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Test report

392183-1TRFWL

Date of issue: April 22, 2020

Applicant:

Cypress Envirosystems, Inc.

Product:

900 MHz module

Model:

121-33089

FCC ID: W3I281333888668 IC ID: 8266A-281333888668

Specifications:

- FCC 47 CFR Part 15, Subpart C – §15.247
- Industry Canada RSS-247, Issue 2

Lab and test locations

Company name	Nemko USA Inc.
Address	2210 Faraday Ave, Suite 150
City	Carlsbad
State	California
Postal code	92008
Country	USA
Telephone	+1 760 444 3500
Website	www.nemko.com
FCC Site Number	Test Firm Registration Number: 392943 Designation Number: US5058
ISED Test Site	2040B-3

Tested by	James Cunningham, Wireless Supervisor
Reviewed by	Juan M Gonzalez, EMC & Wireless Divisions Manager
Review date	April 22, 2020
Reviewer signature	

Limits of responsibility

Note that the results contained in this report relate only to the items tested and were obtained in the period between the date of initial receipt of samples and the date of issue of the report.
This test report has been completed in accordance with the requirements of ISO/IEC 17025. All results contain in this report are within Nemko USA's ISO/IEC 17025 accreditation.
This report must not be used by the client to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the U.S. Government.

Copyright notification

Table of Contents

Section 1 Report summary

1.1 Test specifications

FCC 47 CFR Part 15, Subpart C – §15.247 IC RSS-247 Issue 2	Operation within the bands 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices

1.2 Test methods

ANSI C63.10-2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

1.3 Exclusions

None

1.4 Statement of compliance

In the configuration tested, the EUT was found compliant.

Testing was performed against all relevant requirements of the test standard. Results obtained indicate that the product under test complies in full with the requirements tested. The test results relate only to the items tested.

See "Summary of test results" for full details.

1.5 Test report revision history

Table 1.5-1: Test report revision history

Revision #	Details of changes made to test report
392183-1TRFWL	Original report issued

Notes:

Section 2 Summary of test results

2.1 FCC Part 15.247 / RSS-247

FCC Part	IC Requirement	Test description	Verdict
§15.203/15.247(c)	RSS-Gen §6.8	Antenna requirements	Pass
§15.207	RSS-Gen §8.8	AC conducted limits	Pass
§15.247(a)(1)	RSS-247 §5.1(a)	20 dB occupied bandwidth	Pass
§15.247(a)(1)	RSS-247 §5.1(b)	Carrier frequency separation	Pass
§15.247(a)(1)	RSS-247 §5.1(c)	Hopping channels	Pass
§15.247(a)(2)	RSS-247 §5.1(b)	Minimum 6dB bandwidth	Pass
§15.247(b)(2) / (3)	RSS-247 §5.4(a) / (d)	Peak output power	Pass
§15.247(d)	RSS-247 §5.3	RF conducted spurious emissions and band-edge	Pass
§15.247(d) / §15.209(a) / §15.205	RSS-247 §5.5	Radiated spurious emissions and restricted bands	Pass
§15.247(e)	RSS-247 §5.2(b)	Power spectral density of digital transmission system	Pass
§15.247(f)	RSS-247 §5.3	Average time of occupancy for hybrid system	Pass
§15.247(f)	RSS-247 §5.3	Power spectral density of hybrid system	Pass
---	RSS-Gen §6.7	99% occupied bandwidth	Pass

Note: EUT is powered via USB cable connected to controller laptop. AC conducted emissions were measured on the AC mains port of the controller laptop.

2.2 Operating modes investigated.

The EUT has two distinct operating modes which differ in their operating channels and bandwidths. The 500 kHz channel mode forms a traditional digital transmission system (DTS). The following channels were tested:

LOW: 903 MHz
MID: 914.3 MHz
HIGH: 927.5 MHz

The 125 kHz channel mode a hybrid DTS / frequency hopping system meeting the hybrid system requirements of part 15.247. The following channels were tested:

LOW: 902.3 MHz
MID: 914.3 MHz
HIGH: 927.5 MHz

In hopping mode, the hybrid DTS / frequency hopping system operates over 64 channels with 200 kHz spacing

Section 3 Equipment under test (EUT) details

3.1 Applicant

Company name	Cypress Envirosystems, Inc.
Address	5883 Rue Ferrari, Suite 100
City	San Jose
Province/State	CA
Postal/Zip code	95138
Country	USA

3.2 Manufacturer

Company name	Cypress Envirosystems, Inc.
Address	5883 Rue Ferrari, Suite 100
City	San Jose
Province/State	CA
Postal/Zip code	95138
Country	USA

3.3 Sample information

Receipt date	March 16, 2020
Nemko sample ID number	NEx: 392183

3.4 EUT information

Product name	LoRa module
Model	121-33089
Serial number	BUR173522620
Part number	N/A
Power requirements	Test jig powered by USB
Description/theory of operation	Module product with 902-928 LoRa transceiver
Operational frequencies	125 kHz Channel: 902.3 – 927.5 MHz, 64 channels, 200 kHz spacing 500 kHz Channel: 903 – 927.5 MHz, 8 channels, 1.6 MHz spacing
Software details	Microchip LoRaWan Class A protocol application

3.5 EUT exercise and monitoring details

The EUT was connected to a laptop which was running test software enabling control of the operating mode and frequency to enable the various transmit modes required for testing. The test software used was from. The output power was set to maximum.

Table 3.5-1: EUT sub assemblies

Description	Brand name	Model/Part number	Serial number	Rev.
None				

Table 3.5-2: EUT interface ports

Description	Qty.
USB – provides power and control via test software on laptop	1

Table 3.5-3: Support equipment

Description	Brand name	Model/Part number	Serial number	Rev.
Controller laptop	Dell	P39F		

Table 3.5-4: Inter-connection cables

Cable description	From	To	Length (ft)
USB cable	USB port	Controller laptop	3

Section 4 Engineering considerations

4.1 Modifications incorporated in the EUT

There were no modifications performed to the EUT during this assessment.

4.2 Technical judgment

None

4.3 Deviations from laboratory tests procedures

No deviations were made from laboratory procedures

Section 5 Test conditions

5.1 Atmospheric conditions

Temperature	15-30 °C
Relative humidity	20-75 %
Air pressure	86–106 kPa

When it is impracticable to carry out tests under these conditions, a note to this effect stating the ambient temperature and relative humidity during the tests shall be recorded and stated.

5.2 Power supply range

The normal test voltage for equipment to be connected to the mains shall be the nominal mains voltage. For the purpose of the present document, the nominal voltage shall be the declared voltage, or any of the declared voltages ±5 %, for which the equipment was designed.

Section 6 Measurement uncertainty

6.1 Uncertainty of measurement

Measurement uncertainty budgets for the tests are detailed below. Measurement uncertainty calculations assume a coverage factor of K = 2 with 95% certainty.

Test name	Measurement uncertainty, dB
Radiated spurious emissions	3.78
Powerline conducted emissions	1.38
All antenna port measurements	0.55
Conducted spurious emissions	1.13

Section 7 Testing data

7.1 Antenna requirement

7.1.1 References

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.203
An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited. This requirement does not apply to carrier current devices or to devices operated under the provisions of §§15.211, 15.213, 15.217, 15.219, 15.221, or §15.236. Further, this requirement does not apply to intentional radiators that must be professionally installed, such as perimeter protection systems and some field disturbance sensors, or to other intentional radiators which, in accordance with §15.31(d), must be measured at the installation site. However, the installer shall be responsible for ensuring that the proper antenna is employed so that the limits in this part are not exceeded.

7.1.2 Test summary

Verdict	Pass – The module is intended for use with a dedicated antenna, part number 0915AT43A0026 (-1.0 dBi peak gain in the 902-928MHZ range
Test date	March 16, 2020
Test engineer	James Cunningham

7.2 AC power line conducted emissions

7.2.1 References

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.207
RSS-Gen → §8.8)

Frequency of emission (MHz)	Conducted limit (dBµV)	
	Quasi-peak	Average
0.15-0.5	66 to 56*	56 to 46*
0.5-5	56	46
5-30	60	50

7.2.2 Test summary

Verdict	Pass		
Test date	March 17, 2020	Temperature	20°C
Test engineer	James Cunningham	Air pressure	1007 mbar
Test location	Ground plane	Relative humidity	49%

7.2.3 Notes

Testing was performed in DTS mode and hybrid DTS/frequency hopping mode (hopping disabled) and the EUT transmitting on a fixed channel.

7.2.4 Setup details

Port under test	AC mains of support laptop
EUT setup configuration	Tabletop
Measurement details	A preview measurement was generated with the receiver in continuous scan mode. Emissions detected within 6 dB or above limit were re-measured with the appropriate detector against the correlating limit and recorded as the final measurement.

Receiver settings:

Resolution bandwidth	9 kHz
Video bandwidth	30 kHz
Detector mode	– Peak and Average (Preview measurement) – Quasi-peak and CAverage (Final measurement)
Trace mode	Max Hold
Measurement time	– 100 ms (Peak and Average preview measurement) – 5000 ms (Quasi-peak final measurement) – 5000 ms (CAverage final measurement)

Table 7.2-1: *Conducted disturbance at mains port equipment list*

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
EMI Test Receiver	Rohde & Schwarz	ESCI 7	E1026	1 year	29 May 2020
Transient Limiter	Hewlett-Packard	11947A	684	1 year	20 Jan 2021
Two Line V-Network	Rohde & Schwarz	ENV216	E1019	1 year	12 Jul 2020
LISN	Solar	9348-50-R-24-BNC	384	1 year	8 Aug 2020

Table 7.2-2: *Conducted disturbance at mains port test software details*

Manufacturer of Software	Details
Rohde & Schwarz	EMC 32 V10.20.01

7.2.5 Test data, DTS mode

Table 7.2-3: AC conducted emissions, 150 kHz – 30 MHz, DTS mode, LOW channel (903 MHz)

Frequency (MHz)	QuasiPeak (dBµV)	CAverage (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)
2.294000	---	27.29	46.00	18.71	5000.0	9.000	L1	ON	19.4
2.294000	32.73	---	56.00	23.27	5000.0	9.000	L1	ON	19.4
2.534000	---	27.19	46.00	18.81	5000.0	9.000	L1	ON	19.4
2.534000	33.03	---	56.00	22.97	5000.0	9.000	L1	ON	19.4
4.746000	---	29.61	46.00	16.39	5000.0	9.000	L1	ON	19.3
4.746000	35.74	---	56.00	20.26	5000.0	9.000	L1	ON	19.3
4.838000	---	31.21	46.00	14.79	5000.0	9.000	L1	ON	19.3
4.838000	36.97	---	56.00	19.03	5000.0	9.000	L1	ON	19.3
4.878000	---	29.30	46.00	16.70	5000.0	9.000	L1	ON	19.3
4.878000	35.45	---	56.00	20.56	5000.0	9.000	L1	ON	19.3
4.994000	---	28.03	46.00	17.97	5000.0	9.000	L1	ON	19.3
4.994000	35.04	---	56.00	20.97	5000.0	9.000	L1	ON	19.3

Notes:
Result (dBµV) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factor (dB) = LISN factor IL (dB) + cable loss (dB) + transient limiter (dB)
The maximum measured value observed over a period of 5 seconds was recorded.

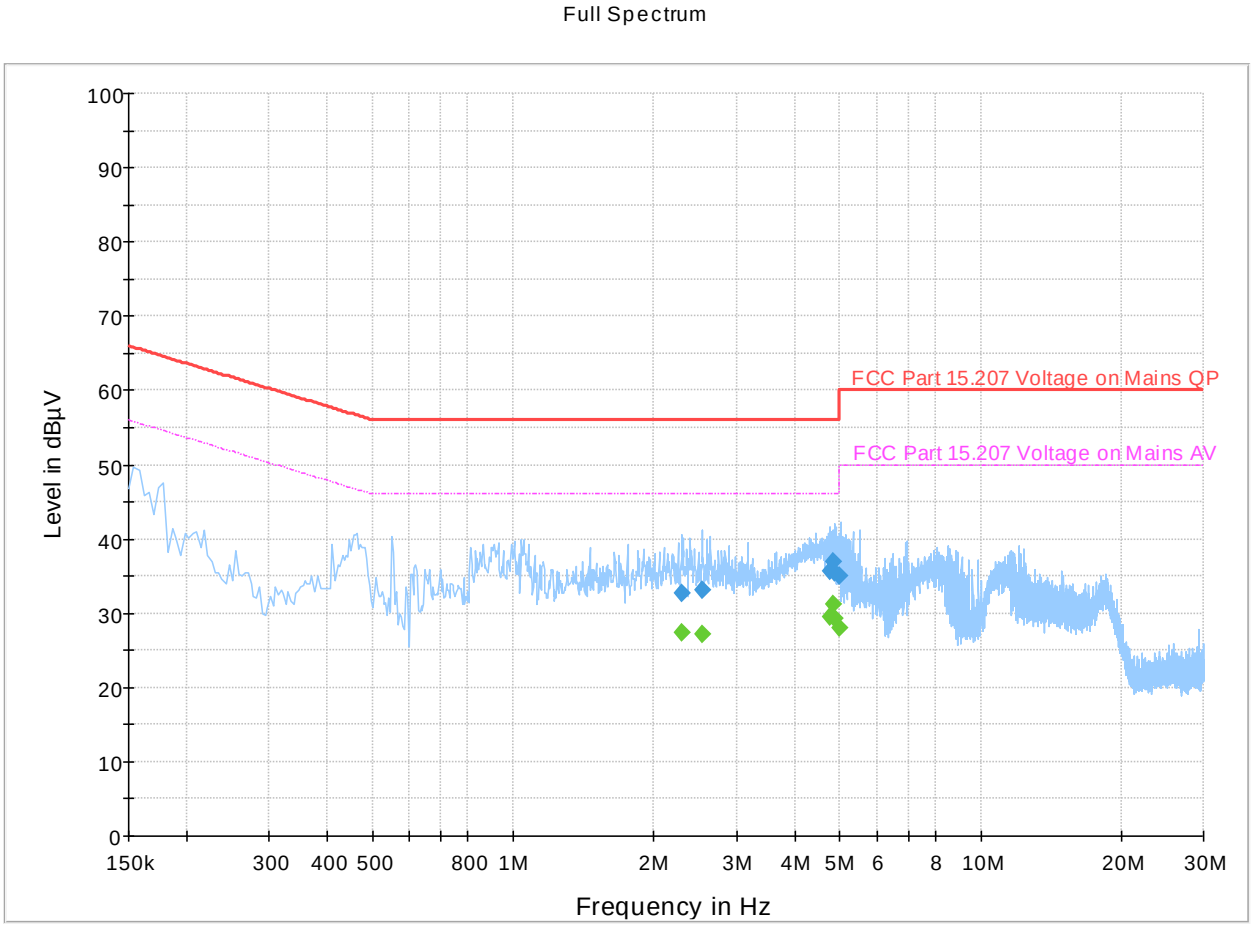


Figure 7.2-1: AC conducted emissions, DTS mode, 903 MHz TX

Table 7.2-4: AC conducted emissions, 150 kHz – 30 MHz, DTS mode, MID channel (914.3 MHz)

Frequency (MHz)	QuasiPeak (dBµV)	CAverage (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)
0.158000	45.64	---	65.57	19.93	5000.0	9.000	N	ON	19.6
0.158000	---	33.86	55.57	21.71	5000.0	9.000	N	ON	19.6
0.458000	37.38	---	56.73	19.35	5000.0	9.000	L1	ON	19.4
0.458000	---	31.48	46.73	15.24	5000.0	9.000	L1	ON	19.4
4.478000	36.29	---	56.00	19.71	5000.0	9.000	L1	ON	19.3
4.478000	---	31.48	46.00	14.52	5000.0	9.000	L1	ON	19.3
4.870000	35.74	---	56.00	20.26	5000.0	9.000	L1	ON	19.3
4.870000	---	29.20	46.00	16.80	5000.0	9.000	L1	ON	19.3
4.910000	35.64	---	56.00	20.36	5000.0	9.000	L1	ON	19.3
4.910000	---	28.90	46.00	17.10	5000.0	9.000	L1	ON	19.3
4.986000	35.23	---	56.00	20.77	5000.0	9.000	L1	ON	19.3
4.986000	---	28.07	46.00	17.93	5000.0	9.000	L1	ON	19.3

Notes:
Result (dBµV) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factor (dB) = LISN factor IL (dB) + cable loss (dB) + transient limiter (dB)
The maximum measured value observed over a period of 5 seconds was recorded.

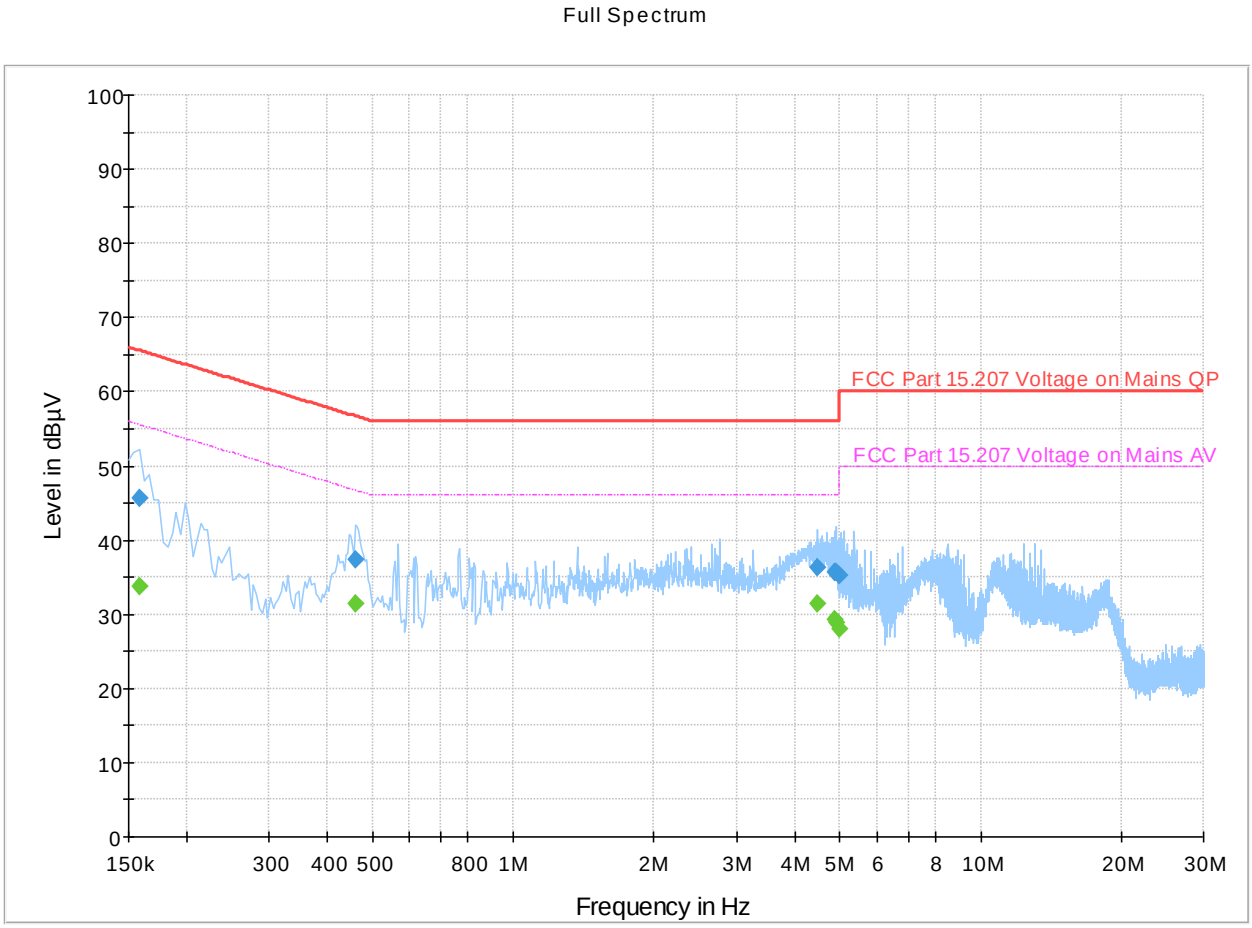


Figure 7.2-2: AC conducted emissions, DTS mode, 914.3 MHz TX

Table 7.2-5: AC conducted emissions, 150 kHz – 30 MHz, DTS mode, HIGH channel (927.5 MHz)

Frequency (MHz)	QuasiPeak (dBµV)	CAverage (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)
0.150000	---	32.45	56.00	23.55	5000.0	9.000	L1	ON	19.6
0.150000	44.18	---	66.00	21.82	5000.0	9.000	L1	ON	19.6
0.550000	---	22.08	46.00	23.92	5000.0	9.000	L1	ON	19.4
0.550000	30.00	---	56.00	26.00	5000.0	9.000	L1	ON	19.4
4.682000	---	30.17	46.00	15.83	5000.0	9.000	L1	ON	19.3
4.682000	35.97	---	56.00	20.03	5000.0	9.000	L1	ON	19.3
4.822000	---	29.03	46.00	16.97	5000.0	9.000	L1	ON	19.3
4.822000	35.59	---	56.00	20.41	5000.0	9.000	L1	ON	19.3
4.938000	---	29.94	46.00	16.06	5000.0	9.000	L1	ON	19.3
4.938000	35.81	---	56.00	20.19	5000.0	9.000	L1	ON	19.3
4.974000	---	28.15	46.00	17.85	5000.0	9.000	L1	ON	19.3
4.974000	34.92	---	56.00	21.08	5000.0	9.000	L1	ON	19.3

Notes: Result (dBµV) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factor (dB) = LISN factor IL (dB) + cable loss (dB) + transient limiter (dB)
The maximum measured value observed over a period of 5 seconds was recorded.

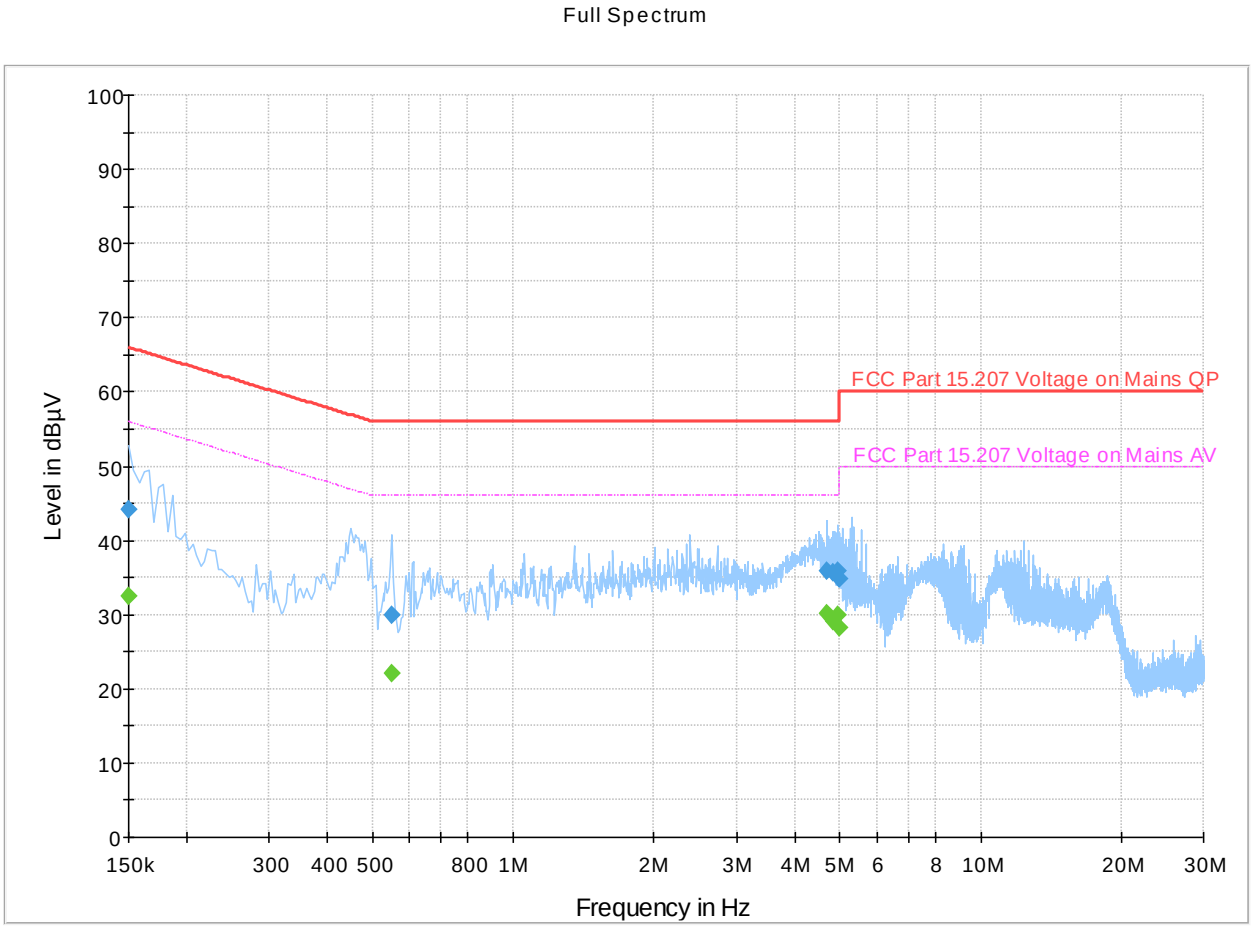


Figure 7.2-3: AC conducted emissions, DTS mode, 927.5 MHz TX

7.2.6 Test data, hybrid mode

Table 7.2-6: AC conducted emissions, 150 kHz – 30 MHz, hybrid mode, LOW channel (902.3 MHz)

Frequency (MHz)	QuasiPeak (dBµV)	CAverage (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)
0.158000	---	33.42	55.57	22.15	5000.0	9.000	N	ON	19.6
0.158000	45.83	---	65.57	19.73	5000.0	9.000	N	ON	19.6
0.302000	---	20.92	50.19	29.27	5000.0	9.000	N	ON	19.5
0.302000	31.16	---	60.19	29.02	5000.0	9.000	N	ON	19.5
0.306000	32.04	---	60.08	28.04	5000.0	9.000	N	ON	19.5
0.306000	---	20.55	50.08	29.53	5000.0	9.000	N	ON	19.5
2.118000	---	28.01	46.00	17.99	5000.0	9.000	L1	ON	19.4
2.118000	33.54	---	56.00	22.46	5000.0	9.000	L1	ON	19.4
2.766000	---	28.30	46.00	17.70	5000.0	9.000	L1	ON	19.4
2.766000	33.64	---	56.00	22.36	5000.0	9.000	L1	ON	19.4
4.738000	36.61	---	56.00	19.39	5000.0	9.000	L1	ON	19.3
4.738000	---	31.68	46.00	14.32	5000.0	9.000	L1	ON	19.3

Notes:
Result (dBµV) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factor (dB) = LISN factor IL (dB) + cable loss (dB) + transient limiter (dB)
The maximum measured value observed over a period of 5 seconds was recorded.

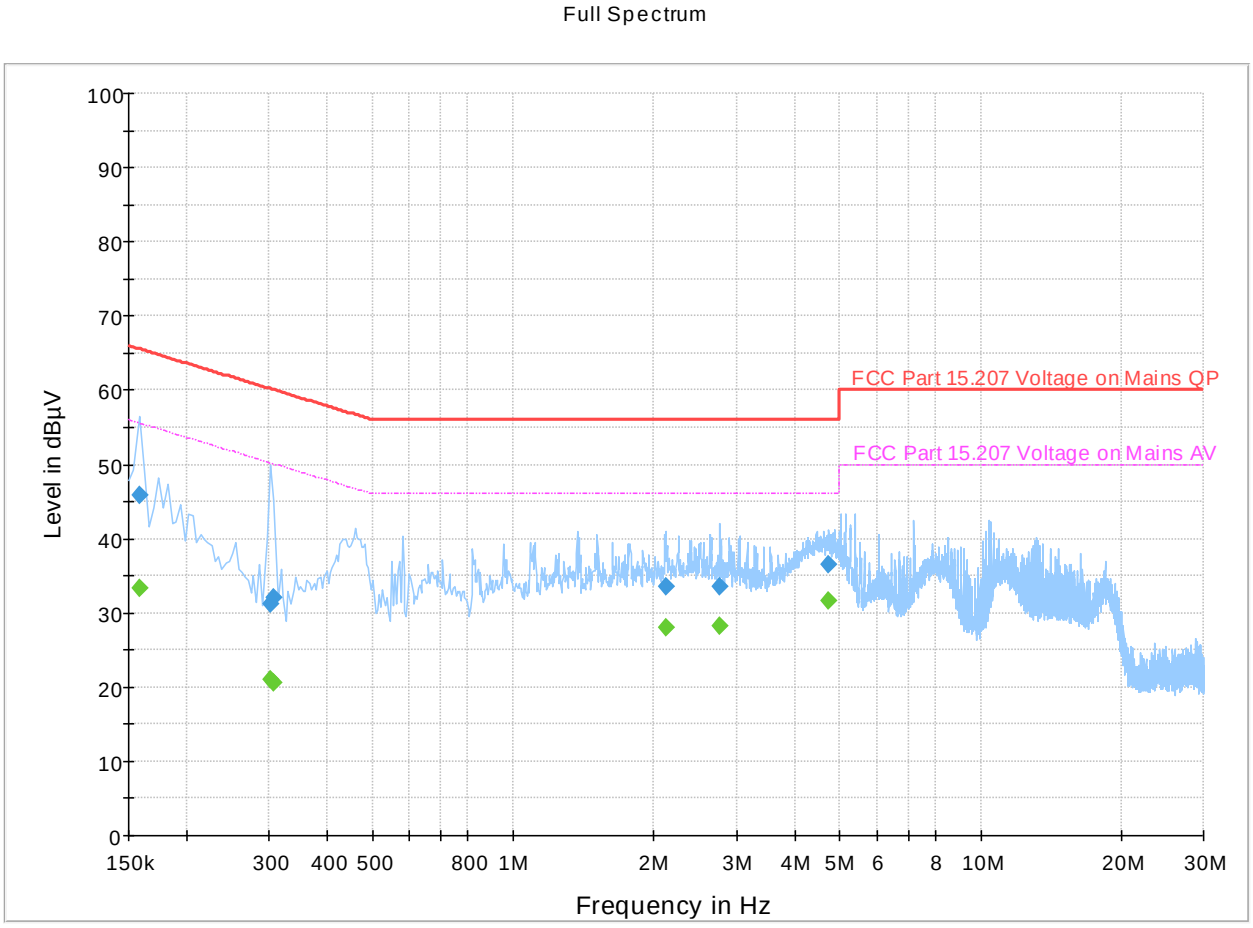


Figure 7.2-4: AC conducted emissions, hybrid mode, 902.3 MHz TX

Table 7.2-7: AC conducted emissions, 150 kHz – 30 MHz, hybrid mode, MID channel (914.7 MHz)

Frequency (MHz)	QuasiPeak (dBµV)	CAverage (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)
0.150000	49.48	---	66.00	16.52	5000.0	9.000	N	ON	19.6
0.150000	---	37.08	56.00	18.92	5000.0	9.000	N	ON	19.6
0.458000	37.13	---	56.73	19.60	5000.0	9.000	L1	ON	19.4
0.458000	---	31.64	46.73	15.09	5000.0	9.000	L1	ON	19.4
2.114000	33.21	---	56.00	22.79	5000.0	9.000	L1	ON	19.4
2.114000	---	27.93	46.00	18.07	5000.0	9.000	L1	ON	19.4
2.634000	33.89	---	56.00	22.11	5000.0	9.000	L1	ON	19.4
2.634000	---	28.53	46.00	17.47	5000.0	9.000	L1	ON	19.4
2.894000	32.93	---	56.00	23.07	5000.0	9.000	L1	ON	19.4
2.894000	---	27.50	46.00	18.50	5000.0	9.000	L1	ON	19.4
4.830000	36.38	---	56.00	19.62	5000.0	9.000	L1	ON	19.3
4.830000	---	31.05	46.00	14.95	5000.0	9.000	L1	ON	19.3

Notes:
Result (dBµV) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factor (dB) = LISN factor IL (dB) + cable loss (dB) + transient limiter (dB)
The maximum measured value observed over a period of 5 seconds was recorded.

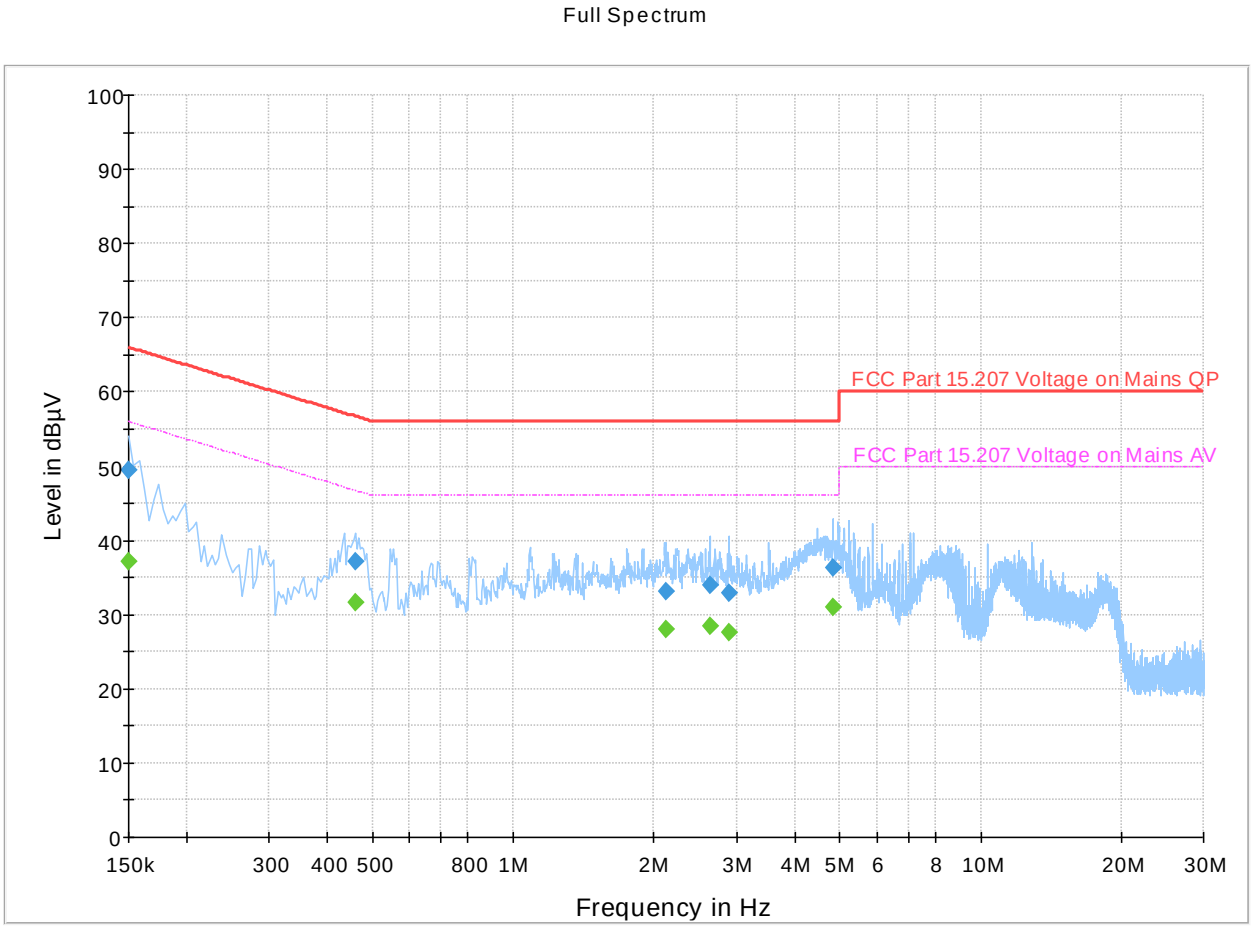


Figure 7.2-5: AC conducted emissions, hybrid mode, 914.7 MHz TX

Table 7.2-8: AC conducted emissions, 150 kHz – 30 MHz, hybrid mode, HIGH channel (927.5 MHz)

Frequency (MHz)	QuasiPeak (dBµV)	CAverage (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)
1.602000	---	26.52	46.00	19.48	5000.0	9.000	L1	ON	19.4
1.602000	31.30	---	56.00	24.70	5000.0	9.000	L1	ON	19.4
2.346000	---	26.96	46.00	19.04	5000.0	9.000	L1	ON	19.4
2.346000	32.35	---	56.00	23.65	5000.0	9.000	L1	ON	19.4
2.994000	---	26.17	46.00	19.83	5000.0	9.000	L1	ON	19.4
2.994000	32.11	---	56.00	23.89	5000.0	9.000	L1	ON	19.4
4.678000	---	30.27	46.00	15.73	5000.0	9.000	L1	ON	19.3
4.678000	35.49	---	56.00	20.51	5000.0	9.000	L1	ON	19.3
4.830000	---	28.84	46.00	17.16	5000.0	9.000	L1	ON	19.3
4.830000	35.22	---	56.00	20.78	5000.0	9.000	L1	ON	19.3
4.946000	---	27.42	46.00	18.58	5000.0	9.000	L1	ON	19.3
4.946000	33.92	---	56.00	22.08	5000.0	9.000	L1	ON	19.3

Notes:
Result (dBµV) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factor (dB) = LISN factor IL (dB) + cable loss (dB) + transient limiter (dB)
The maximum measured value observed over a period of 5 seconds was recorded.

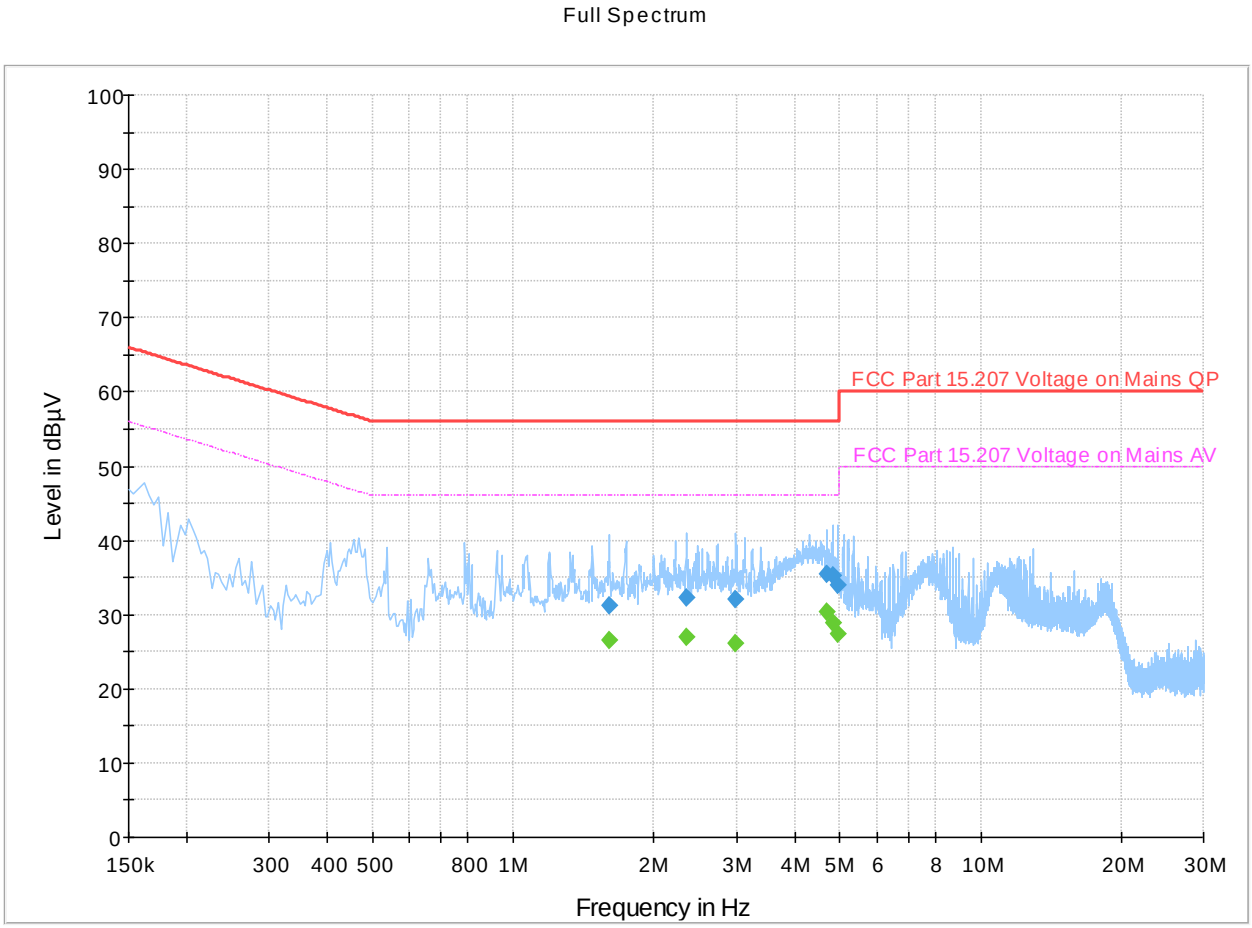


Figure 7.2-6: AC conducted emissions, hybrid mode, 927.5 MHz TX

7.3 20 dB occupied bandwidth

7.3.1 References

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.247(a)(1) / ANSI C63.10: 2013
RSS-247 → §5.1(a)

7.3.2 Test summary

Verdict	Pass		
Test date	April 7, 2020	Temperature	19°C
Test engineer	James Cunningham	Air pressure	1008 mbar
Test location	Wireless bench	Relative humidity	57%

7.3.3 Notes

Testing was performed in hybrid DTS/frequency hopping mode with hopping disabled and the EUT transmitting on a fixed channel.

7.3.4 Setup details

EUT setup configuration	Tabletop
Test facility	Wireless bench
Measurement details	Measurement performed as per C63.10 §6.9.3 using the built-in function of the spectrum analyzer
Measurement Procedure	ANSI C63.10 7.8.7 and 6.9.2

Receiver/spectrum analyzer settings:

Resolution bandwidth	3 kHz
Video bandwidth	10 kHz
Detector mode	Peak
Trace mode	Max Hold
Measurement time	Long enough for trace to stabilize

Table 7.3-1: 20 dB occupied bandwidth equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
Signal and spectrum analyzer	Rohde & Schwarz	FSW	E1302	1 year	10 Jan 2021

7.3.5 Test data

Table 7.3-2: 20 dB occupied bandwidth test data

Test Mode	Test Frequency (MHz)	Bandwidth (kHz)
125 kHz channel (hybrid mode)	902.3	140.4
	914.9	142.4
	927.5	140.9

Figure 7.3-1: 20 dB occupied bandwidth, 902.3 MHz

Figure 7.3-2: 20 dB occupied bandwidth, 914.9 MHz

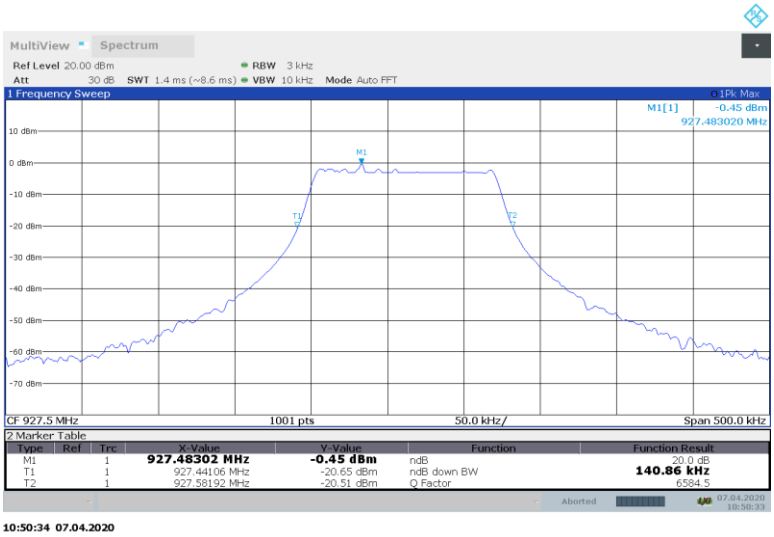


Figure 7.3-3: 20 dB occupied bandwidth, 927.5 MHz

7.4 Carrier frequency separation

7.4.1 References

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.247(a)(1) / ANSI C63.10: 2013
RSS-247 → §5.1(b)

7.4.2 Test summary

Verdict	Pass		
Test date	April 6, 2020	Temperature	19°C
Test engineer	James Cunningham	Air pressure	1004 mbar
Test location	Wireless bench	Relative humidity	44%

7.4.3 Notes

Testing was performed in hybrid DTS/frequency hopping mode.

7.4.4 Setup details

EUT setup configuration	Tabletop
Test facility	Wireless bench
Measurement details	Measurement performed using max hold and marker functions of spectrum analyzer

Receiver/spectrum analyzer settings:

Resolution bandwidth	100 kHz
Video bandwidth	300 kHz
Detector mode	Peak
Trace mode	Max Hold
Measurement time	Long enough for trace to stabilize
Measurement Procedure	ANSI 63.10 7.8.2

Table 7.4-1: Carrier frequency separation equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
Signal and spectrum analyzer	Rohde & Schwarz	FSW	E1302	1 year	10 Jan 2021

7.4.5 Test data

Table 7.4-2: Carrier frequency separation test data

Test Mode	Test Frequency (MHz)	Carrier Frequency Separation (kHz)	Limit (kHz)
125 kHz channel (hybrid mode)	902.3 and 902.5	200	142.4
Note: Limit is 0.025 MHz or the 20 dB bandwidth, whichever is greater. Refer to Section 7.2 for 20 dB bandwidth results.			

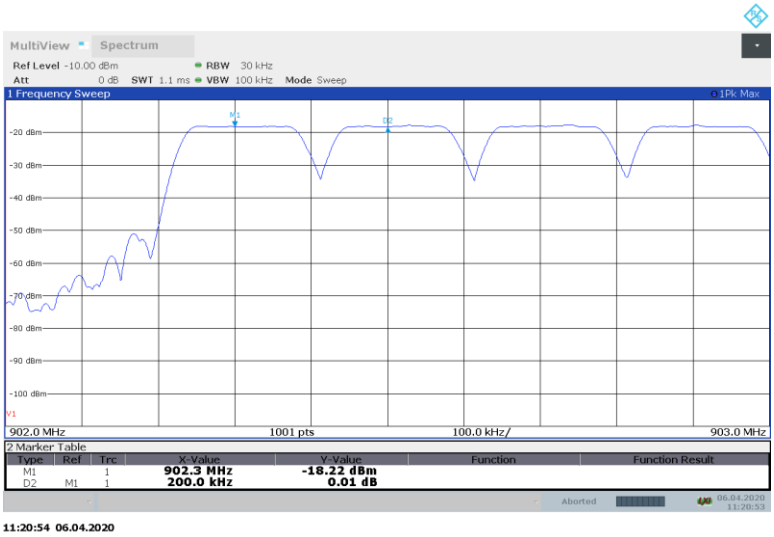


Figure 7.4-1: Carrier frequency separation, hybrid mode

7.5 Hopping channel number

7.5.1 References

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.247(a)(1) / ANSI C63.10: 2013
RSS-247 → §5.1(c)

7.5.2 Test summary

Verdict	Pass		
Test date	March 18, 2020	Temperature	20°C
Test engineer	James Cunningham	Air pressure	1008 mbar
Test location	Wireless bench	Relative humidity	48%

7.5.3 Notes

Testing was performed in hybrid DTS/frequency hopping mode.

7.5.4 Setup details

EUT setup configuration	Tabletop
Test facility	Wireless bench
Measurement details	Measurement performed using spectrum analyzer with max hold trace
Measurement Procedure	ANSI 63.10 7.8.3

Receiver/spectrum analyzer settings:

Resolution bandwidth	30 kHz
Video bandwidth	100 kHz
Detector mode	Peak
Trace mode	Max Hold
Measurement time	Long enough for trace to stabilize

Table 7.5-1: Number of hopping channels equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
Signal and spectrum analyzer	Rohde & Schwarz	FSW	E1302	1 year	10 Jan 2021

7.5.5 Test data

Table 7.5-2: Number of hopping channels (hybrid mode)

Test Mode	Number of hopping channels
125 kHz channel (hybrid mode)	64

Figure 7.5-1: Number of hopping channels, hybrid mode

7.6 6 dB occupied bandwidth

7.6.1 References

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.247(a)(2) / ANSI C63.10: 2013
RSS-247 → §5.2(a)

7.6.2 Test summary

Verdict	Pass		
Test date	March 18, 2020	Temperature	20°C
Test engineer	James Cunningham	Air pressure	1008 mbar
Test location	Wireless bench	Relative humidity	48%

7.6.3 Notes

Testing was performed in DTS mode and the EUT transmitting on a fixed channel.

7.6.4 Setup details

EUT setup configuration	Tabletop
Test facility	Wireless bench
Measurement details	Measurement performed as per C63.10 §6.9.2 using the built-in marker function of the spectrum analyzer

Receiver/spectrum analyzer settings:

Resolution bandwidth	100 kHz
Video bandwidth	300 kHz
Detector mode	Peak
Trace mode	Max Hold
Measurement time	Long enough for trace to stabilize

Table 7.6-1: 6 dB occupied bandwidth equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
Signal and spectrum analyzer	Rohde & Schwarz	FSW	E1302	1 year	10 Jan 2021

7.6.5 Test data

Table 7.6-2: 6 dB occupied bandwidth test data

Test Mode	Test Frequency (MHz)	Bandwidth (kHz)
500 kHz channel (DTS mode)	903.0	779.2
	914.3	754.2
	927.5	769.2

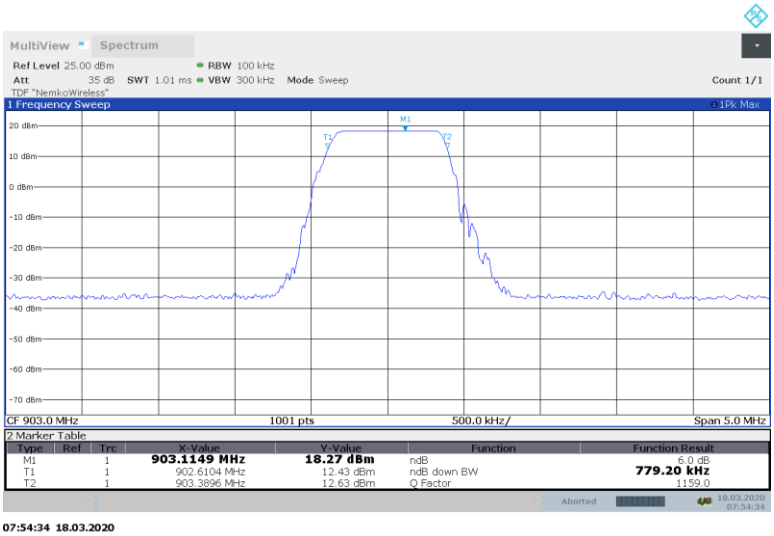


Figure 7.6-1: 6 dB occupied bandwidth, 903.0 MHz

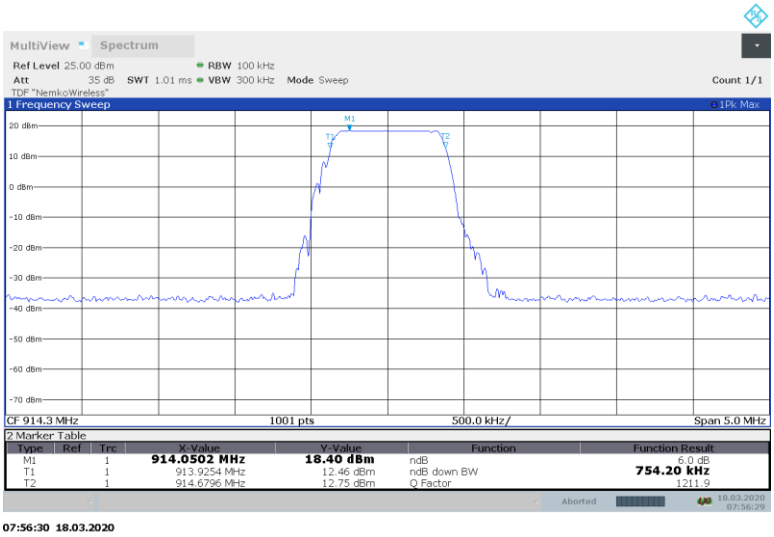


Figure 7.6-2: 6dB occupied bandwidth, 914.3 MHz

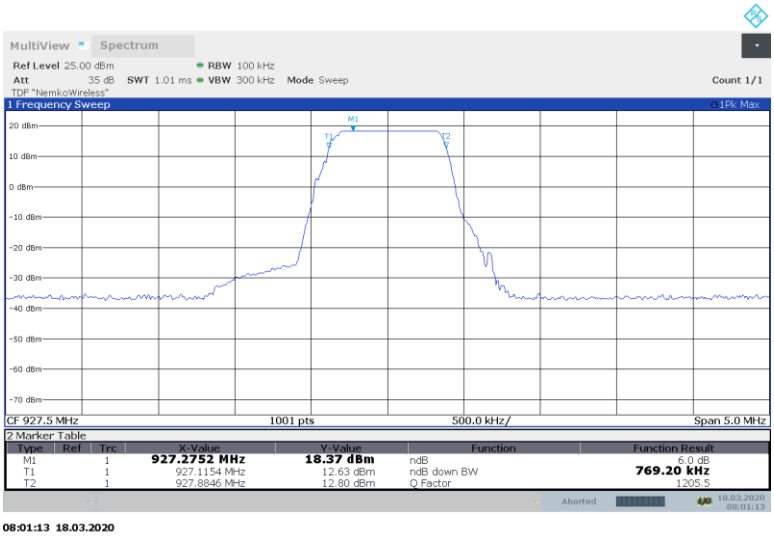


Figure 7.6-3: 6 dB occupied bandwidth, 927.5 MHz

7.7 Peak output power

7.7.1 References

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.247(b)(2) / (3) / ANSI C63.10: 2013
RSS-247 → §5.4(a) / (d)

7.7.2 Test summary

Verdict	Pass		
Test date	March 18, 2020	Temperature	20°C
Test engineer	James Cunningham	Air pressure	1008 mbar
Test location	Wireless bench	Relative humidity	48%

7.7.3 Notes

Testing was performed in DTS mode and hybrid DTS/frequency hopping mode (hopping disabled) and the EUT transmitting on a fixed channel.
The EUT antenna port was connected to the spectrum analyzer via low loss cable and a suitable attenuator. The loss of this assembly was corrected for via a transducer factor in the spectrum analyzer.

7.7.4 Setup details

EUT setup configuration	Tabletop
Test facility	Wireless bench
Measurement details	Measurement performed as per C63.10 §11.9

Receiver/spectrum analyzer settings:

Resolution bandwidth	1 MHz
Video bandwidth	3 MHz
Detector mode	Peak
Trace mode	Max Hold
Measurement time	Long enough for trace to stabilize

Table 7.7-1: Peak output power equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
Signal and spectrum analyzer	Rohde & Schwarz	FSW	E1302	1 year	10 Jan 2021

7.7.5 Test data, DTS mode

Table 7.7-2: Peak output power, DTS mode

Test Mode	Test Frequency (MHz)	Conducted Power (dBm)	Conducted Limit (dBm)	Antenna Gain (dBi)	EIRP (dBm)	EIRP Limit (dBm)
500 kHz channel (DTS mode)	903.0	18.30	30.0	-1.00	17.30	36.0
	914.3	18.40	30.0	-1.00	17.40	36.0
	927.5	18.33	30.0	-1.00	17.33	36.0

Figure 7.7-1: Peak output power, DTS mode, 903.0 MHz

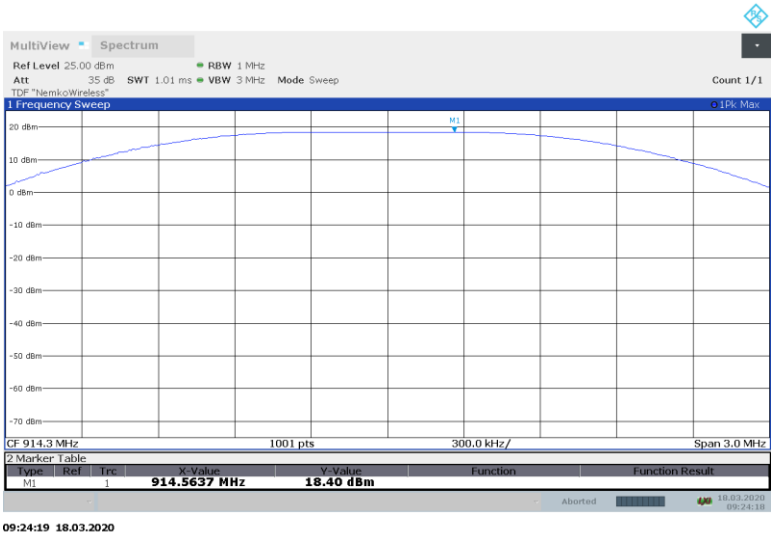


Figure 7.7-2: Peak output power, DTS mode, 914.3 MHz

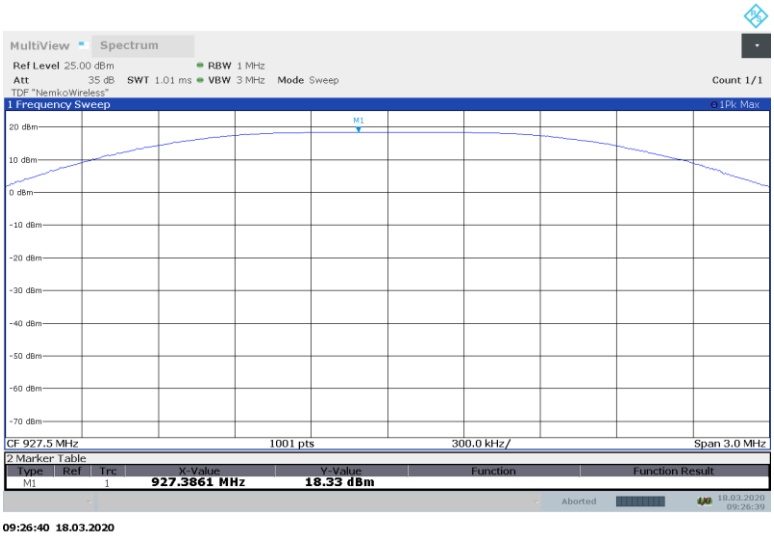


Figure 7.7-3: Peak output power, DTS mode, 927.5 MHz

7.7.6 Test data, hybrid mode

Table 7.7-3: Peak output power, hybrid mode

Test Mode	Test Frequency (MHz)	Conducted Power (dBm)	Conducted Limit (dBm)	Antenna Gain (dBi)	EIRP (dBm)	EIRP Limit (dBm)
125 kHz channel (hybrid mode)	902.3	18.27	30.0	-1.00	17.27	36.0
	914.9	18.35	30.0	-1.00	17.35	36.0
	927.5	18.29	30.0	-1.00	17.29	36.0

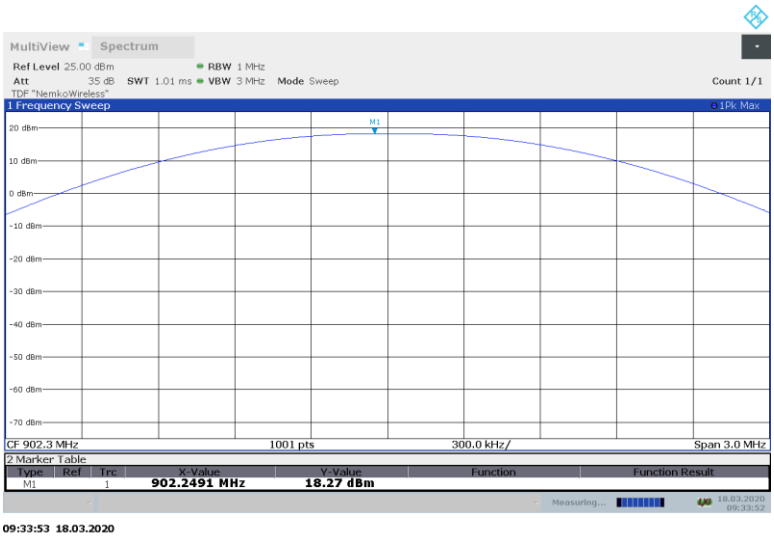


Figure 7.7-4: Peak output power, hybrid mode, 902.3 MHz

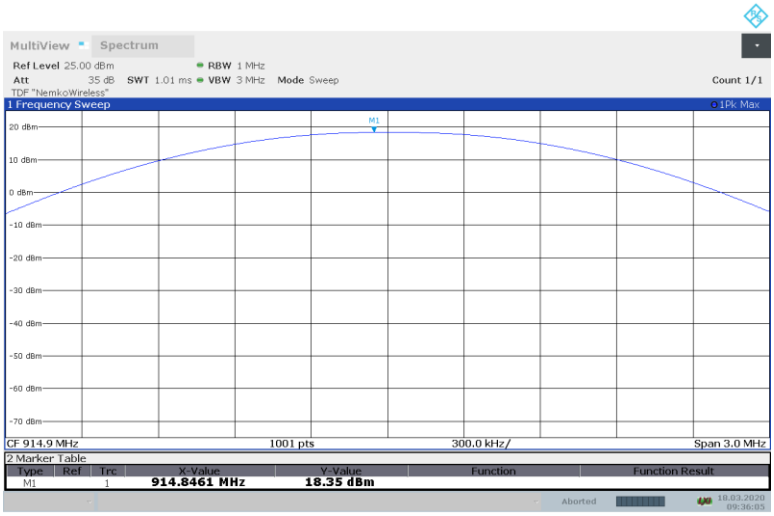


Figure 7.7-5: Peak output power, hybrid mode, 914.9 MHz

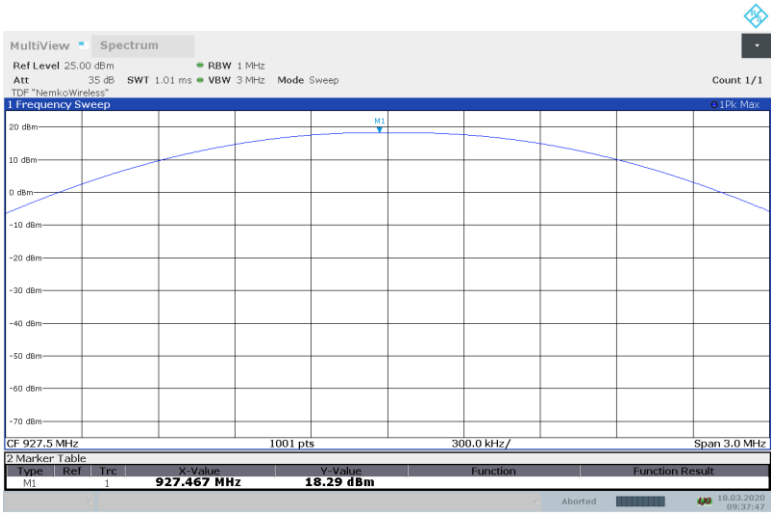


Figure 7.7-6: Peak output power, hybrid mode, 927.5 MHz

7.8 Conducted RF spurious emissions

7.8.1 References

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.247(b)(2) / (3) / ANSI C63.10: 2013
RSS-247 → §5.4(a) / (d)

7.8.2 Test summary

Verdict	Pass		
Test date	March 18, 2020	Temperature	20°C
Test engineer	James Cunningham	Air pressure	1008 mbar
Test location	Wireless bench	Relative humidity	48%

7.8.3 Notes

Testing was performed in DTS mode and hybrid DTS/frequency hopping mode (hopping disabled) and the EUT transmitting on a fixed channel.
The EUT antenna port was connected to the spectrum analyzer via low loss cable and a suitable attenuator. The loss of this assembly was corrected for via a transducer factor in the spectrum analyzer.

Measurements were made up to 10 GHz to include the 10th harmonic of the 902-928 MHz transmitter.

7.8.4 Setup details

EUT setup configuration	Tabletop
Test facility	Wireless bench
Measurement details	Measurement performed as per C63.10 §11.11

Receiver/spectrum analyzer settings:

Resolution bandwidth	100 kHz
Video bandwidth	300 kHz
Detector mode	Peak
Trace mode	Max Hold
Measurement time	Long enough for trace to stabilize

Table 7.8-1: Conducted RF spurious emissions equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
Signal and spectrum analyzer	Rohde & Schwarz	FSW	E1302	1 year	10 Jan 2021

7.8.5 Test data, DTS mode

Table 7.8-2: Conducted RF spurious emissions, DTS mode

Test Mode	Transmitter Frequency (MHz)	Measured Frequency (MHz)	Measured Level (dBm)	Limit (dBm)
500 kHz channel (DTS mode)	903.0	6953.407	-28.94	-1.70
	914.3	6247.837	-28.98	-1.60
	927.5	6185.924	-29.20	-1.67

Note: Example limit calculation for 903 MHz: Limit = Transmitter Power – 20 = 18.30 – 20 = -1.70 dBm. The Transmitter Power is taken from the results in Section 7.7.
Example measured level calculation for 903 MHz: Measured Level = Transmitter power (measured) + delta marker value = 18.31 + (-47.25) = -28.94 dBm

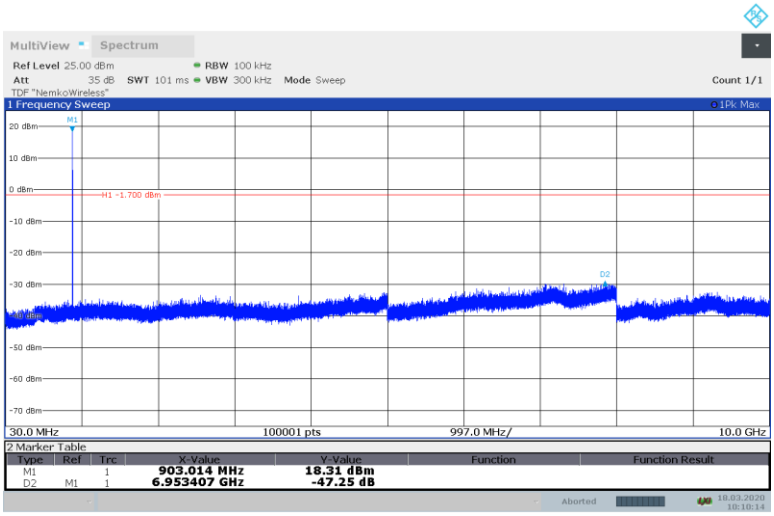


Figure 7.8-1: Conducted RF spurious emissions, DTS mode, 903.0 MHz

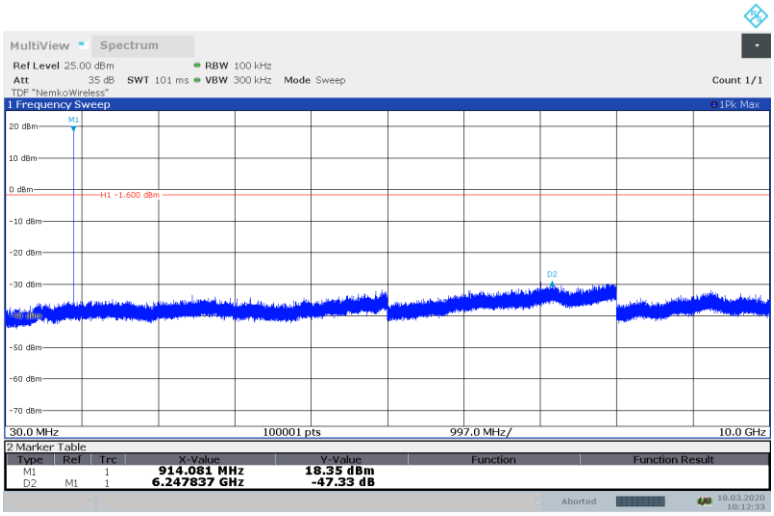


Figure 7.8-2: Conducted RF spurious emissions, DTS mode, 914.3 MHz

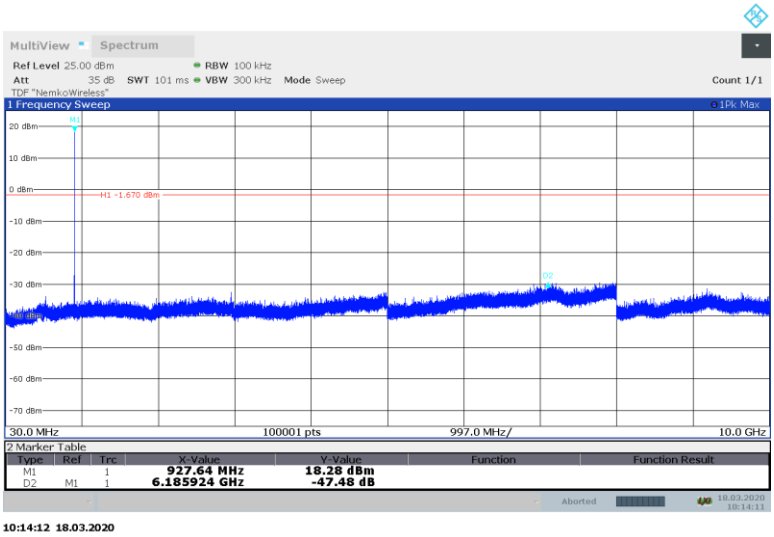


Figure 7.8-3: Conducted RF spurious emissions, DTS mode, 927.5 MHz

7.8.6 Test data, hybrid mode

Table 7.8-3: Conducted RF spurious emissions, Hybrid mode

Test Mode	Transmitter Frequency (MHz)	Measured Frequency (MHz)	Measured Level (dBm)	Limit (dBm)
125 kHz channel (Hybrid mode)	902.3	6974.843	-29.48	-1.73
	914.9	6894.485	-29.74	-1.65
	927.5	7041.441	-29.21	-1.71
Note:	Example limit calculation for 902.3 MHz: Limit = Transmitter Power – 20 = 18.27 – 20 = -1.73 dBm. The Transmitter Power is taken from the results in Section 7.7. Example measured level calculation for 902.3 MHz: Measured Level = Transmitter power + delta marker value = 18.28 + (-47.76) = -29.48 dBm			

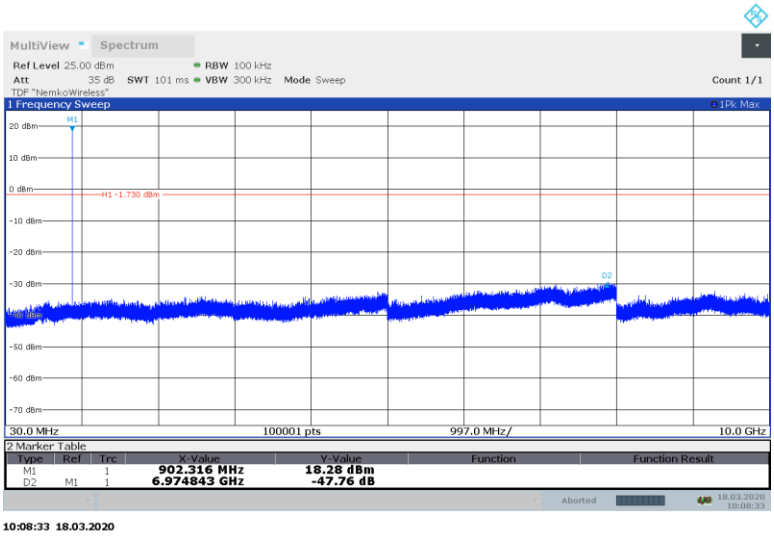
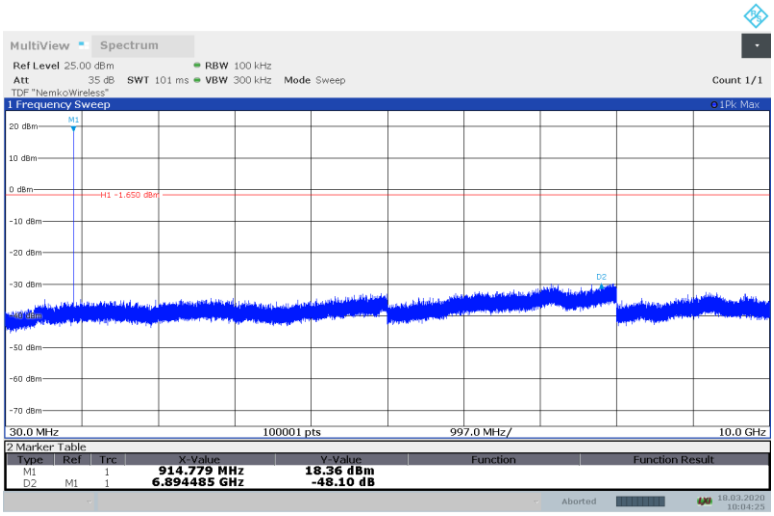
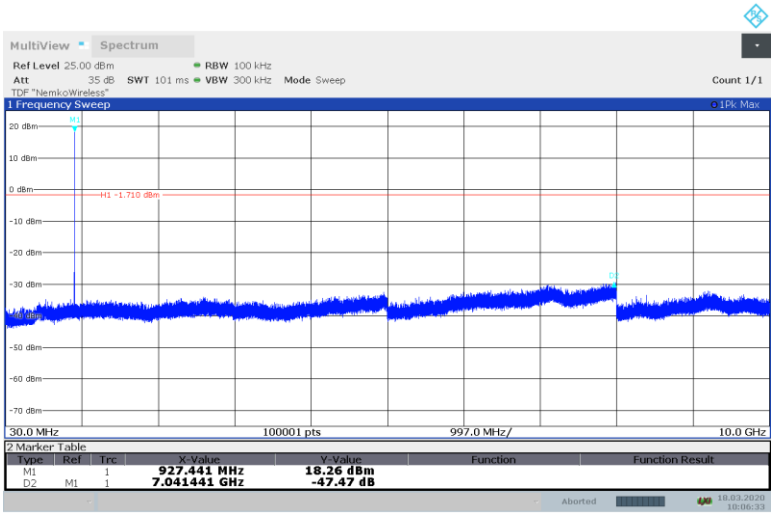


Figure 7.8-4: Conducted RF spurious emissions, hybrid mode, 902.3 MHz



10:04:26 18.03.2020

Figure 7.8-5: Conducted RF spurious emissions, hybrid mode, 914.9 MHz



10:06:33 18.03.2020

Figure 7.8-6: Conducted RF spurious emissions, hybrid mode, 927.5 MHz

7.9 Conducted RF band edge

7.9.1 References

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.247(d) / ANSI C63.10: 2013
RSS-247 → §5.3

7.9.2 Test summary

Verdict	Pass		
Test date	March 18, 2020	Temperature	20°C
Test engineer	James Cunningham	Air pressure	1008 mbar
Test location	Wireless bench	Relative humidity	48%

7.9.3 Notes

Testing was performed in DTS mode and hybrid DTS/frequency hopping mode (hopping disabled) and the EUT transmitting on a fixed channel.
The EUT antenna port was connected to the spectrum analyzer via low loss cable and a suitable attenuator. The loss of this assembly was corrected for via a transducer factor in the spectrum analyzer.

7.9.4 Setup details

EUT setup configuration	Tabletop
Test facility	Wireless bench
Measurement details	Measurement performed as per C63.10 §11.11, 11.13.3.2

Receiver/spectrum analyzer settings:

Resolution bandwidth	100 kHz
Video bandwidth	300 kHz
Detector mode	Peak
Trace mode	Max Hold
Measurement time	Long enough for trace to stabilize
Measurement Procedure	ANSI 63.10 7.8.6 , 6.10

Table 7.9-1: Conducted RF band edge equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
Signal and spectrum analyzer	Rohde & Schwarz	FSW	E1302	1 year	10 Jan 2021

7.9.5 Test data, DTS mode

Table 7.9-2: Conducted RF band edge, DTS mode

Test Mode	Transmitter Frequency (MHz)	Measured Frequency (MHz)	Measured Level (dBm)	Limit (dBm)
500 kHz channel (DTS mode)	903.0	902.0	-36.28	-1.70
	927.5	928.0	-7.92	-1.67
Note: Example limit calculation for 903 MHz: Limit = Transmitter Power – 20 = 18.30 – 20 = -1.70. The Transmitter Power is taken from the results in Section 7.7.				

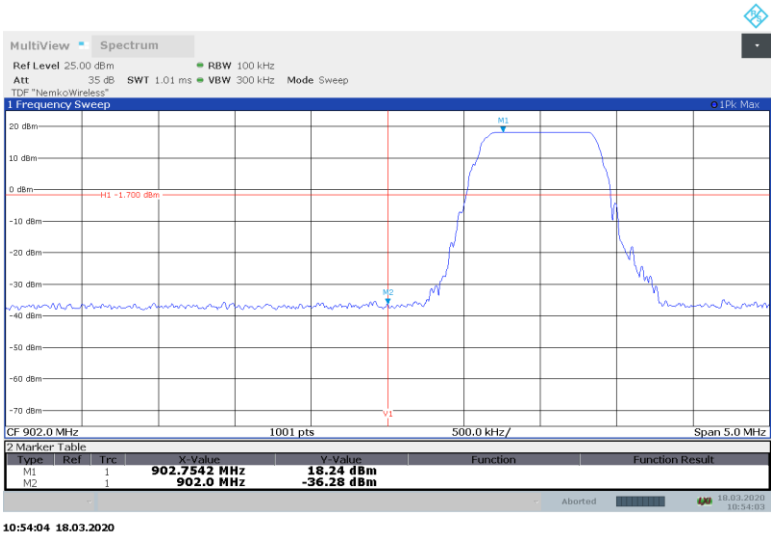


Figure 7.9-1: Conducted RF band edge, DTS mode, 903.0 MHz

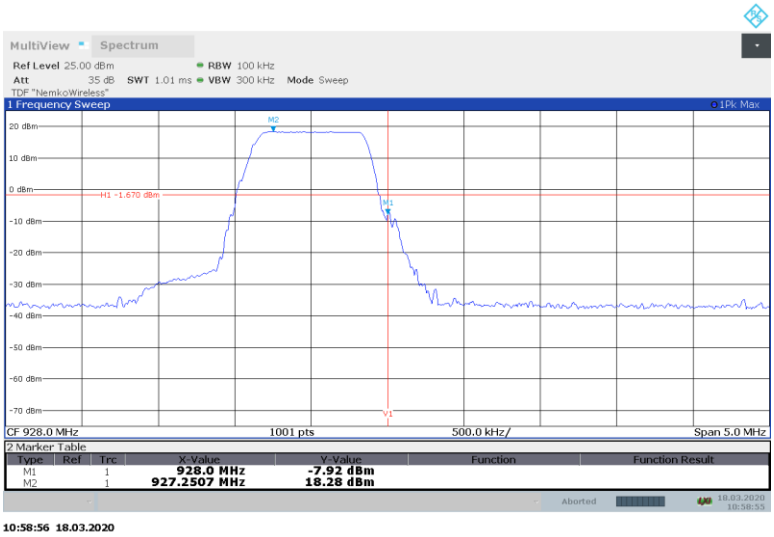


Figure 7.9-2: Conducted RF band edge, DTS mode, 927.5 MHz

7.9.6 Test data, hybrid mode

Table 7.9-3: Conducted RF band edge, Hybrid mode

Test Mode	Transmitter Frequency (MHz)	Measured Frequency (MHz)	Measured Level (dBm)	Limit (dBm)
125 kHz channel (Hybrid mode)	902.3	902.0	-29.87	-1.73
	927.5	928.0	-22.26	-1.71
Note: Example limit calculation for 902.3 MHz: Limit = Transmitter Power – 20 = 18.27 – 20 = -1.73 dBm The Transmitter Power is taken from the results in Section 7.7.				

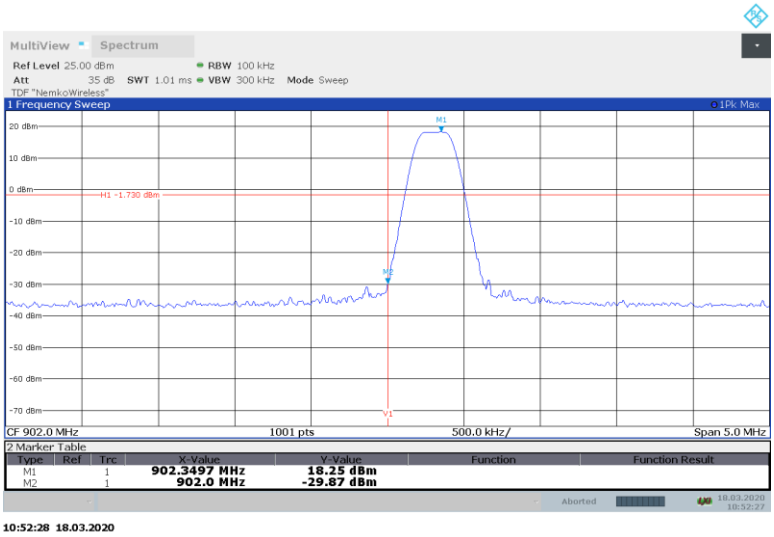


Figure 7.9-3: Conducted RF band edge, hybrid mode, 902.3 MHz

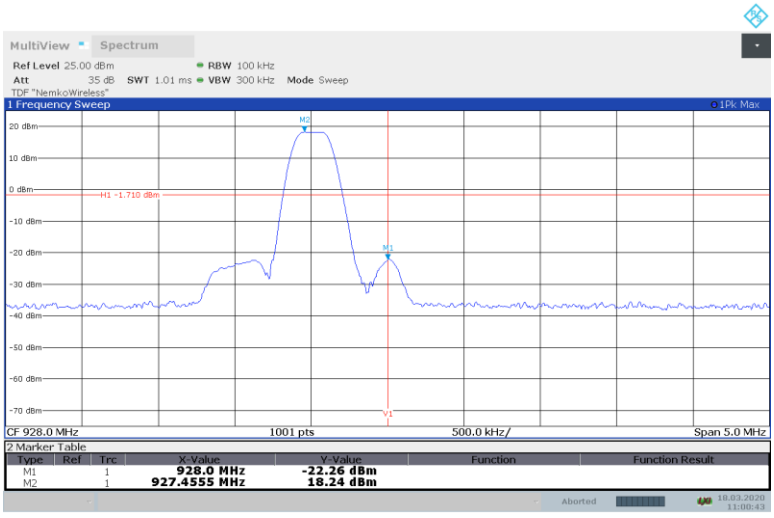


Figure 7.9-4: Conducted RF band edge, hybrid mode, 927.5 MHz

7.10 Radiated spurious emissions and restricted bands

7.10.1 References

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.209 / ANSI C63.4: 2014

Frequency (MHz)	Field strength (microvolts/meter)	Measurement distance (meters)
0.009-0.490	2400/F(kHz)	300
0.490-1.705	24000/F(kHz)	30
1.705-30.0	30	30
30-88	100**	3
88-216	150**	3
216-960	200**	3
Above 960	500	3

RSS-247 → §5.5

7.10.2 Test summary

Verdict	Pass		
Test date	February 26, 2020	Temperature	20 °C
Test engineer	James Cunningham, Wireless Supervisor	Air pressure	1008 mbar
Test location	10m semi anechoic chamber	Relative humidity	54 %

7.10.3 Notes

Testing was performed in DTS mode and hybrid DTS/frequency hopping mode (hopping disabled) and the EUT transmitting on a fixed channel.

7.10.4 Setup details

EUT setup configuration	Tabletop
Test facility	10 m Semi anechoic chamber
Measuring distance	3 m
Antenna height variation	1–4 m
Turn table position	0–360°
Measurement details	A preview measurement was generated with receiver in continuous scan or sweep mode while the EUT was rotated and antenna adjusted to maximize radiated emission. Emissions detected within 6 dB or above limit were re-measured with the appropriate detector against the correlating limit and recorded as the final measurement.

Receiver/spectrum analyzer settings for frequencies below 1 GHz:

Resolution bandwidth	120 kHz
Video bandwidth	300 kHz
Detector mode	– Peak (Preview measurement) – Quasi-peak (Final measurement)
Trace mode	Max Hold
Measurement time	– 100 ms (Peak preview measurement) – 5000 ms (Quasi-peak final measurement)

Table 7.10-1: Radiated disturbance equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
EMI Test Receiver	Rohde & Schwarz	ESU40	E1121	1 year	25 May 2020
System Controller	Sunol Sciences	SC104V	E1129	NCR	NCR
Bilog Antenna	Schaffner	CBL6111C	1480	1 year	18 Apr 2020
DRG Horn	ETS-Lindgren	3117-PA	E1160	1 year	30 Apr 2020
Pre-Amp as part of DRG Horn	ETS-Lindgren	3117-PA	Part of E1160	1 year	30 Apr 2020
Tunable Notch Filter	K&L	3TNF-500/1000N/N	1060	NCR	NCR
High Pass Filter	Wainwright Instruments	WHKX12-900-1000-1500	E1211	NCR	NCR

Notes: NCR - no calibration required

Table 7.10-2: Radiated disturbance test software details

Manufacturer of Software	Details
Rohde & Schwarz	EMC 32 V10.00.00

Notes: None

7.10.5 Test data, DTS mode

Table 7.10-3: Radiated Emissions, 30 – 1000 MHz, DTS mode, LOW channel (903 MHz)

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
54.031333	25.38	40.00	14.62	5000.0	120.000	143.0	V	215.0	13.5
216.021333	29.85	46.00	16.15	5000.0	120.000	123.5	H	293.0	16.6
219.384000	28.80	46.00	17.20	5000.0	120.000	147.3	H	80.0	16.9

Notes: A notch filter was used to reduce the level of the wanted transmitter signal at 903 MHz
Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factors = antenna factor ACF (dB) + cable loss (dB)
Limits converted to dBµV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.

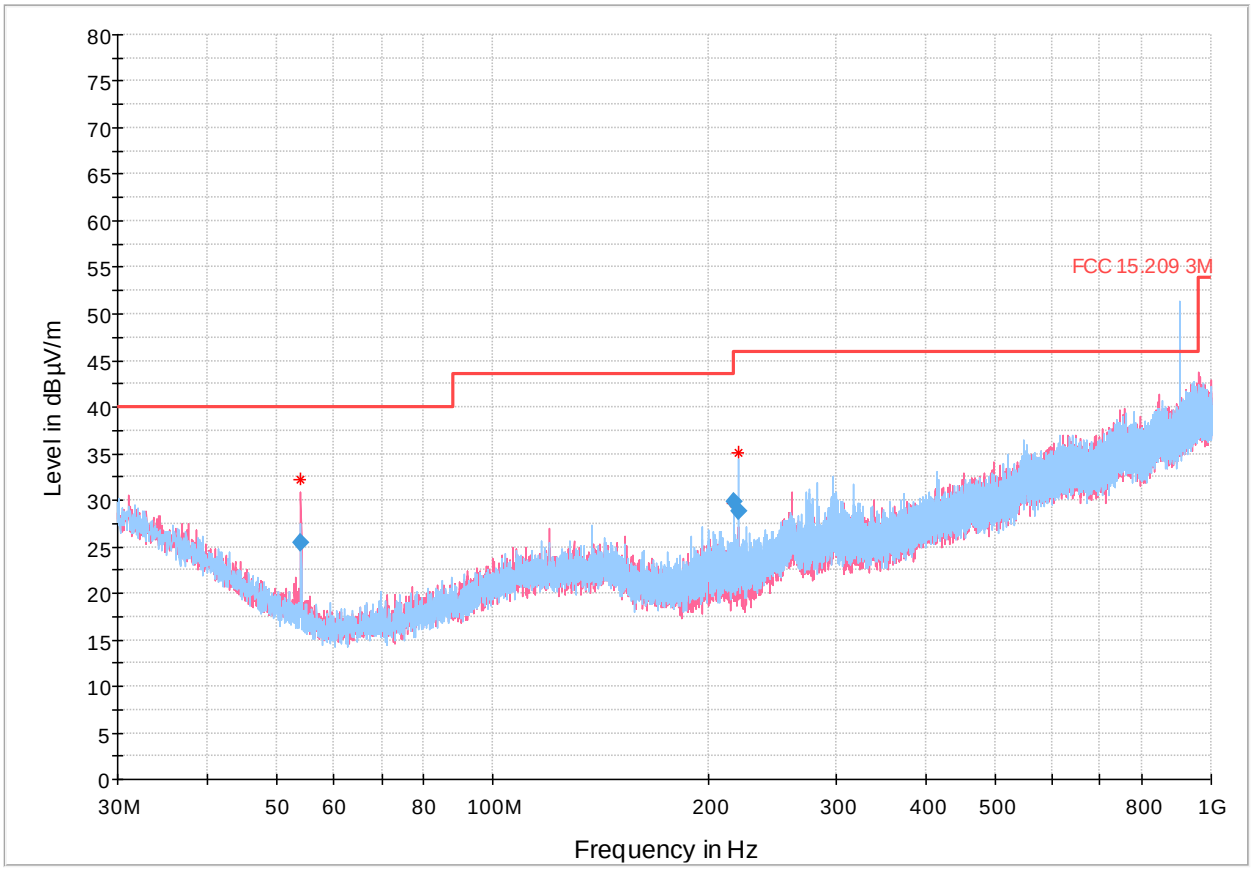


Figure 7.10-1: Radiated emissions, 30 – 1000 MHz, DTS mode, 903 MHz TX

Table 7.10-4: Radiated Emissions, 30 – 1000 MHz, DTS mode, MID channel (914.3 MHz)

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
54.011333	27.85	40.00	12.15	5000.0	120.000	111.2	V	240.0	13.5
199.207667	27.85	43.50	15.65	5000.0	120.000	109.2	H	294.0	16.6
219.471667	31.81	46.00	14.19	5000.0	120.000	120.9	H	287.0	16.9

Notes: A notch filter was used to reduce the level of the wanted transmitter signal at 914.3 MHz
Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factors = antenna factor ACF (dB) + cable loss (dB)
Limits converted to dBµV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.

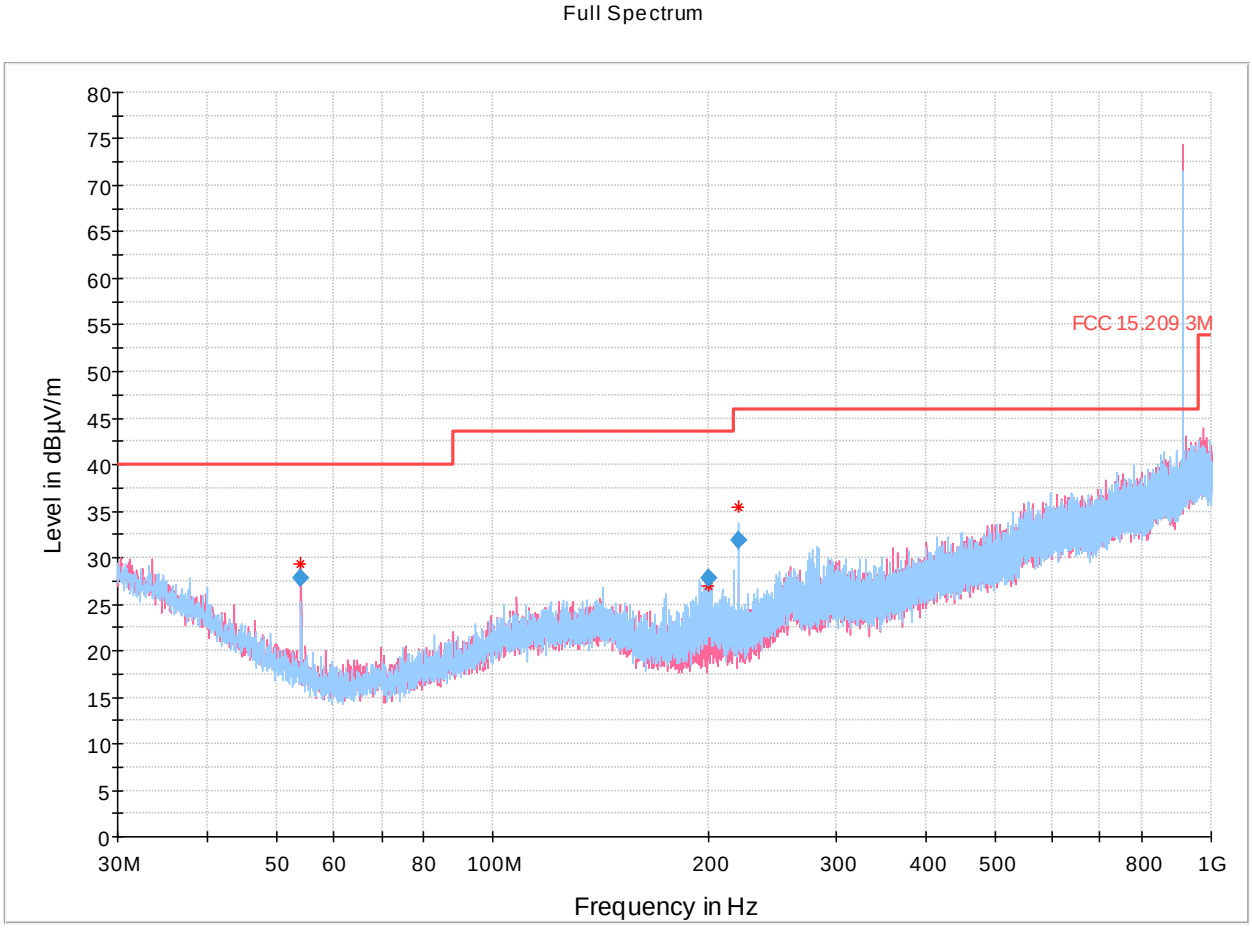


Figure 7.10-2: Radiated emissions, 30 – 1000 MHz, DTS mode, 914.3 MHz TX

Table 7.10-5: Radiated Emissions, 30 – 1000 MHz, DTS mode, HIGH channel (927.5 MHz)

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
54.011333	28.00	40.00	12.00	5000.0	120.000	111.2	V	214.0	13.5
215.993667	28.28	43.50	15.22	5000.0	120.000	160.8	H	295.0	16.6
277.153000	27.12	46.00	18.88	5000.0	120.000	115.6	H	230.0	20.7

Notes: A notch filter was used to reduce the level of the wanted transmitter signal at 927.5 MHz
Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factors = antenna factor ACF (dB) + cable loss (dB)
Limits converted to dBµV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.

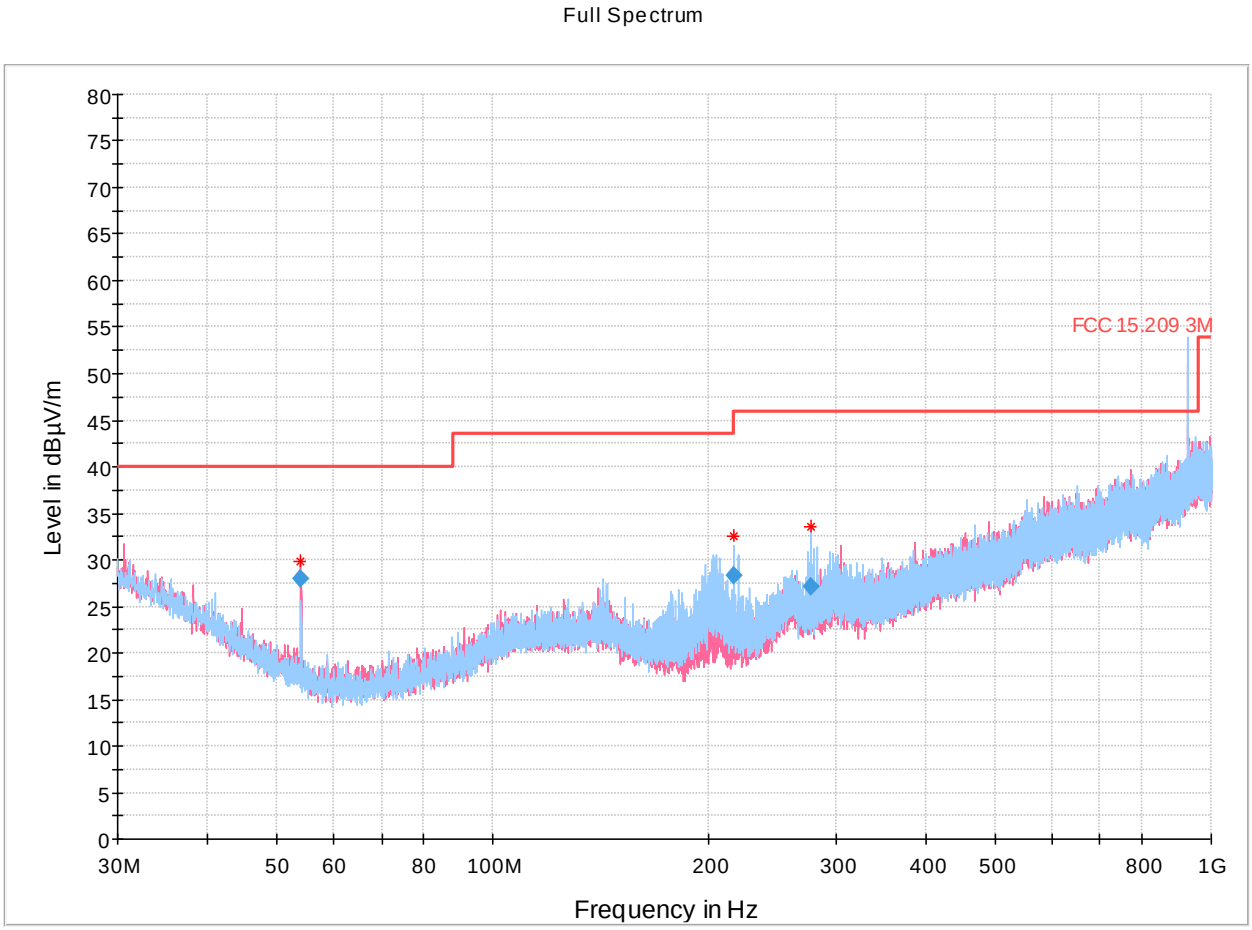


Figure 7.10-3: Radiated emissions, 30 – 1000 MHz, DTS mode, 927.5 MHz TX

Table 7.10-6: Radiated Emissions, 1 – 18 GHz, DTS mode, LOW channel (903 MHz)

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1806.000000	---	39.03	53.90	14.87	5000.0	1000.000	111.0	H	64.0	-11.2
1806.000000	47.55	---	73.90	26.35	5000.0	1000.000	111.0	H	64.0	-11.2
2708.700000	---	33.20	53.90	20.70	5000.0	1000.000	111.2	H	65.0	-8.5
2708.700000	45.32	---	73.90	28.58	5000.0	1000.000	111.2	H	65.0	-8.5
3611.000000	52.94	---	73.90	20.96	5000.0	1000.000	158.3	V	73.0	-5.2
3611.000000	---	36.01	53.90	17.89	5000.0	1000.000	158.3	V	73.0	-5.2
4515.633333	---	37.76	53.90	16.14	5000.0	1000.000	168.3	V	56.0	-2.0
4515.633333	51.08	---	73.90	22.82	5000.0	1000.000	168.3	V	56.0	-2.0
5416.100000	51.71	---	73.90	22.19	5000.0	1000.000	139.8	V	95.0	-1.7
5416.100000	---	30.09	53.90	23.81	5000.0	1000.000	139.8	V	95.0	-1.7
6318.866667	---	32.33	53.90	21.57	5000.0	1000.000	186.9	V	94.0	0.4
6318.866667	57.41	---	73.90	16.49	5000.0	1000.000	186.9	V	94.0	0.4

Notes: A 1 GHz high pass filter was used to protect the measurement equipment
Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factors = antenna factor ACF (dB) + cable loss (dB)
Limits converted to dBµV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.

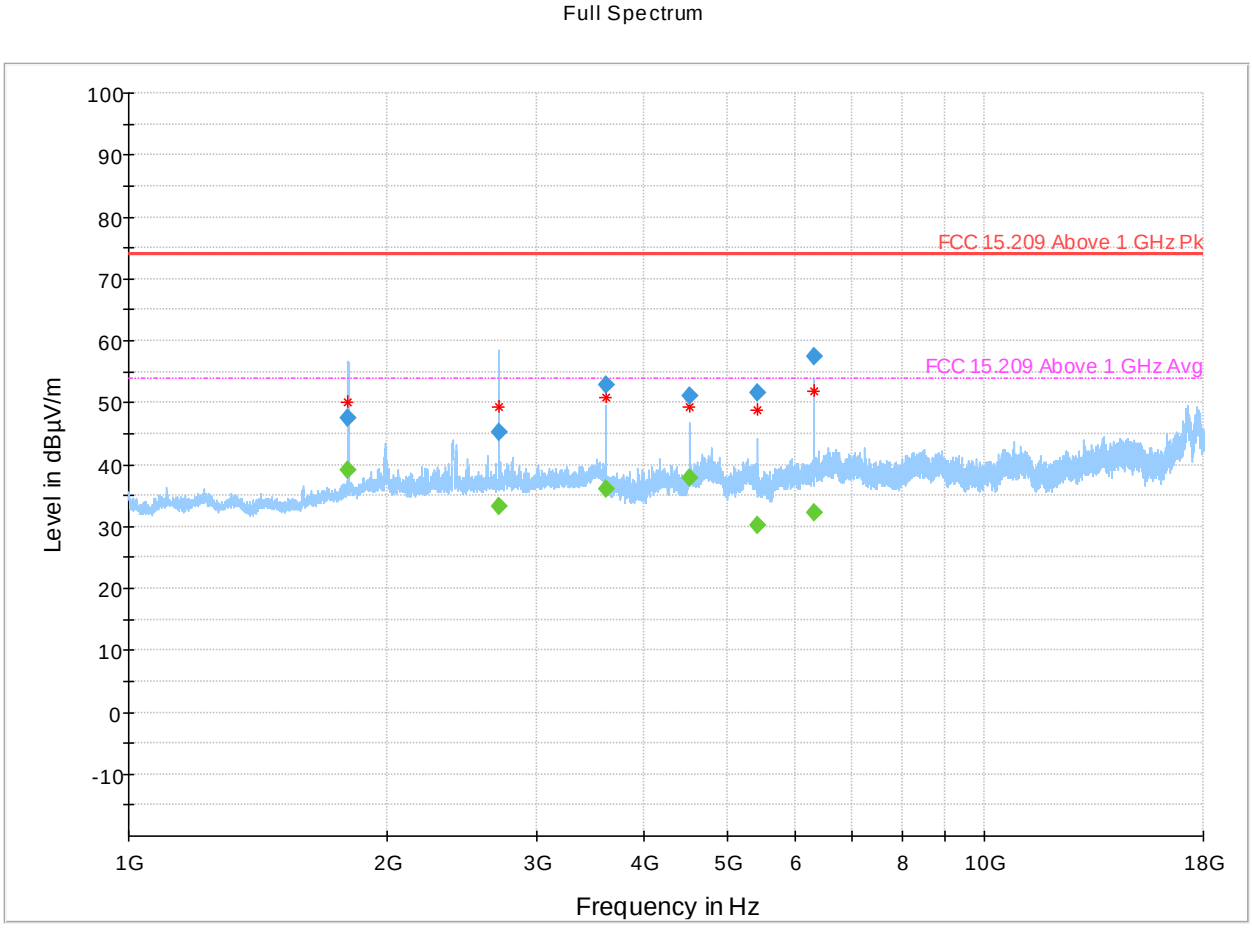


Figure 7.10-4: Radiated emissions, 1 – 18 GHz, DTS mode, 903 MHz TX

Table 7.10-7: Radiated Emissions, 1 – 18 GHz, DTS mode, MID channel (914.3 MHz)

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1830.200000	---	39.86	53.90	14.04	5000.0	1000.000	100.0	H	73.0	-11.2
1830.200000	49.84	---	73.90	24.06	5000.0	1000.000	100.0	H	73.0	-11.2
2744.400000	---	34.57	53.90	19.33	5000.0	1000.000	100.0	H	73.0	-8.3
2744.400000	46.18	---	73.90	27.72	5000.0	1000.000	100.0	H	73.0	-8.3
3659.000000	51.26	---	73.90	22.64	5000.0	1000.000	156.9	V	72.0	-5.0
3659.000000	---	38.17	53.90	15.73	5000.0	1000.000	156.9	V	72.0	-5.0
4574.966667	50.72	---	73.90	23.18	5000.0	1000.000	245.2	V	93.0	-1.8
4574.966667	---	37.38	53.90	16.52	5000.0	1000.000	245.2	V	93.0	-1.8
5488.633333	49.47	---	73.90	24.43	5000.0	1000.000	205.9	V	268.0	-2.1
5488.633333	---	35.23	53.90	18.67	5000.0	1000.000	205.9	V	268.0	-2.1
6404.733333	56.15	---	73.90	17.75	5000.0	1000.000	142.9	V	56.0	0.4
6404.733333	---	41.12	53.90	12.78	5000.0	1000.000	142.9	V	56.0	0.4

Notes: A 1 GHz high pass filter was used to protect the measurement equipment
Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factors = antenna factor ACF (dB) + cable loss (dB)
Limits converted to dBµV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.

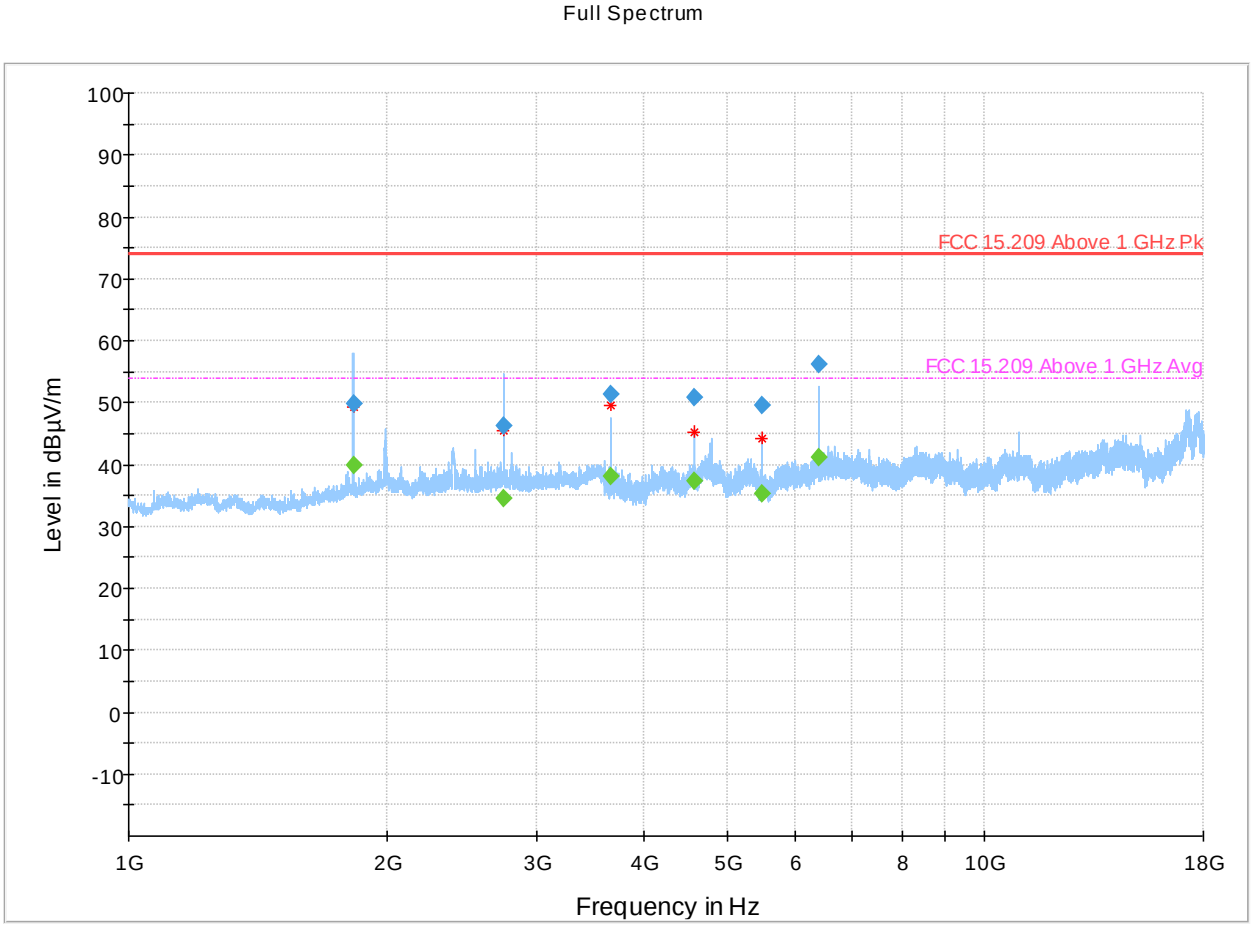


Figure 7.10-5: Radiated emissions, 1 – 18 GHz, DTS mode, 914.3 MHz TX

Table 7.10-8: Radiated Emissions, 1 – 18 GHz, DTS mode, HIGH channel (927.5 MHz)

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1855.300000	---	37.12	53.90	16.78	5000.0	1000.000	173.7	H	38.0	-11.0
1855.300000	47.03	---	73.90	26.87	5000.0	1000.000	173.7	H	38.0	-11.0
2396.466667	---	28.12	53.90	25.78	5000.0	1000.000	100.0	V	318.0	-9.5
2396.466667	49.18	---	73.90	24.72	5000.0	1000.000	100.0	V	318.0	-9.5
2783.333333	---	34.29	53.90	19.61	5000.0	1000.000	132.7	V	86.0	-8.2
2783.333333	48.92	---	73.90	24.98	5000.0	1000.000	132.7	V	86.0	-8.2
3709.433333	---	38.87	53.90	15.03	5000.0	1000.000	166.0	V	86.0	-4.8
3709.433333	51.43	---	73.90	22.47	5000.0	1000.000	166.0	V	86.0	-4.8
5563.900000	48.58	---	73.90	25.32	5000.0	1000.000	194.8	V	270.0	-2.2
5563.900000	---	33.72	53.90	20.18	5000.0	1000.000	194.8	V	270.0	-2.2
6493.200000	56.60	---	73.90	17.30	5000.0	1000.000	154.5	V	302.0	0.6
6493.200000	---	40.01	53.90	13.89	5000.0	1000.000	154.5	V	302.0	0.6

Notes: A 1 GHz high pass filter was used to protect the measurement equipment
Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factors = antenna factor ACF (dB) + cable loss (dB)
Limits converted to dBµV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.

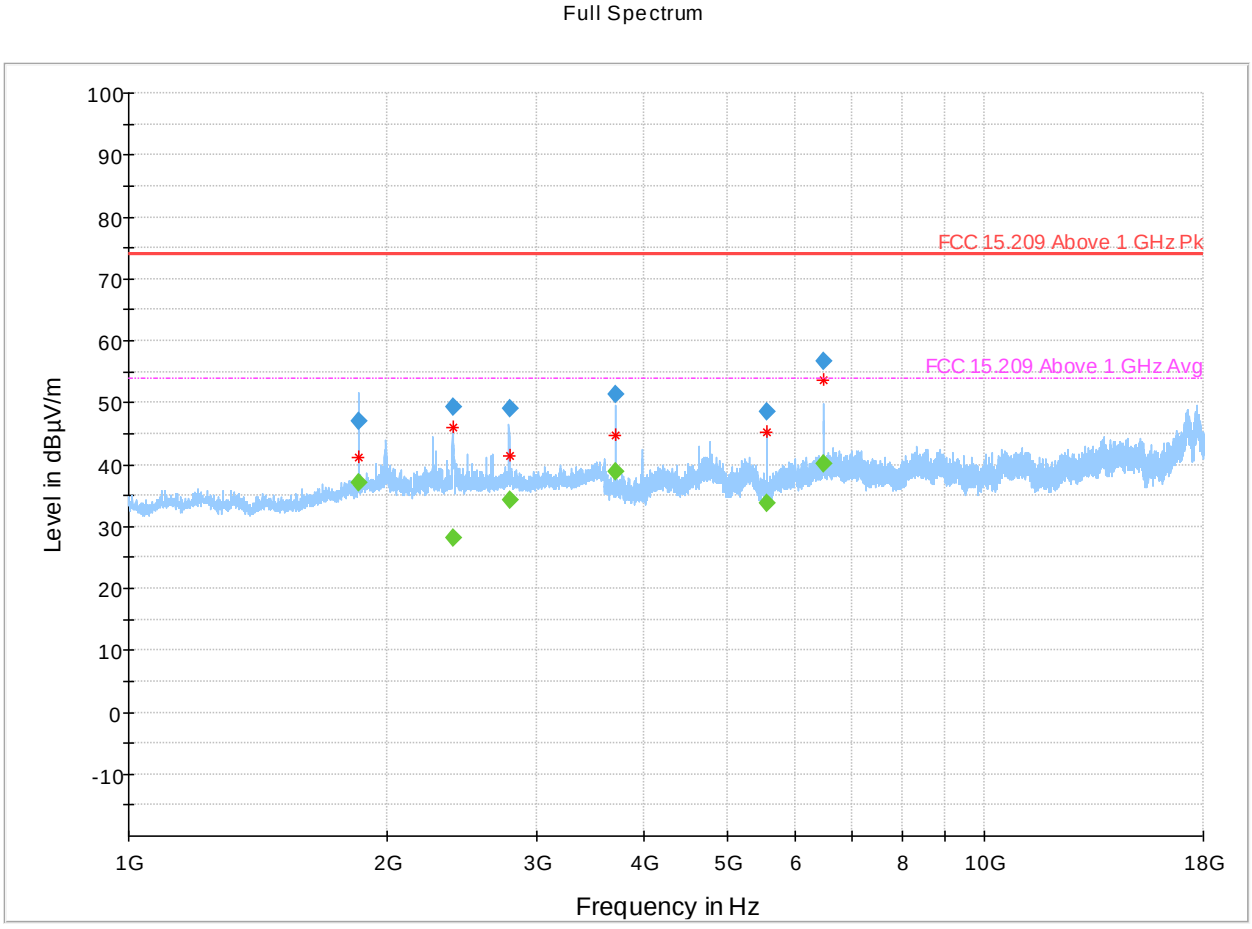


Figure 7.10-6: Radiated emissions, 1 – 18 GHz, DTS mode, 927.5 MHz TX

7.10.6 Test data, hybrid mode

Table 7.10-9: Radiated Emissions, 30 – 1000 MHz, hybrid mode, LOW channel (902.3 MHz)

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
53.991333	27.91	40.00	12.09	5000.0	120.000	100.0	V	208.0	13.5
219.456333	32.59	46.00	13.41	5000.0	120.000	126.9	H	296.0	16.9
263.842333	20.75	46.00	25.25	5000.0	120.000	131.7	H	0.0	22.1

Notes: A notch filter was used to reduce the level of the wanted transmitter signal at 902.3 MHz
Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factors = antenna factor ACF (dB) + cable loss (dB)
Limits converted to dBµV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.

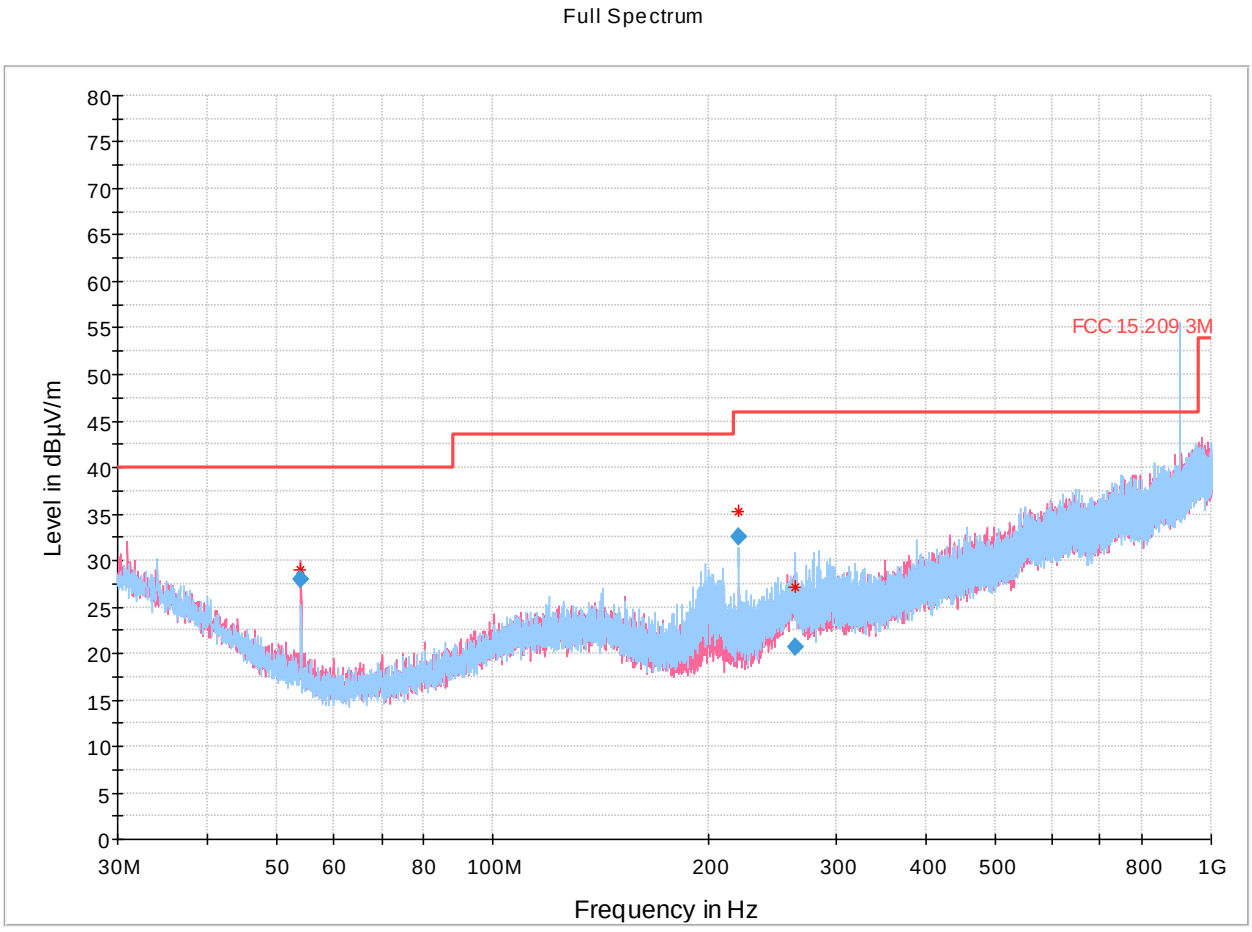


Figure 7.10-7: Radiated emissions, 30 – 1000 MHz, hybrid mode, 902.3 MHz TX

Table 7.10-10: Radiated Emissions, 30 – 1000 MHz, hybrid mode, MID channel (914.9 MHz)

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
53.991333	25.72	40.00	14.28	5000.0	120.000	156.2	V	273.0	13.5
171.826667	17.95	43.50	25.55	5000.0	120.000	268.1	H	270.0	17.2
219.421000	31.84	46.00	14.16	5000.0	120.000	120.4	H	292.0	16.9

Notes: A notch filter was used to reduce the level of the wanted transmitter signal at 914.9 MHz
Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factors = antenna factor ACF (dB) + cable loss (dB)
Limits converted to dBµV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.

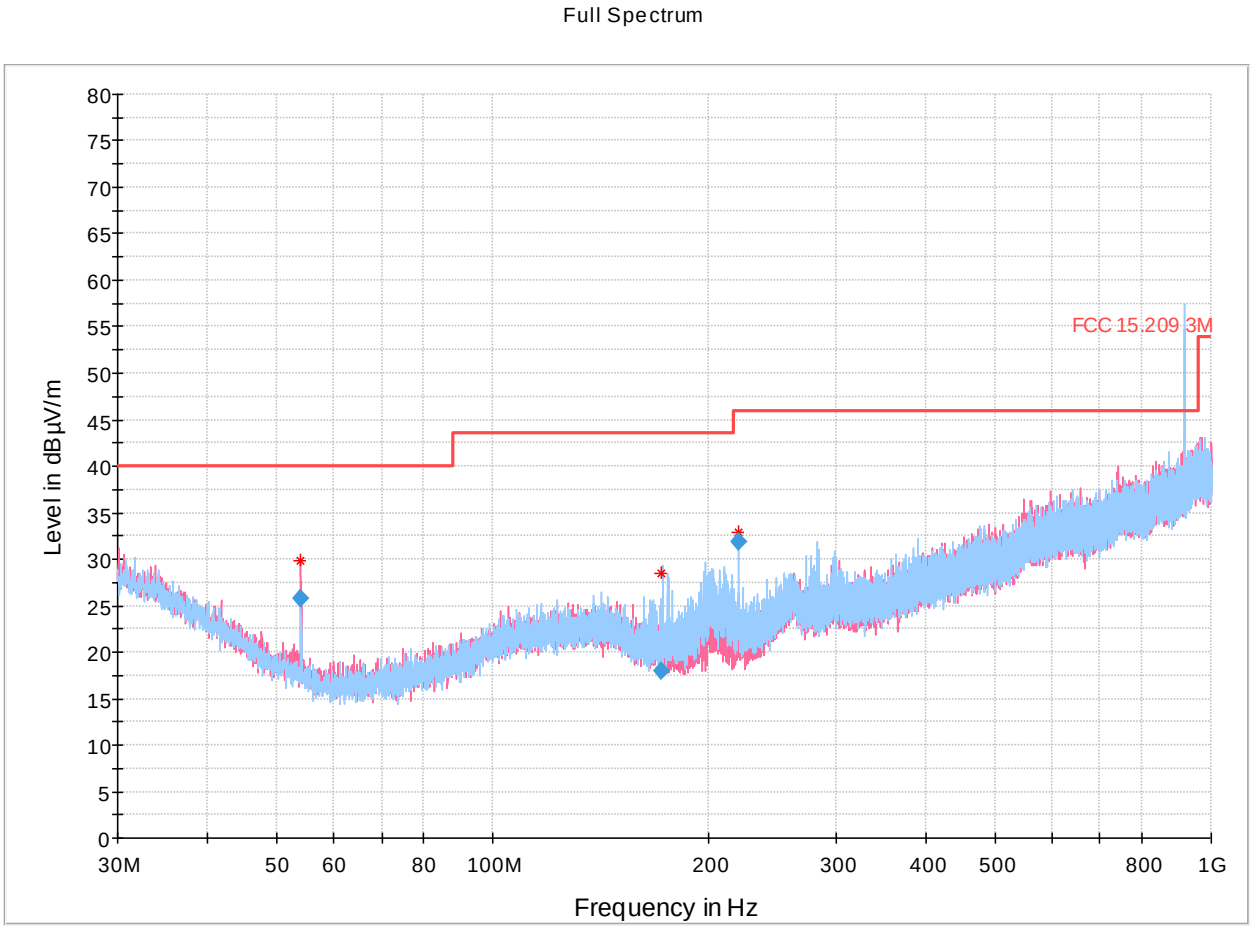


Figure 7.10-8: Radiated emissions, 30 – 1000 MHz, hybrid mode, 914.9 MHz TX

Table 7.10-11: Radiated Emissions, 30 – 1000 MHz, hybrid mode, HIGH channel (927.5 MHz)

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
53.999000	26.13	40.00	13.87	5000.0	120.000	143.9	V	17.0	13.5
219.464000	32.19	46.00	13.81	5000.0	120.000	137.7	H	302.0	16.9
274.035000	26.26	46.00	19.74	5000.0	120.000	143.9	H	232.0	20.6

Notes: A notch filter was used to reduce the level of the wanted transmitter signal at 927.5 MHz
Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factors = antenna factor ACF (dB) + cable loss (dB)
Limits converted to dBµV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.

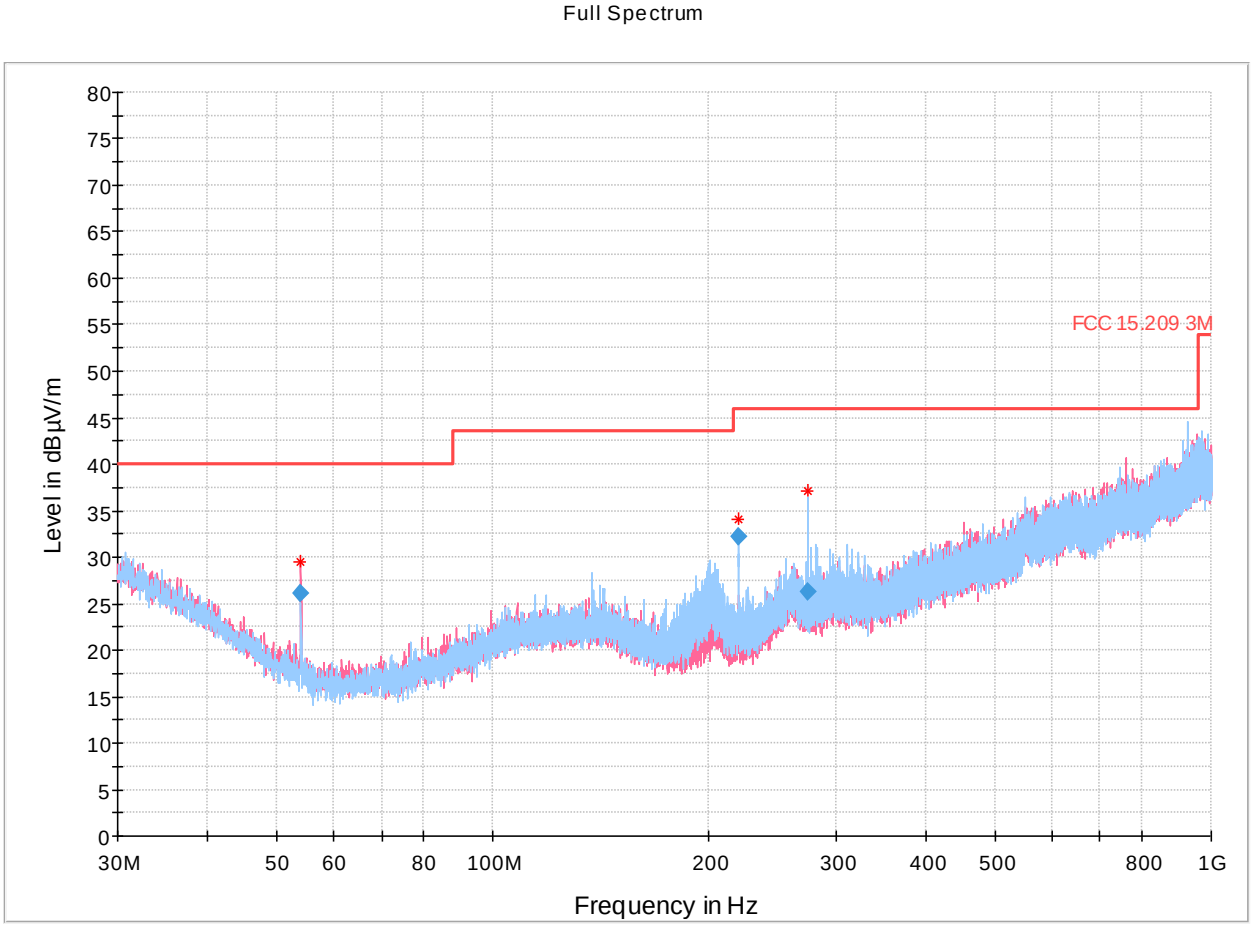


Figure 7.10-9: Radiated emissions, 30 – 1000 MHz, hybrid mode, 927.5 MHz TX

Table 7.10-12: Radiated Emissions, 1 – 18 GHz, hybrid mode, LOW channel (902.3 MHz)

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
2392.900000	---	27.74	53.90	26.16	5000.0	1000.000	100.0	V	0.0	-9.6
2392.900000	48.45	---	73.90	25.45	5000.0	1000.000	100.0	V	0.0	-9.6
2706.433333	---	41.99	53.90	11.91	5000.0	1000.000	250.7	V	196.0	-8.5
2706.433333	47.24	---	73.90	26.66	5000.0	1000.000	250.7	V	196.0	-8.5
3608.733333	---	47.18	53.90	6.72	5000.0	1000.000	167.7	V	188.0	-5.2
3608.733333	51.25	---	73.90	22.65	5000.0	1000.000	167.7	V	188.0	-5.2
4511.100000	49.15	---	73.90	24.75	5000.0	1000.000	141.3	V	180.0	-2.1
4511.100000	---	44.08	53.90	9.82	5000.0	1000.000	141.3	V	180.0	-2.1
4766.100000	---	28.48	53.90	25.42	5000.0	1000.000	196.7	V	258.0	-1.4
4766.100000	41.81	---	73.90	32.09	5000.0	1000.000	196.7	V	258.0	-1.4
6315.533333	55.22	---	73.90	18.68	5000.0	1000.000	160.0	V	23.0	0.4
6315.533333	---	49.70	53.90	4.20	5000.0	1000.000	160.0	V	23.0	0.4

Notes: A 1 GHz high pass filter was used to protect the measurement equipment
Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factors = antenna factor ACF (dB) + cable loss (dB)
Limits converted to dBµV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.

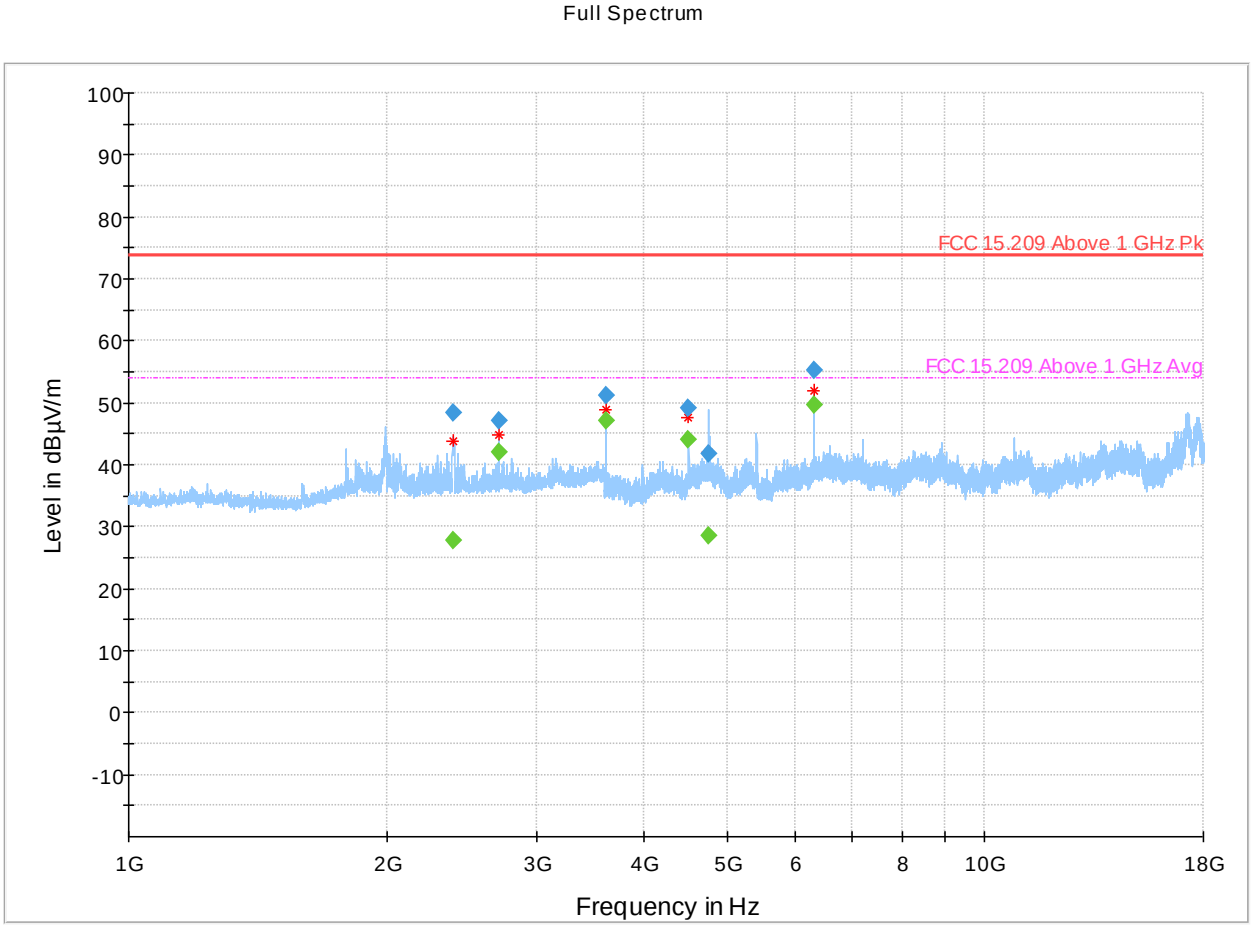


Figure 7.10-10: Radiated emissions, 1 – 18 GHz, hybrid mode, 902.3 MHz TX

Table 7.10-13: Radiated Emissions, 1 – 18 GHz, hybrid mode, MID channel (914.9 MHz)

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
1995.466667	50.22	---	73.90	23.68	5000.0	1000.000	231.0	V	16.0	-10.3
1995.466667	---	26.33	53.90	27.57	5000.0	1000.000	231.0	V	16.0	-10.3
2392.100000	47.78	---	73.90	26.12	5000.0	1000.000	111.4	V	-1.0	-9.6
2392.100000	---	26.50	53.90	27.40	5000.0	1000.000	111.4	V	-1.0	-9.6
3125.500000	40.02	---	73.90	33.88	5000.0	1000.000	197.9	V	16.0	-7.1
3125.500000	---	26.02	53.90	27.88	5000.0	1000.000	197.9	V	16.0	-7.1
3663.933333	---	46.59	53.90	7.31	5000.0	1000.000	154.5	V	148.0	-5.0
3663.933333	50.54	---	73.90	23.36	5000.0	1000.000	154.5	V	148.0	-5.0
4764.400000	41.61	---	73.90	32.29	5000.0	1000.000	131.0	V	126.0	-1.4
4764.400000	---	28.57	53.90	25.33	5000.0	1000.000	131.0	V	126.0	-1.4
6411.633333	---	45.01	53.90	8.89	5000.0	1000.000	152.8	V	-1.0	0.4
6411.633333	53.97	---	73.90	19.93	5000.0	1000.000	152.8	V	-1.0	0.4

Notes: A 1 GHz high pass filter was used to protect the measurement equipment
Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factors = antenna factor ACF (dB) + cable loss (dB)
Limits converted to dBµV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.

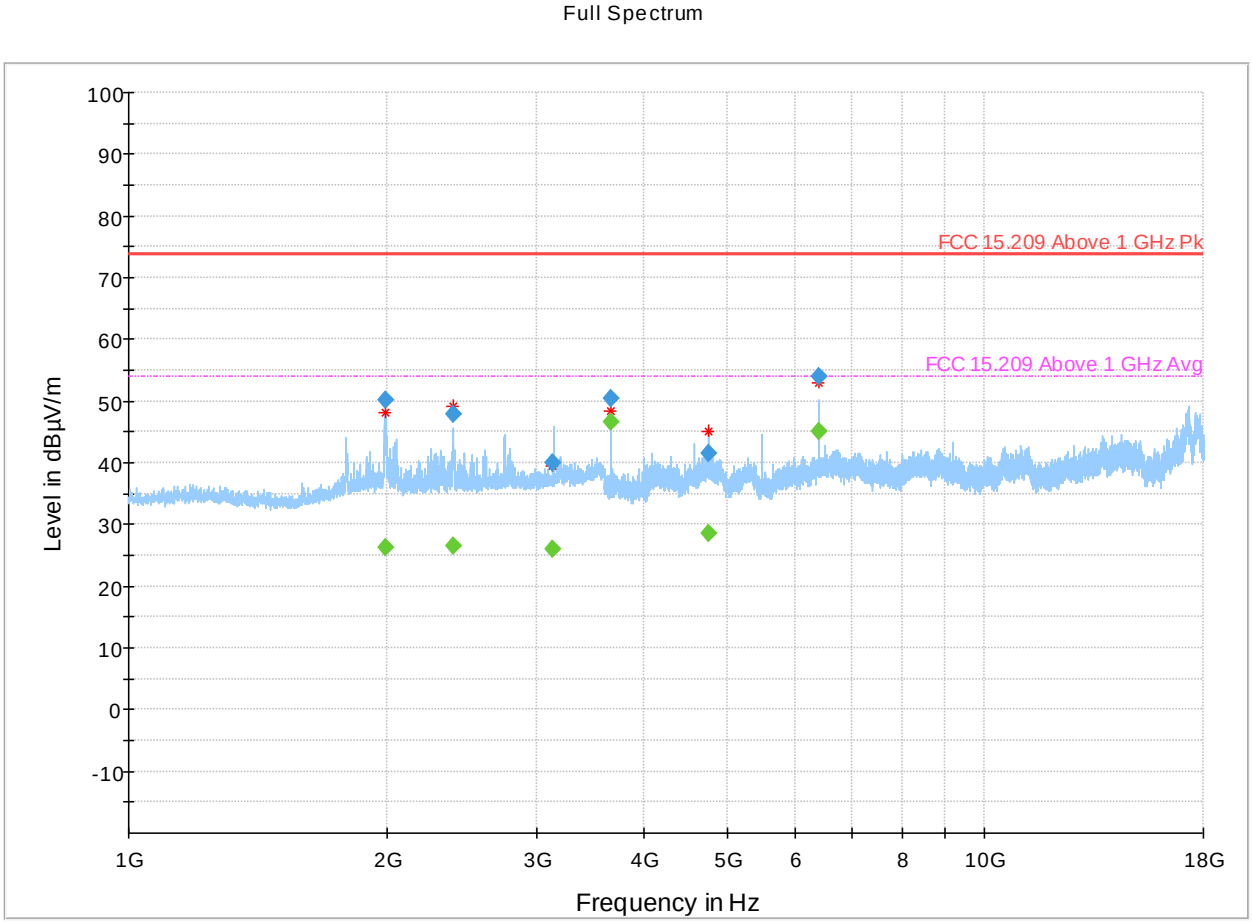


Figure 7.10-11: Radiated emissions, 1 – 18 GHz, hybrid mode, 902.3 MHz TX

Table 7.10-14: Radiated Emissions, 1 – 18 GHz, hybrid mode, HIGH channel (927.5 MHz)

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
2611.033333	---	26.83	53.90	27.07	5000.0	1000.000	100.0	V	0.0	-8.9
2611.033333	43.71	---	73.90	30.19	5000.0	1000.000	100.0	V	0.0	-8.9
2783.500000	---	42.10	53.90	11.80	5000.0	1000.000	237.3	V	198.0	-8.2
2783.500000	46.83	---	73.90	27.07	5000.0	1000.000	237.3	V	198.0	-8.2
3711.533333	49.93	---	73.90	23.97	5000.0	1000.000	138.9	V	189.0	-4.8
3711.533333	---	44.15	53.90	9.75	5000.0	1000.000	138.9	V	189.0	-4.8
5567.200000	50.80	---	73.90	23.10	5000.0	1000.000	147.1	V	33.0	-2.2
5567.200000	---	43.32	53.90	10.58	5000.0	1000.000	147.1	V	33.0	-2.2
6494.200000	---	43.40	53.90	10.50	5000.0	1000.000	149.1	V	312.0	0.6
6494.200000	52.71	---	73.90	21.19	5000.0	1000.000	149.1	V	312.0	0.6
9278.066667	---	38.13	53.90	15.77	5000.0	1000.000	129.7	V	24.0	3.3
9278.066667	48.08	---	73.90	25.82	5000.0	1000.000	129.7	V	24.0	3.3

Notes: A 1 GHz high pass filter was used to protect the measurement equipment
Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
Correction factors = antenna factor ACF (dB) + cable loss (dB)
Limits converted to dBµV/m and an inverse proportionality factor of 20 dB per decade has been used to normalize the specification limit to a measurement distance of 3 meters to determine compliance.

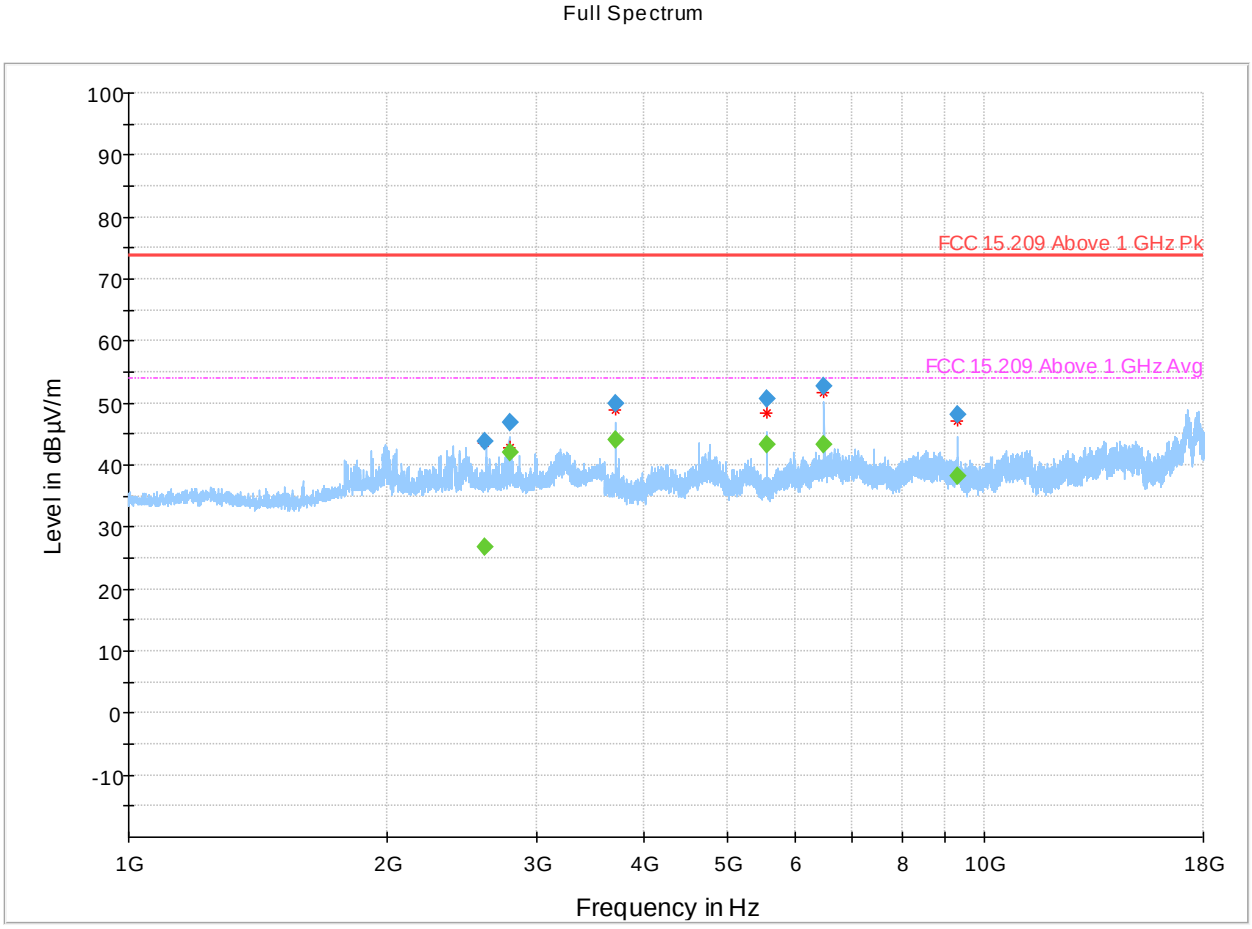


Figure 7.10-12: Radiated emissions, 1 – 18 GHz, hybrid mode, 927.5 MHz TX

7.11 Power spectral density of digital transmission system

7.11.1 References

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.247(e) / ANSI C63.10: 2013
RSS-247 → §5.2(b)

7.11.2 Test summary

Verdict	Pass		
Test date	March 18, 2020	Temperature	20°C
Test engineer	James Cunningham	Air pressure	1008 mbar
Test location	Wireless bench	Relative humidity	48%

7.11.3 Notes

Testing was performed in DTS mode and the EUT transmitting on a fixed channel.
The EUT antenna port was connected to the spectrum analyzer via low loss cable and a suitable attenuator. The loss of this assembly was corrected for via a transducer factor in the spectrum analyzer.

7.11.4 Setup details

EUT setup configuration	Tabletop
Test facility	Wireless bench
Measurement details	Measurement performed as per C63.10 §11.10.4

Receiver/spectrum analyzer settings:

Resolution bandwidth	3 kHz
Video bandwidth	10 kHz
Detector mode	Peak
Trace mode	Clear/Write
Measurement time	500 s

Table 7.11-1: Power spectral density equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
Signal and spectrum analyzer	Rohde & Schwarz	FSW	E1302	1 year	10 Jan 2021

7.11.5 Test data

Table 7.11-2: Power spectral density of DTS

Test Mode	Transmitter Frequency (MHz)	Measured Level (dBm/3 kHz)	Limit (dBm/3 kHz)
500 kHz channel (DTS mode)	903.0	-4.9	8.0
	914.3	-4.8	8.0
	927.5	-4.8	-8.0
Note: None			

Figure 7.11-1: Power spectral density of DTS, 903.0 MHz

Figure 7.11-2: Power spectral density of DTS, 914.3 MHz

Figure 7.11-3: Power spectral density of DTS, 927.5 MHz

7.12 Average time of occupancy for hybrid system

7.12.1 References

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.247(f) / ANSI C63.10: 2013
RSS-247 → §5.3

7.12.2 Test summary

Verdict	Pass		
Test date	March 19, 2020	Temperature	24°C
Test engineer	James Cunningham	Air pressure	1005 mbar
Test location	Wireless bench	Relative humidity	45%

7.12.3 Notes

Testing was performed in DTS mode and the EUT transmitting on a fixed channel.
The EUT antenna port was connected to the spectrum analyzer via low loss cable and a suitable attenuator. The loss of this assembly was corrected for via a transducer factor in the spectrum analyzer.

7.12.4 Setup details

EUT setup configuration	Tabletop
Test facility	Wireless bench
Measurement details	Measurement performed as per C63.10 §7.8.4

Receiver/spectrum analyzer settings:

Resolution bandwidth	1 MHz
Video bandwidth	3 MHz
Detector mode	RMS
Trace mode	Clear/Write
Measurement time	1 s (zero span)

Table 7.12-1: Average time of occupancy for hybrid system equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
Signal and spectrum analyzer	Rohde & Schwarz	FSW	E1302	1 year	10 Jan 2021

7.12.5 Test data

Table 7.12-2: Average time of occupancy for hybrid system

Test Mode	Test Frequency (MHz)	Emission Width (ms)	Number of hopping channels	Limit
125 kHz channel (hybrid mode)	927.5	288	64	400 ms / 25.6 seconds
Note: For 64 hopping channels, 64 x 400 ms = 25.6 seconds. EUT transmits 288 ms / 25.6 seconds and is therefore compliant.				

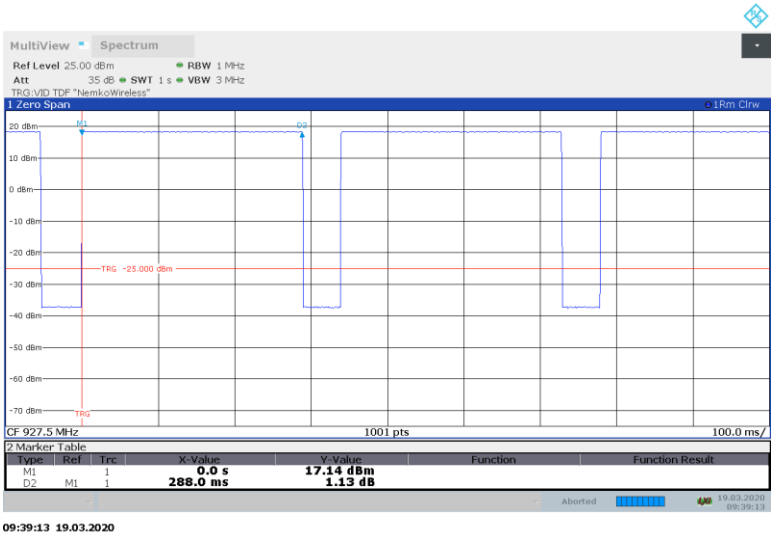


Figure 7.12-1: Average time of occupancy for hybrid system

7.13 Power spectral density of hybrid system

7.13.1 References

Title 47 → Chapter I → Subchapter A → Part 15 → Subpart C → §15.247(f) / ANSI C63.10: 2013
RSS-247 → §5.3

7.13.2 Test summary

Verdict	Pass		
Test date	March 18, 2020	Temperature	20°C
Test engineer	James Cunningham	Air pressure	1008 mbar
Test location	Wireless bench	Relative humidity	48%

7.13.3 Notes

Testing was performed in hybrid mode and the EUT transmitting on a fixed channel.
The EUT antenna port was connected to the spectrum analyzer via low loss cable and a suitable attenuator. The loss of this assembly was corrected for via a transducer factor in the spectrum analyzer.

7.13.4 Setup details

EUT setup configuration	Tabletop
Test facility	Wireless bench
Measurement details	Measurement performed as per C63.10 §11.10.4

Receiver/spectrum analyzer settings:

Resolution bandwidth	3 kHz
Video bandwidth	10 kHz
Detector mode	Peak
Trace mode	Clear/Write
Measurement time	700 s

Table 7.13-1: Power spectral density equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
Signal and spectrum analyzer	Rohde & Schwarz	FSW	E1302	1 year	10 Jan 2021

7.13.5 Test data

Table 7.13-2: Power spectral density of DTS

Test Mode	Transmitter Frequency (MHz)	Measured Level (dBm/3 kHz)	Limit (dBm/3 kHz)
125 kHz channel (hybrid mode)	902.3	1.9	8.0
	914.9	2.0	8.0
	927.5	1.9	-8.0
Note: None			

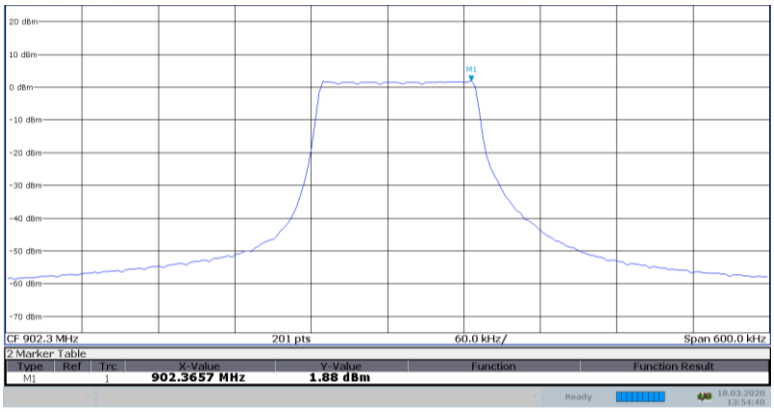


Figure 7.13-1: Power spectral density of hybrid system, 902.3 MHz

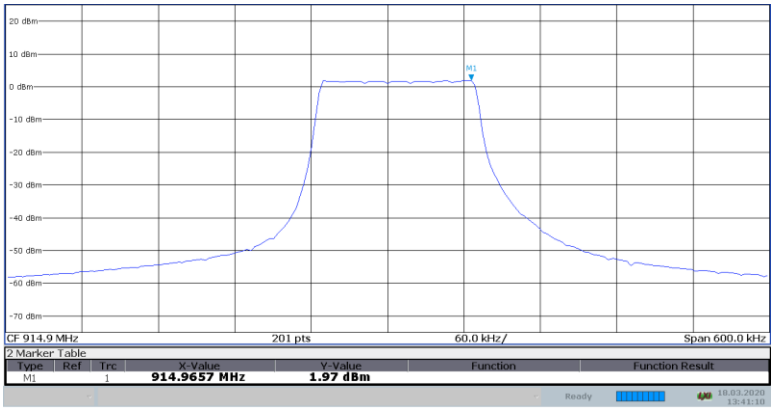


Figure 7.13-2: Power spectral density of hybrid system, 914.9 MHz

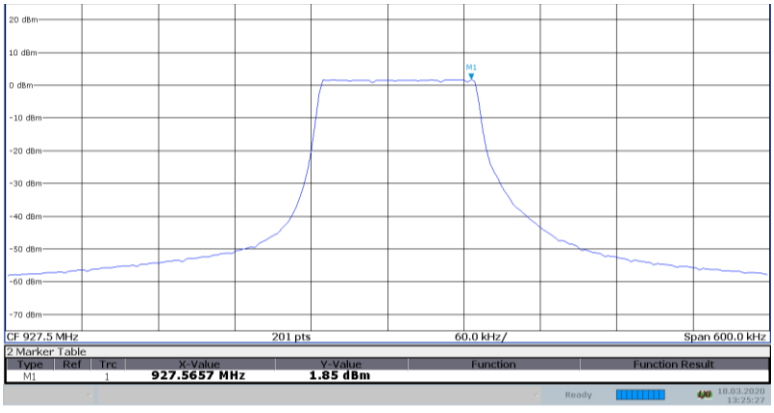


Figure 7.13-3: Power spectral density of hybrid system, 927.5 MHz

7.14 99% occupied bandwidth

7.14.1 References

RSS-Gen → §6.7

7.14.2 Test summary

Verdict	Pass		
Test date	March 18, 2020	Temperature	19°C
Test engineer	James Cunningham	Air pressure	1011 mbar
Test location	Wireless bench	Relative humidity	62%

7.14.3 Notes

Testing was performed in DTS mode and hybrid DTS/frequency hopping mode (hopping disabled) and the EUT transmitting on a fixed channel.
The EUT antenna port was connected to the spectrum analyzer via low loss cable.

7.14.4 Setup details

EUT setup configuration	Tabletop
Test facility	Wireless bench
Measurement details	Measurement performed as per C63.10 §6.9.3 using the built-in function of the spectrum analyzer

Receiver/spectrum analyzer settings:

Resolution bandwidth	30 kHz (DTS mode) 3 kHz (hybrid mode)
Video bandwidth	100 kHz (DTS mode) 10 kHz (hybrid mode)
Detector mode	Peak
Trace mode	Max Hold
Measurement time	Long enough for trace to stabilize

Table 7.14-1: 99% occupied bandwidth equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
Signal and spectrum analyzer	Rohde & Schwarz	FSW	E1302	1 year	10 Jan 2021

7.14.5 Test data

Table 7.14-2: 99% occupied bandwidth test data

Test Mode	Test Frequency (MHz)	Bandwidth (kHz)
125 kHz channel (hybrid mode)	902.3	125.9
	914.9	125.9
	927.5	125.9
500 kHz channel (DTS mode)	903.0	668.6
	914.3	668.6
	927.5	664.3

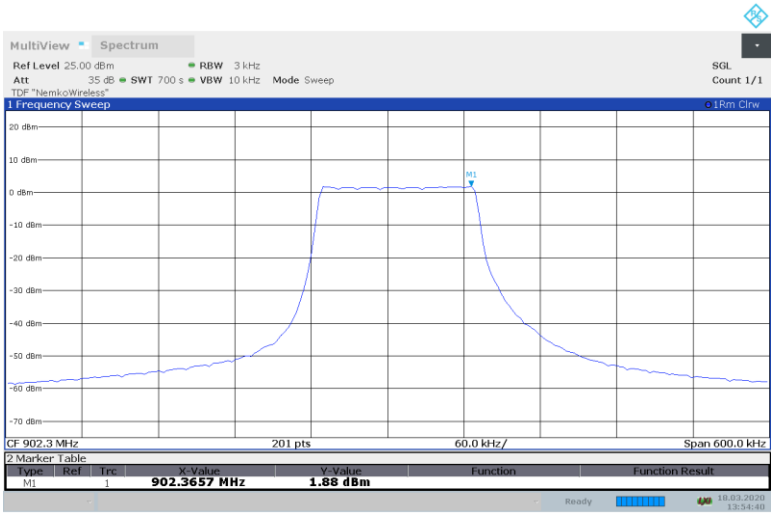


Figure 7.14-1: 99% occupied bandwidth, hybrid mode 902.3 MHz

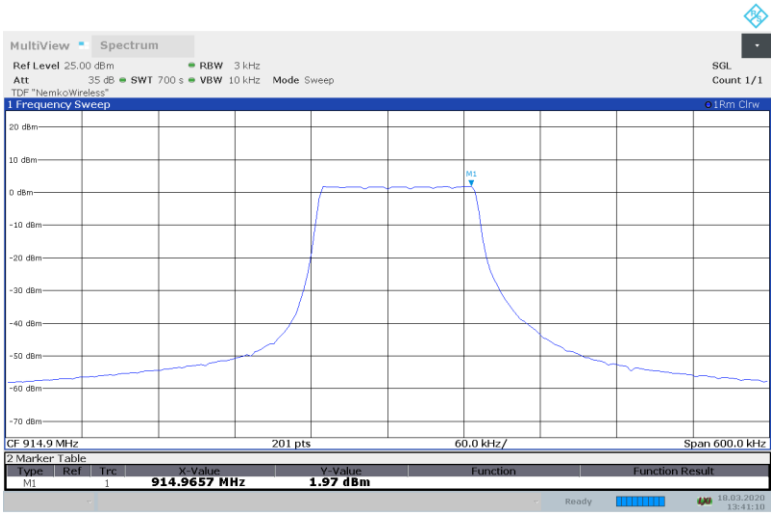


Figure 7.14-2: 99% occupied bandwidth, hybrid mode, 914.9 MHz

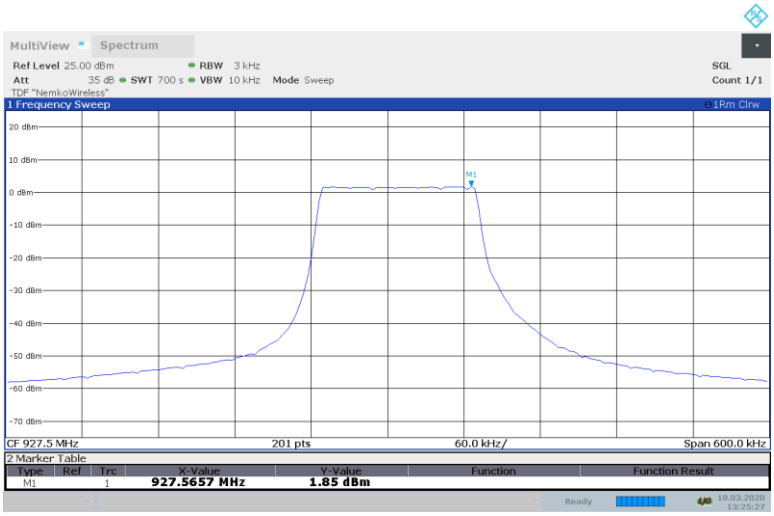


Figure 7.14-3: 99% occupied bandwidth, hybrid mode, 927.5 MHz

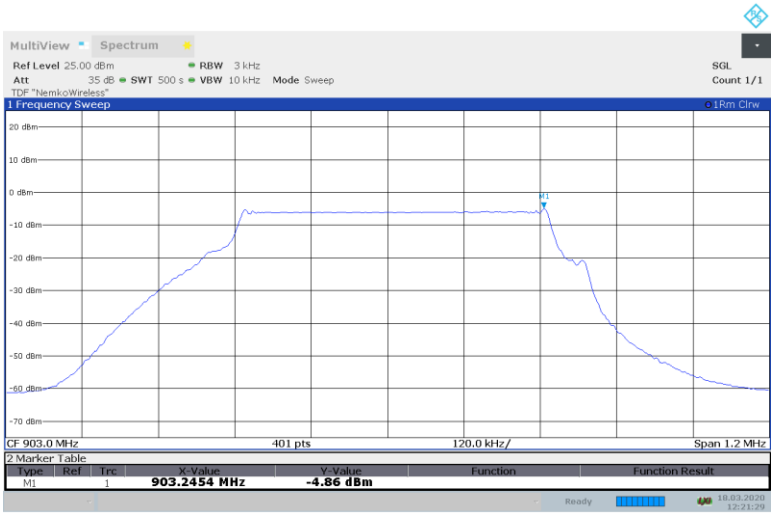


Figure 7.14-4: 99% occupied bandwidth, DTS mode, 903 MHz

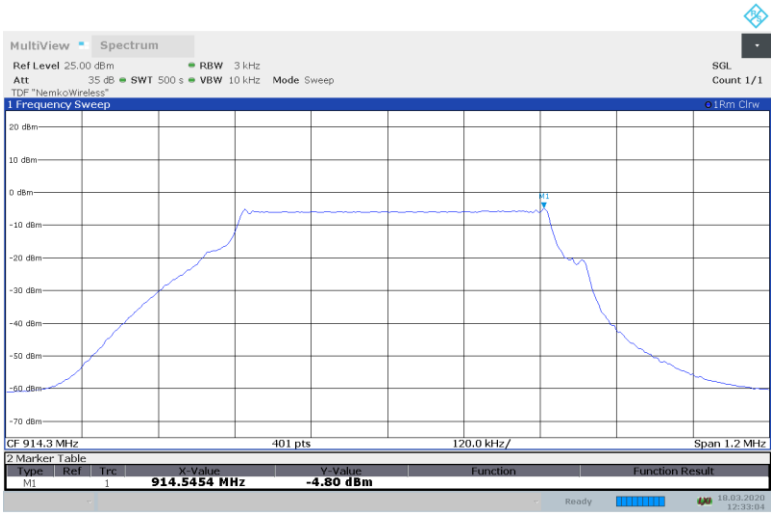


Figure 7.14-5: 99% occupied bandwidth, DTS mode, 914.3 MHz

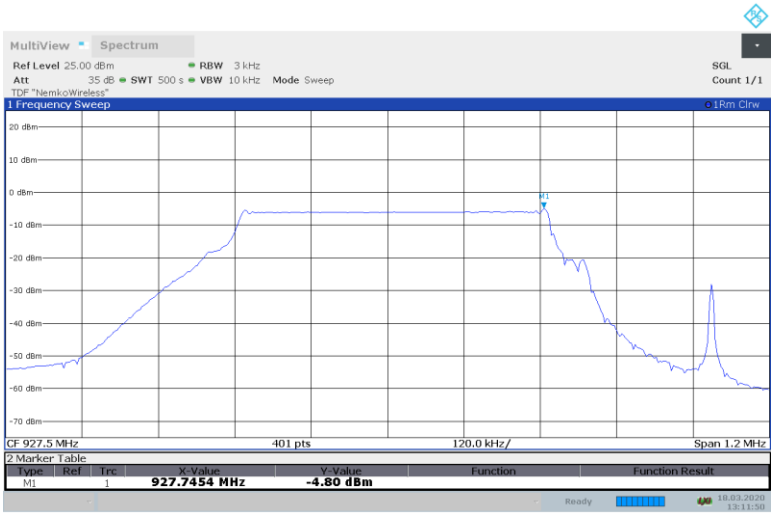


Figure 7.14-6: 99% occupied bandwidth, DTS mode, 927.5 MHz

Section 8 Block diagrams of test set-ups

8.1 Radiated emissions set-up

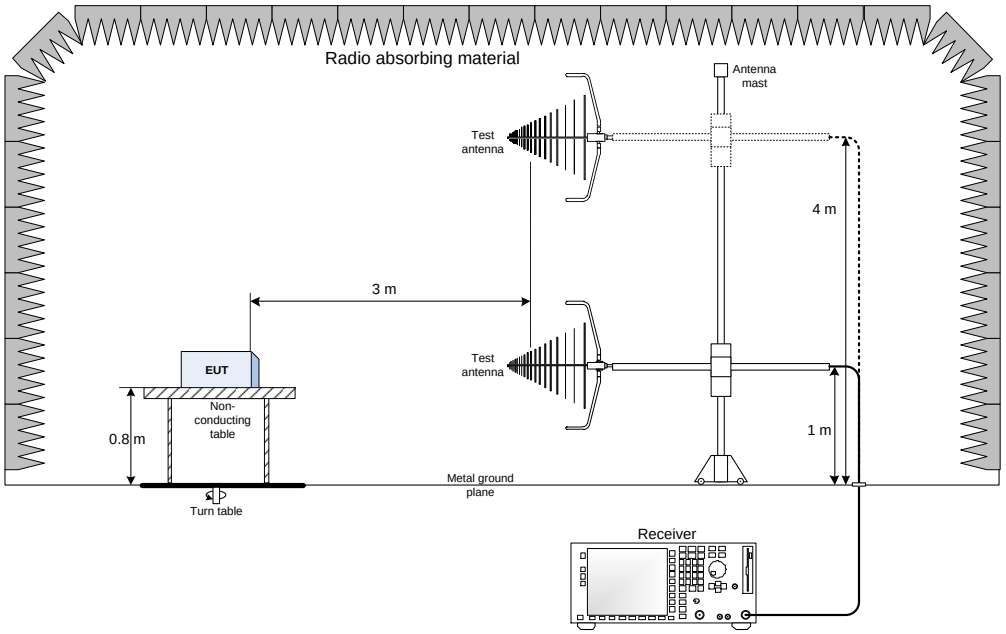


Figure 8.1-1 30 MHz - 1000 MHz Setup

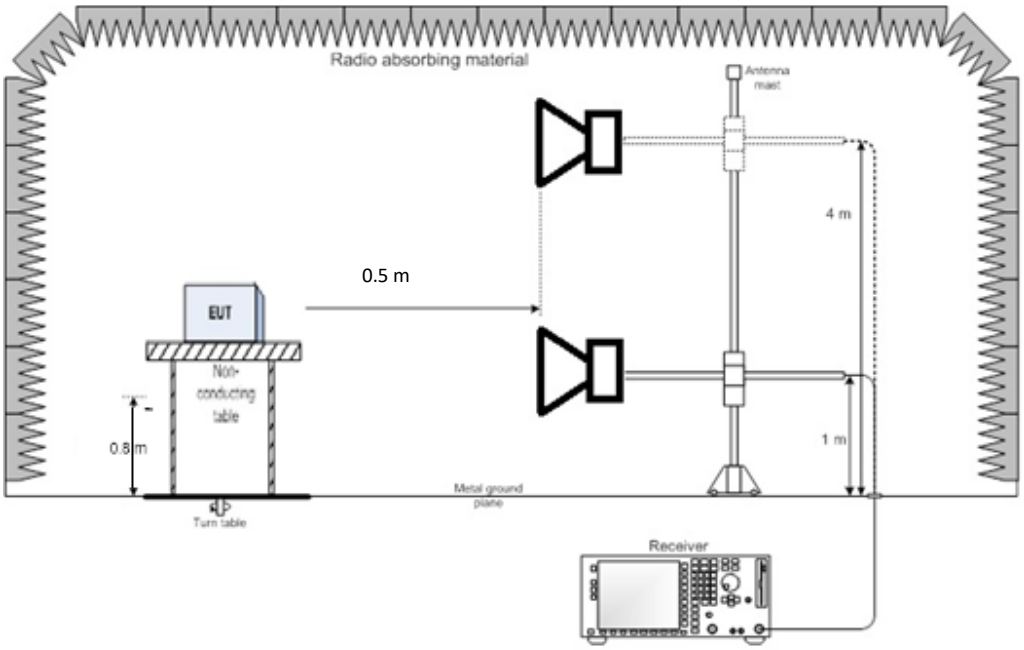


Figure 8.1-2 1 GHz - 26 GHz Setup

Thank you for choosing