Test of Thinkify LLC, T2000, Single Track AEI Reader

To: FCC Part 90 SubPart I, 90.353; IC RSS-137

Test Report Serial No.: THNK13-U2 Rev A

TEST REPORT

FROM

MiCOM Labs

Test of: Thinkify LLC, T2000, Single Track AEI Reader

To: FCC Part 90 SubPart I, 90.353; IC RSS-137

Test Report Serial No.: THNK13-U2 Rev A

This report supersedes: NONE

Manufacturer: Thinkify LLC
18450 Technology Drive, Suite E
Morgan Hill, California 95037
USA

Product Function: RFID Reader

Copy No: pdf **Issue Date:** 17th September 2015

This Test Report is Issued Under the Authority of;

MiCOM Labs, Inc.
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A2LA ACCREDITED
TESTING CERT #2381.01

MiCOM Labs is an ISO 17025 Accredited Testing Laboratory

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ACCREDITATION, LISTINGS and RECOGNITION

TESTING ACCREDITATION

MiCOM Labs, Inc. is an accredited Electrical testing laboratory per the international standard EN ISO/IEC 17025. The company is accredited by the American Association for Laboratory Accreditation (A2LA) www.a2la.org test laboratory number 2381.01. MiCOM Labs test schedule is available at the following URL; http://www.a2la.org/scopepdf/2381-01.pdf

ilac-MRA

American Association for Laboratory Accreditation

Accredited Laboratory

A2LA has accredited

MICOM LABS

Pleasanton, CA

for technical competence in the field of

Electrical Testing

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2005 *General Requirements for the Competence of Testing and Calibration Laboratories*. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (*refer to joint ISO-ILAC-IAF Communiqué dated 8 January 2009*).

Presented this 28th day of February 2014.

President & CEO
For the Accreditation Council
Certificate Number 2381.01
Valid to November 30, 2015

For the tests or types of tests to which this accreditation applies, please refer to the laboratory's Electrical Scope of Accreditation.

RECOGNITION

MiCOM Labs, Inc has widely recognized Electrical testing capabilities. Our international recognition includes Conformity Assessment Body designation by APEC MRA** countries. Our test reports are widely accepted for global type approvals.

Country	Recognition Body	Status	Phase	Identification No.
USA	Federal Communications Commission (FCC)	TCB	-	US0159 Listing #: 102167
Canada	Industry Canada (IC)	FCB	APEC MRA 2	US0159 Listing #: 4143A-2 4143A-3
Japan	MIC (Ministry of Internal Affairs and Communication)	CAB	APEC MRA 2	RCB 210
	VCCI	--	--	A-0012
Europe	European Commission	NB	EU MRA	NB 2280
Australia	Australian Communications and Media Authority (ACMA)	CAB	APEC MRA 1	US0159
Hong Kong	Office of the Telecommunication Authority (OFTA)	CAB	APEC MRA 1	
Korea	Ministry of Information and Communication Radio Research Laboratory (RRL)	CAB	APEC MRA 1	
Singapore	Infocomm Development Authority (IDA)	CAB	APEC MRA 1	
Taiwan	National Communications Commission (NCC) Bureau of Standards, Metrology and Inspection (BSMI)	CAB	APEC MRA 1	
Vietnam	Ministry of Communication (MIC)	CAB	APEC MRA 1	

**APEC MRA – Asia Pacific Economic Community Mutual Recognition Agreement.
Is a recognition agreement under which test lab is accredited to regulatory standards of the APEC member countries.
Phase I - recognition for product testing
Phase II – recognition for both product testing and certification
N/A – Not Applicable

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MiCOM Labs, Inc. is an accredited Product Certification Body per the international standard EN ISO/IEC 17065. The company is accredited by the American Association for Laboratory Accreditation (A2LA) www.a2la.org test laboratory number 2381.02. MiCOM Labs test schedule is available at the following URL; http://www.a2la.org/scopepdf/2381-02.pdf


American Association for Laboratory Accreditation

Accredited Product Certification Body

A2LA has accredited

MICOM LABS

Pleasanton, CA

for technical competence as a

Product Certification Body

This product certification body is accredited in accordance with the recognized International Standard ISO/IEC 17065:2012 - *Requirements for bodies certifying products, processes and services*. This accreditation demonstrates technical competence for a defined scope and the operation of a quality management system.

Presented this 28th day of February 2014.

President & CEO
For the Accreditation Council
Certificate Number 2381.02
Valid to November 30, 2015

For the product certification schemes to which this accreditation applies, please refer to the organization's Product Certification Scope of Accreditation

United States of America – Telecommunication Certification Body (TCB)
TCB Identifier – US0159

Industry Canada – Certification Body
CAB Identifier – US0159

Europe – Notified Body
Notified Body Identifier - 2280

Japan – Recognized Certification Body (RCB)
RCB Identifier - 210

DOCUMENT HISTORY

Document History		
Revision	Date	Comments
Draft		
Rev A	17th September 2015	Initial Release

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1. TEST RESULT CERTIFICATE

Manufacturer:	Thinkify LLC 18450 Technology Drive, Suite E Morgan Hill, California 95037 USA	Tested By:	MiCOM Labs, Inc. 575 Boulder Court Pleasanton California, 94566, USA
EUT:	915 MHz RFID Reader	Telephone:	+1 925 462 0304
Model:	T2000	Fax:	+1 925 462 0306
S/N:	Unknown		
Test Date(s):	20th - 21st July 2015	Website:	www.micomlabs.com

STANDARD(S)	TEST RESULTS
FCC Part 90 SubPart I, 90.353; IC RSS-137	EQUIPMENT COMPLIES

MiCOM Labs, Inc. tested the equipment mentioned in accordance with the requirements set forth in the above standards. Test results indicate that the equipment tested is capable of demonstrating compliance with the requirements as documented within this report.

Notes:

1. This document reports conditions under which testing was conducted and the results of testing performed.
2. Details of test methods used have been recorded and kept on file by the laboratory.
3. Test results apply only to the item(s) tested.

ACCREDITED
TESTING CERT #2381.01

Approved & Released for MiCOM Labs, Inc. by:

Graeme Grieve
Quality Manager MiCOM Labs,

Gordon Hurst
President & CEO MiCOM Labs, Inc.

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2. REFERENCES AND MEASUREMENT UNCERTAINTY

2.1. Normative References

Ref.	Publication	Year	Title
(i)	FCC 47 CFR Part 90	2015	Code of Federal Regulations Private Land Mobile Radio Devices
(ii)	ANSI C63.4	2014	American National Standards for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz
(iii)	CISPR 22/	2008	Limits and Methods of Measurements of Radio Disturbance Characteristics of Information Technology Equipment
(iv)	M 3003	Edition 3 Nov. 2012	Expression of Uncertainty and Confidence in Measurements
(vi)	ETSI TR 100 028	2001-12	Parts 1 and 2 Electromagnetic compatibility and Radio Spectrum Matters (ERM); Uncertainties in the measurement of mobile radio equipment characteristics
(Vii)	A2LA	June 2015	Reference to A2LA Accreditation Status – A2LA Advertising Policy

2.2. Test and Uncertainty Procedures

Conducted and radiated emission measurements were conducted in accordance with American National Standards Institute ANSI C63.4, listed in the Normative References section of this report.

Measurement uncertainty figures are calculated in accordance with ETSI TR 100 028 Parts 1 and 2.

Measurement uncertainties stated are based on a standard uncertainty multiplied by a coverage factor k = 2, providing a level of confidence of approximately 95 % in accordance with UKAS document M 3003 listed in the Normative References section of this report.

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3. PRODUCT DETAILS AND TEST CONFIGURATIONS

3.1. Technical Details

Details	Description	
Purpose:	Test of the Thinkify LLC, T2000, Single Track AEI Reader to FCC Part 90 SubPart I, 90.353; IC RSS-137 regulations.	
Applicant:	Thinkify LLC 18450 Technology Drive, Suite E Morgan Hill, California 95037 USA	
Manufacturer:	As Applicant	
Laboratory performing the tests:	MiCOM Labs, Inc. 575 Boulder Court Pleasanton, California 94566 USA	
Test report reference number:	THNK13-U2 Rev A	
Date EUT received:	20h July 2015	
Dates of test (from - to):	20th - 21st July 2015	
Standard(s) applied:	FCC Part 90 SubPart I, 90.353; IC RSS-137	
No of Units Tested:	1	
Type of Equipment:	RFID Reader	
Model:	T2000	
Location for use:	Outdoor use	
Declared Frequency Range(s):	902 – 904 MHz & 909.75 - 921.75 MHz	
Type of Modulation:	Continuous Wave (CW)	
Operational Bandwidths:	15.531 kHz	
Declared Maximum Output Power:	+33 dBm	
ITU Emission Designator:	Modulation	ITU Designator
	Single Tone (CW)	NON-Continuous Wave Emission
Transmit/Receive Operation:	Transceiver, Half-Duplex	
Software Revision:	Not Provided	
Rated Input Voltage and Current:	15 Vdc 300 mA	
Operating Temperature Range:	-40ºC to +80ºC	
Equipment Dimensions:	12 x 12 x 4 inches	
Weight:	8.0 lbs	
Primary function of equipment:	Radio Frequency Identification (RFID) Reader, reading tags on rail cars	

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3.2. Scope of Test Program

The scope of the test program was to test the Thinkify LLC, T2000, Single Track AEI Reader for compliance against;-

FCC 47 CFR Part 90, Subpart I regulatory requirements.

The Thinkify LLC, T2000, Single Track AEI Reader has two operational modes Continuous Wave and Modulated OOK and operates in the range 902 – 928 MHz.

Transmission Restrictions
The Thinkify LLC, T2000, Single Track AEI Reader RFID Reader per Part 90 SubPart I, 90.357 falls into category (b) Non-multilatersation LMS systems authorized in the following frequency bands:

- 902 – 904 MHz
- 909.75 - 921.75 MHz

Definition of Non-Multilateration LMS System.
A non-multilateration LMS system employs any of a number of non-multilateration technologies to transmit information to and/or from vehicular units.

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3.3. Equipment Model(s) and Serial Number(s)

EUT/ Support	Manufacturer	Equipment Description (Including Brand Name)	Model No.	Serial No.
EUT	Thinkify LLC	RFID Reader 902-928 MHz	T2000	Unknown
Support		Laptop Computer		

3.4. Antenna Details

Antenna Type	Manufacturer	Model Number	Antenna Gain (dBi)
Dipole	Kathrein Scala	Not Provided	12.0
Dipole	Thinkify LLC	Thinkify	12.0
Dipole	Thinkify LLC	Thinkify	6.0

3.5. Cabling and I/O Ports

Number and type of I/O ports

1. 3 x RF Ports
2. Vdc Supply
3. Serial Port (9 pin) Local Maintenance Terminal
4. GPIO (input/output)

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3.6. Test Configurations

Test Matrix V's Variants

Parameter	Standard Section #	Operational Mode	Test Conditions
Occupied Bandwidth	2.1049/ 90.210	CW, OOK	Ambient, Nominal Vdc
Effective Radiated Power	2.1046/ 90.205		
Exposure to Mobile Devices	2.1091/ 90.1217	Calculated	--
Frequency Stability	2.1055/ 90.213	CW	Ambient, -40ºC, 80ºC Nominal & Extremes of Voltage[1]
Audio Frequency Response	TIA EIA-603.3.2.6	--	N/A[2]
Audio Low-Pass Filter Response	TIA EIA-603.3.2.6	--	N/A[2]
Conducted Spurious Emissions	2.1053/ 90.210	CW	Ambient, Nominal Vdc
Radiated Spurious Emissions	2.1053/ 90.210	CW	Ambient, Nominal Vdc
Transient Frequency Response	90.214	--	N/A[3]
AC Wireline Emissions	15.207	CW	Ambient, Nominal Vdc

Note 1.. Fixed Non-Multilateration transmitters with an authorized bandwidth more than 40 kHz from the band-edge are not subject to Frequency Stability restrictions. The EUT was measured to show compliance with Part 2 requirements.
Note 2.. The EUT does not support audio modulation therefore Audio Frequency Response and Audio Low-Pass Filter Response testing was not performed
Note 3.. The EUT is not a keyed carrier system therefore Transient Frequency Behavior was not performed

Test Frequencies

Frequency Band (MHz)	Frequency Channel (MHz)		
	Low	Mid	High
902.00 – 904.00	902.50	903.00	903.50
909.75 – 921.75	910.00	915.00	920.00

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3.7. Equipment Modifications

The following modifications were required to bring the equipment into compliance:

1. NONE

3.8. Deviations from the Test Standard

The following deviations from the test standard were required in order to complete the test program:

1. NONE

3.9. Subcontracted Testing or Third Party Data

1. NONE

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4. TEST SUMMARY

List of Measurements

The following table represents the list of measurements required under the **FCC CFR47 Part 90**, **Subpart Z.**

Section(s)	Test Items	Description	Condition	Result	Test Report Section
2.1049/ 90.210	99% Occupied Bandwidth + Band-edge	Bandwidth measurement(s)	Conducted	Complies	5.1.1
2.1046; 90.1321 (a)	Effective Radiated Power	CW & Modulated Output Power	Conducted	Complies	5.1.2
Subpart C 90.1217	Maximum Permissible Exposure	Exposure to radio frequency energy levels	Calculated	--	5.1.3
2.1055(a)(1)	Frequency Stability	Includes temperature and voltage variations	Conducted	Complies	5.1.4
2.1051; 90.1323	Conducted Spurious Emissions	Emissions from the antenna port	Conducted	Complies	5.1.5
2.1053; 90.1323 ANSI/TIA-603	Radiated Spurious Emissions	Spurious emissions	Radiated	Complies	5.1.6
15.207	AC Wireline Conducted	Emissions 150 kHz–30 MHz	Conducted	*Not Tested	5.1.7

*The device was not tested for ac Wireline Emissions as it was dc powered

Note 1: *Test results reported in this document relate only to the items tested*
Note 2: *The required tests demonstrated compliance as per client declaration of test configuration, monitoring methodology and associated pass/fail criteria*
Note 3: *Section 3.7 'Equipment Modifications' highlight the equipment modifications that were required to bring the product into compliance with the above matrix*

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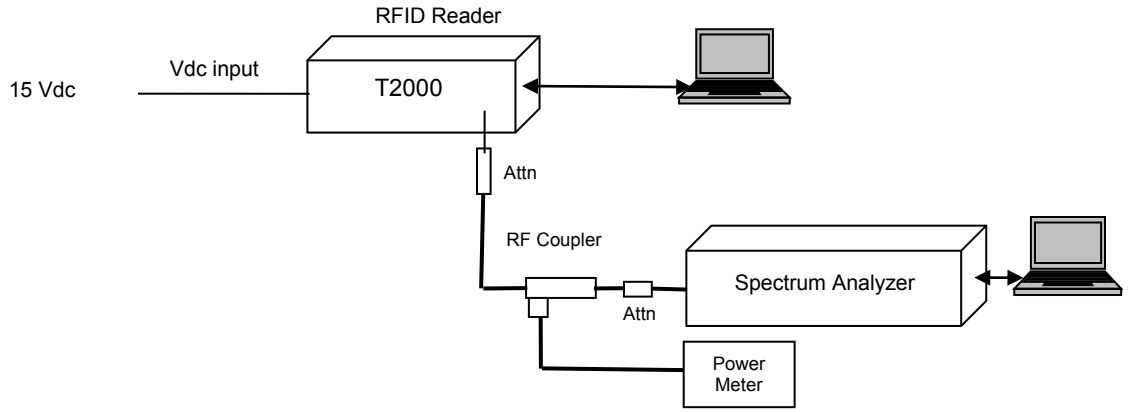
4.1. Conducted Test Set-Up

Test software was available to exercise the RFID Reader and the equipment was tested using the following test configuration.



Conducted Test Set-Up

Test Equipment Details

Asset#	Description	Manufacturer	Model#	Serial#	Calibration Due Date
158	Barometer/Thermometer	Control Company	4196	E2846	04 Dec 2015
249	Resistance Thermometer	Thermotronics	GR2105-02	9340 #2	30 Oct 2015
287	Rohde & Schwarz 40 GHz Receiver	Rhode & Schwarz	ESIB40	100201	31 Jul 2015
405	DC Power Supply 0-60V	Agilent	6654A	MY4001826	Cal when used
408	USB to GPIB interface	National Instruments	GPIB-USB HS	14C0DE9	Not Required
436	USB Wideband Power Sensor	Boonton	55006	8731	31 Jul 2015
75	Environmental Chamber	Thermatron	SE-300-2-2	27946	28 Nov 2015
RF#1 GPIB#1	GPIB cable to Power Supply	HP	GPIB	None	Not Required

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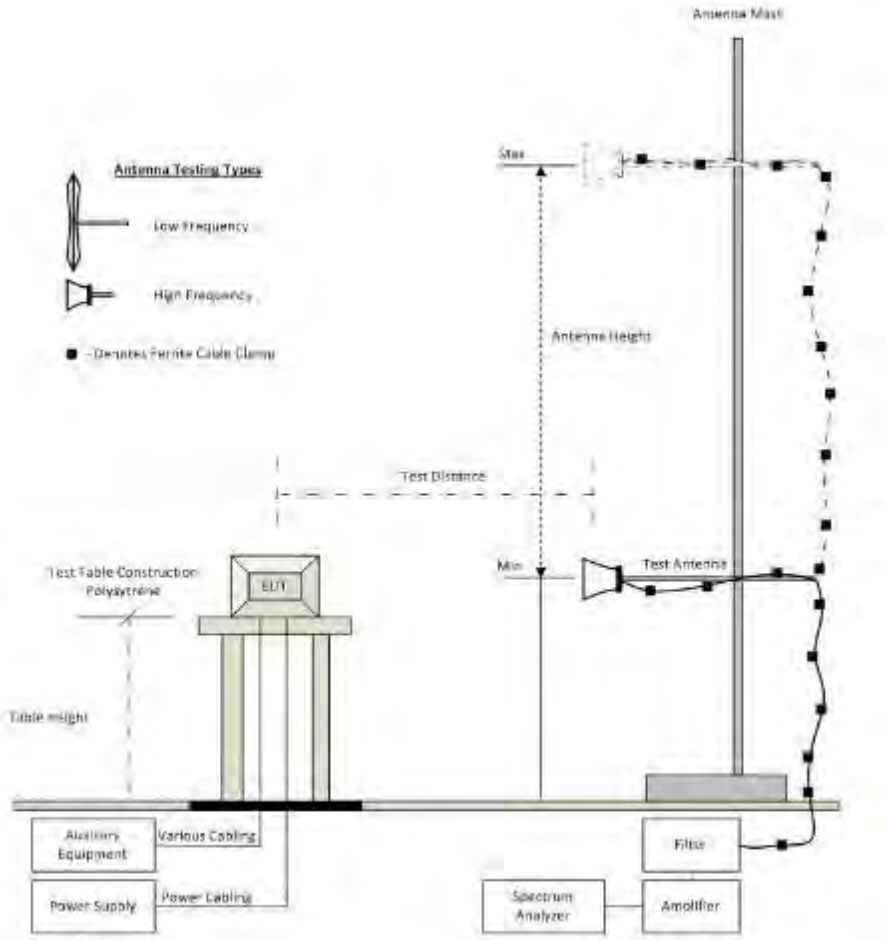
4.2. Radiated Test Set-Up

The following tests were performed using the conducted test set-up shown in the diagram below.

1. Section 6.1.6.1 Spurious Emissions >1 GHz
2. Section 6.1.6.2 Digital Emissions 0.03 – 1 GHz



Radiated Emission Test Setup

A full system calibration was performed on the test station and any resulting system losses (or gains) were taken into account in the production of all final measurement data.

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Asset#	Description	Manufacturer	Model#	Serial#	Calibration Due Date
158	Barometer/Thermometer	Control Company	4196	E2846	04 Dec 2015
170	Video System Controller for Semi Anechoic Chamber	Panasonic	WV-CY101	04R08507	Not Required
287	Rohde & Schwarz 40 GHz Receiver	Rhode & Schwarz	ESIB40	100201	31 Jul 2015
310	SMA Cable	Micro-Coax	UFA210A-0-0787-3G03G0	209089-001	30 Oct 2015
338	Sunol 30 to 3000 MHz Antenna	Sunol	JB3	A052907	14 Aug 2015
397	Amp 10 - 2500MHz	MiCOM Labs	Amp 10 - 2500 MHz	NA	23 Oct 2015
399	ETS 1-18 GHz Horn Antenna	ETS	3117	00154575	10 Oct 2015
406	Amplifier for Radiated Emissions	MiCOM Labs	40dB 1 to 18GHz Amp	0406	28 May 2016
410	Desktop Computer	Dell	Inspiron 620	WS38	Not Required
411	Mast/Turntable Controller	Sunol Sciences	SC98V	060199-1D	Not Required
412	USB to GPIB Interface	National Instruments	GPIB-USB HS	11B8DC2	Not Required
413	Mast Controller	Sunol Science	TWR95-4	030801-3	Not Required
415	Turntable Controller	Sunol Sciences	Turntable Controller	None	Not Required
416	Gigabit ethernet filter	ETS-Lingren	Gigafoil 260366	None	Not Required
462	Schwarzbeck cable from Antenna to Amplifier.	Schwarzbeck	AK 9513	462	25 Aug 2015
463	Schwarzbeck cable from Amplifier to Bulkhead.	Schwarzbeck	AK 9513	463	25 Aug 2015
464	Schwarzbeck cable from Bulkhead to Receiver	Schwarzbeck	AK 9513	464	25 Aug 2015

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5. TEST RESULTS

5.1. Device Characteristics

5.1.1. Occupied Bandwidth

FCC 47 CFR Part 90.210, 2.1049;

Test Procedure

The transmitter terminal of EUT was connected to the input of the spectrum analyzer set to measure the 99% occupied bandwidth. The system highest power setting was selected with modulation OFF (CW) and ON.

The measurement of channel bandwidth used a resolution bandwidth of at least one percent of the occupied bandwidth of the fundamental emission and a video bandwidth higher than the RBW.

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Occupied Bandwidth

Modulation	Center Frequency (MHz)	99% Bandwidth (kHz)
CW	902.50	15.531
	903.00	15.531
	903.50	15.531
	910.00	15.531
	915.00	15.531
	920.75	15.531

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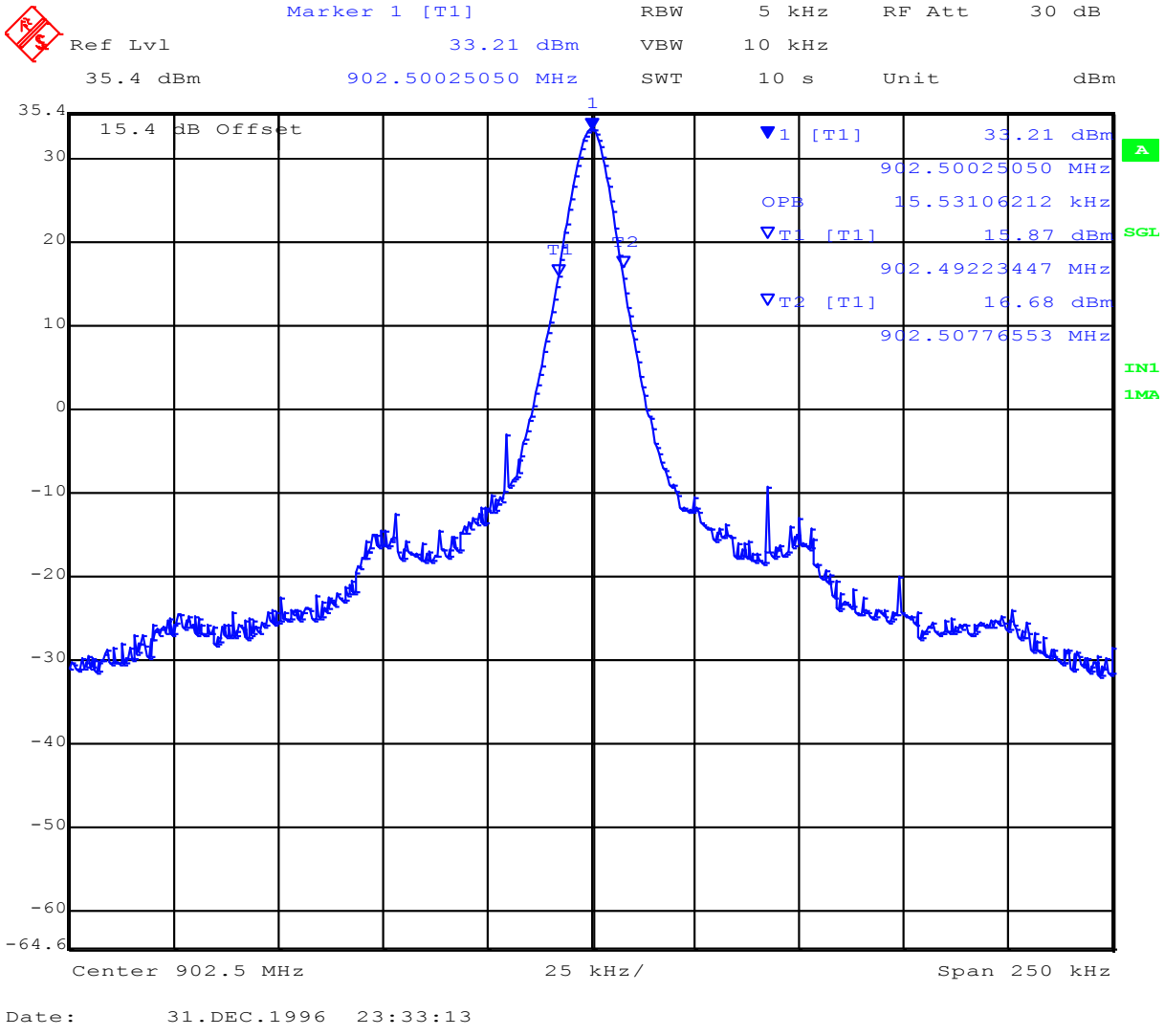
Channel 902.50, CW 99% Bandwidth



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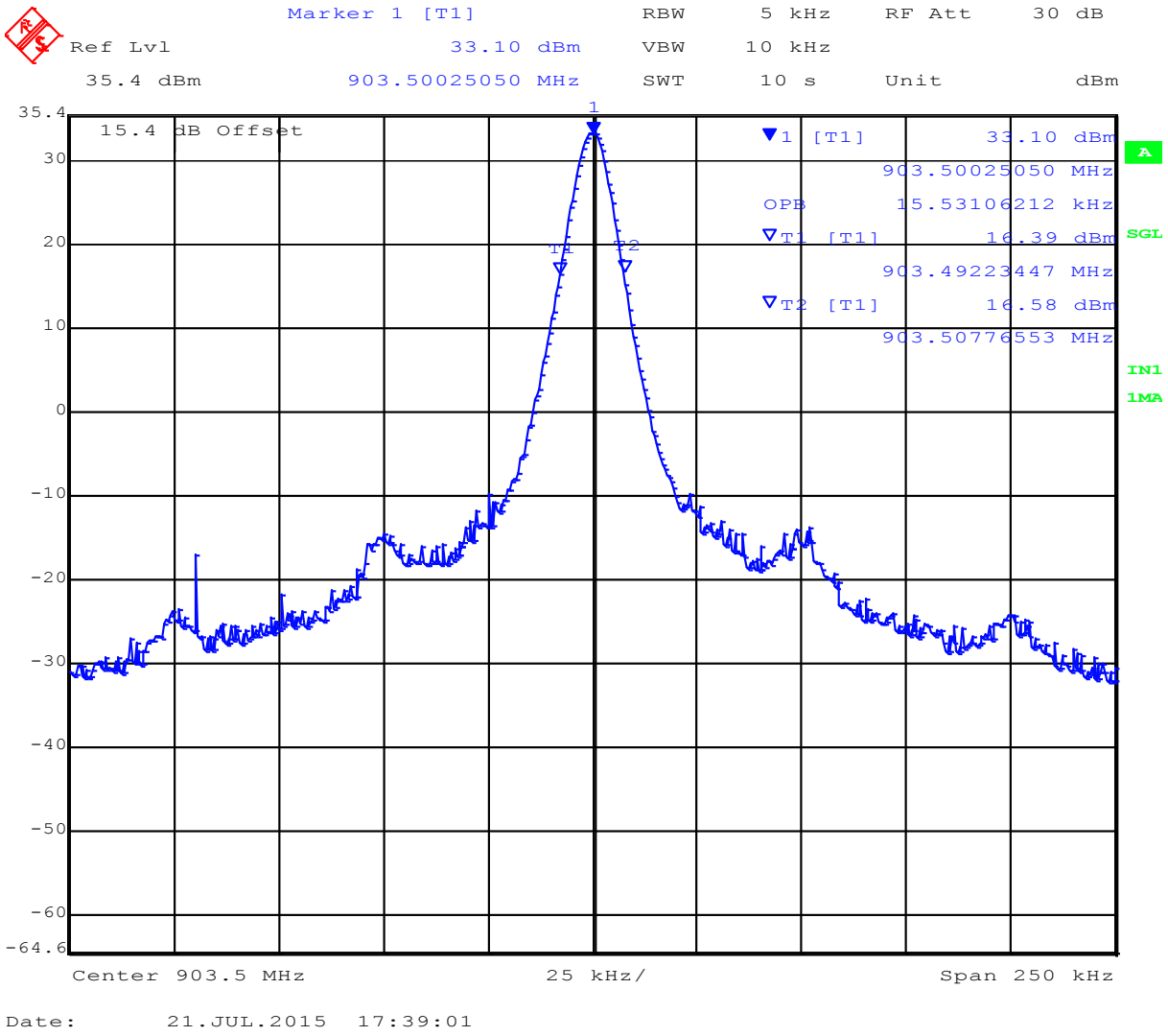
Channel 903.50, CW 99% Bandwidth



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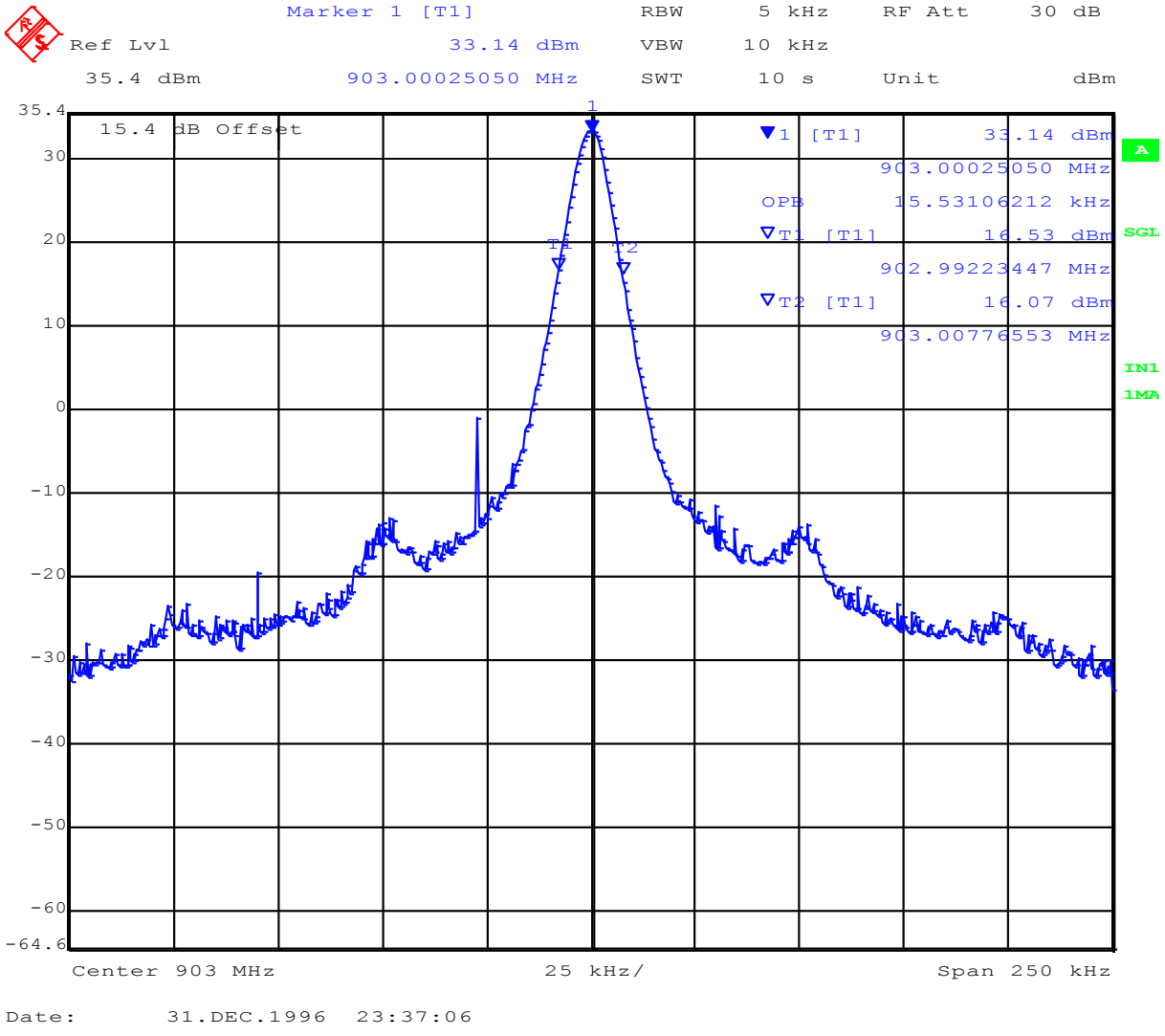
Channel 903.00, CW 99% Bandwidth



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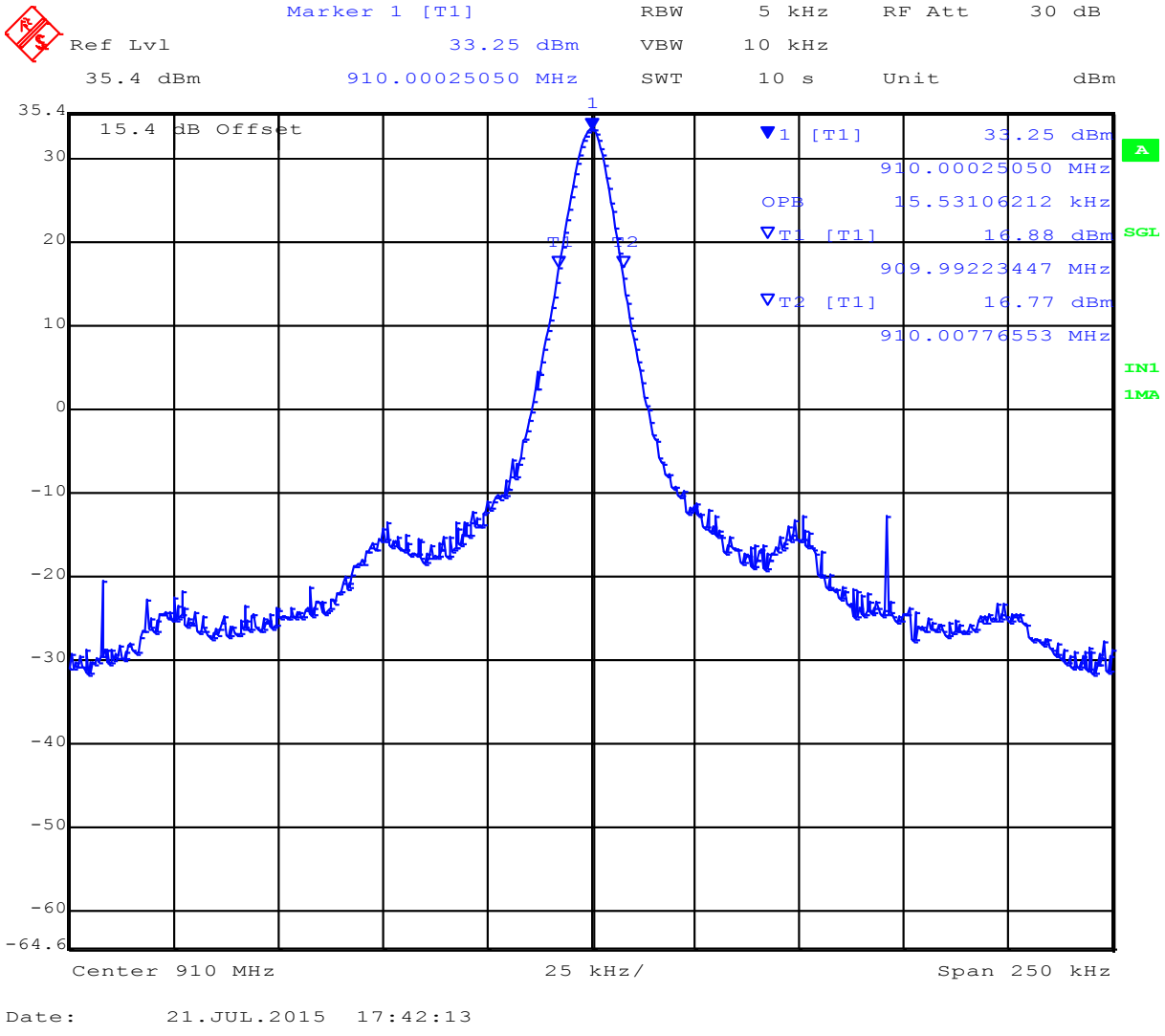
Channel 910.00, CW 99% Bandwidth



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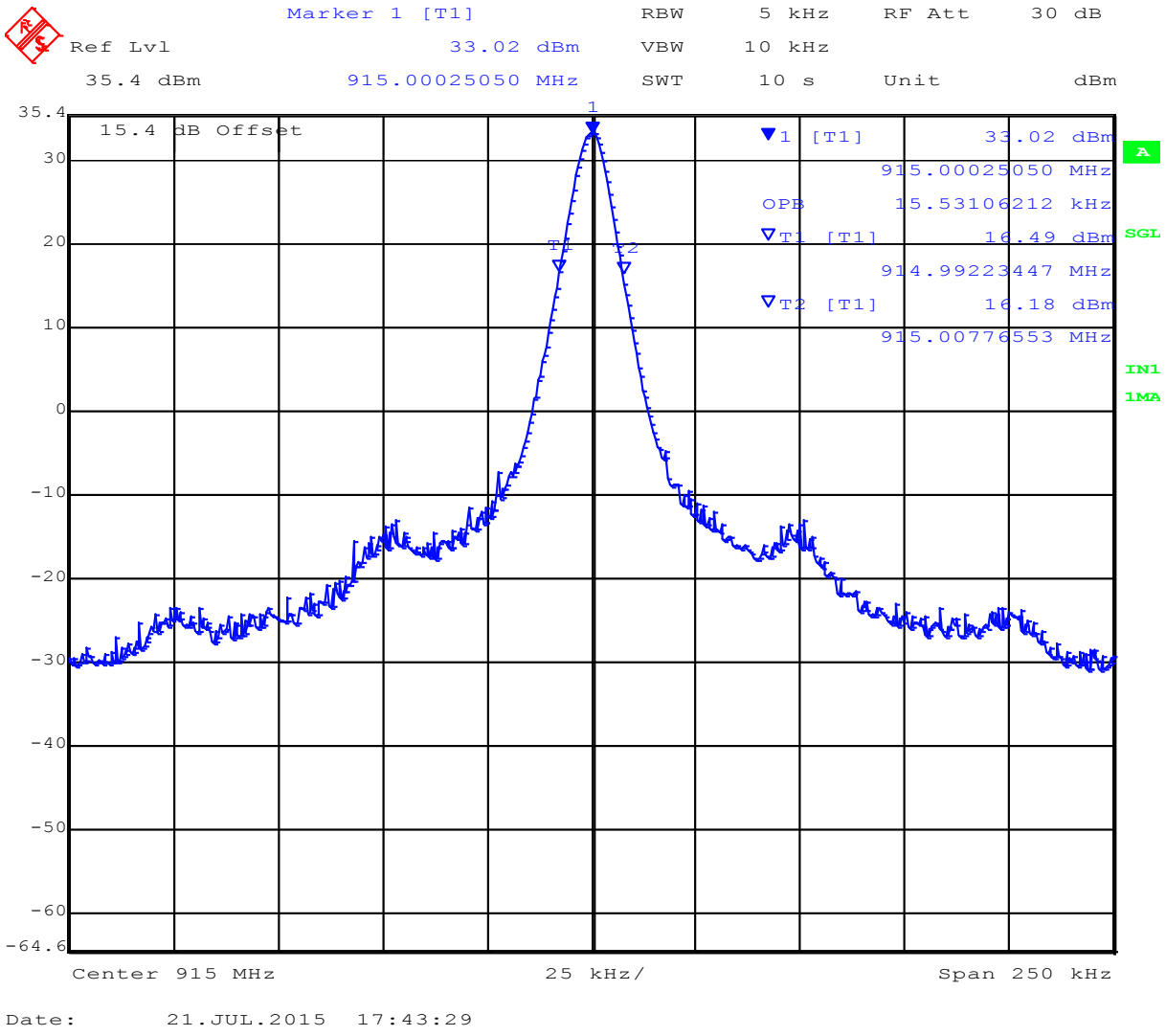
Channel 915.00, CW 99% Bandwidth



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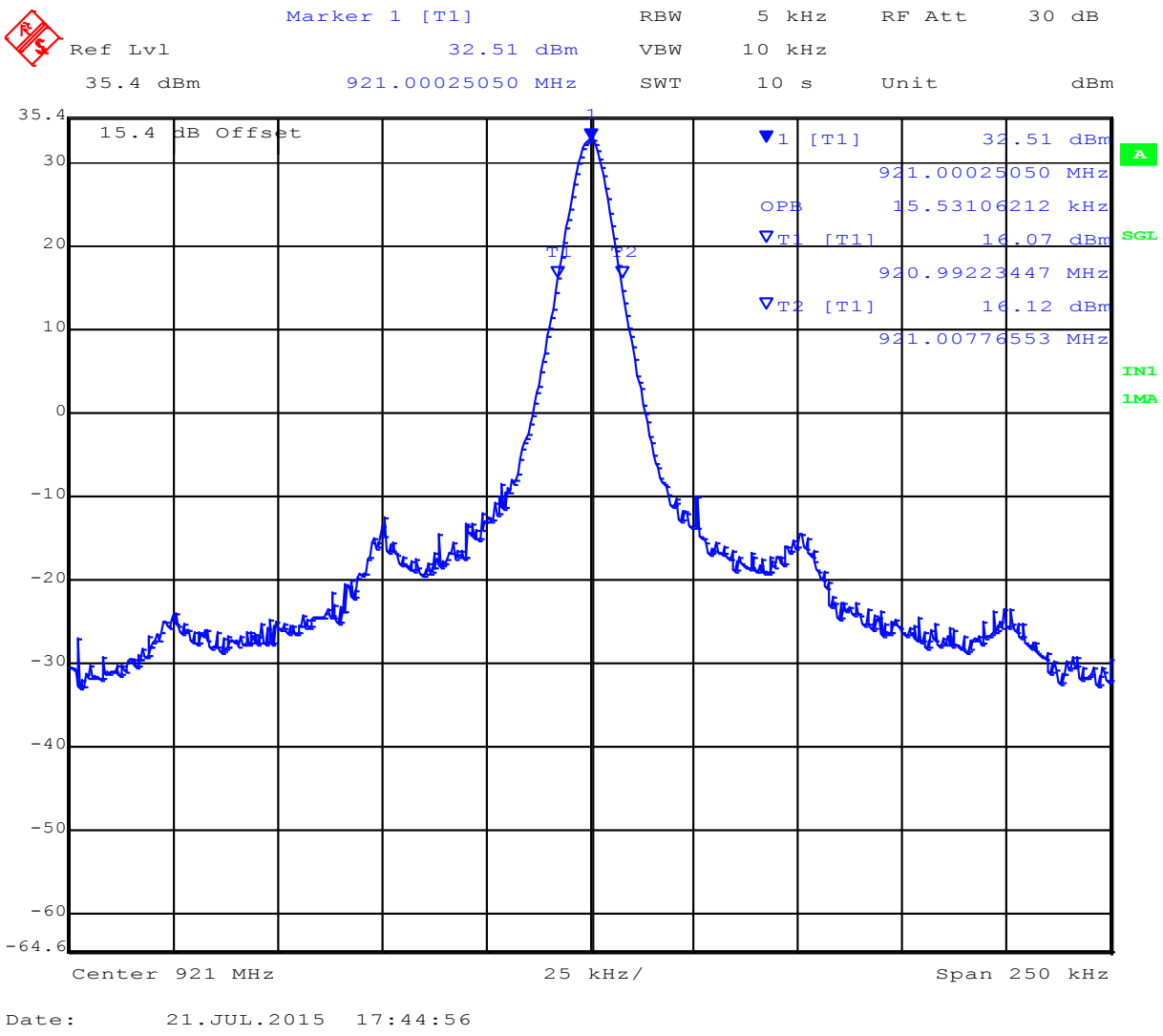
Channel 921.00, CW 99% Bandwidth



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Laboratory Measurement Uncertainty for Power Measurements

Measurement uncertainty	±1.33 dB

Traceability

Method
Measurements were made per work instruction WI-03 'Measurement of RF Spectrum Mask'

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5.1.2. Effective Radiated Power

FCC 47 CFR Part 90.205, Subpart I; §**2.1046**

The following power limits apply to the 902 – 928 MHz frequency band MHz band.

Power is limited to 30W (44.7 dBm) equivalent effective radiated power (ERP).

Test Procedure

Average power measurements were measured with the use of an average power sensor. The system highest power setting was selected with modulation OFF (CW).

ERP (dBm) = Transmit Power (dBm) + Antenna Gain (dBi) – Antenna Conversion to ERP (2.14dB)

Antenna Gain = 12.0 dBi

ERP (dBm) = Transmit Power (dBm) + 9.86 dB

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Ambient conditions.
Temperature: 17 to 23 °C Relative humidity: 31 to 57 % Pressure: 999 to 1012 mbar

Modulation	Center Frequency (MHz)	Measured Power (dBm)	ERP (dBm)	ERP Limit		Margin (dB)
				W	dBm	
CW	902.50	+31.78	+41.64	30	+44.7	-3.06
	903.00	+31.69	+41.55			-3.15
	903.50	+31.68	+41.54			-3.16
	910.00	+31.66	+41.52			-3.18
	915.00	+31.72	+41.58			-3.12
	921.00	+31.21	+41.07			-3.63

Equipment Duty Cycle
Device operates continuous wave transmission and therefore operating at 100% duty cycle. No duty cycle correction factor was required for the above measured power.

Range of Output Power
The device range of output power can operate between 0.1 to 2.2 Watts

Final Stage Voltage and Current
The final stage amplifier (voltage and current) under normal operating conditions are 5 vdc and 1.8 A.

Laboratory Measurement Uncertainty for Power Measurement

Measurement uncertainty	±1.33 dB

Traceability

Method
Measurements were made per work instruction WI-03 ‘Measurement of RF Output Power’

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5.1.3. Maximum Permissible Exposure

Calculations for Maximum Permissible Exposure Levels

Power Density = Pd (mW/cm^2) = EIRP/(4πd^2)

EIRP = P * G

P = Peak output power (mW)

G = Antenna numeric gain (numeric)

d = Separation distance (cm)

Numeric Gain = 10 ^ (G (dBi)/10)

The Thinkify T2000 has dual identical transmitters. The peak power in the table below is calculated by assuming a worst case scenario for the maximum gain antenna and output power. The calculated separation distance is for worst case highest power level. In order to take into account the dual transmitter situation the output power was doubled i.e. +3dB

Because the EUT belongs to the General Population/Uncontrolled Exposure the limit of power density is 2.74 W/m^2

Antenna Model	Type	Ant Gain (dBi)	Numeric Gain (numeric)	Peak Output Power (dBm)	Peak Output Power (W)	Calculated Safe Distance @ 2.74 W/m^2 Limit (m)	Power Density @ 20cm (W/m^2)
Thinkify	*Dipole*	12	*15.85*	*34.78*	3.006	*1.*17	9.48

Minimum safe distance = 1.17 m

Specification Maximum Permissible Exposure Limits

§90.1217 Systems operating under the provisions of this section shall be operated in a manner that ensures that the public is not exposed to radio frequency levels in excess of the Commission's guidelines. See §1.1307 (b)(1) of this chapter.

Limit = 2.74 W / m^2 from 1.310 Table 1

Note: for mobile or fixed location transmitters the minimum separation distance is 20cm, even if calculations indicate the MPE distance to be less.

Laboratory Measurement Uncertainty for Power Measurements

Measurement uncertainty	±1.33dB

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5.1.4. Frequency Stability; Temperature Variations, and Voltage Variations

FCC 47 CFR Part 90, Subpart Z; 2.1055(a)(1)

Test Procedure
The transmitter output was connected to a spectrum analyzer and the frequency stability was measured in a CW (un-modulated) operational mode.

Frequency stability was measured through the extremes of temperature on the mid channel only. Before measurements were taken at each temperature the equipment waited until thermal balance was obtained.

Test Set-up is shown in Section 3.6 Test Configuration

Ambient conditions.
Temperature: 17 to 23 °C Relative humidity: 31 to 57 % Pressure: 999 to 1012 mbar

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TABLE OF RESULTS Frequency Stability – Channel Measured 915.75 MHz

Delta kHz and ppm were measured from the actual channel frequency 915.75 MHz

Voltage (Vdc)	Temperature (°C)	Marker Frequency (MHz)	Delta (kHz)	ppm
+15.0	-35	914.9999975	-0.0025	-0.003
	-25	915.00013402	0.1340	0.146
	-15	915.00025526	0.2553	0.279
	-5	915.00032240	0.3224	0.352
	+5	915.00028132	0.2813	0.307
	+15	915.00025526	0.2553	0.279
+13.5	+25	915.00015106	0.1511	0.165
+16.5	+25	915.00013703	0.1370	0.150
+15.0	+33	915.00009394	0.0939	0.103
	+45	915.00006488	0.0649	0.071
	+55	915.00009695	0.0970	0.106
	+65	915.00007891	0.0789	0.086
	+75	915.00002580	0.0258	0.028
Maximum Frequency Drift with respect to the nominal frequency (lowest/highest)		-0.0025 kHz / 0.322 kHz -0.003 ppm / -0.352 ppm		

With reference to the band-edge plots in Section 5.1.1 Occupied Bandwidth and Band-Edge the above Frequency Error proves that the EUT remains inside the frequency band of operation during changes in environmental conditions.

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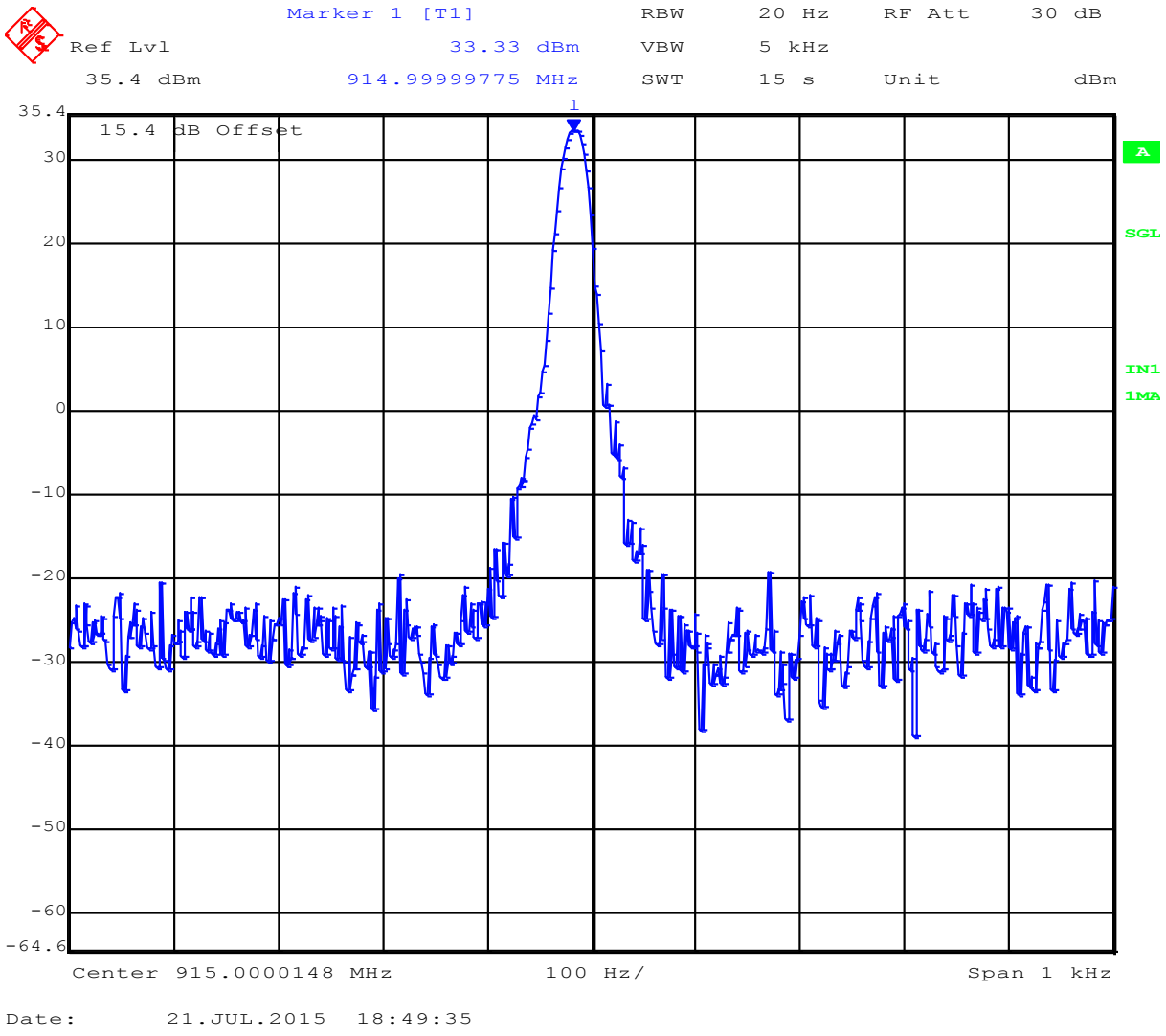
Frequency Error -35°C +15.0 Vdc



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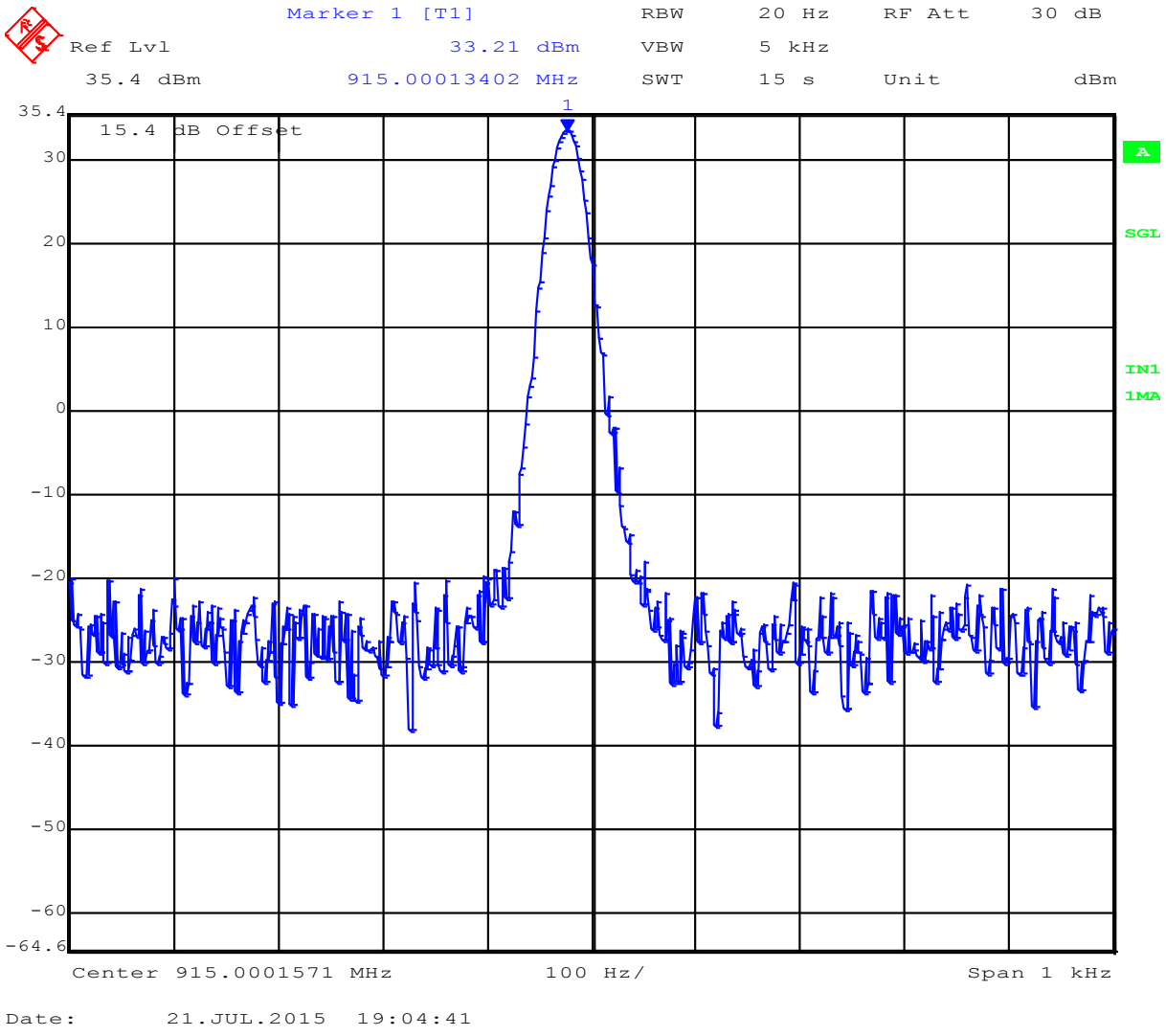
Frequency Error -25°C +15.0 Vdc



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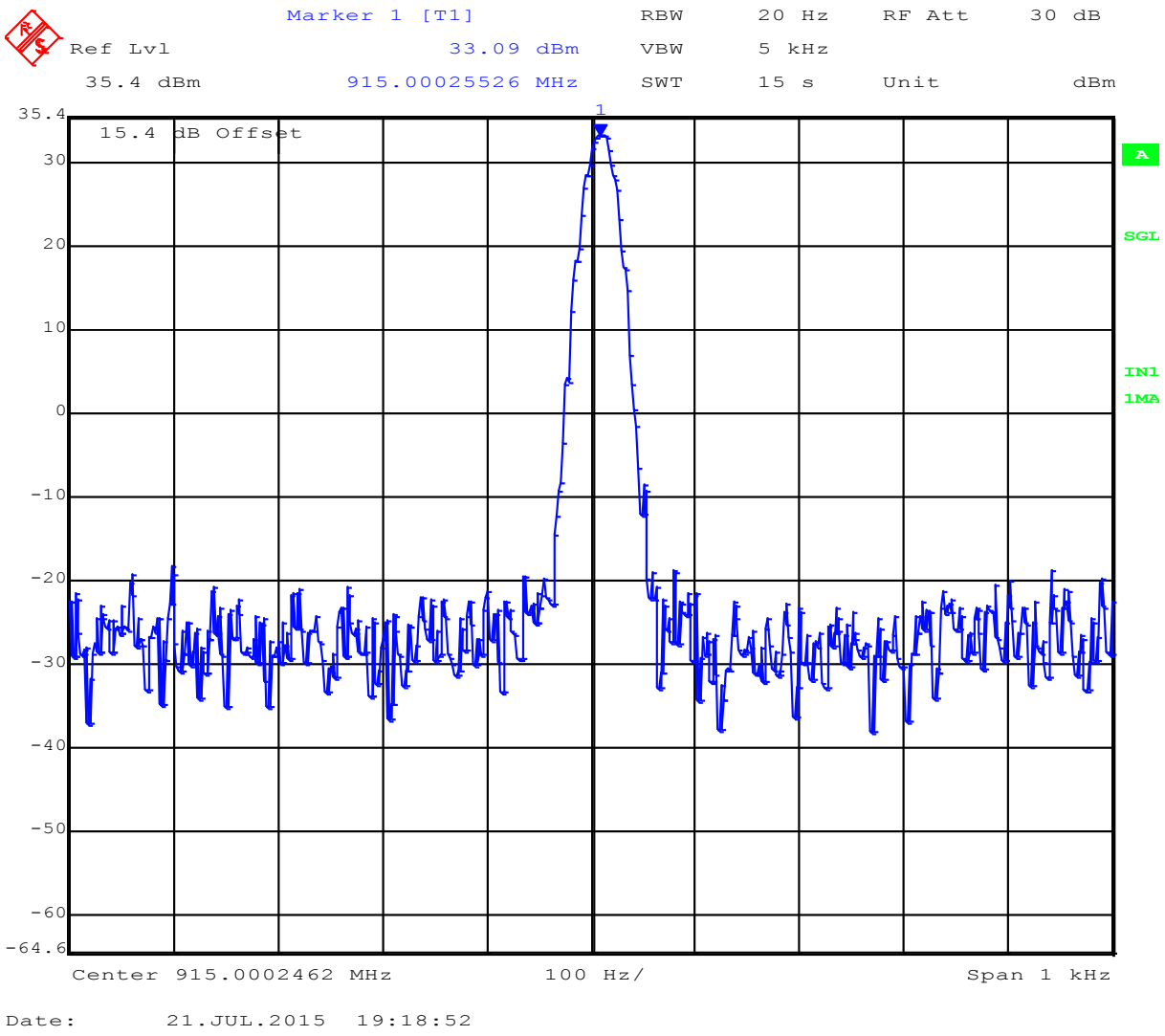
Frequency Error -15°C +15.0 Vdc



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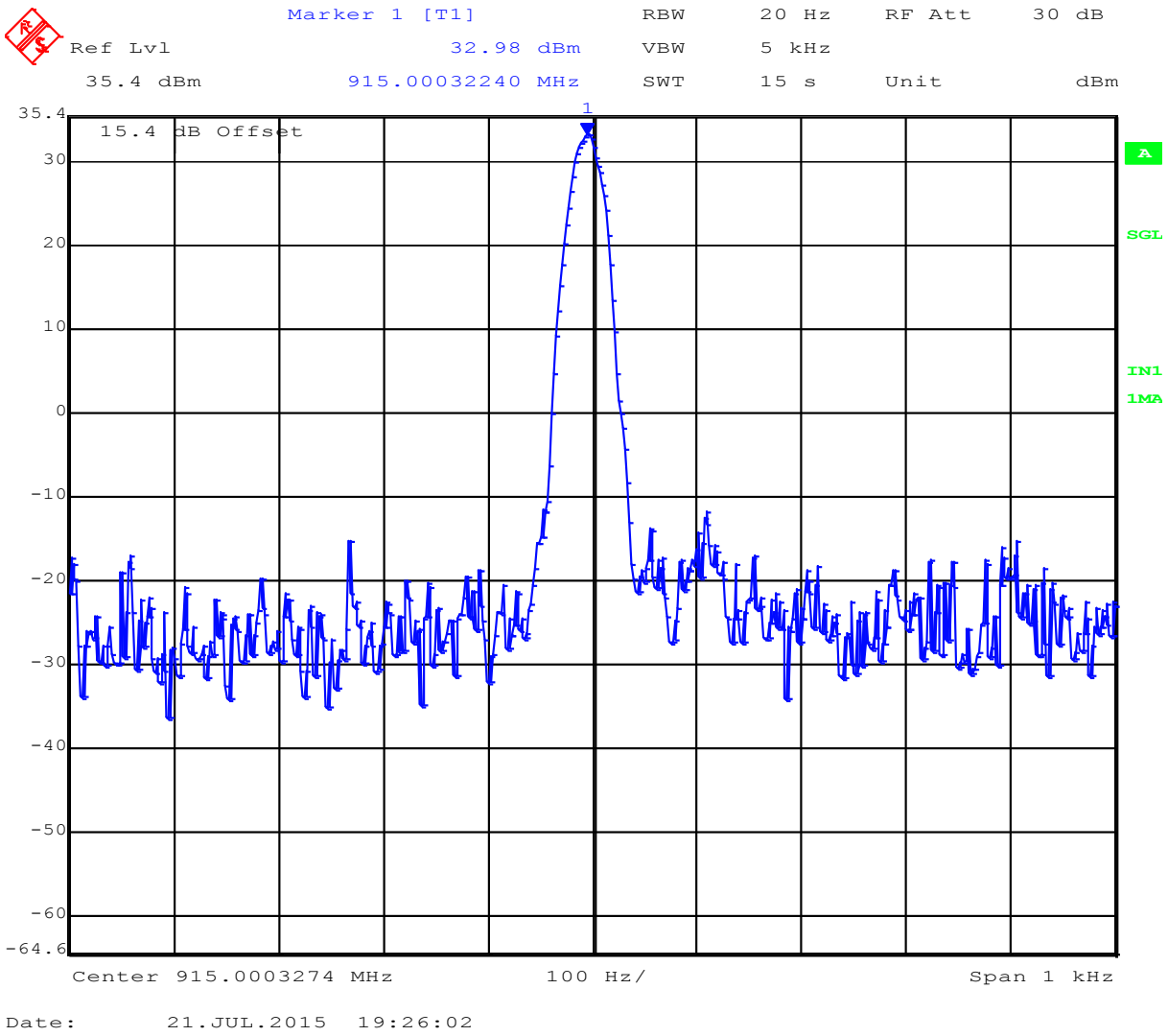
Frequency Error -5.0°C +15.0 Vdc



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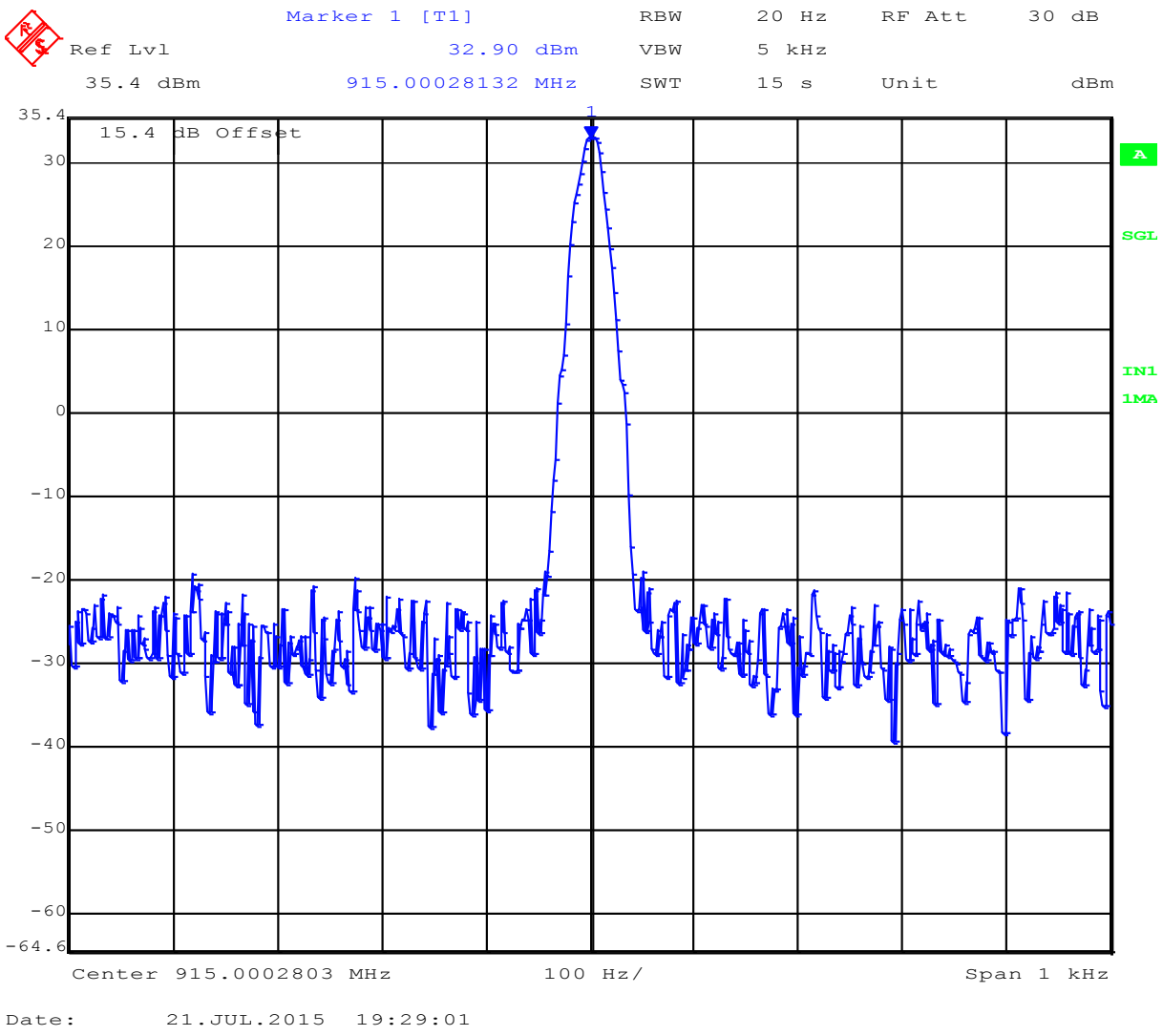
Frequency Error +5.0°C +15.0 Vdc



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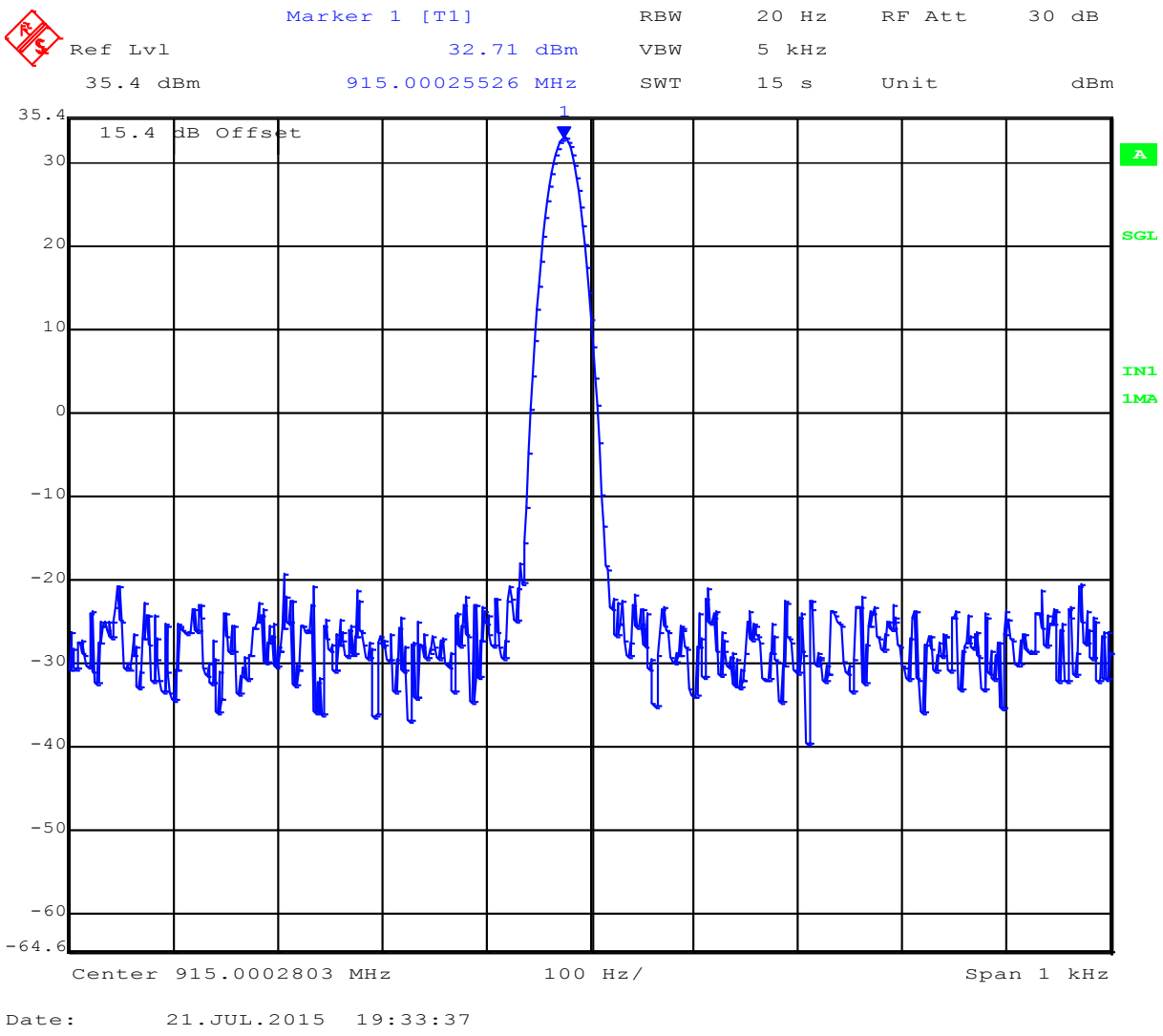
Frequency Error +15°C +15.0 Vdc



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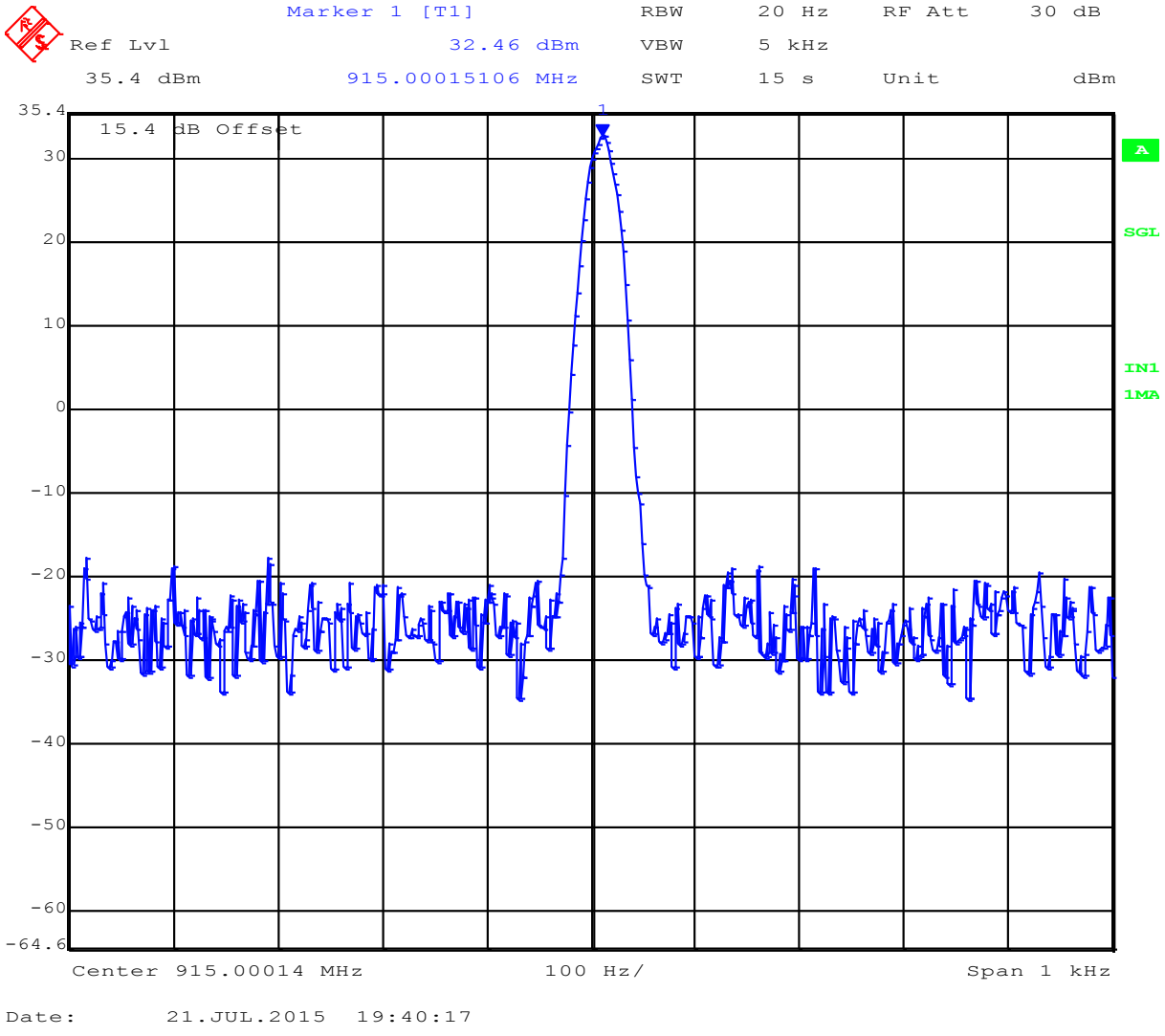
Frequency Error +25.0°C +13.5 Vdc



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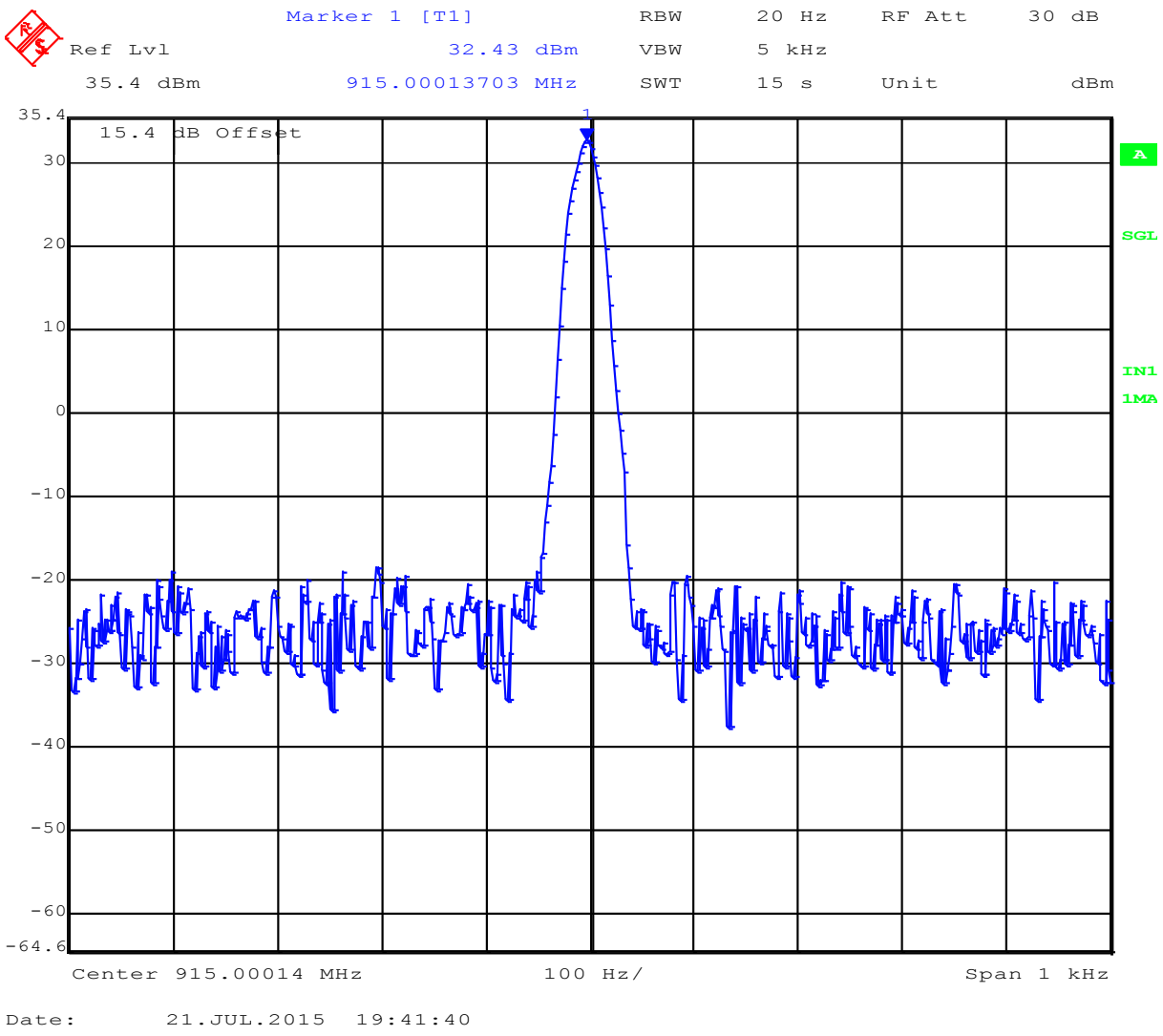
Frequency Error +25°C +16.5 Vdc



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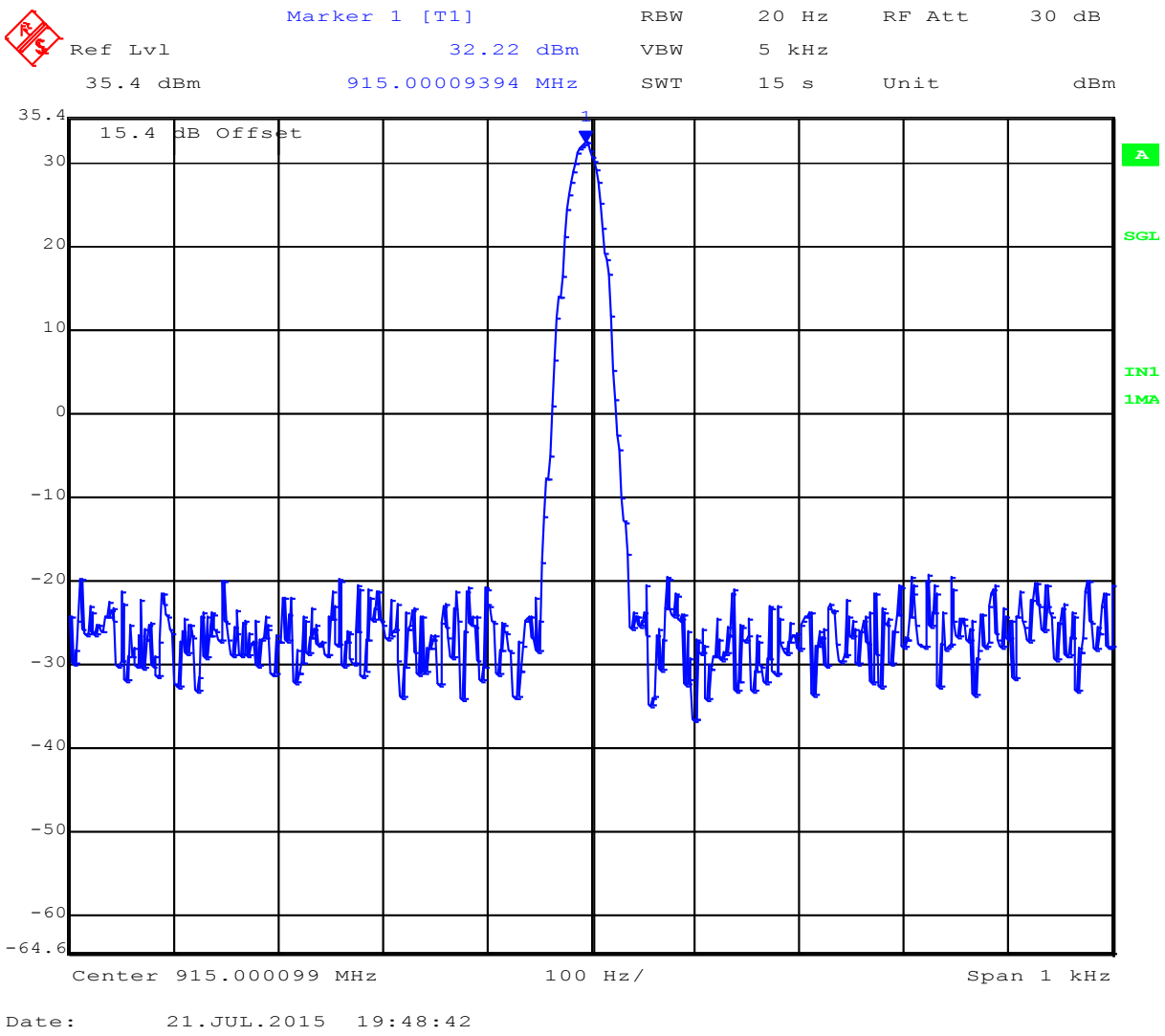
Frequency Error +35°C +15.0 Vdc



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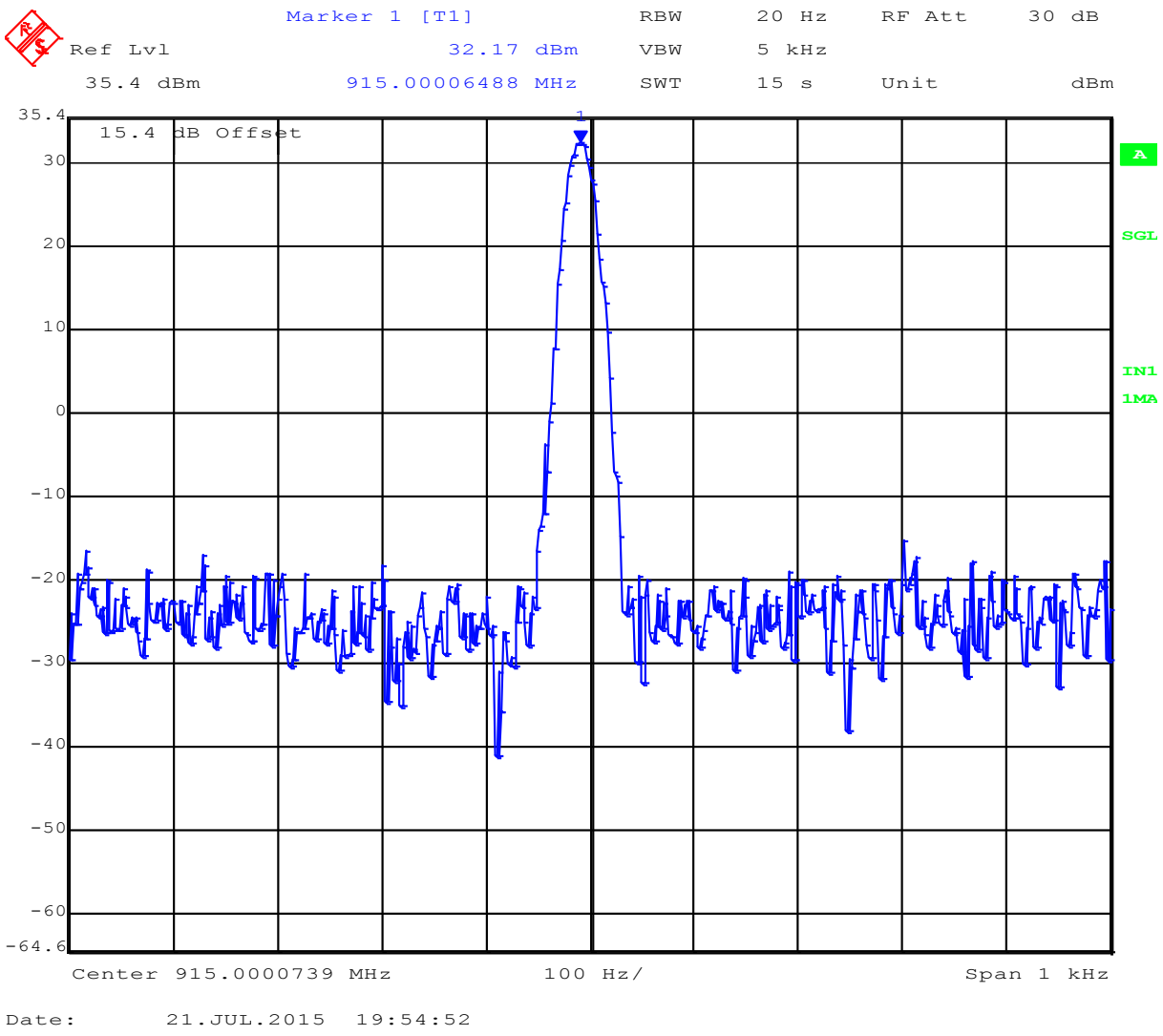
Frequency Error +45°C +15.0 Vdc



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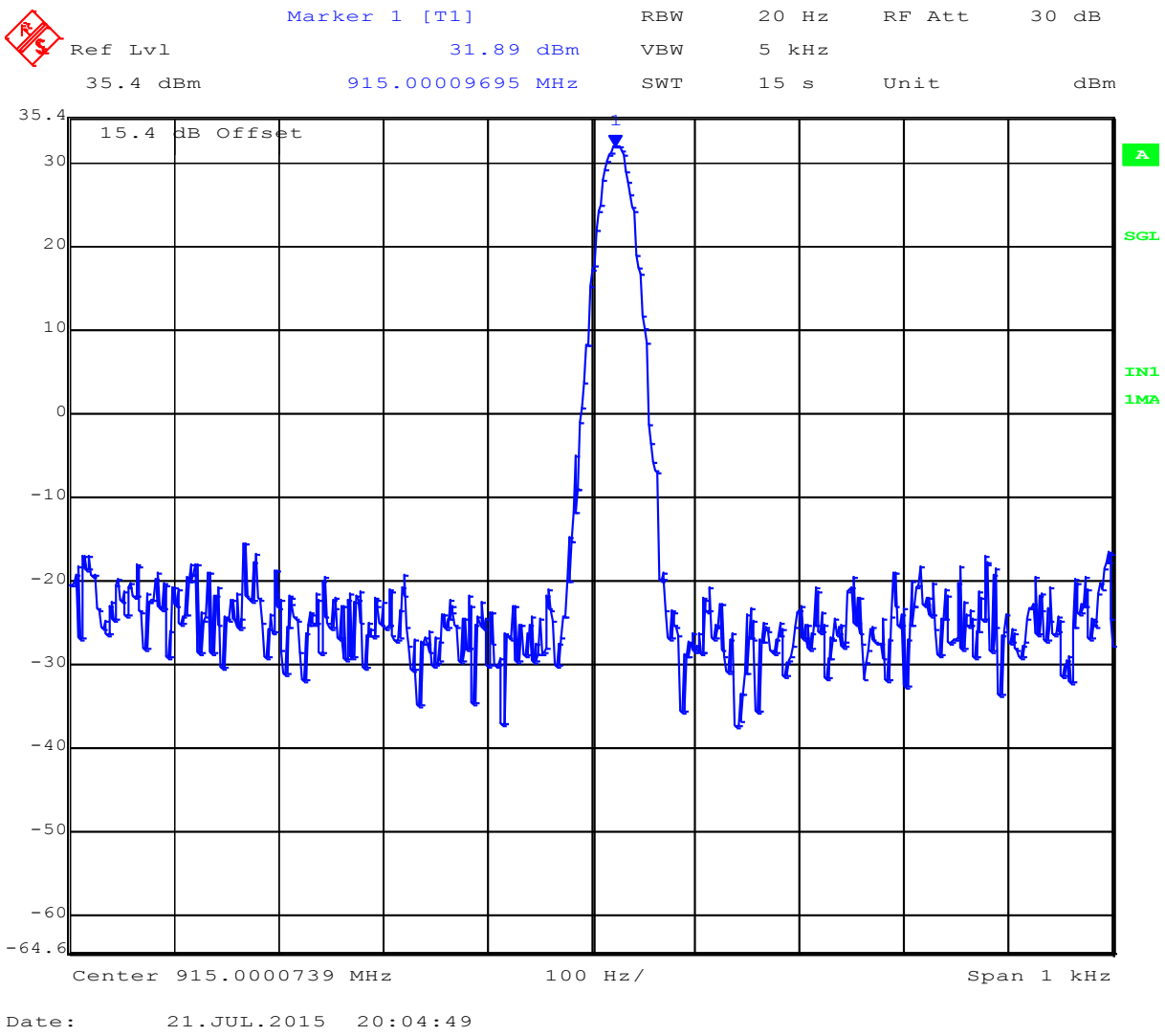
Frequency Error +55°C +15.0 Vdc



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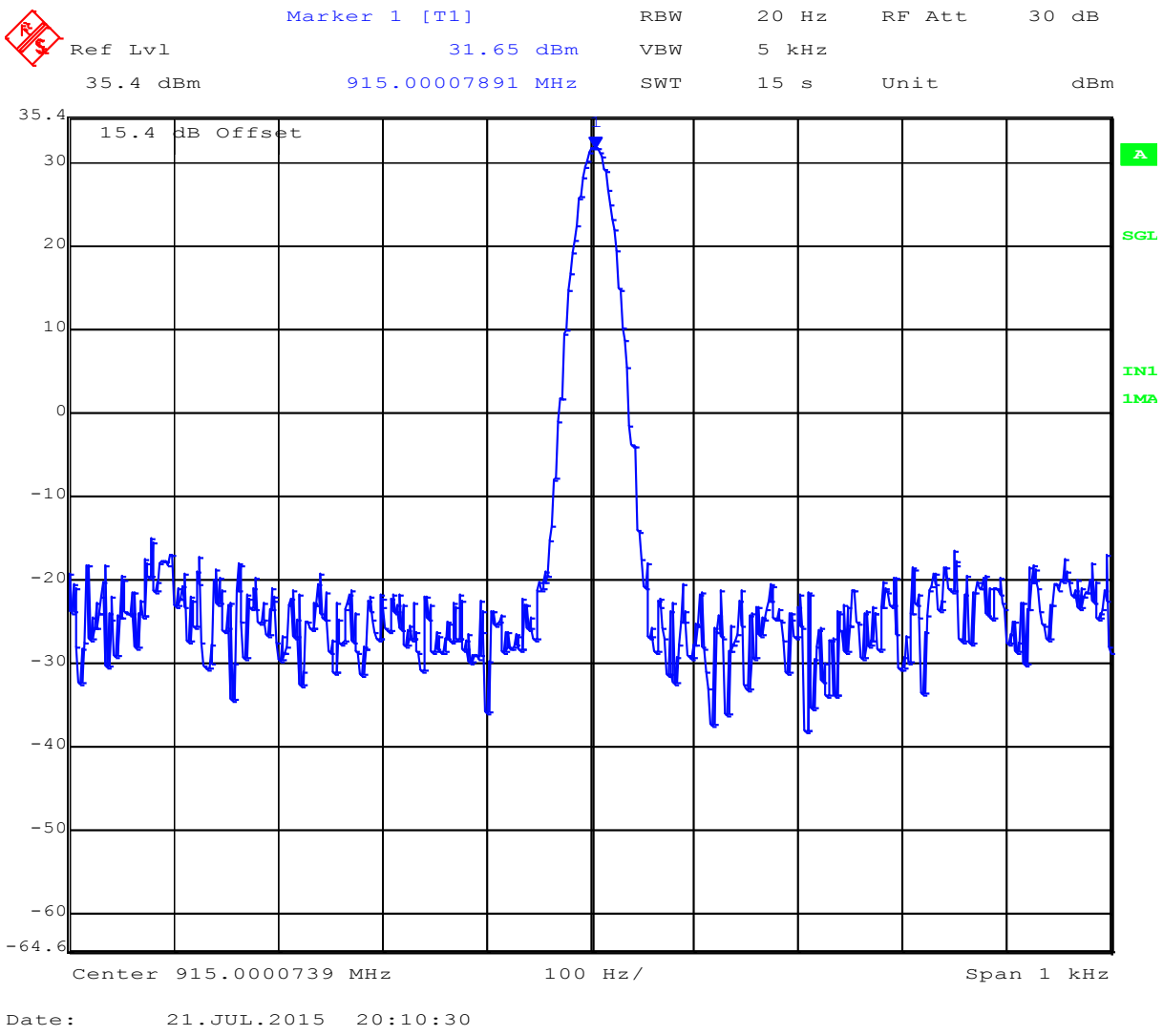
Frequency Error +65°C +15.0 Vdc



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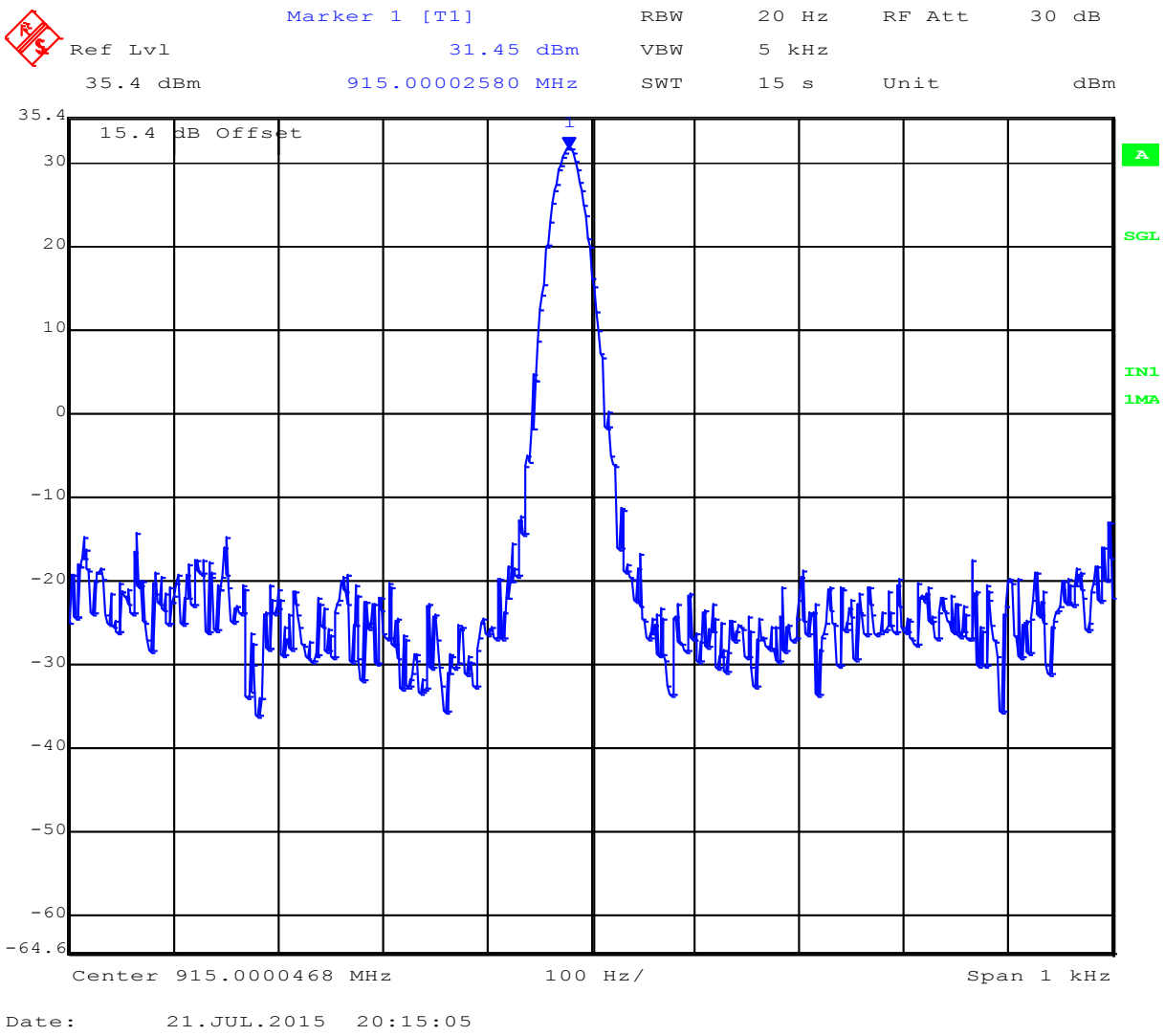
Frequency Error +75°C +15.0 Vdc



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Laboratory Measurement Uncertainty for Frequency Stability

Measurement uncertainty	±0.866 ppm

Traceability

Method
Measurements were made per work instruction WI-02 'Frequency Measurement'

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5.1.5. Spectrum Mask (Band-Edge) & Spurious Emissions

FCC 47 CFR Part 90, Subpart Z; §90.1323, 2.1051

5.1.5.1. Spectrum Mask (Band-Edge)

Test Procedure
The widest operational bandwidth was used in order to prove compliance with Spectrum Mask (Band-Edge) compliance. Maximum operational mode for 99% bandwidth was modulated (OOK) and therefore only these results are reported.

Conducted spurious emissions were measured to 10 GHz in a peak hold mode.

Test Set-up is shown in Section 3.6 Test Configuration

Limits

For operation in the 902 – 928 MHz band the limits are defined as the power of any emission outside the frequency band of operation being attenuated below the transmitter power (P) within the licensed band of operation, measured in Watts, by at least
55 + 10*Log (P) = -25 dBm.

P = Maximum Power = +33.28 dBm = 2.1281 W
Attenuation = 57.13 dB

Limit = -25 dBm

Band-edges
Lower Frequency Band 902 MHz, 904 MHz
Upper Frequency Band 909.75 MHz, 921.75 MHz

Ambient conditions.
Temperature: 17 to 23 °C Relative humidity: 31 to 57 % Pressure: 999 to 1012 mbar

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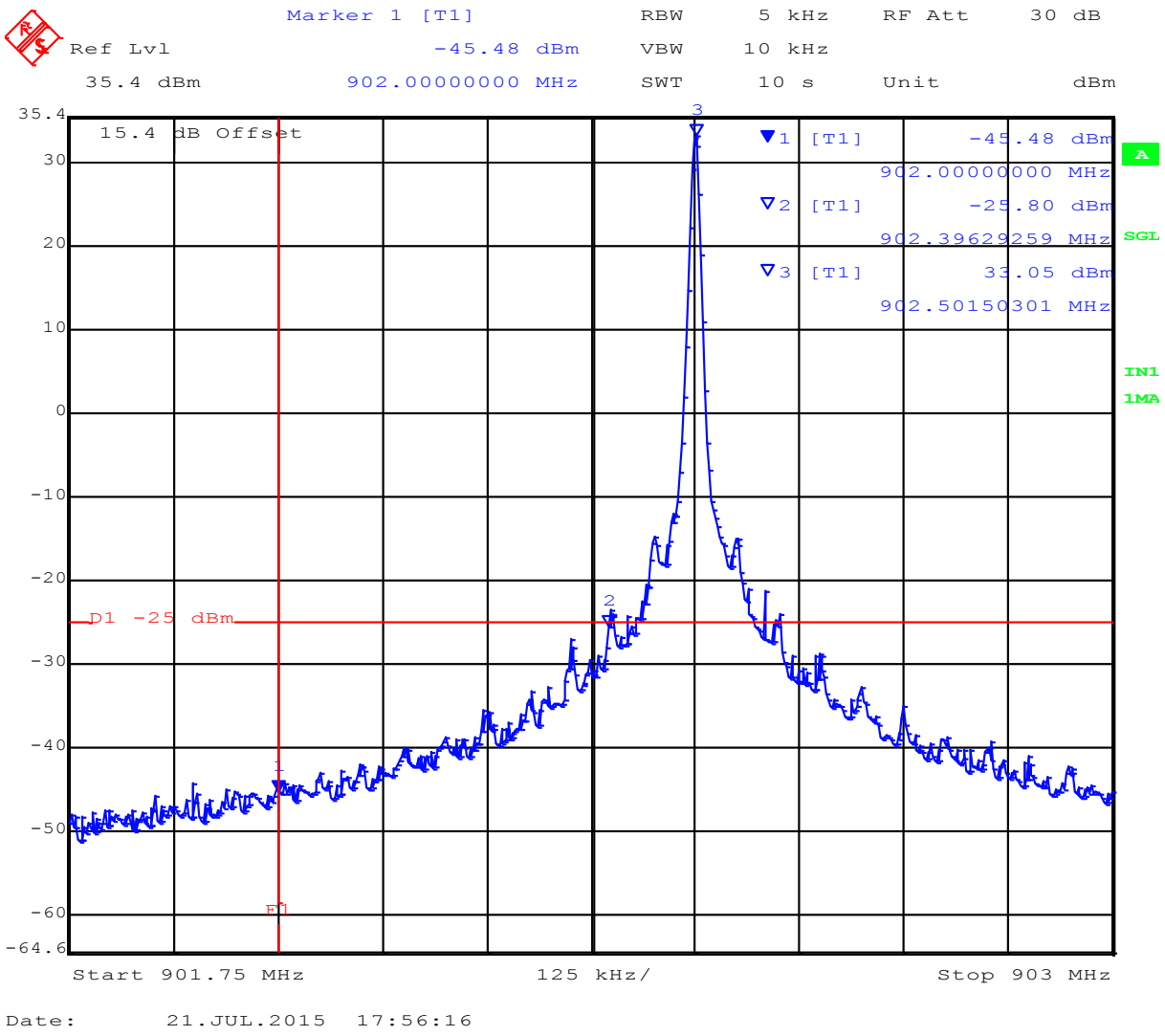
Band-edge 902 MHz, Channel 902. 50 MHz



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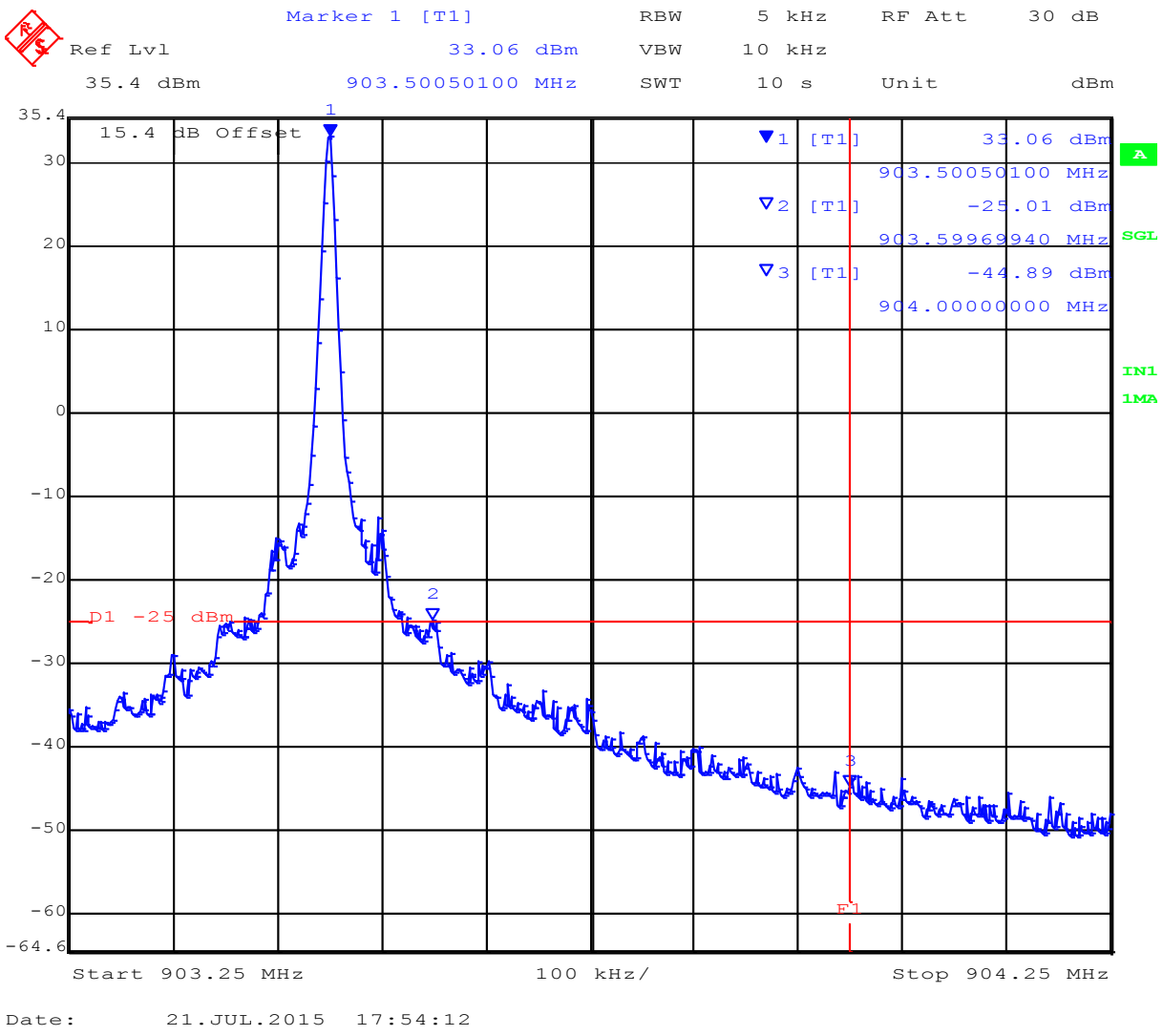
Band-edge 904 MHz Channel, 903.50 MHz



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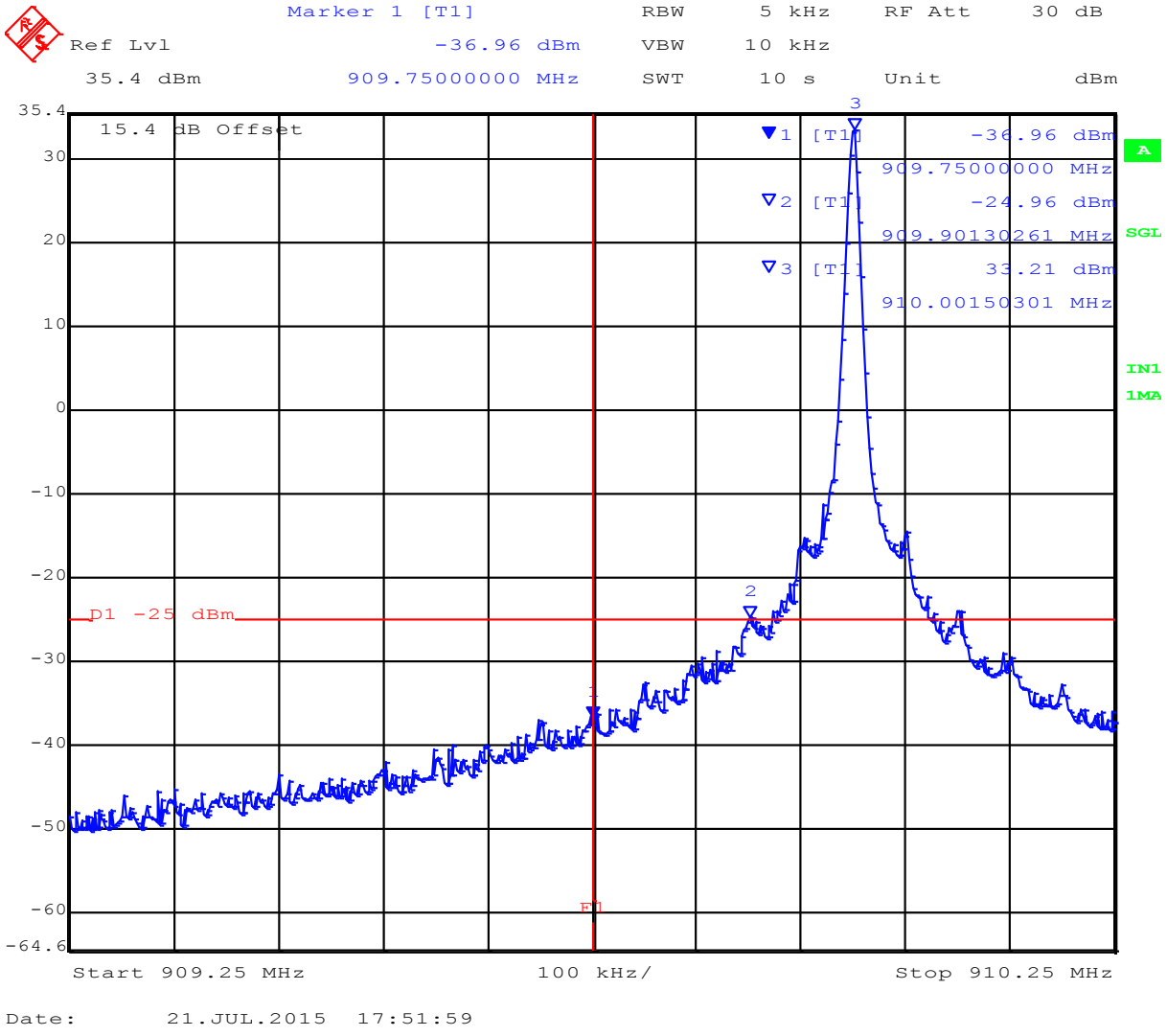
Band-edge 909.75 MHz, Channel 910.00 MHz



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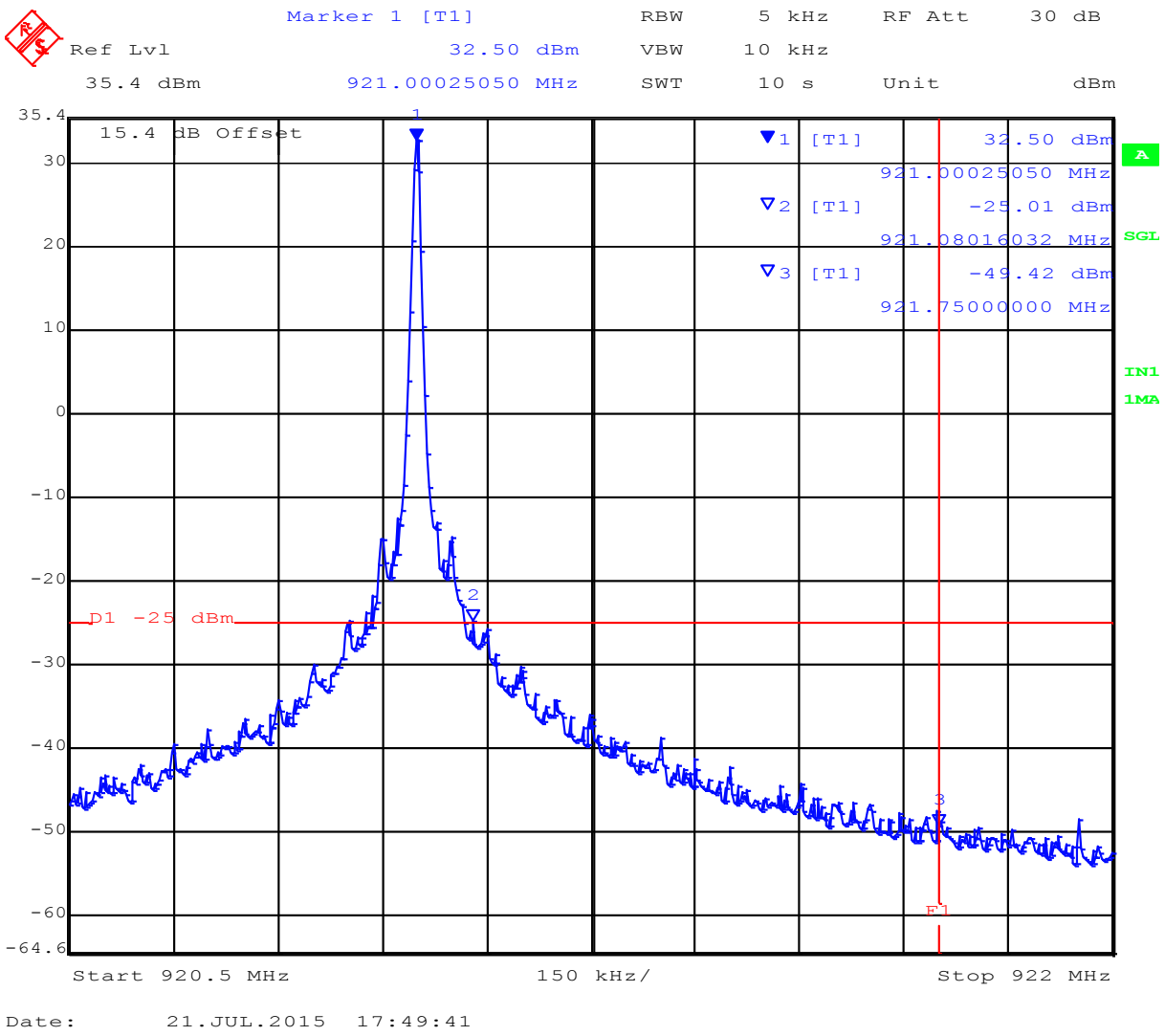
Band-edge 921.75 MHz Channel, 921.75 MHz



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5.1.5.2. Transmitter Conducted Spurious Emissions (30 M- 10 GHz)

Spurious Emissions at Antenna Terminal

CW Operational Mode used in order to prove compliance

Frequency Band 902 – 904 MHz

Channel Centre Frequency (MHz)	Start Frequency (MHz)	Stop Frequency (MHz)	Maximum Emission Observed (dBm)	Limit (dBm)	Margin (dB)
902.50	30.00	1,000	-36.61	-25	-11.61
	1,000	10,000	-33.58		-8.58
903.00	30.00	1,000	-36.48		-11.48
	1,000	10,000	-34.23		-9.23
903. 50	30.00	1,000	-32.59		-7.59
	1,000	10,000	-33.79		-8.79

Frequency Band 909.75 – 921.75 MHz

Channel Centre Frequency (MHz)	Start Frequency (MHz)	Stop Frequency (MHz)	Maximum Emission Observed (dBm)	Limit (dBm)	Margin (dB)
910.00	30.00	1,000	-36.90	-25	-11.9
	1,000	10,000	-33.74		-8.74
915.00	30.00	1,000	-36.87		-11.87
	1,000	10,000	-34.03		-9.03
921.00	30.00	1,000	-36.86		-11.86
	1,000	10,000	-34.29		-9.29

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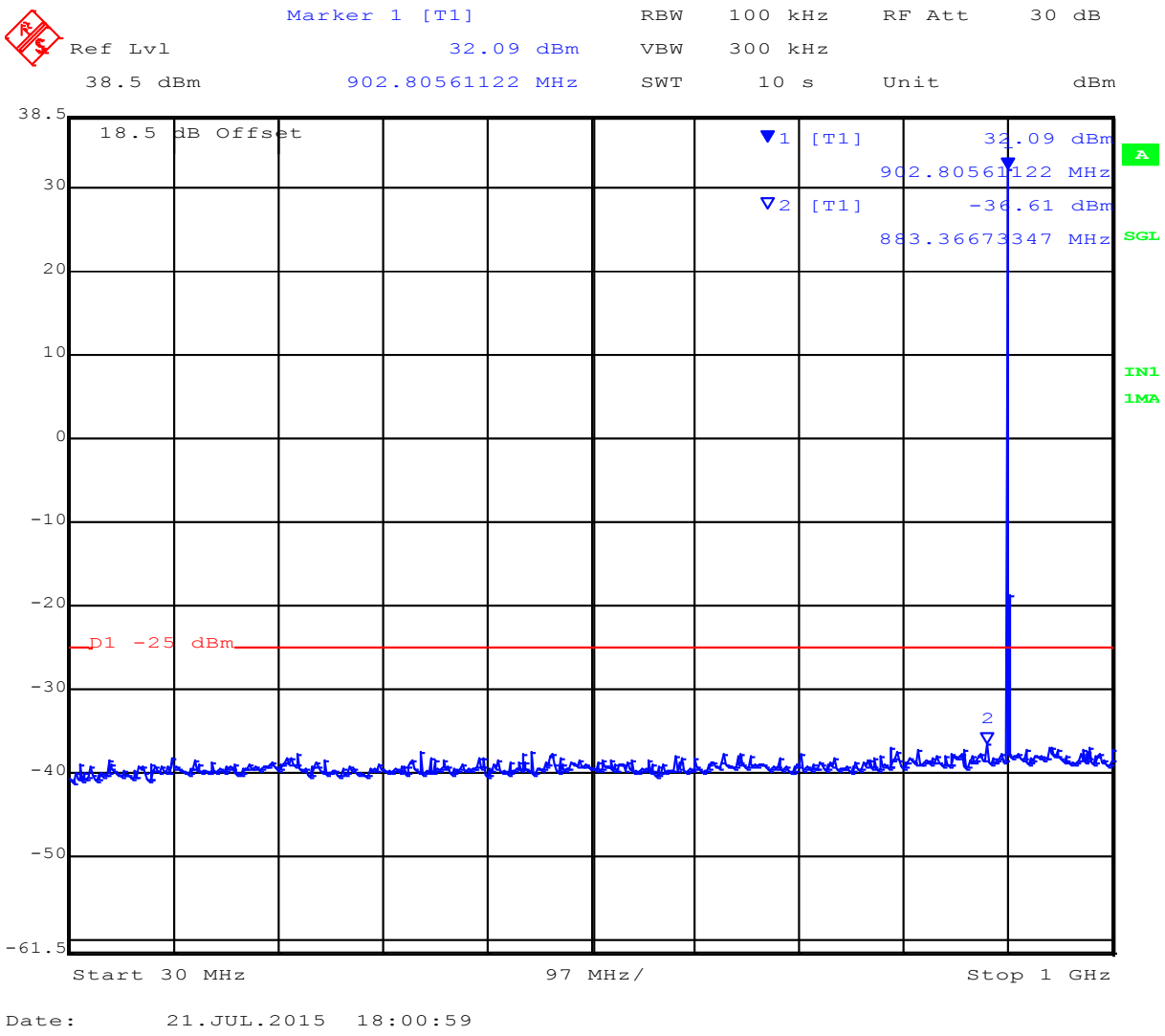
CW Mode Channel 902.50 MHz Conducted Spurious Emissions 0.03 - 1 GHz



Note: The emission breaking the limit line is the fundamental carrier

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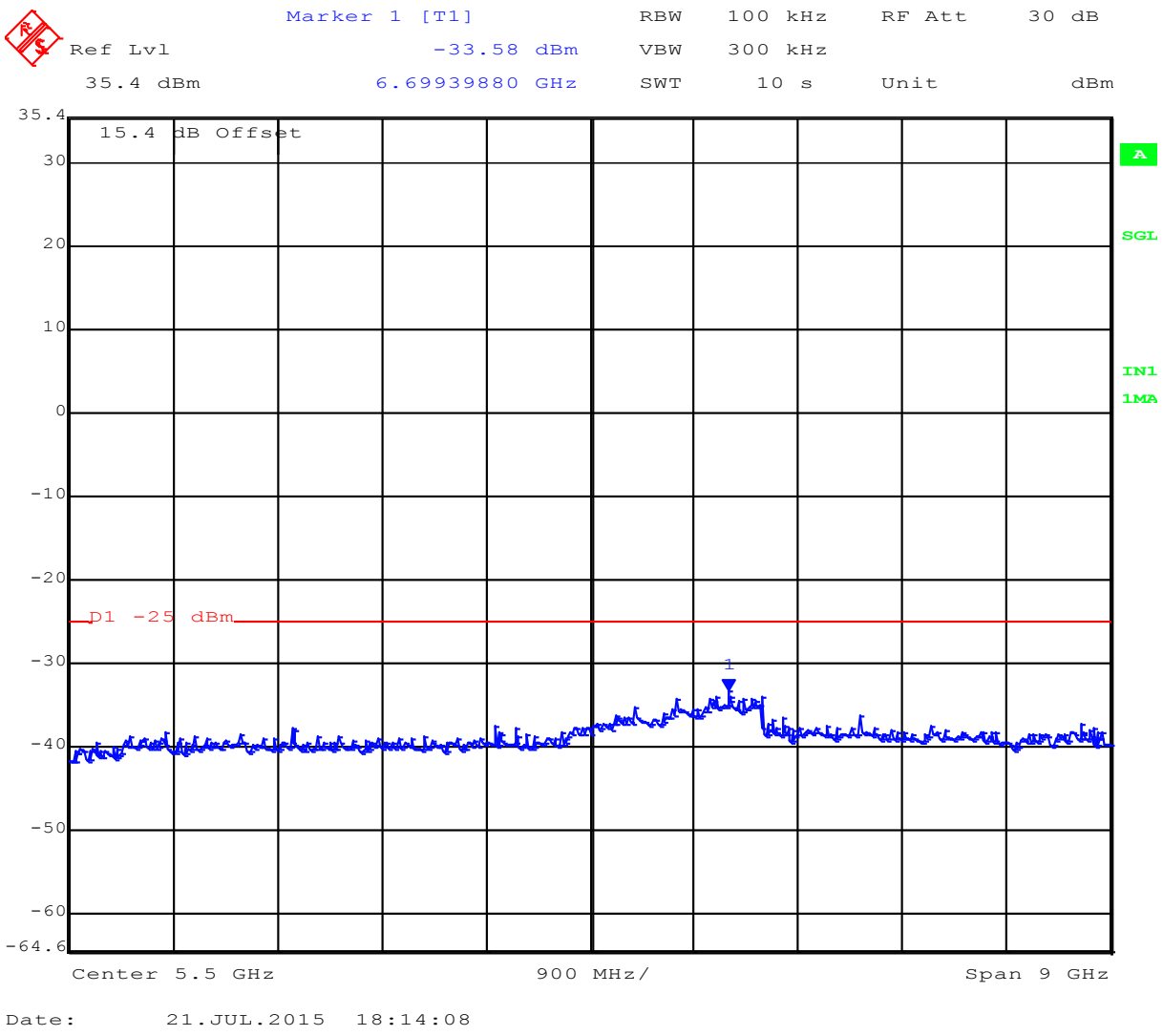
CW Mode Channel 902.50 MHz Conducted Spurious Emissions 1 - 10 GHz



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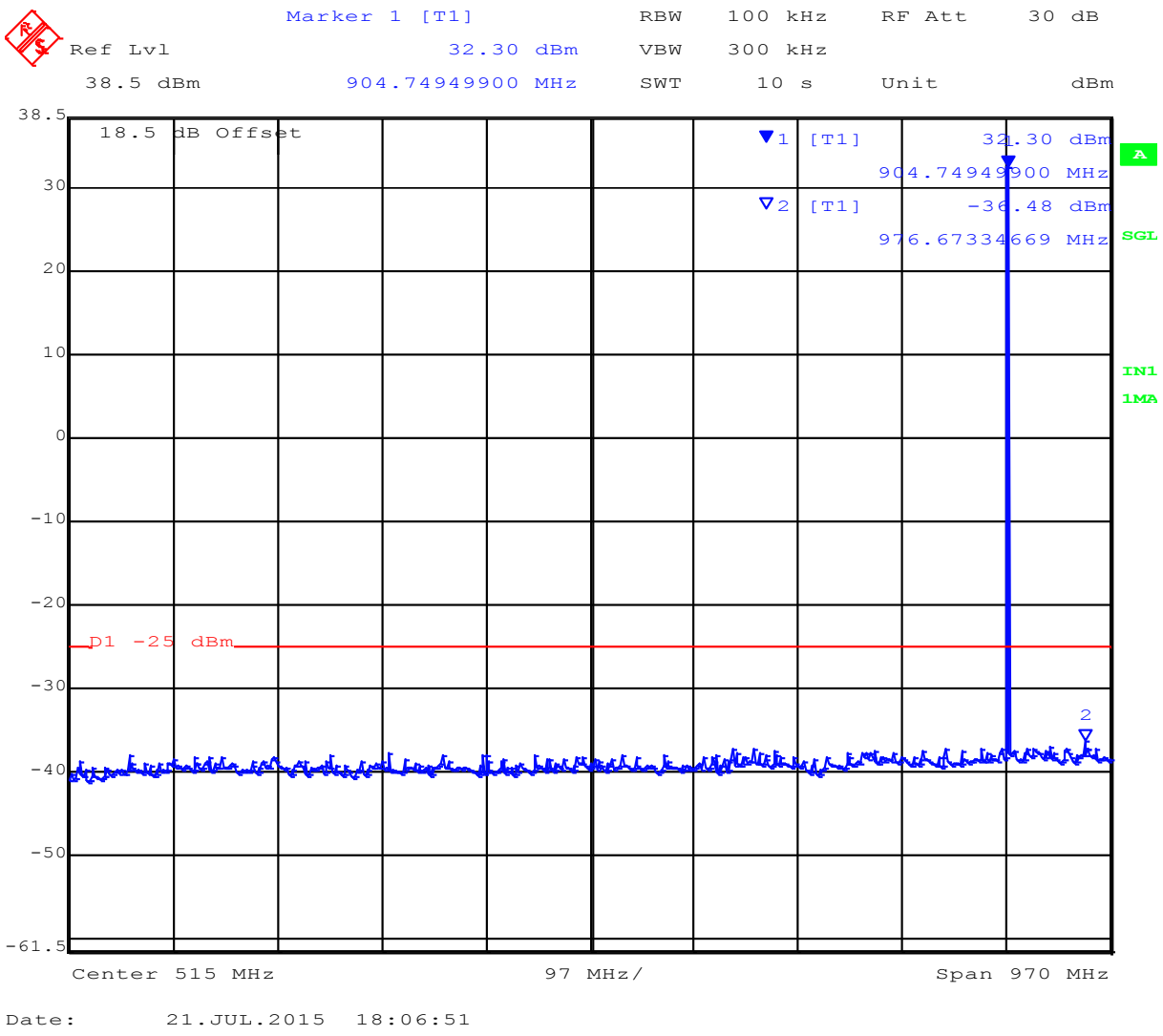
CW Mode Channel 903.00 MHz Conducted Spurious Emissions 0.03 - 1 GHz



Note: The emission breaking the limit line is the fundamental carrier

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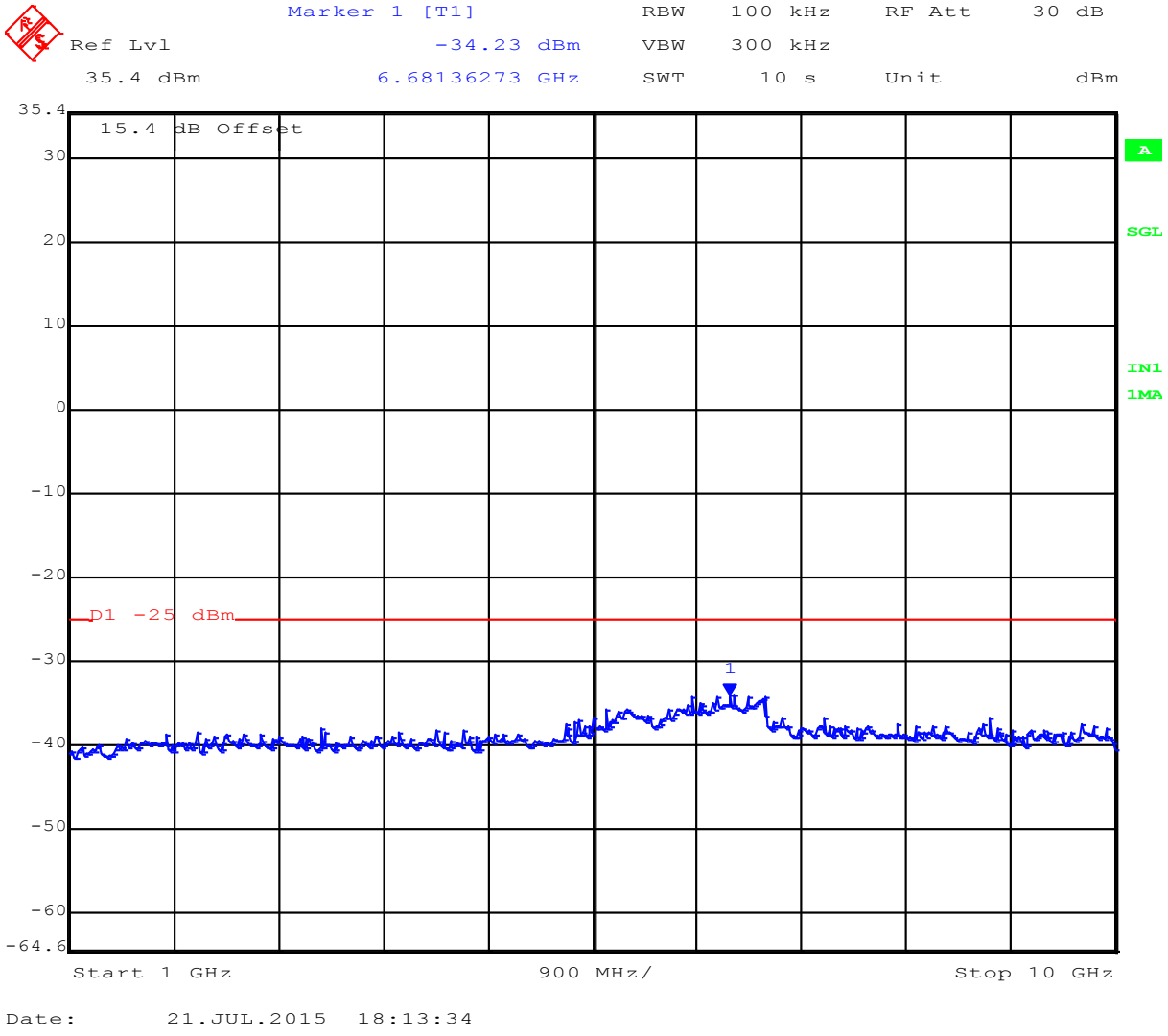
CW Mode Channel 903.00 MHz Conducted Spurious Emissions 1 - 10 GHz



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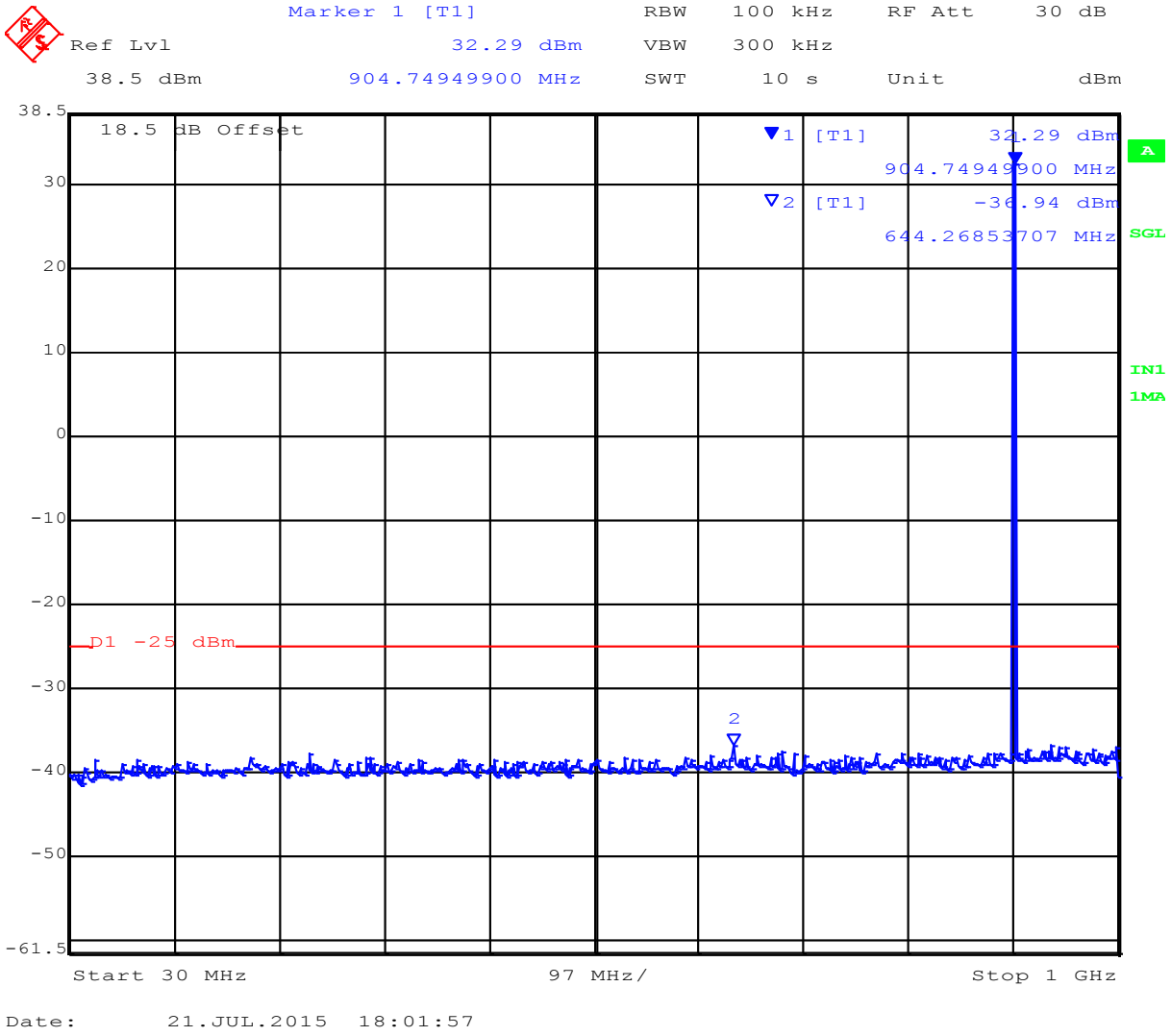
CW Mode Channel 903.50 MHz Conducted Spurious Emissions 0.03 - 1 GHz



Note: The emission breaking the limit line is the fundamental carrier

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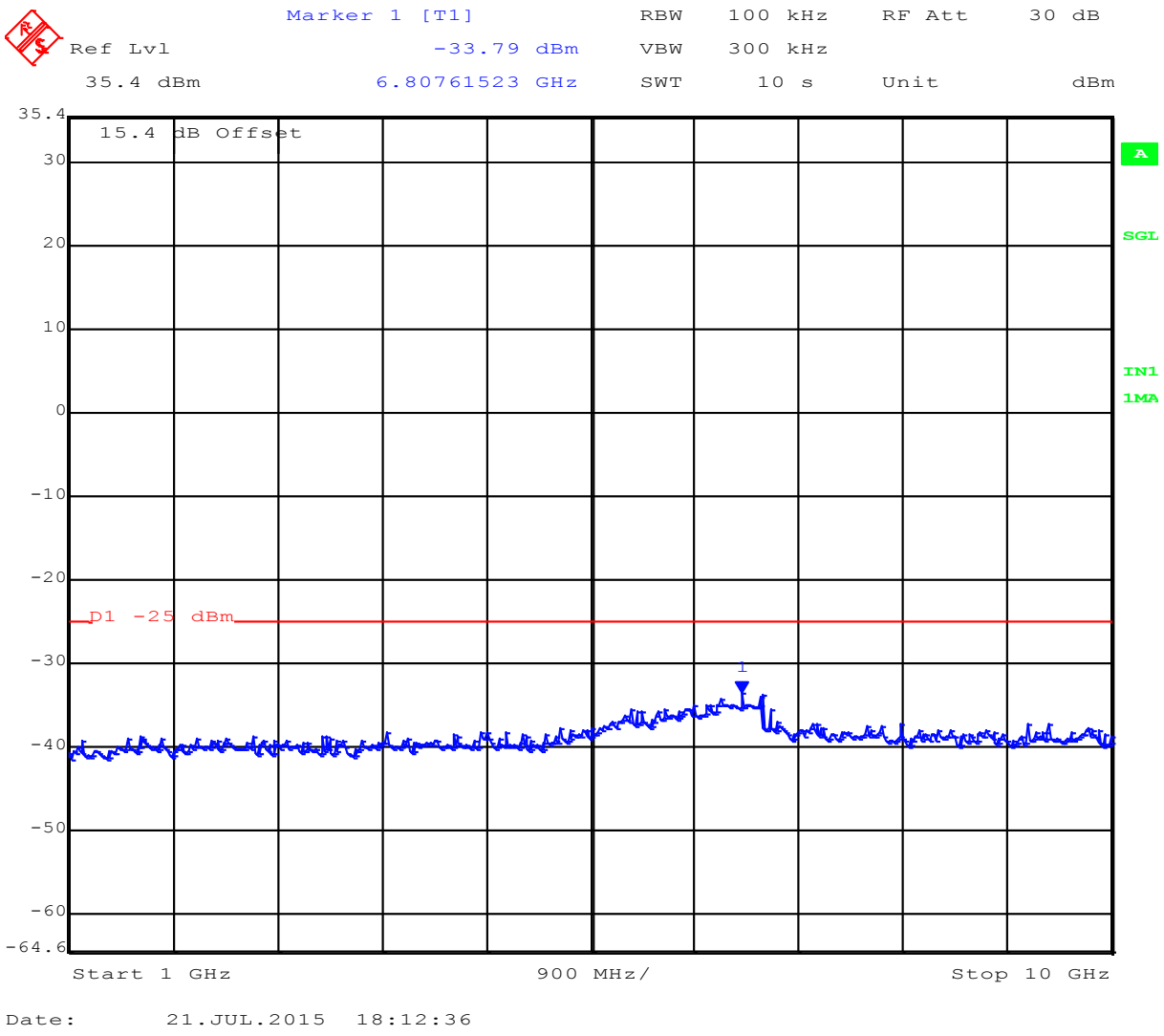
CW Mode Channel 903.50 MHz Conducted Spurious Emissions 1 - 10 GHz



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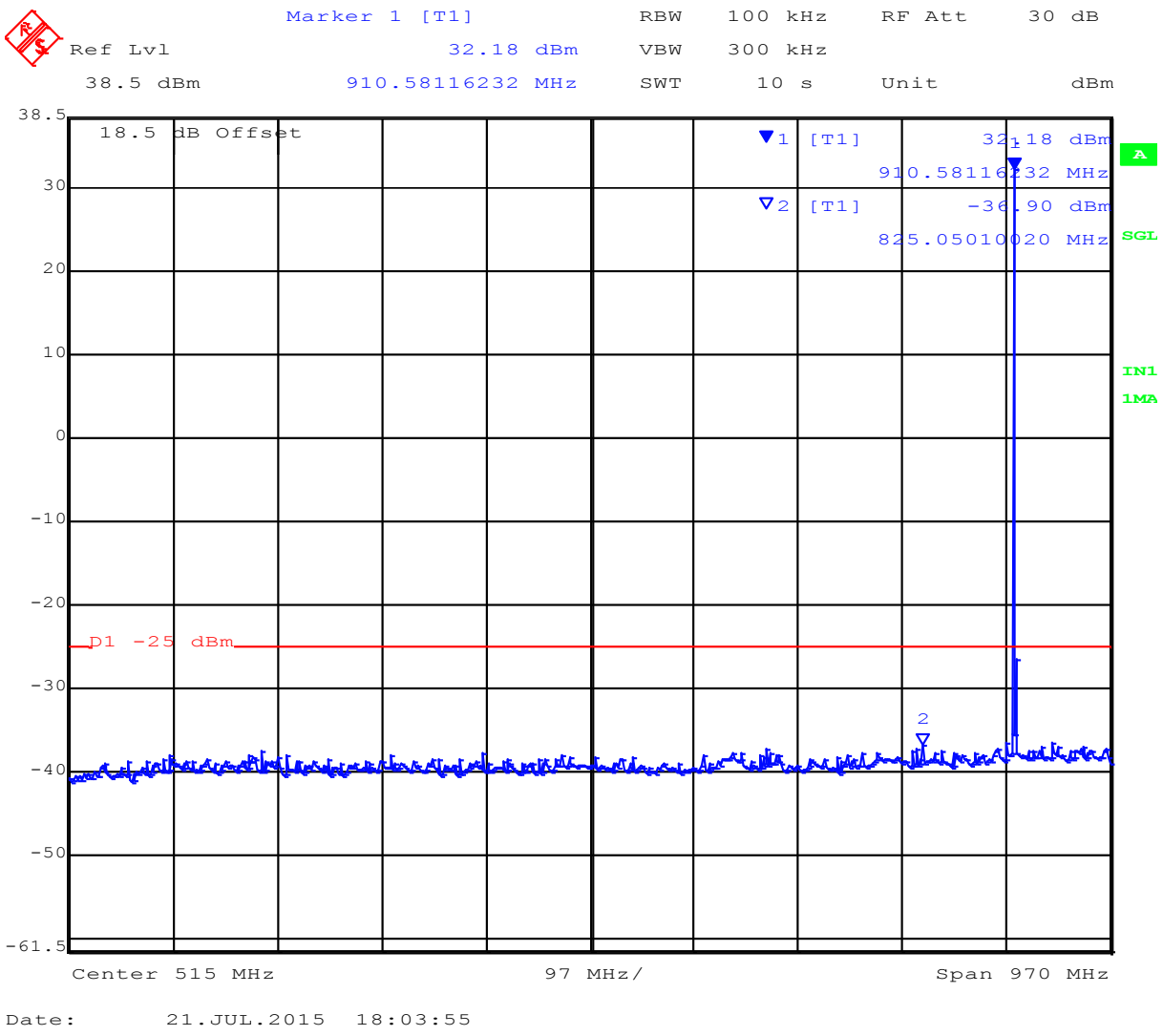
CW Mode Channel 910.00 MHz Conducted Spurious Emissions 0.03 - 1 GHz



Note: The emission breaking the limit line is the fundamental carrier

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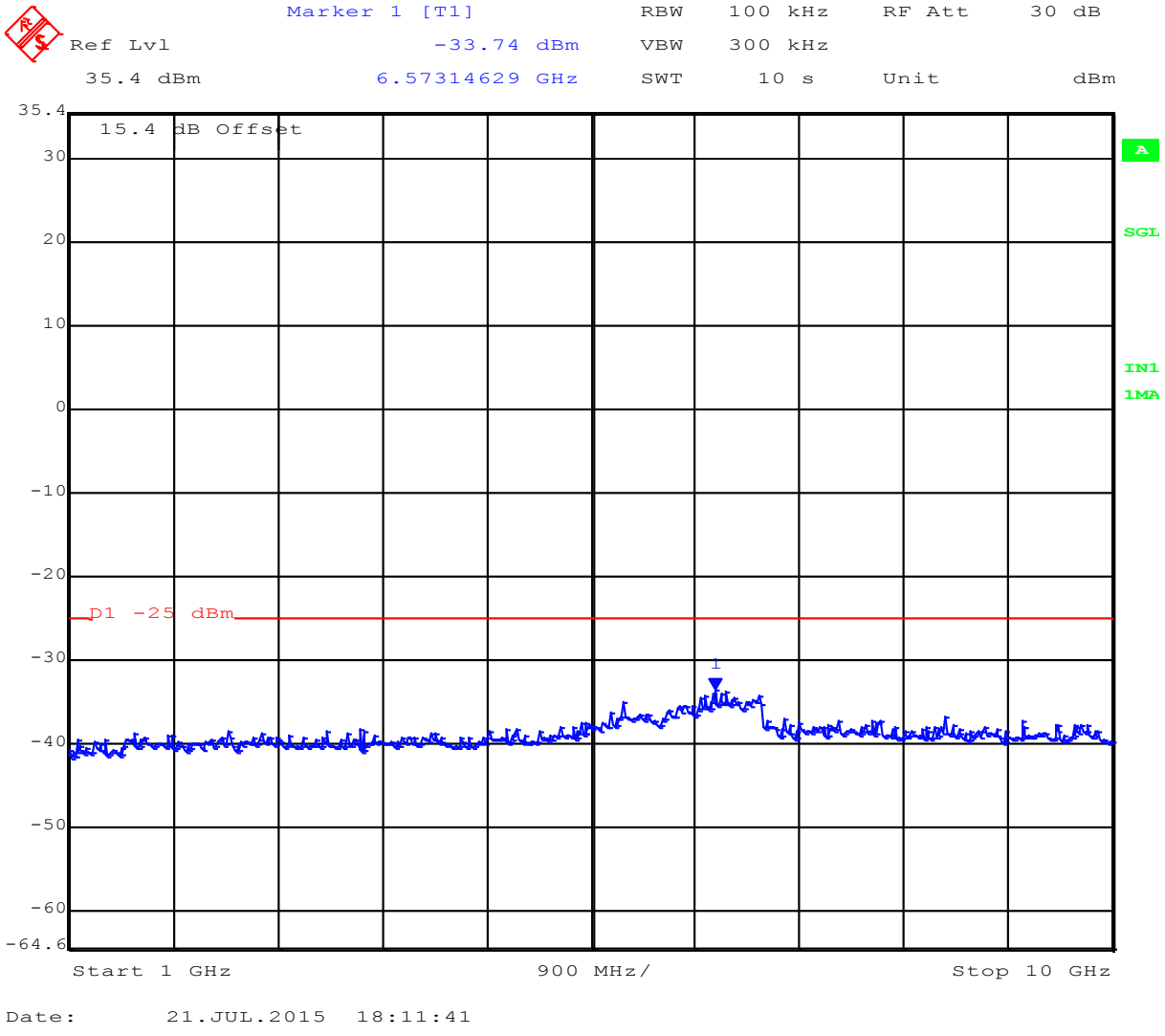
CW Mode Channel 910.00 MHz Conducted Spurious Emissions 1 - 10 GHz



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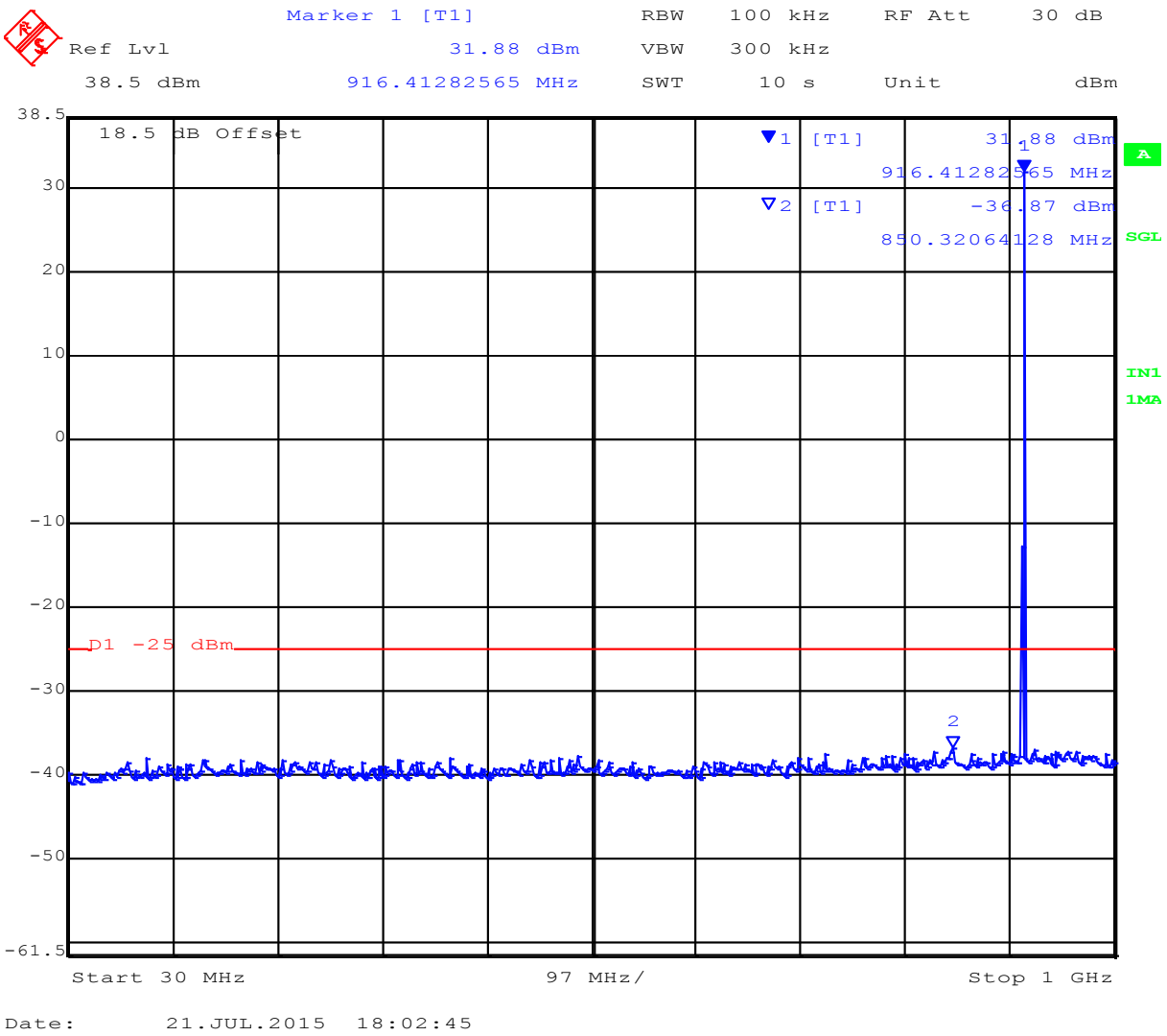
CW Mode Channel 915.00 MHz Conducted Spurious Emissions 0.03 - 1 GHz



Note: The emission breaking the limit line is the fundamental carrier

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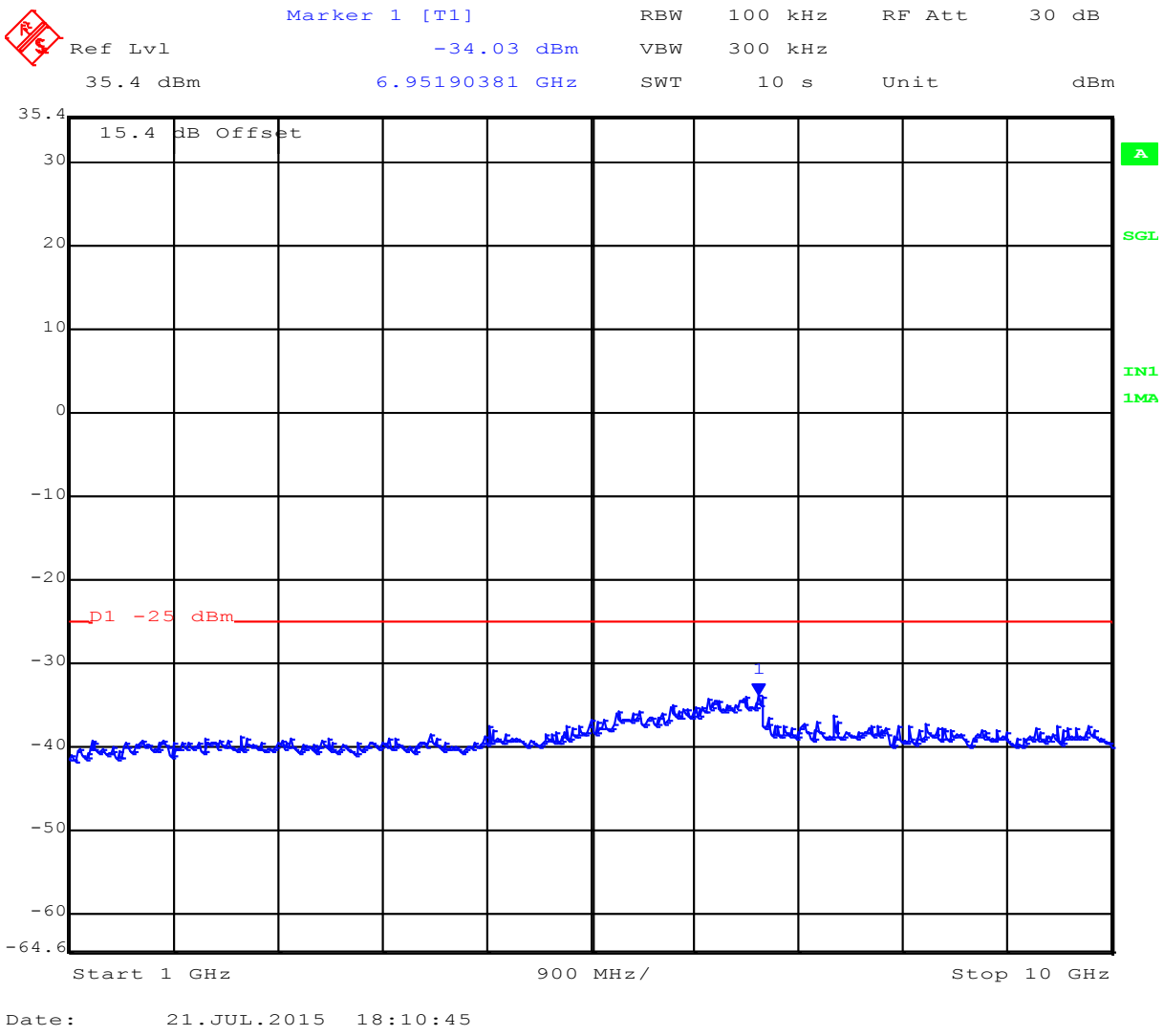
CW Mode Channel 915.00 MHz Conducted Spurious Emissions 1 - 10 GHz



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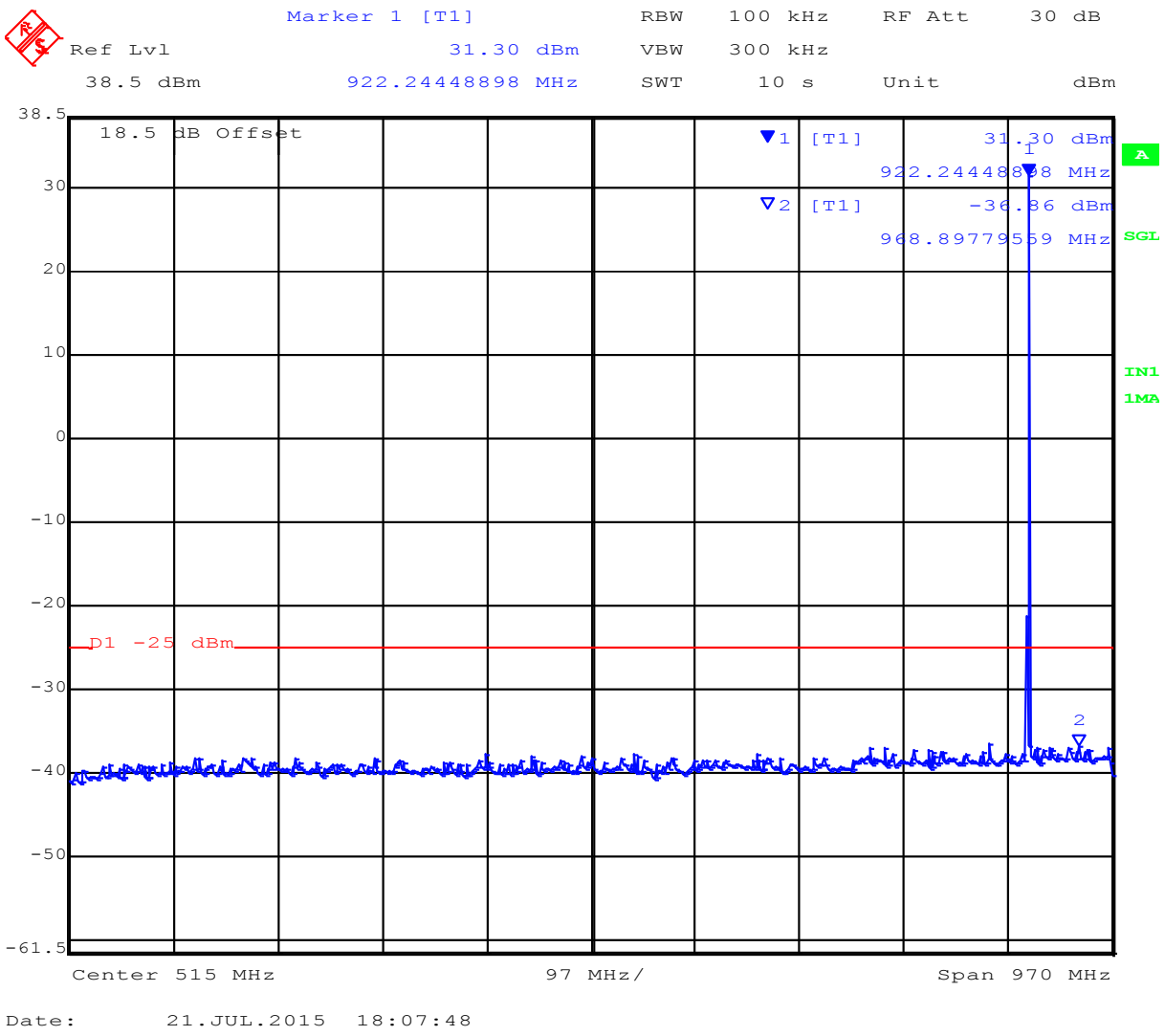
CW Mode Channel 921.00 MHz Conducted Spurious Emissions 0.03 - 1 GHz



Note: The emission breaking the limit line is the fundamental carrier

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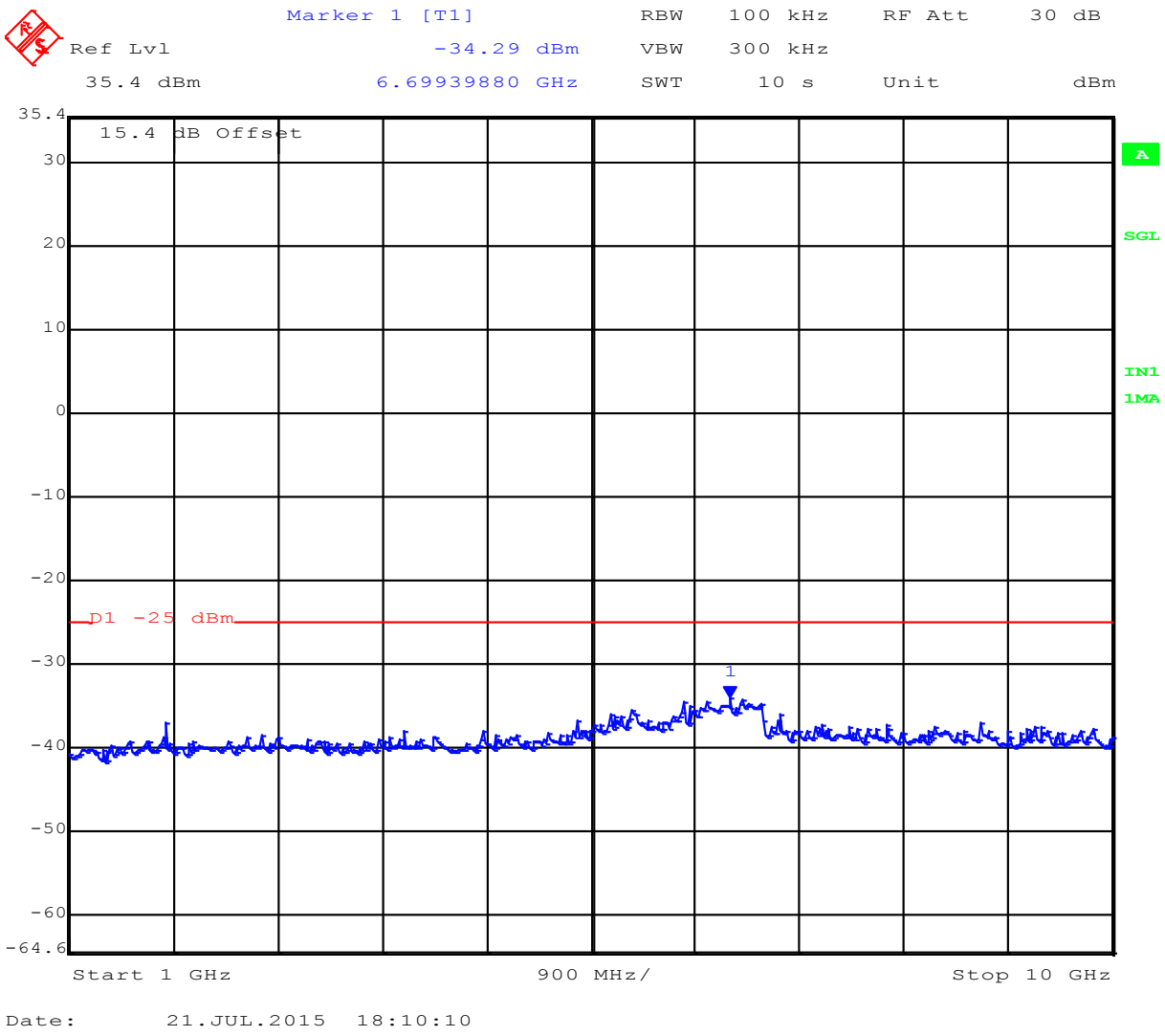
CW Mode Channel 921.00 MHz Conducted Spurious Emissions 1 - 10 GHz



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Laboratory Measurement Uncertainty for Conducted Spurious Emissions

Measurement uncertainty	±2.37 dB

Traceability

Method
Measurements were made per work instruction WI-05 'Measurement of Spurious Emissions'

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5.1.6. Radiated Spurious Emissions

5.1.6.1. Transmitter Radiated Emissions above 1 GHz

FCC 47 CFR Part 90, Subpart Z; §90.1323, 2.1053;
ANSI/TIA-603

Test Procedure
Measurements were made while EUT was operating in the worst case CW mode of operation at the appropriate center frequency. Substitution was performed on any emissions observed. The antenna port was attenuated with a 50 Ω termination.

The measurement equipment was set to measure in peak hold mode. The emissions were measured in the anechoic chamber at a 3-meter distance on every azimuth in both horizontal and vertical polarities. The emissions are recorded and maximized as a function of azimuth by rotation through 360° with a spectrum analyzer in peak hold mode.

The highest emissions relative to the limit are listed for each frequency band measured.

Limits

For operation in the 902 – 928 MHz band the limits are defined as the power of any emission outside the frequency band of operation being attenuated below the transmitter power (P) within the licensed band of operation, measured in Watts, by at least
55 + 10*Log (P) = -25 dBm.

P = Maximum Power = +33.28 dBm = 2.1281 W
Attenuation = 57.13 dB

Limit = -25 dBm (to correct for ERP measurement an offset was included in the measurement equipment)

TIA/EIA 603 Compliance
For measurement purposes the antenna ports were terminated in 50 ohm's in accordance with TIA/EIA 603 measurement procedure.

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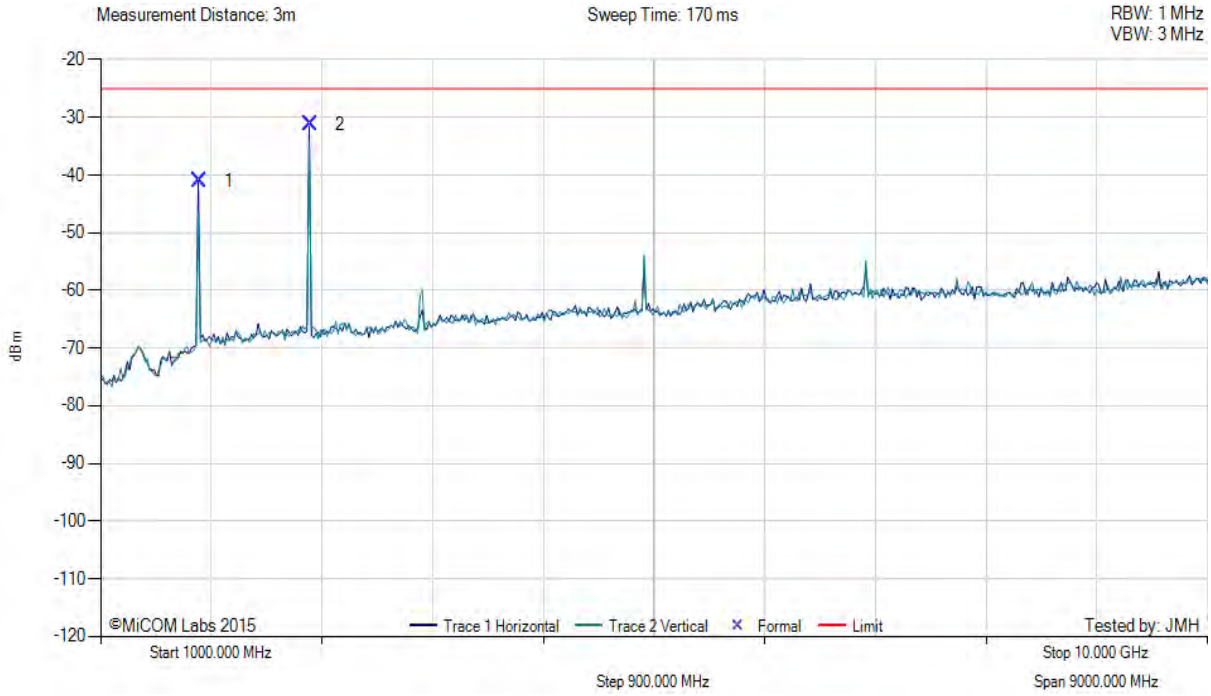
Equipment Configuration for Radiated Transmitter Unwanted Emissions in the Spurious Domain (1 - 12.75 GHz)			
Antenna:	50 Ohm Term	**Variant:**	TX Spur
Antenna Gain (dBi):	Antenna port terminated in 50Ω	**Modulation:**	CW
Beam Forming Gain (Y):	Not Applicable	**Duty Cycle (%):**	100
Channel Frequency (MHz):	902.50	**Data Rate:**	
Power Setting:	MAX	**Tested By:**	JMH

Test Measurement Results

Variant: TX Spur, Test Freq: 902.50 MHz, Antenna: 50 Ohm Term, Power Setting: MAX, Duty Cycle (%): 100



Num	Frequency MHz	Raw dBµV	Cable Loss	AF dB	Level dBµV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBµV/m	Margin dB	Pass /Fail
1	1804.97	-30.90	3.48	-13.63	-41.05	Peak	Horizontal	150	194	-25.0	-16.1	Pass
2	2707.50	-24.18	4.30	-11.37	-31.25	Peak	Horizontal	150	287	-25.0	-6.3	Pass

Test Notes: EUT at max power with 50 ohm Term on Antenna Port

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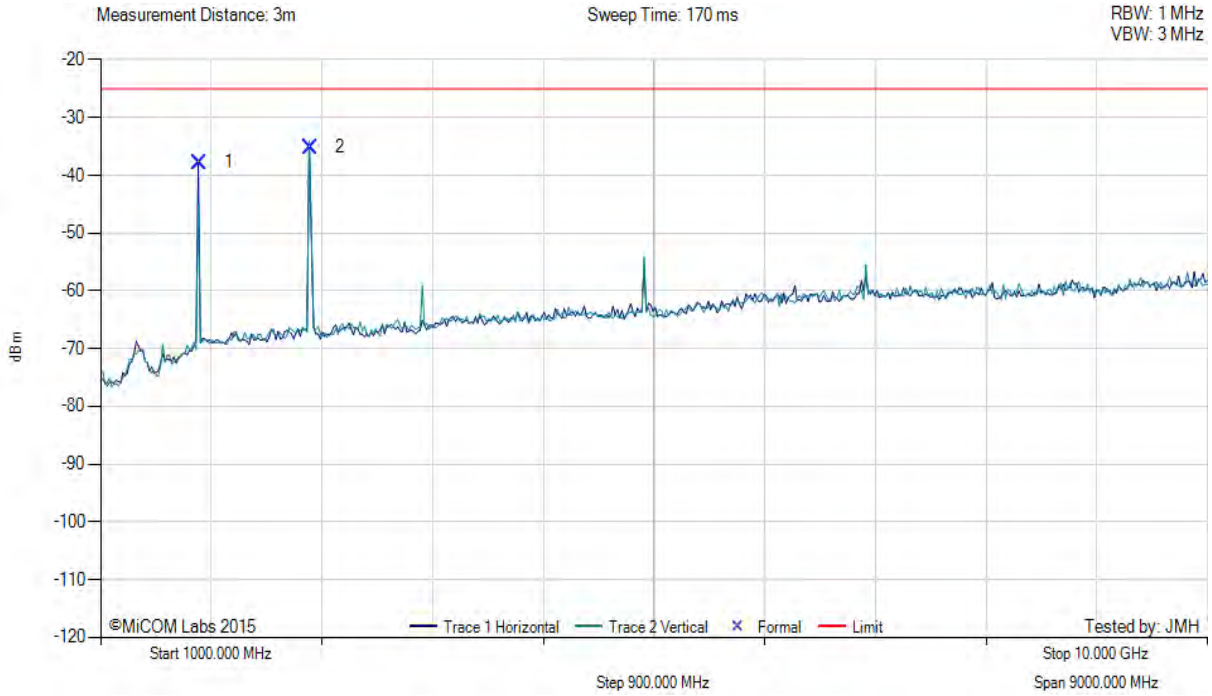
Equipment Configuration for Radiated Transmitter Unwanted Emissions in the Spurious Domain (1 - 12.75 GHz)

Antenna:	50 Ohm Term	**Variant:**	TX Spur
Antenna Gain (dBi):	Antenna port terminated in 50Ω	**Modulation:**	CW
Beam Forming Gain (Y):	Not Applicable	**Duty Cycle (%):**	100
Channel Frequency (MHz):	903.00	**Data Rate:**	
Power Setting:	RA4	**Tested By:**	JMH

Test Measurement Results

Variant: TX Spur, Test Freq: 903.00 MHz, Antenna: 50 Ohm Term, Power Setting: MAX, Duty Cycle (%): 100



Num	Frequency MHz	Raw dBµV	Cable Loss	AF dB	Level dBµV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBµV/m	Margin dB	Pass /Fail
1	1805.98	-27.62	3.48	-13.63	-37.77	Peak	Horizontal	150	311	-25.0	-12.8	Pass
2	2709.02	-28.10	4.31	-11.37	-35.16	Peak	Vertical	150	302	-25.0	-10.2	Pass

Test Notes: EUT at max power with 50 ohm Term on Antenna Port

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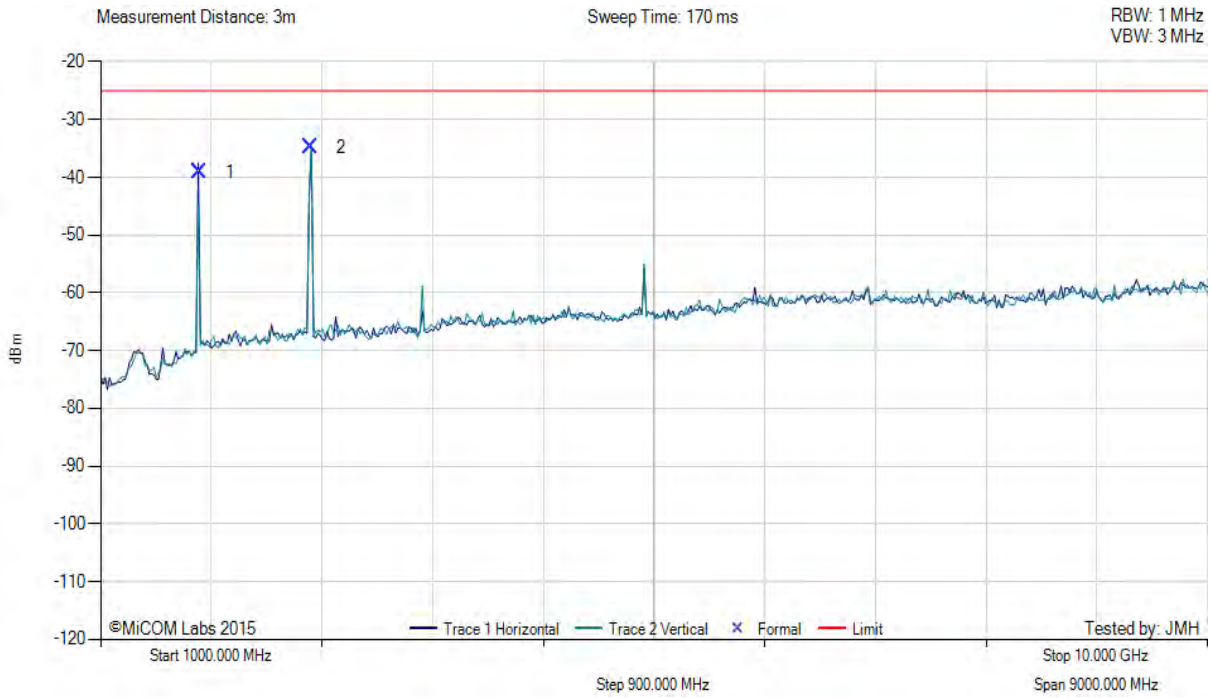
Equipment Configuration for Radiated Transmitter Unwanted Emissions in the Spurious Domain (1 - 12.75 GHz)

Antenna:	50 Ohm Term	**Variant:**	TX Spur
Antenna Gain (dBi):	Antenna port terminated in 50Ω	**Modulation:**	CW
Beam Forming Gain (Y):	Not Applicable	**Duty Cycle (%):**	100
Channel Frequency (MHz):	903.50	**Data Rate:**	
Power Setting:	RA4	**Tested By:**	JMH

Test Measurement Results

Variant: TX Spur, Test Freq: 903.50 MHz, Antenna: 50 Ohm Term, Power Setting: MAX, Duty Cycle (%): 100



Num	Frequency MHz	Raw dBµV	Cable Loss	AF dB	Level dBµV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBµV/m	Margin dB	Pass /Fail
1	1807.03	-28.96	3.48	-13.62	-39.10	Peak	Horizontal	150	309	-25.0	-14.1	Pass
2	2710.48	-27.72	4.31	-11.37	-34.78	Peak	Vertical	150	46	-25.0	-9.8	Pass

Test Notes: EUT at max power with 50 ohm Term on Antenna Port

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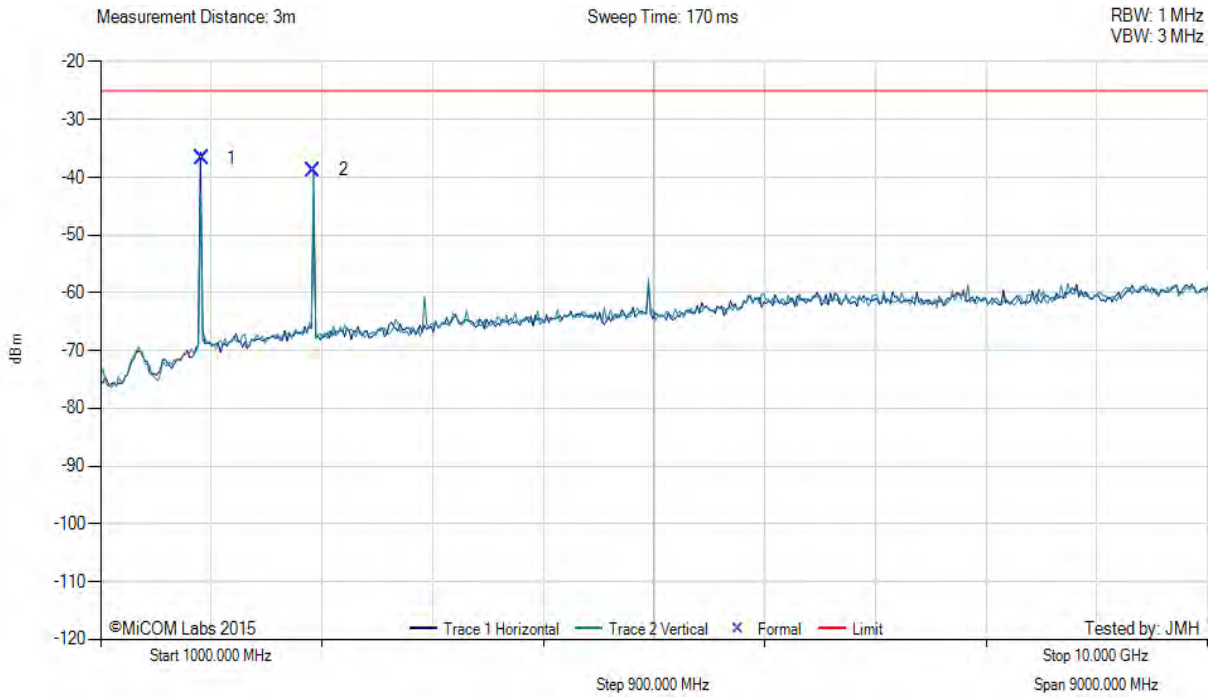
Equipment Configuration for Radiated Transmitter Unwanted Emissions in the Spurious Domain (1 - 12.75 GHz)

Antenna:	50 Ohm Term	**Variant:**	TX Spur
Antenna Gain (dBi):	Antenna port terminated in 50Ω	**Modulation:**	CW
Beam Forming Gain (Y):	Not Applicable	**Duty Cycle (%):**	100
Channel Frequency (MHz):	910.50	**Data Rate:**	
Power Setting:	RA4	**Tested By:**	JMH

Test Measurement Results

Variant: TX Spur, Test Freq: 910.50 MHz, Antenna: 50 Ohm Term, Power Setting: MAX, Duty Cycle (%): 100



Num	Frequency MHz	Raw dBµV	Cable Loss	AF dB	Level dBµV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBµV/m	Margin dB	Pass /Fail
1	1821.04	-26.69	3.49	-13.57	-36.77	Peak	Horizontal	150	267	-25.0	-11.8	Pass
2	2731.50	-31.69	4.31	-11.36	-38.74	Peak	Vertical	150	296	-25.0	-13.7	Pass

Test Notes: EUT at max power with 50 ohm Term on Antenna Port

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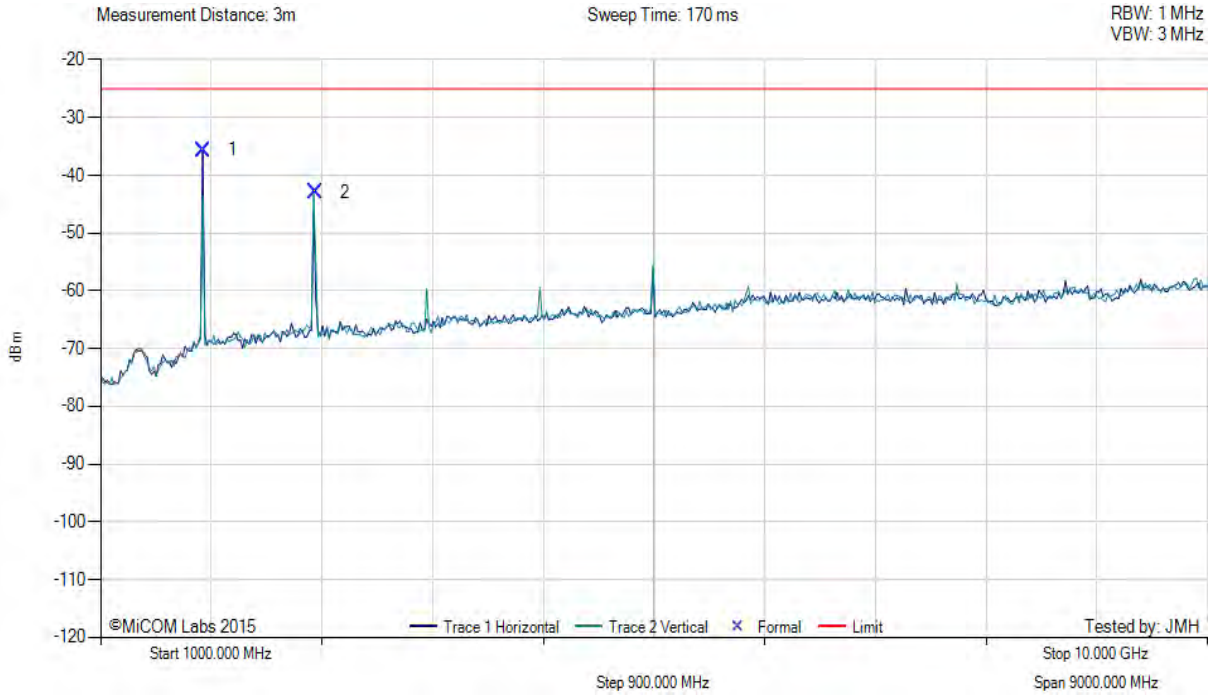
Equipment Configuration for Radiated Transmitter Unwanted Emissions in the Spurious Domain (1 - 12.75 GHz)

Antenna:	50 Ohm Term	**Variant:**	TX Spur
Antenna Gain (dBi):	Antenna port terminated in 50Ω	**Modulation:**	CW
Beam Forming Gain (Y):	Not Applicable	**Duty Cycle (%):**	100
Channel Frequency (MHz):	915.00	**Data Rate:**	
Power Setting:	RA4	**Tested By:**	JMH

Test Measurement Results

Variant: TX Spur, Test Freq: 915.00 MHz, Antenna: 50 Ohm Term, Power Setting: MAX, Duty Cycle (%): 100



Num	Frequency MHz	Raw dBµV	Cable Loss	AF dB	Level dBµV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBµV/m	Margin dB	Pass /Fail
1	1829.98	-25.64	3.50	-13.54	-35.68	Peak	Horizontal	150	270	-25.0	-10.7	Pass
2	2745.01	-35.91	4.31	-11.35	-42.95	Peak	Vertical	150	293	-25.0	-18.0	Pass

Test Notes: EUT at max power with 50 ohm Term on Antenna Port

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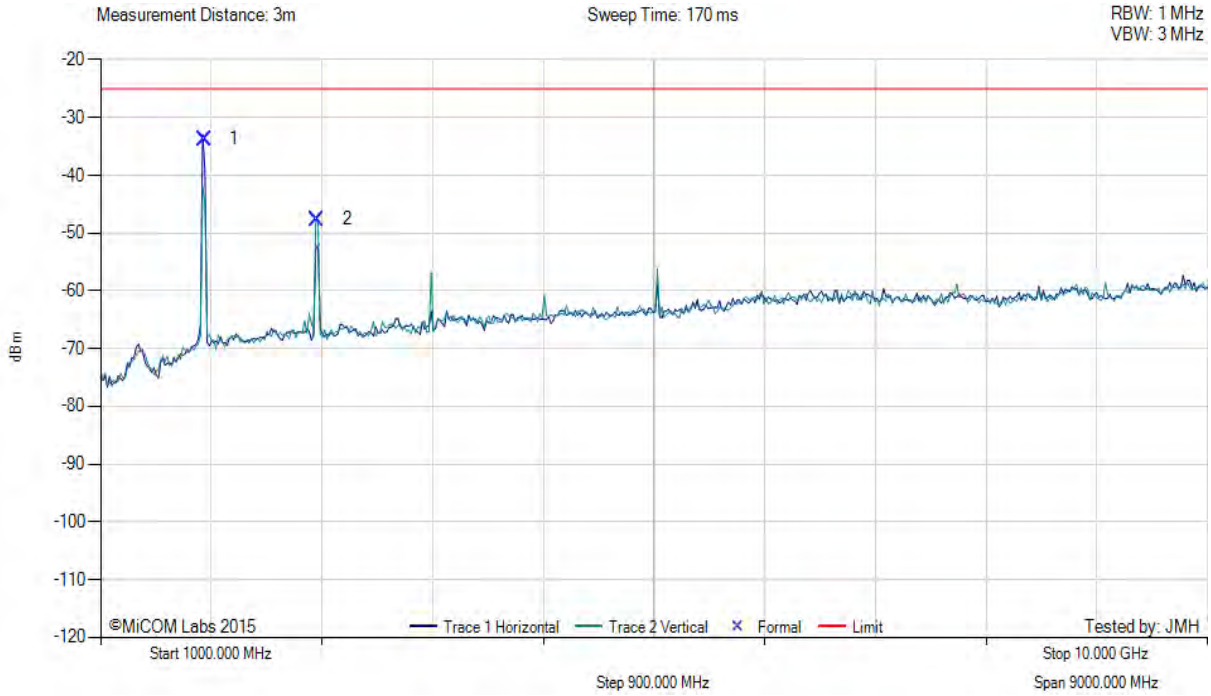
Equipment Configuration for Radiated Transmitter Unwanted Emissions in the Spurious Domain (1 - 12.75 GHz)

Antenna:	50 Ohm Term	**Variant:**	TX Spur
Antenna Gain (dBi):	Antenna port terminated in 50Ω	**Modulation:**	CW
Beam Forming Gain (Y):	Not Applicable	**Duty Cycle (%):**	100
Channel Frequency (MHz):	921.00	**Data Rate:**	
Power Setting:	RA4	**Tested By:**	JMH

Test Measurement Results

Variant: TX Spur, Test Freq: 921.00 MHz, Antenna: 50 Ohm Term, Power Setting: MAX, Duty Cycle (%): 100



Num	Frequency MHz	Raw dBµV	Cable Loss	AF dB	Level dBµV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBµV/m	Margin dB	Pass /Fail
1	1842.02	-23.78	3.51	-13.48	-33.75	Peak	Horizontal	150	270	-25.0	-8.8	Pass
2	2763.00	-40.60	4.35	-11.34	-47.59	Peak	Vertical	150	274	-25.0	-22.6	Pass

Test Notes: EUT at max power with 50 ohm Term on Antenna Port

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Laboratory Measurement Uncertainty for Radiated Emissions

Measurement uncertainty	+5.6/ -4.5 dB

Traceability

Method
Measurements were made per work instruction WI-03 'Measurement of Radiated Emissions'

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5.1.6.2. Transmitter Radiated Spurious Emissions (30M-1 GHz)

FCC, Part 15 Subpart C §15.205/ §15.209
Industry Canada RSS-111 §4.4

Test Procedure

Preliminary radiated emissions were measured in the anechoic chamber at a 3-meter distance on every azimuth in both horizontal and vertical polarity. The emissions were recorded with a spectrum analyzer in peak hold mode. Emissions closest to the limits are measured in the quasi-peak mode with the tuned receiver using a bandwidth of 120 kHz. Only the highest emissions relative to the limit are listed. The anechoic chamber test set-up is identified in Section 6 Test Set-Up Photographs.

System operation was completed with the antenna operating at center frequency. A notch filter was used to remove the fundamental frequency.

Field Strength Calculation

The field strength is calculated by adding the Antenna Factor and Cable Loss, and subtracting Amplifier Gain from the measured reading. In this test facility, the Antenna Factor, Cable Loss, and Amplifier Gains are loaded into the Rohde & Schwarz Receiver and the corrected field strength can be read directly on the receiver.

$$FS = R + AF + CORR$$

where:

FS = Field Strength
R = Measured Receiver Input Amplitude
AF = Antenna Factor
CORR = Correction Factor = CL – AG + NFL
CL = Cable Loss
AG = Amplifier Gain

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For example:
Given a Receiver input reading of 51.5dBμV; Antenna Factor of 8.5dB; Cable Loss of 1.3dB; Falloff Factor of 0dB, an Amplifier Gain of 26dB and Notch Filter Loss of 1dB. The Field Strength of the measured emission is:

FS = 51.5 + 8.5 + 1.3 - 26.0 +1 = 36.3dBμV/m

Conversion between dBμV/m (or dBμV) and μV/m (or μV) are done as:

Level (dBμV/m) = 20 * Log (level (μV/m))

40 dBμV/m = 100μV/m
48 dBμV/m = 250μV/m

Measurement Results for Spurious Emissions (30 MHz – 1 GHz)

Ambient conditions.
Temperature: 17 to 23 °C Relative humidity: 31 to 57 % Pressure: 999 to 1012 mbar

Radio parameters.

Modulation: CW
Full Power: +33.28 dBm

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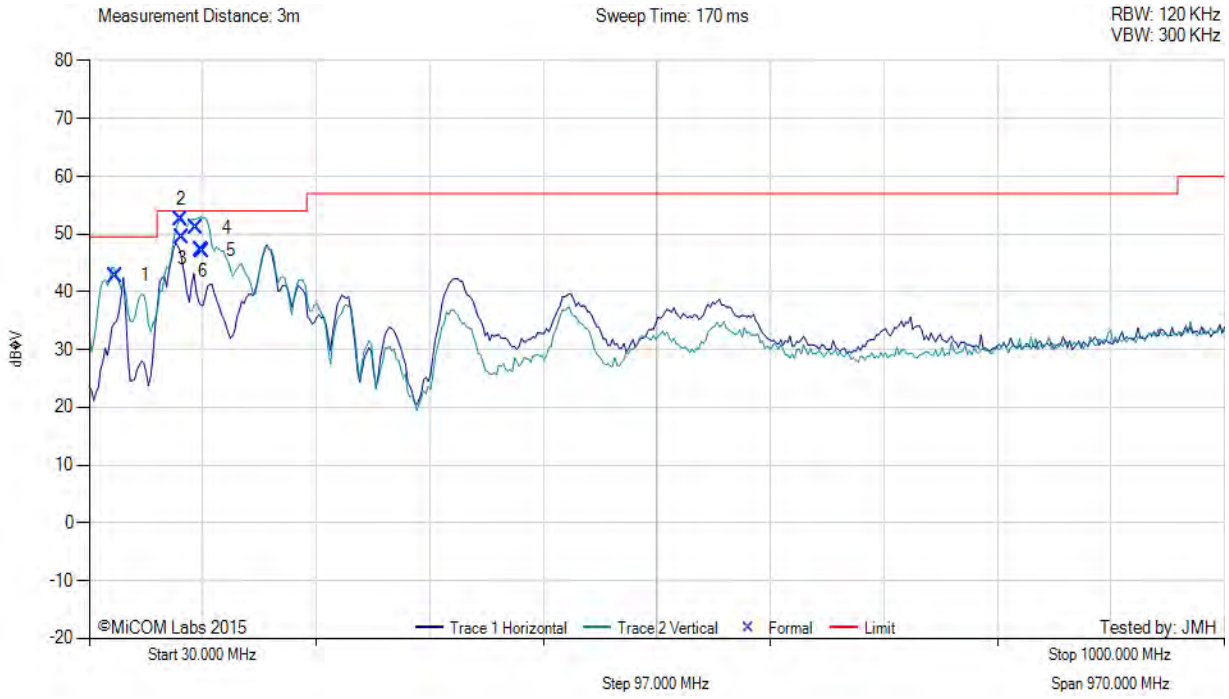
Equipment Configuration for Radiated Digital Emissions (0.03 - 1 GHz) Class A			
Antenna:	N/A	**Variant:**	Digital Emissions
Antenna Gain (dBi):	Antenna port terminated in 50Ω	**Modulation:**	CW
Beam Forming Gain (Y):	Not Applicable	**Duty Cycle (%):**	100.0
Channel Frequency (MHz):	902.5	**Data Rate:**	
Power Setting:	Max	**Tested By:**	JMH

Test Measurement Results

Variant: Tx Spur, Test Freq: 0.00 MHz, Antenna: 50 Ohm Term, Power Setting: RA4 Duty Cycle (%): 100



Num	Frequency MHz	Raw dBµV	Cable Loss	AF dB	Level dBµV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBµV/m	Margin dB	Pass /Fail
1	52.08	62.77	3.59	-23.53	42.83	MaxQP	Vertical	100	183	49.5	-6.7	Pass
2	107.94	67.80	3.92	-19.22	52.50	MaxQP	Vertical	100	288	54.0	-1.5	Pass
3	109.29	64.47	3.93	-19.02	49.38	MaxQP	Vertical	100	0	54.0	-4.6	Pass
4	121.70	64.41	3.99	-17.38	51.02	MaxQP	Vertical	100	235	54.0	-3.0	Pass
5	125.54	60.55	4.01	-17.27	47.29	MaxQP	Vertical	103	236	54.0	-6.7	Pass
6	127.12	60.35	4.01	-17.27	47.09	MaxQP	Vertical	100	229	54.0	-6.9	Pass

Test Notes: EUT XMit 902.5 into 50 Ohm Load, GPS, GPIO cables. Powered up with Beast DC supply. Internal Ground from DC Neg to chassis (Normal to rack install). Class A Limits

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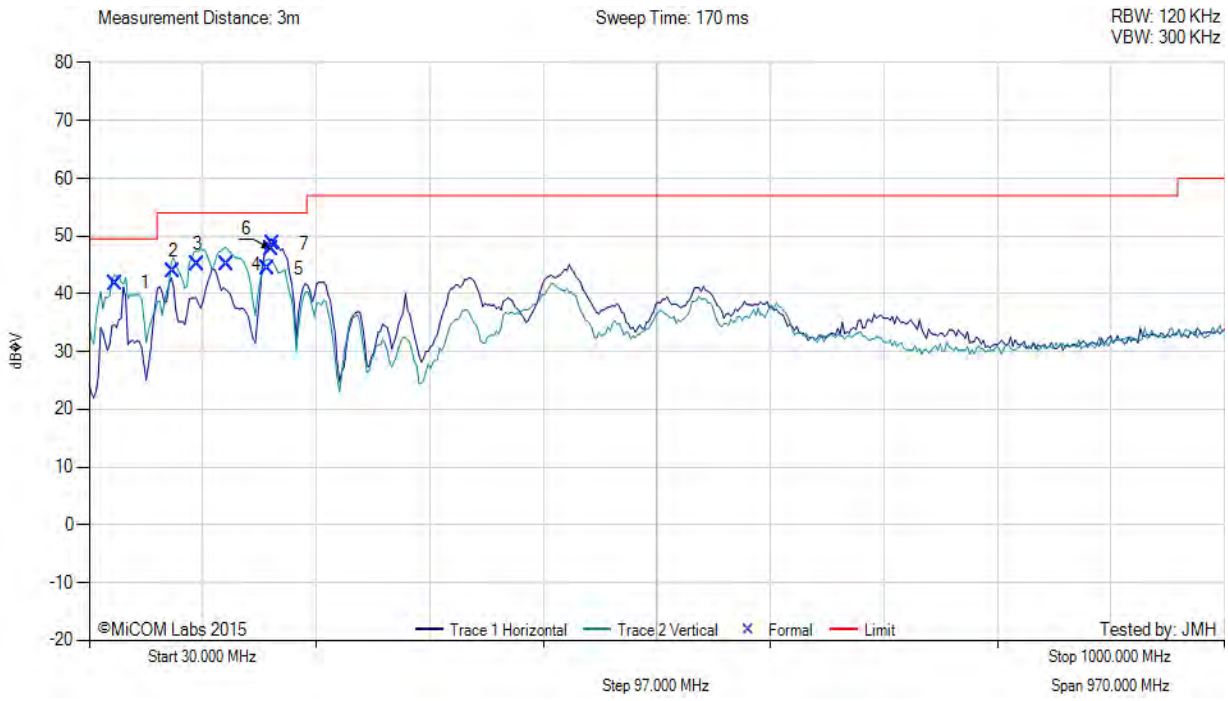
Equipment Configuration for Radiated Digital Emissions (0.03 - 1 GHz) Class A

Antenna:	N/A	**Variant:**	Digital Emissions
Antenna Gain (dBi):	Antenna port terminated in 50Ω	**Modulation:**	CW
Beam Forming Gain (Y):	Not Applicable	**Duty Cycle (%):**	100.0
Channel Frequency (MHz):	903.00	**Data Rate:**	
Power Setting:	NA	**Tested By:**	JMH

Test Measurement Results

Variant: Dig Em, Test Freq: 903.00 MHz, Antenna: 12.0 dBi, Power Setting: RA4 Duty Cycle (%): 100



Num	Frequency MHz	Raw dBµV	Cable Loss	AF dB	Level dBµV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBµV/m	Margin dB	Pass /Fail
1	52.08	61.75	3.59	-23.53	41.81	MaxQP	Vertical	100	161	49.5	-7.7	Pass
2	101.89	60.58	3.89	-20.63	43.84	MaxQP	Vertical	100	38	54.0	-10.2	Pass
3	122.68	58.42	4.00	-17.28	45.14	MaxQP	Vertical	100	236	54.0	-8.9	Pass
4	147.74	59.72	4.12	-18.72	45.12	MaxQP	Vertical	100	327	54.0	-8.9	Pass
5	182.82	59.96	4.27	-19.90	44.33	MaxQP	Horizontal	210	280	54.0	-9.7	Pass
6	185.79	63.25	4.29	-19.85	47.69	MaxQP	Horizontal	205	291	54.0	-6.3	Pass
7	187.17	64.15	4.29	-19.80	48.64	MaxQP	Horizontal	190	284	54.0	-5.4	Pass

Test Notes: EUT on Table with antenna, GPS, GPIO cables. Powered up with Beast DC supply. Internal Ground from DC Neg to chassis (Normal to rack install). Class A Limits

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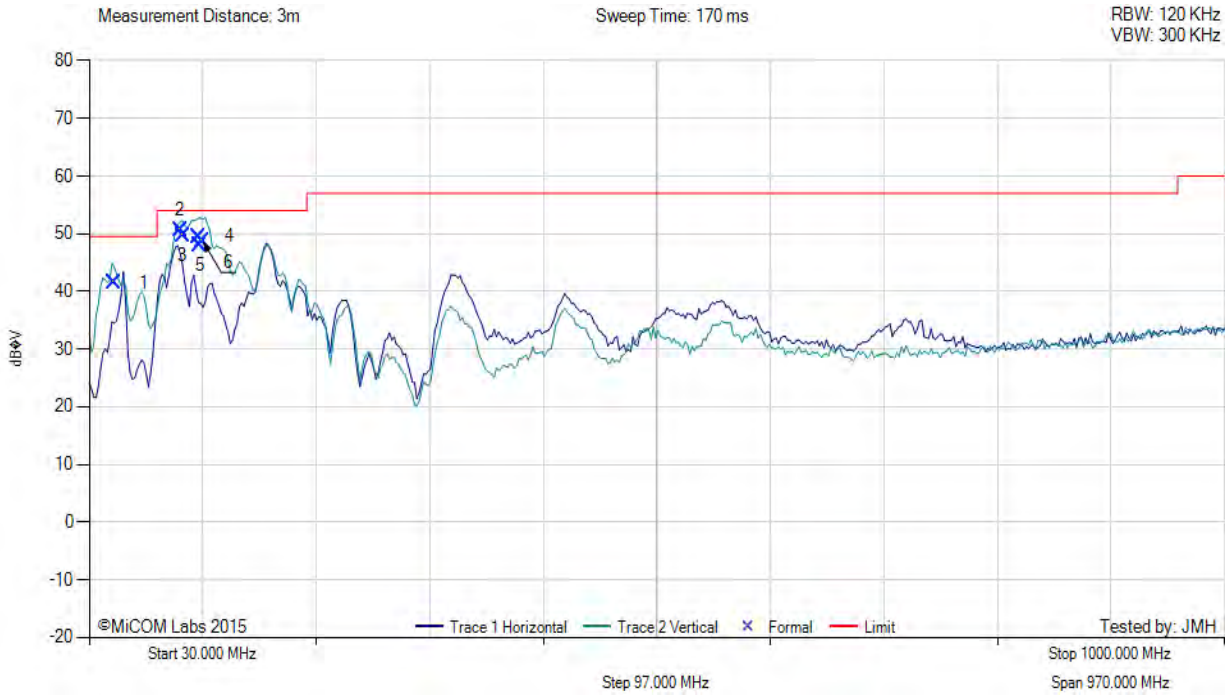
Equipment Configuration for Radiated Digital Emissions (0.03 - 1 GHz) Class A			
Antenna:	N/A	**Variant:**	Digital Emissions
Antenna Gain (dBi):	Antenna port terminated in 50Ω	**Modulation:**	CW
Beam Forming Gain (Y):	Not Applicable	**Duty Cycle (%):**	100.0
Channel Frequency (MHz):	921.00	**Data Rate:**	
Power Setting:	Max	**Tested By:**	JMH

Test Measurement Results

Variant: Dig Em, Test Freq: 921.00 MHz, Antenna: 50 Ohm Term, Power Setting: RA4, Duty Cycle (%): 100



Num	Frequency MHz	Raw dBµV	Cable Loss	AF dB	Level dBµV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBµV/m	Margin dB	Pass /Fail
1	50.93	61.39	3.58	-23.44	41.53	MaxQP	Vertical	101	227	49.5	-8.0	Pass
2	107.73	65.89	3.92	-19.22	50.59	MaxQP	Vertical	106	321	54.0	-3.4	Pass
3	110.00	64.59	3.93	-18.82	49.70	MaxQP	Vertical	100	272	54.0	-4.3	Pass
4	123.73	62.77	4.00	-17.27	49.50	MaxQP	Vertical	100	238	54.0	-4.5	Pass
5	124.60	61.37	4.00	-17.27	48.10	MaxQP	Vertical	100	248	54.0	-5.9	Pass
6	127.12	61.98	4.01	-17.27	48.72	MaxQP	Vertical	110	229	54.0	-5.3	Pass

Test Notes: EUT XMit 921.275 into 50 Ohm Load, GPS, GPIO cables. Powered up with Beast DC supply. Internal Ground from DC Neg to chassis (Normal to rack install). Class A Limits

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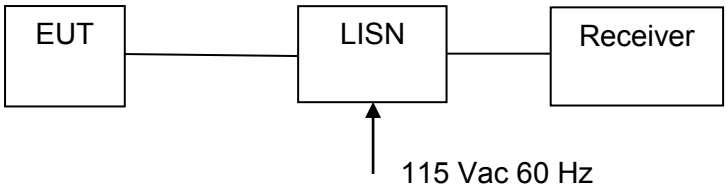
5.1.7. AC Wireline Conducted Emissions (0.15 – 30 MHz)

FCC, Part 15 Subpart C §15.207
Industry Canada RSS-Gen §7.2.2

Test Procedure

The EUT is configured in accordance with ANSI C63.4. The conducted emissions are measured in a shielded room with a spectrum analyzer in peak hold in the first instance. Emissions closest to the limit are measured in the quasi-peak mode (QP) with the tuned receiver using a bandwidth of 9 kHz. The emissions are maximized further by cable manipulation. The highest emissions relative to the limit are listed.

Test Measurement Set up



Measurement set up for AC Wireline Conducted Emissions Test

Measurement Results for AC Wireline Conducted Emissions (150 kHz – 30 MHz)

NOTE: This test is not applicable as the T2000 is Vdc powered

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Specification

Limit

§15.207 (a) Except as shown in paragraphs (b) and (c) of this section, for an intentional radiator that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies within the band 150 kHz to 30 MHz shall not exceed the limits in the following table, as measured using a 50 μΩ line impedance stabilization network (LISN), see §15.207 (a) matrix below. Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal.

§15.207 (a) Limit Matrix

The lower limit applies at the boundary between frequency ranges

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

* Decreases with the logarithm of the frequency

Laboratory Measurement Uncertainty for Conducted Emissions

Measurement uncertainty	±2.64 dB

Traceability

Method	Test Equipment Used
Measurements were made per work instruction WI-EMC-01 'Measurement of Conducted Emissions'	0158, 0184, 0193, 0190, 0293, 0307

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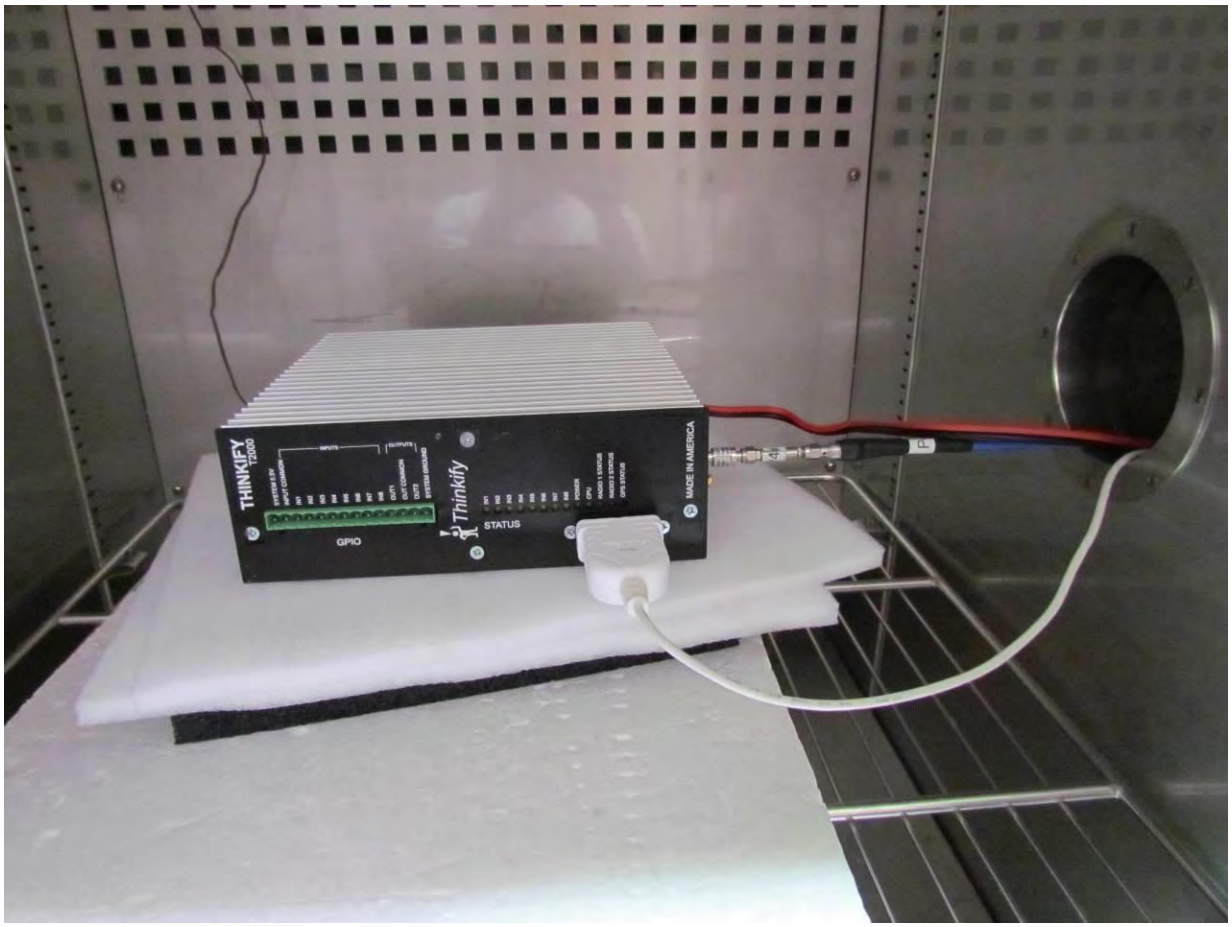
6. TEST SET-UP PHOTOGRAPHS

6.1. General Measurement Test Set-Up



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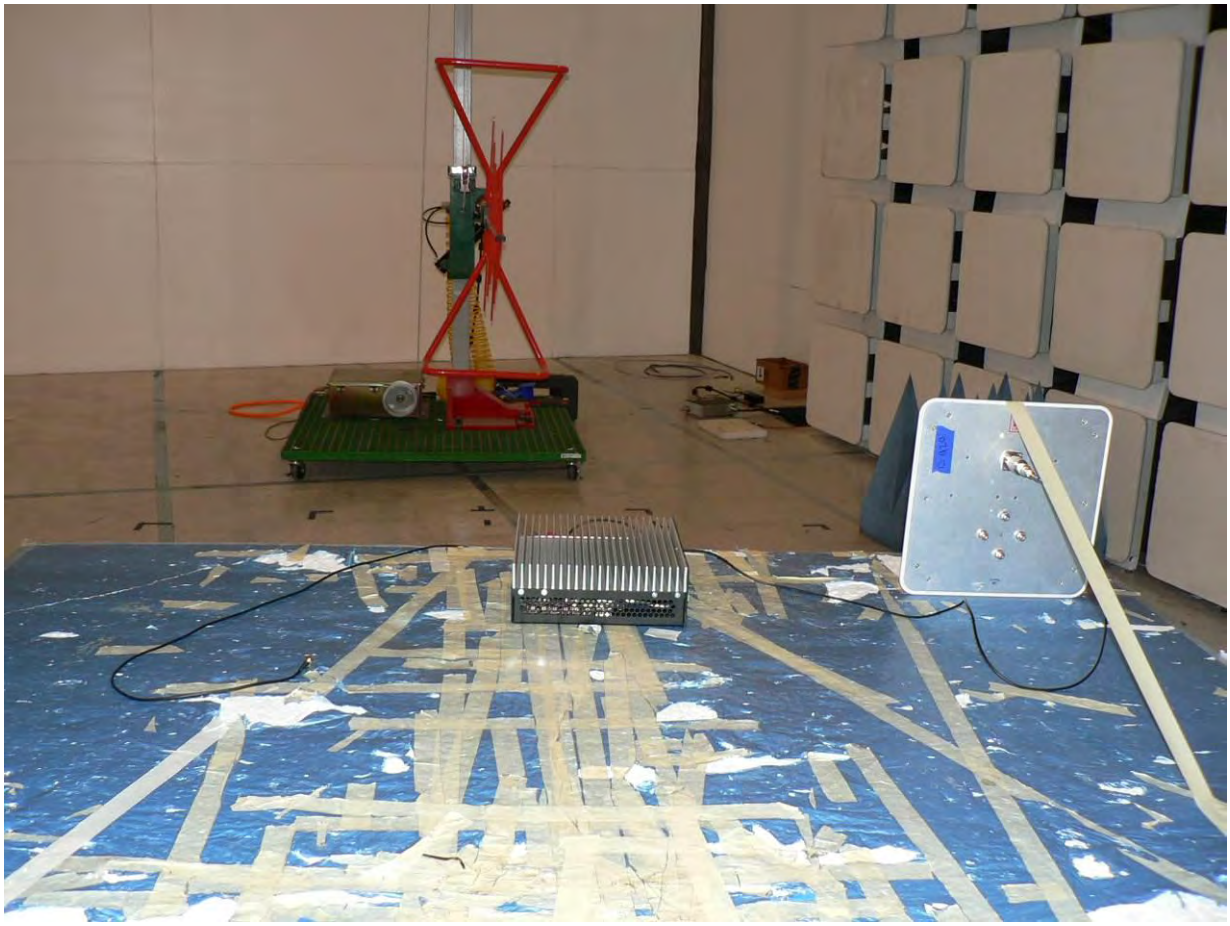
6.2. Radiated Emissions < 1GHz



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