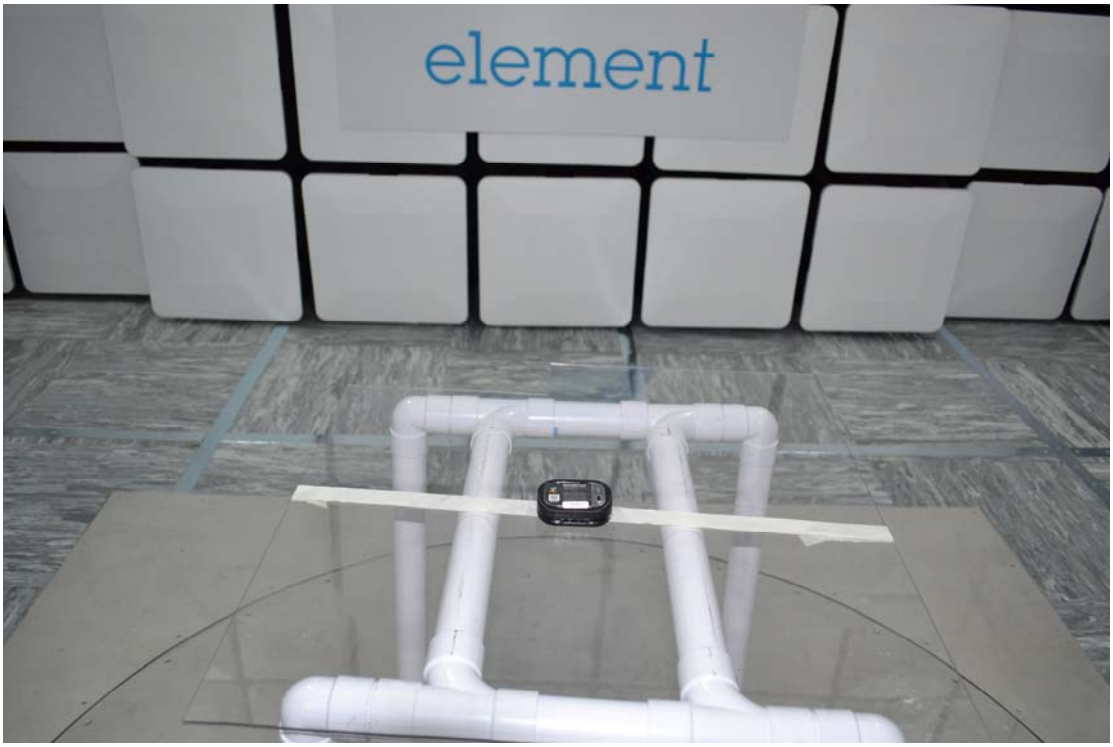
9.1 Block Diagram

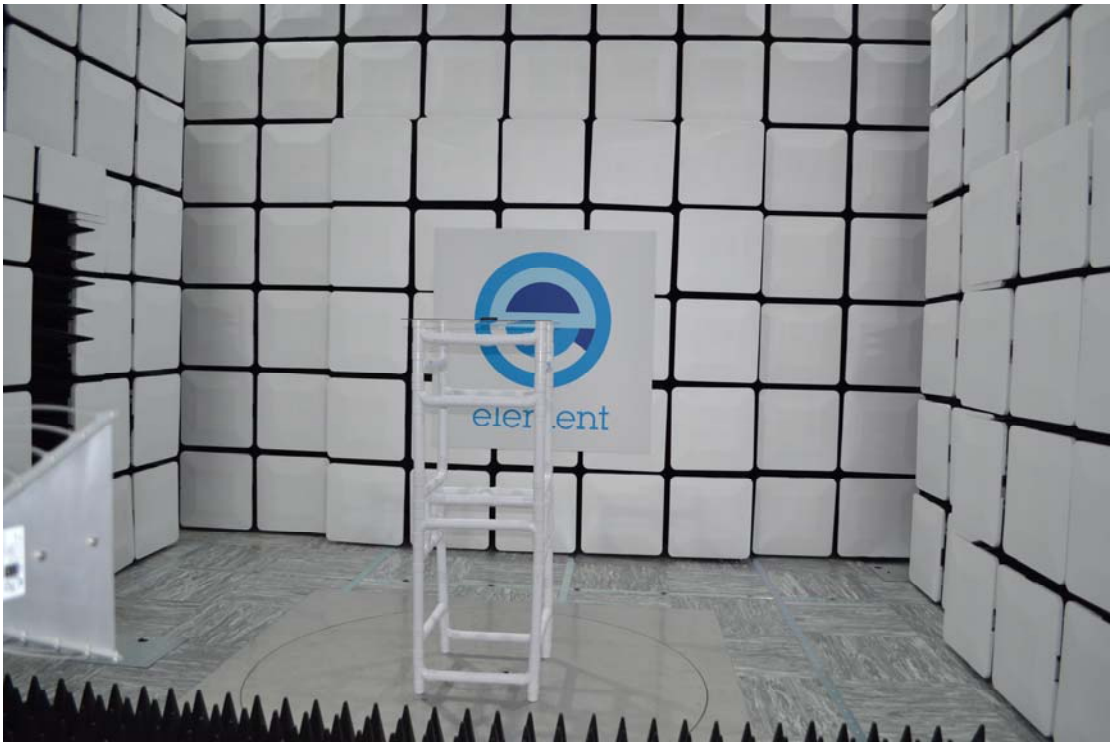
The following diagram shows basic EUT interconnections:



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 (See Note)

Note:

The version of the Element software used is recorded in the results sheets contained within this report.

10 General Technical Parameters

10.1 Normal Conditions

The E U T was tested under the normal environmental conditions of the test laboratory, except where otherwise stated. The normal power source applied was 3.6 V dc from Lithium Thionyl Chloride 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 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 V ac +/-2 %	85 % and 115 %
☒	Battery	3.6 Vdc	New battery

11 Radiated emissions

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 Hull
Test Chamber:	Wireless Lab 3
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.5 and 6.6
EUT Frequency Measured:	923 MHz
EUT Channel Bandwidths:	600 kHz
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: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 50 % RH	20 % RH to 75 % RH (as declared)
Supply: 3.6 V dc	

11.3 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)*
30 to 88	100
88 to 216	150
216 to 960	200
Above 960	500

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:

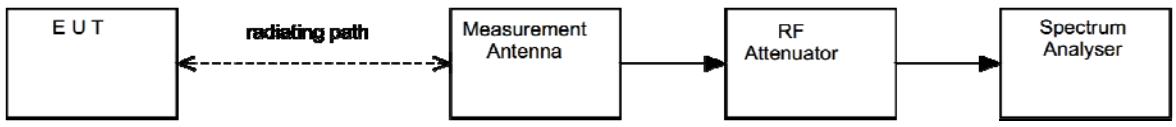
$$FS = PR + CL + AF – PA + DC + CF$$

Where,

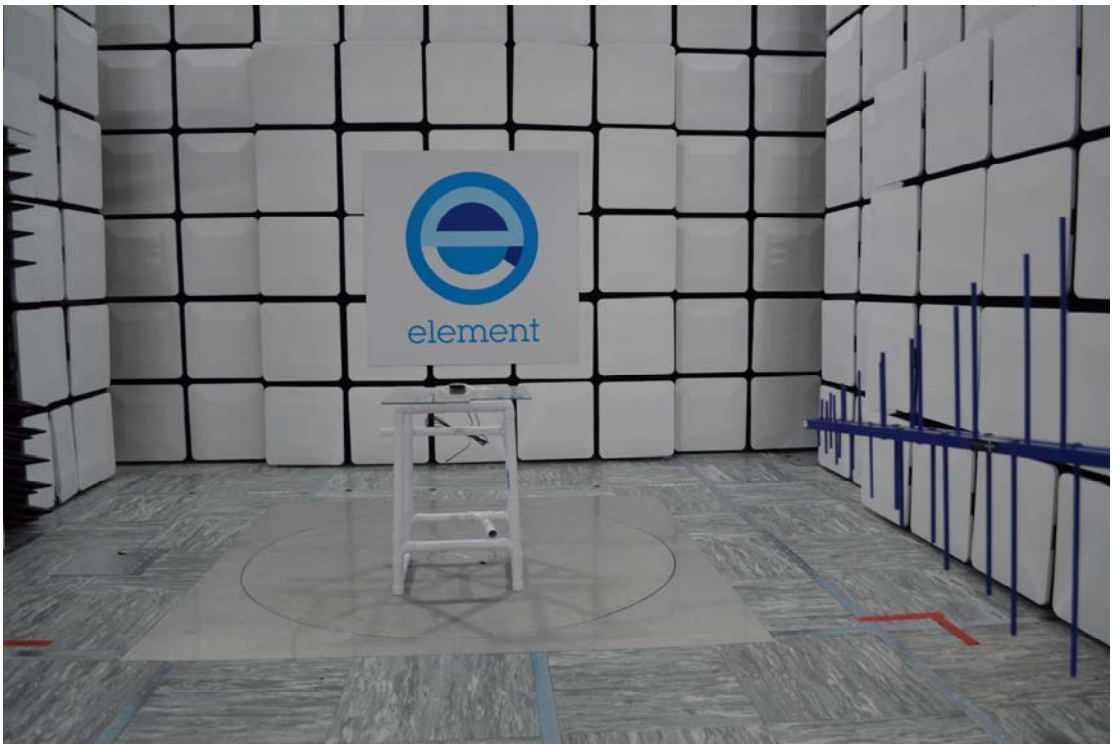
PR is the power recorded on the receiver / spectrum analyzer in dBµV;
CL is the cable loss in dB;
AF is the test antenna factor in dB/m;
PA is the pre-amplifier gain in dB (where used);
DC is the duty correction factor in dB (where used, e.g. harmonics of pulsed fundamental);
CF is the distance factor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

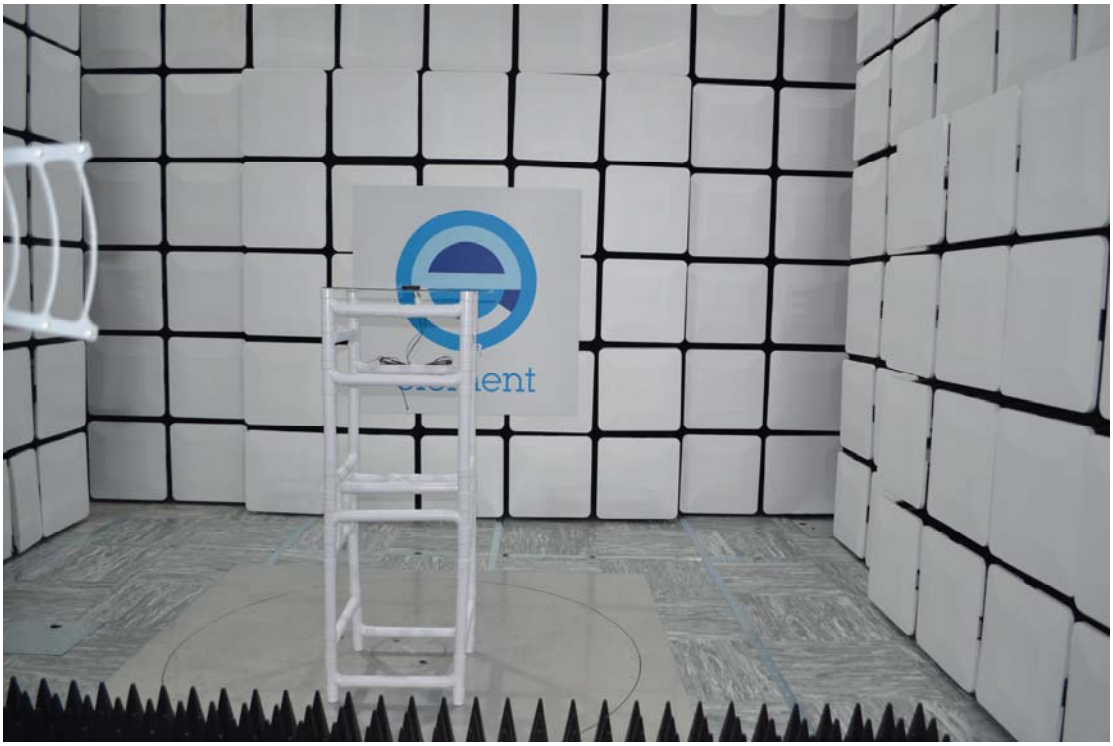
This field strength value is then compared with the regulatory limit.

Figure i Test Setup



11.5 Test Set-up Photograph





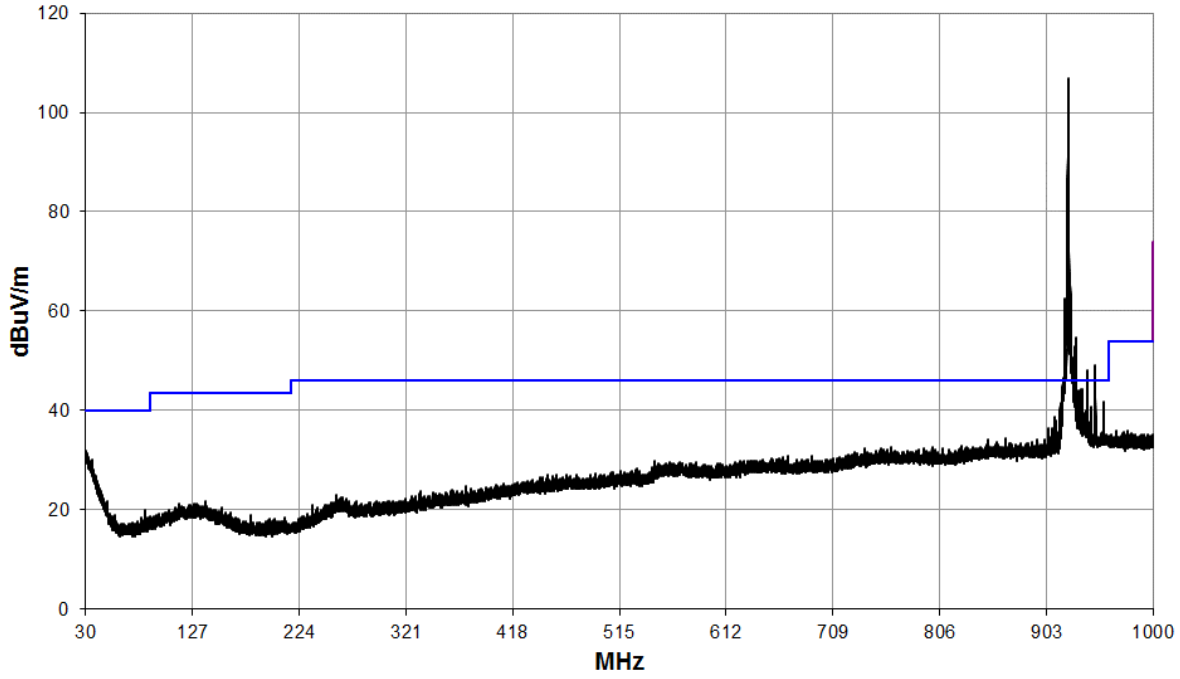
11.6 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
Ferrite Lined Chamber	Rainford	Chamber	REF2259	2020-08-03
EMI Test Receiver	R&S	ESW26	REF2235	2020-07-26
Bilog Antenna	Chase	CBL6111B	REF2218	2019-11-06
Horn Antenna	A Info Inc	LB-10180-NF	REF2241	2020-07-13
Horn Antenna	A Info Inc	LB-90-25-C2-SF	REF2243	2020-07-16
Emissions R5	Element	Radiated Test Software	REF9000	Cal not required

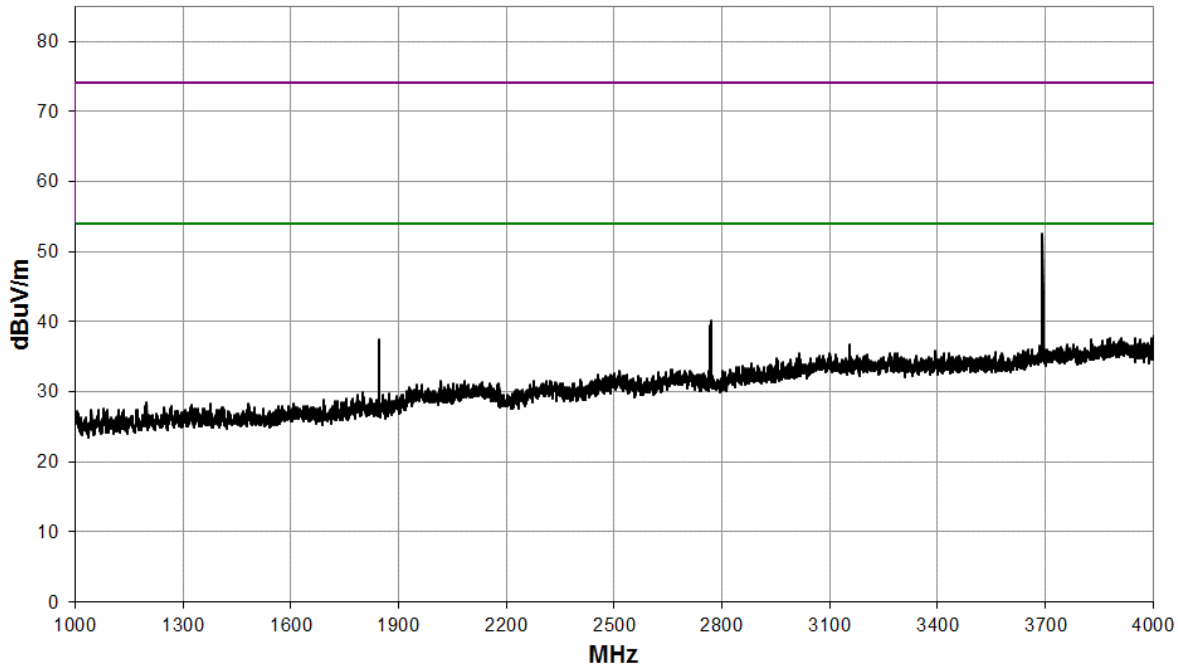
11.7 Test Results

FS-TDX-03; High Power; Frequency: 923 MHz										
Detector	***Freq. (MHz)***	***Meas'd Emission (dBµV)***	***Cable Loss (dB)***	***Antenna Factor (dB/m)***	***Pre-amp Gain (dB)***	***Duty Cycle Corr'n (dB)***	***Distance Extrap'n Factor (dB)***	***Field Strength (dBµV/m)***	***Field Strength (µV/m)***	***Limit (µV/m)***
PK	7385.998	14.2	6.9	38.3	0.0	0.0	0.0	59.4	933.3	5000
PK	3691.295	21.2	4.6	31.2	0.0	0.0	0.0	57.0	707.9	5000
PK	5536.707	16.0	5.9	34.9	0.0	0.0	0.0	56.8	691.8	5000
PK	4613.962	17.3	5.3	33.0	0.0	0.0	0.0	55.6	602.6	5000
PK	3691.253	19.5	4.6	31.2	0.0	0.0	0.0	55.3	582.1	5000
PK	6462.661	11.7	6.6	36.6	0.0	0.0	0.0	54.9	555.9	5000
AV	7382.421	-0.4	6.9	38.3	0.0	0.0	0.0	44.8	173.8	500
AV	3692.709	6.9	4.6	31.2	0.0	0.0	0.0	42.7	136.5	500
AV	5536.832	1.6	5.9	34.9	0.0	0.0	0.0	42.4	131.8	500
AV	4616.042	3.2	5.3	33.0	0.0	0.0	0.0	41.5	118.8	500
AV	3691.378	5.4	4.6	31.2	0.0	0.0	0.0	41.2	114.8	500
AV	6459.541	-2.6	6.6	36.6	0.0	0.0	0.0	40.6	107.2	500
AV	1846.042	8.0	3.1	26.5	0.0	0.0	0.0	37.6	75.9	500
AV	2769.539	0.8	3.9	28.9	0.0	0.0	0.0	33.6	47.9	500
QP	934.684	-3.5	4.3	30.1	0.0	0.0	0.0	30.9	35.1	200
QP	943.206	-6.5	4.3	30.5	0.0	0.0	0.0	28.3	26.0	200
QP	958.804	-7.3	4.4	30.7	0.0	0.0	0.0	27.8	24.5	200

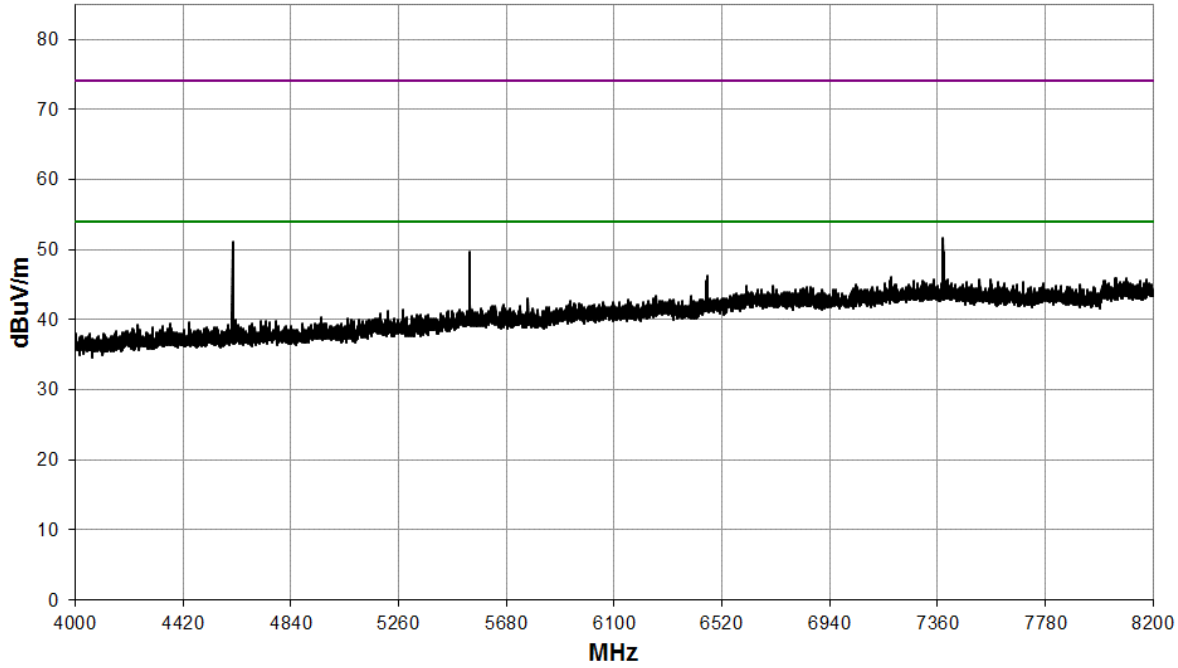
30 MHz to 1 GHz (FS-TDX-03)



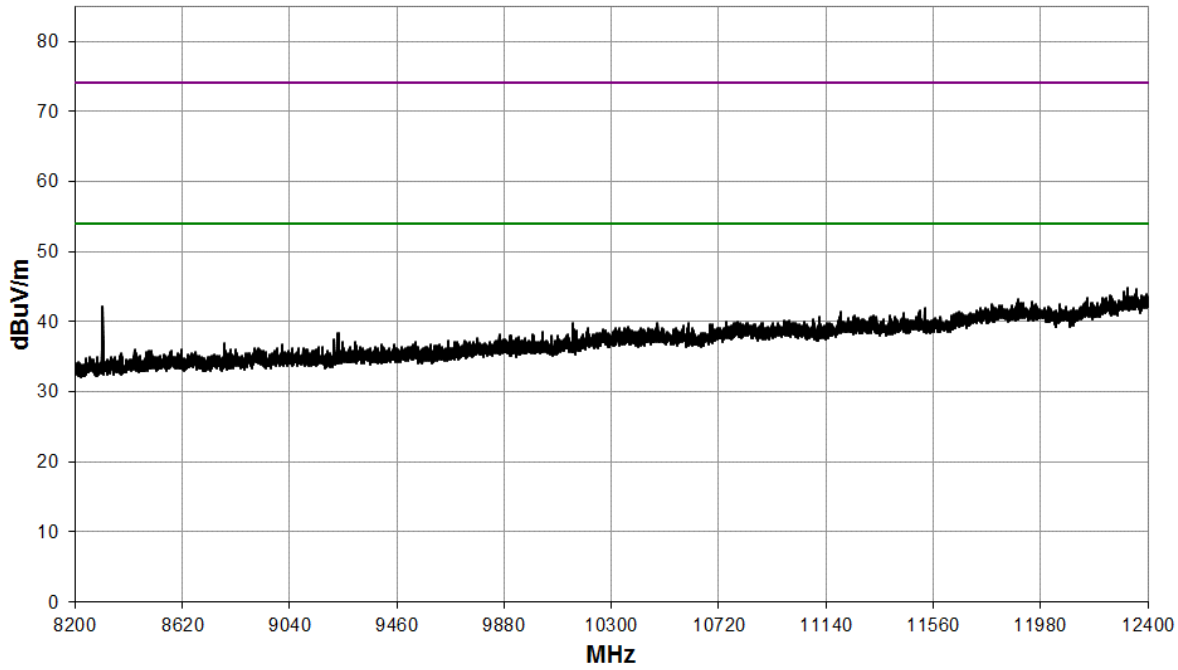
1 GHz to 4 GHz (FS-TDX-03)



4 GHz to 8.2 GHz (FS-TDX-03)

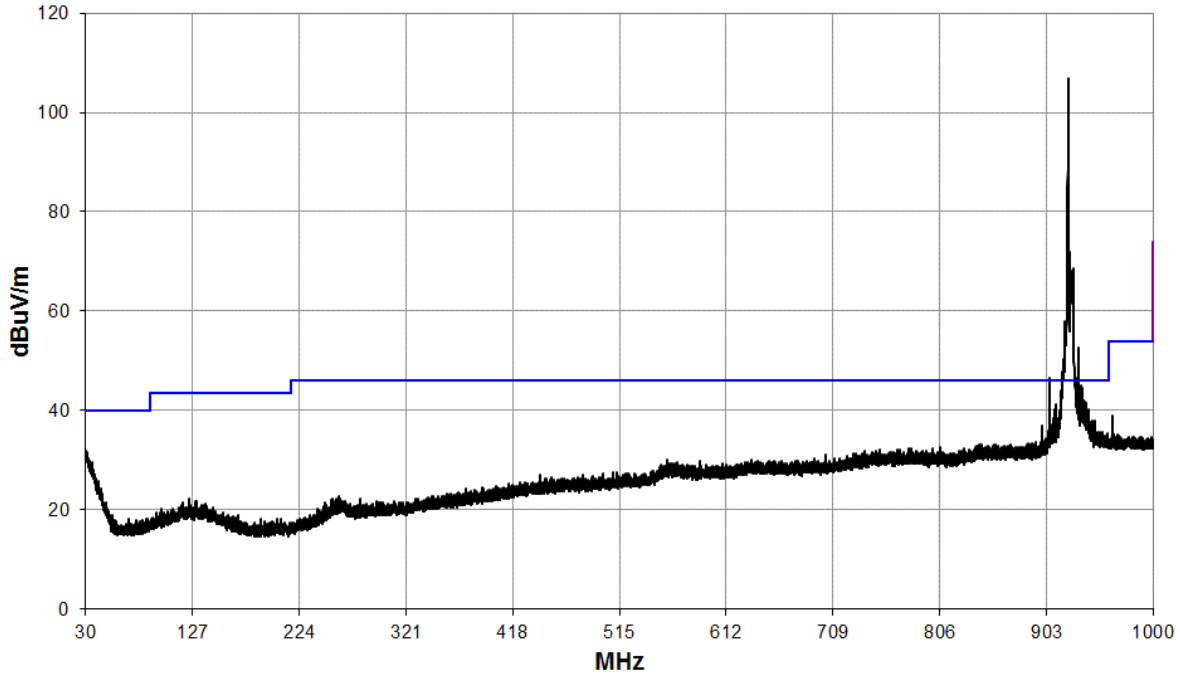


8.2 GHz to 12.4 GHz (FS-TDX-03)

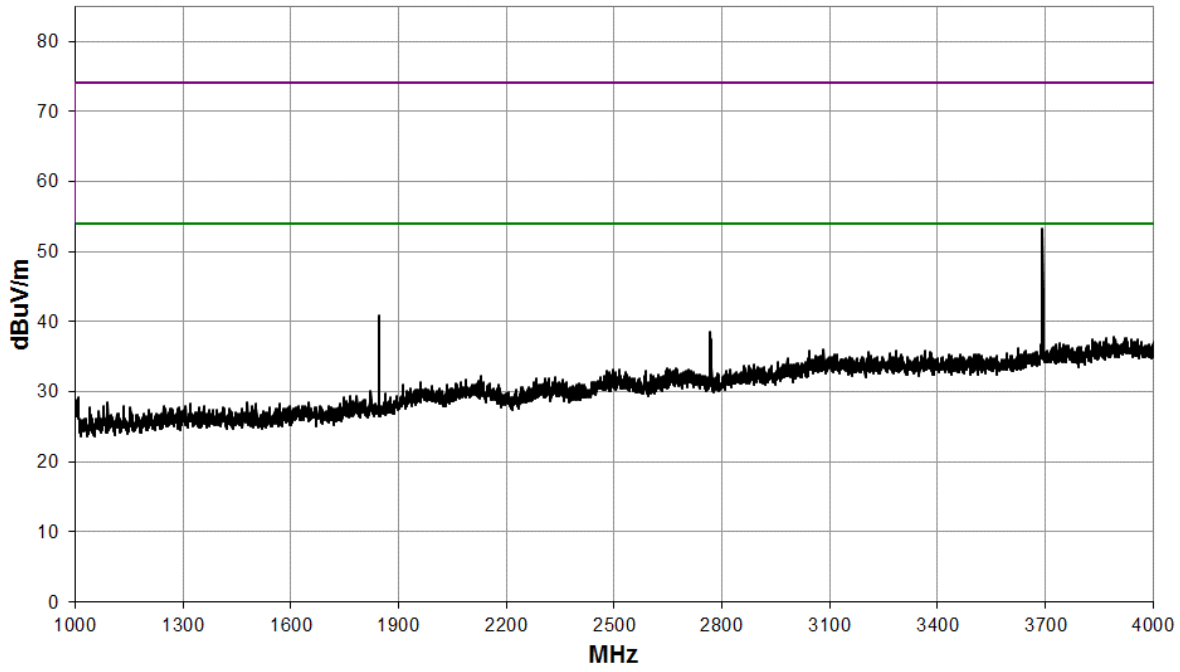


FS-THX-03; High Power; Frequency: 923 MHz										
Detector	***Freq. (MHz)***	***Meas'd Emission (dBµV)***	***Cable Loss (dB)***	***Antenna Factor (dB/m)***	***Pre-amp Gain (dB)***	***Duty Cycle Corr'n (dB)***	***Distance Extrap'n Factor (dB)***	***Field Strength (dBµV/m)***	***Field Strength (µV/m)***	***Limit (µV/m)***
PK	7385.707	14.8	6.9	38.3	0.0	0.0	0.0	60.0	1000.0	5000
PK	5536.962	17.4	5.9	34.9	0.0	0.0	0.0	58.2	812.8	5000
PK	3691.216	21.6	4.6	31.2	0.0	0.0	0.0	57.4	741.3	5000
AV	7385.832	0.1	6.9	38.3	0.0	0.0	0.0	45.3	184.1	500
AV	5539.333	3.0	5.9	34.9	0.0	0.0	0.0	43.8	154.9	500
AV	3691.416	7.2	4.6	31.2	0.0	0.0	0.0	43.0	141.3	500
AV	1846.033	9.5	3.1	26.5	0.0	0.0	0.0	39.1	90.2	500
AV	4616.125	-0.8	5.3	33.0	0.0	0.0	0.0	37.5	75.0	500
AV	2768.549	1.2	3.9	28.9	0.0	0.0	0.0	34.0	50.1	500
QP	933.023	7.2	4.3	30.0	0.0	0.0	0.0	41.5	118.9	200

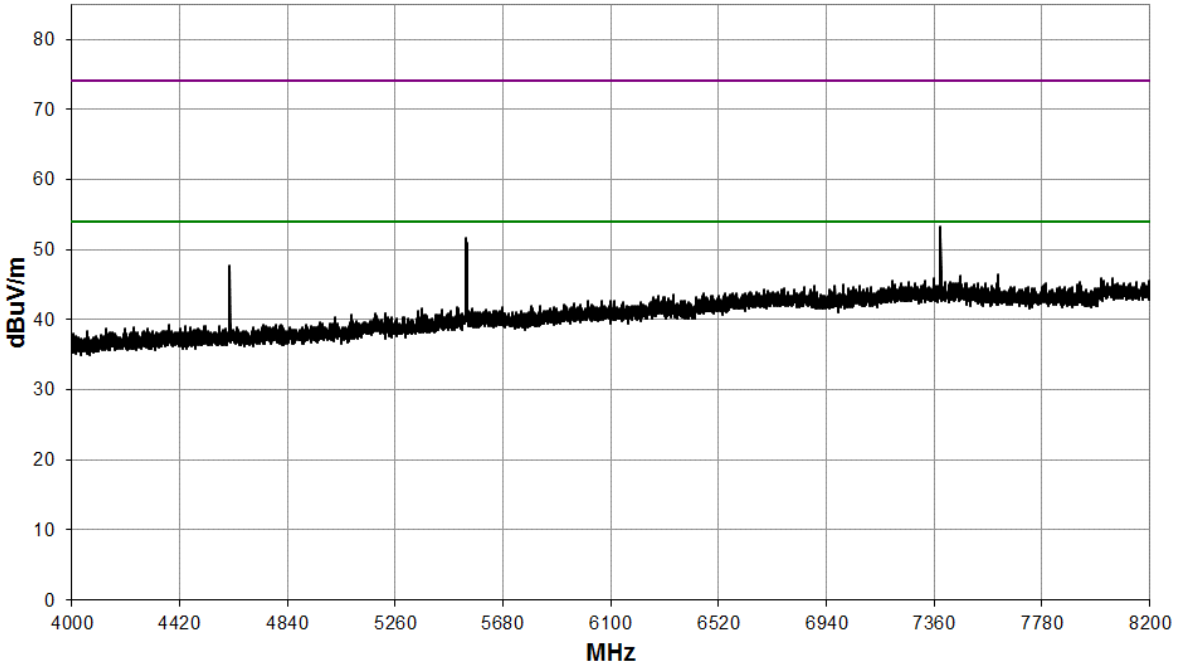
30 MHz to 1 GHz (FS-THX-03)



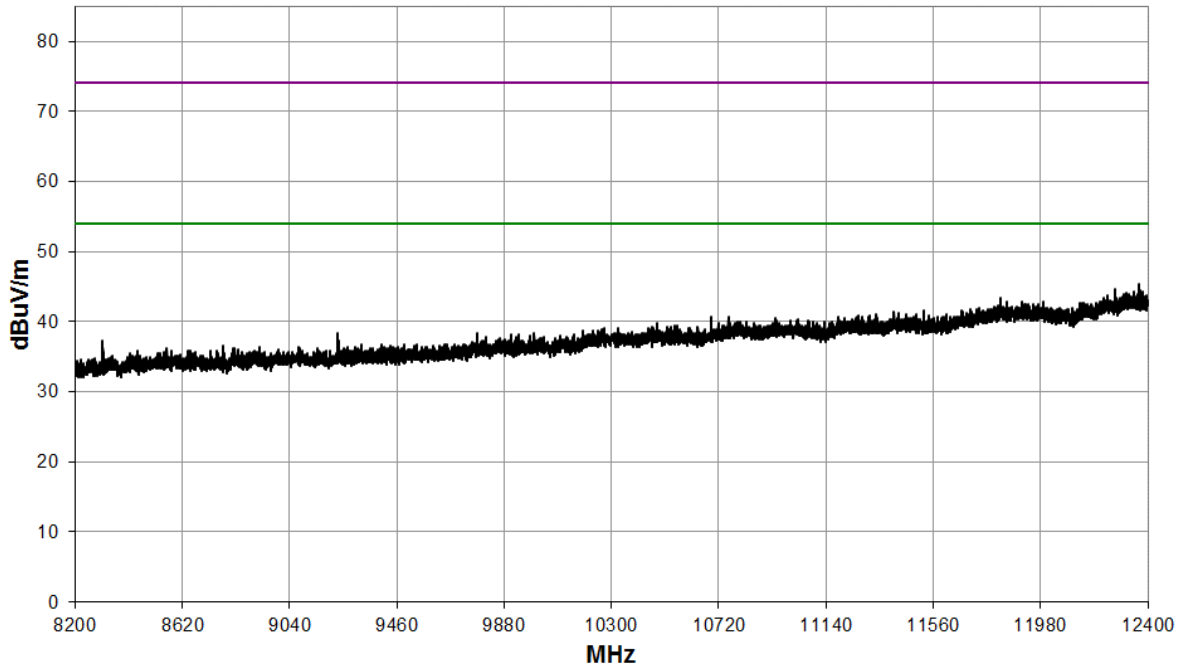
1 GHz to 4 GHz (FS-THX-03)



4 GHz to 8.2 GHz (FS-THX-03)

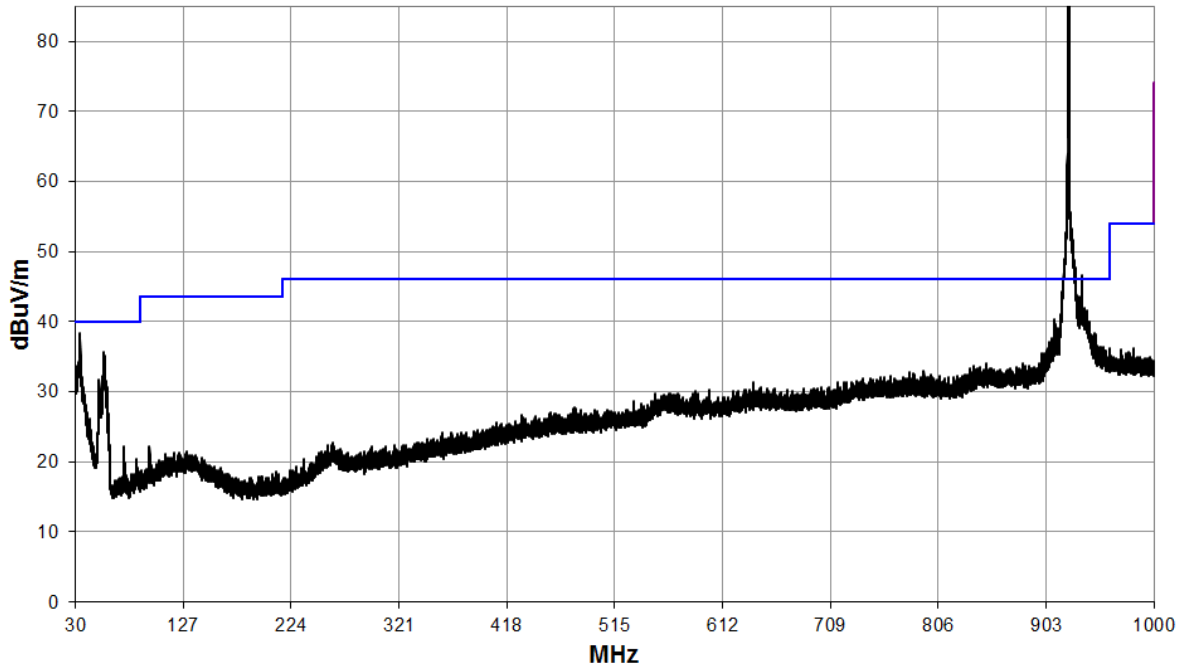


8.2 GHz to 12.4 GHz (FS-THX-03)

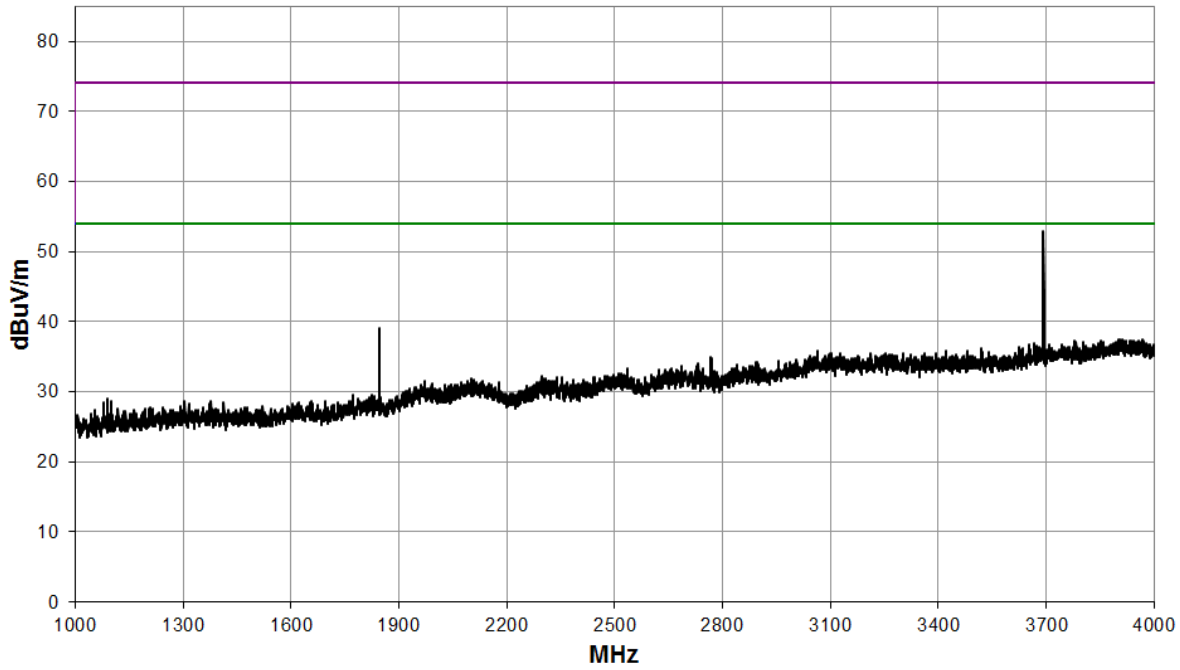


FS-TSX-03; High Power; Frequency: 923 MHz										
Detector	***Freq. (MHz)***	***Meas'd Emission (dBµV)***	***Cable Loss (dB)***	***Antenna Factor (dB/m)***	***Pre-amp Gain (dB)***	***Duty Cycle Corr'n (dB)***	***Distance Extrap'n Factor (dB)***	***Field Strength (dBµV/m)***	***Field Strength (µV/m)***	***Limit (µV/m)***
PK	7382.338	13.3	6.9	38.3	0.0	0.0	0.0	58.5	841.4	5000
PK	3691.082	21.1	4.6	31.2	0.0	0.0	0.0	56.9	699.8	5000
PK	5539.458	15.2	5.9	34.9	0.0	0.0	0.0	56.0	631.0	5000
AV	7382.421	-1.9	6.9	38.3	0.0	0.0	0.0	43.3	146.2	500
AV	3691.456	6.6	4.6	31.2	0.0	0.0	0.0	42.4	131.8	500
AV	5536.879	0.8	5.9	34.9	0.0	0.0	0.0	41.6	120.2	500
AV	4616.080	0.3	5.3	33.0	0.0	0.0	0.0	38.6	85.1	500
AV	1846.000	5.6	3.1	26.5	0.0	0.0	0.0	35.2	57.5	500
QP	935.258	8.7	4.3	30.2	0.0	0.0	0.0	43.2	144.5	200
QP	36.361	16.4	0.7	21.4	0.0	0.0	0.0	38.5	84.1	100
QP	57.045	18.6	0.9	12.0	0.0	0.0	0.0	31.5	37.6	100

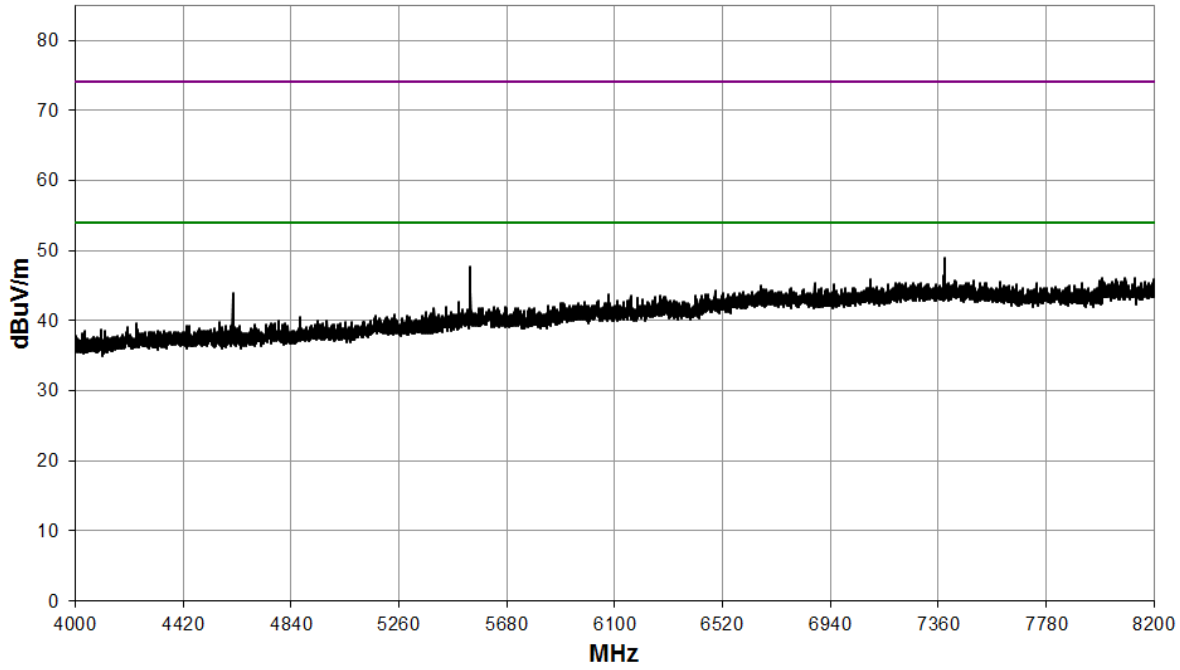
30 MHz to 1 GHz (FS-TSX-03)



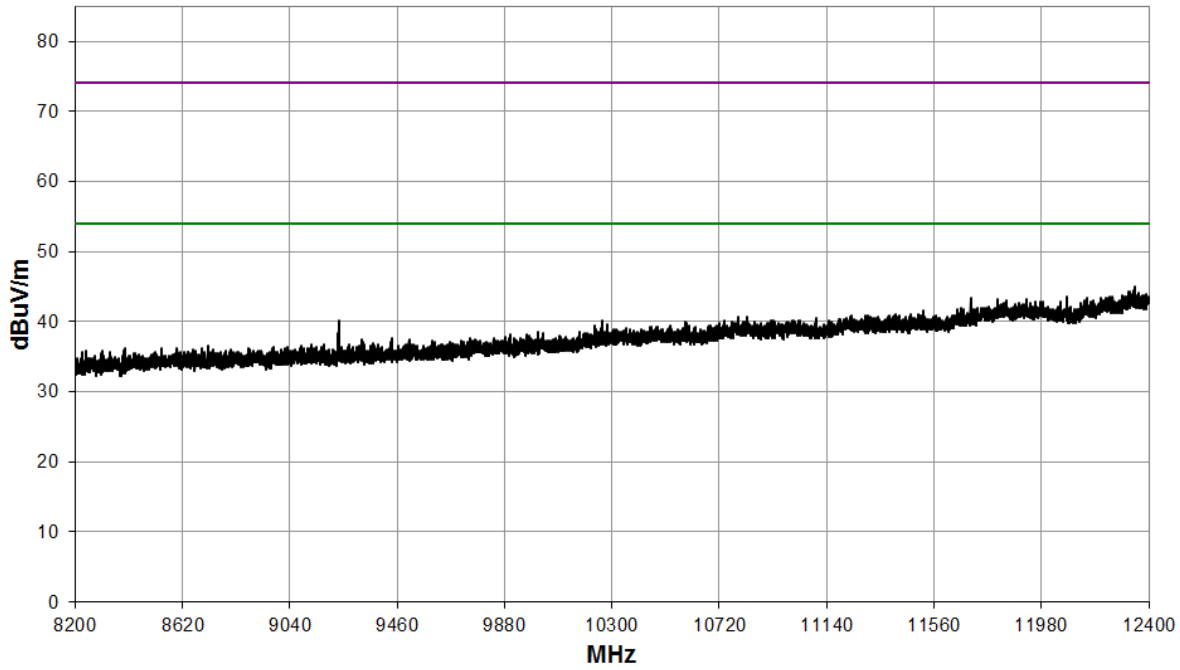
1 GHz to 4 GHz (FS-TSX-03)



4 GHz to 8.2 GHz (FS-TSX-03)



8.2 GHz to 12.4 GHz (FS-TSX-03)



12 Occupied Bandwidth

12.1 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.

12.2 Test Parameters

Test Location:	Element Hull
Test Chamber:	Wireless Laboratory 1
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.8
EUT Frequencies Measured:	923 MHz
EUT Channel Bandwidths:	600 kHz
EUT Test Modulations:	GFSK
Deviations From Standard:	None
Measurement BW: (FCC requirement: 100 kHz)	100 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	300 kHz
Measurement Span: (requirement 2 to 5 times OBW)	2 MHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 21 °C	+15 ºC to +35 ºC (as declared)
Humidity: 51 % RH	20 % RH to 75 % RH (as declared)
Supply: 3.6 V dc	230 V ac ±10 % (as declared)

12.3 Test Limit

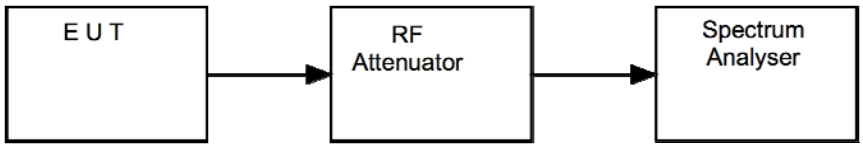
The minimum -6 dB bandwidth shall be at least 500 kHz.

12.4 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

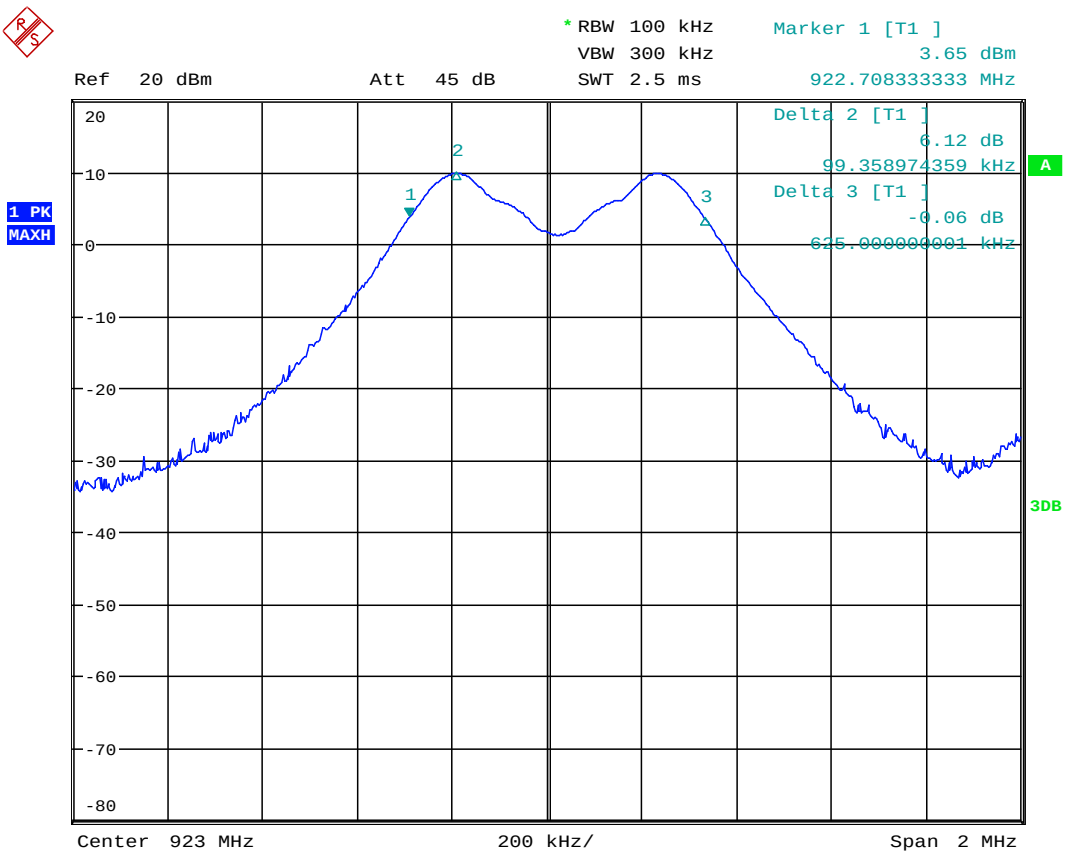


12.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU50	R&S	Spectrum Analyser	U544	2020-06-05
LT30-2	Farnell	Power Supply	RFG035	Cal with REF887
34405A	Agilent	Multimeter	REF887	2019-10-05

12.6 Test Results

FCC 15.247. Modulation: GFSK				
Channel Frequency (MHz)	F_L (MHz)	F_H (MHz)	6dB Bandwidth (kHz)	Result
923	922.708333333	923.333333333	625	PASS



Date: 13.SEP.2019 04:55:25

13 Maximum peak conducted output power

13.1 Definition

The maximum peak conducted output power is defined as the maximum power level measured with a peak detector using a filter with width and shape of which is sufficient to accept the signal bandwidth.

The maximum conducted output power is defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level.

13.2 Test Parameters

Test Location:	Element Hull
Test Chamber:	Wireless Lab 3
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.9.1
EUT Frequency Measured:	923 MHz
EUT Channel Bandwidths:	600 kHz
Deviations From Standard:	None
Measurement BW:	120 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	300 kHz
Measurement Detector:	Peak
Voltage Extreme Environment Test Range:	Battery Power = new battery.

Environmental Conditions (Normal Environment)

Temperature: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 50 % RH	20 % RH to 75 % RH (as declared)

13.3 Test Limit

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.

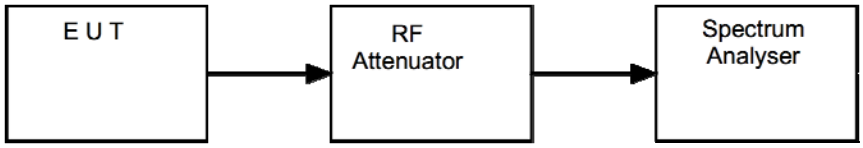
13.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure iv, the resolution bandwidth of the spectrum analyser was increased above the EUT occupied bandwidth and the peak emission data noted.

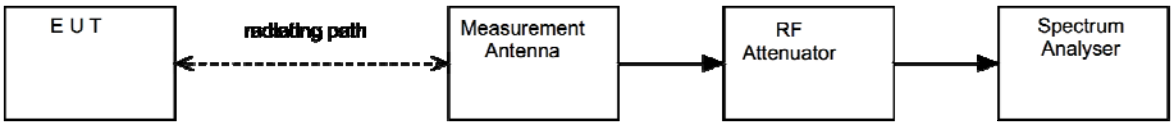
The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst-case configuration in each bandwidth.

Figure iv Test Setup

Conducted Measurement Setup



Radiated Measurement Setup:



13.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
-	Rainford	Ferrite Lined Chamber	REF2259	2020-08-03
ESW26	R&S	EMI Test Receiver	REF2235	2020-07-26
CBL6111B	Chase	Bilog Antenna	REF2218	2019-11-06
FSU50	R&S	Spectrum Analyser	U544	2020-06-05

13.6 Test Results

Conducted measurements were performed on a single example of product FS-TDX-03 and are presented in the table below:

Modulation: GFSK				
Channel Frequency (MHz)	***Analyzer Level (dBm)***	***Cable loss (dB)***	***Power (mW)***	***Result***
923	9.9	0	9.8	PASS

Radiated measurements were performed on examples of each of the 3 products (FS-TDX-03, DS-THX-03 and FS-TSX-03) for cross-comparison purposes and are detailed below.

The following formula may be used to convert field strength (FS) in volts/metre to transmitter output power (TP) in watts:

$$TP = (FS \times D)^2 / (30 \times G)$$

where D is the distance in metres between the two antennas and G is the antenna numerical gain referenced to isotropic gain.

Modulation: GFSK						
Product	***Channel Frequency (MHz)***	***Peak Field Strength (dBµV/m)***	***Distance (m)***	***Antenna Gain (dBi)***	***Max. Power (W)***	***Result***
FS-TDX-03	923	105.1	3	2.6	0.005	PASS
FS-THX-03	923	107.3	3	2.6	0.009	PASS
FS-TSX-03	923	102.4	3	2.6	0.003	PASS

14 Out-of-band and conducted spurious emissions

14.1 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.

14.2 Test Parameters

Test Location:	Element Hull
Test Chamber:	Wireless Laboratory 1
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.11
EUT Frequencies Measured:	923 MHz
EUT Channel Bandwidths:	600 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:	9 kHz to 10 GHz

Environmental Conditions (Normal Environment)

Temperature: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 50 % RH	20 % RH to 75 % RH (as declared)
Supply: 3.6 Vdc	(as declared)

14.3 Test Limit

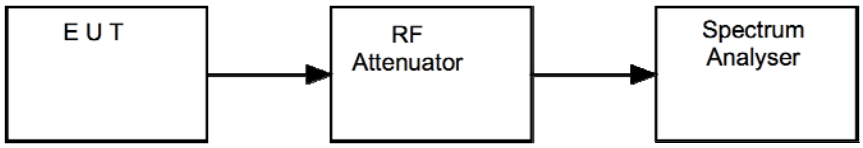
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either 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.

14.4 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

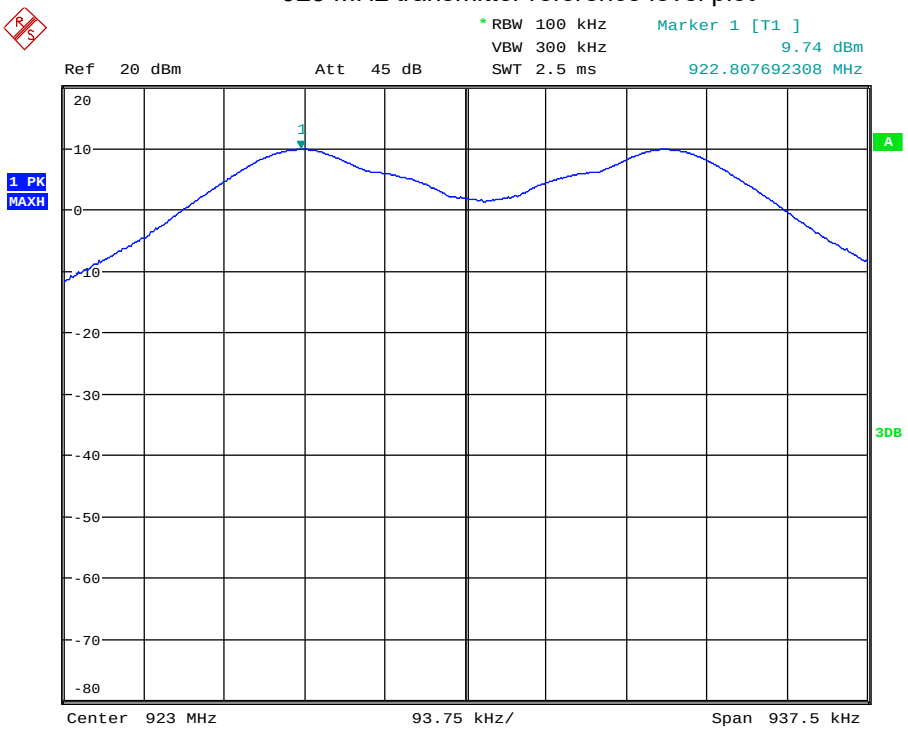


14.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU50	R&S	Spectrum Analyser	U544	2020-06-05
LT30-2	Farnell	Power Supply	RFG035	Cal with REF887
34405A	Agilent	Multimeter	REF887	2019-10-05

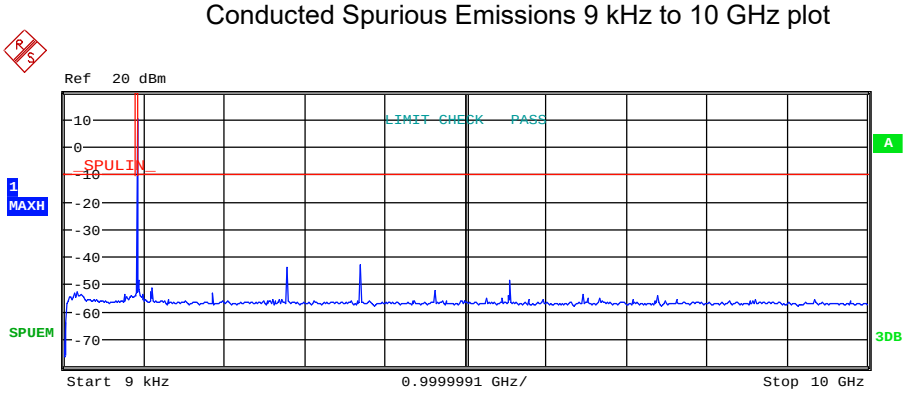
14.6 Test Results

923 MHz transmitter reference level plot



Date: 13.SEP.2019 08:08:38

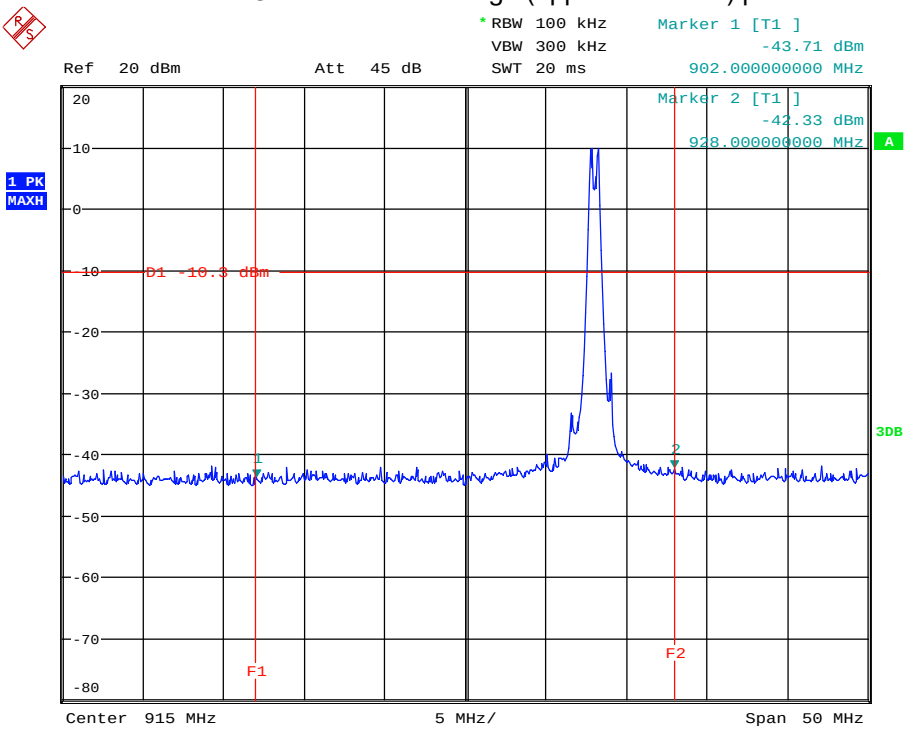
Conducted Spurious Emissions 9 kHz to 10 GHz plot



Start [Hz]	Stop [Hz]	RBW [Hz]	Freq [Hz]	PwrAbs [dBm]	ΔLimit [dB]
9.000 k	150.000 k	1.00 k	9.225962 k	-76.55	-66.25
150.000 k	30.000 M	10.00 k	23.418075 M	-64.32	-54.02
30.000 M	902.000 M	100.00 k	167.950400 M	-53.11	-42.81
902.000 M	928.000 M	100.00 k	922.826000 M	9.69	-10.31
928.000 M	1.000 G	100.00 k	928.072000 M	-49.00	-38.70
1.000 G	5.000 G	100.00 k	3.693200 G	-42.99	-32.69
5.000 G	10.000 G	100.00 k	5.539000 G	-48.56	-38.26

Date: 13.SEP.2019 08:28:04

Conducted Band Edge (upper and lower) plot



Date: 13.SEP.2019 08:54:09

15 Power spectral density

15.1 Definition

The power per unit bandwidth.

15.2 Test Parameters

Test Location:	Element Hull
Test Chamber:	Wireless Laboratory 1
Test Standard and Clause:	ANSI C63.10-2013, Clause 11.10
EUT Channels / Frequencies Measured:	923 MHz
EUT Channel Bandwidths:	600 kHz
Deviations From Standard:	None
Measurement BW:	3 kHz
Spectrum Analyzer Video BW: (requirement at least 3x RBW)	10 kHz
Measurement Span: (requirement 1.5 times Channel BW)	937.5 kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 52 % RH	20 % RH to 75 % RH (as declared)
Supply: 3.6 Vdc	230 V ac ±10% (as declared)

15.3 Test Limit

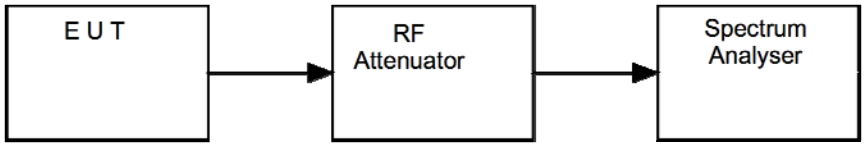
The transmitter power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

15.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure vi, the peak 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

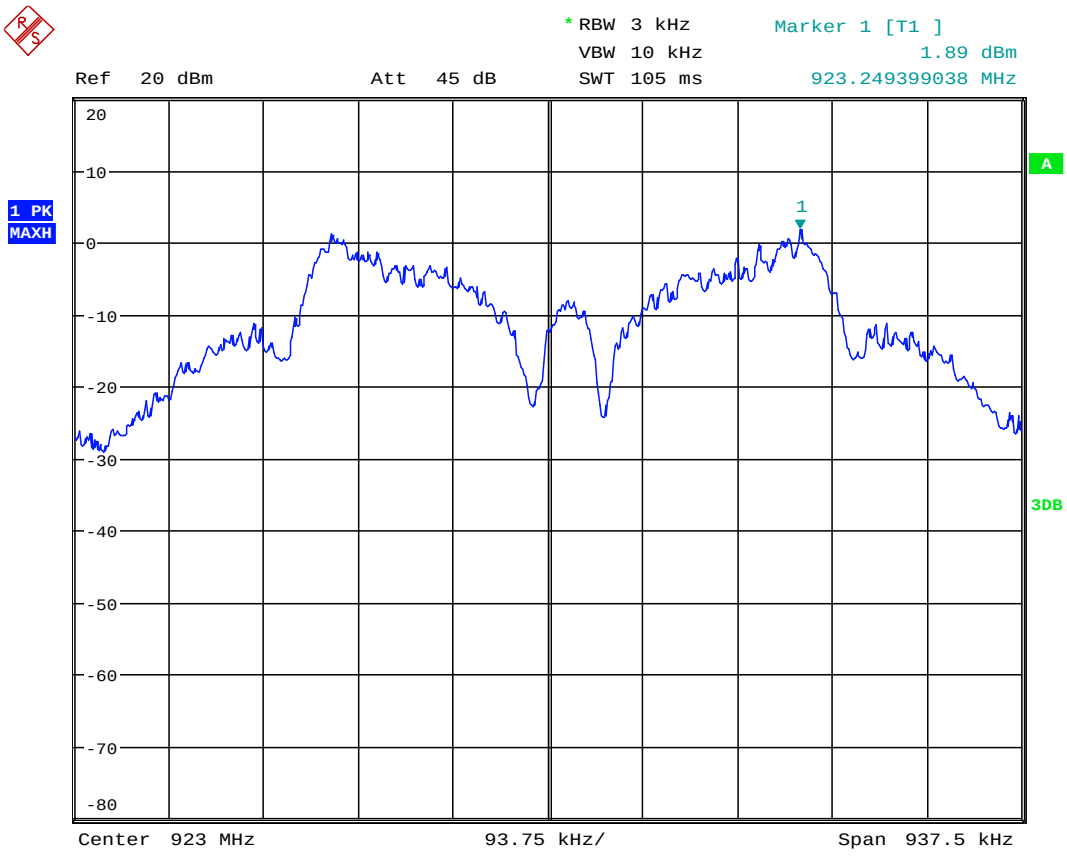


15.5 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
FSU50	R&S	Spectrum Analyser	U544	2020-06-05
LT30-2	Farnell	Power Supply	RFG035	Cal with REF887
34405A	Agilent	Multimeter	REF887	2019-10-05

15.6 Test Results

Modulation: GFSK				
Channel Frequency (MHz)	***Analyzer Level (dBm)***	***Cable loss (dB)***	***Power (dBm)***	***Result***
923	1.89	0	1.89	PASS



Date: 13.SEP.2019 05:33:17

16 Measurement Uncertainty

Calculated Measurement Uncertainties

All statements of uncertainty are expanded standard uncertainty using a coverage factor of 1.96 to give a 95 % confidence:

[1] Radiated spurious emissions

Uncertainty in test result (30 MHz to 1 GHz) = **4.75 dB**
Uncertainty in test result (1 GHz to 18 GHz) = **4.46 dB**

[2] AC power line conducted emissions

Uncertainty in test result = **3.2 dB**

[3] Occupied bandwidth

Uncertainty in test result = **15.58 %**

[4] Conducted carrier power

Uncertainty in test result (Power Meter) = **0.93 dB**

[5] Conducted RF power out-of-band

Uncertainty in test result – up to 8.1 GHz = **3.31 dB**
Uncertainty in test result – 8.1 GHz to 15.3 GHz = **4.43 dB**

[6] Radiated RF power out-of-band

Uncertainty in test result (30 MHz to 1 GHz) = **4.75 dB**
Uncertainty in test result (1 GHz to 18 GHz) = **4.46 dB**

[7] Power spectral density

Uncertainty in test result (Spectrum Analyser) = **3.11 dB**

[8] ERP / EIRP

Uncertainty in test result (Laboratory) = **4.71 dB**

17 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

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

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***
923	17.8	0.6	1.52