Washington Laboratories, Ltd
7560 Lindbergh Drive
Gaithersburg, MD 20879

FCC PART 90 CERTIFICATION TEST REPORT

for the

R1400 (AKA GS1000-04)

FCC ID: 2APK5 –R1400

REPORT# 15532-01 REV 3

Prepared for:

SRC, Inc.

5801 East Taft Road

North Syracuse, NY 13212

Prepared By:

Washington Laboratories, Ltd.
7560 Lindbergh Drive
Gaithersburg, Maryland 20879

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FCC ID: 2APK5 –R1400

MAY 1, 2018
WLL REPORT# 15532-01 -01 REV 3

Prepared by:

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Reviewed by:

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ABSTRACT

This report has been prepared on behalf of SRC, Inc. to support compliance of a Private Land Mobile Radio under Part 90 of the FCC Rules. This Part 90 Test Report documents the test configuration and test results for a SRC, Inc. R1400 (AKA GS1000-04).

Testing was performed on an Open Area Test Site (OATS) of Washington Laboratories, Ltd, 7560 Lindbergh Drive, Gaithersburg, MD 20879. Site description and site attenuation data have been placed on file with the FCC's Sampling and Measurements Branch at the FCC laboratory in Columbia, MD. Washington Laboratories, Ltd. Has been accepted by the FCC and approved by ANAB under Certificate AT-1448 as an independent FCC test laboratory.

These tests are accredited and meet the requirements of ISO/IEC 17025 as verified by the ANSI-ASQ National Accreditation Board/ANAB. Refer to certificate and scope of accreditation AT-1448.The SRC, Inc. R1400 (AKA GS1000-04) complies with the limits for a X-Band transmitter under FCC Part 90.

Revision History	Description of Change	Date
Rev 0	Initial Release	MAY 1, 2018
Rev 1	Customer Review	MAY 24, 2018
REV 3	Customer Review	MAY 25, 2018
Rev 3	FCC Review, Inclusion of NTIA data	JUNE 22, 2018

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1 INTRODUCTION

1.1 COMPLIANCE STATEMENT

The EUT was tested to Part 90 Private Land Mobile Radio Services Subpart I- General Technical Standards section of the FCC Rules and Regulations (10/2014).

1.2 TEST SCOPE

Tests	Reference Requirement	Test Method	Report section
RF Output Power	90.205	2.1046	Section 4.1
Emissions Type	90.207		Not applicable
Occupied Bandwidth	90.209	2.1049	Section 4.2
Spurious Emissions(Conducted)	90.210	2.1051	Section 4.3
Spurious Emissions(Radiated)	90.210	2.1053	Section 4.3
Frequency Stability	90.213	2.1055	Section 4.4
Modulation Characteristics	2.1047		Not Applicable

1.3 CONTRACT INFORMATION

Customer: SRC, Inc.

Address 5801 East Taft Road

North Syracuse, NY 13212

Purchase Order Number: 129177

Quotation Number: 70653

1.4 TEST DATES

Testing was performed on the following date(s): 4/9/2018 – 4/11/2018

1.5 REFERENCES

1. Section 5: Addendum 1: NTIA Spectral Mask and Power Out Measurements

1.6 TEST AND SUPPORT PERSONNEL

Washington Laboratories, LTD	Nikolas Allen
Customer Representative	TJ Vitale, Tony Walkup

1.7 ABBREVIATIONS

A	**A**mpere
ac	**a**lternating **c**urrent
AM	Amplitude Modulation
Amps	Amperes
b/s	**b**its per **s**econd
BW	**B**and**W**idth
CE	**C**onducted **E**mission
cm	**C**enti**m**eter
CW	**C**ontinuous **W**ave
dB	**d**eci**B**el
dc	**d**irect **c**urrent
EMI	**E**lectro**m**agnetic **I**nterference
EUT	**E**quipment **U**nder **T**est
FM	**F**requency **M**odulation
G	**g**iga – prefix for 10^9 multiplier
Hz	**H**ertz
IF	**I**ntermediate **F**requency
k	**k**ilo – prefix for 10^3 multiplier
LISN	**L**ine **I**mpedance **S**tabilization **N**etwork
M	**M**ega – prefix for 10^6 multiplier
m	**M**eter
μ	**m**icro – prefix for 10^{-6} multiplier
NB	**N**arrow**b**and
QP	**Q**uasi-**P**eak
RE	**R**adiated **E**missions
RF	**R**adio **F**requency
rms	**r**oot-**m**ean-**s**quare
SN	**S**erial **N**umber
S/A	**S**pectrum **A**nalyzer
V	**V**olt

2 Equipment Under Test

2.1 EUT Identification & Description

The SRC, Inc. R1400 (AKA GS1000-04) radar system is designed to detect, track, and provide actionable information on small airborne targets. The primary missions are:

1) Commercial UAS Detect and Avoid (DAA)
2) UAS Surveillance
3) Bird Detection at Airports and Windfarms

Table 1: Device Summary

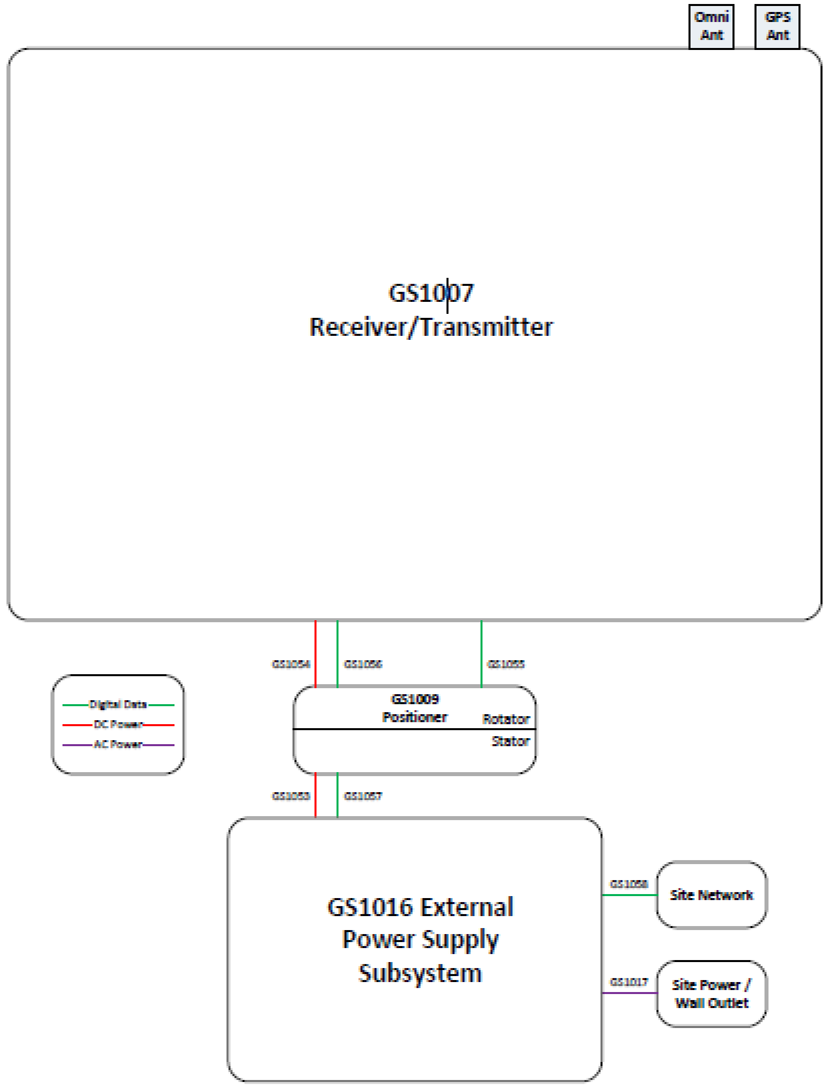
EUT Specifications:	
Manufacturer:	SRC, Inc - Gryphon Sensors
FCC ID:	2APK5-R1400
IC:	None
EUT Description:	Commercial UAS and GA Detection Radar
Model:	R1400 (AKA GS1000-04)
FCC Rule Parts:	§90
Frequency Range:	9.3 – 9.8 GHz, X-Band, tunable in 5 MHz steps
Maximum Power:	512 W, 2W per element, 256 radiating elements
Average Power:	51W, 10% Pulse Doppler Duty Cycle
Necessary Bandwidth:	5 MHz, Instantaneous waveform bandwidth
Target Scan Rate:	0.5 - 3 sec (fixed panel), 2 – 6 sec (rotating panel), Scan rate is mission/mode dependent. Values shown are typical.
Number of Channels:	5, Mono-pulse: Upper and Lower Sum, Upper and Lower Delta Azimuth 5th channel : Omni for side lobe blanking
Measured Power:	445.0W @9.3GHz, 329.9W@9.55GHz, 310.5W @9.8GHz
Frequency Tolerance:	+25/-5kHz
Antenna Type:	Panel Array
Alignment:	Automatic/Manual, GPS for internal timing and location, INS for gross alignment, optical scope for precision manual survey
Total System Weight:	< 240 lbs, Includes tripod, positioner, and power supply
Interface Cables:	AC Input(115VAC) and Site Network Cables

The EUT was comprised of the following equipment. (All Modules, PCBs, etc. listed were considered as part of the EUT, as tested.)

Table 2: Device Components

Name / Description	Model Number	Part Number	Serial Number	Rev #
Array Panel/RT Unit	GS1007	GS1000-04-00-WHTGV	002	0
Positioner/Pan	GS1009	GS1009-02	105	4
External Power Supply/AC-DC	GS1016	GS1016-WHTGV	002	3

Figure 1. EUT



2.2 TESTING ALGORITHM

The R1400 (AKA GS1000-04) was tested operating in fixed panel mode while transmitting at array panel boresight.

2.3 TEST LOCATION

All measurements herein were performed at Washington Laboratories, Ltd. test center in Gaithersburg, MD. Site description and site attenuation data have been placed on file with the FCC's Sampling and Measurements Branch at the FCC laboratory in Columbia, MD. The ISED Canada OATS numbers are 3035A-1 and 3035A-2 for Washington Laboratories, Ltd. Site 1 and Site 2, respectively. Washington Laboratories, Ltd. has been accepted by the FCC and approved by ANAB under Testing Certificate AT-1448 as an independent FCC test laboratory.

2.4 MEASUREMENTS

2.4.1 References

ANSI C63.2 (Jan-2016) Specifications for Electromagnetic Noise and Field Strength Instrumentation

ANSI C63.4 (Jan 2014) American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz

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

ANSI C63.26 (Dec 2015) American National Standard for Compliance Testing of Transmitters Used in Licensed Radio Services

2.5 MEASUREMENT UNCERTAINTY

All results reported herein relate only to the equipment tested. The basis for uncertainty calculation uses ANSI/NCSL Z540-2-1997 (R2002) with a type B evaluation of the standard uncertainty. Elements contributing to the standard uncertainty are combined using the method described in Equation 1 to arrive at the total standard uncertainty. The standard uncertainty is multiplied by the coverage factor to determine the expanded uncertainty which is generally accepted for use in commercial, industrial, and regulatory applications and when health and safety are concerned (see Equation 2). A coverage factor was selected to yield a 95% confidence in the uncertainty estimation.

Equation 1: Standard Uncertainty

$$u_c = \pm\sqrt{\frac{a^2}{div_a^2}+\frac{b^2}{div_b^2}+\frac{c^2}{div_c^2}+\ldots\ldots}$$

Where u_c = standard uncertainty

a, b, c,.. = individual uncertainty elements

$Div_{a,\ b,\ c}$ = the individual uncertainty element divisor based on the probability distribution

Divisor = 1.732 for rectangular distribution

Divisor = 2 for normal distribution

Divisor = 1.414 for trapezoid distribution

Equation 2: Expanded Uncertainty

$$U = k u_c$$

Where U = expanded uncertainty

k = coverage factor

$k \le 2$ for 95% coverage (ANSI/NCSL Z540-2 Annex G)

u_c = standard uncertainty

The measurement uncertainty complies with the maximum allowed uncertainty from CISPR 16-4-2. Measurement uncertainty is not used to adjust the measurements to determine compliance. The expanded uncertainty values for the various scopes in the WLL accreditation are provided in Table 3 below.

Table 3: Expanded Uncertainty List

Scope	Standard(s)	Expanded Uncertainty
Conducted Emissions	CISPR11, CISPR22, , CISPR32, CISPR14, FCC Part 15	±2.63 dB
Radiated Emissions	CISPR11, CISPR22, , CISPR32, CISPR14, FCC Part 15	±4.55 dB

3 TEST EQUIPMENT

Table 4 shows a list of the test equipment used for measurements along with the calibration information.

Table 4: Test Equipment List

Test Name:	**Conducted Emissions Voltage**	Test Date:	**04/09/2018**
Asset #	**Manufacturer/Model**	**Description**	**Cal. Due**
125	SOLAR - 8028-50-TS-24-BNC	LISN	5/16/2018
126	SOLAR - 8028-50-TS-24-BNC	LISN	5/16/2018
823	AGILENT - N9010A	EXA SPECTRUM ANALYZER	4/30/2018
53	HP - 11947A	LIMITER TRANSIENT	2/1/2019
Test Name:	**Radiated Emissions**	Test Date:	**04/10/2018**
Asset #	**Manufacturer/Model**	**Description**	**Cal. Due**
4	ARA - DRG-118/A	ANTENNA DRG 1-18GHZ	12/14/2018
826	MEGAPHASE - TM40-K1K5-36	RF CABLE - 2.9MM-2.9MM 36	8/15/2018
842	CDI TORQUE PRODUCTS - 61SM	TORQUE SCREWDRIVER	Cal before use
382	SUNOL SCIENCES CORPORATION - JB1	ANTENNA BICONLOG	4/30/2018
276	ELECTRO-METRICS - BPA-1000	RF PRE-AMPLIFIER	2/7/2019
627	AGILENT - 8449B	AMPLIFIER 1-26GHZ	02/12/2019

4 TEST RESULTS

4.1 RF POWER OUTPUT (FCC 90.205)

4.1.1 Test Method (Part 2.1046 (a))

There is no RF output port on the radar, & due to the complex nature of the device, the radiated measurements were performed by the customer and are detailed in the test report attached as an Annex (Reference 1). The pulse characteristics were also supplied by the customer.

4.1.2 Test Limit

There is no defined power limit for this frequency range.

4.1.3 Test Results

The test results are shown in Table 5.

4.1.4 Test Summary

From Reference 1, Table 16:

Table 5: Output Power

Freq [GHz]	R1400 Peak Tx power [dBm/W]
9.30	56.5/445.0
9.55	55.2/329.9
9.80	54.9/310.5

4.2 OCCUPIED BANDWIDTH [FCC PART 90.209]

The occupied bandwidth, that is the frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers radiated are each equal to 0.5 percent of the total mean power radiated by a given emission shall be measured under the following conditions as applicable

4.2.1 Test Method (Part 2.1049(h))

Transmitters employing digital modulation techniques - when modulated by an input signal such that its amplitude and symbol rate represent the maximum rated conditions under which the equipment will be operated. The signal shall be applied through any filter networks, pseudo-random generators or other devices required in normal service. Additionally, the occupied bandwidth shall be shown for operation with any devices used for modifying the spectrum when such devices are optional at the discretion of the user.

4.2.2 Signal Characteristics

The following tables list the various data rates available for this transmitter.

Table 6: Pulse Widths

Freq [GHz]	Waveform Pulse Width [uS]	Measured 50% Voltage Pulse Width [uS]	Measured 10/90 Rise Time [uS]	Measured 10/90 Fall Time [uS]
9.30	1	0.675	0.172	0.162
9.30	2	1.386	0.319	0.279
9.30	10	6.854	1.515	1.309
9.30	50	34.300	7.194	6.661
9.55	1	0.712	0.150	0.145
9.55	2	1.466	0.258	0.243
9.55	10	7.339	1.194	1.089
9.55	50	36.390	5.896	5.632
9.80	1	0.650	0.180	0.179
9.80	2	1.326	0.354	0.306
9.80	10	6.575	1.742	1.472
9.80	50	33.060	8.338	7.574

4.2.3 Test Results

Table 7 lists the OBW for all available data rates.

Table 7: Measured Bandwidths

Frequency (MHz)	Pulse Width (us)	Occupied Bandwidth (MHz)			
		3dB	20dB	40dB	60dB
9300	1	2.9	9.5	16.3	65.6
	2	3.6	7.9	12.4	22.3
	10	2.6	4.4	6	9
	50	2.4	3.6	4.6	5.4
9550	1	3.6	10.8	21.7	75.9
	2	3.6	7.8	12.1	19.4
	10	2.5	4.4	6.0	9.0
	50	2.6	3.8	4.7	5.5
9800	1	3.9	10.1	18.7	69.1
	2	3.1	7.6	12.0	18.9
	10	2.6	4.5	6.0	8.2
	50	2.1	3.5	4.5	5.5

4.3 EMISSIONS MASK& OUT OF BAND UNWANTED RADIATION [FCC PART 90.210 (B)(1)(2)(3)]

4.3.1 Test Method

In addition the EUT was tested out of band (>250 % of authorized bandwidth) for radiated emissions on an open air test site (OATS) using a substitution method The EUT was placed on motorized turntable for radiated testing on a 3-meter open field test site. The emissions from the EUT were measured continuously at every azimuth by rotating the turntable. Receiving antennas were mounted on an antenna mast to determine the height of maximum emissions. The EUT was tested in 3 orthogonal positions for compliance. A resolution bandwidth of 100 kHz was used for radiated measurements. The EUT antenna was in place for these readings.

4.3.2 Test Limit

(a) Emission Mask C. For transmitters utilizing J3E emission, the carrier must be at least 40 dB below the peak envelope power and the power of emissions must be reduced below the output power (P in watts) of the transmitter as follows:

(1) On any frequency removed from the assigned frequency by more than 50 percent, but not more than 150 percent of the authorized bandwidth: At least 25dB.

(2) On any frequency removed from the assigned frequency by more than 150 percent, but not more than 250 percent of the authorized bandwidth: At least 35dB.

(3) On any frequency removed from the assigned frequency by more than 250 percent of the authorized bandwidth: At least 43 + 10 log P dB.

(b) Emission Mask B. For transmitters that are equipped with an audio low-pass filter, the power of any emission must be attenuated below the unmodulated carrier power (P) as follows:

(1) On any frequency removed from the assigned frequency by more than 50 percent, but not more than 100 percent of the authorized bandwidth: At least 25dB.

(2) On any frequency removed from the assigned frequency by more than 100 percent, but not more than 250 percent of the authorized bandwidth: At least 35dB.

(3) On any frequency removed from the assigned frequency by more than 250 percent of the authorized bandwidth: At least 43 + 10 log (P) dB.

In addition to the masks specified in Part 90, the emissions mask to the NTIA's Radar Spectrum Engineering Criteria (RSEC) were performed (see Reference 1, pp 13-15.

4.3.3 Test Results

The emissions mask tests are shown in Figures. Radiated spurious emissions were collected and are shown in Table 8.

Figure 2: Emissions Mask

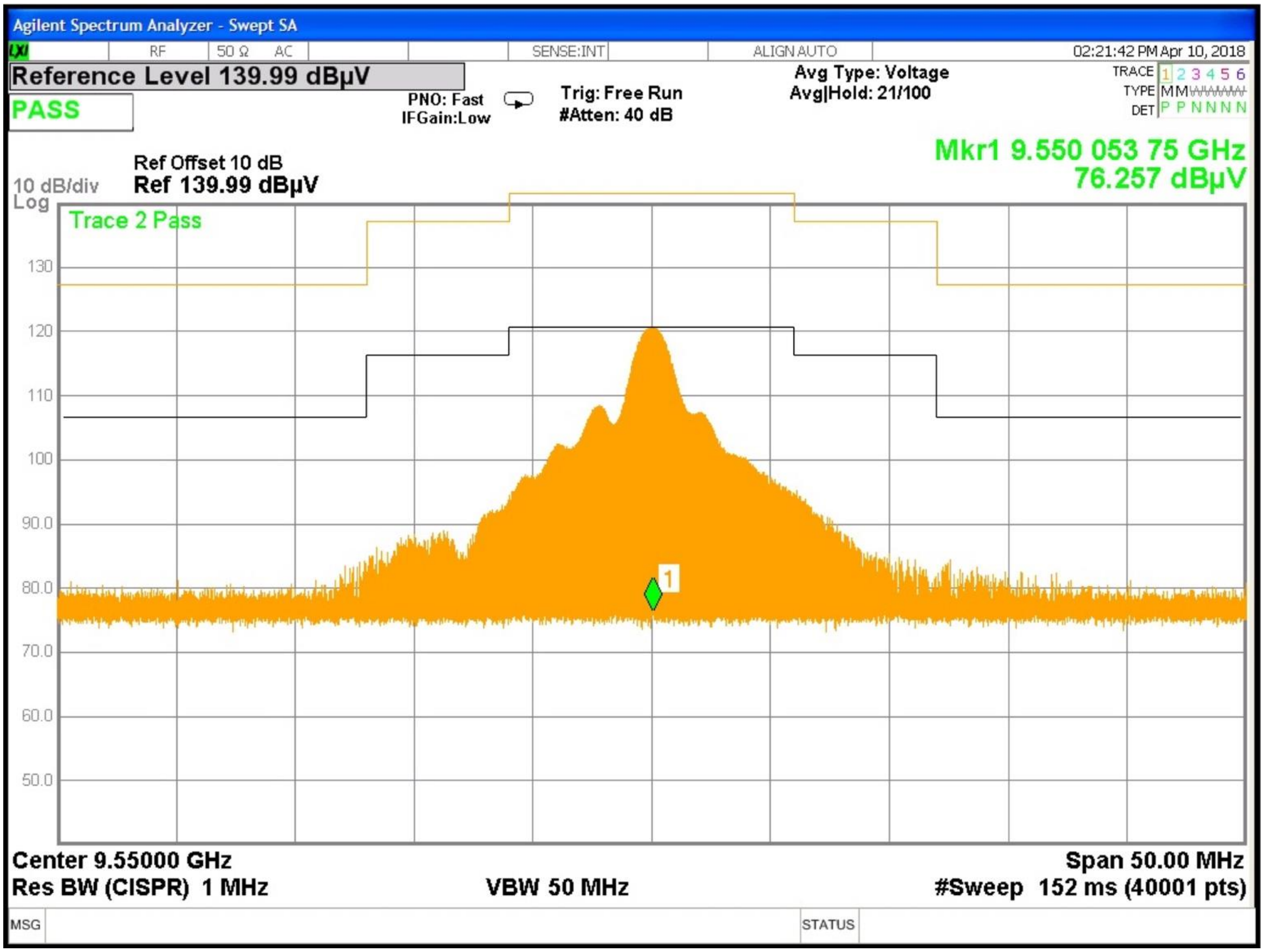


Table 8: Spurious Emissions

Frequency (MHz)	Polarity (H/V)	Azimuth (Degree)	Ant. Height (m)	SA Level (dBuV)	Corr Factors (dB)	Corr. Level (dBuV/m)	EIRP (dBm)	Limit (dBm)	Margin (dB)	Peak or Average	Comments
35.00	V	180.0	1.0	64.8	-7.7	57.0	-38.2	-13.0	-25.2	Peak	
46.17	V	180.0	1.0	67.6	-15.7	51.8	-43.4	-13.0	-30.4	Peak	
162.55	V	0.0	1.0	61.7	-12.5	49.2	-46.1	-13.0	-33.1	Peak	
176.75	V	180.0	1.0	66.4	-13.0	53.5	-41.8	-13.0	-28.8	Peak	
189.33	V	180.0	1.0	69.5	-13.0	56.5	-38.8	-13.0	-25.8	Peak	
209.77	V	180.0	1.0	62.6	-13.6	49.0	-46.2	-13.0	-33.2	Peak	
380.48	V	180.0	1.0	63.6	-7.8	55.8	-39.4	-13.0	-26.4	Peak	
400.00	V	180.0	1.0	45.3	-7.7	37.6	-57.6	-13.0	-44.6	Peak	
500.00	V	180.0	1.5	46.7	-7.0	39.7	-55.5	-13.0	-42.5	Peak	
1735.58	V	270.0	2.0	53.2	-6.8	46.4	-48.9	-13.0	-35.9	Peak	
3765.00	V	45.0	2.0	38.2	1.4	39.6	-55.7	-13.0	-42.7	Peak	
6071.70	V	180.0	3.0	51.4	6.3	57.7	-37.6	-13.0	-24.6	Peak	
9538.20	V	150.0	2.0	61.3	13.1	74.4	-20.8	-13.0	-7.8	Peak	LBE
9563.20	V	270.0	2.0	65.9	13.2	79.1	-16.2	-13.0	-3.2	Peak	UBE
72.36	H	180.0	2.0	63.2	-17.0	46.2	-49.1	-13.0	-36.1	Peak	
83.25	H	90.0	2.5	63.7	-17.5	46.2	-49.0	-13.0	-36.0	Peak	
189.31	H	0.0	3.0	71.4	-13.0	58.4	-36.9	-13.0	-23.9	Peak	
380.48	H	180.0	3.2	62.0	-7.8	54.2	-41.0	-13.0	-28.0	Peak	
476.31	H	180.0	3.0	68.2	-7.1	61.1	-34.2	-13.0	-21.2	Peak	
495.39	H	0.0	3.0	59.5	-7.0	52.5	-42.7	-13.0	-29.7	Peak	
504.29	H	270.0	4.0	44.0	-6.9	37.1	-58.2	-13.0	-45.2	Peak	
701.00	H	270.0	4.0	38.2	-5.7	32.5	-62.8	-13.0	-49.8	Peak	
1196.39	H	0.0	3.5	47.3	-8.8	38.6	-56.7	-13.0	-43.7	Peak	
2805.85	H	0.00	3.0	50.8	-0.8	50.0	-45.2	-13.0	-32.2	Peak	
3864.66	H	0.00	4.0	51.5	1.4	52.9	-42.3	-13.0	-29.3	Peak	
6807.58	H	180	3.0	43.5	8.6	52.1	-43.2	-13.0	-30.2	Peak	
9538.20	H	180.0	2.0	63.1	13.1	76.2	-19.0	-13.0	-6.0	Peak	LBE
9563.20	H	180.0	2.0	64.2	13.2	77.4	-17.9	-13.0	-4.9	Peak	UBE

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4.3.4 Test Summary

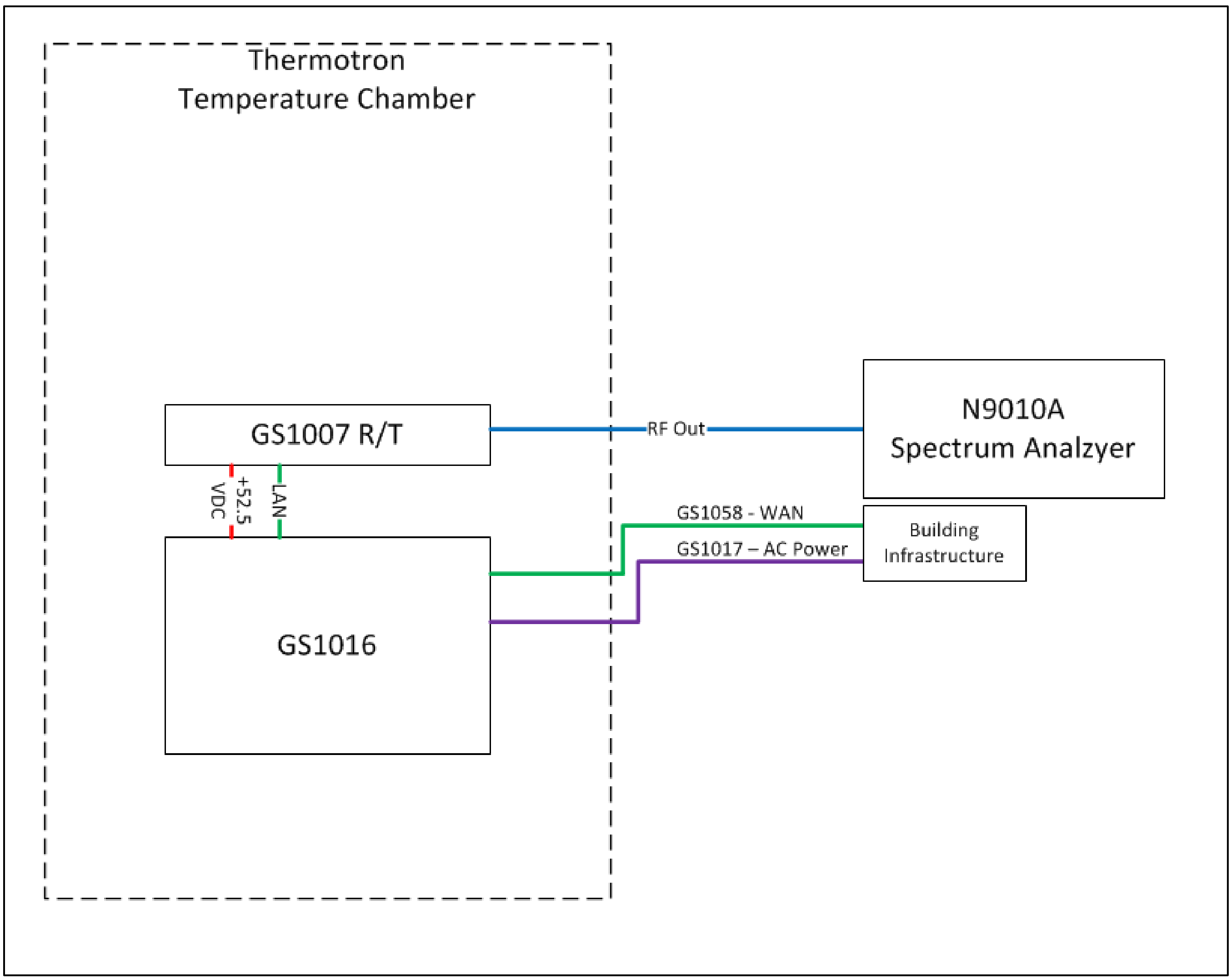
The EUT complied with the requirements of FCC Part [90.210 b (1)(2)(3)].

4.4 FREQUENCY STABILITY [FCC PART 90.213]

4.4.1 Test Method

The EUT was placed in a calibrated temperature chamber. Temperature and voltage deviation tests were performed as per FCC Part 2.1055. The R1400 radar was tested in 10° increments from -30°C to +50°C, the operational temperature range, and the deviation in frequency of the carrier was recorded. In addition, the AC input voltage is varied +/- 15% about nominal line voltage. The results are recorded.

Figure 3: Frequency Stability Test Setup Block Diagram



4.4.2 Test Limit

There is no limit in this frequency range (9300-9800MHz).

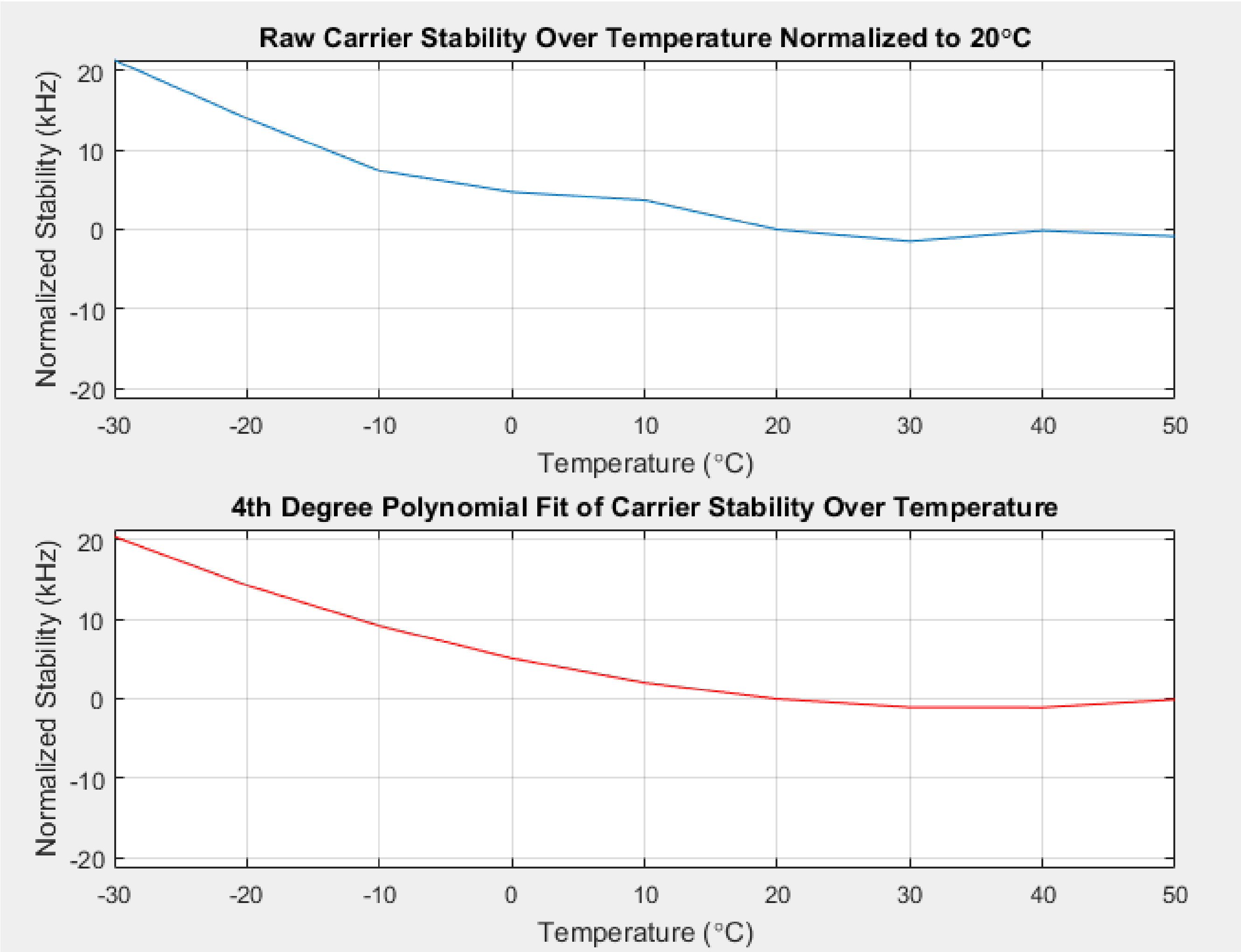
4.4.3 Test Results

Frequency Stability: +25/-5kHz, from -30°C to +50°C and AC input Voltage from 93.5 to 126.5VAC. Table 9 summarizes the frequency stability of the R1400 over temperature and normalized to 20°C.

Table 9: Frequency Stability

Temperature (°C)	Deviation (kHz)
-30	21.4
-20	14.0
-10	7.4
0	4.8
10	3.7
20	0
30	-1.5
40	-0.1
50	-0.8

Figure 4: Raw Carrier Plots



4.4.4 Test Summary

The EUT complied with the requirements of Part 90.213 since there are no defined limits.

5 ADDENDUM 1: NTIA SPECTRAL MASK AND POWER OUT MEASUREMENTS

5.1 INTRODUCTION

The following technical memo details test setups and results for Output Power and NTIA Spectral Measurements for the R1400 Radar.

5.2 REFERENCES

Supporting data stored in the following data package:

.\16 Report of Measurements\Supporting Data\R1400 Spectral Data\Pulse Data

5.3 DETAILS

The transmit spectrum and peak power of the R1400 radar system SN002 was quantified using the SRC4905 NTIA Test Set. All data represents typical performance.

5.3.1 Set-up Details

Testing was performed on SRC's campus. An erectable tower was used to place the receive standard gain horn at the appropriate elevation. Lat/Long coordinates of the radar and the tower were collected from an iphone demonstrating a distance of greater than 164 ft. Note that absolute accuracy of locations was not a concern. Our goal was to guarantee that we were in the far field of the R1400's transmit beam. The far field is approximately 80 ft. and is given by

$$\frac{2D^2}{\lambda} \text{ where } \lambda = 1.204\text{''} \text{ @ } 9.8\text{GHz and } D = \sim 24\text{''}$$

Note, the tower was erected to a height approximately 10 degrees above the radar such that the boresight Tx beam would be directly on the horn. The height of the tower was fine-tuned based on maximizing the received power level.

5.3.2 Transmit Peak Power Calibration Details

Typically, transmit testing would be done in an anechoic chamber or over an outdoor range where multipath is not as much of a concern. This lends itself to easily calculating the distance between the transmitter and the receiving standard gain horn. Since the R1400's far field is larger than available anechoic chambers an outdoor range is not available, a tower test configuration was employed to prevent multipath from impacting results. As stated prior, the exact path length between the standard gain horn and the R1400 was not known so over-the-air (OTA) calibration was performed. A diagram of the OTA calibration setup is shown below in Figure 5.

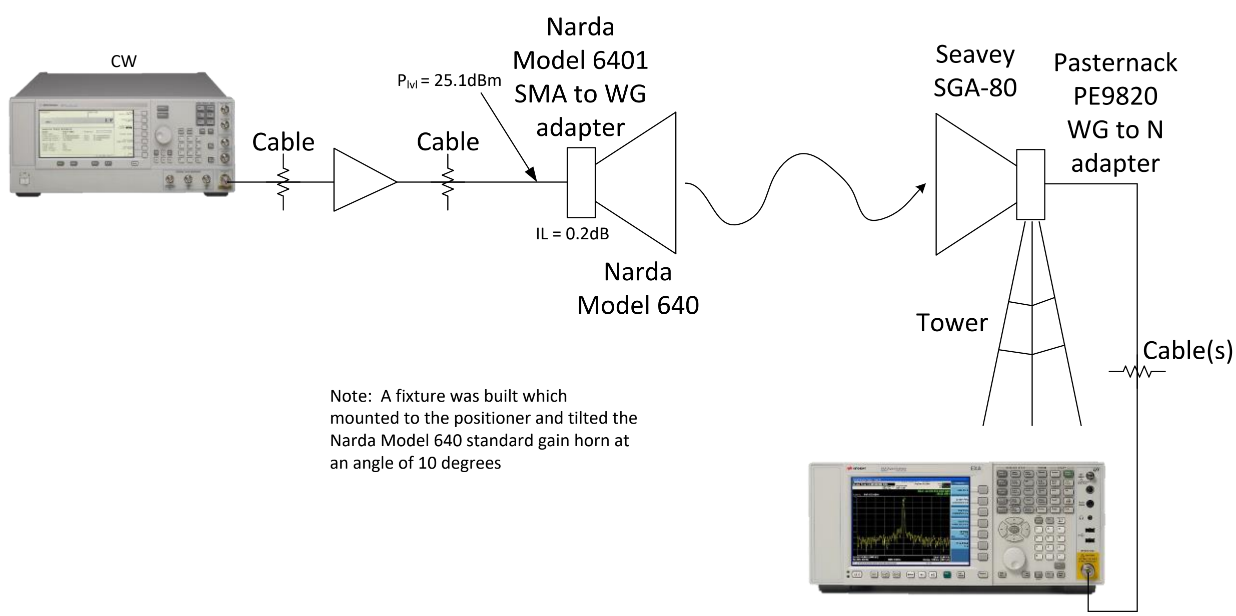


Figure 5 OTA Calibration Set-up

Note, a bracket was designed to mount the Narda Model 640 standard gain horn to the GS1009 Positioner. The goal of the bracket was to place the phase center of the horn in the same location as the R1400 phase center. The bracket also incorporated a 10-degree tilt back, which mimics the R1400 tilt back angle in this setup. Pictures of the setup are shown below in Figure 6.

Figure 6. OTA Calibration Setup

The resultant OTA calibration for SN002 tower testing were as follows:

Freq [GHz]	OTA Cal [dBm]
9.30	-38.7
9.55	-39.3
9.80	-39.1

Table 10 OTA Calibration Factors

Noise levels were quantified during system OTA calibration at -74.2 dBm. Trace averaging of 100 was employed to buy back some SNR which resulted in a 20 dB improvement factor. As a result, the worst case SNR during the OTA calibration was ~55 dB.

5.3.2.1 R1400 Transmit Peak Power Measurements

The next step was to swap out the Narda Model 640 standard gain horn with the R1400. A block diagram of the setup is shown below in Figure 7.

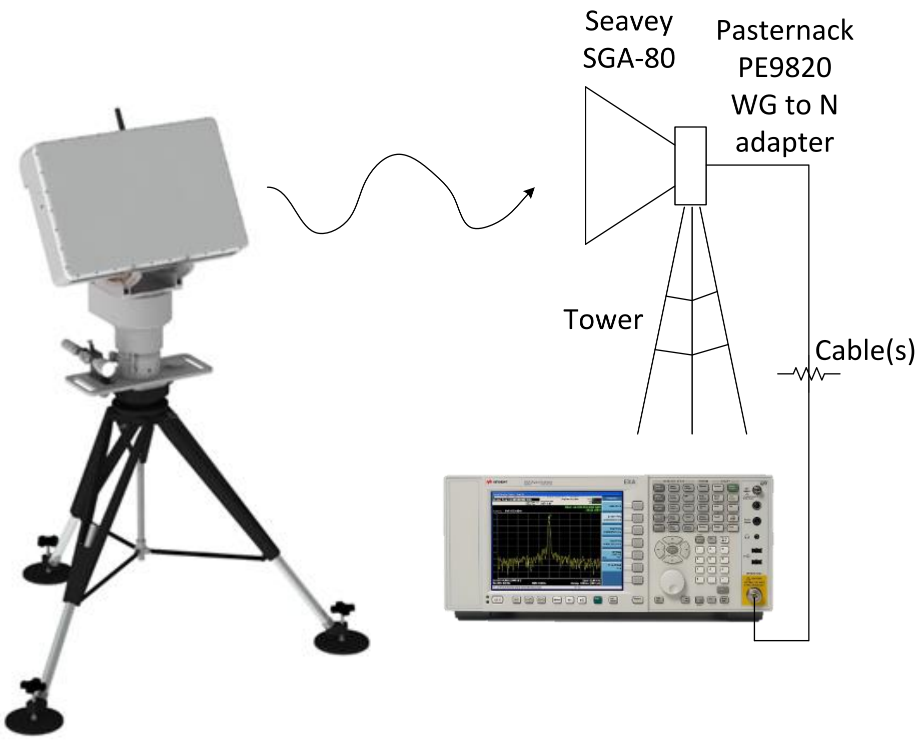


Figure 7 R1400 Transmit Peak Power Measurement Setup

The radar was placed in a mode where it was only transmitting a single waveform type at boresight. The radar was incrementally moved in azimuth to guarantee we were at the peak of the transmit beam. Below are the results of the measured transmit power levels made by the EXA 9010A spectrum analyzer in zero span mode. The peak power reported is the maximum from all pulse widths tested.

Freq [GHz]	Peak Tx Level [dBm]
9.30	6.484
9.55	4.804
9.80	4.900

Table 11 R1400 Measured Tx Peak Power Levels

5.3.2.2 *The Process*

The next step is to take the known quantities and back out the R1400's transmit peak power according to the following equation:

$$R1400_{directivity} + R1400_{PkPwr} = \text{Narda Model } 640_{directivity} + \text{OTA Cal}_{PkPwr} + \Delta \text{ in Tx Measurements}$$

Rearranging and solving for $R1400_{PkPwr}$ yields

$$R1400_{PkPwr} = \text{Narda Model } 640_{directivity} + \text{OTA Cal}_{PkPwr} + \Delta \text{ in Tx Measurements} - R1400_{directivity}$$

5.3.2.2.1 R1400 Directivity

The directivity of the R1400 is taken directly from NFP chamber calibration process. The data is summarized below in Table 12 R1400 Directivity. The maximum directivity was taken from the beam pointed at boresight.

Freq [GHz]	R1400 Directivity [dBi]
9.30	29.75
9.55	30.05
9.80	30.37

Table 12 R1400 Directivity

5.3.2.2.2 Narda Model 640 Directivity

The directivity curves, ideal and measured, for the Narda Model 640 standard gain horn are shown below.

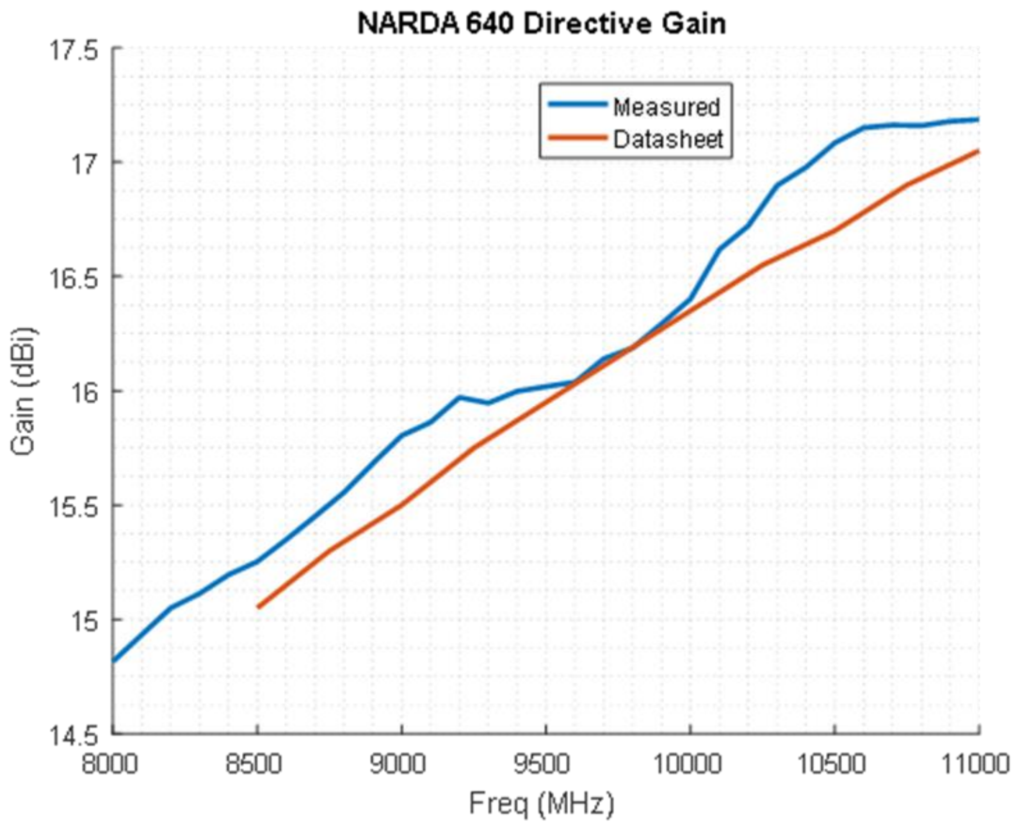


Figure 8 Narda Model 640 Measured Directivity (Narda640Ideal), (Narda640Meas)

In order to guarantee as much accuracy in our calculations we will use the measured data, which is summarized below in Table 13 Narda Model 640 Directivity.

Freq [GHz]	Narda Model 640 Directivity [dBi]
9.30	15.95
9.55	16.03
9.80	16.19

Table 13 Narda Model 640 Directivity

5.3.2.2.3 OTA Calibration Peak Transmit Power

An E8257C signal generator was used to stim the Narda Model 640 standard gain horn. It was calibrated using a N1912A power meter. The setup is shown below.

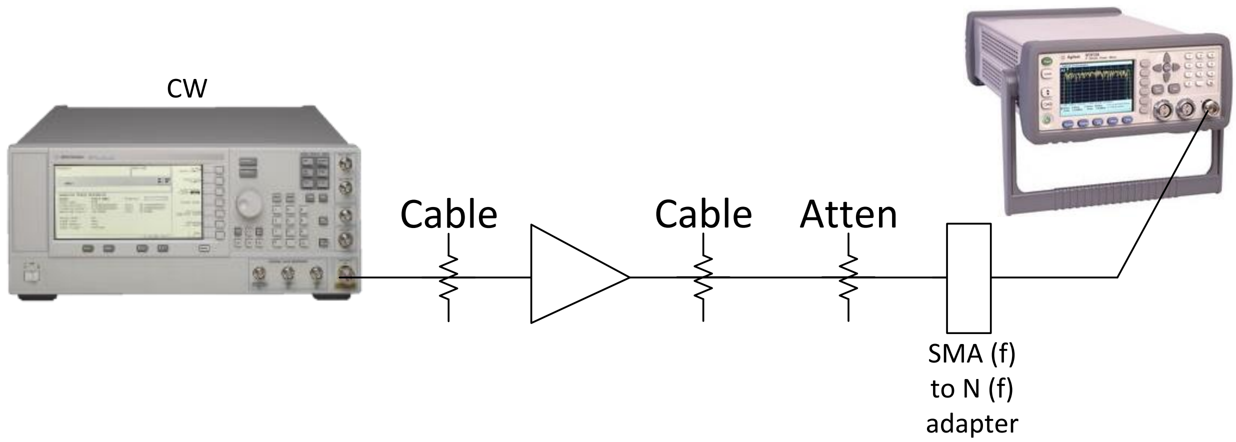


Figure 9 OTA Peak Power Calibration Setup

The input of the E8257C signal generator was tuned in order to achieve +5 dBm at the N1912A power meter. The attenuator was then swept on a network analyzer as it is removed in the final OTA measurement. The measurements of the attenuator are shown below in Figure 10.

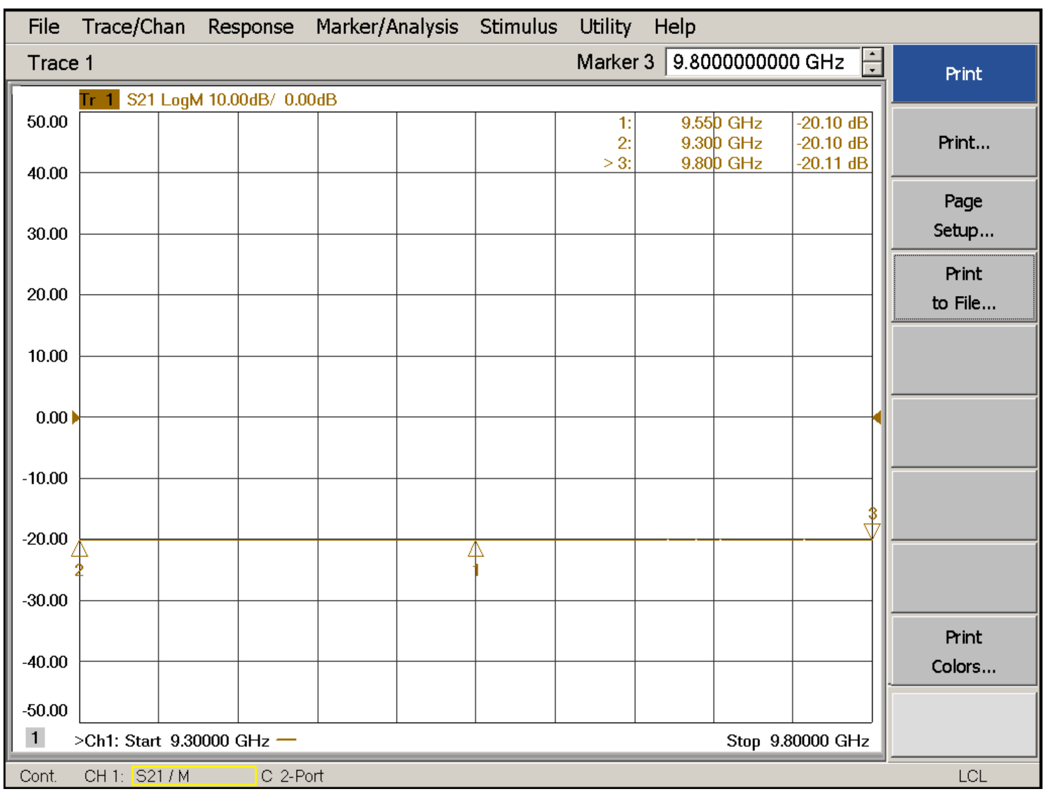


Figure 10. OTA Cal Attenuator Measurements

Effectively, the output power at all frequencies was +5 dBm + 20.1 dB = 25.1 dBm.

Note, the insertion loss of the SMA to N type adapter was not accounted for. It's insertion loss is estimated to be ~0.15 dB which is assumed to be equal to the loss of the SMA to waveguide adapter shown in Figure 9, hence they will cancel each other out.

Freq [GHz]	OTA Cal Pk Power [dBm]
9.30	25.1
9.55	25.1
9.80	25.1

Table 14 OTA Peak Power

5.3.2.2.4 Delta in Transmit Measurements

Lastly, the difference between the OTA cal and the R1400 measurements are calculated. The data is already presented in Table 10 & Table 11, but the final numbers are shown below for completeness.

Freq [GHz]	Measurement Δ [dB]
9.30	45.184
9.55	44.104
9.80	44.000

Table 15 Delta in Transmit Power Levels

5.3.2.2.5 R1400 Peak Transmit Power Calculations

The power out for this radar as designed will be on the order of 57dBm. Running the numbers, one can back out the peak transmitted power of the radar using the equation in section 4.4 resulting in the measured output of SN002 in Table 16.

Freq [GHz]	R1400 Peak Tx Power [dBm/W]
9.30	56.5/445.0
9.55	55.2/329.9
9.80	54.9/310.5

Table 16. R1400 Peak Transmit Power vs Frequency

5.3.3 R1400 Spectral Emissions Testing

A diagram of the setup for spectral emissions testing is shown below in Figure 11. Note, the addition of the SRC4905 NTIA receiver. The SRC4905 is a wideband receiver developed with the assistance of the Institute for Telecommunication Sciences (ITS) which is the research and engineering arm of the NTIA. The device was designed to optimize dynamic range while making spectral emissions measurements.

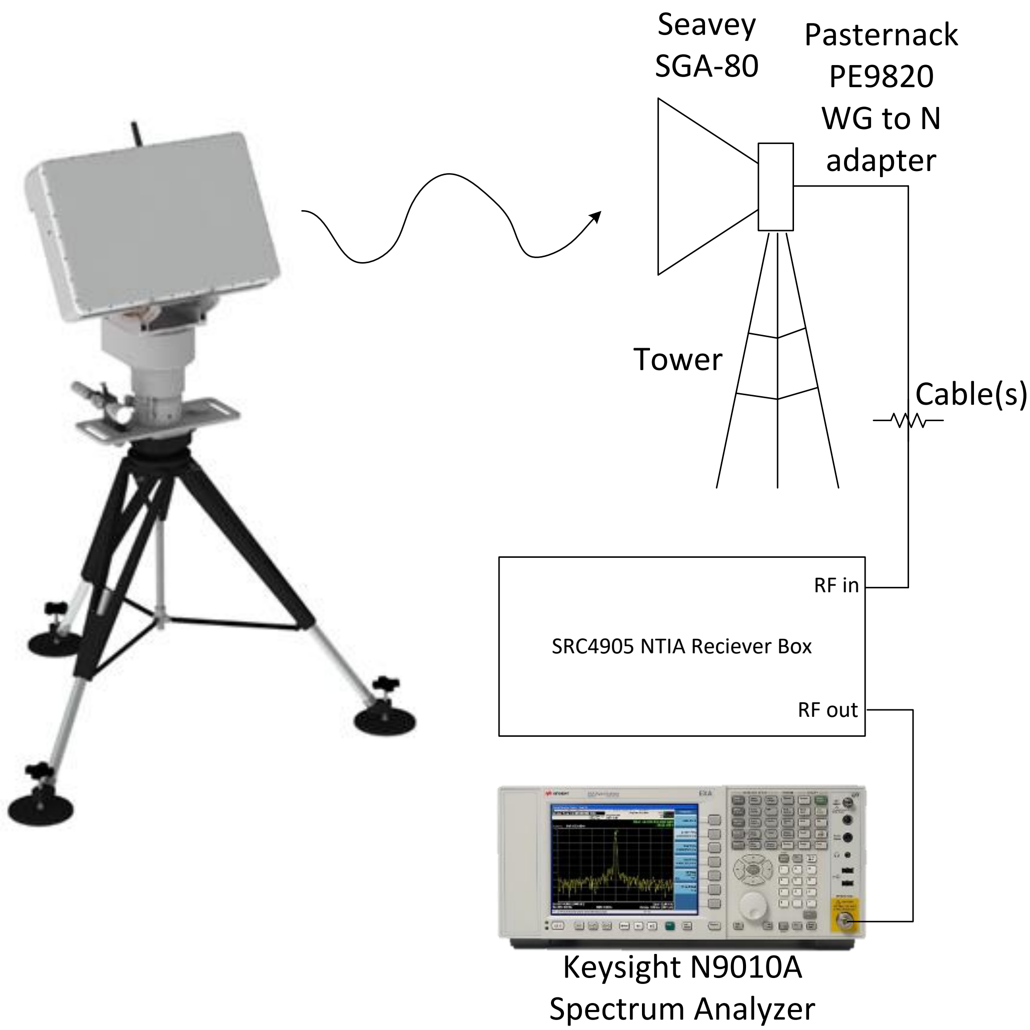


Figure 11. Spectrum Emissions Test Set-up

Data was collected at the low, mid and high points of the R1400 frequency range, or 9.3 GHz, 9.55 GHz and 9.8 GHz respectively. The data collected is representable of the range of pulse widths the R1400 is intended to utilize for its mission space, 1 uSec to 50 uSec. The waveform pulse width is defined by the sampled data written to the digital-to-analog converter (DAC). The R1400 will operate anywhere from 1 uSec to 50 uSec waveform pulse widths in 0.5 uSec pulse width increments. For completeness, two other pulse widths, 2 uSec and 10 uSec, were measured as sampling points. The measured pulse width is shorter than the waveform pulse width due to a taper applied to the transmit waveform in order to optimize the waveform rise/fall times to control the spectral emissions of the radar. Below in Table 17 is a summary of the waveform characteristics used to calculate NTIA criteria A spectral masks.

Raw data is also available under the supporting material folder.

Freq [GHz]	Waveform Pulse Width [uSec]	Measured 50% Voltage Pulse Width [uSec]	Measured 10/90 Rise Time [uSec]	Measured 10/90 Fall Time [uSec]
9.30	1	0.675	0.172	0.162
9.30	2	1.386	0.319	0.279
9.30	10	6.854	1.515	1.309
9.30	50	34.300	7.194	6.661
9.55	1	0.712	0.150	0.145
9.55	2	1.466	0.258	0.243
9.55	10	7.339	1.194	1.089
9.55	50	36.390	5.896	5.632
9.80	1	0.650	0.180	0.179
9.80	2	1.326	0.354	0.306
9.80	10	6.575	1.742	1.472
9.80	50	33.060	8.338	7.574

Table 17 Waveform Measured Rise/Fall Times

Commensurate with the data above in Table 17 is the criteria A NTIA spectral masks plotted with the associated spectral emissions arranged by pulse width.

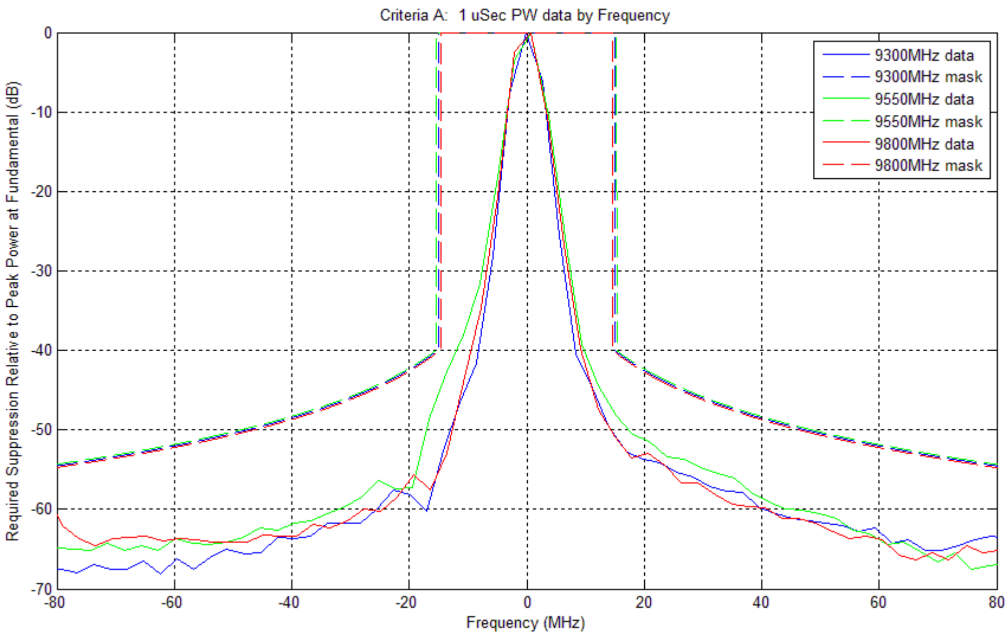


Figure 12 1 uSec Spectral Emissions

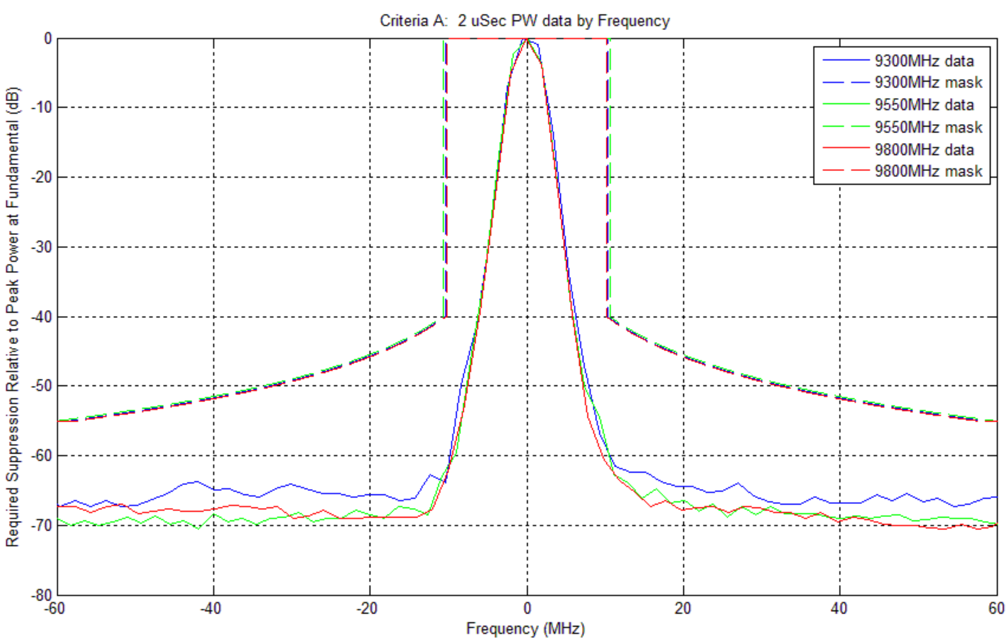


Figure 13 2 uSec Spectral Emissions

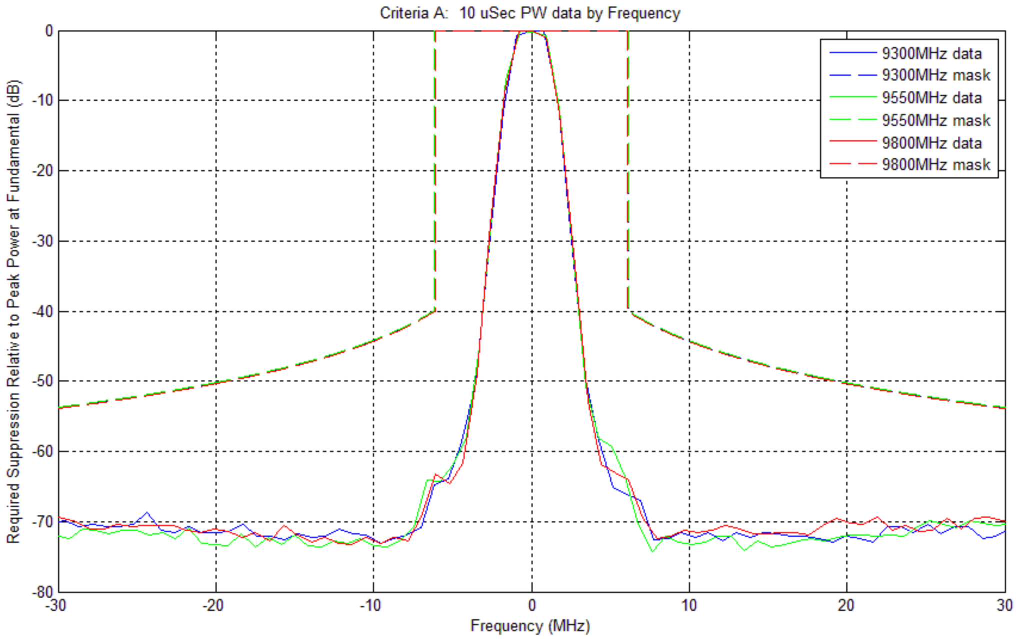


Figure 14 10 uSec Spectral Emissions

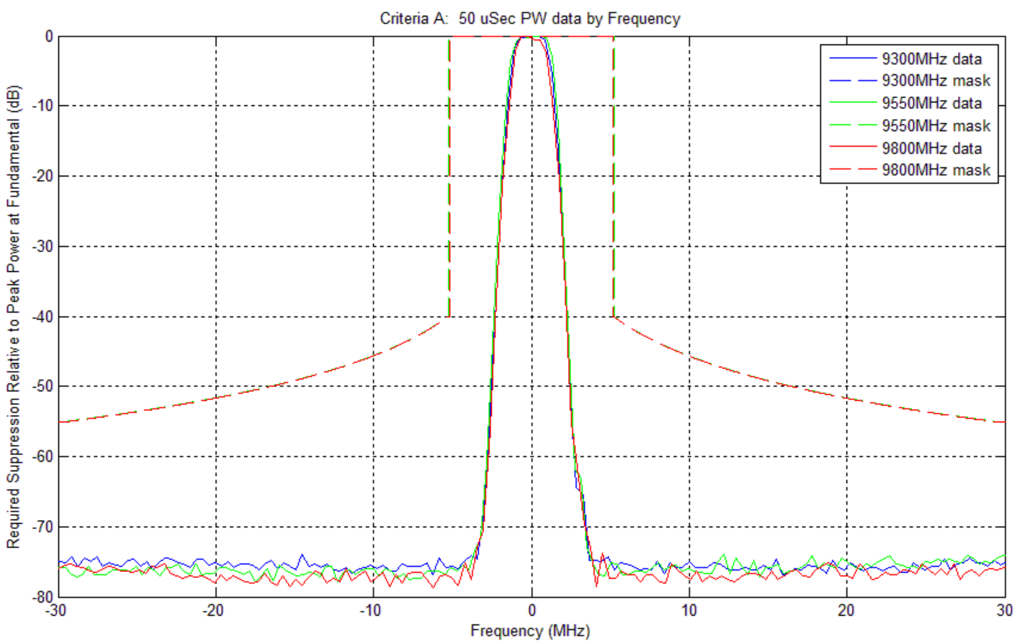


Figure 15 50 uSec Spectral Emissions

Lastly, listed below in Table 18 is a summary of the occupied bandwidth at the 3, 20, 40 and 60 dB points of all the measured waveforms.

Frequency (MHz)	Pulse Width (µs)	Occupied Bandwidth (MHz)			
		3dB	20dB	40dB	60dB
9300	1	2.9	9.5	16.3	65.6
	2	3.6	7.9	12.4	22.3
	10	2.6	4.4	6	9
	50	2.4	3.6	4.6	5.4
9550	1	3.6	10.8	21.7	75.9
	2	3.6	7.8	12.1	19.4
	10	2.5	4.4	6	9.8
	50	2.6	3.8	4.7	5.5
9800	1	3.9	10.1	18.7	69.1
	2	3.1	7.6	12	18.9
	10	2.6	4.5	6	8.2
	50	2.1	3.5	4.5	5.5

Table 18 Waveform Occupied Bandwidths