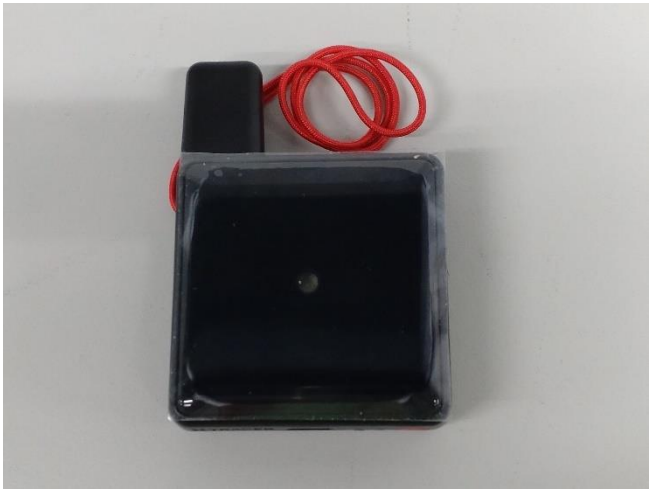
Prüfbericht – Produkte
Test Report - Products

Prüfbericht-Nr.: *Test Report No.*:	**CN23ESW5 001**	**Auftrags-Nr.:** *Order No.*:	**158270496**	**Seite 1 von 24** *Page 1 of 24*
Kunden-Referenz-Nr.: *Client Reference No.*:	**N/A**	**Auftragsdatum:** *Order date*:	**02.05.2023**	
Auftraggeber: *Client*:	**XC Tracer GmbH** **Junkerngasse 53, 3011 Bern, Switzerland**			
Prüfgegenstand: *Test item*:	**Flight Instrument with LoRa / FSK Connectivity**			
Bezeichnung / Typ-Nr.: *Identification / Type No.*:	**XC Tracer Mini V**			
Auftrags-Inhalt: *Order content*:	**FCC Certification**			
Prüfgrundlage: *Test specification*:	**FCC Part 15 Subpart C, ANSI C63.10-2013**			
Wareneingangsdatum: *Date of receipt*:	**02.05.2023**			
Prüfmuster-Nr.: *Test sample No.*:	**003467260 001~004**			
Prüfzeitraum: *Testing period*:	**06.07.2023 - 06.10.2023**			
Ort der Prüfung: *Place of testing*:	**Hong Kong**			
Prüflaboratorium: *Testing laboratory*:	**TÜV Rheinland Hong Kong Ltd.**			
Prüfergebnis*: *Test result**:	**Pass**			

geprüft von / *tested by*:			**kontrolliert von /** *reviewed by*:		
07/11/2023	Eddy Tsang / Engineer		07/11/2023	Sharon Li / Senior Manager	
Datum *Date*	**Name / Stellung** *Name / Position*	**Unterschrift** *Signature*	**Datum** *Date*	**Name / Stellung** *Name / Position*	**Unterschrift** *Signature*

Sonstiges / *Other*: FCC_ID : 2AVOQ03

"Decision Rule" document announced in our website (https://www.tuv.com/landingpage/en/qm-gcn/) describes the statement of conformity and its rule of enforcement for test results are applicable throughout this test report.

Zustand des Prüfgegenstandes bei Anlieferung: Prüfmuster vollständig und unbeschädigt
Condition of the test item at delivery: *Test item complete and undamaged*

* Legende:	1 = sehr gut	2 = gut	3 = befriedigend	4 = ausreichend	5 = mangelhaft
	P(ass) = entspricht o.g. Prüfgrundlage(n)		F(ail) = entspricht nicht o.g. Prüfgrundlage(n)	N/A = nicht anwendbar	N/T = nicht getestet
Legend:	*1 = very good*	*2 = good*	*3 = satisfactory*	*4 = sufficient*	*5 = poor*
	P(ass) = passed a.m. test specification(s)		*F(ail) = failed a.m. test specification(s)*	*N/A = not applicable*	*N/T = not tested*

1	Alle eingesetzten Prüfmittel waren zum angegebenen Prüfzeitraum gemäß eines festgelegten Kalibrierungsprogramms unseres Prüfhauses kalibriert. Sie entsprechen den in den Prüfprogrammen hinterlegten Anforderungen. Die Rückverfolgbarkeit der eingesetzten Prüfmittel ist durch die Einhaltung der Regelungen unseres Managementsystems gegeben. Detaillierte Informationen bezüglich Prüfkonditionen, Prüfequipment und Messunsicherheiten sind im Prüflabor vorhanden und können auf Wunsch bereitgestellt werden. *The equipment used during the specified testing period was calibrated according to our test laboratory calibration program. The equipment fulfils the requirements included in the relevant standards. The traceability of the test equipment used is ensured by compliance with the regulations of our management system.* *Detailed information regarding test conditions, equipment and measurement uncertainty is available in the test laboratory and could be provided on request.*
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3	Prüfklausel mit der Note * wurden an qualifizierte Unterauftragnehmer vergeben und sind unter der jeweiligen Prüfklausel des Berichts beschrieben. Abweichungen von Prüfspezifikation(en) oder Kundenanforderungen sind in der jeweiligen Prüfklausel im Bericht aufgeführt. *Test clauses with remark of * are subcontracted to qualified subcontractors and descripted under the respective test clause in the report.* *Deviations of testing specification(s) or customer requirements are listed in specific test clause in the report.*
4	Die Entscheidungsregel für Konformitätserklärungen basierend auf numerischen Messergebnisen in diesem Prüfbericht basiert auf der "Null-Grenzwert-Regel" und der "Einfachen Akzeptanz" gemäß ILAC G8:2019 und IEC Guide 115:2021, es sei denn, in der auf Seite 1 dieses Berichts genannten angewandten Norm ist etwas anderes festgelegt oder vom Kunden gewünscht. Dies bedeutet, dass die Messunsicherheit nicht berücksichtigt wird und daher auch nicht im Prüfbericht angegeben wird. Zu weiteren Informationen bezueglich des Risikos durch diese Entscheidungsregel siehe ILAC G8:2019. The decision rule for statements of conformity, based on numerical measurement results, in this test report is based on the “Zero Guard Band Rule” and “Simple Acceptance” in accordance with ILAC G8:2019 and IEC Guide 115:2021, unless otherwise specified in the applied standard mentioned on Page 1 of this report or requested by the customer. This means that measurement uncertainty is not taken in account and hence also not declared in the test report. For additional information to the resulting risk based of this decision rule please refer to ILAC G8:2019.

Table of Content

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Product information

Manufacturers declarations

	Transceiver	
Operating frequency range	902.6 - 927.4 MHz	920.8 MHz
Type of modulation	FHSS modulation	DSSS modulation
Number of channels	64	1
Channel separation	200 KHz	n/a
Type of antenna	Internal PCB Antenna	
Antenna gain (dBi)	-3.50 dBi	
Power level	fix	
Type of equipment	Standalone Device	
Connection to public utility power line	Yes	
Nominal voltage (Battery)	V_{nor}: 3.7 VDC	
Nominal voltage (USB-C)	V_{nor}: 5.0 VDC	
Independent Operation Modes	Transceiver	

Product function and intended use

The equipment under test (EUT) is a LoRa Radio Module.

FCC_ID : 2AVOQ03

Models	Product description	Authorized Antenna
XC Tracer Mini V	GPS Device with LoRa Connectivity	Internal PCB Antenna

Submitted documents

Circuit Diagram
Block Diagram
Technical Description
User manual
Label

Independent Operation Modes

The basic operation modes are:

- Transceiver mode.

For further information refer to User Manual

Related Submittal(s) Grants

- This is a single application for certification of the Transceiver Module.

Remark

The test results in this test report are only relevant to the tested sample and does not involve any assessment in the production.

Test Set-up and Operation Mode

Principle of Configuration Selection

Emission: The equipment under test (EUT) was configured to measure its highest possible radiation level. The test modes were adapted accordingly in reference to the instructions for use.

Test Operation and Test Software

Test operation should refer to test methodology.

- During test, Channel & Power Controlling Software provided by the customer was used to control the operating channel as well as the output power level. The RF output power is fixed.

Special Accessories and Auxiliary Equipment

- Nil

Countermeasures to achieve EMC Compliance

- Nil

Test Methodology

Radiated Emission

The radiated emission measurements of the transmitter part were performed according to the procedures in ANSI C63.10-2013.

For measurement below 1GHz - the equipment under test (EUT) was placed at the middle of the 80 cm height turntable. For measurement above 1GHz - the EUT was placed at the middle of the 1.5 m height turntable and RF absorbing material was placed on ground plane between turntable and measuring antenna. During the testing, the EUT was operated standalone and arranged for maximum emissions. The EUT was tested in three orthogonal planes.

The investigation is performed with the EUT rotated 360 ° , the antenna height scanned between 1m and 4m, and the antenna rotated to repeat the measurements for both the horizontal and vertical antenna polarizations. Repeat the measurement steps until the maximum emissions were obtained.

All radiated tests were performed at an antenna to EUT with 3 meters distance, unless stated otherwise in particular parts of this test report.

Field Strength Calculation

The field strength at 3 m was established by adding the meter reading of the spectrum analyzer to the factors associated with antenna correction factor, cable loss, preamplifiers and filter attenuation.

The equation is expressed as follow:

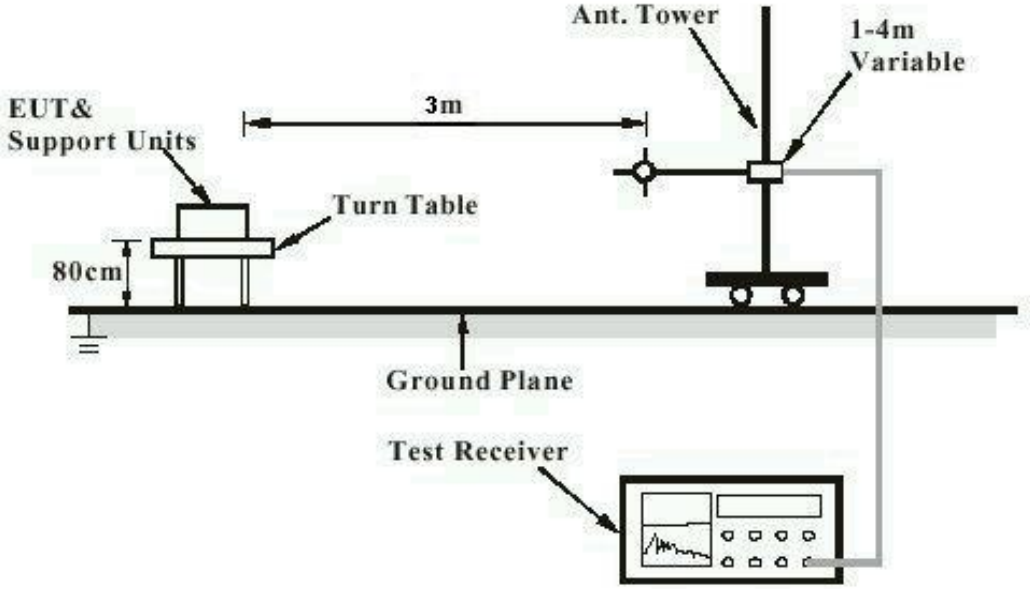
FS = R + AF + CF + FA – PA

Where FS = Field Strength in dBuV/m at 3 meters.
R = Reading of Spectrum Analyzer in dBuV.
AF = Antenna Factor in dB.
CF = Cable Attenuation Factor in dB.
FA = Filter Attenuation Factor in dB.
PA = Preamplifier Factor in dB.

FA and PA are only be used for the measuring frequency above 1 GHz.

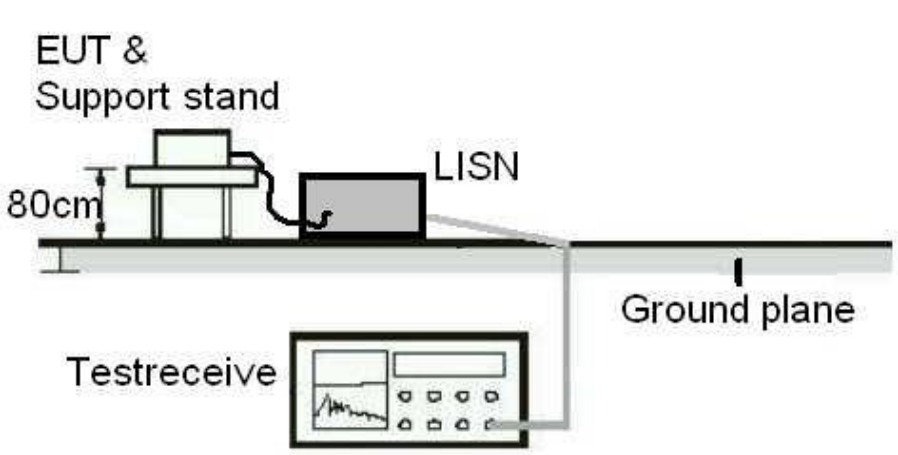
Test Setup Diagram

Diagram of Measurement Configuration for Radiation Test



Note: Measurements above 1 GHz are done with a table height of 1.5m. In addition, there is RF absorbing material on the floor of the test site for above 1GHz measurement.

Diagram of Measurement Equipment Configuration for Mains Conduction Measurement (if applicable)



Test Facility

Test Laboratory Information

TÜV Rheinland Hong Kong Ltd.
Address: 3-4/F, Fou Wah Industrial Building, 10-16 Pun Shan Street, Tsuen Wan, N.T., Hong Kong·
Tel.: +852 2192 1000
Fax: +852 2192 1001
Email service-gc@tuv.com

The test facility is recognized or accredited by the following organizations:

FCC

Test Firm Registration Number : 371735

List of Test and Measurement Instruments

Hong Kong Productivity Council

Radiated Emission

Equipment	Manufacturer	Type	Cal. Date	Due Date
Semi-anechoic Chamber	Frankonia	Nil	03 Mar 23	03 Mar 24
Multi-functional Anechoic Chamber	Albatross	Nil	04 Jan 23	04 Jan 24
Test Receiver	R & S	ESU40	09 Mar 23	09 Mar 24
Active Loop Antenna	EMCO	6502	03 Nov 22	03 Nov 24
Bi-conical Antenna	R & S	HK116	24 Oct 22	24 Oct 24
Log Periodic Antenna	R & S	HL223	25 Oct 22	25 Oct 24
Standard Gain Horn	ETS-Lindgren	3160-07	25 Nov 22	25-Nov 24
Standard Gain Horn	ETS-Lindgren	3160-08	25 Nov 22	25 Nov 24
Standard Gain Horn	ETS-Lindgren	3160-10	30 Nov 22	30 Nov 24
Double-Ridged Waveguide Horn	EMCO	3116	30 Nov 22	30 Nov 24
Double-Ridged Waveguide Horn	EMCO	3117	21 Nov 22	21 Nov 24
Coaxial cable	Harbour	SF118/11n/11n/12000.0	03 Aug 22	03 Aug 24
High Frequency Cable	Pasternack	PE3VNA4001-3M	29 Jan 23	29 Jan 25
Microwave amplifer 0.5-26.5GHz, 25dB gain	COM-POWER Corporation	PAM-118A	04 Mar 23	04 Mar 24
Preamplifier 18GHz to 40GHz with cable (EMC656)	A.H. Systems, Inc.	PAM-1840VH	28 Jan 23	28 Jan 24
High Pass Filter (cutoff freq. =1000MHz)	Trilithic	23042	30 Oct 21	30 Oct 23

Radio Test

Equipment	Manufacturer	Type	Cal. Date	Due Date
Spectrum Analyzer	R & S	FSP30	29 Nov 22	29 Nov 23
Signal Generator	R & S	SMB100A	12 Mar 23	12 Mar 24
Temperature/ Humidity Chamber	Kson	THS-B4H-150	26 Sep 22	26 Sep 24

Electrostatic Discharge Test

Equipment	Manufacturer	Type	Cal. Date	Due Date
ESD Simulator	TESEQ	NSG437	30-Jun-2022	30-Jun-24

Terminal Disturbance Voltage at Mains Terminals and Discontinuous Disturbance

Equipment	Manufacturer	Type	Cal. Date	Due Date
Test Receiver	Rohde & Schwarz	ESU40	09 Mar 23	09 Mar 24
LISN	Rohde & Schwarz	ENV216	30 Sep 22	30 Sep 24
Double Shield Cable	Huber + Suhner	RG223/U-01	22 May 23	22 May 25

TÜV Rheinland Hong Kong Ltd.

Radio Test

Equipment	Manufacturer	Type	Cal. Date	Due Date
Spectrum Analyzer	R & S	FSV40	13 Jul 23	13 Jul 24

Measurement Uncertainty

The estimated combined standard uncertainty for power-line conducted emissions measurements is ±2.42dB.

The estimated combined standard uncertainty for radiated emissions measurements is ±4.81dB (9kHz to 30MHz) and ±4.62dB (30MHz to 200MHz) and ±5.67dB (200MHz to 1000MHz) and is ±5.07dB (1GHz to 8.2GHz) and ±4.58dB (8.2GHz to 12.4GHz) and ±4.78dB (12.4GHz to 18GHz)

The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor of k=2, which for the level of confidence is approximately 95%.

Results FCC Part 15 – Subpart C

Common to DTS & FHSS

FCC 15.203 – Antenna Requirement 1		**Pass**
FCC Requirement:	No antenna other than that furnished by the responsible party shall be used with the device	
Results :		
Antenna 1	a) Antenna type:	Internal PCB Antenna
	b) Manufacturer and model no:	N/A
	c) Peak Gain:	-3.50 dBi at 928MHz
Verdict:	Pass	

FCC 15.204 – Antenna Requirement 2	**Pass**
An intentional radiator may be operated only with the antenna with which it is authorized. If an antenna is marketed with the intentional radiator, it shall be of a type which is authorized with the intentional radiator.	
Only one authorized antennas can be used.	
Verdict:	Pass

FCC 15.207 – Conducted Emission on AC Mains **Pass**

Test Specification : ANSI C63.10-2013
Test date : 19.09.2023
Mode of operation : TX mode DTS 920.8 MHz; FHSS 902.6 - 927.4 MHz
Port of testing : AC Mains input port of power supply
Supply voltage : 120Vac 60Hz
Temperature : 23ºC
Humidity : 60%

Requirement: 15.207(a)

Results: Pass

Mode : DTS 920.8 MHz Live measurement

Frequency range (MHz)	Frequency (MHz)	Quasi-peak dBµV	Average dBµV	Limit QP (dBµV)	Limit AV (dBµV)	Verdict
0,15 – 0,5	0.200	46.3	34.1	66 - 56	56 - 46	Pass
0,15 – 0,5	0.245	47.6	36.9	66 - 56	56 - 46	Pass
0,15 – 0,5	0.267	40.8	28.8	66 - 56	56 - 46	Pass
> 0,5 - 5	No peak found	--	--	56	46	Pass
> 5 - 30	No peak found	--	--	60	50	Pass

Mode : DTS 920.8 MHz Neutral measurement

Frequency range (MHz)	Frequency (MHz)	Quasi-peak dBµV	Average dBµV	Limit QP (dBµV)	Limit AV (dBµV)	Verdict
0,15 – 0,5	0.202	44.6	33.5	66 - 56	56 - 46	Pass
0,15 – 0,5	0.224	43.7	36.8	66 - 56	56 - 46	Pass
> 0,5 - 5	2.546	37.1	22.9	56	46	Pass
> 5 - 30	No peak found	--	--	60	50	Pass

Mode : FHSS 902.6 - 927.4 MHz			Live measurement			
Frequency range (MHz)	**Frequency (MHz)**	**Quasi-peak dBµV**	**Average dBµV**	**Limit QP (dBµV)**	**Limit AV (dBµV)**	**Verdict**
0,15 – 0,5	0.225	42.3	32.0	66 – 56	56 – 46	Pass
0,15 – 0,5	0.240	48.5	41.9	66 – 56	56 – 46	Pass
> 0,5 - 5	2.846	31.7	21.2	56	46	Pass
> 5 - 30	No peak found	--	--	60	50	Pass
Mode : FHSS 902.6 - 927.4 MHz			Neutral measurement			
Frequency range (MHz)	**Frequency (MHz)**	**Quasi-peak dBµV**	**Average dBµV**	**Limit QP (dBµV)**	**Limit AV (dBµV)**	**Verdict**
0,15 – 0,5	0.165	36.3	27.8	66 - 56	56 - 46	Pass
0,15 – 0,5	0.242	47.1	42.1	66 - 56	56 - 46	Pass
> 0,5 - 5	2.458	33.5	20.2	56	46	Pass
> 5 - 30	No peak found	--	--	60	50	Pass

Remarks: Pre-scan has been conducted to determine the worst-case mode from all possible combinations between available modulations and data rate.

The radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies within the band 150kHz to 30MHz does not exceed the limits. For test Results plots refer to Appendix 1, page 2.

FCC 15.247 (a) – Receiver Input Bandwidth	**Pass**
FCC Requirement: The associated receiver(s) complies with the requirement that its input bandwidth matches the bandwidth of the transmitted signal.	
Refer to LoRa Specification	

Digital Modulation System (DTS)

FCC 15.247 (a)(2) – 6dB Bandwidth Measurement			**Pass**
FCC Requirement:	Systems using digital modulation techniques may operate in the 902 – 928 MHz, 2400 – 2483.5 MHz, and 5725 – 5850 MHz bands. The minimum 6dB bandwidth shall be at least 500kHz.		
Test Specification Test date Mode of operation Supply voltage Temperature Humidity	: : : : : :	ANSI C63.10 – 2013 06.10.2023 Tx mode USB-C 5.0 VDC 23ºC 51%	
Results:	For test protocols please refer to Appendix 1		
Channel frequency (MHz)	**6dB bandwidth (kHz)**		**Limit (kHz)**
920.8	627.9		≥ 500

FCC 15.247 (b)(3) – Maximum conducted output power			**Pass**
FCC Requirement:	For systems using digital modulation in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850MHz bands: 1 Watt (30dBm)		
Test Specification Test date Mode of operation Supply voltage Temperature Humidity	: : : : : :	ANSI C63.10 – 2013 06.10.2023 Tx mode USB-C 5.0 VDC 23ºC 51%	
Results:	For test protocols please refer to Appendix 1		
Frequency (MHz)	**Maximum peak output power (dBm) | (mW)**	**Limit (dBm | W)**	**Verdict**
920.8	12.41 | 17.42	30.0 | 1	Pass

FCC 15.247 (e) – Power Spectral Density			**Pass**
FCC Requirement: For systems using digital modulation, the power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.			
Test Specification : ANSI C63.10 – 2013 Test date : 06.10.2023 Mode of operation : Tx mode Supply voltage : USB-C 5.0 VDC Temperature : 23ºC Humidity : 51%			
Results: For test protocols please refer to Appendix 1.			
Frequency (MHz)	**Maximum Power Spectral Density (dBm)**	**Limit (dBm)**	**Verdict**
920.8	7.20	8.0	Pass

FCC 15.247 (d) – Spurious Conducted Emissions	**Pass**

Test Specification : ANSI C63.10 – 2013
Test date : 06.10.2023
Mode of operation : Tx mode
Supply voltage : USB-C 5.0 VDC
Temperature : 25ºC
Humidity : 56%

FCC Requirement: In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator 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.

Results: Pre-scan has been conducted to determine the worst-case mode from all possible combinations between available modulations and data rate.

Only the worst cases is shown below. For test protocols refer to Appendix 1

Operating frequency (MHz)	Spurious frequency (MHz)	Spurious Level (dBm)	Reference value (dBm)	Limit (dBm)	Margin (dB)	Verdict
920.8	No peak found	--	--	--	--	Pass

FCC 15.205 – Radiated Emissions in Restricted Frequency Bands **Pass**

Test Specification : ANSI C63.10 – 2013
Test date : 06.07.2023 ~18.09.2023
Mode of operation : Tx mode
Frequency range : 9kHz – 10GHz
Supply voltage : Battery 3.7 VDC; USB-C 5.0 VDC
Temperature : 25.2ºC
Humidity : 50%

FCC Requirement: In any 100kHz bandwidth outside the frequency band at least 20dB below the highest level of the desired power. In addition, radiated emissions which fall in the restricted bands must also comply with the radiated emission general limits.

Results: Pre-scan has been conducted to determine the worst-case mode from all possible combinations between available modulations and data rate.
All three transmit frequency modes comply with the field strength within the restricted bands. There is no spurious found below 30MHz.

Mode: Battery, 920.8 MHz TX Vertical Polarization

Frequency MHz	Level dBuV/m	Limit/ Detector dBuV/m
1841.597	47.5	74.0 / PK
1841.597	44.9	54.0 / AV
2762.394	46.8	74.0 / PK
2762.394	42.7	54.0 / AV

Mode: Battery, 920.8 MHz TX Horizontal Polarization

Frequency MHz	Level dBuV/m	Limit/ Detector dBuV/m
1841.596	42.6	74.0 / PK
1841.596	36.7	54.0 / AV
2762.392	43.7	74.0 / PK
2762.392	37.6	54.0 / AV
3683.192	42.3	74.0 / PK
3683.192	33.0	54.0 / AV

Mode: USB-C, 920.8 MHz TX Vertical Polarization

Frequency MHz	Level dBuV/m	Limit/ Detector dBuV/m
48.3	26.7	46.0 / QP
No peak found	--	74.0 / PK
No peak found	--	54.0 / AV

Mode: USB-C, 920.8 MHz TX Horizontal Polarization

Frequency MHz	Level dBuV/m	Limit/ Detector dBuV/m
1841.596	44.6	74.0 / PK
1841.596	35.3	54.0 / AV
2762.394	47.8	74.0 / PK
2762.394	38.5	54.0 / AV

Frequency Hopping Spread Spectrum (FHSS)

FCC 15.247 (a) – 20 dB Bandwidth	**Pass**
FCC Requirement: N/A	
Test Specification : ANSI C63.10 – 2013 Test date : 28.09.2023 Mode of operation : Tx mode Port of testing : Temporary antenna port Supply voltage : USB-C 5.0 VDC Temperature : 22ºC Humidity : 55%	
Results: Pre-scan has been conducted to determine the worst-case mode from all possible combinations between available modulations and packet types. For test protocols refer to Appendix 1.	

Frequency (MHz)	**20 dB left (MHz)**	**20 dB right (MHz)**	**20dB bandwidth (KHz)**
902.6	902.496	902.693	198
914.6	914.496	914.702	206
927.4	927.296	927.502	206

FCC 15.247 (a)(1) – Carrier Frequency Separation	**Pass**
Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25kHz or the 20dB bandwidth of the hopping channel, whichever is greater.	
Test Specification : ANSI C63.10 – 2013 Test date : 28.09.2023 Mode of operation : Tx mode (hopping on) Port of testing : Temporary antenna port Supply voltage : USB-C 5.0 VDC Temperature : 22ºC Humidity : 55%	
Results: Pre-scan has been conducted to determine the worst-case mode from all possible combinations between available modulations and packet types. For test Results plots refer to Appendix 1.	

Channel Separation (kHz)	**Limit (kHz)**	**Verdict**
400	206	Pass

FCC 15.247 (a)(1)(iii) – Number of hopping channels	**Pass**

For frequency hopping systems operating in the 902-928 MHz band: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping frequencies; if the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping frequencies.

Test Specification : ANSI C63.10 – 2013
Test date : 28.09.2023
Mode of operation : Tx mode (hopping on)
Port of testing : Temporary antenna port
Supply voltage : USB-C 5.0 VDC
Temperature : 22ºC
Humidity : 55%

Results: For test Results plots refer to Appendix 1.

No. of hopping channels	Limit	Verdict
63	50	Pass

FCC 15.247 (a)(1)(iii) – Time of Occupancy (Dwell Time)	**Pass**

For frequency hopping systems operating in the 902-928 MHz band: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period; if the 20 dB bandwidth of the hopping channel is 250 kHz or greater, average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 10 second period.

Test Specification : ANSI C63.10 – 2013
Test date : 28.09.2023
Mode of operation : Tx mode (hopping on)
Port of testing : Temporary antenna port
Supply voltage : USB-C 5.0 VDC
Temperature : 22ºC
Humidity : 55%

902.6 MHz

Results: Time period calculation = 20s

Dwell time = 1 x 5.21 x 10^{-3} = 0.00521 s
<= 0.4 s

For test protocols please refer to Appendix 1.

Verdict: Pass

914.6 MHz

Results: Time period calculation = 20s

Dwell time = 1 x 5.2 x 10^{-3} = 0.0052 s
<= 0.4 s

For test protocols please refer to Appendix 1.

Verdict: Pass

927.4 MHz	
Results:	Time period calculation = 20s Dwell time = 1 x 5.2 x 10^{-3} = 0.0052 s <= 0.4 s For test protocols please refer to Appendix 1.
Verdict:	Pass

FCC 15.247 (a) – Hopping Sequence	**Pass**
The system radio frequency (RF) bandwidth is equal to the channel bandwidth multiplied by the number of channels in the hop set. The hop set shall be such that the near-term distribution of frequencies appears random, with sequential hops randomly distributed in both direction and magnitude of change in the hop set, while the long-term distribution appears evenly distributed.	
Refer to LoRa Specification	

FCC 15.247 (a) – Equal Hopping Frequency Use	**Pass**
Each of the transmitter's hopping channels is used equally on average. The system radio frequency (RF) bandwidth is equal to the channel bandwidth multiplied by the number of channels in the hop set. The hop set shall be such that the near-term distribution of frequencies appears random, with sequential hops randomly distributed in both direction and magnitude of change in the hop set, while the long-term distribution appears evenly distributed.	
Refer to LoRa Specification	

FCC 15.247 (a) – Receiver Input Bandwidth	**Pass**
The associated receiver(s) complies with the requirement that its input bandwidth matches the bandwidth of the transmitted signal.	
Refer to LoRa Specification	

FCC 15.247 (a) – Receiver Hopping Capability	**Pass**
The associated receiver has the ability to shift frequencies in synchronisation with the transmitted signals.	
Refer to LoRa Specification	

FCC 15.247 (b)(1) – Peak Output Power	**Pass**

Test Specification : ANSI C63.10 – 2013
Test date : 28.09.2023
Mode of operation : Tx mode
Port of testing : Temporary antenna port
Supply voltage : USB-C 5.0 VDC
Temperature : 23ºC
Humidity : 50%

For frequency hopping systems operating in the 902-928 MHz band: 1 watt for systems employing at least 50 hopping channels; 0.25 watts for systems employing less than 50 hopping channels, but at least 25 hopping channels.

For test protocols please refer to Appendix 1.

Frequency (MHz)	Cable loss (dB)	Maximum peak output power (dBm) | (mW)	Limit (dBm | W)	Verdict
902.6	0.5	13.21 | 20.94	30.0 | 1	Pass
914.6	0.5	12.82 | 19.14	30.0 | 1	Pass
927.4	0.5	12.78 | 18.97	30.0 | 1	Pass

FCC 15.247 (d) – Spurious Conducted Emissions	**Pass**

Test Specification : ANSI C63.10 – 2013
Test date : 28.09.2023
Mode of operation : Tx mode
Supply voltage : USB-C 5.0 VDC
Temperature : 25ºC
Humidity : 56%

FCC Requirement: In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator 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.

Results: Pre-scan has been conducted to determine the worst-case mode from all possible combinations between available modulations and data rate.
Only the worst cases is shown below. For test protocols refer to Appendix 1

Operating frequency (MHz)	Spurious frequency (MHz)	Spurious Level (dBm)	Reference value (dBm)	Limit (dBm)	Margin (dB)	Verdict
902.6	No peak found	--	--	--	--	Pass
914.6	No peak found	--	--	--	--	Pass
927.4	No peak found	--	--	--	--	Pass

FCC 15.205 – Radiated Emissions in Restricted Frequency Bands	**Pass**

Test Specification : ANSI C63.10 – 2013
Test date : 06.07.2023 ~18.09.2023
Mode of operation : Tx mode
Frequency range : 9kHz – 10GHz
Supply voltage : Battery 3.7 VDC; USB-C 5.0 VDC
Temperature : 25.2ºC
Humidity : 50%

FCC Requirement: In any 100kHz bandwidth outside the frequency band at least 20dB below the highest level of the desired power. In addition, radiated emissions which fall in the restricted bands must also comply with the radiated emission general limits.

Results: Pre-scan has been conducted to determine the worst-case mode from all possible combinations between available modulations and data rate.
All three transmit frequency modes comply with the field strength within the restricted bands. There is no spurious found below 30MHz.

Mode: Battery, Mode: 902.6 MHz TX Vertical Polarization

Frequency MHz	**Level dBuV/m**	**Limit/ Detector dBuV/m**
1805.197	44.3	74.0 / PK
1805.197	40.4	54.0 / AV
2707.798	50.4	74.0 / PK
2707.798	48.0	54.0 / AV
3610.394	47.2	74.0 / PK
3910.394	42.7	54.0 / AV

Mode: Battery, Mode: 902.6 MHz TX Horizontal Polarization

Frequency MHz	**Level dBuV/m**	**Limit/ Detector dBuV/m**
1805.201	41.4	74.0 / PK
1805.201	35.1	54.0 / AV
2707.798	49.0	74.0 / PK
2707.798	46.7	54.0 / AV
3610.387	45.6	74.0 / PK
3610.387	41.3	54.0 / AV

Mode: USB-C, Mode: 902.6 MHz TX Vertical Polarization

Frequency MHz	**Level dBuV/m**	**Limit/ Detector dBuV/m**
2707.796	47.9	74.0 / PK
2707.796	32.4	54.0 / AV

Mode: USB-C, Mode: 902.6 MHz TX Horizontal Polarization

Frequency MHz	**Level dBuV/m**	**Limit/ Detector dBuV/m**
2707.796	49.2	74.0 / PK
2707.796	33.2	54.0 / AV

Mode: Battery, Mode: 914.6 MHz TX	Vertical Polarization	
Frequency MHz	**Level dBuV/m**	**Limit/ Detector dBuV/m**
1829.201	46.7	74.0 / PK
1829.201	43.4	54.0 / AV
2743.798	48.3	74.0 / PK
2743.798	45.3	54.0 / AV
Mode: Battery, Mode: 914.6 MHz TX	Horizontal Polarization	
Frequency MHz	**Level dBuV/m**	**Limit/ Detector dBuV/m**
2743.745	48.5	74.0 / PK
2743.745	45.5	54.0 / AV
3658.394	44.4	74.0 / PK
3658.394	38.8	54.0 / AV
Mode: USB-C, Mode: 914.6 MHz TX	Vertical Polarization	
Frequency MHz	**Level dBuV/m**	**Limit/ Detector dBuV/m**
1829.200	53.0	74.0 / PK
1829.200	36.5	54.0 / AV
Mode: USB-C, Mode: 914.6 MHz TX	Horizontal Polarization	
Frequency MHz	**Level dBuV/m**	**Limit/ Detector dBuV/m**
1829.248	56.8	74.0 / PK
1829.248	39.7	54.0 / AV
2743.796	50.3	74.0 / PK
2743.796	34.3	54.0 / AV
Mode: Battery, Mode: 927.4 MHz TX	Vertical Polarization	
Frequency MHz	**Level dBuV/m**	**Limit/ Detector dBuV/m**
1854.794	48.3	74.0 / PK
1854.794	45.9	54.0 / AV
2782.195	44.3	74.0 / PK
2782.195	37.9	54.0 / AV
Mode: Battery, Mode: 927.4 MHz TX	Horizontal Polarization	
Frequency MHz	**Level dBuV/m**	**Limit/ Detector dBuV/m**
1854.748	42.2	74.0 / PK
1854.748	35.7	54.0 / AV
2782.193	42.4	74.0 / PK
2782.193	33.5	54.0 / AV
3709.591	43.1	74.0 / PK
3709.591	34.0	54.0 / AV

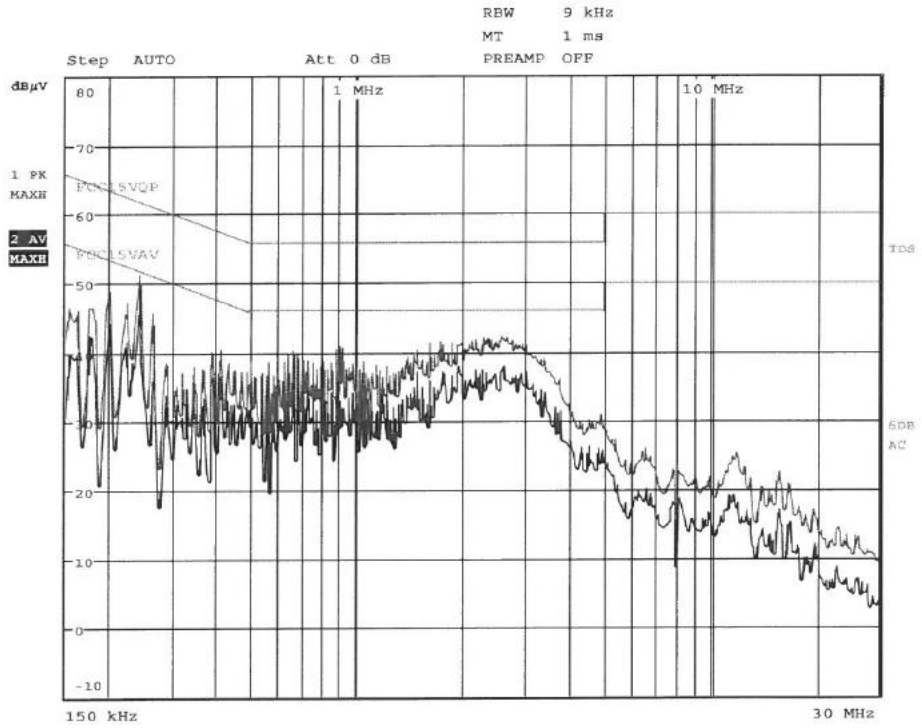
Mode: USB-C, Mode: 927.4 MHz TX	Vertical Polarization	
Frequency MHz	**Level dBuV/m**	**Limit/ Detector dBuV/m**
1854.897	59.8	74.0 / PK
1854.897	42.4	54.0 / AV
Mode: USB-C, Mode: 927.4 MHz TX	Horizontal Polarization	
Frequency MHz	**Level dBuV/m**	**Limit/ Detector dBuV/m**
1854.800	47.4	74.0 / PK
1854.800	31.6	54.0 / AV

Appendix 1

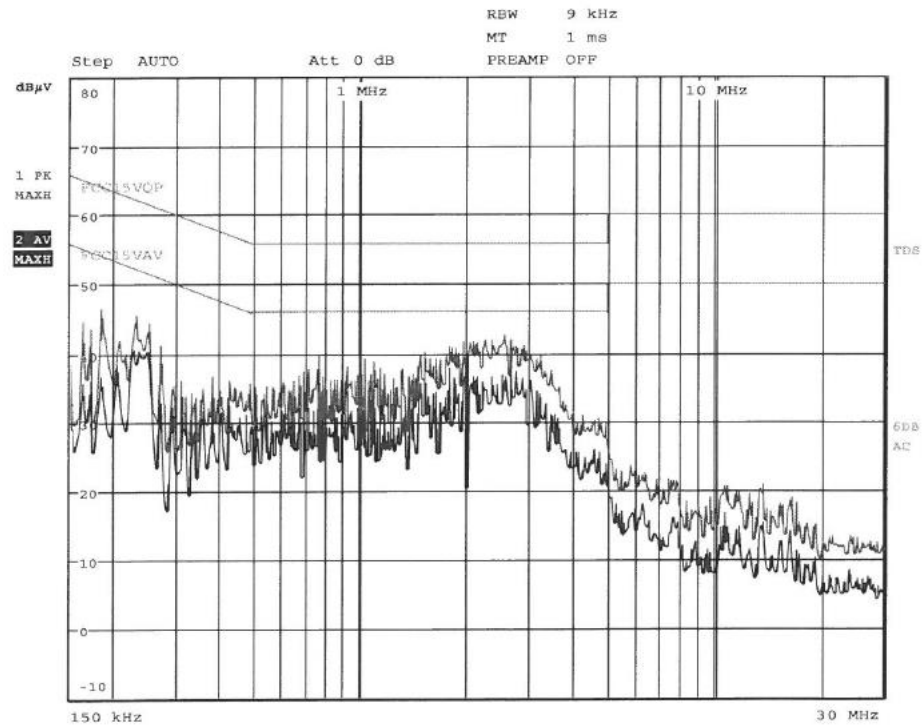
Test Results

Conducted Emission on AC Mains

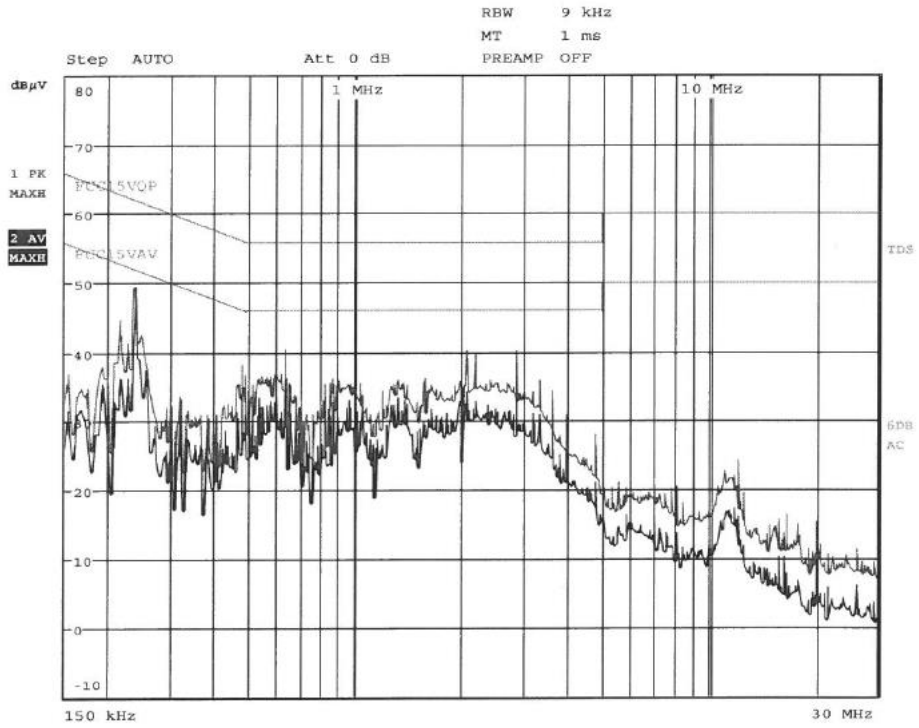
Mode : TX DTS 920.8 MHz; Line : L1



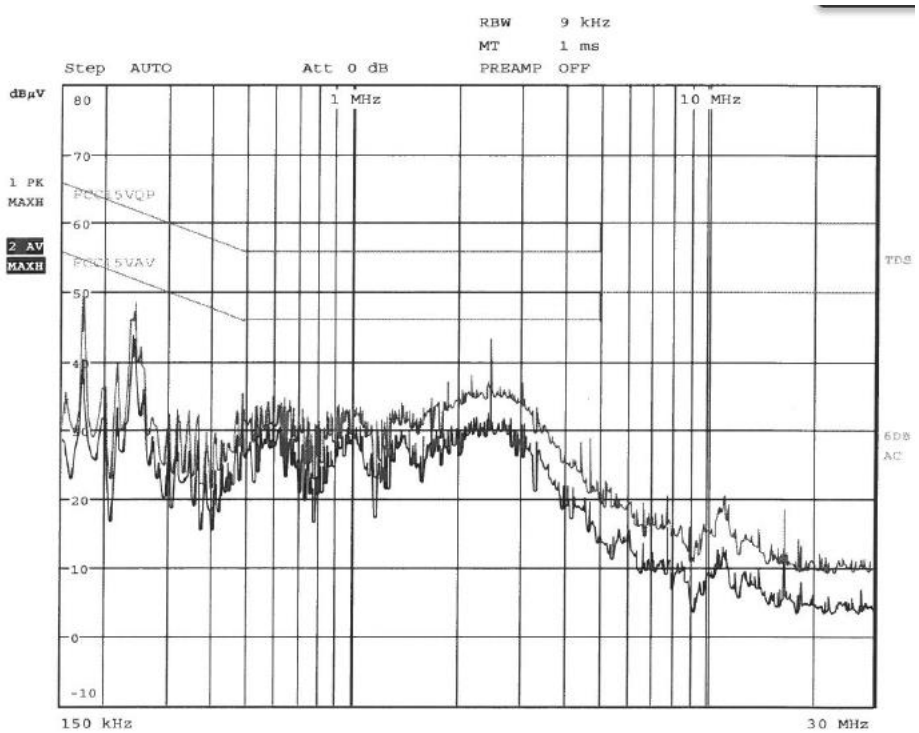
Mode : TX DTS 920.8 MHz; Line : N



Mode : TX FHSS 902.6 - 927.4 MHz; Line : L1



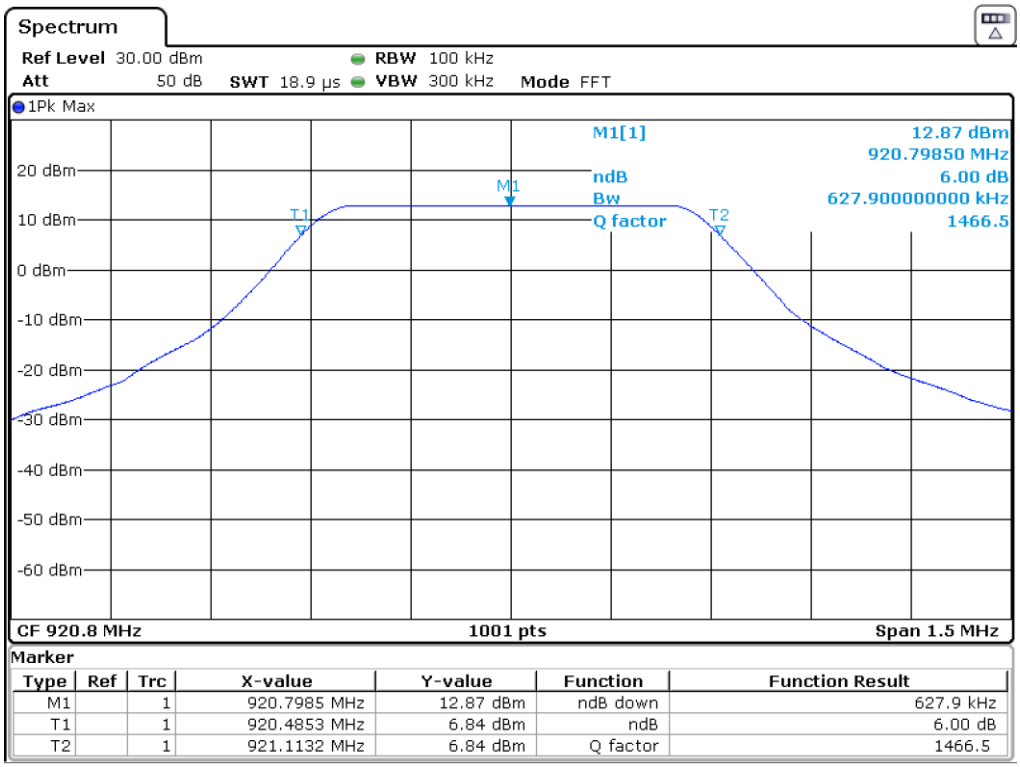
Mode : TX FHSS 902.6 - 927.4 MHz; Line : N



Digital Modulation System (DTS)

6 dB Bandwidth Measurement

TX Frequency 920.8MHz

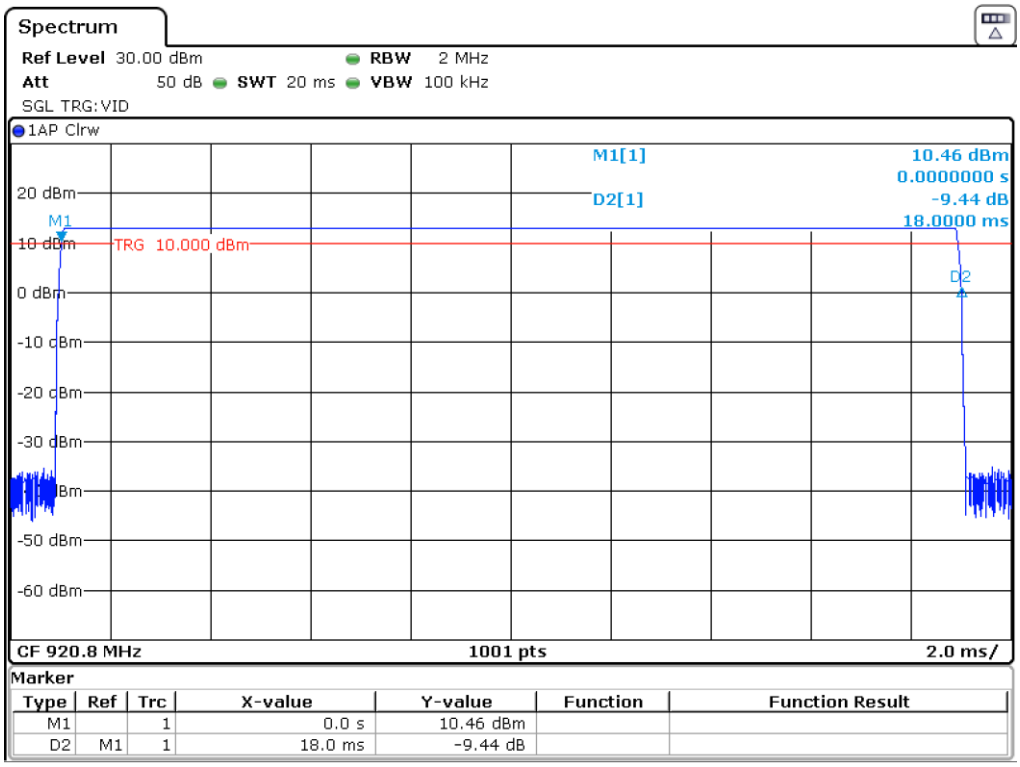


Marker

Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	920.7985 MHz	12.87 dBm	ndB down	627.9 kHz
T1		1	920.4853 MHz	6.84 dBm	ndB	6.00 dB
T2		1	921.1132 MHz	6.84 dBm	Q factor	1466.5

Transmission Duty Cycle

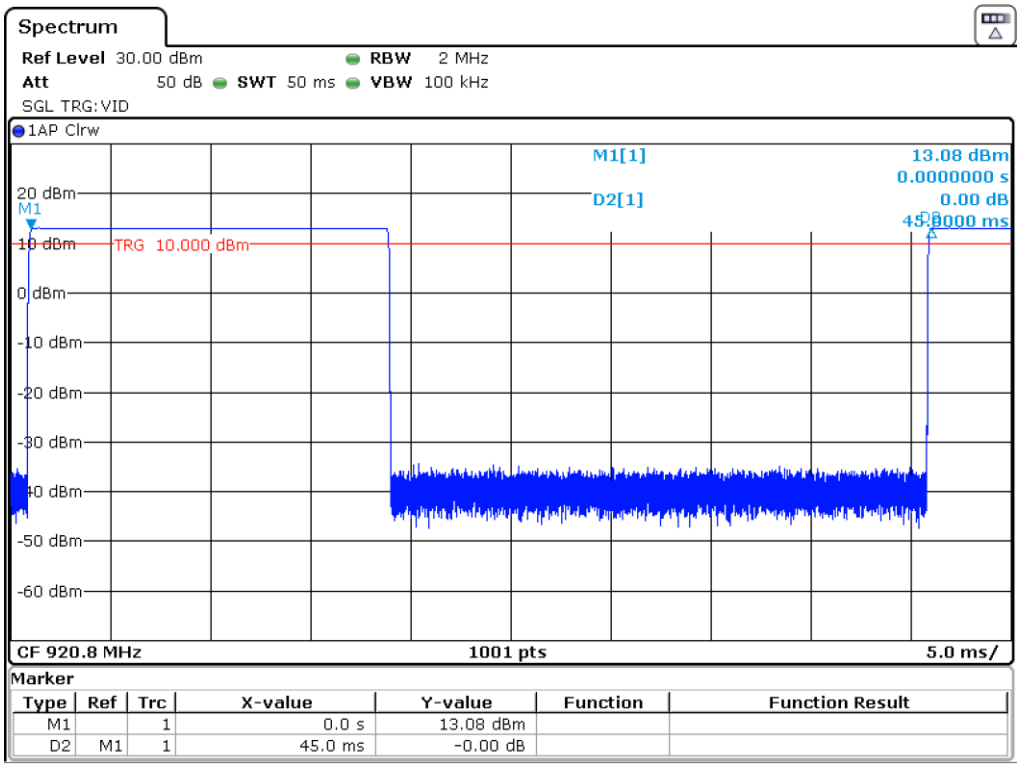
TX Frequency 920.8MHz, On Time



Marker

Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	0.0 s	10.46 dBm		
D2	M1	1	18.0 ms	-9.44 dB		

TX Frequency 920.8MHz, Period

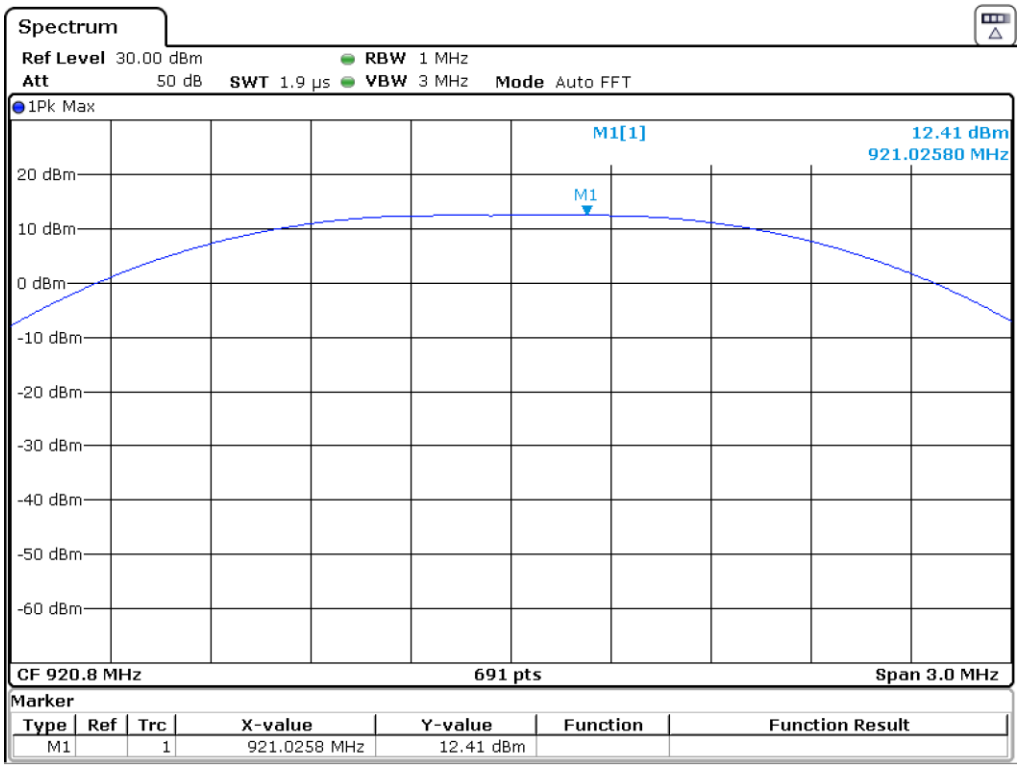


Marker

Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	0.0 s	13.08 dBm		
D2	M1	1	45.0 ms	-0.00 dB		

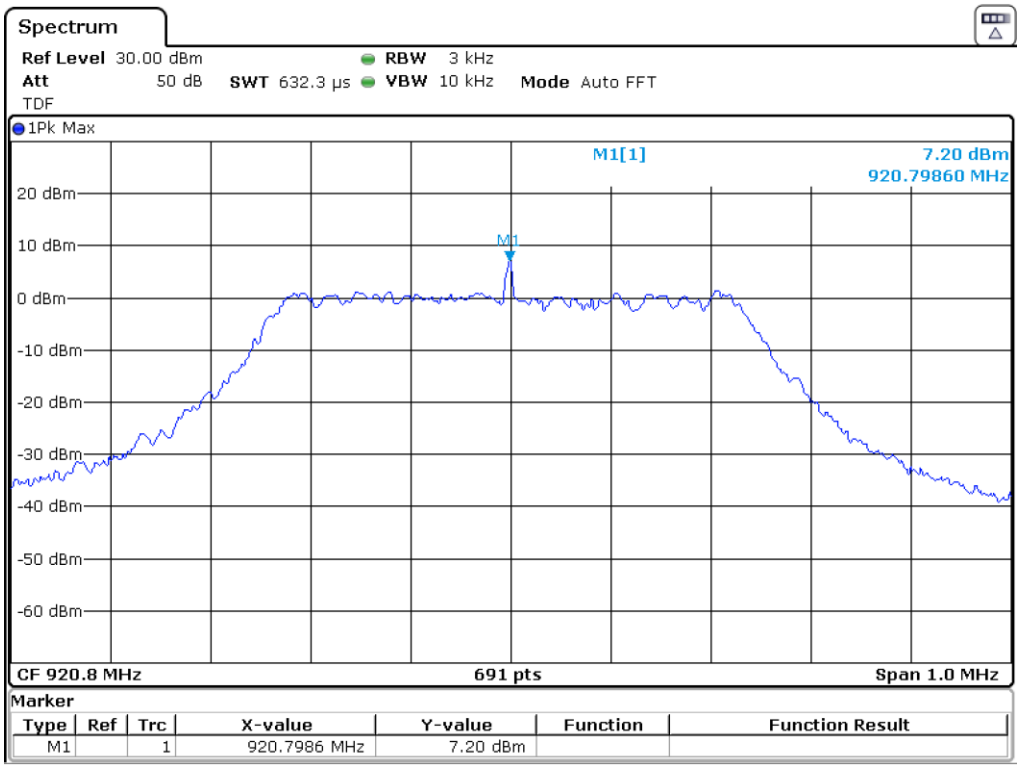
Conducted (Peak) Output power

TX Frequency 920.8MHz



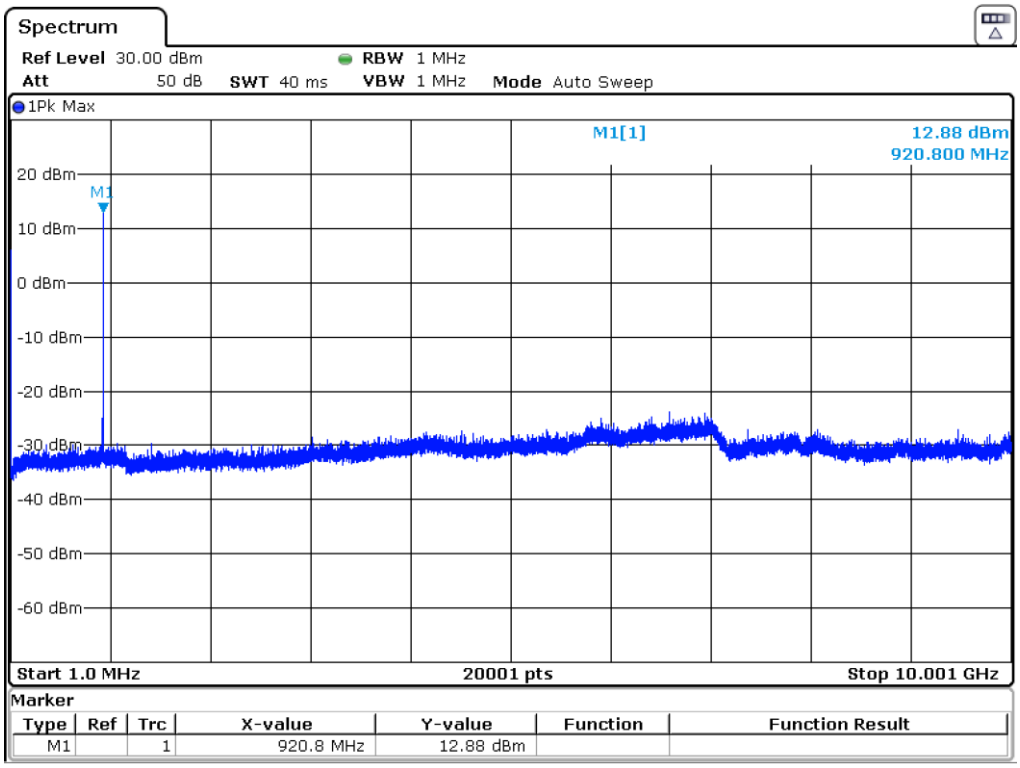
Power Spectral Density

TX Frequency 920.8MHz



Spurious Conducted Emissions

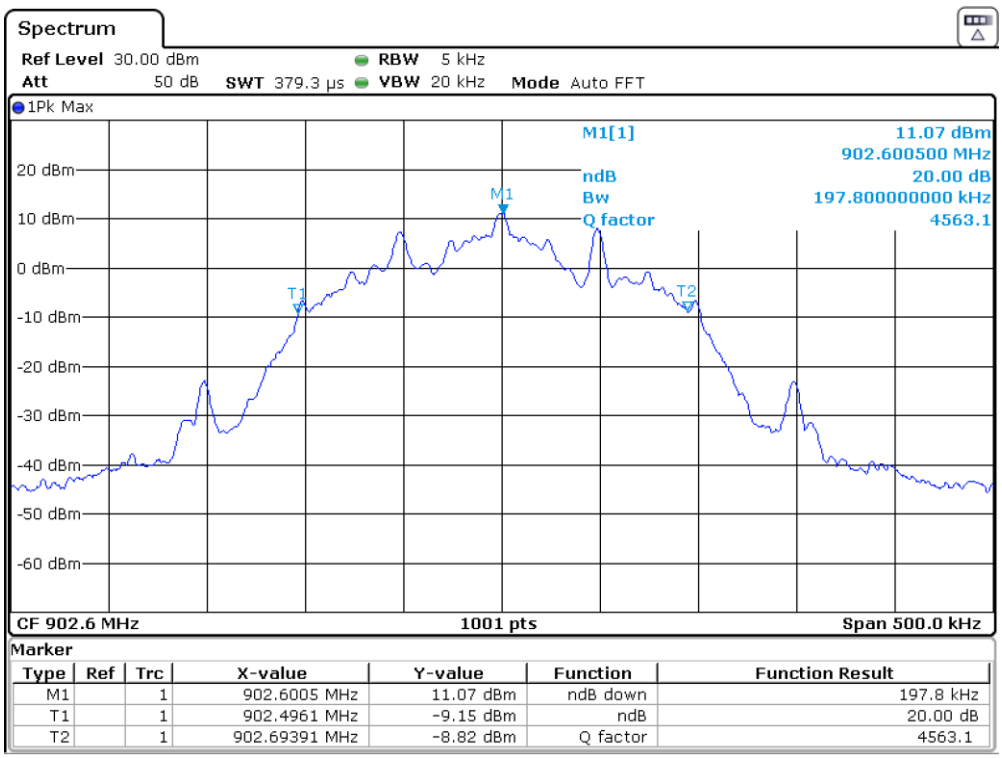
TX Frequency 920.8MHz _ 1M~10GHz



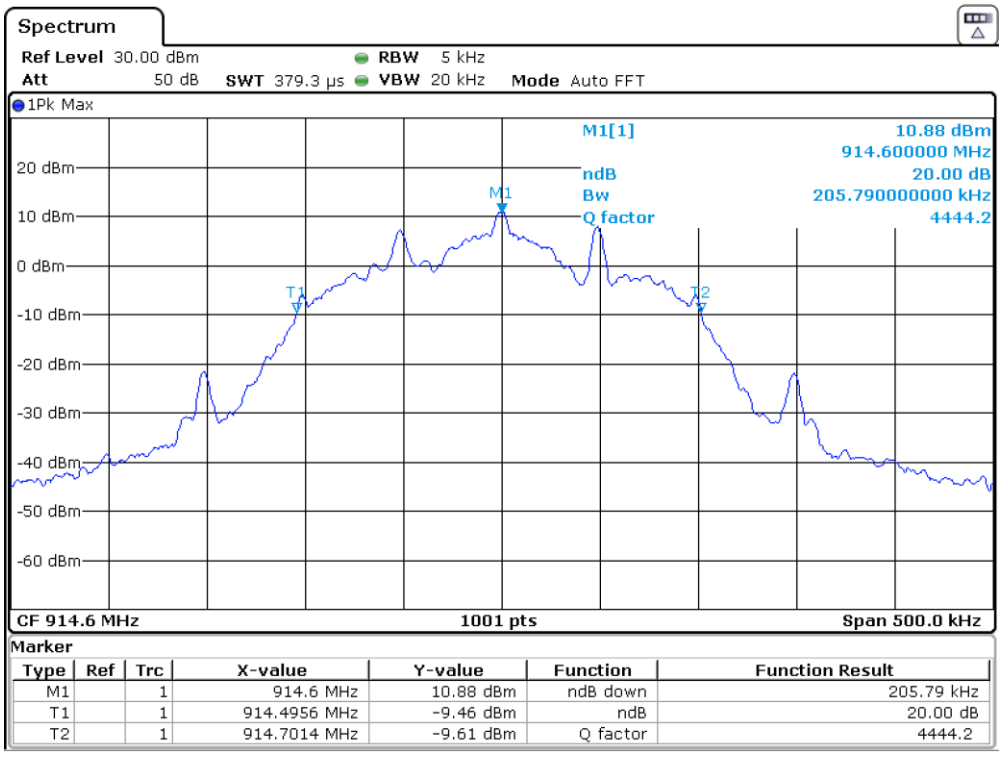
Frequency Hopping Spread Spectrum (FHSS)

20 dB Bandwidth Measurement

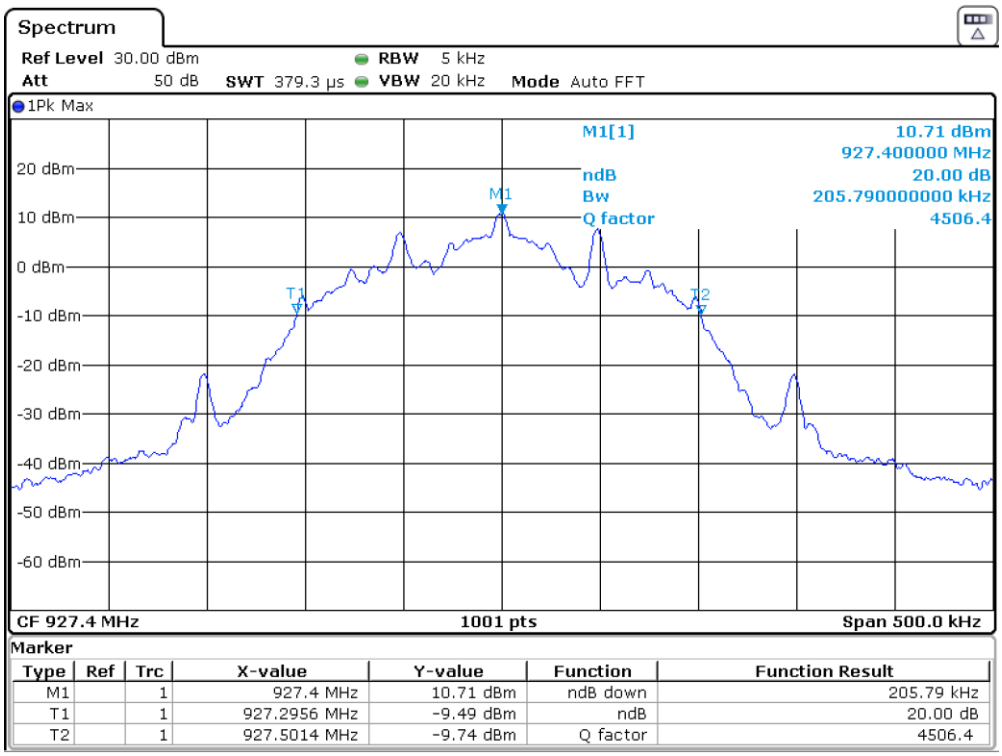
TX Frequency 902.6MHz



TX Frequency 914.6MHz



TX Frequency 927.4MHz

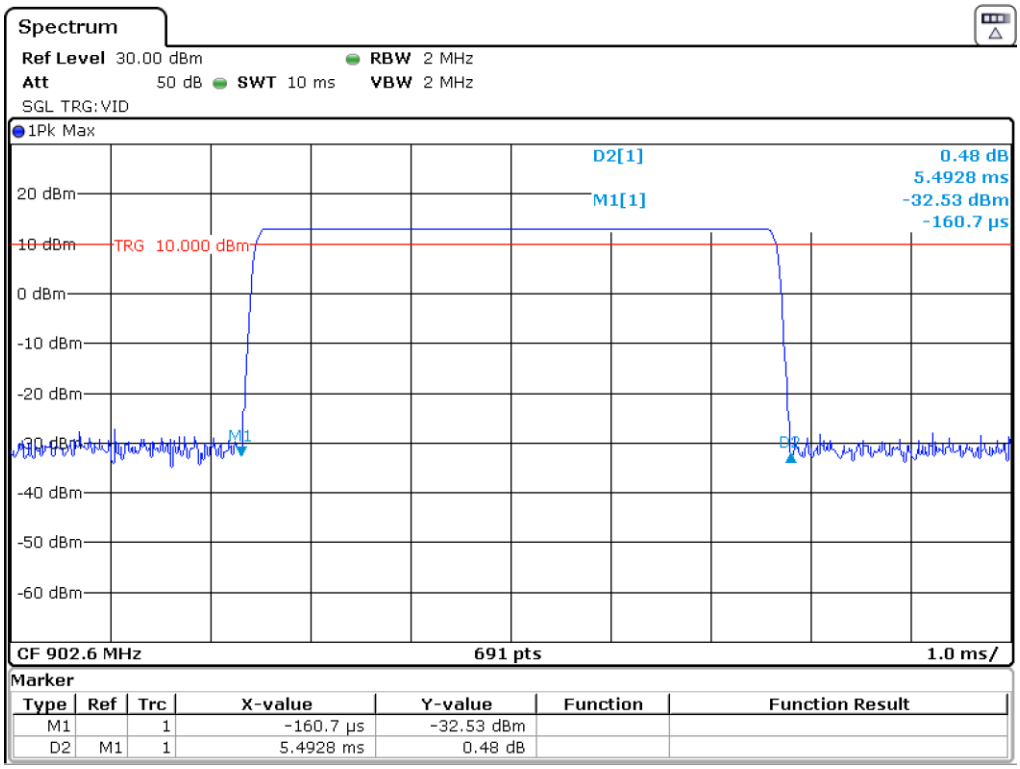


Marker

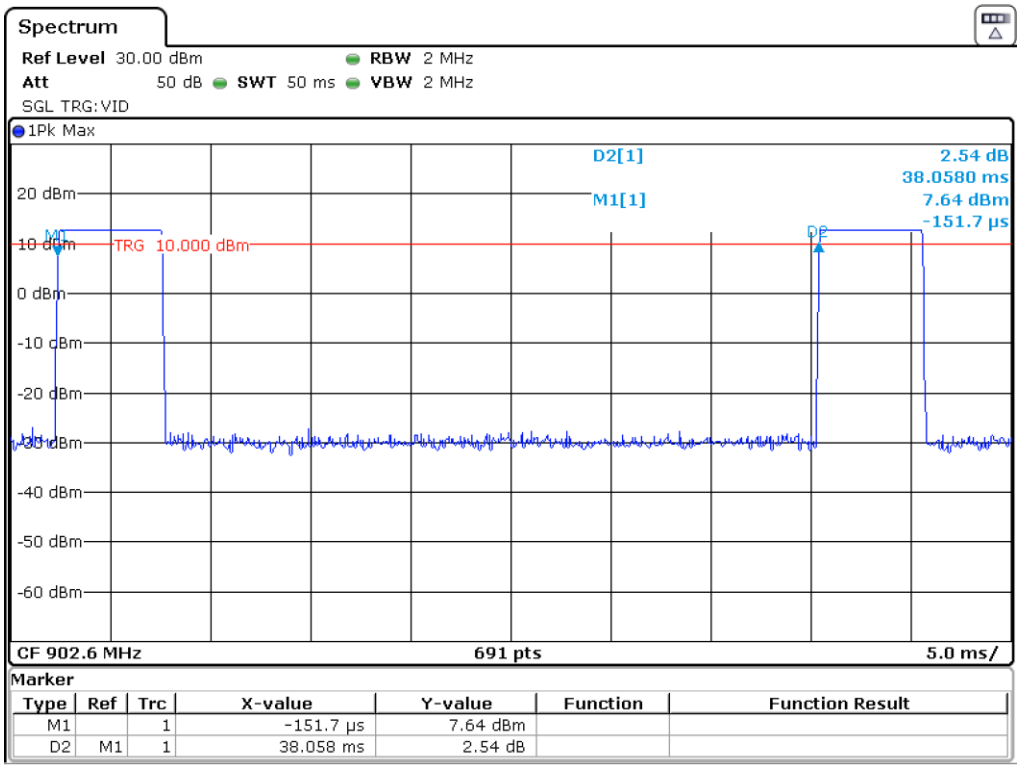
Type	Ref	Trc	X-value	Y-value	Function	Function Result
M1		1	927.4 MHz	10.71 dBm	ndB down	205.79 kHz
T1		1	927.2956 MHz	-9.49 dBm	ndB	20.00 dB
T2		1	927.5014 MHz	-9.74 dBm	Q factor	4506.4

Transmission Duty Cycle

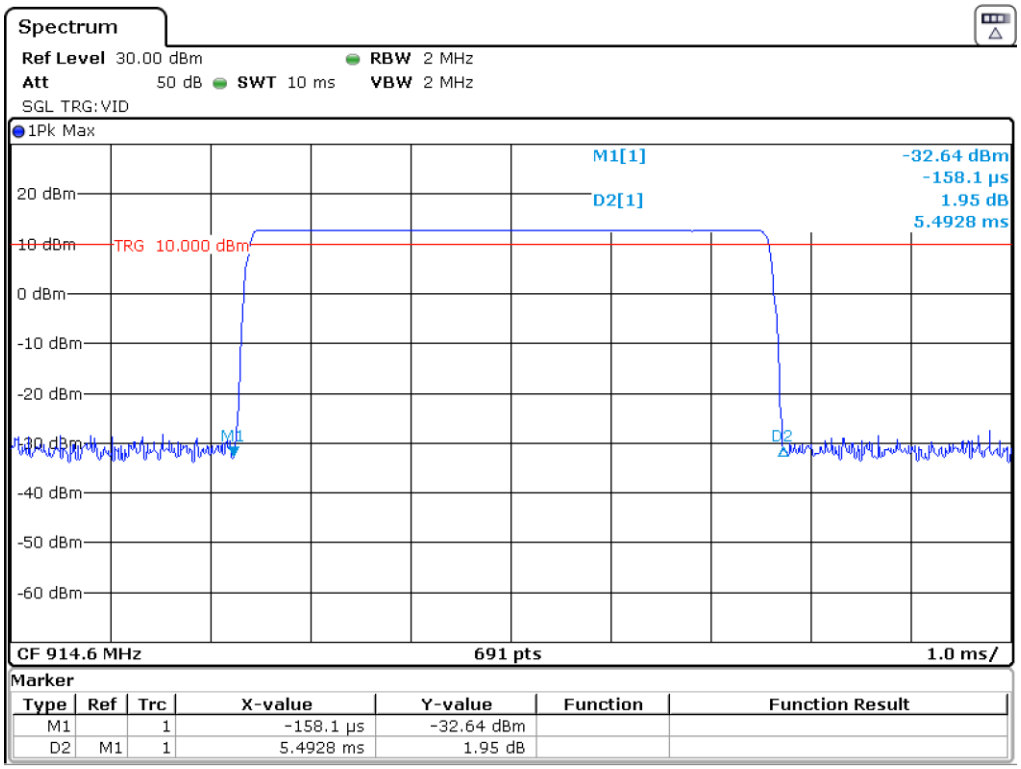
TX Frequency 902.6MHz, On Time



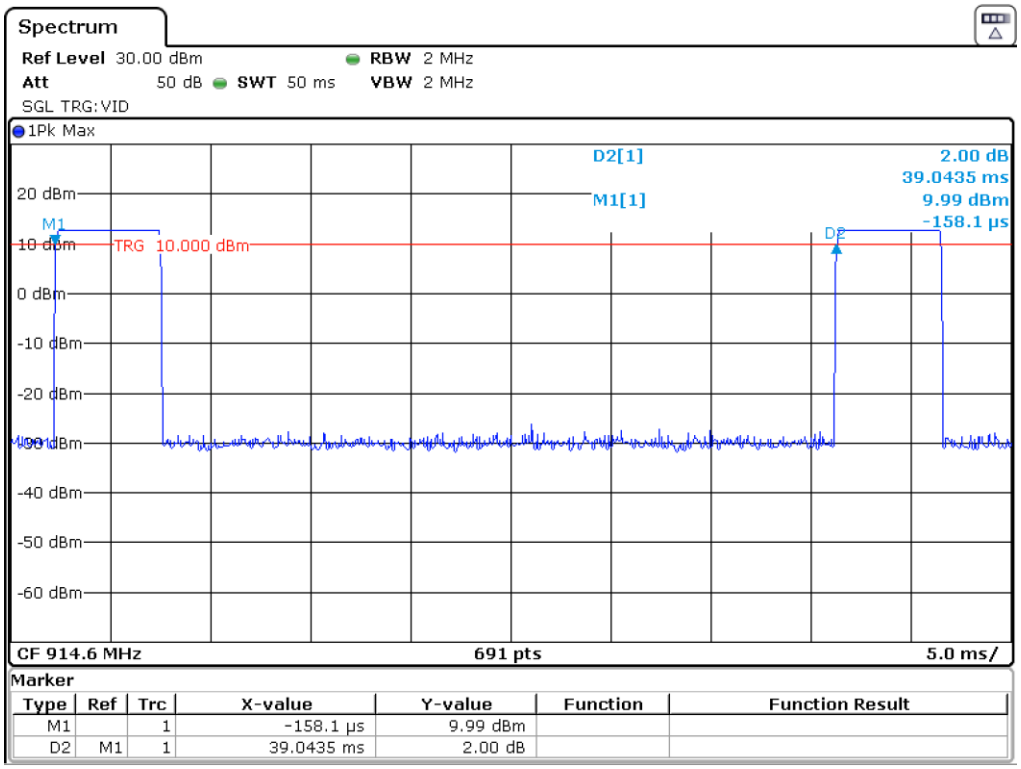
TX Frequency 902.6MHz, Period



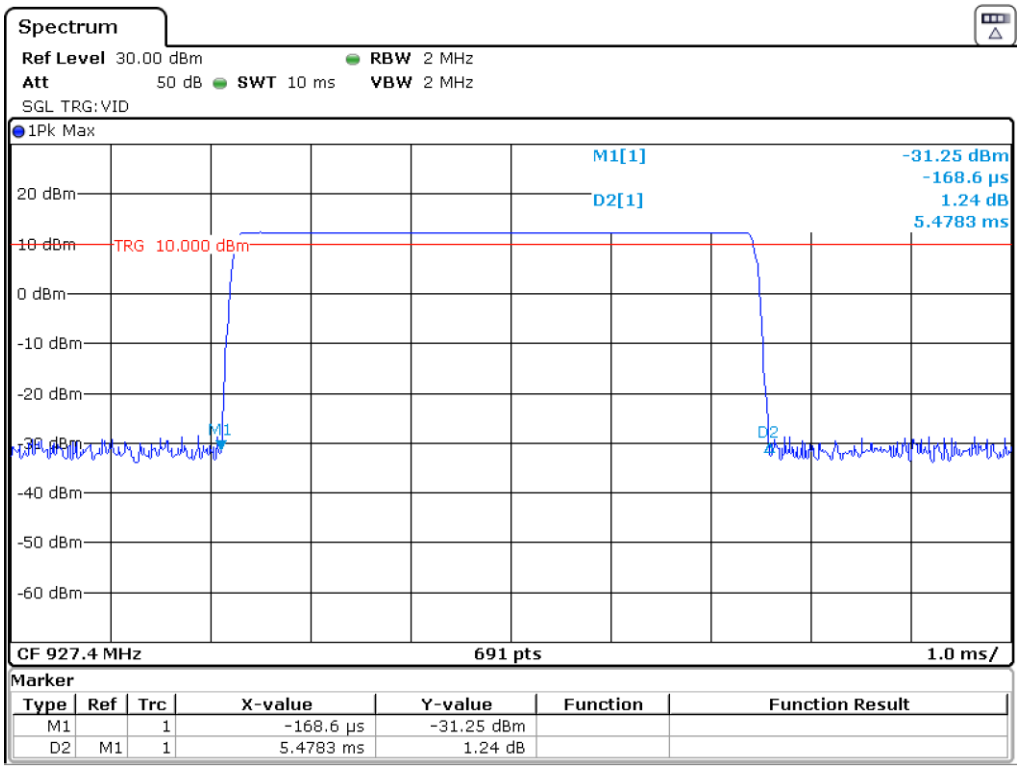
TX Frequency 914.6MHz, On Time



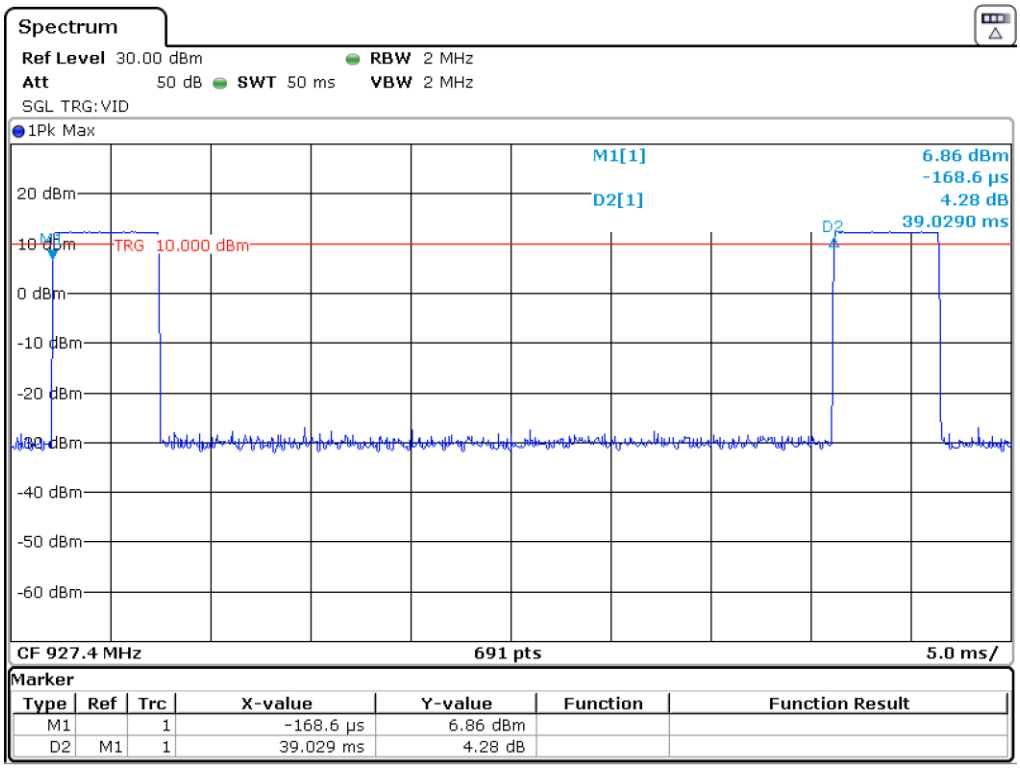
TX Frequency 914.6MHz, Period



TX Frequency 927.4MHz, On Time

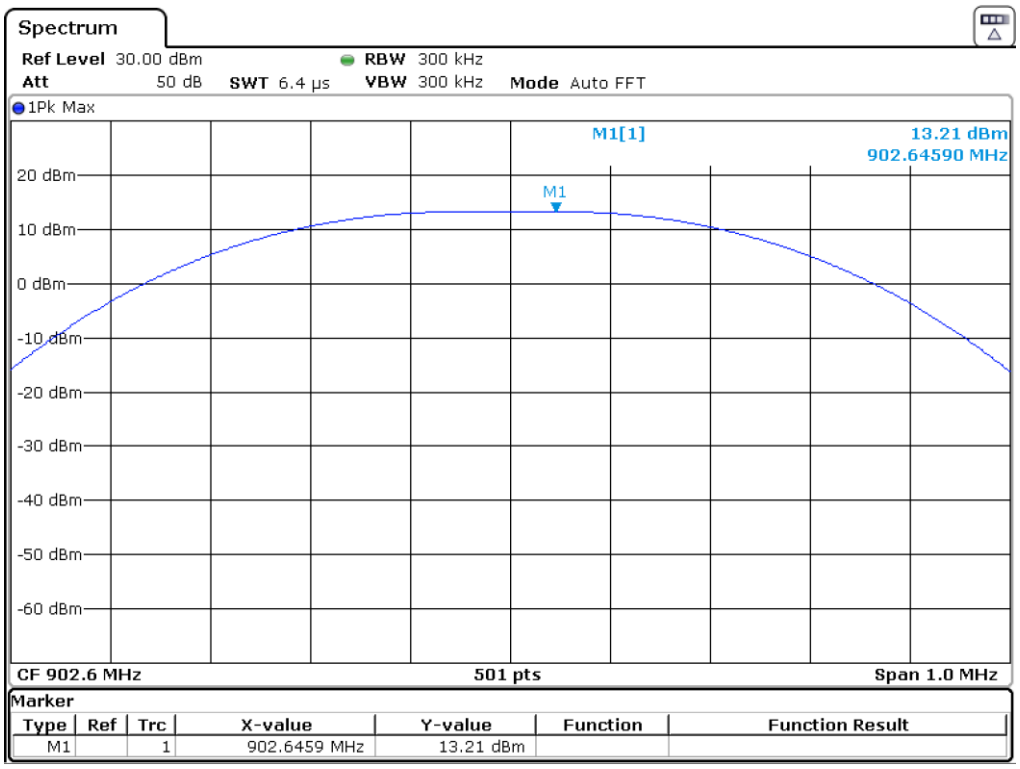


TX Frequency 927.4MHz, Period

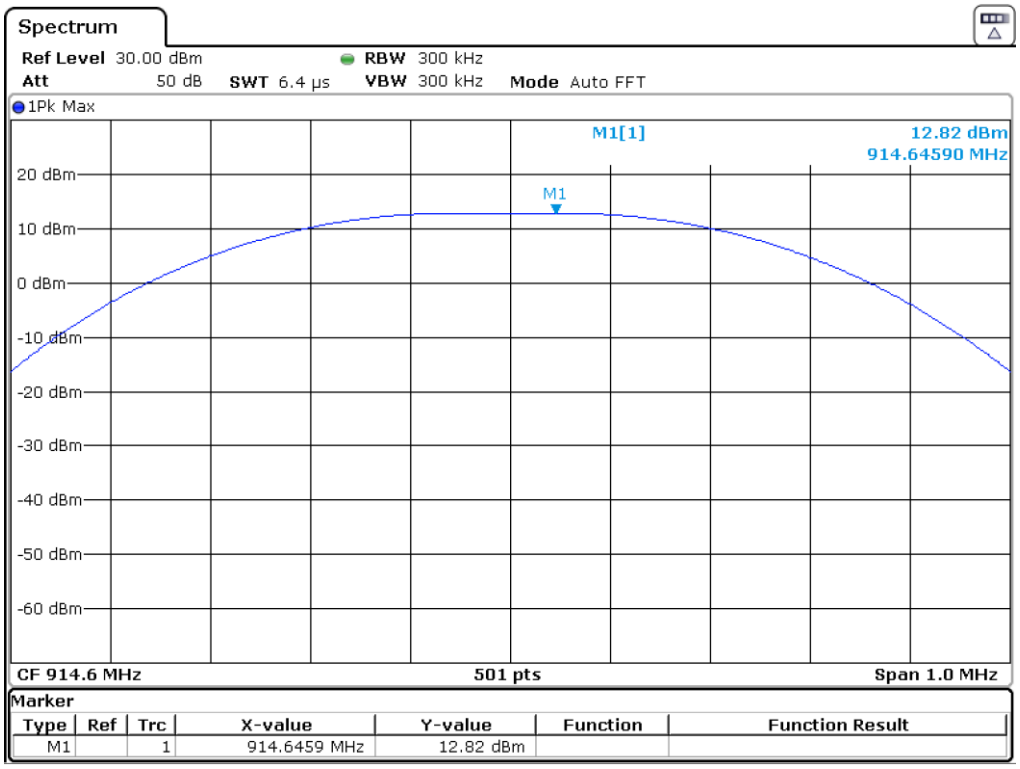


Conducted (Peak) Output power

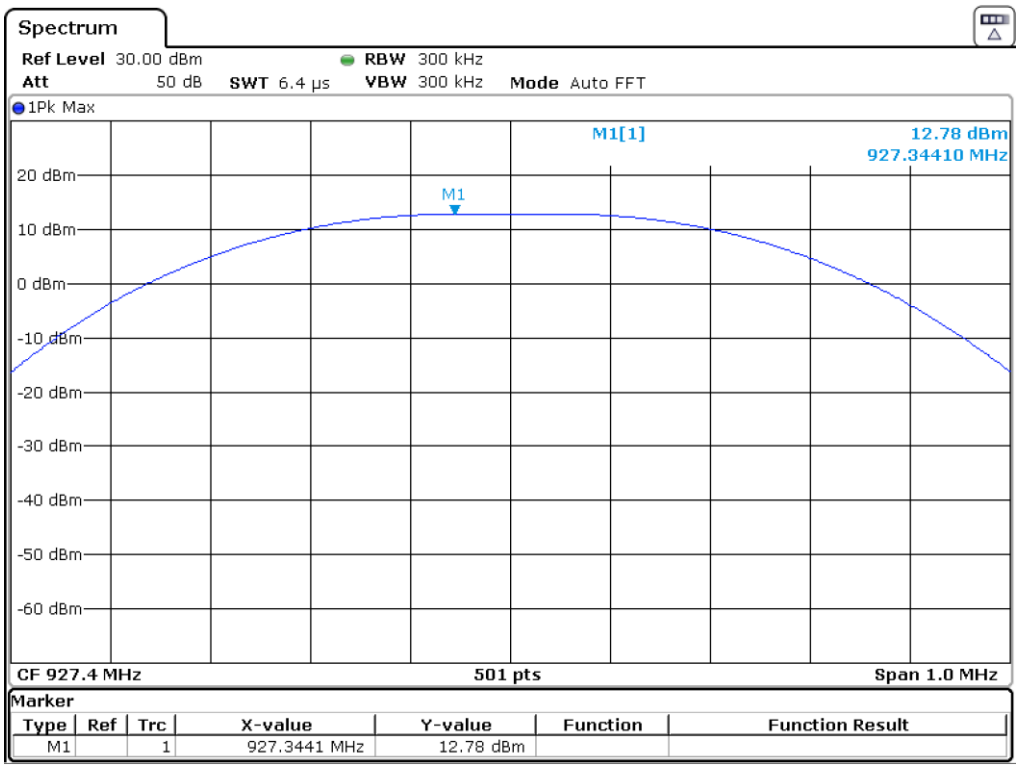
TX Frequency 902.6MHz



TX Frequency : 914.6MHz

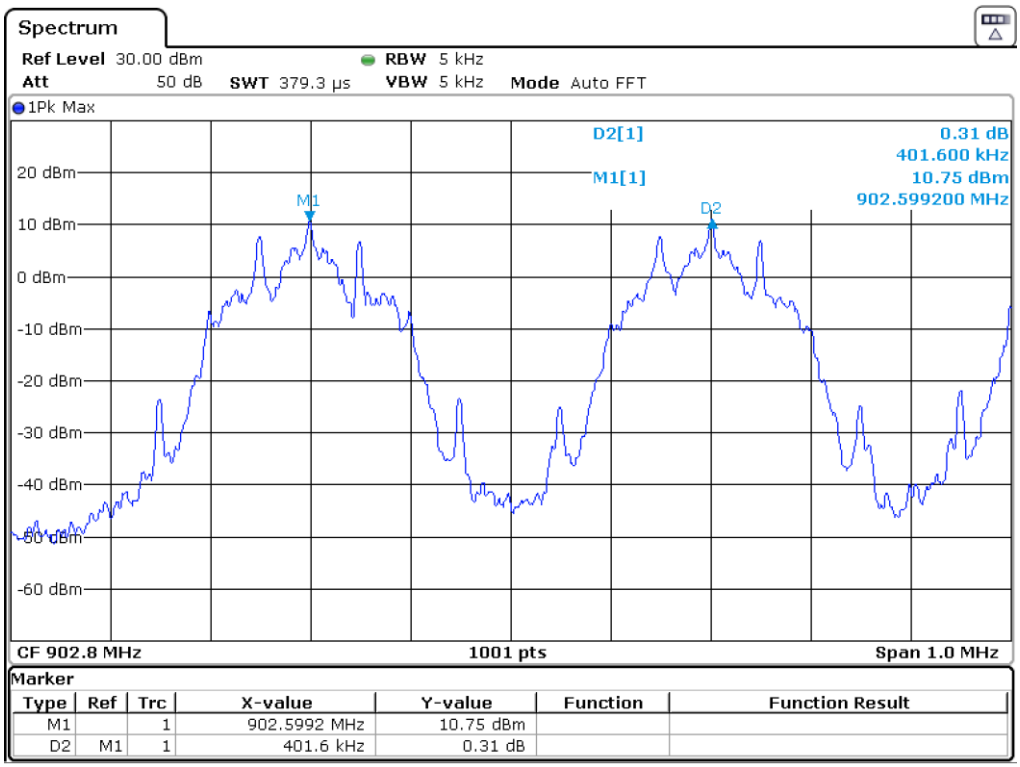


TX Frequency 927.4MHz

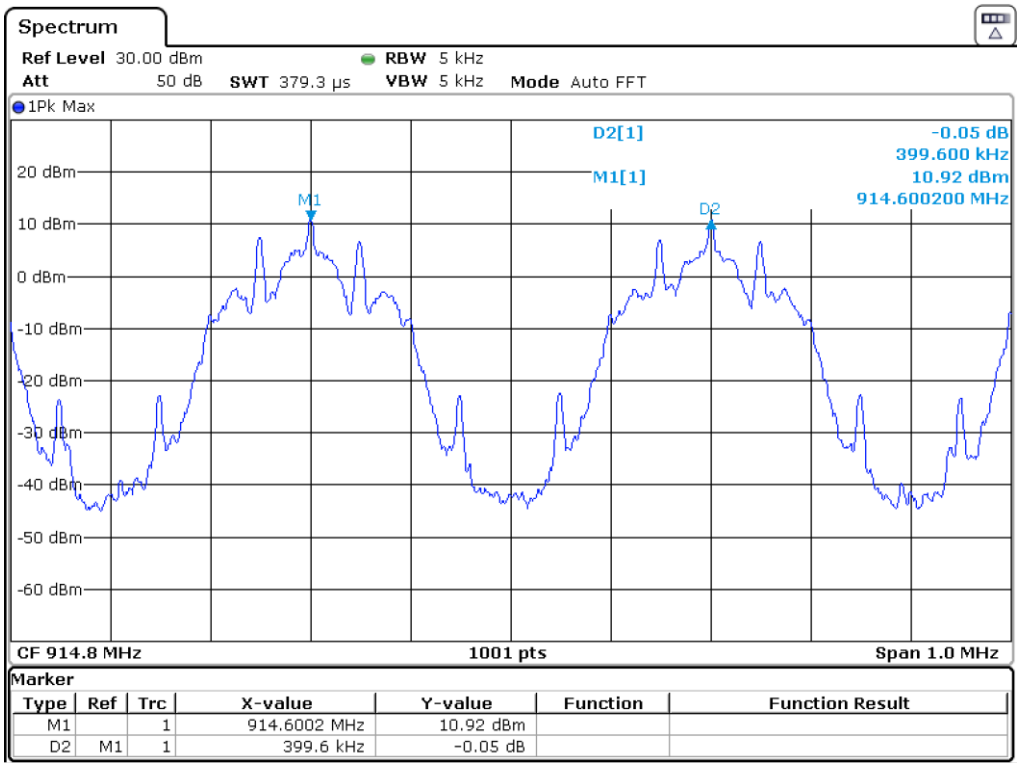


Carrier Frequency Separation

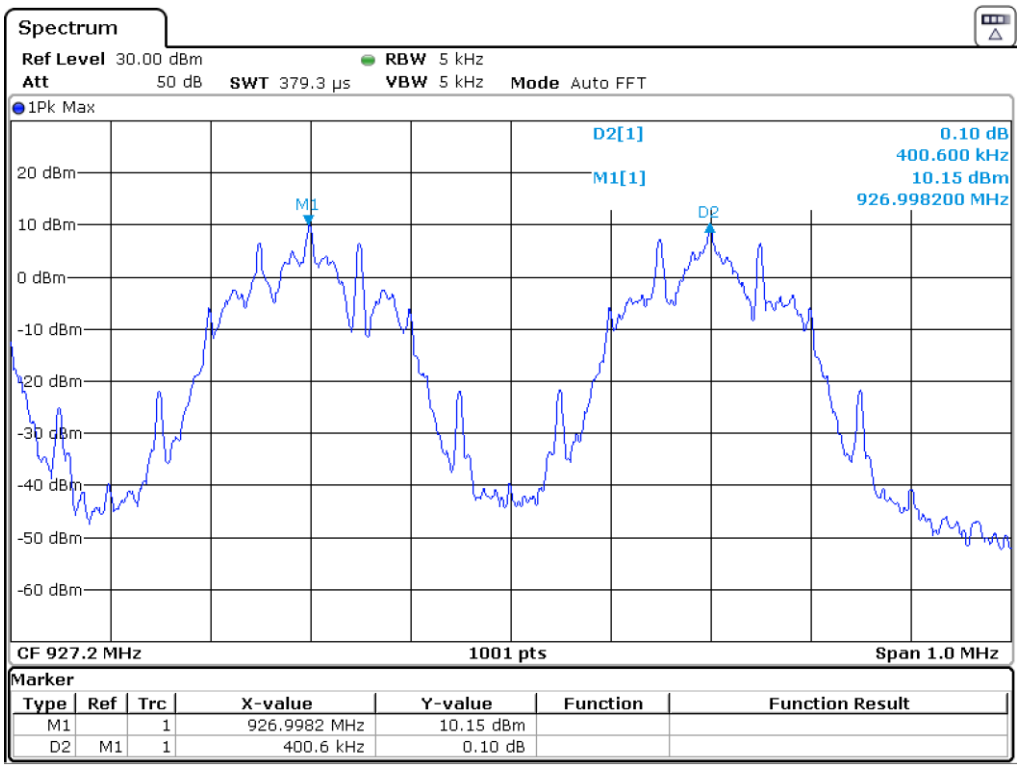
TX Frequency 902.6MHz



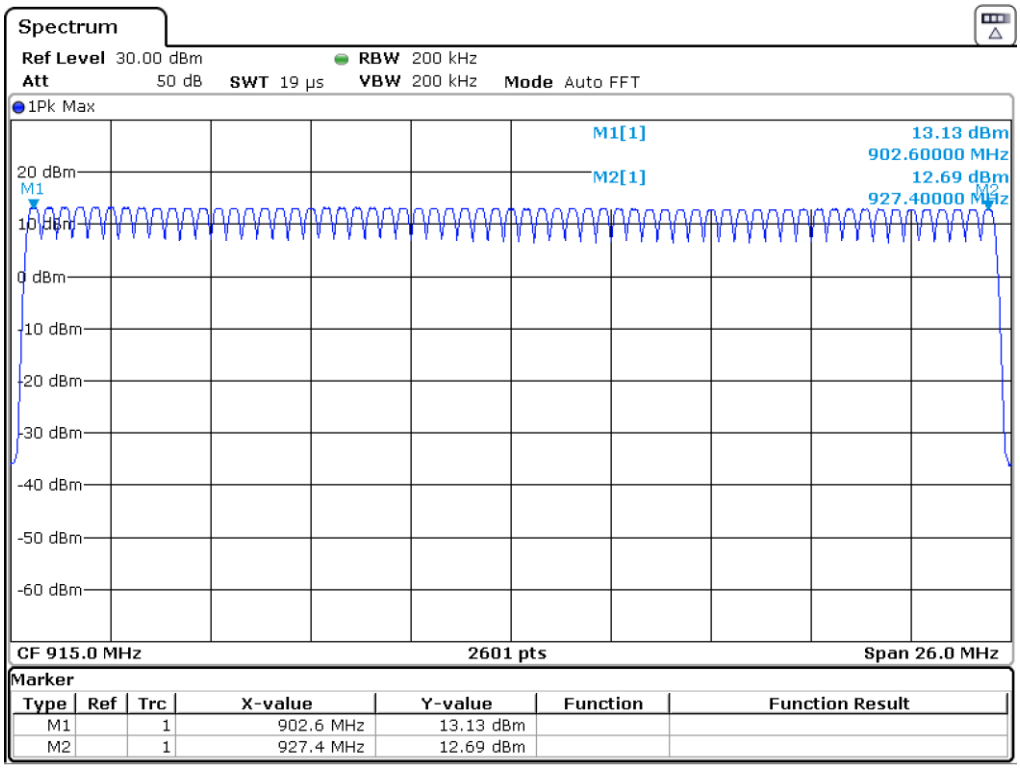
TX Frequency : 914.6MHz



TX Frequency 927.4MHz

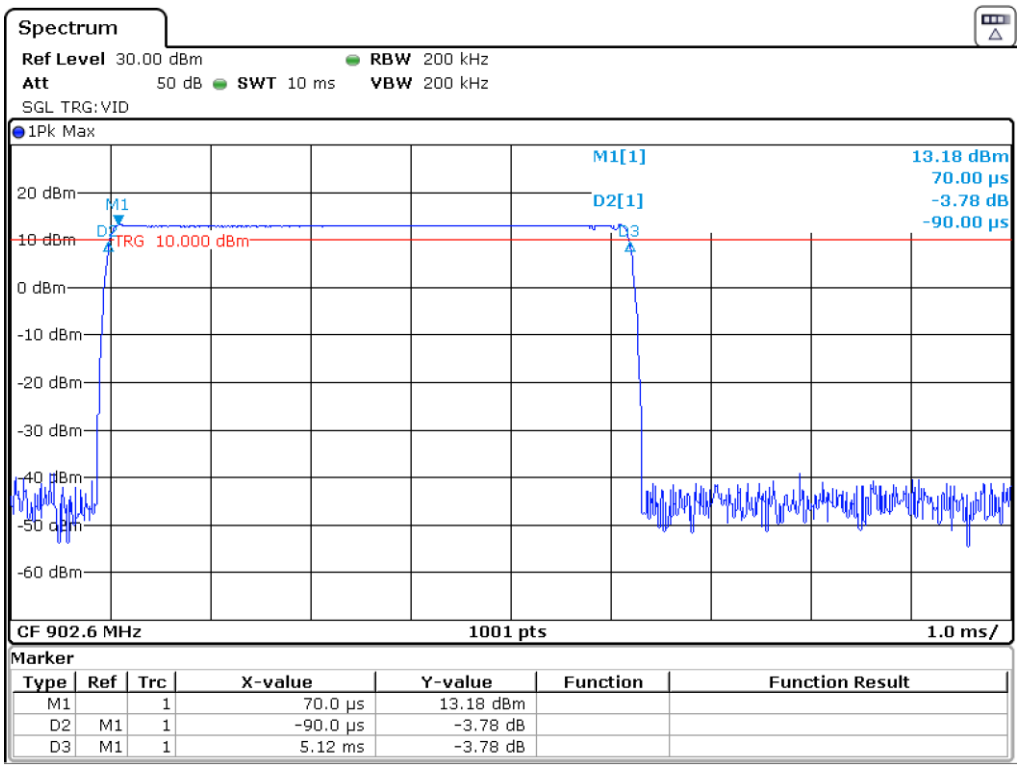


Number of hopping channels

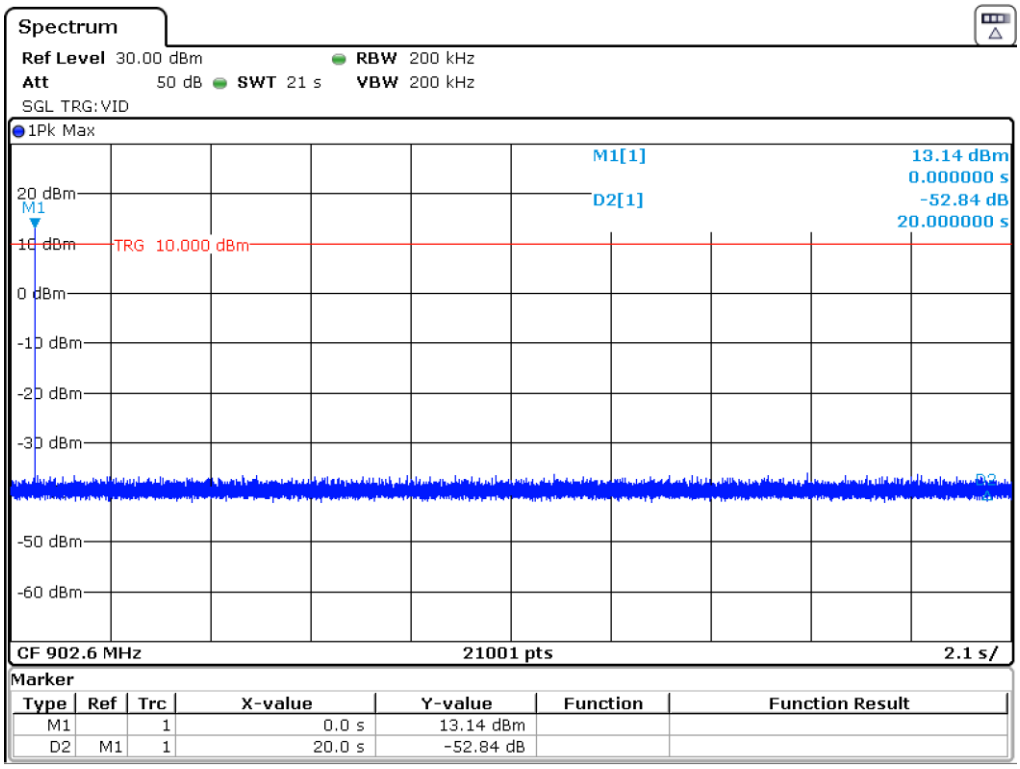


Time of Occupancy

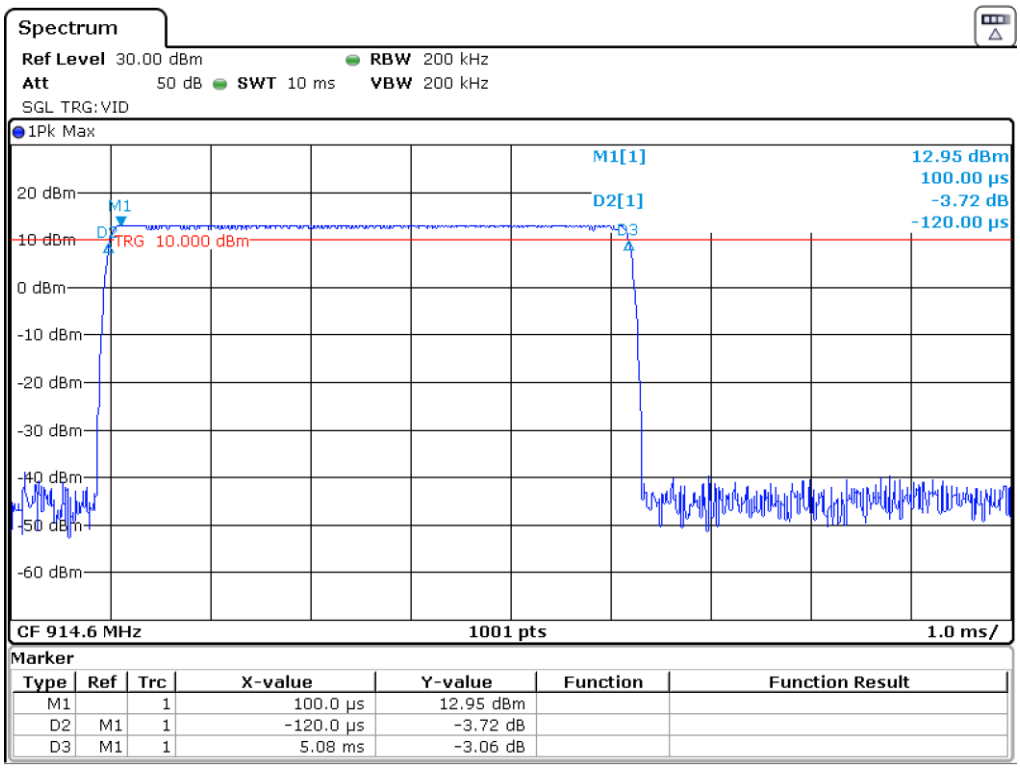
TX Frequency 902.6MHz, On time



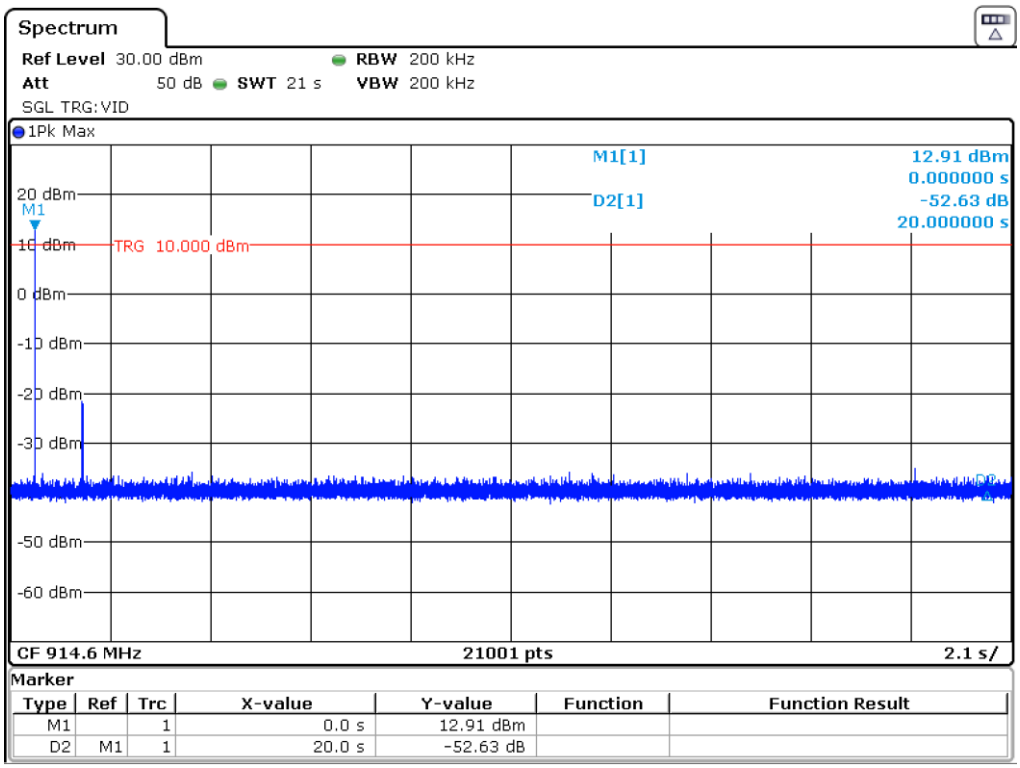
TX Frequency : 902.6MHz, Period of 20s



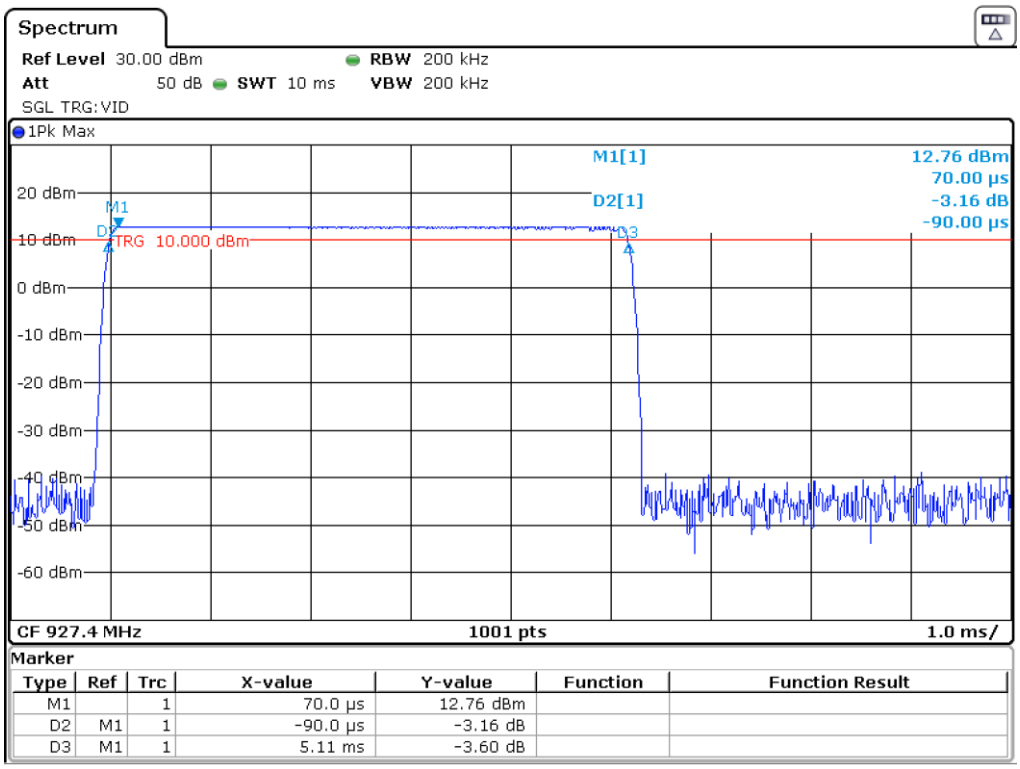
TX Frequency 914.6MHz, On time



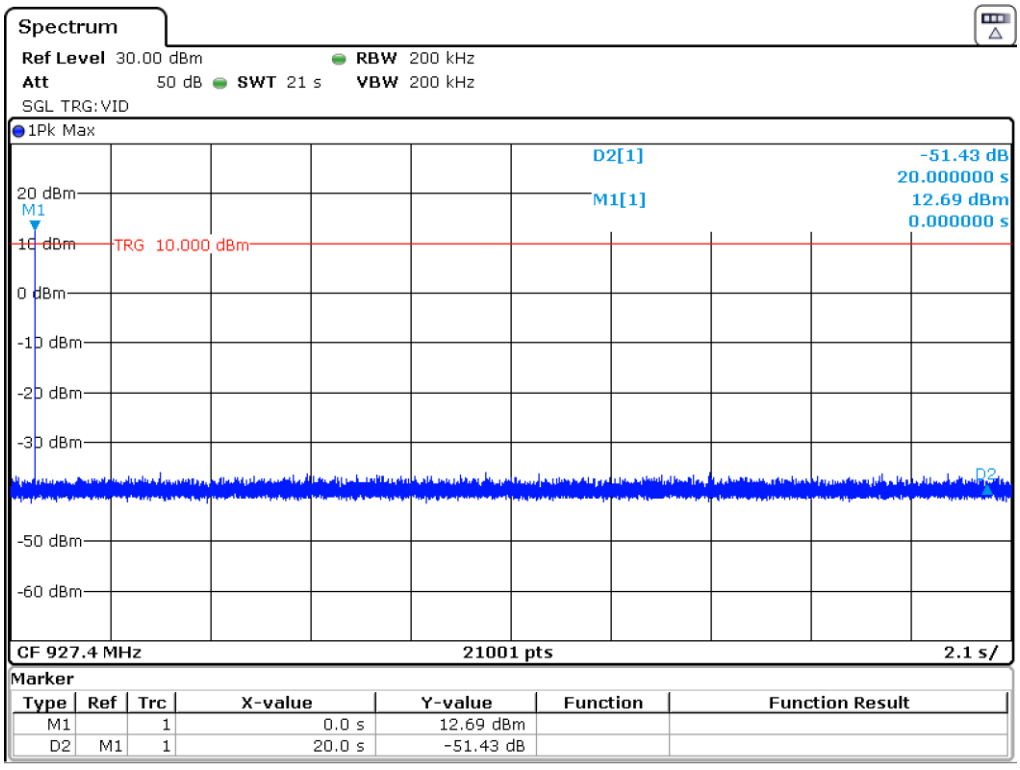
TX Frequency : 914.6MHz, Period of 20s



TX Frequency 927.4MHz, On time

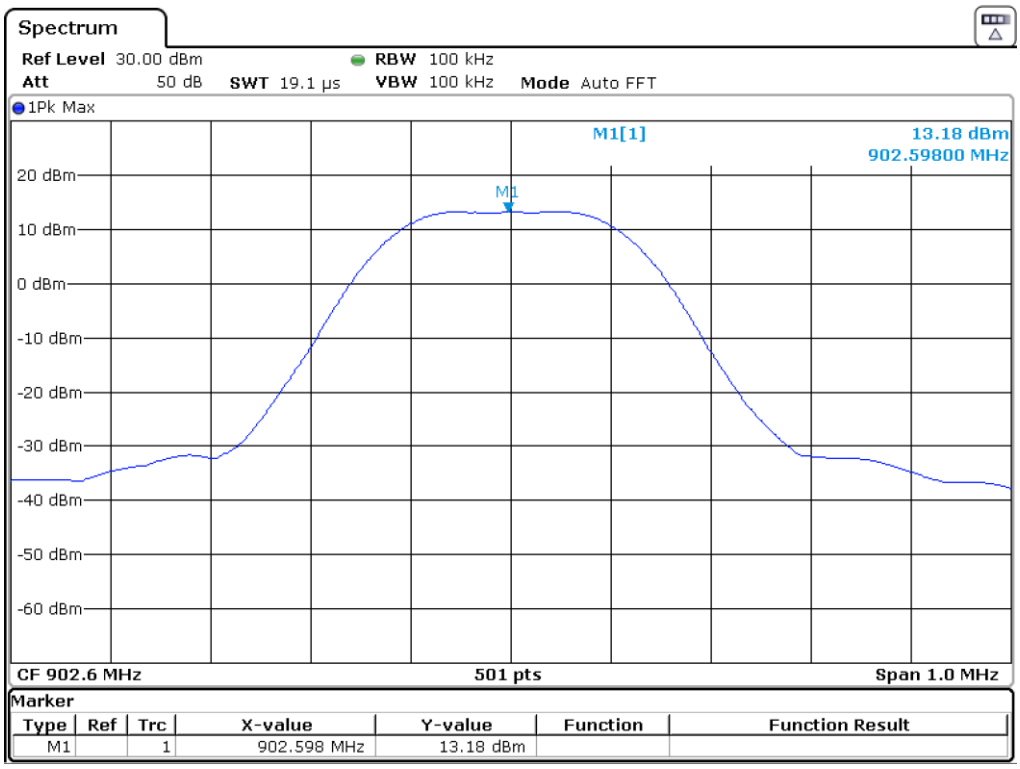


TX Frequency : 927.4MHz, Period of 20s

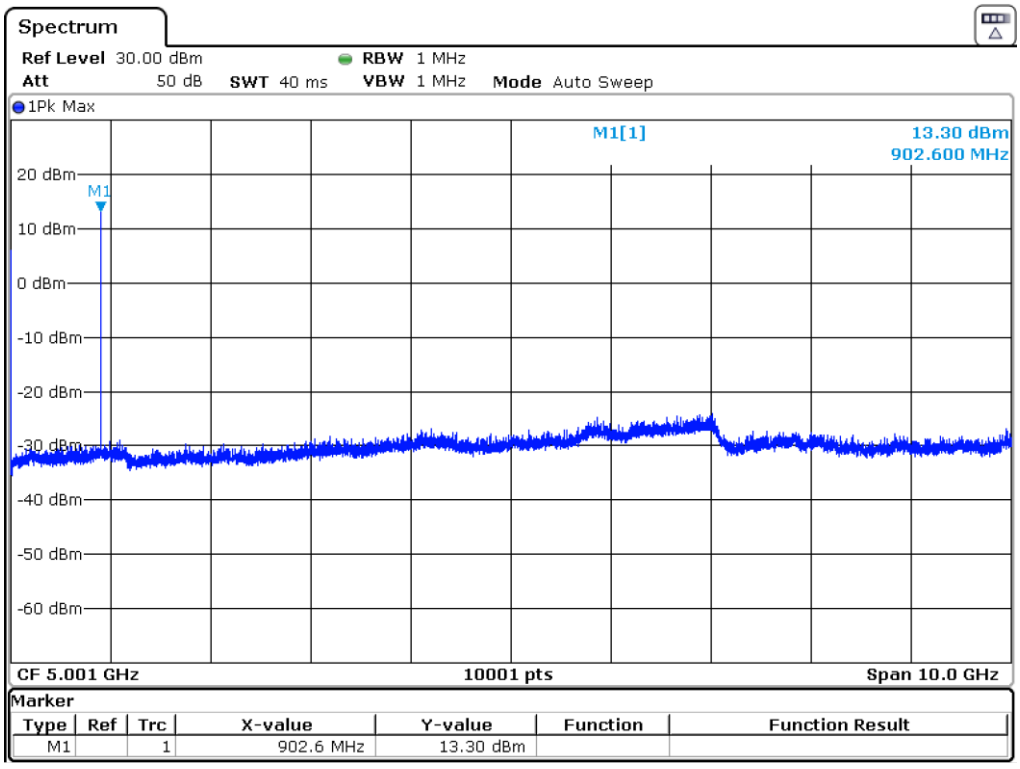


Spurious Conducted Emissions

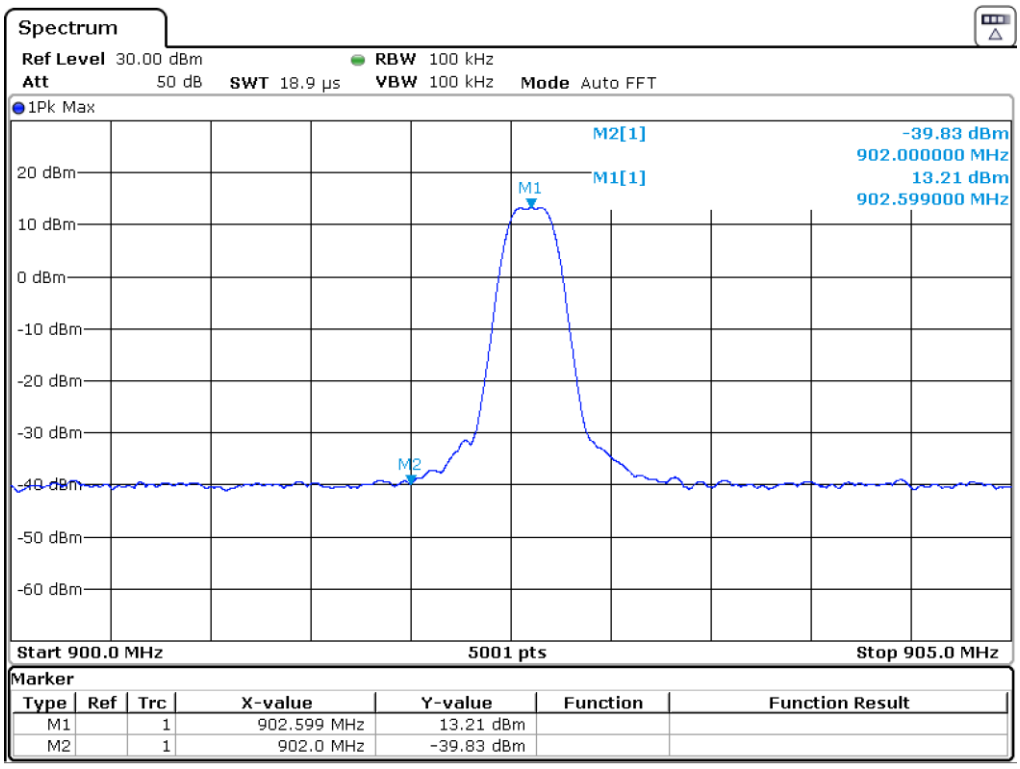
TX Frequency 902.6MHz _ Reference



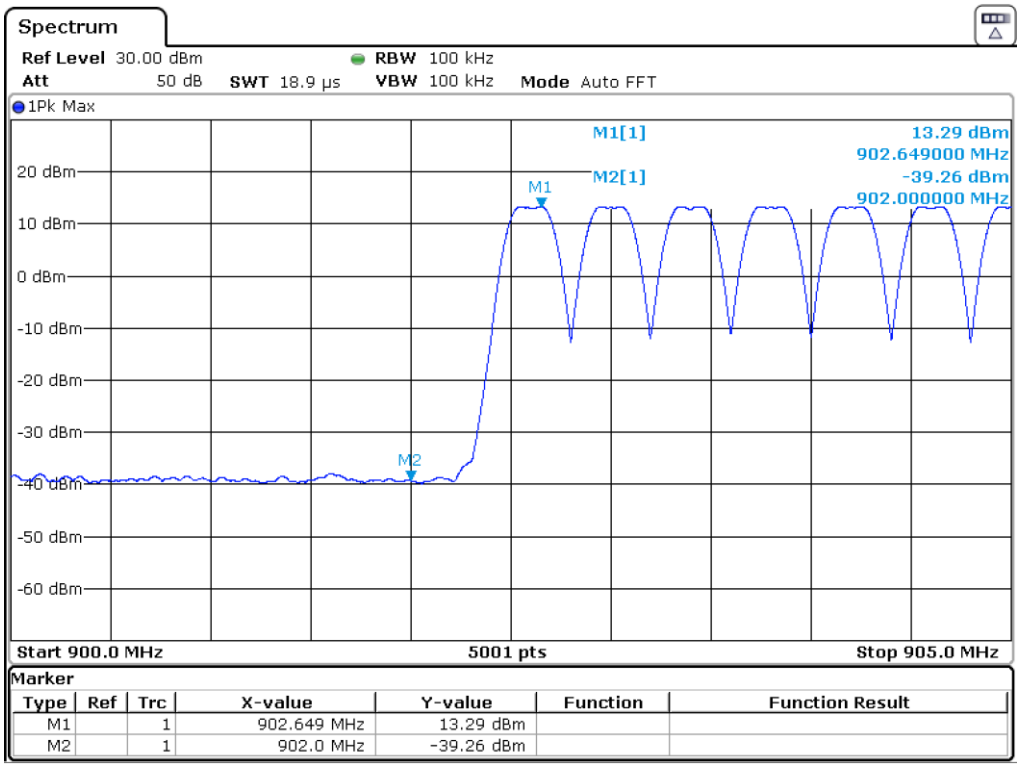
TX Frequency 902.6MHz _ 1M~10GHz Pre-Scan



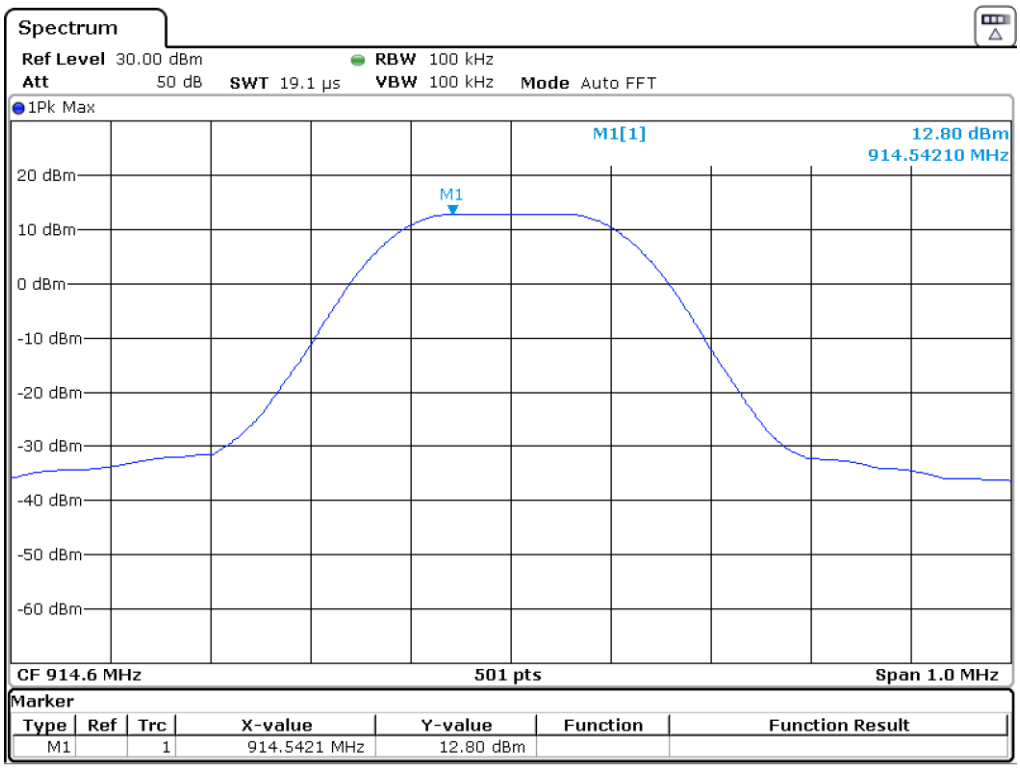
TX Frequency 902.6MHz _ Band Edge Hopping Off



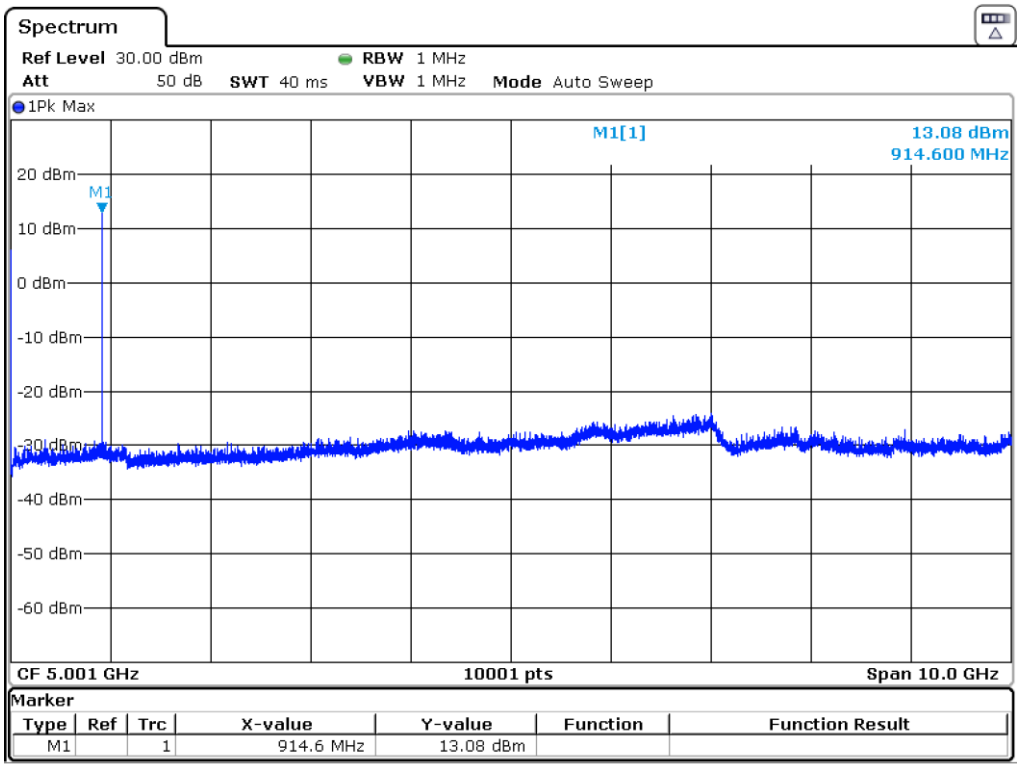
TX Frequency 902.6MHz _ Band Edge Hopping On



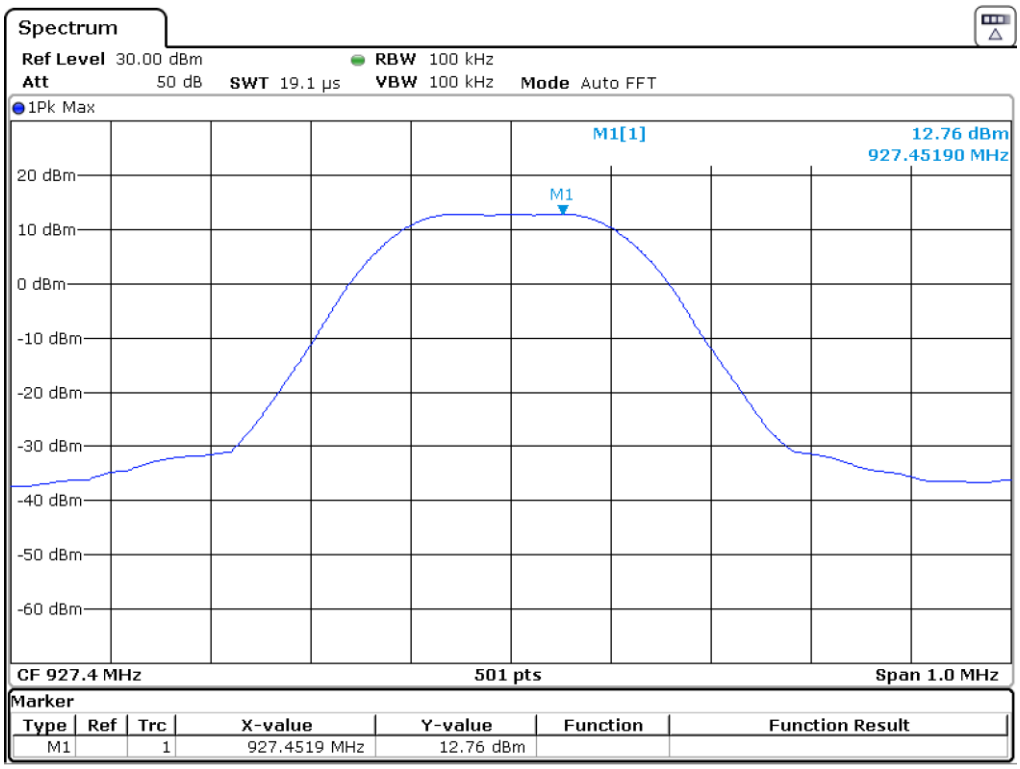
TX Frequency 914.6MHz _ Reference



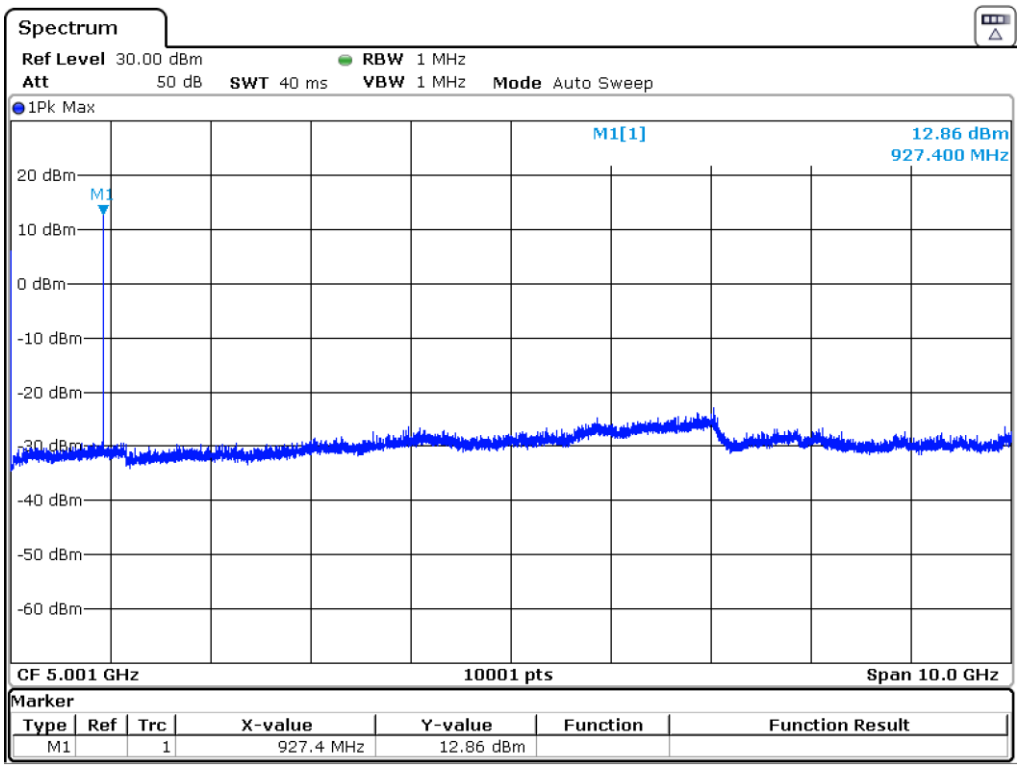
TX Frequency 914.6MHz _ 1M~10GHz Pre-Scan



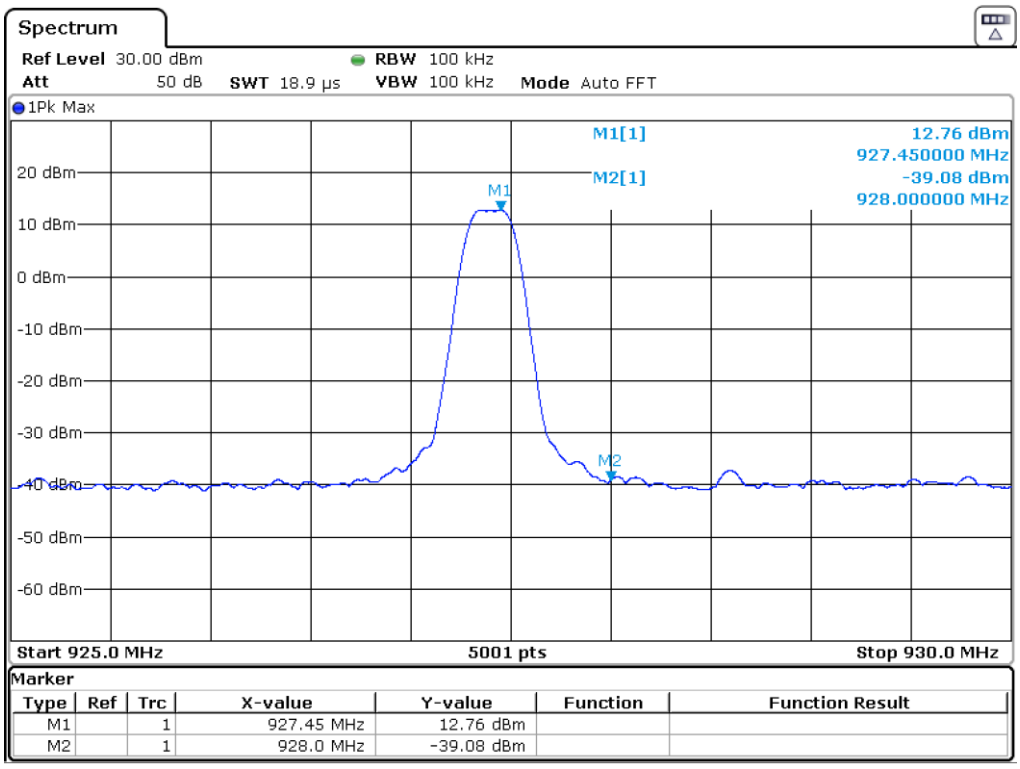
TX Frequency 927.4MHz _ Reference



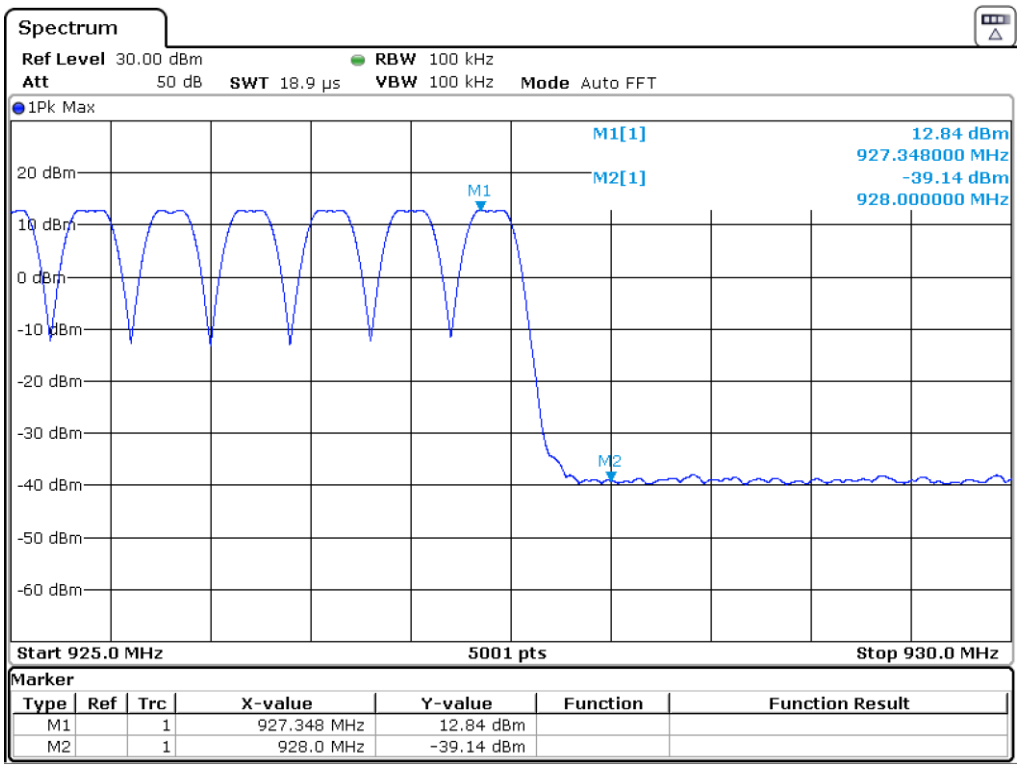
TX Frequency 927.4MHz _ 1M~10GHz Pre-Scan



TX Frequency 927.4MHz _ Band Edge Hopping Off

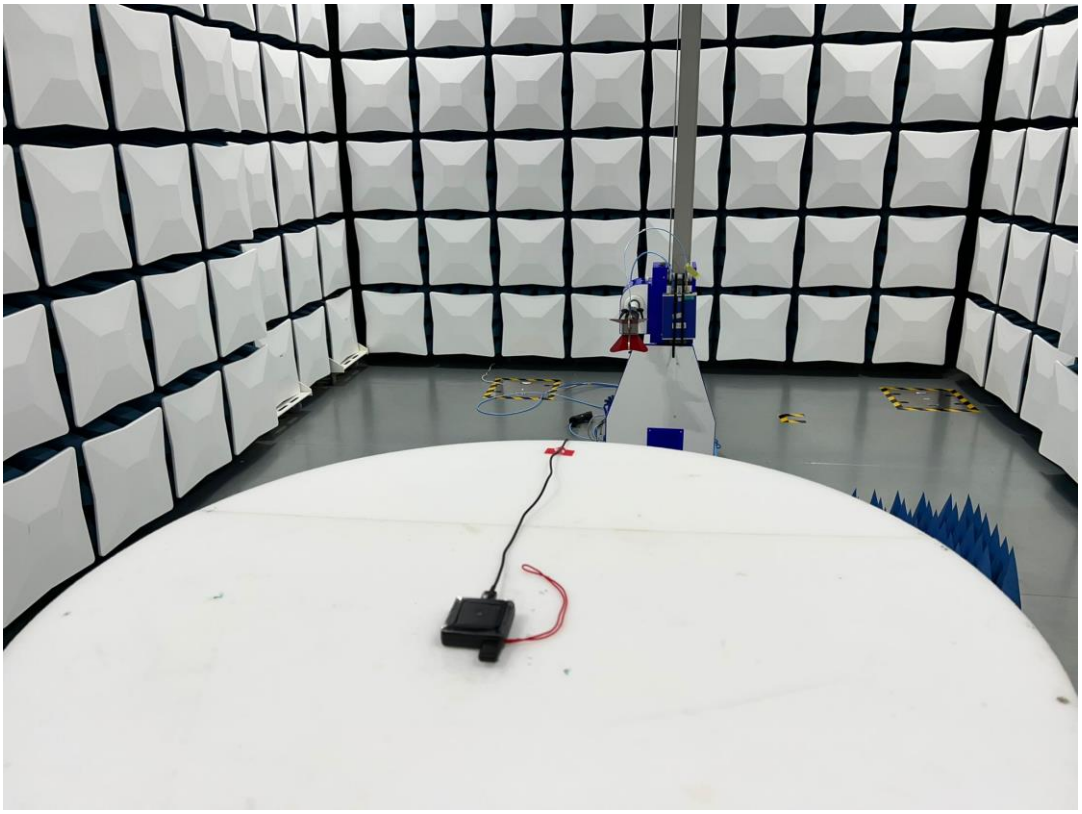


TX Frequency 927.4MHz _ Band Edge Hopping On

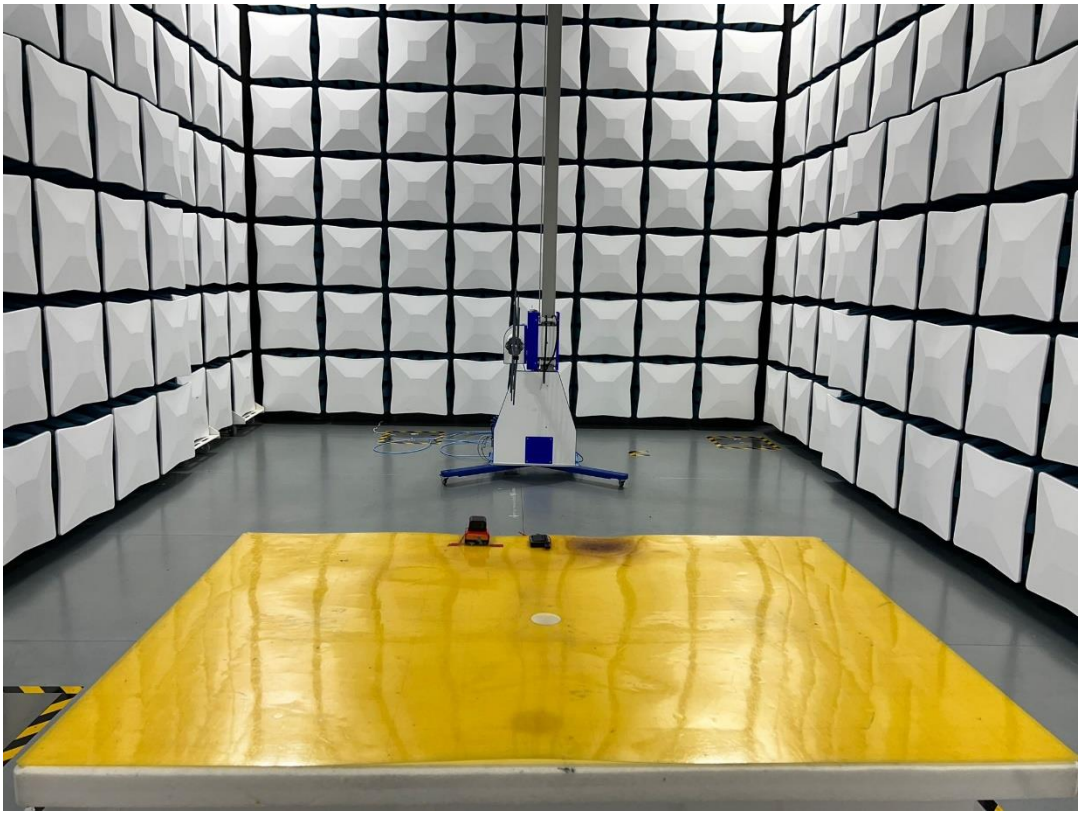


Appendix 2

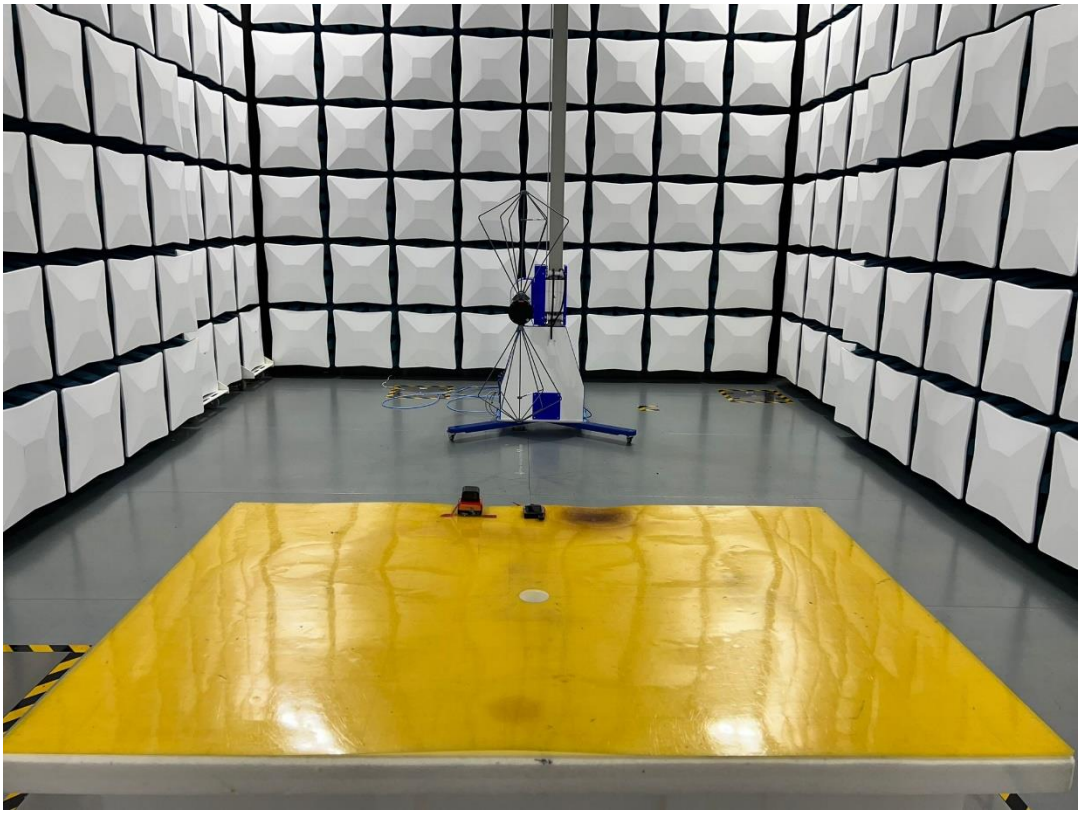
Test Setup Photos



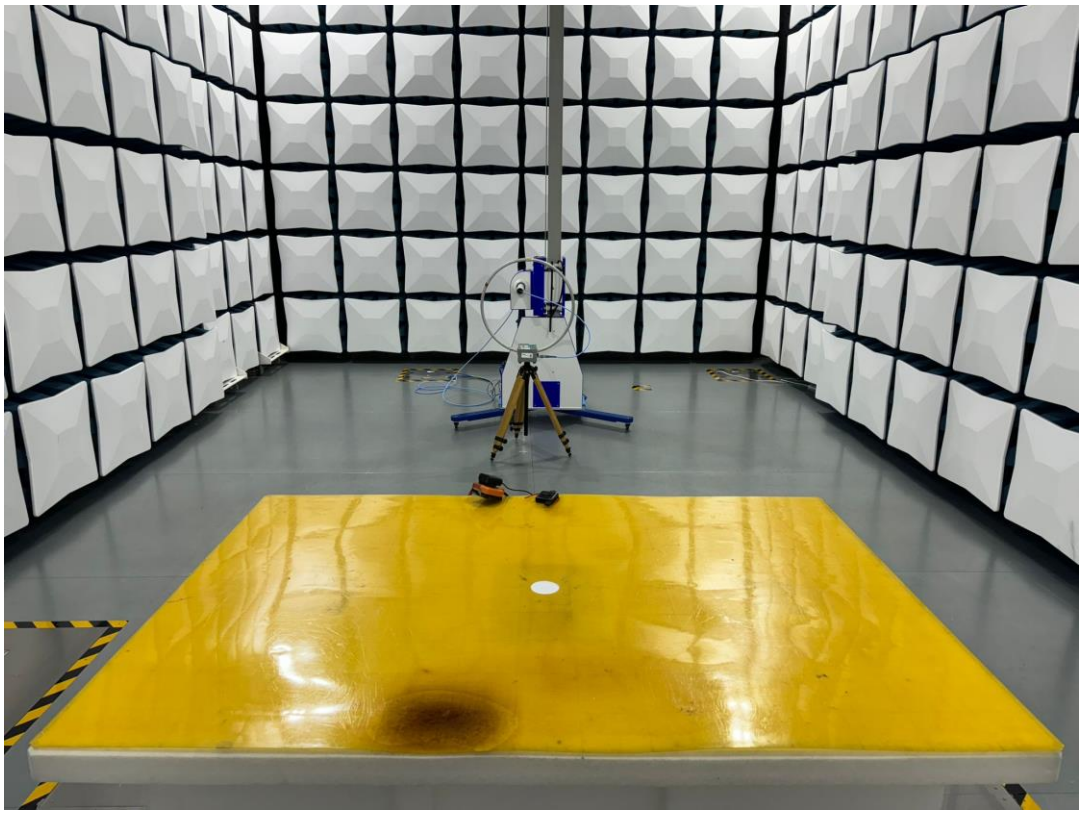
Set up for Radiated Emission Above 1G



Set up for Radiated Emission Below 200M~1G



Set up for Radiated Emission 30M~200MHz



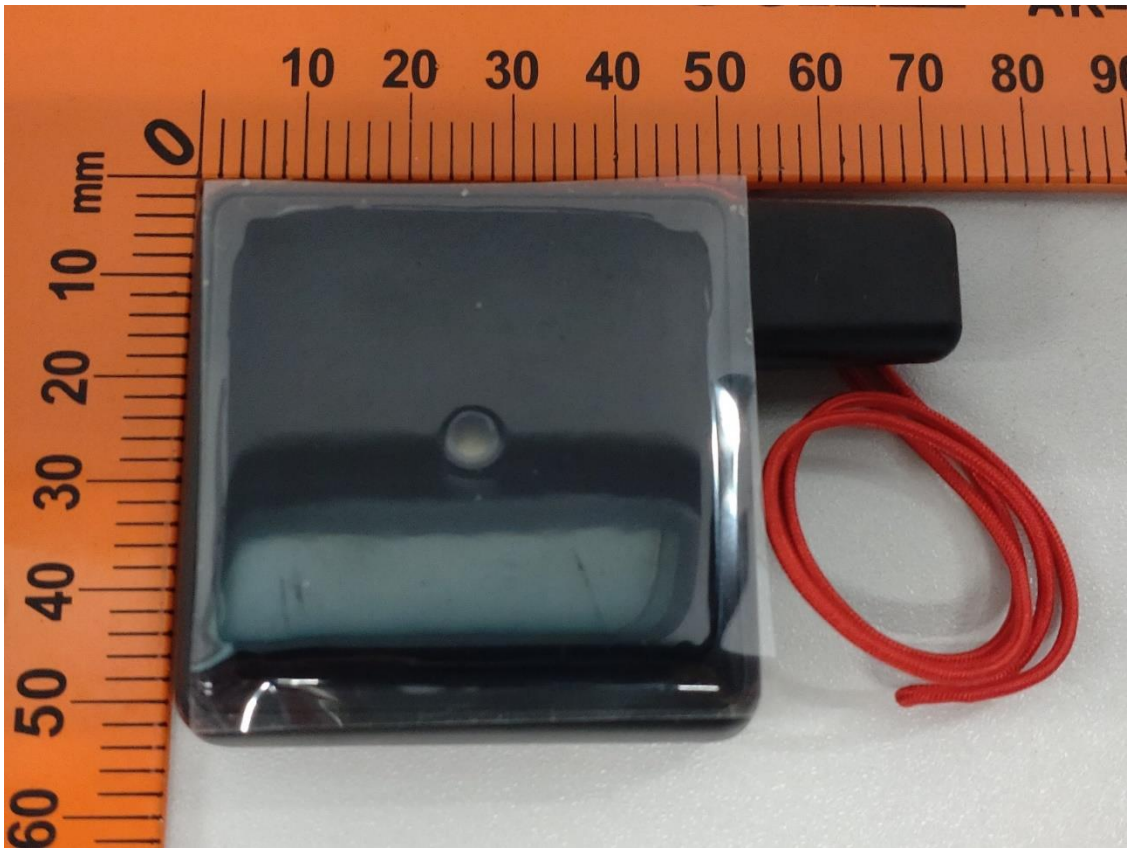
Set up for Radiated Emission Below 30MHz

Conducted Emissions on AC Mains

Appendix 3

EUT External Photos

FCC_ID : 2AVOQ03

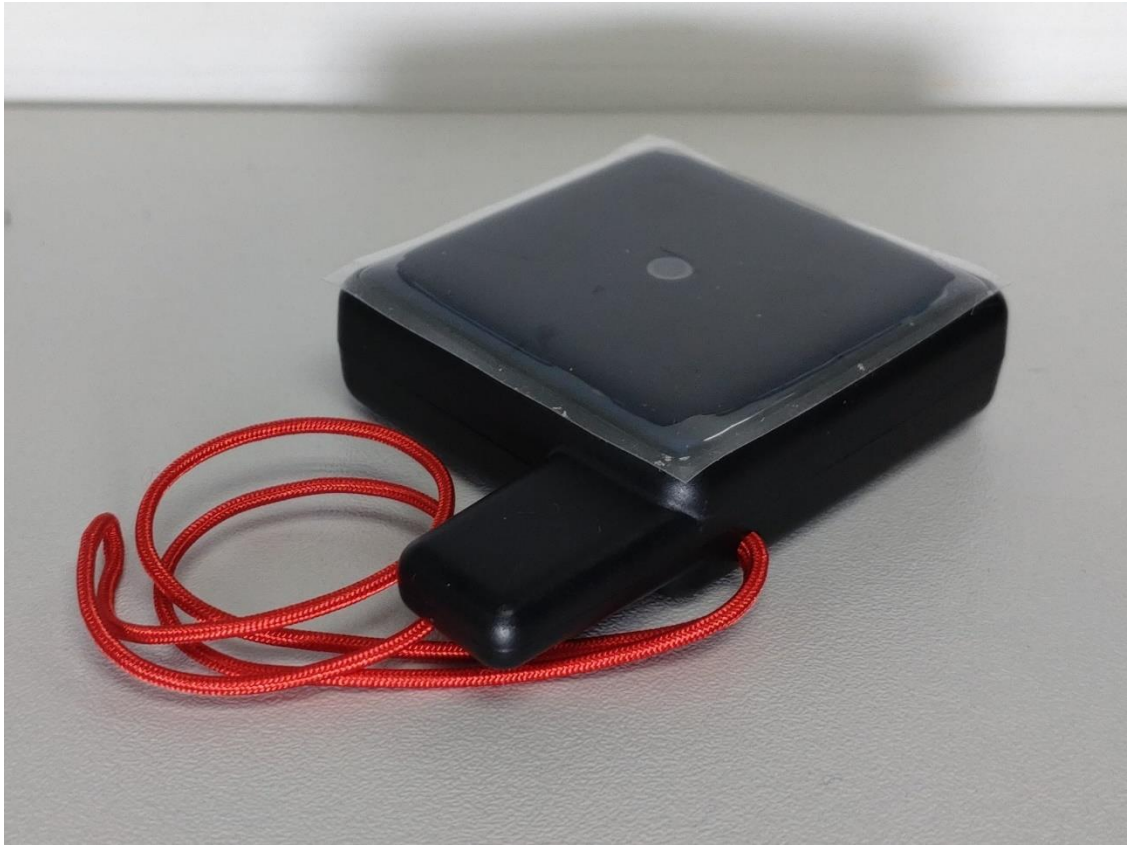


External View

External View

External View

External View



External View

External View

External View

Appendix 4

EUT Internal Photos

FCC_ID : 2AVOQ03

Appendix 5

RF Exposure Information

FCC_ID : 2AVOQ03

Time-averaged maximum conducted output power:

Frequency (MHz)	Maximum output power (dBm)	Pulse duration (ms)	Period (ms)	10 log (1 / D) (dB)	Time-averaged maximum conducted output power (dBm) / (mW)
920.8	12.41	18.0	45.0	3.98	8.43 / 6.96
902.6	13.21	5.5	38.1	8.41	4.80 / 3.02
914.6	12.82	5.5	39.0	8.51	4.31 / 2.68
927.4	12.78	5.5	39.0	8.51	4.27 / 2.67

Note:
- The maximum conducted output power was taken from table of Subclause “FCC 15.247(b)(1) – Peak Output Power”
- Time-averaged maximum conducted output power is calculated by subtracting [10 log (1 / D)] dB from maximum output power, where D is duty cycle, 1 / D = period / pulse duration

For FCC

According to KDB 447498 D01:
The 1-g and 10-g SAR test exclusion thresholds for 100 MHz to 6 GHz at *test separation distances* ≤5 mm are determined by:
[(*max. power of channel, including tune-up tolerance, mW*)/(*min. test separation distance, mm*)] · [√f(GHz)] ≤3.0 for 1-g SAR and ≤7.5 for 10-g extremity SAR, where
• f(GHz) is the RF channel transmit frequency in GHz
• Power and distance are rounded to the nearest mW and mm before calculation
• The result is rounded to one decimal place for comparison
• 3.0 and 7.5 are referred to as the numeric thresholds in the step 2 below

Result:

(6.96/5)*√0.9208 = 1.336 <3.0

(3.02/5)*√0.9026 = 0.574 <3.0

(2.68/5)*√0.9146 = 0.513 <3.0

(2.67/5)*√0.9274 = 0.514 <3.0

Conclusion:
No SAR is required.