NOKIA Bell Labs

Global Product Compliance Laboratory
600-700 Mountain Avenue
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TESTING
NVLAP LAB CODE: 100275-0

FCC Certification Part 30 Test Report

Product Evaluated
AirScale 28 GHz Radio Unit (AEUD-AEUE) Band 30
AEUD-AEUE,

(AEUD AirScale MAA 2x2T2R 256AE n257 4W
AEUE AirScale MAA 2x2T2R 256AE n257 4W)

FCC ID: 2AD8UAEUDAEUE01

Customer
Nokia Solutions and Networks, OY
2000 Lucent Lane
Naperville, Illinois 60563

Test Laboratory
Nokia Bell Labs
Nokia, Global Product Compliance Laboratory
600-700 Mountain Avenue, Rm 5B-108
Murray Hill, New Jersey 07974-0636 USA

Date: September 9, 2019

Revisions

Date	Revision	Section	Change
9/9/2019	0		Initial Release

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Prepared By: W. Steve Majkowski NCE

9/9/2019

Product Certification Filing Lead
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9/9/2019

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Nokia Bell Labs
Nokia, Global Product Compliance Laboratory

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1. ATTESTATION OF TEST RESULTS

Company Name	**Nokia Solutions and Networks, OY** 2000 Lucent Lane Naperville, Illinois 60563
FCC ID	**2AD8UAEUDAEUE01**
Product Name	**AirScale 28 GHz Radio Unit (AEUD-AEUE) Band 30**
Product Designations	**AEUD AirScale MAA 2x2T2R 256AE n257 4W** **AEUE AirScale MAA 2x2T2R 256AE n257 4W**
Model Name	**AEUD – AEUE (Base Unit and Extension Unit)**
Part No	474611A.101, & 474690A.101,
Serial Number(s)	AC/DC Models: L1192413253, L1192304478 & L11923096402
Test Standard(s)	• 47 CFR FCC Parts 2 • KDB 971168 D01 Licensed DTS Guidance v02 June 4, 2013 • KDB 662911 D01 Multiple Transmitter Output v02r01 Oct 2013 • Procedures on TRP Compliance for Out of Band and Spurious Emissions C63.26 mmWave JTG - Version # 1 July 14th 2018
Reference(s)	• 47 CFR FCC Part 2 and Part 30 • ANSI C63.26 (2015) • ANSI C63.4 (2014) • TR 14-1001, MMW Measurements with Harmonic Mixers (April-4-2014)
Frequency Band	(Tx: 27.5 – 28.35 GHz), NR Band n261
Technology	5G-New Radio, LTE-TDD: 98M0G7W,
Test Frequency Range	10MHz – 100GHz
Operation Mode(s)	2x 48 dBm EIRP, 51 dBm EIRP Total. 1 – 4 carriers MIMO
Submission Type	Initial Filing
FCC Part 15 Subpart B	Compliance with Class B
Test Date	July 10, through September 6, 2019
Test Laboratory	Nokia Global Product Compliance Laboratory 600-700 Mountain Avenue, Rm 5B-108 Murray Hill, New Jersey 07974-0636 USA **NVLAP** Lab Code: 100275-0 FCC **Registration Number: 395774**

This is to certify that the above product has been evaluated and found to be in compliance with the Rules and Regulations set forth in the above standard(s). The data and the descriptions about the test setup, procedures and configuration presented in this report are accurate. The results of testing in this report

apply only to the product/system which was tested. Other similar equipment will not necessarily produce the same results due to production tolerance and measurement uncertainties.

Per the requirement of Section 2.911(d) Certification of Technical Test Data, I hereby certify that the technical test data are the results of tests either performed or supervised by me.

W. Steve Majkowski NCE
Member of Technical Staff
Nokia, Global Product Compliance Laboratory

2. SUMMARY OF THE TEST RESULTS

47 CFR FCC Sections	Description of Tests	Compliance Results
2.1046, 30.202 (a)	RF Power Output	Pass
2.1047,	Modulation Characteristics	Pass
2.1049, 30.203	(a) Occupied Bandwidth (b) Edge-of-Band Emissions	Pass
2.1051, 30.203	Spurious Emissions at Antenna Terminals - Radiated	Pass
2.1053, 30.203	Field Strength of Spurious Radiation	Pass
2.1055,	Measurement of Frequency Stability	Pass

2.1 Measurement Uncertainty

The results of the calculations to estimate uncertainties for the several

Worst-Case Estimated Measurement Uncertainties

Standard, Method or Procedure	Condition	Frequency MHz	Expanded Uncertainty (k=2)
a. Classical Emissions, (*e.g.*, ANSI C63.4, CISPR 11, 14, 22, *etc.*, using ESHS 30,	Conducted Emissions	0.009 - 30	±3.5 dB
	Radiated Emissions (AR-8 Semi-Anechoic Chamber)	30 MHz – 200MHz H 30 MHz – 200 MHz V 200 MHz – 1000 MHz H 200 MHz – 1000 MHz V 1 GHz- 18 GHz	±5.4 dB ±5.4 dB ±4.7 dB ±4.7 dB ±3.3 dB

Antenna Port Test	Signal Bandwidth	Frequency Range	Expanded Uncertainty (k=2), Amplitude
Occupied Bandwidth, Edge of Band,	10 Hz 100 Hz 10 kHz to 1 MHz 1MHz to 100 MHz	9 kHz to 20 MHz 20 MHz to 1 GHz 1 GHz to 10 GHz 10 GHz to 40 GHz:	±2.2 dB
Conducted Spurious Emissions	30 kHz to 100 MHz	10 MHz to 40 GHz:	±2.8 dB
RF Power, Channel Power	10 Hz to 100 MHz	10 MHz to 40 GHz	±1.4 dB

3. GENERAL INFORMATION

3.1 Product Descriptions

The equipment under test (EUT) has the following specifications.

Table 3.1.1 Product Specifications

Specification Items	Description
Product Type	Compact Base Station LTE Module (2Tx, 2Rx), 2x2 MIMO
Radio Type	Intentional Transceiver
Power Type	115 VAC or -48 VDC
Modulation	5G New Radio LTE-TDD with QPSK, 16QAM and 64QAM
Operating Frequency Range	TDD (Tx/Rx: 27.5-28.35 GHz),
Channel Bandwidth	100 MHz,
Max Radiated Power (EIRP)	48 dBm EIRP per polarizations; based upon 25 dBm Tx output. 51 dBm EIRP Total for the two polarizations.
Antenna Gain	23 dBi
Operating Mode	2x2 MIMO (2 duplex Tx/Rx Ports)
Software Version	FLF17SP, 5GH49.06.R04
Hardware Version	474611A.101, & 474690A.101
Antenna(s)	Refer to Section 3.2

The EUT supports the following carrier configurations:

Table 3.1.2 EUT Supported Configurations

Carrier Bandwidth (MHz)	Carriers per Path	MIMO Modes	Signal Type	Modulation
100	1	2x	5G-NR LTE-TDD	QPSK, 16QAM & 64QAM

The operating band consists of the following channels and spectrum:

Table 3.1.3 NRARFCN per 38.101-2, for n261 with 100 MHz Carriers

NRARFCN	TDD Center Reference Frequency (GHz)	Raster Delta, MHz
2071674	27.550510	99.96
2073340	27.650470	99.96
2075006	27.750430	99.96
2076672	27.850390	99.96
2078338	27.950350	99.96
2080004	28.050310	99.96
2081670	28.150270	99.96
2083336	28.250230	99.96

3.2 EIRP/ PSD Compliance and Antenna Information.

The product incorporates integrated antennas. Externally mounted antennas cannot be attached to the unit or mounted remotely. The units integrated antennas are electronically steerable with a maximum gain of 29 dBi. There are two antenna assemblies inside the product. Each antenna assembly is a 8x8 matrix (64 elements). One assembly is vertically polarized and the second is horizontally polarized. The antennas RF drive level is 25 dBm. The 25 dBm RF power and 23 dBi gain results in a 48 dBm EIRP per assembly. The sum of the two 48 dBm EIRP beams results in a maximum EIRP of 51 dBm. Antenna Gain vs frequency is detailed in Exhibit 6 of the filing package.

3.3 Antenna Far Field Determination Distance

The Moongilan Test (1) was performed to determine the far field boundary location using calculations and low power measurements. For the antenna array we can calculate the Fraunhofer distance from

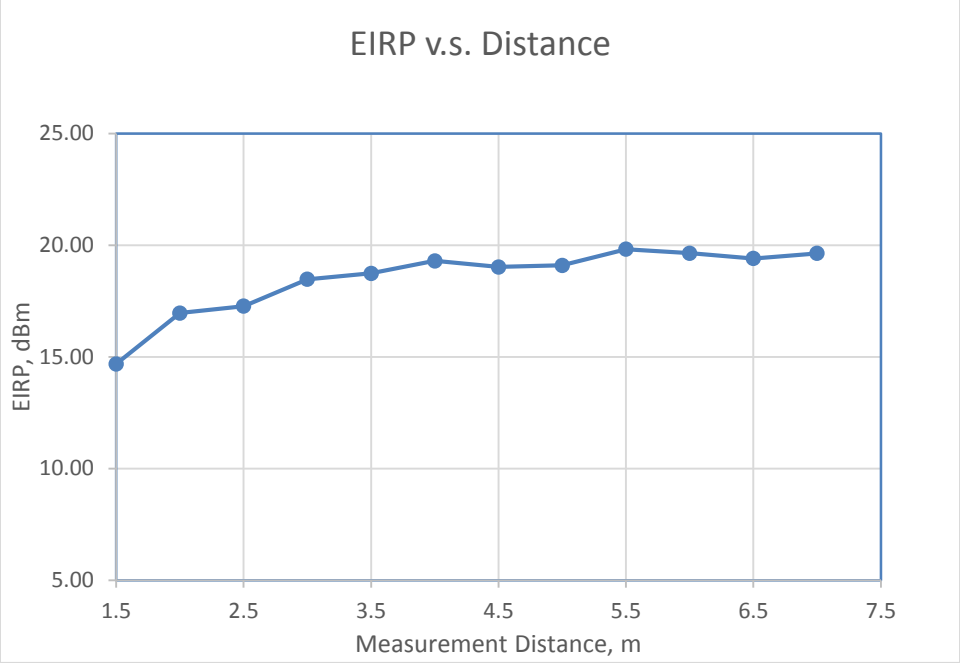
$$d_{ff} = 2D^2/\lambda$$

where d_{ff} = Far Field distance in meters,
D is the maximum size of the radiating array λ = wavelength of the operating signal in meters

The antenna patch are approximately 5 cm x 5 cm and the patches are 13 cm apart .
At 28 GHz the diagonal 5 x 5 cm array dimensions results in a far field distance d_{ff} of 1 meter.

Measurements for the Moongilan Test were performed at low power using a standard gain horn antenna In the horizontal polarization the determined boundary was 3.5 m.
To eliminate any inconsistancy all Power, OBW and OOBE measurements were made at 4.5 m.

(1) The Moongilan Test is named in honor of the late Dheena Moongilan who discovered it and formulated its use into C63.26.



4. REQUIRED MEASUREMENTS AND RESULTS

Per 47CFR FCC Section 2.1033(c)(14), the following certification tests are required by Section 2.1046 through Section 2.1057. These tests are identified in Table 4.0a below.

Table 4.0a Required Certification Measurements

47 CFR FCC Sections	Description of Tests	Test Required for Original Authorization
2.1046, 30.202 (a)	**RF Power Output** **(a) Power Limits, EIRP, PSD**	**Yes**
2.1047,	**Modulation Characteristics**	**Yes**
2.1049, 30.203	**(a) Occupied Bandwidth** **(b) Out-of-Band Emissions**	**Yes**
2.1051, 30.203	**Spurious Emissions at Antenna Terminals**	**Yes**
2.1053, 30.203, 30.204, 15.109(a) Class B	**Field Strength of Spurious Radiation**	**Yes**
2.1055,	**Measurement of Frequency Stability**	**Yes**

The measurements were conducted in accordance with the procedures set out in Section 2.1041 and as appropriate per the test Standards listed in Table 4.0b below. The comprehensive list of tests performed included measurements at Left, Center and Right side of the Part 30 Band. These tests are presented to demonstrate compliance with FCC requirements.

Table 4.0b Test Standards Used for Radiated Measurements of Radio Performance

Test Standard(s)	• 47 CFR FCC Parts 2 • KDB 971168 D01 Licensed DTS Guidance v02 June 4, 2013 • KDB 662911 D01 Multiple Transmitter Output v02r01 Oct 2013 • Procedures on TRP Compliance for Out of Band and Spurious Emissions C63.26 mmWave JTG - Version # 1 July 14th 2018
Reference(s)	• 47 CFR FCC Part 2 and Part 30 • ANSI C63.26 (2015) • ANSI C63.4 (2014) • TR 14-1001, MMW Measurements with Harmonic Mixers (April-4-2014)

4.1 Section 2.1046 MEASUREMENT REQUIRED: RF POWER OUTPUT

This test is a measurement of the total Radiated Power level transmitted at the antenna-transmitting terminal. The product was configured for test as shown in Figure 4.1.1 below and allowed to warm up and stabilize per KDB 971168 D01 and ANSI C63.26.

The **Nokia AirScale 28 GHz Radio Unit (AEUD-AEUE), FCC ID: 2AD8UAEUDAEUE01,** is a 5G-NR LTE TDD transceiver specified to provide a maximum power output of 48 dBm EIRP/63 W EIRP per transmit polarization for a sum total of 51 dBm EIRP /126W EIRP per unit.

The power is under digital control. The product is designed to operate under Part 30 rules for Band n261. Under Part 30 the average power of the sum of all antenna elements is limited to an equivalent isotopically radiated power (EIRP) density of +75dBm/100 MHz.

The product incorporates +23 dBi internal antenna arrays and substitution of the Tx antennas is not possible.

4.1.1 RF Power Output Measurement

Power measurements of the 5G New Radio transmit signal were conducted with FSW Spectrum Analyzers per KDB 971168 D01. Measurements were performed at a distance of 4.5 m. The path loss, cable loss and measurement antenna gain were offset and displayed on the screen. The transmitted signals were TDD LTE based and had the general modulation characteristics of QPSK, 16 QAM and 64QAM.

The maximum rated average EIRP at the 4.5 m boundary distance was measured at the Left, Center and Right side of the 27.5-28.35 GHz frequency range for the nominal 100 MHz bandwidth carrier in three different Modulations modes. These were 3GPP standard base station test models for QPSK+16QAM and 64QAM modulation. This power level was documented on each data sheet for Channel Power.

Additional measurements were performed for the two, three and four carrier configurations documenting MIMO operation.

4.1.1.1 RF Power Output Results

The Power output measurement results verified the expected performance of 48 dBm EIRP per polarization which is 51 dBm total. The maximum measured level was **51.30** dBm. This level is well within the maximum Part 30.202a limit of 75 dBm EIRP. Measurements were performed for each modulation.

The measured performance was in full compliance with the Rules of the Commission. Sample data plots are detailed below.

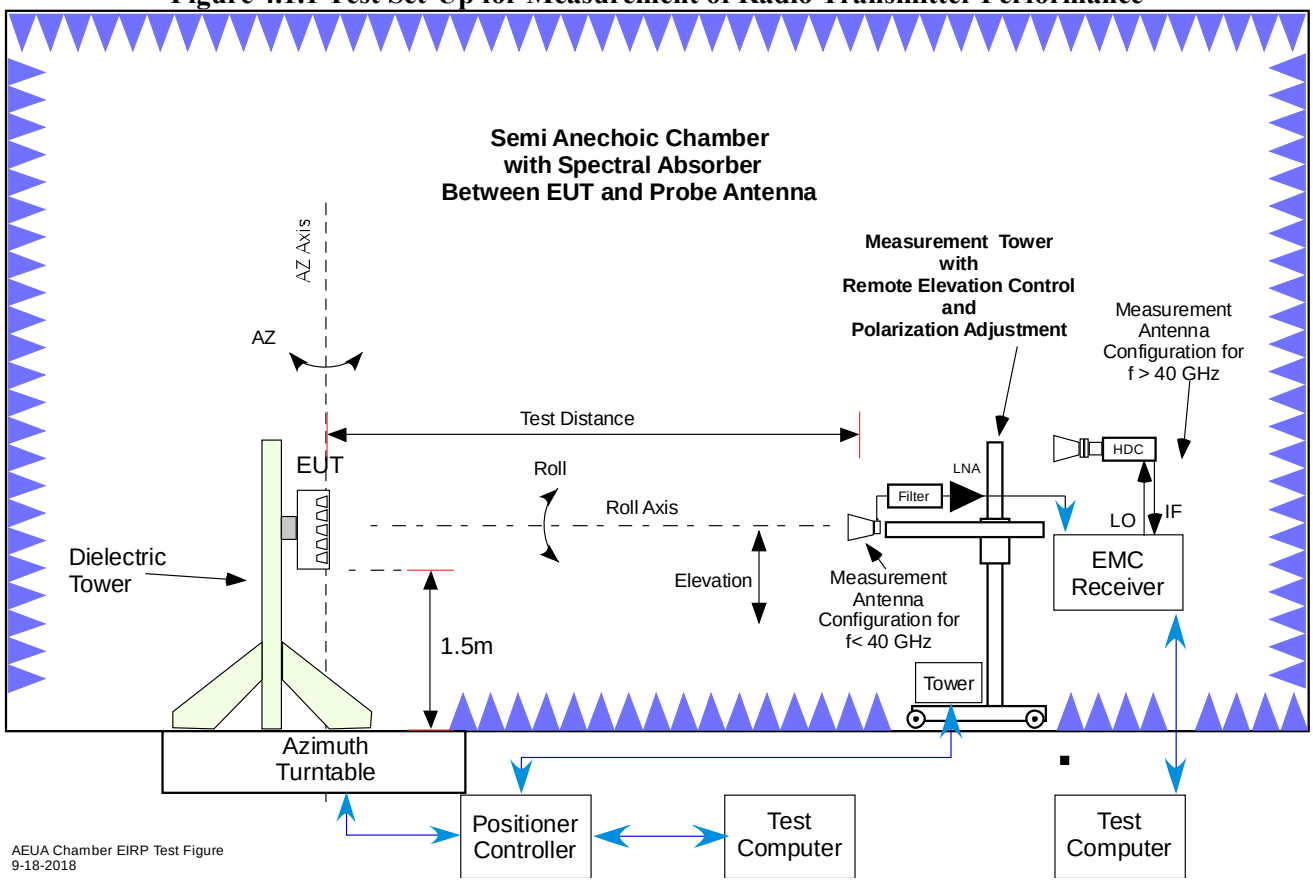
4.1.1.2 RF Power Output Data

Table 4.1.1.1 below summarizes the Total Measured EIRP for the different configurations and modulations for 1 carrier, 2 carrier, 3 carrier and 4 carrier configurations. Sample data plots follow.

Table 4.1.1.1 Summary of Channel Power Measurements

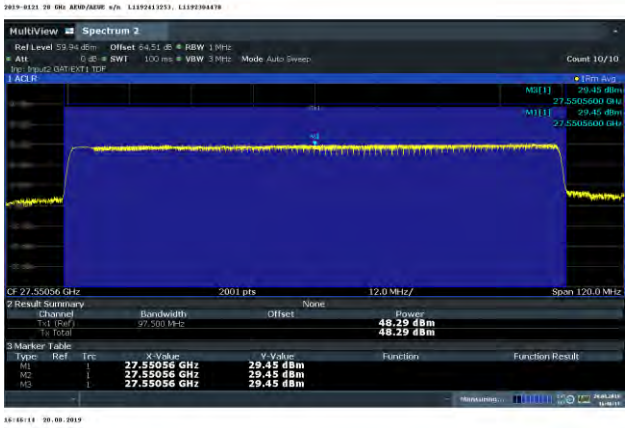
Channel Power Measurement Summary						
				Polarization		Both Polarizations
				Horizontal	Vertical	
Location in Band	Freq., GHz	# of carriers	Modulation	Total Measured Channel Power		Total Output Power
				EIRP- dBm	EIRP- dBm	EIRP- dBm
Left	27.55056	1	QPSK	48.29	47.91	51.11
Center	27.95040	1	QPSK	48.11	48.35	51.24
Right	28.25016	1	64QAM	48.36	48.18	51.28
Far Right	28.29996	1	64QAM	48.16	48.08	51.13
Left	27.55056	2	16QAM	45.04	44.41	
	27.65052			45.09	45.47	
Total per Polarization Power for 2 Carriers				48.08	47.98	51.04
Right	28.05036	3	16QAM	42.20	43.43	
	28.15032			44.38	43.24	
	28.25028			43.57	43.37	
Total per Polarization Power for 3 Carriers				48.25	48.12	51.20
Left	27.55056	4	64QAM	41.93	41.76	
	27.65052			41.92	42.07	
	27.75048			42.31	42.23	
	27.85044			42.10	42.64	
Total per Polarization Power for 4 Carriers				48.10	48.21	51.17
Right	27.95040	4	64QAM	41.40	41.98	
	28.05036			41.95	42.19	
	28.15032			42.54	41.93	
	28.25028			43.44	42.40	
Total per Polarization Power for 4 Carriers				48.42	48.15	51.30
Spread Center	27.55056	4	QPSK + 16QAM	42.02	42.38	
	27.75048			41.31	42.00	
	27.95040			41.55	42.44	
	28.15032			42.69	42.76	
Total per Polarization Power for 4 Carriers				47.98	48.44	51.23

Figure 4.1.1 Test Set-Up for Measurement of Radio Transmitter Performance

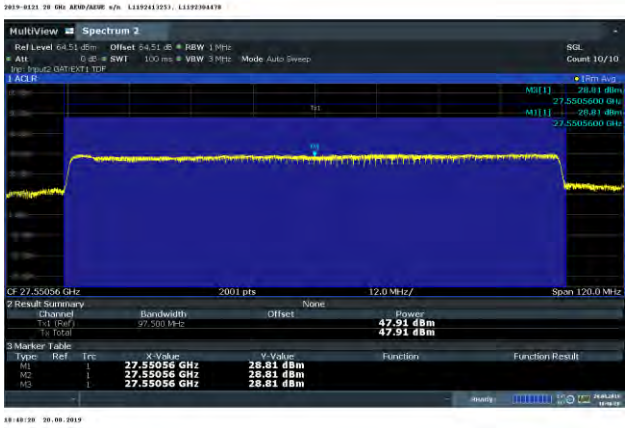


Channel Power Measurements, 4.5m, QPSK, Left, Tx Panels P1, 1 Carrier

27.55056 GHz Horizontal –

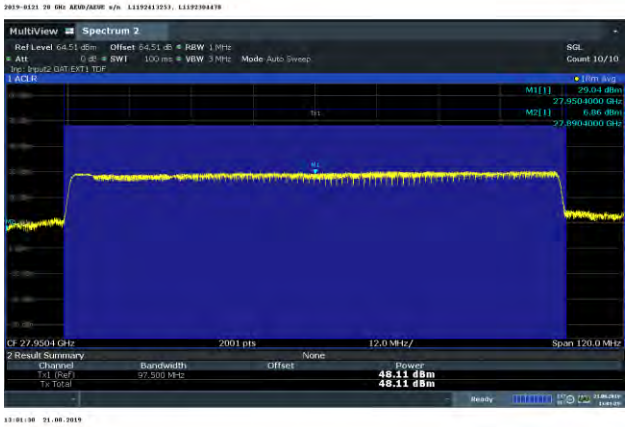


27.55056 GHz Vertical

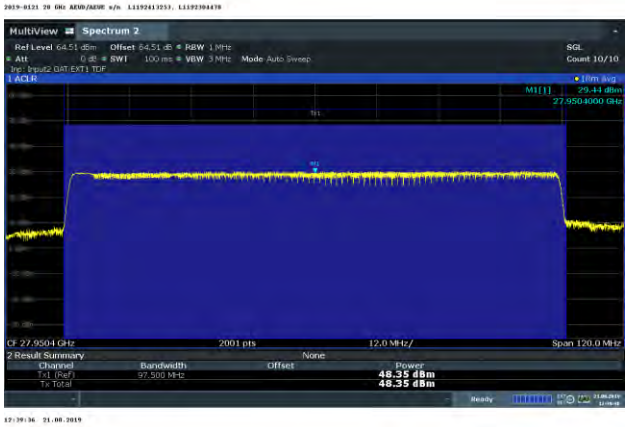


Channel Power Measurements, 4.5m, QPSK, Middle, Tx Panels P2, 1 Carrier

27.9504 GHz Horizontal

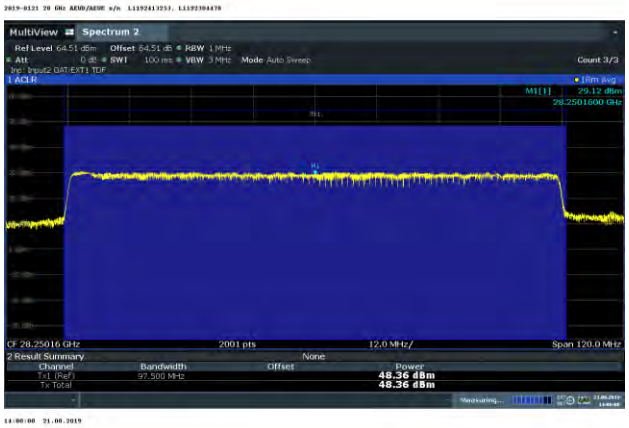


27.9504 GHz Vertical

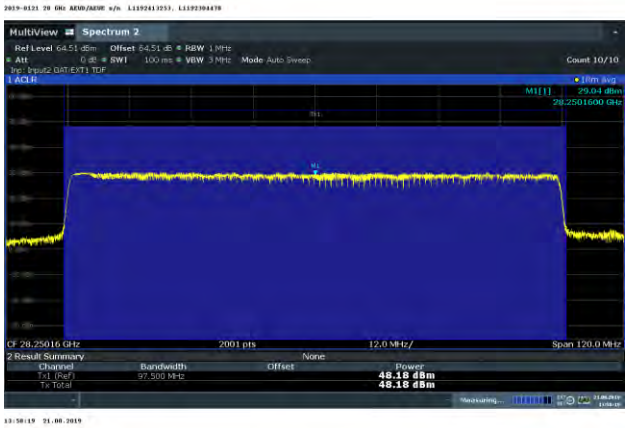


Channel Power Measurements, 4.5m, 64QAM, Right, Tx Panels P2, 1 Carrier

28.25016 GHz Horizontal

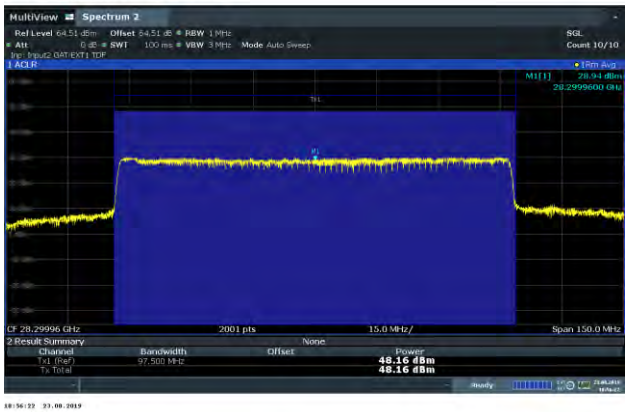


28.25016 GHz Vertical

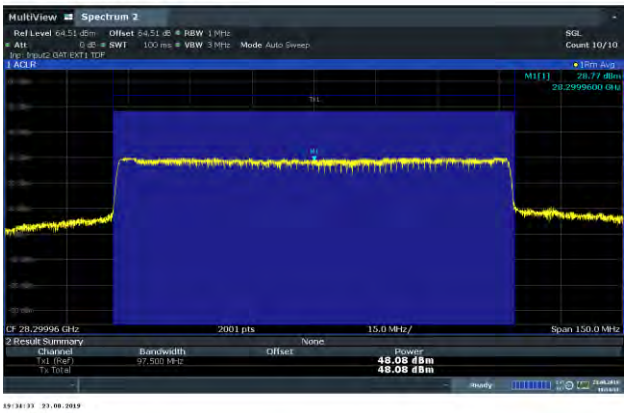


Channel Power Measurements, 4.5m, 64QAM, FRight, Tx Panels P4, 1 Carrier

28.29996 GHz Horizontal



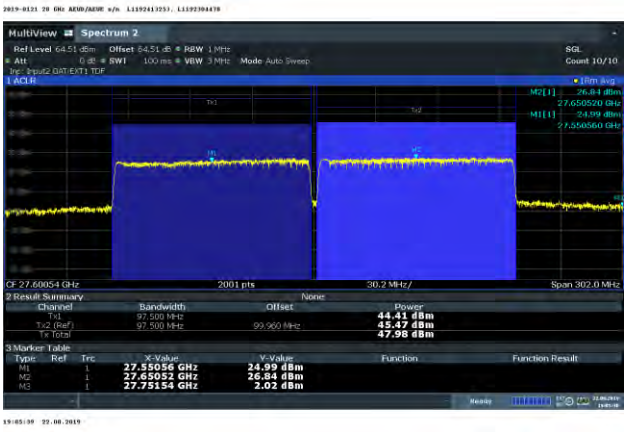
28.29996 GHz Vertical



Channel Power Measurements, 4.5m, 2 Carriers on Left Side of Band.

27.55056 GHz + 27.65052 GHz Horizontal

27.55056 GHz + 27.65052 GHz Vertical



Channel Power Measurements, 4.5m, 3 Carriers on Right Side of Band

28.05036 GHz + 28.15032GHz + 28.250028 GHz Horizontal

Vertical

Channel Power Measurement at 4.5m, 4 Carriers - Left Side of Band
27.55056 GHz + 27.65052 GHz + 27.75048 GHz + 27.85044 GHz

Horizontal

Vertical

Channel Power Measurement at 4.5m, 4 Carriers - Right Side of Band
27.9504 GHz + 28.05036 GHz + 28.15032 GHz + 28.25028 GHz

Horizontal

Vertical

Channel Power Measurement at 4.5m, 4 Spread Carriers in Center of Band
27.55056 GHz + 27.75048 GHz + 27.9504 GHz + 27.15032 GHz

Horizontal

Vertical

4.2 Section 2.1047 MEASUREMENT REQUIRED: MODULATION CHARACTERISTICS

The **2AD8UAEUDAEUE01** supports the 5G New Radio Modulation Format based upon LTE TDD technologies. LTE utilizes Orthogonal Frequency Division Multiplexing (OFDM) which splits the carrier frequency bandwidth into many small subcarriers. Each individual subcarrier can be modulated with a combined QPSK + 16QAM and 64QAM digital modulation formats.

In QPSK, there are 4 possible symbol states and each symbol carries 2 bits of information. In 16QAM, there are 16 possible symbol states and each 16-QAM symbol carries 4 bits of information. In 64QAM, there are 64 possible symbol states and each 64-QAM symbol carries 6 bits of information. The higher-order modulations, where the constellations become more dense, are more sensitive to poor channel conditions than the lower-order modulation.

The modulation characteristics measurement of LTE carriers measures the difference between the ideal symbols and the measured symbols after the equalization. The 5G-New Radio format is still in revision in 3GPP and Release 16 is expected Q4 of 2018. This present evolutionary nature of 5G-NR prevents all of the nominal EVM measurements from being performed at this time. However, constellations were recorded to assess that the subcarrier configurations were achieved.

There are no FCC Limits for Modulation and all of the formats above look spectrally the same from a channel edge and regrowth standpoint. It is expected that greater fidelity will be available after test equipment is configurable with the final format of Release 16. A Class II change is planned for this unit for Multi-carrier operation and Release 16 should be testable at that time.

4.2.1 Modulation Characteristics Measurement

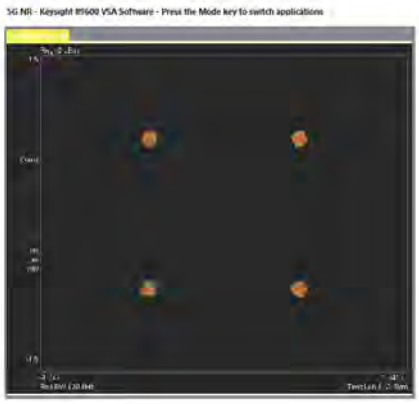
The measurements were performed at a distance of 4.5 m from the unit utilizing the test configuration in Figure 4.4.1 utilizing a 44 GHz MXA Signal analyzer. Representative screen plots of the modulation measurement are attached below for the various subcarrier configurations and various Polarizations.

4.2.2 Modulation Measurements Results:

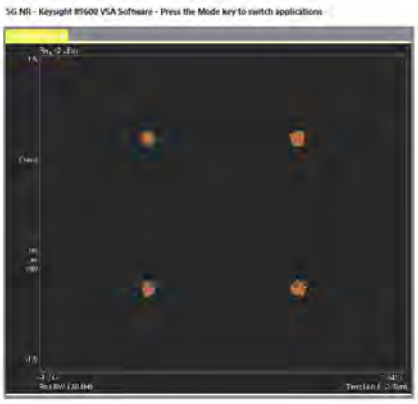
The typical measured modulation characteristics of the EUT are shown below:

Figure 4.2 Modulation Results (old – from 0112)

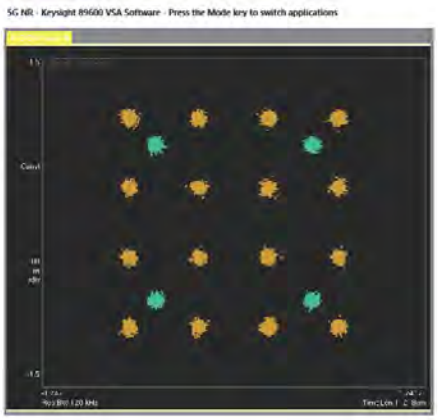
Sample QPSK 27.54996 GHz Vertical



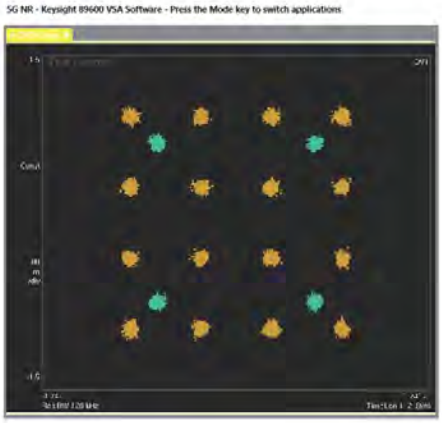
Sample QPSK 27.54996 GHz Horizontal



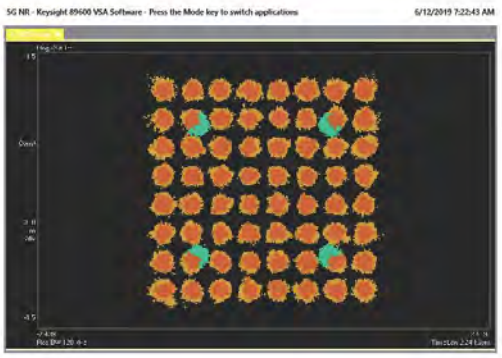
Sample 16QAM 27.6 GHz Vertical



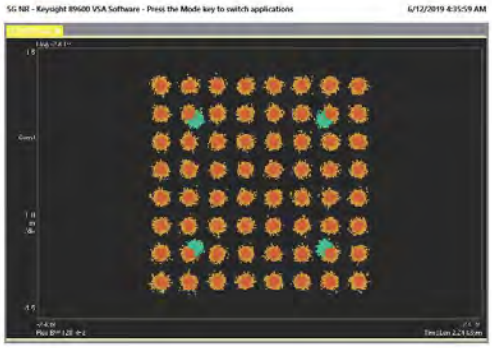
Sample 16QAM 27.6 GHz Horizontal



Sample 16QAM 27.6 GHz Vertical



Sample 16QAM 27.6 GHz Horizontal



4.3 Section 2.1049 MEASUREMENT REQUIRED: OCCUPIED BANDWIDTH and EDGE of BAND EMISSIONS

This test measures the Occupied Bandwidth of the transmitting carrier and the Edge of-Block Emissions in the frequency spectrum immediately outside and adjacent to the transmitting carrier(s).

The occupied bandwidth (OBW) is usually defined either as the 99% power OBW or a relative OBW. The 99% OBW is the signal bandwidth such that, below its lower and above its upper frequency limits, the mean power radiated or conducted are each equal to 0.5 percent of the total mean power radiated or conducted by a given emission. The relative -26 dB OBW is defined as the width of the signal between two points, one below the carrier center frequency and one above the carrier center frequency, outside of which all emissions are attenuated by at least 26 dB below the transmitter power.

Per KDB 971168 D01 v02, the relative OBW must be measured and reported when it is specified in the applicable rule part; otherwise, the 99% OBW shall be measured and reported. The OBW shall be measured when modulated by an input signal such that its amplitude and symbol rate represent the maximum rated conditions under which the equipment is operated.

The ANSI C63.26 Section 5.4.3 Occupied Bandwidth-Relative measurement procedure was followed using the functionality of the FSW spectrum Analyzer. Measurements were performed to assess the OBW Signal Bandwidth when measured with as stated the *"nominal RBW shall be in the range of 1% to 5% of the anticipated OBW"*. That given, individual carriers OBW-Signal bandwidths were measured with RBW's of 1 MHz, 3 MHz and 5 MHz. This was performed for both the Horizontally and Vertically polarized beams and for every nominal 100 MHz carrier. The aggregated 4 carrier configurations were measured with RBW's of 5 MHz and 10 MHz.

4.3.1 Results - Occupied Bandwidth (Signal Bandwidth)

The 99% occupied bandwidth was measured with a Rohde & Schwarz FSW spectrum analyzer using the occupied bandwidth functionality. The results for multiple configurations and modulations are tabulated in Table 4.3.1 below. The maximum measured individual carrier was **98.51 MHz** while the maximum average was **97.43 MHz**. The measurement of 4 adjacent carriers resulted in a maximum 4 carrier bandwidth of **397.83 MHz**. The results shows that the measured signals are within the parameters of the 98M0G7W emissions designator and aggregated emissions designator of 398MG7W. Sample carrier measurements are documented in Figure 4.3.1 below.

Table 4.3.1 Occupied Bandwidth - Signal Bandwidth Measurements

Carrier Location in Band	Tx. Carriers Center Frequency, GHz	Number of Tx. Carriers	Modulation	Measured w/5 MHz RBW		Measured w/3 MHz RBW	
				Horizontal	Vertical	Horizontal	Vertical
				MHz	MHz	MHz	MHz
Left	27.55056	1	QPSK	92.27	97.05	95.50	95.32
Center	27.95040	1	QPSK	**98.51**	97.50	96.53	95.70
Right	28.25016	1	64QAM	98.38	97.31	96.41	95.56
Far Right	28.29996	1	64QAM	97.90	97.85	95.87	95.98
Average Measured Bandwidth				96.77	**97.43**	96.08	95.64
				Measured w/10 MHz RBW		Measured w/5 MHz RBW	
				Horizontal	Vertical	Horizontal	Vertical
Left	27.55056 27.65052	2	16QAM	200.08	200.09	195.66	195.64
Right	28.05036 28.15032 28.25028	3	16QAM		297.02	294.16	297.017
Left	27.55056 27.65052 27.75048 27.85044	4	64QAM	**397.83**	395.48	394.35	397.52
Right	27.95040 28.05036 28.15032 28.25028	4	64QAM	396.45	395.52	393.44	392.76

4.3.1.1 Carrier Aggregation

The April 12, 2016 TCBC viewgraph package identified that Carrier Aggregation data need be supplied. This requirement is not yet formalized in a KDB for LTE, 5G-NR or UMFUS. The 4 carrier bandwidth of the AEUD-AEUE is defined as follows. The individual carriers, 98 MHz maximum, are spaced 99.96 MHz apart and do not overlap. The overall signal bandwidth for 4 adjacent carriers is depicted in Figure 4.3.1.1. The calculated assessment that the 4 carrier aggregated bandwidth is 398 MHz. The maximum measured value was 397.83 MHz

Figure 4.3.1.1 Carrier Aggregation

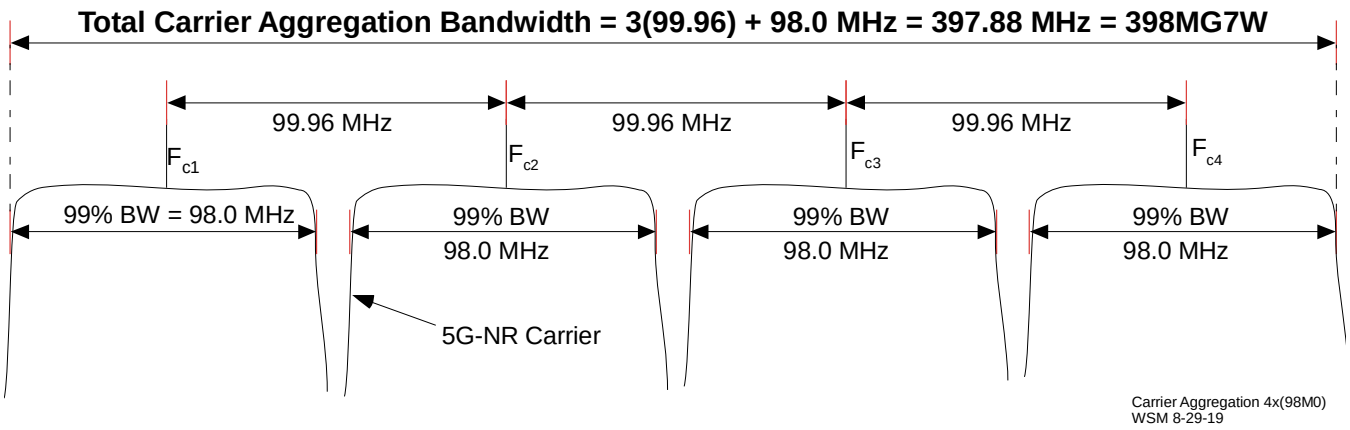
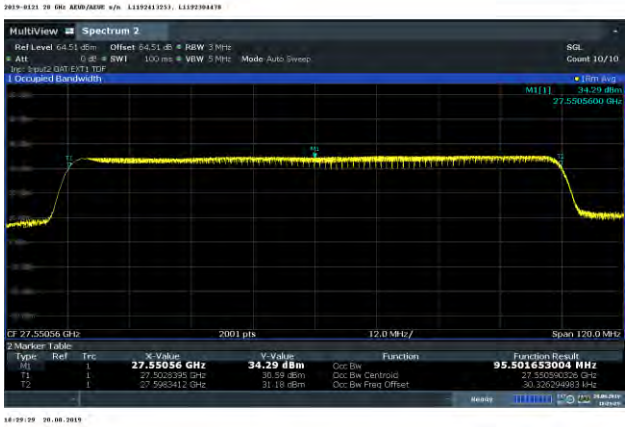
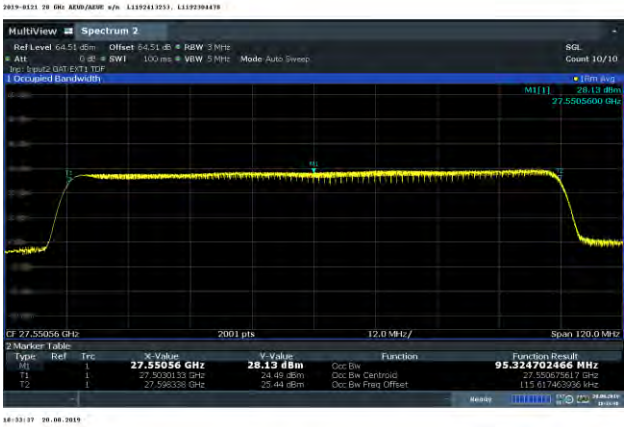


Figure 4.3.1- Occupied Bandwidth - Typical Signal Bandwidth

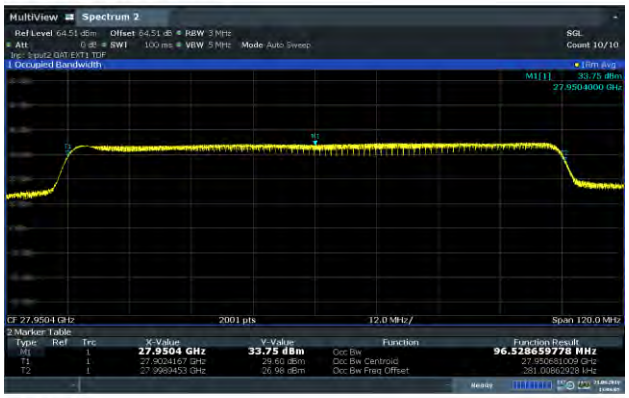
Single Carrier Configuration

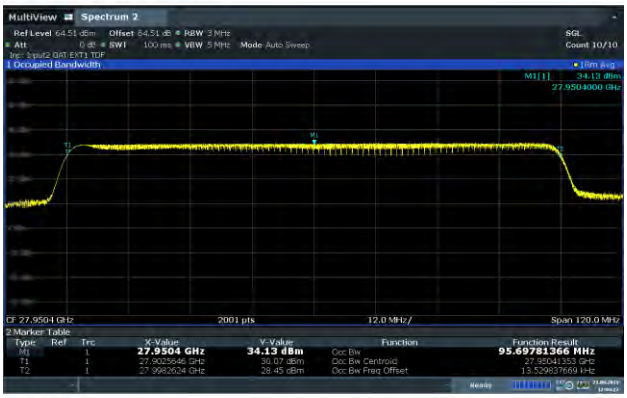
99% Signal Bandwidth **3MHz RBW, 27.55056 GHz, Left, Tx Panels P1, 1 Carrier**
Horizontal -QPSK **Vertical - QPSK**



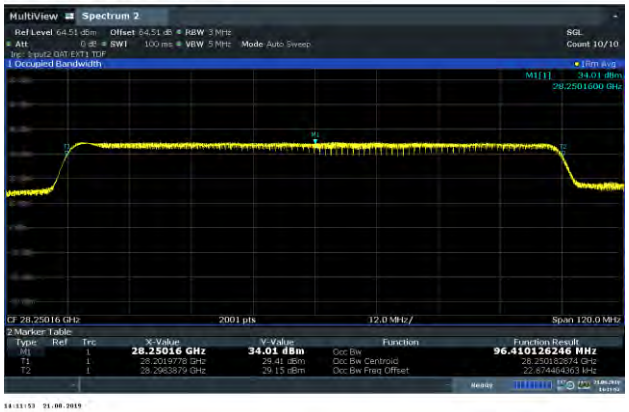


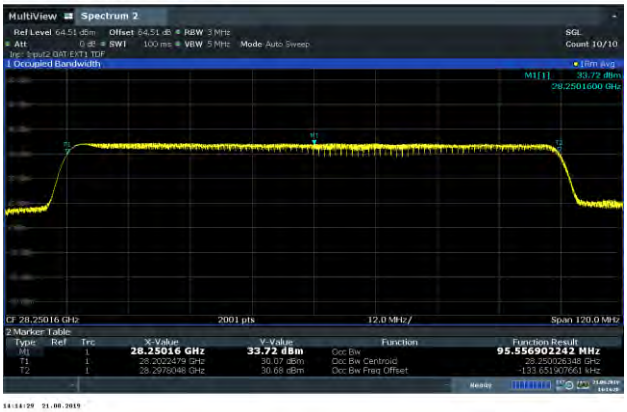
99% Signal Bandwidth **3MHz RBW, 27.9504 GHz, Middle, Tx Panels P2, 1 Carrier**
Horizontal -QPSK **Vertical - QPSK**



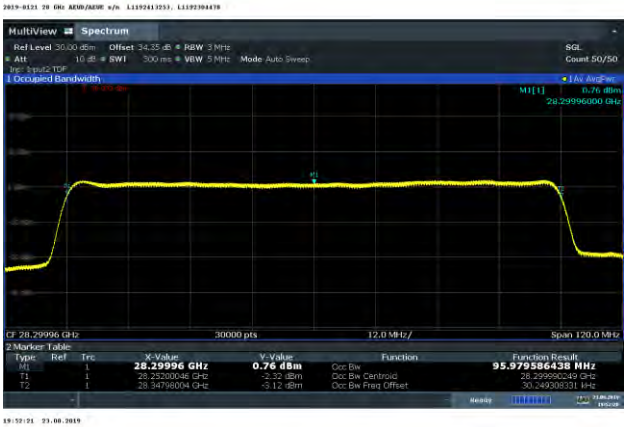


99% Signal Bandwidth **3MHz RBW, 28.25016 GHz, Right, Tx Panels P2, 1 Carrier**
Horizontal – 64QAM **Vertical – 64QAM**

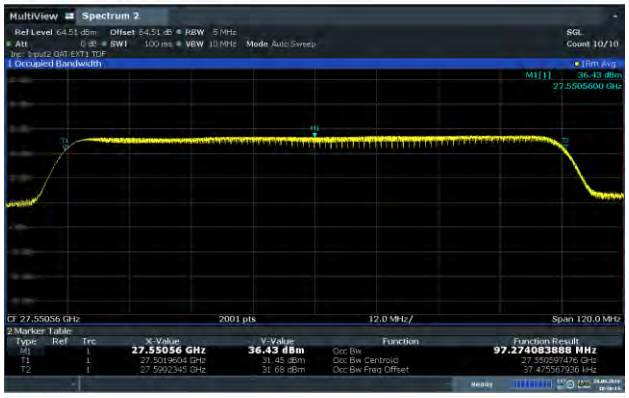


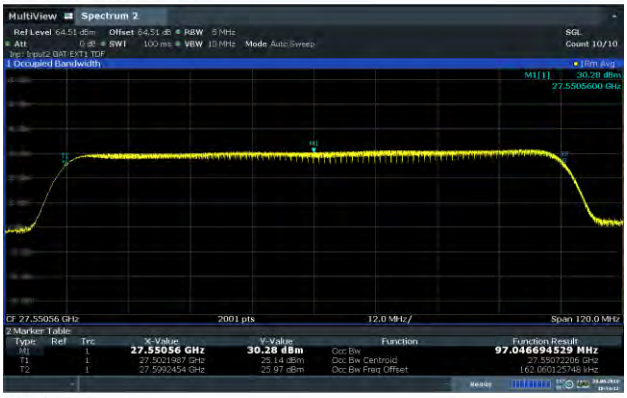


99% Signal Bandwidth **3MHz RBW, 28.29996 GHz, Far Right, Tx Panels P4, 1 Carrier**
Horizontal - 64QAM **Vertical - 64QAM**

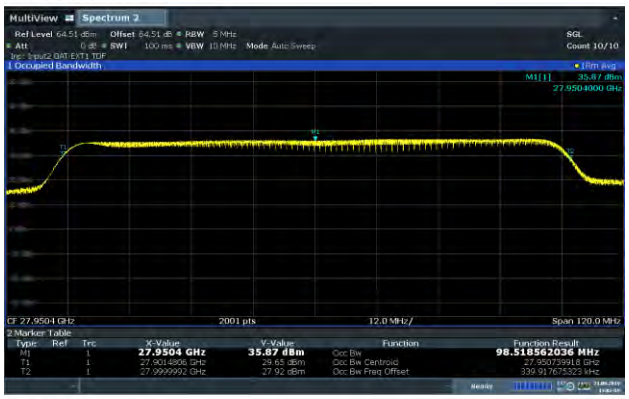


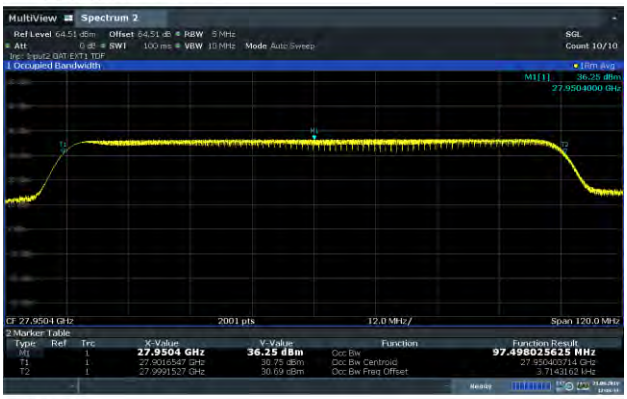
99% Signal Bandwidth **5MHz RBW, 27.55056 GHz, Left, Tx Panels P1, 1 Carrier**
Horizontal -QPSK **Vertical - QPSK**





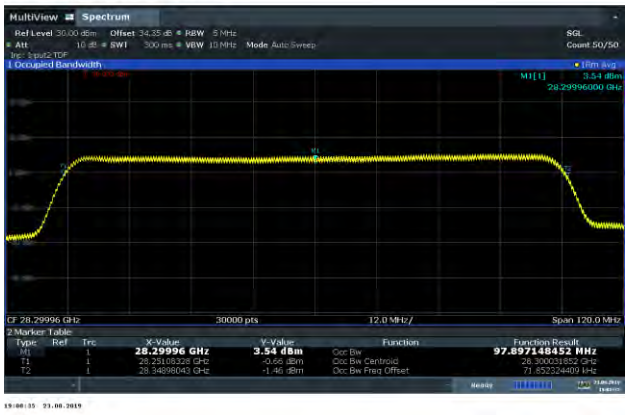
99% Signal Bandwidth **5MHz RBW, 27.9504 GHz, Middle, Tx Panels P2, 1 Carrier**
Horizontal -QPSK **Vertical - QPSK**

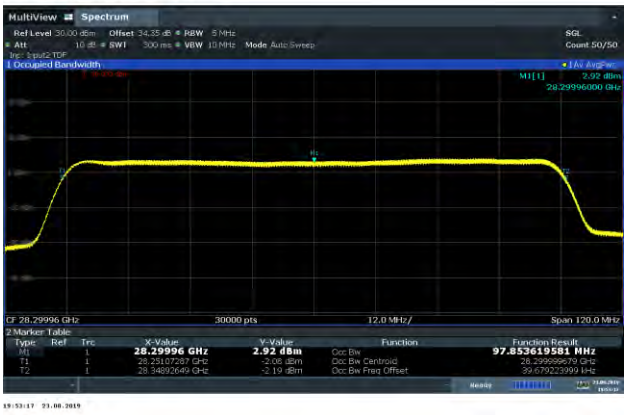




99% Signal Bandwidth **5MHz RBW, 28.25016 GHz, Right, Tx Panels P2, 1 Carrier**
Horizontal – 64QAM **Vertical – 64QAM**

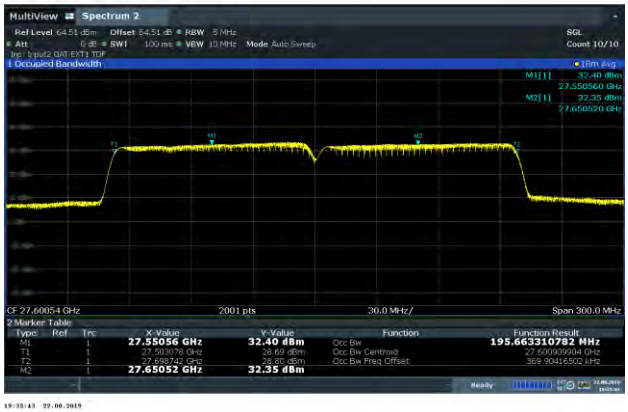
99% Signal Bandwidth **5MHz RBW, 28.29996 GHz, Far Right, Tx Panels P4, 1 Carrier**
Horizontal - 64QAM **Vertical - 64QAM**

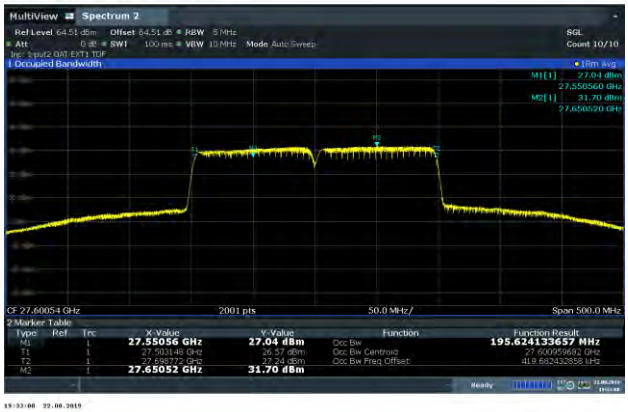




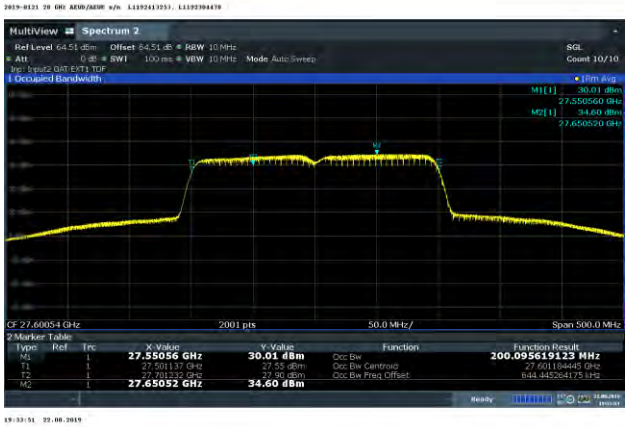
Two Carrier Configuration

99% Signal Bandwidth **5MHz RBW, Left, Tx Panels P4, 2 Carrier**
Horizontal - 16QAM **Vertical - 16QAM**





99% Signal Bandwidth **10MHz RBW, Left, Tx Panels P4, 2 Carrier**
Horizontal - 16QAM **Vertical - 16QAM**



Three Carrier Configuration

99% Signal Bandwidth **5MHz RBW, Right, Tx Panels P2, 3 Carrier**
Horizontal - 16QAM **Vertical - 16QAM**

99% Signal Bandwidth **10MHz RBW, Right, Tx Panels P2, 3 Carrier**
Vertical - 16QAM

99% Signal Bandwidth
Horizontal - 64QAM

5 MHz RBW - 4 Carrier Left Side of Band, Tx Panels P2
Vertical - 64QAM

99% Signal Bandwidth
Horizontal - 64QAM

5 MHz RBW - 4 Carrier Right Side of Band, Tx Panels P4
Vertical - 64QAM

99% Signal Bandwidth
Horizontal - 64QAM

10 MHz RBW - 4 Carrier Left Side of Band, Tx Panels P2
Vertical - 64QAM

99% Signal Bandwidth **10 MHz RBW - 4 Carrier Right Side of Band, Tx Panels P4**
Horizontal - 64QAM **Vertical - 64QAM**

4.3.2 Occupied Bandwidth-Edge of Band Emissions

Classical Occupied Bandwidth – Edge of Block Emissions is an evaluation of the transmit carrier compliance with edge of band requirements and characterizes Out Of Band Emissions (OOBE). This measurement documents the product's ability to maintain compliance with FCC Parts 2 and Part 30.203 limitations on emissions outside the band of operation. Since there are presently no internal blocks measurements are required at the Left side and Right side of band.

The **2AD8UAEUDAEUE01** 28 GHz Radio Unit presently supports single 5G-New Radio LTE TDD technologies. This evaluation addresses 2x2 MIMO operation with 100 MHz carriers. In each test configuration the carriers were configured at the left side and right side of the Part 30 band as appropriate. All power measurements were performed prior to other measurements. Power was set to the total per polarization maximum. The measurements are described below.

The occupied bandwidth of each of the signals identified in Table 4.3.6.1 was measured using a Rohde & Schwarz FSW Spectrum analyzer, a remote PC based instrumentation controller and the same calibrated RF attenuation path used for channel power. The measurement process meets the requirements of ANSI C63.26 and ISO17025. The test setup was as shown in Figure 4.1.1. Measurements were performed at 4.5 m for both vertical and horizontal polarizations.

Plots are provided using the triggered functionality of the test analyzer and demonstrate compliance with edge of band limits. These sheets contain data for single carrier configurations for "Left Edge of Block", and "Right Edge of Block" across the Part 30 Upper Microwave Flexible Use Service spectrum.

4.3.3 Requirements 28 GHz Emissions Limits

The Limit in 47 CFR 30.203 for Emissions Limits is as follows:

(a) The conductive power or the total radiated power of any emission outside a licensee's frequency block shall be −13 dBm/MHz or lower. However, in the bands immediately outside and adjacent to the licensee's frequency block, having a bandwidth equal to 10 percent of the channel bandwidth, the conductive power or the total radiated power of any emission shall be −5 dBm/MHz or lower.

(b)(1) Compliance with this provision is based on the use of measurement instrumentation employing a resolution bandwidth of 1 megahertz or greater.

(2) When measuring the emission limits, the nominal carrier frequency shall be adjusted as close to the licensee's frequency block edges as the design permits.

(3) The measurements of emission power can be expressed in peak or average values.

In order to address the limit as imposed for the requirement in 47CFR 30.203 we evaluated emissions per the requirements in ANSI C63.26 and per KDB 940660 D01 Part 30 CBRS Equipment.
The average detector function was used for all MXA measurements and the Peak detector function were used for EMC receiver measurements.

4.3.4 Measurement Offset and MIMO

As this was a radiated EIRP measurement no MIMO adjustment was used.

For the 5G-NR LTE system there is no carrier without modulation. Since the 5G-NR LTE signal is broadband and is 100 MHz wide, all of the measurements performed at the specified 1 MHz resolution bandwidths. The following relationship was used to provide the correct level different resolution bandwidths..

10*log (Resolution Bandwidth/ Transmit Bandwidth) = Signal Offset (1)

4.3.5 Mask Parameters

The mask parameters are in units as stated in Part 30 and are listed in Table 4.3.5

Table 4.3.5 - Mask Parameters Out Of Band / Edge of Band Emissions

Frequency	Part 30 Limit
GHz	dBm
26.50	-13
27.49	-13
27.49	-5
27.50	-5
27.50	52
28.35	52
28.35	-5
28.36	-5
28.36	-13
29.00	-13
40.00	-13

4.3.6 Measurement Path Corrections

The measured power at the spectrum analyzer input was corrected for calculated free space loss, cable loss, measurement antenna gain and the product antenna gain over its applicable frequency range as documented in Exhibit 6 of the filing and Table 4.3.6 below. This is appropriate for Out Of Band Emissions / Edge of Band emissions only for the frequency range that the transmit antenna has documentable and consistent gain. The documentable antenna gain of the product applies only for the operational frequency range of the products antenna gain. This adjustment was not used outside the OOBE/EoB frequency range. Table 4.3.6 below lists the offset and correction factors used for the measurement distance of 4.5 m including the AEUD-AEUE product gain.

Table 4.3.6 - OOBE Offset and Correction Factors for 4.5m Measurement Distance

Freq.	Free Space Path Loss, PL	Measurement Antenna Gain, G1	Measurement Cable Loss, L1	Correction for Channel Power PL-G1+L1	AEUD-AEUE Antenna Gain	Total Correction for OOBE	Offset for OOBE	Transducer Factor for OOBE
GHz	dB	dBi	dB	dB	dBi	dB	dB	dB
26.00	73.81	23.07	12.58	63.32	21.50	41.82	41	0.818
26.50	73.97	23.15	12.61	63.43	22.00	41.43	41	0.428
27.00	74.13	23.12	12.63	63.64	22.50	41.14	41	0.144
27.50	74.29	23.28	12.77	63.78	22.75	41.03	41	0.029
28.00	74.45	23.31	12.90	64.04	22.90	41.14	41	0.139
28.50	74.60	23.51	13.03	64.12	23.00	41.12	41	0.125
29.00	74.75	23.58	13.15	64.32	23.20	41.12	41	0.124
29.50	74.90	23.69	13.26	64.47	23.00	41.47	41	0.472
30.00	75.05	23.61	13.36	64.80	22.80	42.00	41	0.999
30.50	75.19	23.75	13.51	64.95	21.75	43.20	41	2.200
31.00	75.33	23.84	13.63	65.13	20.80	44.33	41	3.326

OOBE Correction Factors = Free Space Path Loss – Measurement Antenna Gain + Cable Loss – Product Gain.

The following sample calculation is the correction for 30 GHz;

Sample calculation at 28 GHz: Correction = 74.45 dB -23.31 dBi + 12.90 dB – 22.90 dBi = 41.14 dB
= Offset Value (41 dB) + Transducer Factor (0.14 dB)

All OOBE measurements were made using a flat offset of 41 dB and the transducer factor from the Table 4.3.6.

4.3.7 Edge of Band Measurements

The measurements were performed with an FSW spectrum analyzer in compliance with the procedure and requirements of ANSI C63.26. The test set-up diagram in Figure 4.1.1 was used. Testing was performed for the 100 MHz carrier configurations at the left side, and right side of the Part 30 Band.
Mask parameters were as stated in Table 4.3.5. Mask Edge Offsets = ½ the Resolution Bandwidth of the measurement were not used.

4.3.7.1 Results - Occupied Bandwidth-Edge of Block Emissions

The occupied bandwidth plots for operation at the left side, center and the right side of the band for the 100 MHz signal bandwidth are below. The mask accurately depicts the limits for the Part 30 NAR Band to determine compliance with FCC requirements. The mask limits include the appropriate considerations for operation.

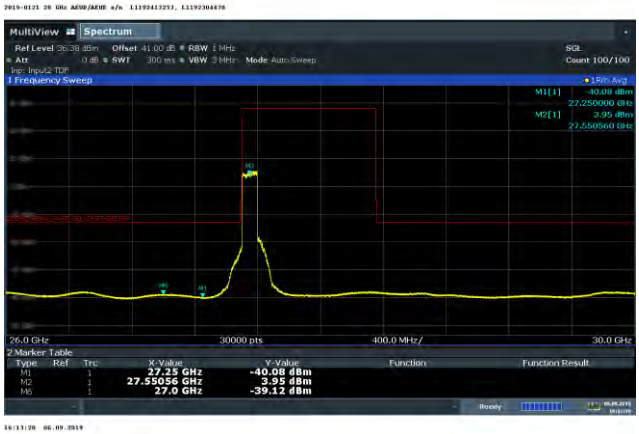
From the out-of-band emissions plots attached below, it can be seen that all the emissions are under the required emission masks.

The measurement results of the occupied bandwidth and the out-of-band emissions as documented in the plots and Table 4.3.7.1 demonstrate the full compliance with the Rules of the Commission for the operating band.

Figure 4.3.7.1 - Occupied Bandwidth - OOBE/EoB Band - Single carrier

Left, Tx Panels P1, 1 Carrier

OOBE/EoB – H - QPSK - 27.55056GHz.



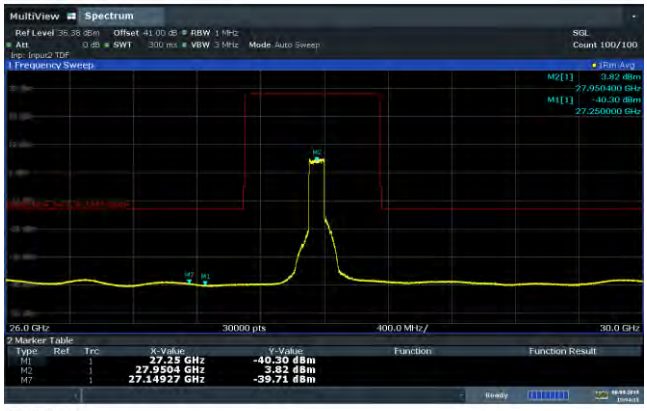
OOBE/EoB – V - QPSK - 27.55056GHz

OOBE/EoB – H - QPSK - 27.55056GHz.

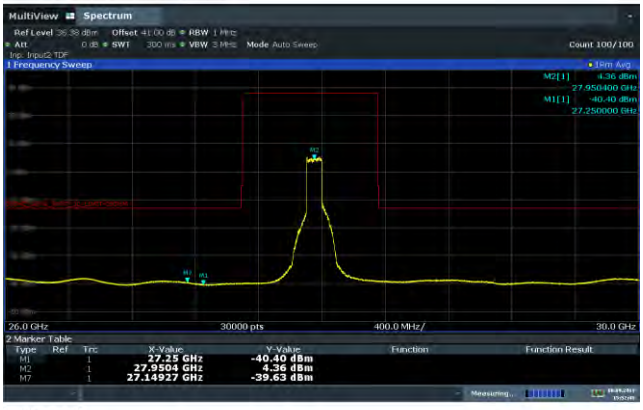
OOBE/EoB – V - QPSK - 27.55056GHz

Middle , Tx Panels P2, 1 Carrier

OOBE/EoB – H - QPSK - 27.9504GHz.

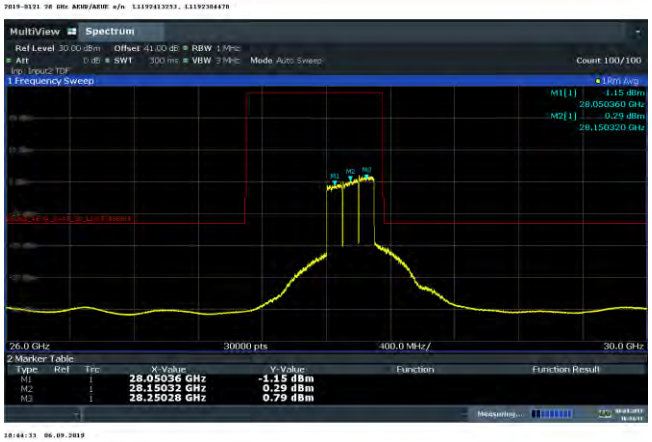


OOBE/EoB – V - QPSK - 27.9504

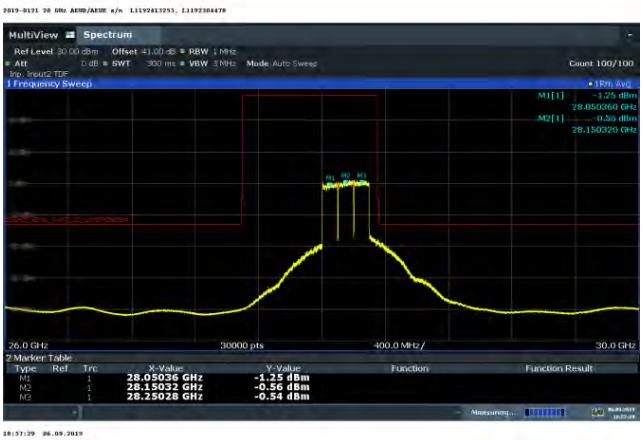


Right , Tx Panels P2, 1 Carrier

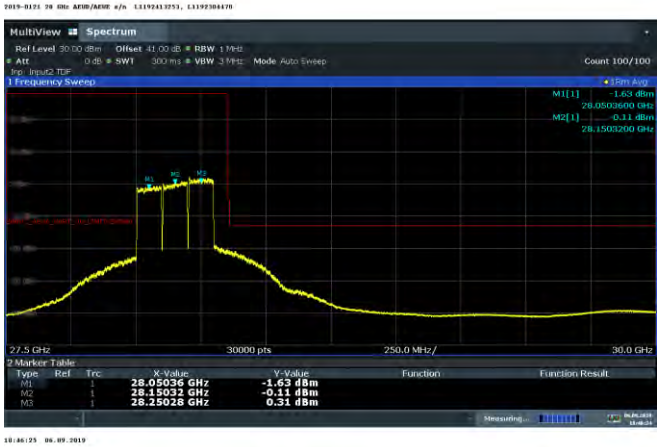
OOBE/EoB – H – 64QAM - 28.25016 GHz.



OOBE/EoB – V - 64QAM - 28.25016 GHz



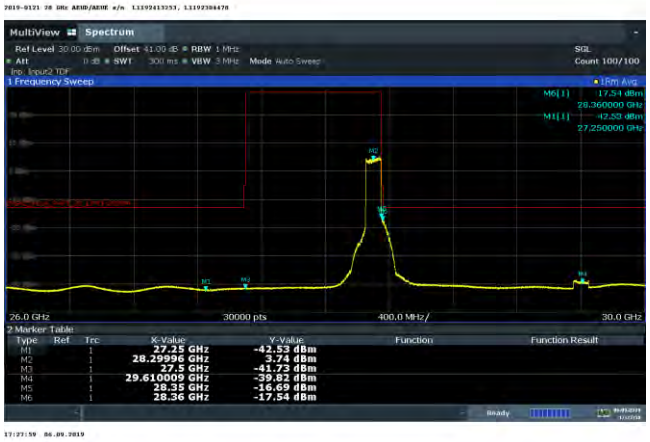
OOBE/EoB – H - 64QAM - 28.25016 GHz.



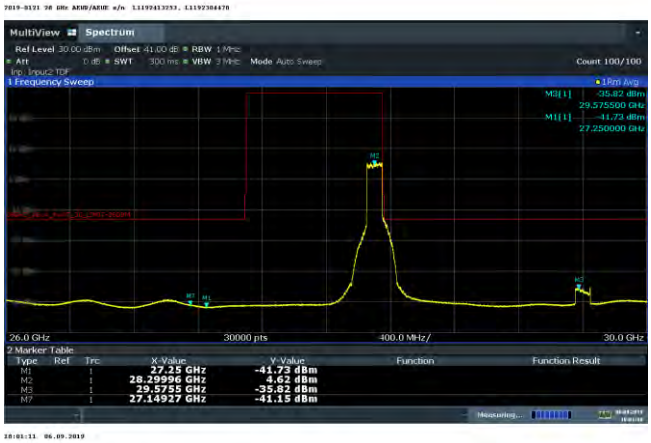
OOBE/EoB – V - 64QAM - 28.25016 GHz

Far Right , Tx Panels P4, 1 Carrier

OOBE/EoB – H – 64QAM - 28.29996 GHz.



OOBE/EoB – V - 64QAM - 28.29996 GHz



OOBE/EoB – H - 64QAM - 28.29996 GHz.

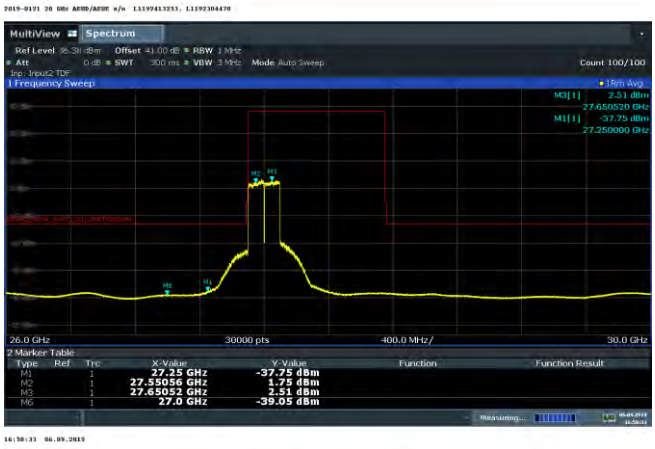
OOBE/EoB – V - 64QAM - 28.29996 GHz

The Occupied Bandwidth and Edge-of-Band emissions measurements were made as a radiated measurement at a distance of 4.5 m

Figure 4.3.7.1 - Occupied Bandwidth - OOBE/EoB Band - Dual carrier

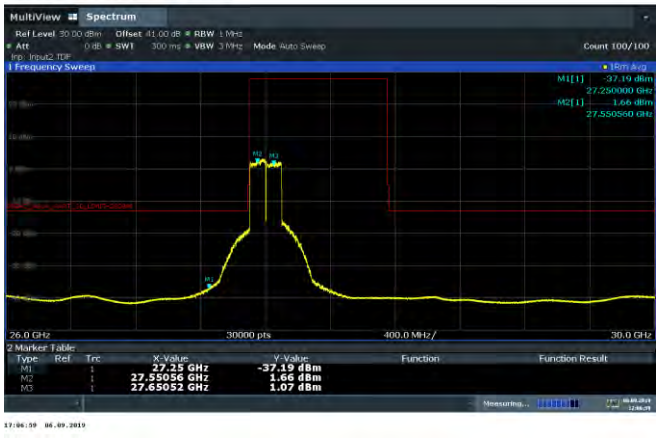
Left Side of Band - 16QAM - 27.55056 GHz + 27.650452 GHz.

OOBE/EoB – Horizontal Polarization



Vertical Polarization

OOBE/EoB – Horizontal Polarization

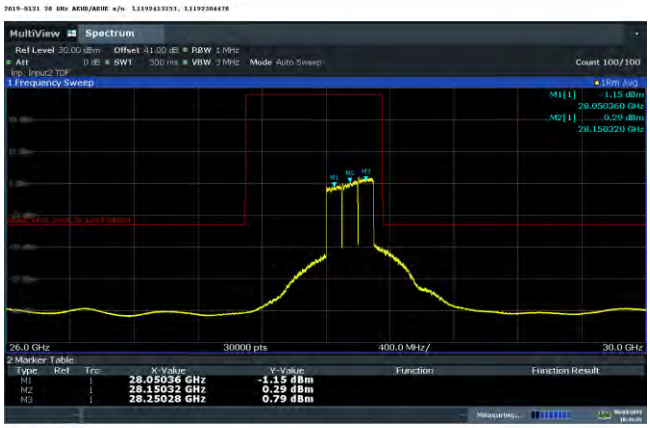


Vertical Polarization

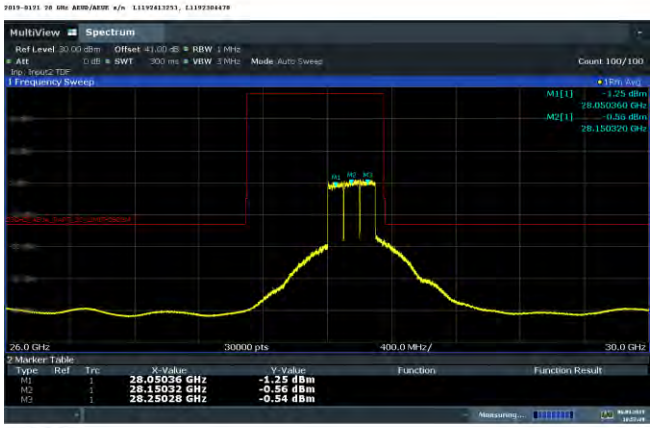
Figure 4.3.7.1 - Occupied Bandwidth - OOBE/EoB Band - Three carrier

Right Side of Band 16QAM - 28.05036+28.15032+28.25028

OBE/EoB – Horizontal Polarization



Vertical Polarization



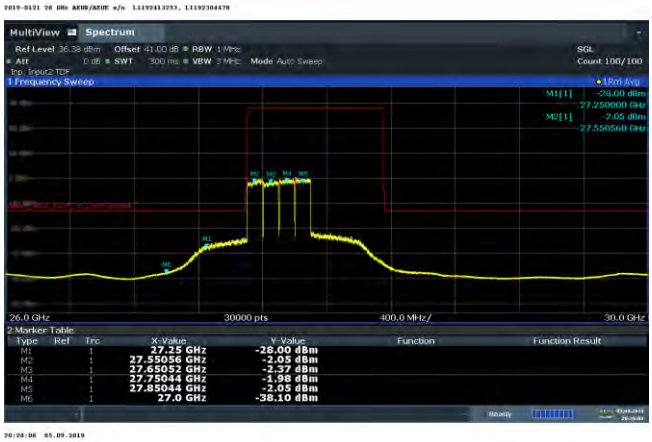
OOBE/EoB – Horizontal Polarization

Vertical Polarization

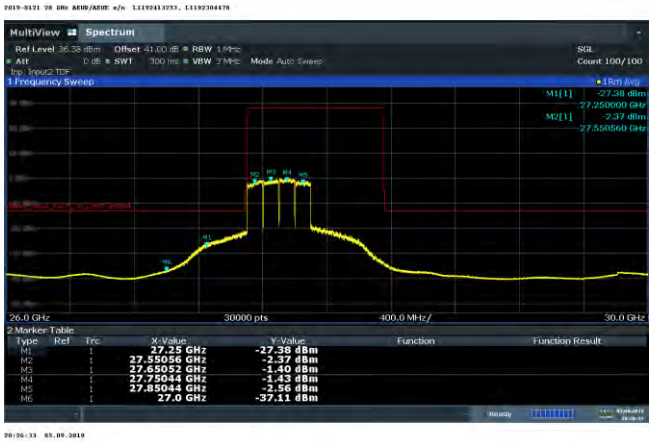
Figure 4.3.7.1 - Occupied Bandwidth - OOBE/EoB Band - Four carrier

Left Side of Band - 64QAM - 27.55056 GHz + 27.65052 GHz. + 27.75044 GHz + 27.85044 GHz

OOBE/EoB – Horizontal Polarization



Vertical Polarization

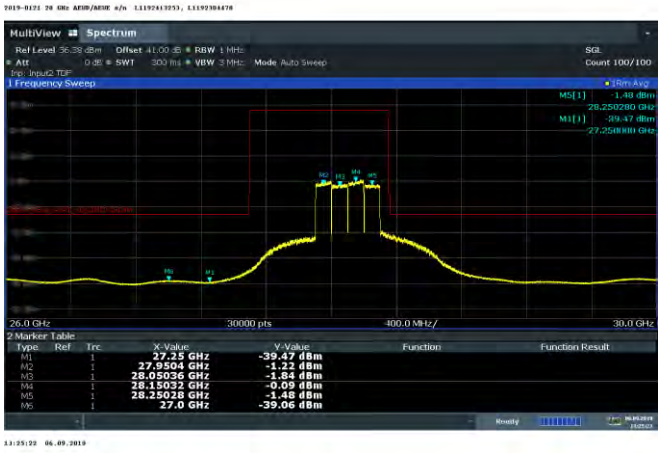


OOBE/EoB – Horizontal Polarization

Vertical Polarization

Right Side of Band 64QAM - 27.9504 + 28.05036 + 28.15032 + 28.25028

OOBE/EoB – Horizontal Polarization



Vertical Polarization

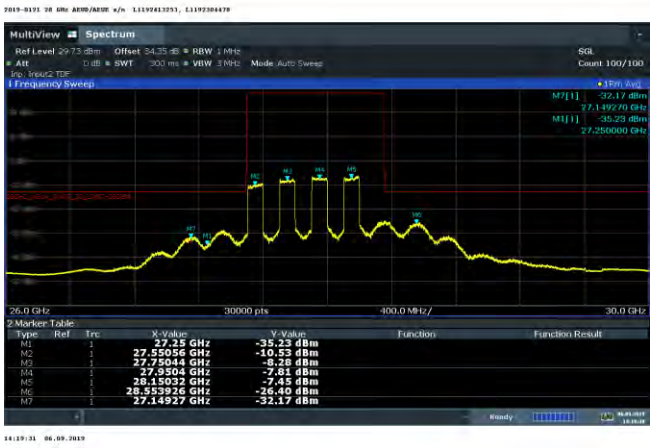
OOBE/EoB – Horizontal Polarization

Vertical Polarization

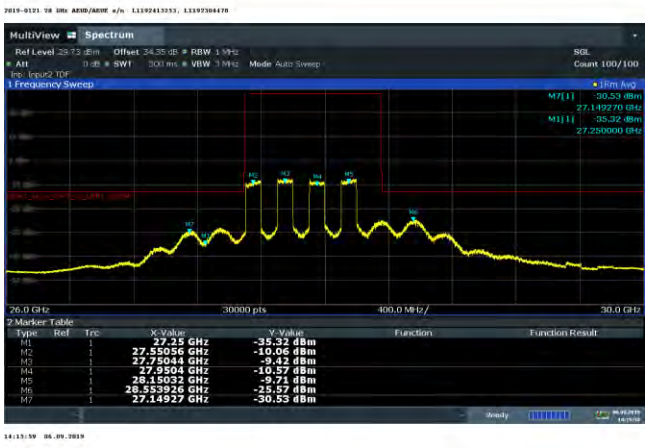
Figure 4.3.7.1 - Occupied Bandwidth - OOBE/EoB Band - Four carrier

Spread Center Channels Across the Band QPSK + 16QAM – 27.55056+27.75044+27.9504+28.15032

OOBE/EoB – Horizontal Polarization



Vertical Polarization



4.4 Section 2.1051 MEASUREMENT REQUIRED: SPURIOUS EMISSIONS AT THE ANTENNA TERMINALS

This test measures the emissions of spurious signals which may come from harmonic, parasitic, intermodulation and frequency conversion products and are outside the necessary bandwidth but excludes Edge-of-Band emissions.

4.4.1 Section 2.1051 Spurious Emissions at Antenna Terminals

Spurious Emissions were investigated per 47CFR Section 2.1057(a)(1) over the frequency range of 30 MHz to 100 GHz as specified in 2.1057(a)(2).

2.1057(a)(2) If the equipment operates at or above 10 GHz and below 30 GHz: to the fifth harmonic of the highest fundamental frequency or to 100 GHz, whichever is lower.

Since there is no antenna terminal, all measurements were performed as radiated measurements and standard radiated emissions. These latter are documented in Section 4.5 "*Section 2.1053 Measurement Required: Field Strength of Spurious Radiation*". The test configuration is shown in Figure 4.4.1 documents the test set up used for the measurements.

The measurements were performed in compliance with ANSI C63.26, C63.26 mmWave JTG and our ISO17025 process. The measurement meets the ANSI C63.26 requirements in paragraphs 5.2.4.4.1 and 5.7 which requires that the number of points in the sweep be > 2 × Span/RBW. The ESU spectrum analyzer measurements examine the 30 MHz to 40 GHz range. The FSW based mmWave transmitter test system overlaps the transmit band for 27-29 GHz and extends the frequency range to examine the 40 GHz to 100 GHz range.

4.4.2 Required Limit

The required emission limitation specified in **47CFR 30.203 (a)** was applied to these tests. Based upon the criterion given in Section 30 of the Code and as developed in 4.3.3, the required emission limit for emissions outside a licensee's frequency block is:

47CFR 30.203 (a) (a) The conductive power or the total radiated power of any emission outside a licensee's frequency block shall be −13 dBm/MHz or lower. However, in the bands immediately outside and adjacent to the licensee's frequency block, having a bandwidth equal to 10 percent of the channel bandwidth, the conductive power or the total radiated power of any emission shall be −5 dBm/MHz or lower.

4.5 Section 2.1053 MEASUREMENT REQUIRED: FIELD STRENGTH OF SPURIOUS RADIATION

The field strength measurements of radiated spurious emissions were made in FCC registered five and ten meter semi-anechoic chambers AR-4 and AR-8 , (FCC Registration Number: 395774) **NVLAP** Lab Code: 100275-0 and IC (Filing Number: 6933F-4 & 8) which are maintained by Nokia Bell Labs in Murray Hill, New Jersey.
The **2AD8UAEUDAEUE01** (EUT) was configured in semi-anechoic chamber in a manner simulating a normal field installation. The product's field installation hardware was used to mount the product to a wooden tower with the bottom of the product 1.5m above the turntable ground plane. The recommendations of ANSI C63.4–2014, C63.26-2015 and C63.26 mmWave JTG were followed for EUT testing setup and cabling. The EUT was configured to operate in a 5G-NR test model per the constraints identified in section 4.2. A photograph of this setup is in Exhibit 12 of the filing package.

The base station was configured into the full power forward beam transmit configuration to transmit two 48 dBm EIRP 100 MHz bandwidth 5G-NR carriers, one Vertical and one Horizontal polarization, with the total transmit power of 51 dBm EIRP. This configuration provides the highest Power Spectral Density transmit signal for the product. The product in the below configurations was evaluated over the 30 MHz to 100 GHz frequency range as required by .

Table 4.5.1 EUT Configurations

Test Configuration NRARFCN	AEUD-AEUE Tx Reference Frequencies GHz	Transmit Active Polarization	Signal Bandwidth, MHz	Modulation	Total Power, dBm EIRP	Radiated Emissions Pass / Fail
2071665 To 2084165	27.55056, To 28.29996	H & V	100	QPSK & 64QAM	51	Pass

4.5.1 Spurious Radiation and Radiated Emissions Requirements Below 40 GHz.

This product meets Part 15B, and Part 30.203 requirements. . FCC Part 15 Class B require emissions to be below 54.5 dBuV/m at 3m. Part 30.203 requires emissions to be below the value generated by a conducted emission of -13 dBm. This is a standard value for wireless products typically defined as

$$-43+10\text{LogP}=-13 \text{ dBm.}$$

The emissions at the Edge of Band were adjusted by the 23 dBi gain of the transmit antenna as the product is designed to operate globally over the 26.5 to 29.5 GHz frequency band. Emissions removed from the transmit band were evaluated identically to other wireless products.

Measurements were performed in compliance with Section 2.1053, FCC publication 442401 and clause 5.5 of ANSI C63.26. For this case the evaluation of acceptable radiated field strength is as follows.

The calculated emission levels were found by:

$$\text{Pmeas (dBm)} + \text{Cable Loss(dB)} + \text{Antenna Factor(dB)} + 107\ (\text{dB}\mu\text{V/dBm}) - \text{Amplifier Gain (dB)} = \text{Field Strength (dB}\mu\text{V/m)}$$

Title 47CFR section 30.203 and 2.1053 contains the requirements for the levels of spurious radiation as a function of the EIRP of the modulated carrier with 100 MHz of bandwidth. The reference level for the modulated carrier is calculated as the field produced by an isotropic radiator excited by the transmitter output power according to the following relation taken from Reference Data for Radio Engineers, page 27-7, 6th edition, IT&T Corp.

$$\mathbf{E = (120\pi P)^{1/2} = [(30*P)^{1/2}] / R}$$

$$\mathbf{20 \log (E*10^{6}) - (43 + 10 \log P) = 82.23\ dB\ \mu V/meter}$$

Where: E = Field Intensity in Volts/ meter R = Distance in meters = 3 m
P = Transmitted Power, Watts = 1000 W

The field strength of radiated spurious emissions measured was determined by

$$E\ (\mathrm{dB}\mu\mathrm{V/m}) = V_{meas}\ (\mathrm{dB}\mu\mathrm{V}) + \text{Cable Loss (dB)} + \text{Antenna Factor (dBi/m)}.$$

Field strength measurements of radiated spurious emissions were made in the 10m semi-anechoic chamber, AR-8 as detailed above. The recommendations of ANSI C63.4 and ANSI C63.26 were followed for EUT testing setup, cabling, and measurement approach and procedures. All the measurement equipment used, including antennas, was calibrated in accordance with ISO 9001 process. The EUT setup diagram is given in the Figure 4.5. The minimum margins to the Part 30.203 limit is as measured in accordance with 2.1053. The test data follows.

4.5.2 Radiated Spurious Emissions Measurements: 40 GHz - 100 GHz:

The radiated spurious emissions spectrum was investigated per 47CFR Section 2.1057(a)(1) for spurious emissions over the frequency range of 40 GHz to 100 GHz. The procedure and methodology followed the recommendations of ANSI C63.4–2014, C63.26-2015 and C63.26 mmWave JTG.

A Rohde & Schwarz FSW 67 was employed with external three port harmonic down converters and 23 dB Standard Gain Horns. Operation of the harmonic down converters utilizes a swept LO with a fixed IF frequency of 1.325 GHz. The IF cable loss for the 6m of cable was 1.03 dB and was corrected internally to the FSW along with the Conversion loss for the harmonic down converters.

Cable loss compensation for the LO cable loss was necessary to enable scan heights from 1-3 meters. The experience of this test indicated that a 3m maximum test height with this product is adequate (0.5 m above the top of product). This will allow for a reduction of the test cables length, will reduce the amount of LO amplification required and reduce IF images which occurred at multiples of the 1.325 GHz IF frequency.

The harmonic down converters provided coverage for 40-60 GHz (U), 60-90 GHz (E) and 90-140 GHz (F) bands. Operation was verified prior to testing by bore-sighting a mmWave signal generator or mmWave source module with an antenna identical to the measurement antenna at the test distance. The location of the maximum beams had previously been ascertained for both vertical and horizontal polarizations. The beam is extremely narrow and radiated power is down 18 dB at just $\pm$ 5 degrees off center. All of the emissions and harmonics were found to be centered on the beam as well.

Two methods were then employed for full coverage scanning of the product. Method one was a parametric scan at different angles and heights. Method two utilized a continuous max hold (average detector) sweep of the product in elevation and azimuth. For this measurement the scan was started at the beam peak location of 356 degrees azimuth, and nominal elevations 176 cm for Vertical 155 cm for Horizontal. The elevation was then swept down to 1m and back up back to 3m and returned to the beam peak. The product was then rotated continuously to 360 degrees back to 0 degrees and back to 356

degrees. This second method provided the minimum margin but required operation without the analyzer internal noise reduction function. Measurements for 40-60 GHz and 60-90 GHz were performed this way. It should be noted that for method two, averaging of the signal was not performed and this method provides a worst case assessment. Method two could not be used for the 90-100 GHz range as Internal noise reduction was required to have the noise floor below the limit. For all of the measurements no emissions were found outside the steerable angle of the beam. There were >97 scans recorded of the emissions. The plots presented for emissions above 40 GHz are the maximum levels and provide the clearest representation for emissions in these bands.

4.5.2.1 Bandwidth Limits and Corrections: Radiated Measurements 40 GHz - 100 GHz,

All corrections were made to the signal level as detailed below.

4.5.2.2 Resolution Bandwidth and # of Points:

For measurements above 40 GHz we performed scans with the required 1 MHz resolution bandwidth and a 3 MHz resolution bandwidth. In all cases the resolution bandwidth and span limitations of ANSI C63.26 were followed so that the "Number of Measurement Points" $\geq$ 2(Span/RBW).
The FSW-67 internal firmware was updated from the initial filing and is now capable of 100,001 data points. Multiple spans, scans and heights were used to evaluate the peak spurious emissions detected. The search for out of beam spurious was appropriately performed with a 10 MHz RBW while final assessment was performed with a 1 MHz RBW.
Since the intended transmission is a 100 MHz signal, the use of a 10 MHz RBW is a suitable methodology for the initial search for spurious.

4.5.2.3 Part 30 Limit:

The -13 dBm emissions limit was not adjusted in any way.

4.5.2.4 Emissions Corrections.

The measured signal was corrected by the FSW for the harmonic downconverter (HDC) conversion loss. In addition a correction consisting of the radiated path loss, the gain of the measurement antenna and a 1 dB IF cable loss (at 1.3 GHz) was applied. There was no correction applied for the product antenna gain as these measurements are outside the transmit frequency range.

$$\text{Emissions Correction} = \text{Path Loss} - \text{Antenna Gain} + \text{IF Cable loss (1dB)}$$

$$\text{Where Free Space Path Loss} = ((4\pi d)/\lambda))^2$$

Table 4.5.2.4 details the correction for the three bands.

Table 4.5.2.4a Radiated Emissions Corrections for 40-60 GHz at 4.5 m .

Frequency	λ	Measurement Distance, d	Path Loss	Measurement Antenna Gain	IF Cable Loss	Emissions Correction Total
GHz	m	m	dB	dB	dB	dB
40.0	0.007500	4	76.52	21.80	1.03	55.754
42.5	0.007059	4	77.05	22.20	1.03	55.881
45.0	0.006667	4	77.55	22.50	1.03	56.077
47.5	0.006316	4	78.02	22.70	1.03	56.347
50.0	0.006000	4	78.46	23.00	1.03	56.492
52.5	0.005714	4	78.89	23.30	1.03	56.616
55.0	0.005455	4	79.29	23.40	1.03	56.920
57.5	0.005217	4	79.68	23.60	1.03	57.106
60.0	0.005000	4	80.05	23.70	1.03	57.376

Table 4.5.2.4b Radiated Emissions Corrections for 60-90 GHz at 3m.

Frequency	λ	Measurement Distance, d	Path Loss	Measurement Antenna Gain	IF Cable Loss	Emissions Correction Total
GHz	m	m	dB	dB	dB	dB
60.0	0.005000	4	80.05	21.80	1.03	59.276
65.0	0.004615	4	80.74	22.30	1.03	59.471
70.0	0.004286	4	81.38	22.70	1.03	59.715
75.0	0.004000	4	81.98	23.00	1.03	60.014
80.0	0.003750	4	82.54	23.40	1.03	60.175
85.0	0.003529	4	83.07	23.60	1.03	60.501
90.0	0.003333	4	83.57	23.80	1.03	60.798

Table 4.5.2.4c Radiated Emissions Corrections for 90-100GHz at 3m.

Frequency	λ	Measurement Distance, d	Path Loss	Measurement Antenna Gain	IF Cable Loss	Emissions Correction Total
GHz	m	m	dB	dB	dB	dB
90.0	0.003333	3	81.07	21.90	1.03	60.199
95.0	0.003158	3	81.54	22.20	1.03	60.369
100.0	0.003000	3	81.98	22.60	1.03	60.414
105.0	0.002857	3	82.41	23.00	1.03	60.438
110.0	0.002727	3	82.81	23.30	1.03	61.542
115.0	0.002609	3	83.20	23.63	1.03	60.603
120.0	0.002500	3	83.57	23.83	1.03	60.773
125.0	0.002400	3	83.92	24.00	1.03	60.952
130.0	0.002308	3	84.26	24.20	1.03	61.093
135.0	0.002222	3	84.59	24.40	1.03	61.221
140.0	0.002143	3	84.91	24.50	1.03	61.437

4.5.3 Field Strength of Spurious Radiation Results:

For the Title 47CFR section 30.203 and 2.1053 test, the field strength of any spurious radiation, measured at 3m, is required to be less than 82.23 dBμV/meter. Emissions equal to or less than 62.23 dBμV/meter are not reportable.

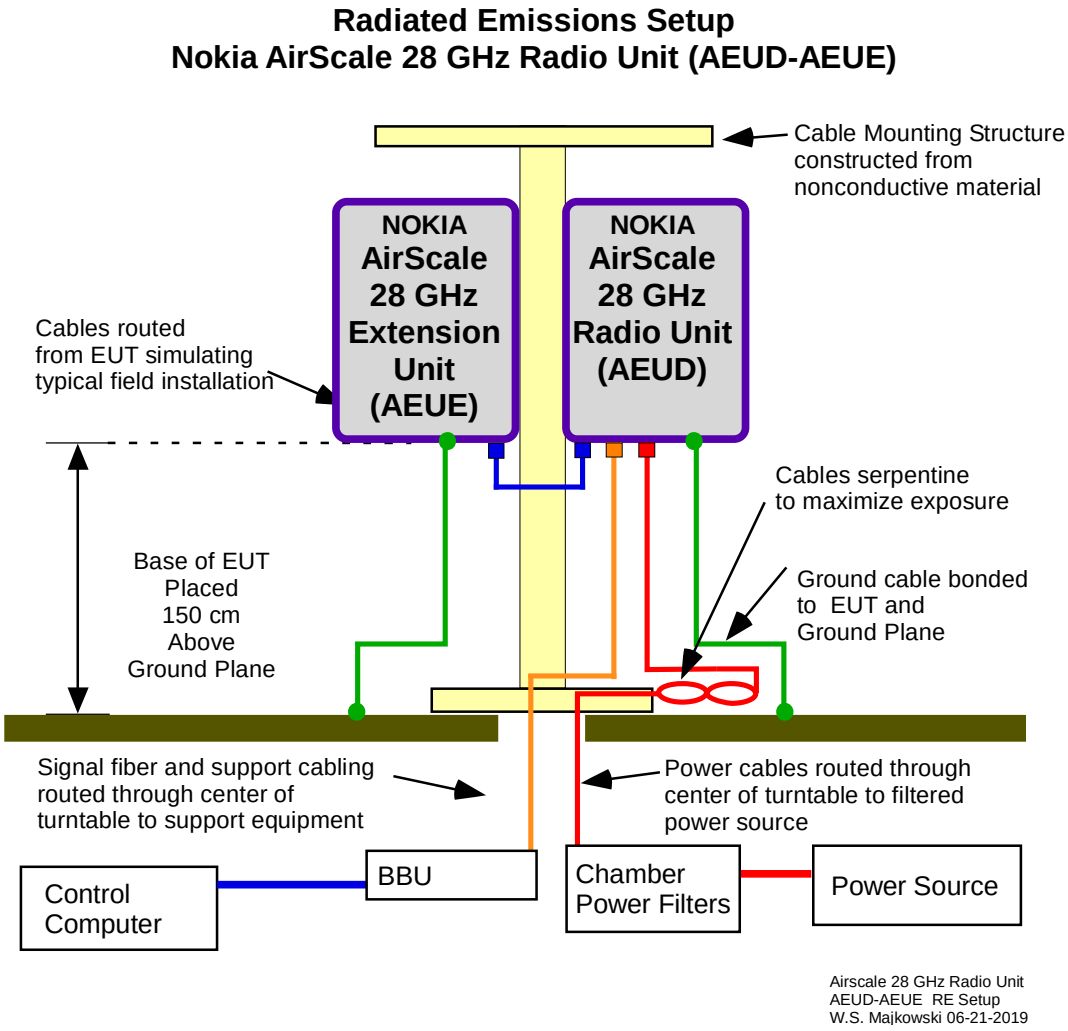
Reportable emissions were only found in the 30 GHz to 40 GHz frequency range where there was insufficient dynamic range to document 20 dB margin to the 82.23 dBm limit.

Presented results include that range and the three mmWave bands as measured with a 1 MHz Resolution Bandwidth. The limit is the -13 dBm limit as specified in Part 30.203. Corrections to the emissions levels consisted of only the HDC conversion loss, the Free space Path Loss and measurement antenna gain as detailed in Table 4.5.2.4.

Over the out of band spectrum investigated from 30 MHz to 100 GHz, reportable spurious emissions were detected and determined to be compliant with the Part 30 limit. Additionally, from 30 MHz to 10 GHz all emissions were below 54.5 dBμV/m. This demonstrates that the **AirScale 28 GHz Radio Unit (AEUD-AEUE) Band 30, FCC ID: VBN2AD8UAEUDAEUE01**, the subject of this application, complies with FCC Part 15 Class B, and FCC Sections 2.1053, 30.203 and 2.1057 of the Rules.

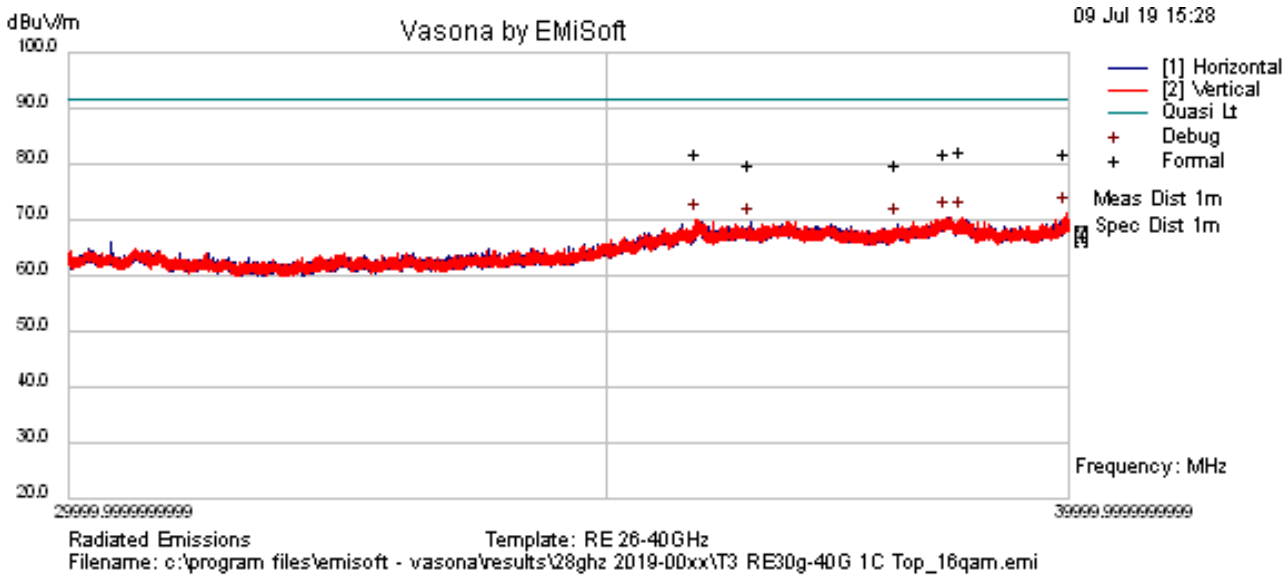
Photographs of the measurement setup are in the filing exhibits.

Figure 4.5 Radiated Emissions Product Setup



4.5.4 Transmitter Measurements of Radiated Spurious Emissions

T3 Radiated Emissions 30GHz - 40GHz FCC Part 30 1C Top of band



Results Title:	RE 26-40GHz
File Name:	c:\program files\emisoft - vasona\results\28ghz 2019-00xx\T3 RE30g-40G 1C Top_16qam.emi
Test Laboratory:	AR4-MH, 24C, 52% 977mB
Test Engineer:	MJS / JY
Test Software:	Vasona by EMISoft, version 2.161
Equipment:	Nokia Wireless
EUT Details:	AEUD dc 28G Radio Unit, SNL1192309640, Model-474611A.101, Transmitting 1C, 28G top of band QPSK, Tx – 28.25016GHz.
Configuration:	Powered by -48VDC, 6 Amps, 1C Top, 16QAM Tested to FCC Class B, RE 30G-40GHz, @ 1-Meter, ESU IH69, Horn Ant E526 with preamp and cable, 28G-Notch Filter E1315. Internal attenuation 0dB, Preview BW (30 kHz RBW/ 3000 KHz VBW); Formal BW (1MHz RBW). Radiated Emissions 30GHz-40GHz
Date:	2019-07-09 15:28:20

FORMAL DATA												
Freq. MHz	**Raw dBµV**	**Cable dB**	**Factor dB**	**Level dBµV/m**	**Emission Type**	**Pol H/V**	**Ht. cm**	**Az. Deg.**	**Limit dBµV/m**	**Margin dB**	**Pass /Fail**	**Comments**
38784.1	50.32	1.52	27.21	79.05	Average	V	201	272	91.77	-12.72	Pass	
38611.9	49.86	1.48	27.28	78.62	Average	V	112	55	91.77	-13.15	Pass	
35941.9	50.27	1.26	27.07	78.61	Average	V	120	282	91.77	-13.16	Pass	
39957.5	49.45	1.81	27.36	78.61	Average	V	200	107	91.77	-13.16	Pass	
38074	47.76	1.36	27.82	76.94	Average	H	227	110	91.77	-14.83	Pass	
36498.6	47.49	1.22	28.17	76.88	Average	H	220	37	91.77	-14.89	Pass	

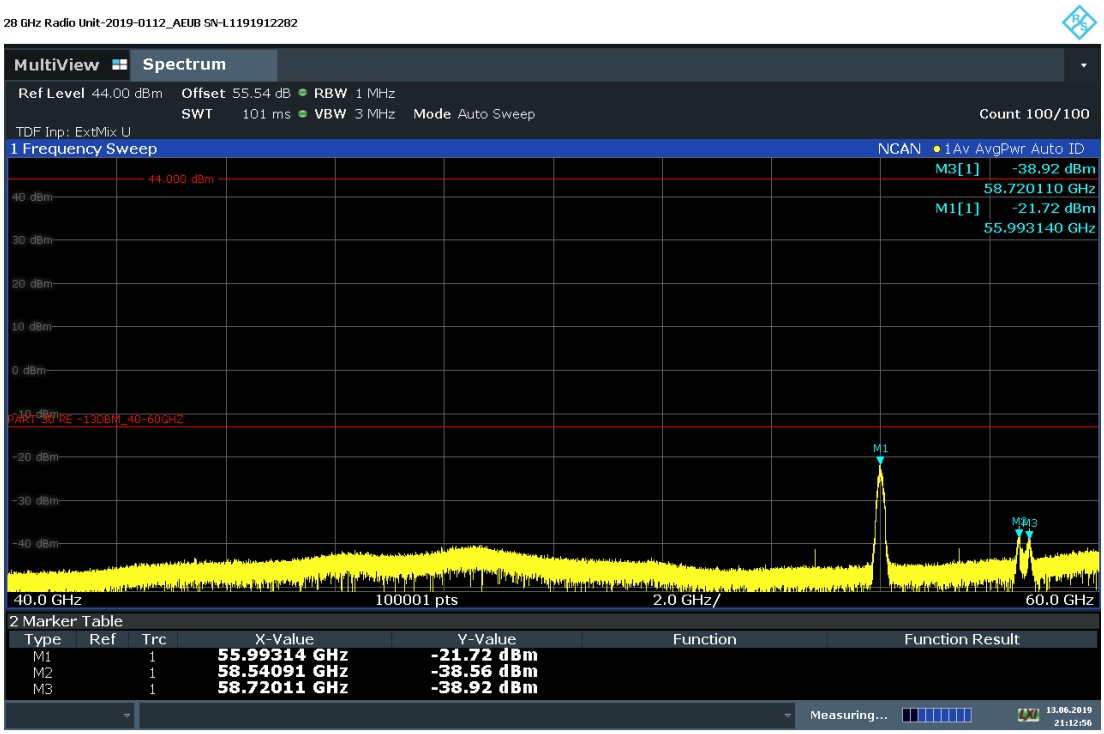
The 12.72 dB margin to the 91.77 dBµV/m limit is the minimum margin to the 82.23 Part 30 Limit below 30 GHz. **(i.e. the** 91.77 dBµV/m is the 3m / 82.23 dBµV/m limit when evaluated at 1m.)

PREVIEW DATA												
Freq. MHz	**Raw dBµV**	**Cable dB**	**Factor dB**	**Level dBµV/m**	**Emission Type**	**Pol H/V**	**Ht. cm**	**Az. Deg.**	**Limit dBµV/m**	**Margin dB**	**Pass /Fail**	**Comments**
35941.9	41.76	1.26	27.07	70.1	Debug	V	98	350	91.77	-21.67	Pass	
38611.9	41.62	1.48	27.28	70.38	Debug	V	98	350	91.77	-21.39	Pass	
38784.1	41.68	1.52	27.21	70.41	Debug	V	98	350	91.77	-21.36	Pass	
39957.5	41.99	1.81	27.36	71.16	Debug	V	98	350	91.77	-20.61	Pass	
36498.6	39.98	1.22	28.17	69.37	Debug	H	98	350	91.77	-22.4	Pass	
38074	39.95	1.36	27.82	69.13	Debug	H	98	350	91.77	-22.64	Pass	

Note: Preview data was measured using a peak detector to identify frequencies of interest for formal measurement. Formal data consist of all frequencies in the preview list within 6 dB of specification limit or the top six frequencies. Failure in preview data does not necessarily constitute failure in formal data.

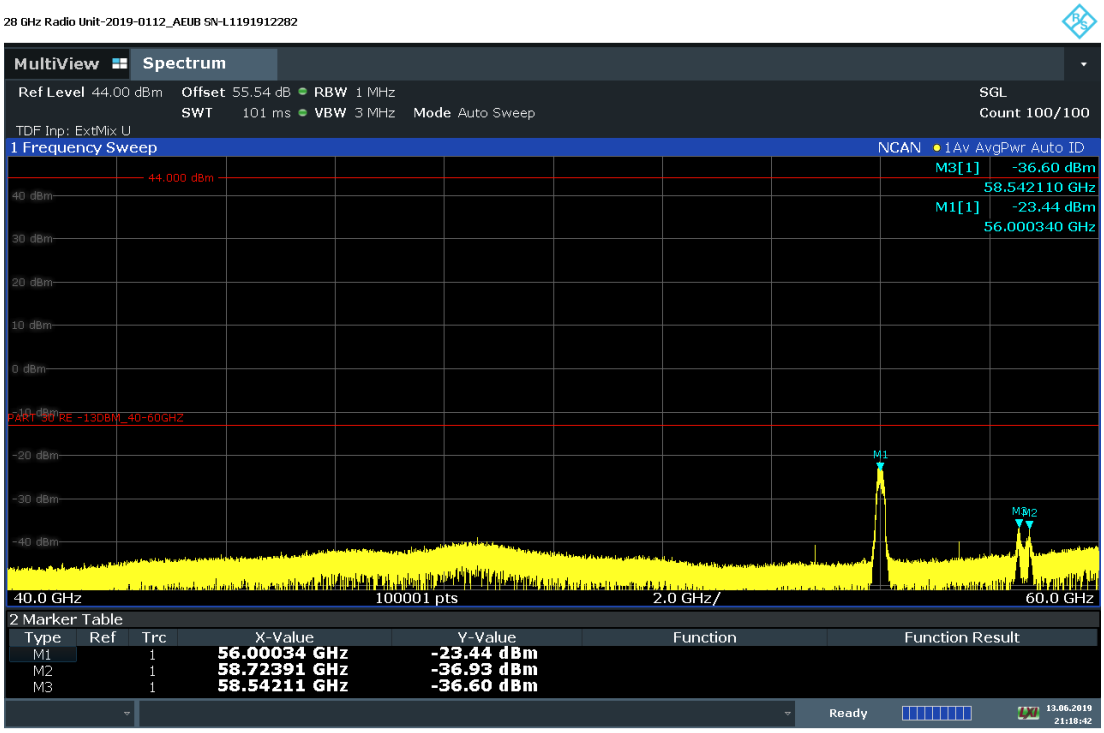
Maximum Measured Radiated Emissions -U Band 40GHz-60GHz FCC B Part 30

Vertical Polarization - 1 MHz RBW



21:12:57 13.06.2019

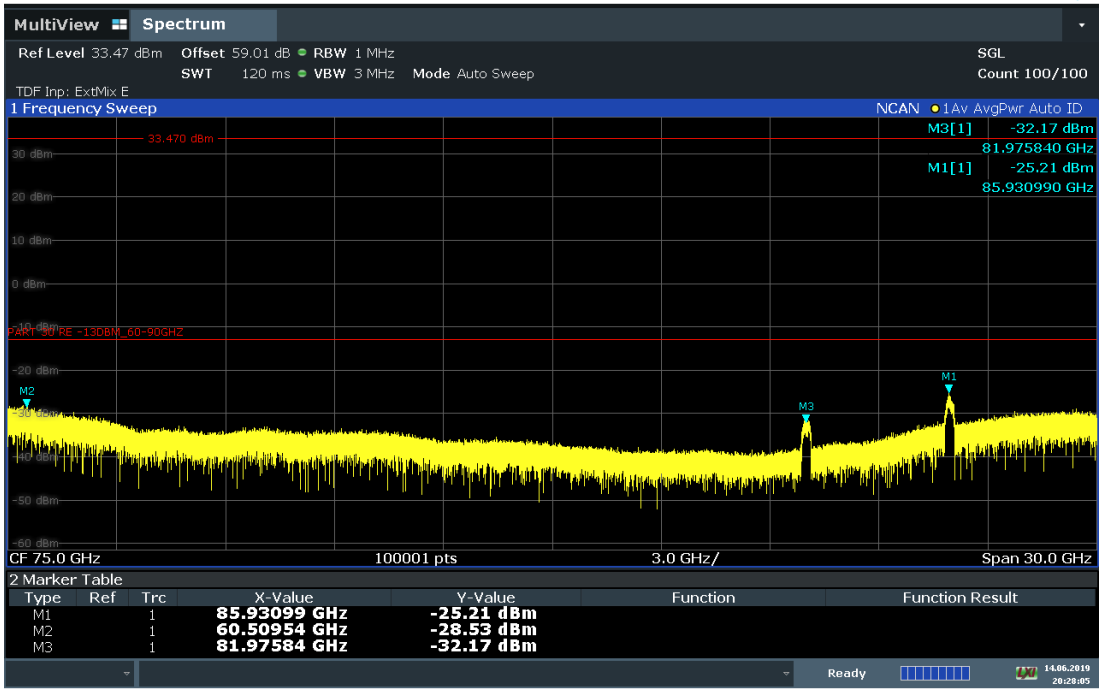
Horizontal Polarization - 1 MHz RBW



21:18:42 13.06.2019

Maximum Measured Radiated Emissions -E Band 60GHz-90GHz FCC B Part 30
Vertical Polarization - 1 MHz RBW

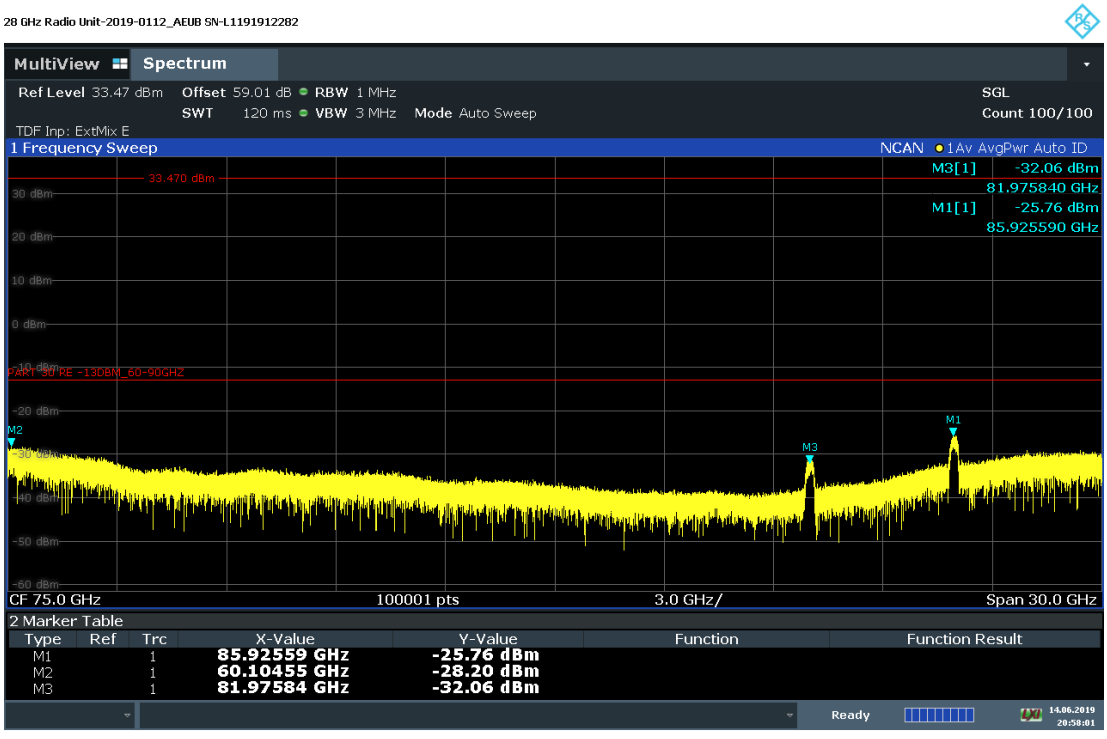
28 GHz Radio Unit-2019-0112_AEUB SN-L1191912282



20:28:05 14.06.2019

Horizontal Polarization - 1 MHz RBW

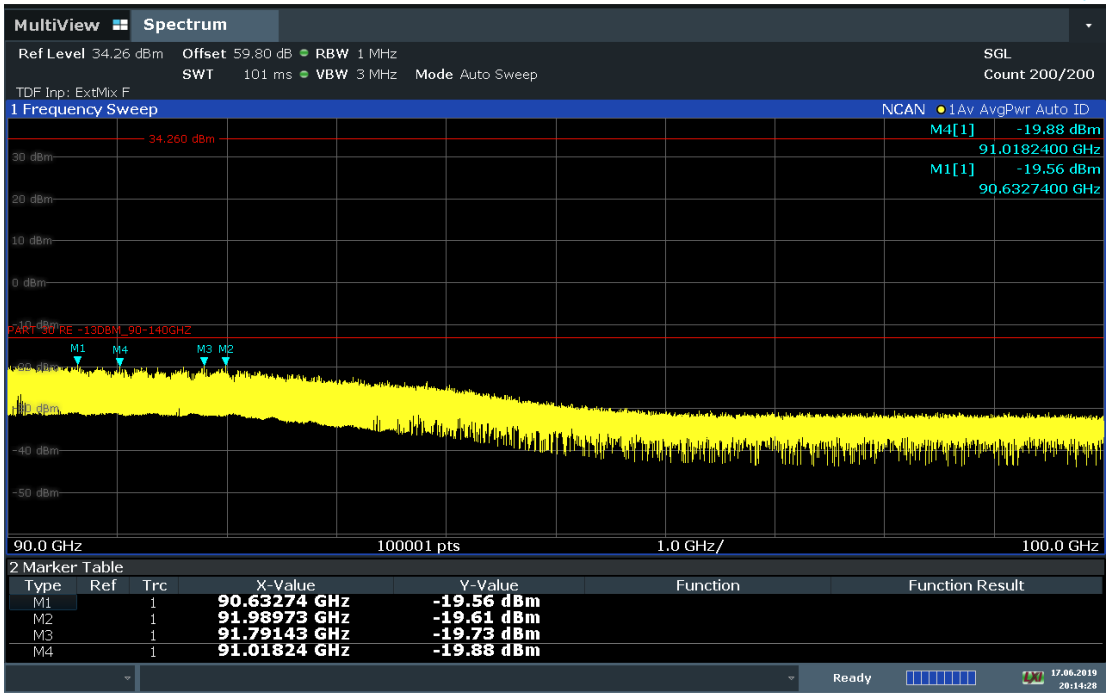
28 GHz Radio Unit-2019-0112_AEUB SN-L1191912282



20:58:02 14.06.2019

Maximum Measured Radiated Emissions -F Band 90GHz-100GHz FCC B Part 30
Vertical Polarization - 1 MHz RBW

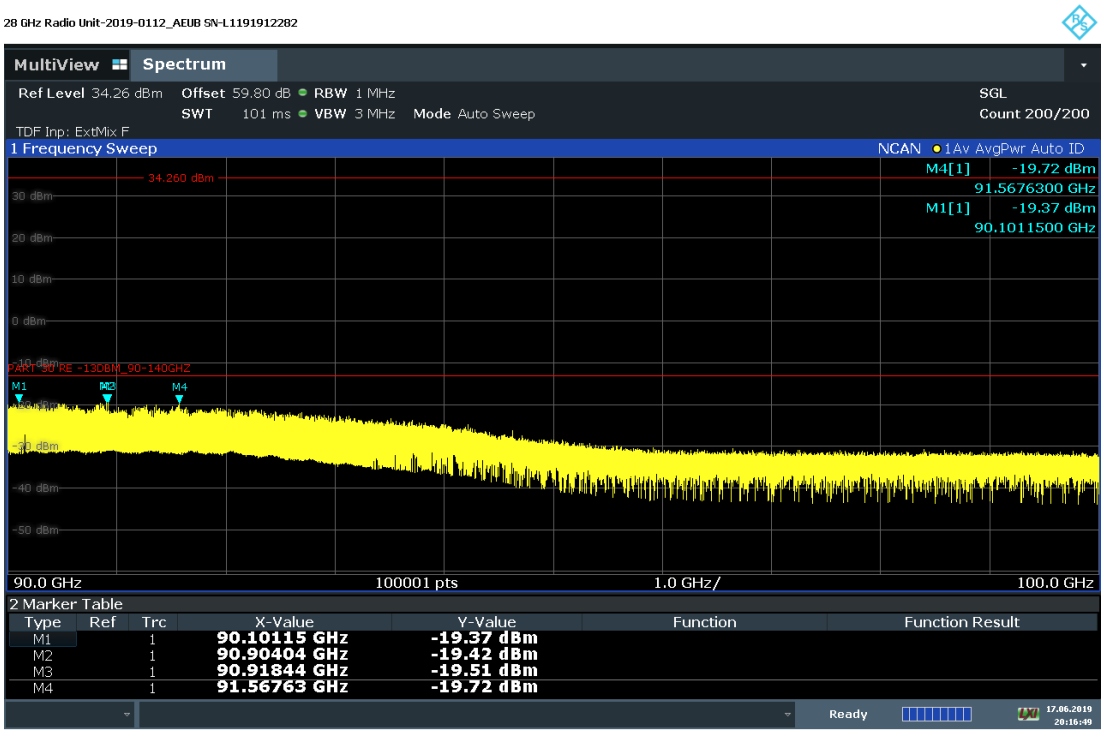
28 GHz Radio Unit-2019-0112_AEUB SN-L1191912282



20:14:29 17.06.2019

Horizontal Polarization - 1 MHz RBW

28 GHz Radio Unit-2019-0112_AEUB SN-L1191912282



20:16:50 17.06.2019

4.6 Section 2.1055 MEASUREMENT REQUIRED: FREQUENCY STABILITY

This measurement evaluates the frequency difference between the actual transmit carrier frequency and the specified transmit frequency assignment. Only the portion of the transmitter system containing the frequency determining and stabilizing circuitry need be put in an environmental chamber and subjected to the temperature variation test per FCC Section 2.1055 and RSS-133. The unit which provides baseband signals, such as BBU (baseband unit), can be located outside the chamber if it is a separate unit.

4.6.1 Frequency Stability Test Article and Configuration

The unit under test is identified as follows:

Series	Vendor	Serial Number	Comcode	Version
AEUD	Nokia	L11923096402	47611A.101	AC or DC

4.6.2 Frequency Stability Test

Frequency Stability Testing was performed on– AEUD-AEUE 28GHz RRH CF 27,950.4 MHz. The testing was performed on the AEUD-AEUE AC & DC 28GHz RRH from 08/01-02/2019 and 08/05-06/2019. The AEUD-AEUE was configured and tested in the T-14 Thermal chamber of the GPCL test facility located in Bldg 4, Room 4-278, Murray Hill, NJ. Testing was witnessed by Joe Bordonaro from GPCL. The AEUD-AEUE supports operation with either AC or DC input power. The AEUD-AEUE was configured per Figure 4.6.2 in each of these power configurations and subjected to a range of temperature from ambient to +50ºC to -30ºC and back to ambient. The transmit frequency error in this case was measured by capturing the transmitted signal using a receiving antenna and then cabling it to an MXA signal analyzer. Frequency Tolerance is a measurement of the difference between the actual transmit frequency and the assigned frequency (27,950.4 MHz). The system level Frequency Stability testing of the AEUD-AEUE yielded results in compliance with established design criteria.

4.6.3 Frequency Stability Test Equipment

Asset ID	Manufacturer	Type	Description	Model	Serial	Calibration Date	Calibration Due
TH536-T14	Envirotronics	Controller		SPPCM	SP001513	2019-03-14	2021-03-14
TH069	Extech	Data Logger	Barometric Pressure / Humidity / Temperature	SD700	Q690305	2019-06-20	2021-06-20
TH073	Fluke	Multimeter	Digital Multimeter	87V	25910080	2018-02-12	2020-02-12
E1338	KeySight Technologies	MXA Signal Analyzer	MXA Signal Analyzer	N9020B	MY57430927	2018-09-13	2019-09-13
TH-T14	Thermotron	Thermal Chamber	Thermal Chamber	N/A	28431	2017-09-27	2019-09-27
TH090	Yokogawa	Data Logger	10 Channel Paperless Recorder	GP10	S5V108472	2019-05-20	2021-05-20
	TDK-Lambda	DC Source	Laboratory DC Power Supply	GEN60-85	13N111I	N/A	N/A
	Behlman	AC Source	Laboratory AC Power Supply	BL 1350	04824	N/A	N/A

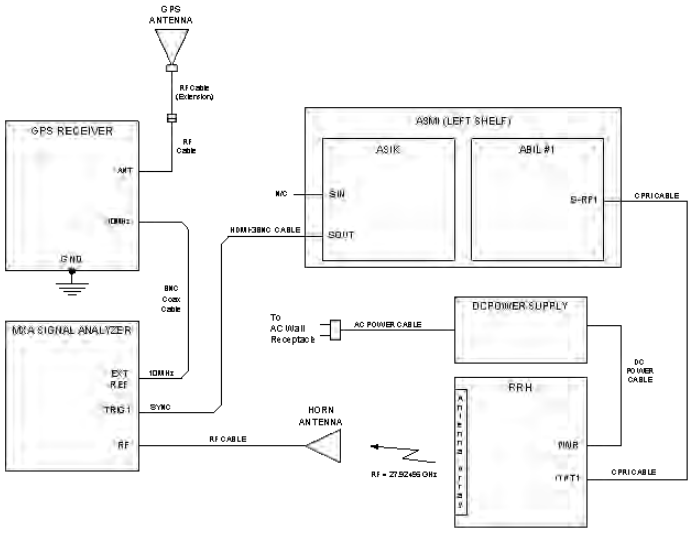
4.6.4 Frequency Stability Test process

Set the power supply to nominal Voltage. (b) Record the frequency at ~25°C. (c)Raise EUT operating temperature to 50°C. (d)Record the frequency difference. (e) Repeat step (d) at each 10°C step down to -30°C. Result will be 10 readings and take temperature readings to establish thermal stability at each point.

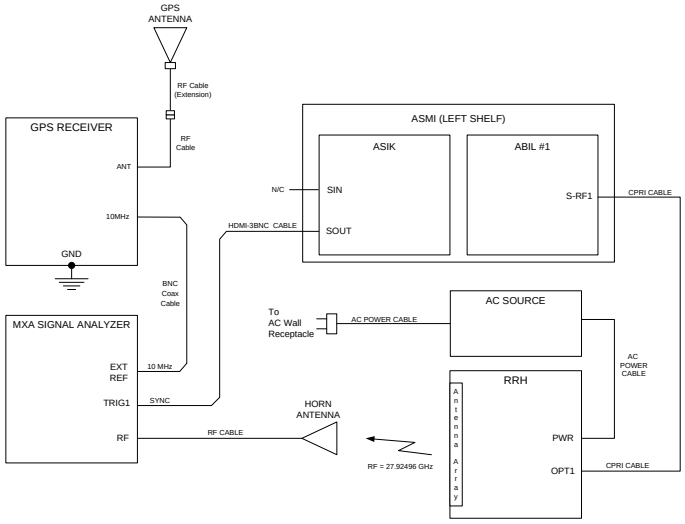
4.6.5 Frequency Stability Results:

The worst case Frequency Stability over temperature and voltage for the product with DC power was **-143.59 Hz** which is **0.0051 ppm.**
The worst case Frequency Stability over temperature and voltage for the product with AC power was **-233.29 Hz** which is **0.0083 ppm.**
These performance values are within the +/- 0.05 ppm desired performance required for 5G-NR operation.

FIGURE 4.6.2: Frequency Stability Test Set-Up



DC Power



AC Power

4.6.6 Frequency Stability Test Photos

Photographs of the Frequency Stability test setups are in section 4.8.2 and are also in the filing exhibits.

4.6.7 Frequency Stability Data:

4.6.7.1 DC Powered Frequency Stability Data:

Frequency Block Tested: ***AEUD 28GHz RADIO (CF = 27,9504MHz)***

1. (a)Set the power supply to nominal Voltage. (b) Record the frequency at ~25°C. (c)Raise EUT operating temperature to 50°C. (d)Record the frequency difference. (e) Repeat step (d) at each 10°C step down to -30°C. Result will be 10 readings and take temperature readings to establish thermal stability at each point.

Baseline Measurement at +25°C

Transmit Frequency Deviation at +25°C at 100% of Nominal Voltage, -48VDC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**87.992**
0.5	**113.13**
1.0	**107.50**
1.5	**102.40**
2.0	**111.38**
2.5	**116.56**
3.0	**94.781**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm) ±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at +50°C at 100% of Nominal Voltage, -48VDC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**98.227**
0.5	**121.88**
1.0	**107.74**
1.5	**119.31**
2.0	**104.51**
2.5	**112.82**
3.0	**116.07**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm) ±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at +40°C at 100% of Nominal Voltage, -48VDC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**88.088**
0.5	**114.23**
1.0	**101.28**
1.5	**120.33**
2.0	**79.071**
2.5	**118.42**
3.0	**101.65**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm) ±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at +30°C at 100% of Nominal Voltage, -48VDC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**120.40**
0.5	**105.77**
1.0	**98.490**
1.5	**102.57**
2.0	**114.20**
2.5	**126.74**
3.0	**109.89**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm) ±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at +20°C at 100% of Nominal Voltage, -48VDC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**120.19**
0.5	**125.08**
1.0	**101.55**
1.5	**117.11**
2.0	**106.81**
2.5	**126.05**
3.0	**109.11**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm) ±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at +10°C at 100% of Nominal Voltage, -48VDC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**114.63**
0.5	**105.56**
1.0	**117.52**
1.5	**123.36**
2.0	**112.51**
2.5	**117.94**
3.0	**97.668**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at 0°C at 100% of Nominal Voltage, -48VDC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**120.09**
0.5	**100.50**
1.0	**118.19**
1.5	**130.70**
2.0	**113.66**
2.5	**104.24**
3.0	**117.31**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at -10°C at 100% of Nominal Voltage, -48VDC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**116.22**
0.5	**131.11**
1.0	**114.00**
1.5	**100.02**
2.0	**107.59**
2.5	**120.36**
3.0	**124.80**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at -20°C at 100% of Nominal Voltage, -48VDC	
Time, (minutes)	**Transmit Carrier Deviation, (Hz)**
0	**121.06**
0.5	**133.47**
1.0	**119.38**
1.5	**122.22**
2.0	**118.69**
2.5	**129.52**
3.0	**133.89**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm) ±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at -30°C at 100% of Nominal Voltage, -48VDC	
Time, (minutes)	**Transmit Carrier Deviation, (Hz)**
0	**112.11**
0.5	**142.08**
1.0	**121.65**
1.5	**134.52**
2.0	**124.30**
2.5	**135.37**
3.0	**143.59**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm) ±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Upon return to +25°C.

2. At ambient, vary voltage to +15% and -15% of nominal VAC and record frequency difference. Result will be 12 readings for each voltage (nominal, ~+ 3%, ~+6%, ~+%9, ~+12%, +15%, and nominal, ~- 3%, ~-6%, ~-%9, ~-12%, -15%).

Transmit Frequency Deviation at +25°C at 100% of Nominal Voltage, -48VDC	
Time, (minutes)	**Transmit Carrier Deviation, (Hz)**
0	**123.87**
0.5	**135.17**
1.0	**111.87**
1.5	**130.86**
2.0	**113.27**
2.5	**135.65**
3.0	**125.75**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm) ±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at +25°C at 103% of Nominal Voltage, -49.44VDC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**129.11**
0.5	**104.79**
1.0	**117.40**
1.5	**110.04**
2.0	**117.76**
2.5	**130.98**
3.0	**123.07**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at +25°C at 106% of Nominal Voltage, -50.88VDC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**135.76**
0.5	**119.55**
1.0	**124.39**
1.5	**136.99**
2.0	**128.85**
2.5	**115.96**
3.0	**135.36**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at +25°C at 109% of Nominal Voltage, -52.32VDC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**103.71**
0.5	**127.18**
1.0	**119.44**
1.5	**122.46**
2.0	**111.20**
2.5	**123.35**
3.0	**120.81**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at +25°C at 112% of Nominal Voltage, -53.76VDC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**120.39**
0.5	**134.20**
1.0	**113.41**
1.5	**127.36**
2.0	**131.06**
2.5	**124.66**
3.0	**116.00**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at +25°C at 115% of Nominal Voltage, -55.20VDC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**137.52**
0.5	**125.31**
1.0	**114.59**
1.5	**126.61**
2.0	**129.48**
2.5	**133.99**
3.0	**119.01**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at +25°C at 100% of Nominal Voltage, -48.0VDC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**134.56**
0.5	**119.93**
1.0	**129.53**
1.5	**109.78**
2.0	**122.31**
2.5	**114.88**
3.0	**110.33**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at +25°C at -3% of Nominal Voltage, -46.56VDC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**128.54**
0.5	**117.46**
1.0	**115.70**
1.5	**127.90**
2.0	**116.14**
2.5	**124.24**
3.0	**130.59**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at +25°C at -6% of Nominal Voltage, -45.12VDC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**124.43**
0.5	**110.23**
1.0	**115.98**
1.5	**117.02**
2.0	**134.13**
2.5	**123.78**
3.0	**118.08**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at +25°C at -9% of Nominal Voltage, -43.68VDC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**122.98**
0.5	**127.51**
1.0	**119.55**
1.5	**126.13**
2.0	**113.35**
2.5	**121.58**
3.0	**131.51**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at +25°C at -12% of Nominal Voltage, -42.24VDC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**127.44**
0.5	**116.01**
1.0	**102.04**
1.5	**122.80**
2.0	**115.60**
2.5	**121.57**
3.0	**138.48**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

Transmit Frequency Deviation at +25°C at -15% of Nominal Voltage, -40.80VDC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**135.19**
0.5	**118.76**
1.0	**137.71**
1.5	**111.38**
2.0	**123.42**
2.5	**132.38**
3.0	**113.68**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**PASS**

4.6.7.2 AC Powered Frequency Stability Data:

Frequency Block Tested: ***– AEUD 28GHz Radio (CF = 27,9504MHz)***

1. (a)Set the power supply to nominal Voltage. (b) Record the frequency at ~25°C. (c)Raise EUT operating temperature to 50°C. (d)Record the frequency difference. (e) Repeat step (d) at each 10°C step down to -30°C. Result will be 10 readings and take temperature readings to establish thermal stability at each point.

Baseline Measurement at +25°C

Transmit Frequency Deviation at +25°C at 100% of Nominal Voltage, 120VAC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**207.49**
0.5	**214.93**
1.0	**222.12**
1.5	**215.90**
2.0	**233.29**
2.5	**213.25**
3.0	**230.68**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm) ±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Transmit Frequency Deviation at +50°C at 100% of Nominal Voltage, 120VAC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**207.74**
0.5	**191.30**
1.0	**219.48**
1.5	**204.14**
2.0	**206.68**
2.5	**222.06**
3.0	**192.84**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm) ±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Transmit Frequency Deviation at +40°C at 100% of Nominal Voltage, 120VAC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**202.45**
0.5	**193.84**
1.0	**190.81**
1.5	**200.30**
2.0	**188.78**
2.5	**201.51**
3.0	**207.17**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Transmit Frequency Deviation at +30°C at 100% of Nominal Voltage, 120VAC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**200.05**
0.5	**194.62**
1.0	**204.99**
1.5	**177.56**
2.0	**184.42**
2.5	**199.90**
3.0	**201.42**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Transmit Frequency Deviation at +20°C at 100% of Nominal Voltage, 120VAC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**187.22**
0.5	**208.71**
1.0	**193.74**
1.5	**199.45**
2.0	**206.72**
2.5	**184.55**
3.0	**209.58**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Transmit Frequency Deviation at +10°C at 100% of Nominal Voltage, 120VAC	
Time (minutes)	Transmit Carrier Deviation (Hz)
0	**196.22**
0.5	**185.86**
1.0	**191.35**
1.5	**185.88**
2.0	**197.11**
2.5	**195.28**
3.0	**192.13**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Transmit Frequency Deviation at 0°C at 100% of Nominal Voltage, 120VAC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**198.70**
0.5	**195.18**
1.0	**179.10**
1.5	**202.82**
2.0	**177.92**
2.5	**194.24**
3.0	**197.31**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Transmit Frequency Deviation at -10°C at 100% of Nominal Voltage, 120VAC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**179.09**
0.5	**184.82**
1.0	**191.71**
1.5	**182.02**
2.0	**169.14**
2.5	**201.52**
3.0	**193.78**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Transmit Frequency Deviation at -20°C at 100% of Nominal Voltage, 120VAC	
Time, (minutes)	**Transmit Carrier Deviation, (Hz)**
0	**180.11**
0.5	**197.14**
1.0	**182.04**
1.5	**195.28**
2.0	**175.90**
2.5	**189.94**
3.0	**179.08**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm) ±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Transmit Frequency Deviation at -30°C at 100% of Nominal Voltage, 120VAC	
Time, (minutes)	**Transmit Carrier Deviation, (Hz)**
0	**177.35**
0.5	**185.95**
1.0	**199.39**
1.5	**174.60**
2.0	**194.40**
2.5	**200.12**
3.0	**191.04**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm) ±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Upon return to +25°C.

2. At ambient, vary voltage to +15% and -15% of nominal VAC and record frequency difference. Result will be 12 readings for each voltage (nominal, ~+ 3%, ~+6%, ~+%9, ~+12%, +15%, and nominal, ~- 3%, ~-6%, ~-%9, ~-12%, -15%).

Transmit Frequency Deviation at +25°C at 100% of Nominal Voltage, 120VAC	
Time, (minutes)	**Transmit Carrier Deviation, (Hz)**
0	**185.99**
0.5	**192.12**
1.0	**179.99**
1.5	**190.29**
2.0	**186.80**
2.5	**171.27**
3.0	**199.59**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm) ±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Transmit Frequency Deviation at +25°C at +15% of Nominal Voltage, 138.0VAC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**178.79**
0.5	**187.19**
1.0	**172.70**
1.5	**195.36**
2.0	**188.19**
2.5	**178.17**
3.0	**194.89**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Transmit Frequency Deviation at +25°C at +12% of Nominal Voltage, 134.40VAC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**195.84**
0.5	**180.20**
1.0	**189.92**
1.5	**184.11**
2.0	**188.40**
2.5	**169.20**
3.0	**175.59**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Transmit Frequency Deviation at +25°C at +9% of Nominal Voltage, 130.80VAC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**182.66**
0.5	**196.18**
1.0	**204.86**
1.5	**187.11**
2.0	**197.73**
2.5	**185.49**
3.0	**196.69**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Transmit Frequency Deviation at +25°C at +6% of Nominal Voltage, 127.20VAC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**174.84**
0.5	**186.13**
1.0	**196.12**
1.5	**168.56**
2.0	**190.20**
2.5	**199.86**
3.0	**201.79**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Transmit Frequency Deviation at +25°C at +3% of Nominal Voltage, 123.60VAC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**172.44**
0.5	**191.57**
1.0	**199.32**
1.5	**164.79**
2.0	**183.81**
2.5	**195.46**
3.0	**197.37**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Transmit Frequency Deviation at +25°C at -3% of Nominal Voltage, 116.40VAC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**190.50**
0.5	**172.79**
1.0	**181.11**
1.5	**191.80**
2.0	**184.45**
2.5	**192.76**
3.0	**194.41**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Transmit Frequency Deviation at +25°C at -6% of Nominal Voltage, 112.80VAC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**183.23**
0.5	**176.26**
1.0	**192.78**
1.5	**180.35**
2.0	**194.46**
2.5	**179.71**
3.0	**189.52**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Transmit Frequency Deviation at +25°C at -9% of Nominal Voltage, 109.20VAC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**176.72**
0.5	**188.40**
1.0	**190.08**
1.5	**165.31**
2.0	**180.44**
2.5	**203.12**
3.0	**182.32**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Transmit Frequency Deviation at +25°C at -12% of Nominal Voltage, 105.60VAC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**182.66**
0.5	**179.03**
1.0	**191.34**
1.5	**198.35**
2.0	**180.52**
2.5	**188.54**
3.0	**198.58**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

Transmit Frequency Deviation at +25°C at -15% of Nominal Voltage, 102.0VAC	
Time (minutes)	**Transmit Carrier Deviation (Hz)**
0	**194.09**
0.5	**182.52**
1.0	**174.76**
1.5	**182.94**
2.0	**188.59**
2.5	**195.29**
3.0	**173.31**
FCC SPECIFICATION	**27,9504MHz (±0.05ppm)** **±0.05ppm = ±1398Hz**
FCC RESULT	**Pass**

4.7 LIST OF TEST EQUIPMENT

4.7.1 List of Radiated Emissions and Radio Radio Measurements Test Equipment

The following equipment was used for the measurement of Radiated Emissions.

Asset ID	Manufacturer	Type	Description	Model	Serial	Cal Date	Cal Due	Cal Type
E1328	A-Info	Horn Antenna	26.5-40GHz WR28 dB	LB-28-25-C2-KF	J202023250	2018-10-16	2021-10-16	Requires Calibration
E1363	A-Info	Horn Antenna	26.5-40GHz WR28 dB	LB-28-25-C2-KF	J202062675	2018-10-16	2021-10-16	Requires Calibration
E1373	A-Info	Horn Antenna	26.5-40GHz WR28 dB	LB-28-25-C2-KF	J202062735	2018-12-05	2021-12-05	Requires Calibration
E950	Agilent Technologies	Power Meter	P-Series	N1911A	MY45101984	2018-03-29	2020-03-29	Requires Calibration
E949	Agilent Technologies	Power Sensor	-35 - +20 dBm 0.05 -18 GHz	N1921A	MY45242502	2018-04-02	2020-04-02	Requires Calibration
E1356	Hewlett Packard	Pre-Amplifier	Pre-Amplifier 1-26.5GHz	8449B	3008A01353	2018-09-10	2020-09-10	Requires Calibration
E447	Hewlett Packard	Pre-Amplifier	Pre-amplifier 1-26.5 GHz	8449B	3008A01384	2018-04-10	2020-04-10	Requires Calibration
E602	A.H. Systems Inc.	Bilogical Antenna	25 - 2000 MHz	SAS-521-2	410	2019-02-11	2021-02-11	Requires Calibration
E1255	ETS Lindgren	Multi-Device Controller		2090	00078509			Calibration Not Required
E1338r	KeySight Technologies	MXA Signal Analyzer	10 Hz–44 GHz	N9020B	MY57431033	2018-08-2	2018-08-22	Requires Calibration
E1264	KeySight Technologies	PSG Signal Generator	Analog Sig Gen 100kHz-67 GHz	E8257D	MY53402943	2017-08-28	2019-08-28	Requires Calibration
E485	Kikusui	Power Supply	DC 55 Volts 120 Amps	PAD 55-120L	DL000416			Verification
E1315	RS Microwave Company, Inc.	Microwave Filter		P/N 60733A	007			Verification
E1308	Rohde & Schwarz	Harmonic Mixer	Down Converter 90-140GHz	FS-Z140	101008	2017-04-06 in Service 2018-07-01		Factory
E1311	Rohde & Schwarz	Harmonic Mixer	Down Converter 40-60GHz	FS-Z60	100977	2017-12-21 in Service 2018-07-01		Factory
E1312	Rohde & Schwarz	Harmonic Mixer	Down Converter 60-90GHz	FS-Z90	101719	2017-08-09 in Service 2018-07-01		Factory
E1260	Rohde & Schwarz	Spectrum Analyzer	20Hz- 67GHz	FSW67	104007	2018-02-12	2020-02-12	Requires Calibration
E907	Rohde & Schwarz	Test Receiver	20 Hz-40 GHz	ESIB40	100101	2018-04-17	2020-04-17	Requires Calibration
EIH69	Rohde & Schwarz	Test Receiver	20 Hz-40 GHz	ESU40	100247	2018-05-22	2020-05-22	Requires Calibration
E1260	Rohde & Schwarz	Spectrum Analyzer	2 Hz - 67 GHz	FSW67	104007	2018-02-12	2020-02-12	Requires Calibration
E1384	Rohde & Schwarz	Spectrum Analyzer	2 Hz - 85 GHz	FSW85	101537	2018-12-17	2020-12-17	Requires Calibration

Asset ID	Manufacturer	Type	Description	Model	Serial	Cal Date	Cal Due	Cal Type
E1332	Sage Millimeter, Inc.	Horn Antenna	E-band pyramidal horn antenna - 60 to 90 GHz.	SAR-2309-12-S2	14853-01			Factory
E1335	Sage Millimeter, Inc.	Horn Antenna	F-band pyramidal horn antenna - 90 to 140 GHz	SAR-2309-08-S2	14853-02			Factory
E1340	Sage Millimeter, Inc.	Horn Antenna	Pyramidal horn antenna - 26.5 to 40 GHz, 25 dB gain	SAR-2507-28-S2	15309-01			Factory
E1330	Sage Millimeter, Inc.	Horn Antenna	U-band pyramidal horn antenna - 40 to 60 GHz	SAR-2309-19-S2	14853-01			Factory
E1331	Sage Millimeter, Inc.	Horn Antenna	U-band pyramidal horn antenna - 40 to 60 GHz	SAR-2309-19VF-R2	14853-01			Factory
E812	Sonoma Instrument Co.	Amplifier	9kHz-1GHz Vasona File TRANS 261	310N	186744	2018-09-14	2020-09-14	Requires Calibration
E980	Trilithic	Low Pass Filter	PCS 0.01-2 GHz	10LC1790-3-AA	PCS-LPF-12			Verification
E520	EMC Test Systems	Horn Antenna	Double Ridged Horn 18-40 GHz	3116	2537	2018-08-09	2020-08-09	Requires Calibration
E057	EMCO	Horn Antenna	Double Ridged Horn 1-18 GHz	3115	9006-3460	2017-05-24	2019-05-24	Requires Calibration
E889	Weinschel	Attenuator	6 dB DC-18GHz 5 Watt	2-6	BX3438	5/23/18	5/23/20	
E1150	Extech	Data Logger	Pressure Humidity Temp Data Logger	SD700	Q752767	2019-01-16	2021-01-16	Requires Calibration

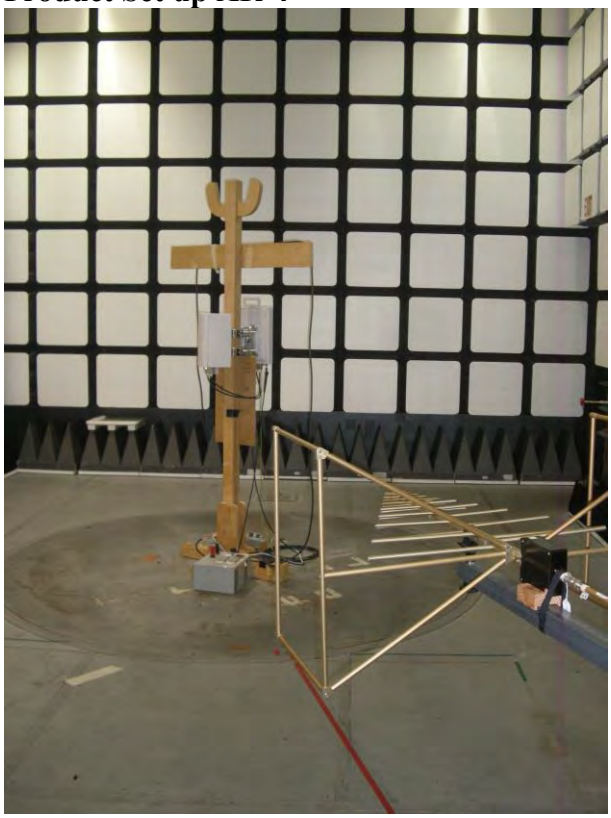
4.8 PHOTOGRAPHS OF THE TEST SETUPS

Response:

The photographs of the test setups for the **AirScale 28 GHz Radio Unit (AEUD-AEUE) Band 30, FCC ID: 2AD8UAEUDAEUE01** are provided in the Filing exhibits.

4.8.1 Radiated Emissions and Radio Measurements Test Photos

Product Set up AR-4



Product Set up AR-8

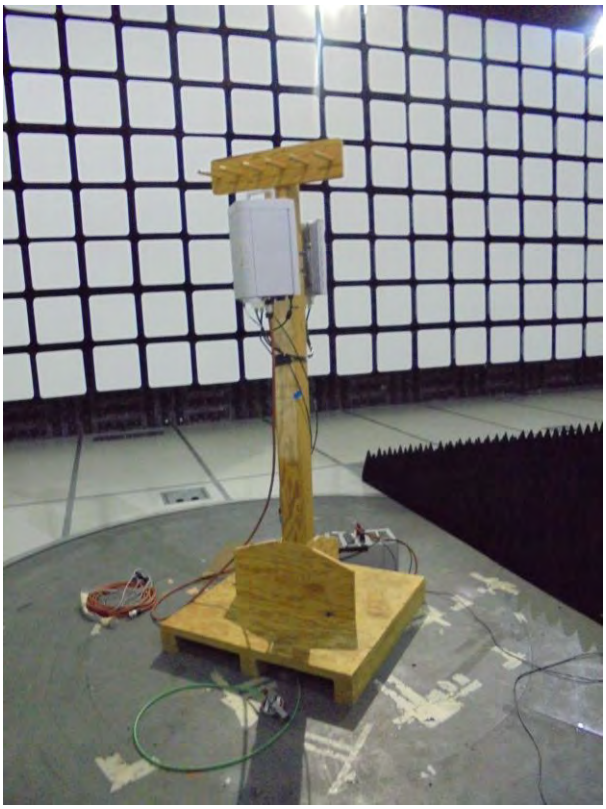
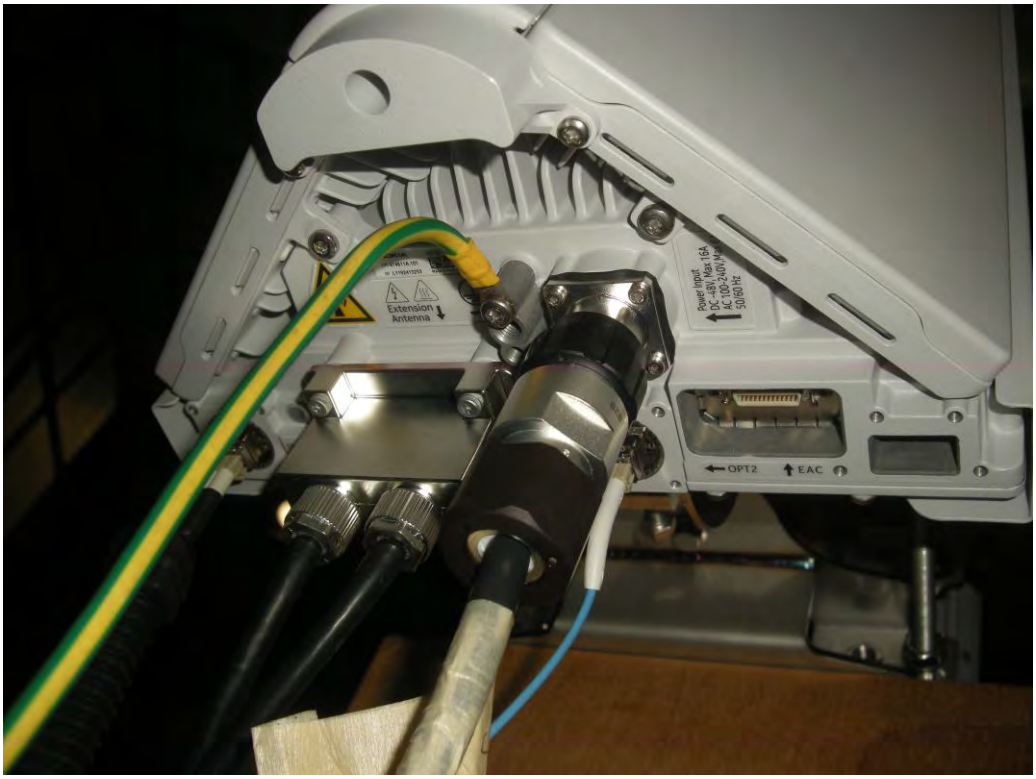


Exhibit 12 –*continued*
Test Setup Photographs

Base of Unit AEUD



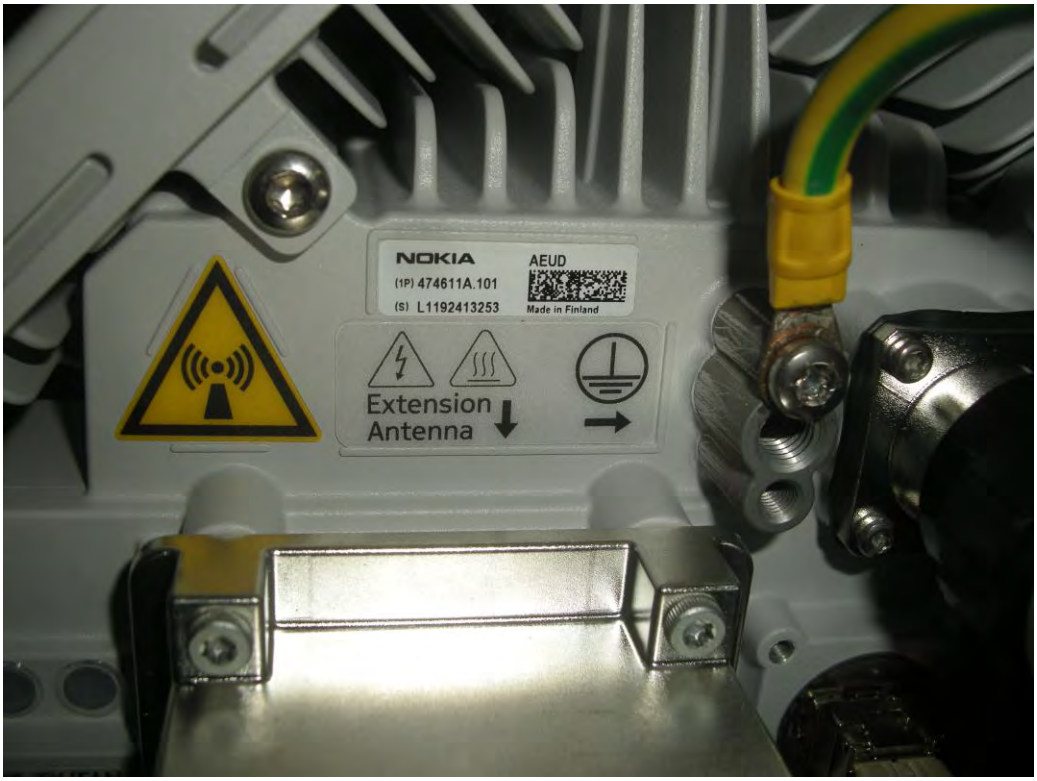
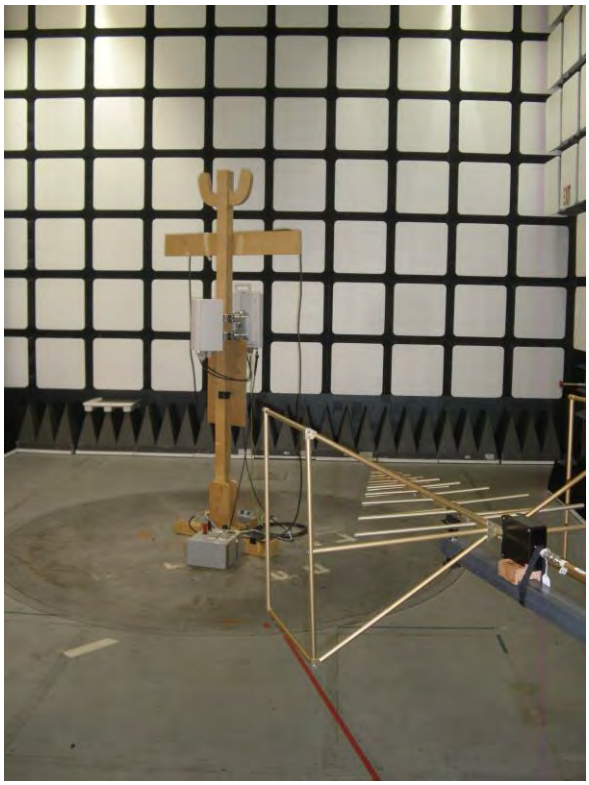

NOKIA
AEUD
(1P) 474611A.101
(S) L1192413253
Made in Finland
Extension
Antenna

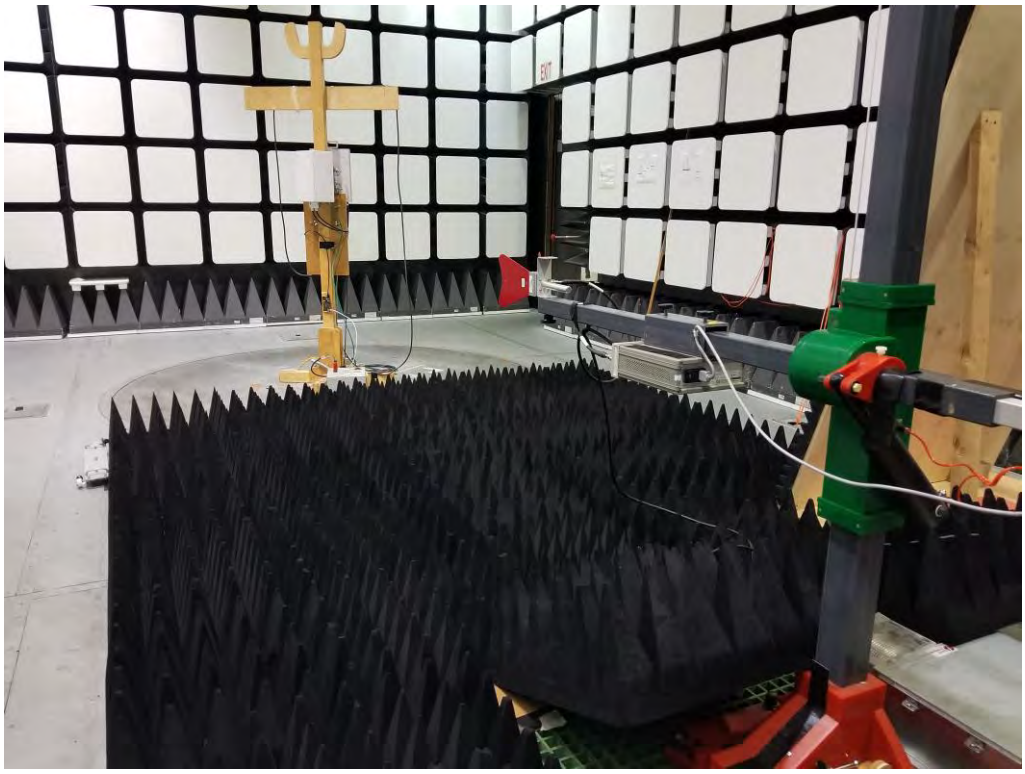
Exhibit 12 –*continued*
Test Setup Photographs

Base of Unit AEUE

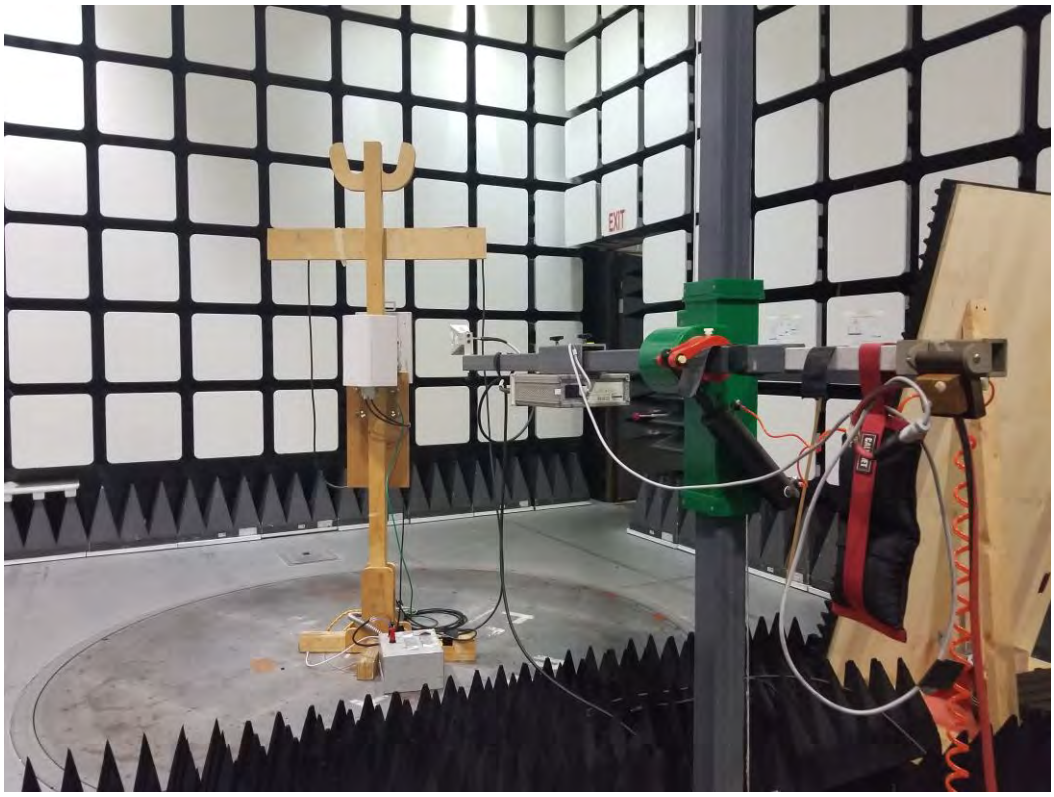
Radiated Emissions 30 MHz-1 GHz at 3m



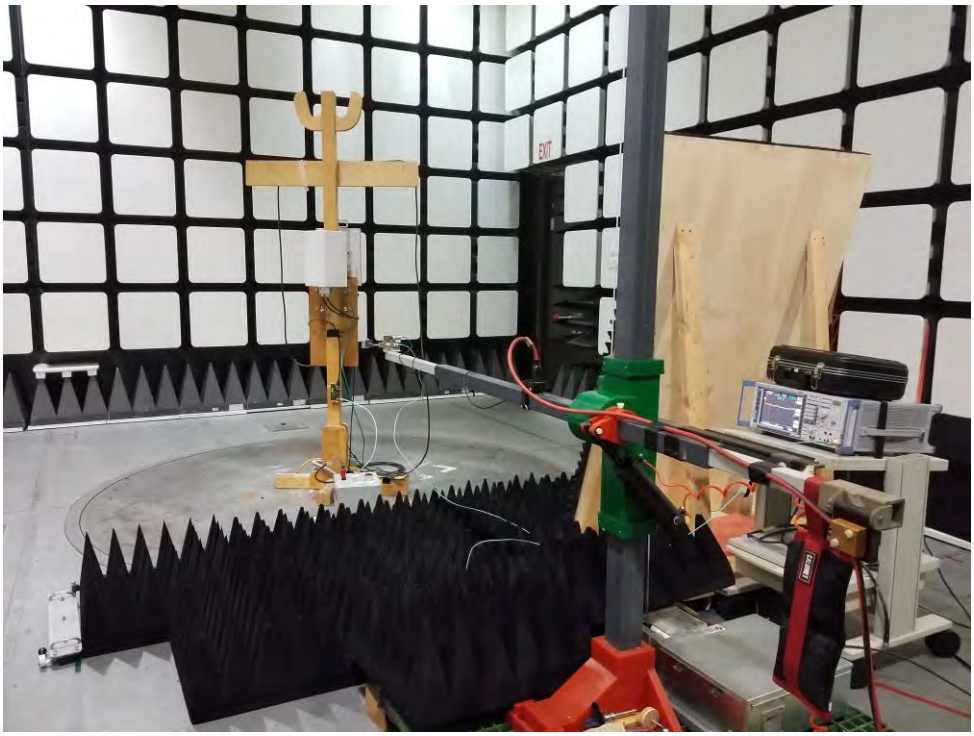
Radiated Emissions 1 GHz – 18 GHz at 3m



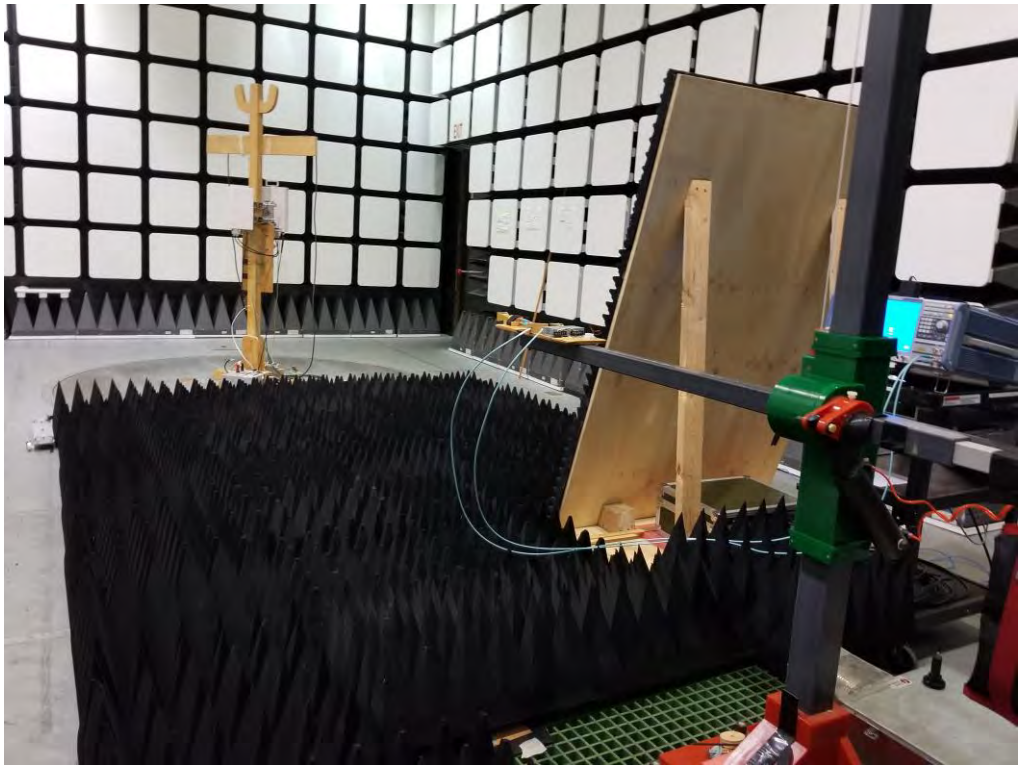
Radiated Emissions 18 GHz – 26.5 GHz at 1m



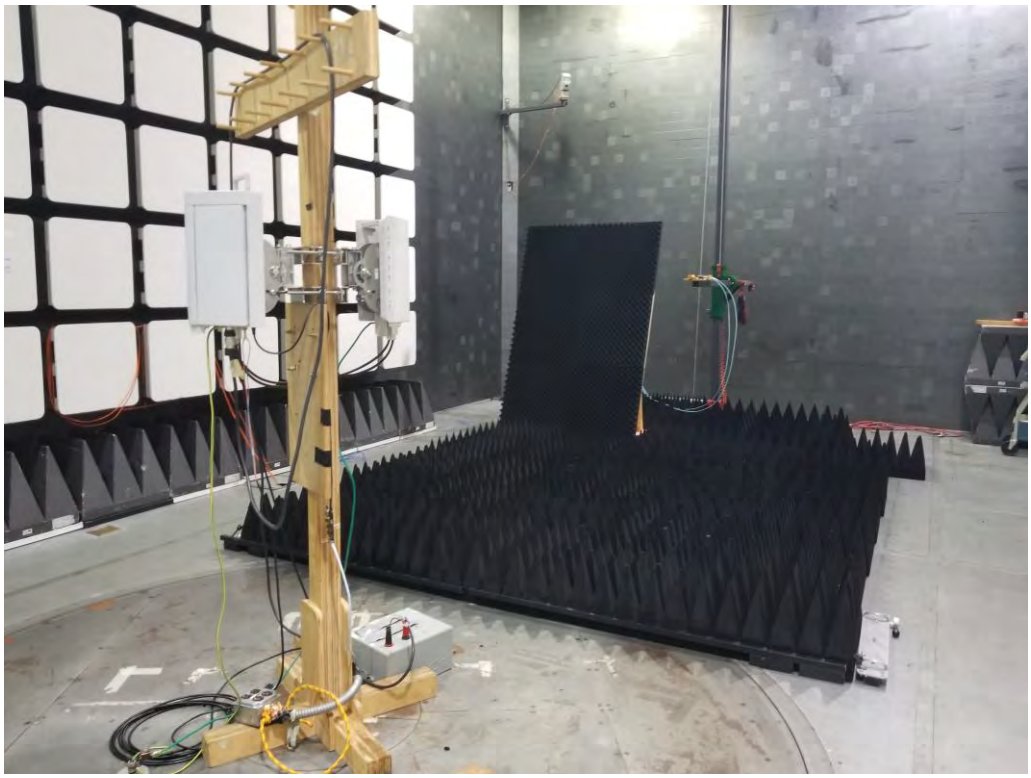
Radiated Emissions 26.5 GHz – 36 GHz GHz at 1m



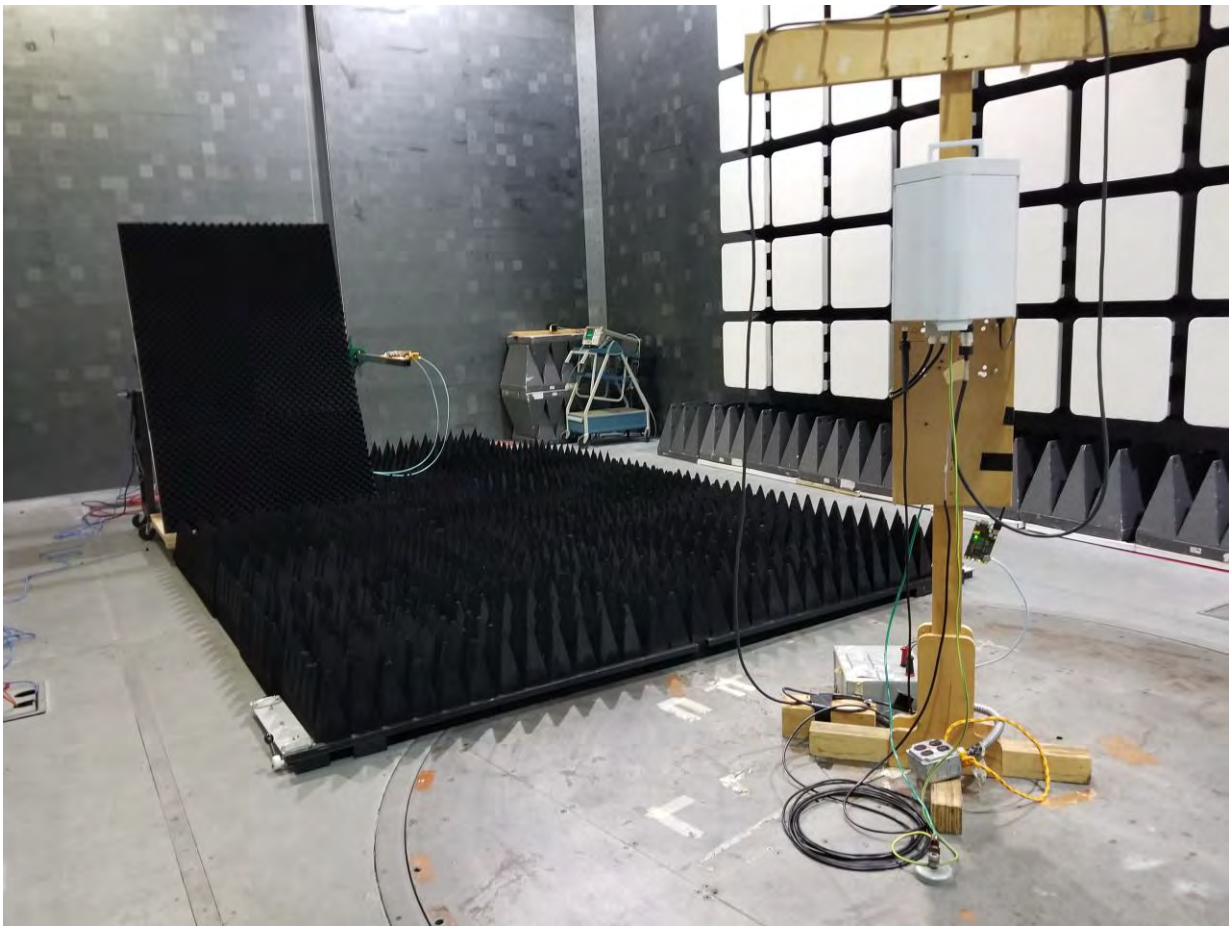
Radiated Emissions 40 GHz – 60 GHz GHz at 4m



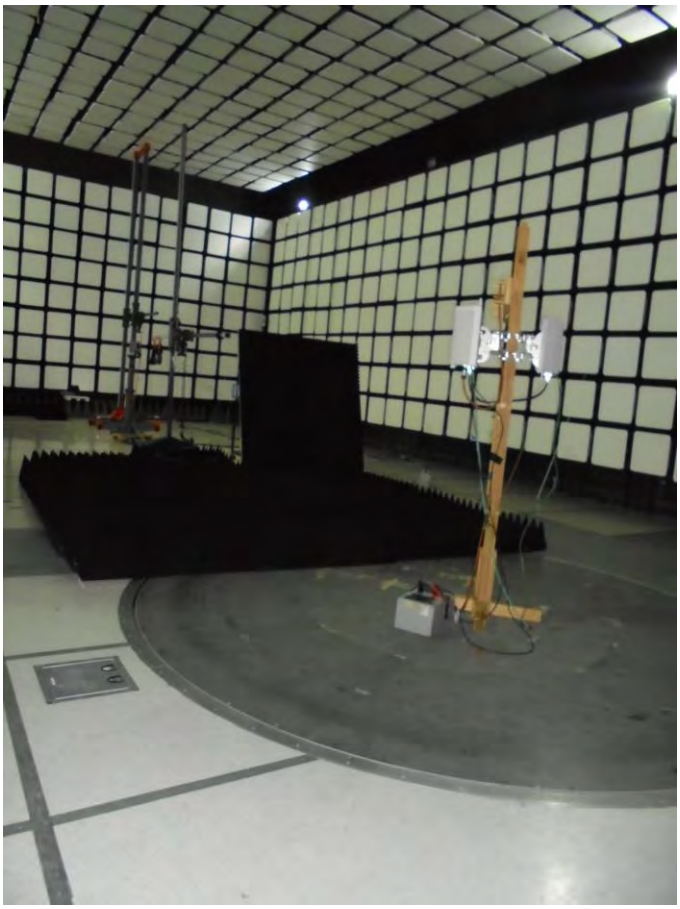
60 GHz – 90 GHz GHz at 4



Radiated Emissions 90 GHz – 100 GHz at 3



Radio Measurements 26-31 GHz at 4.5m



Test and Support Equipment

4.8.2 Frequency Stability Test Photos

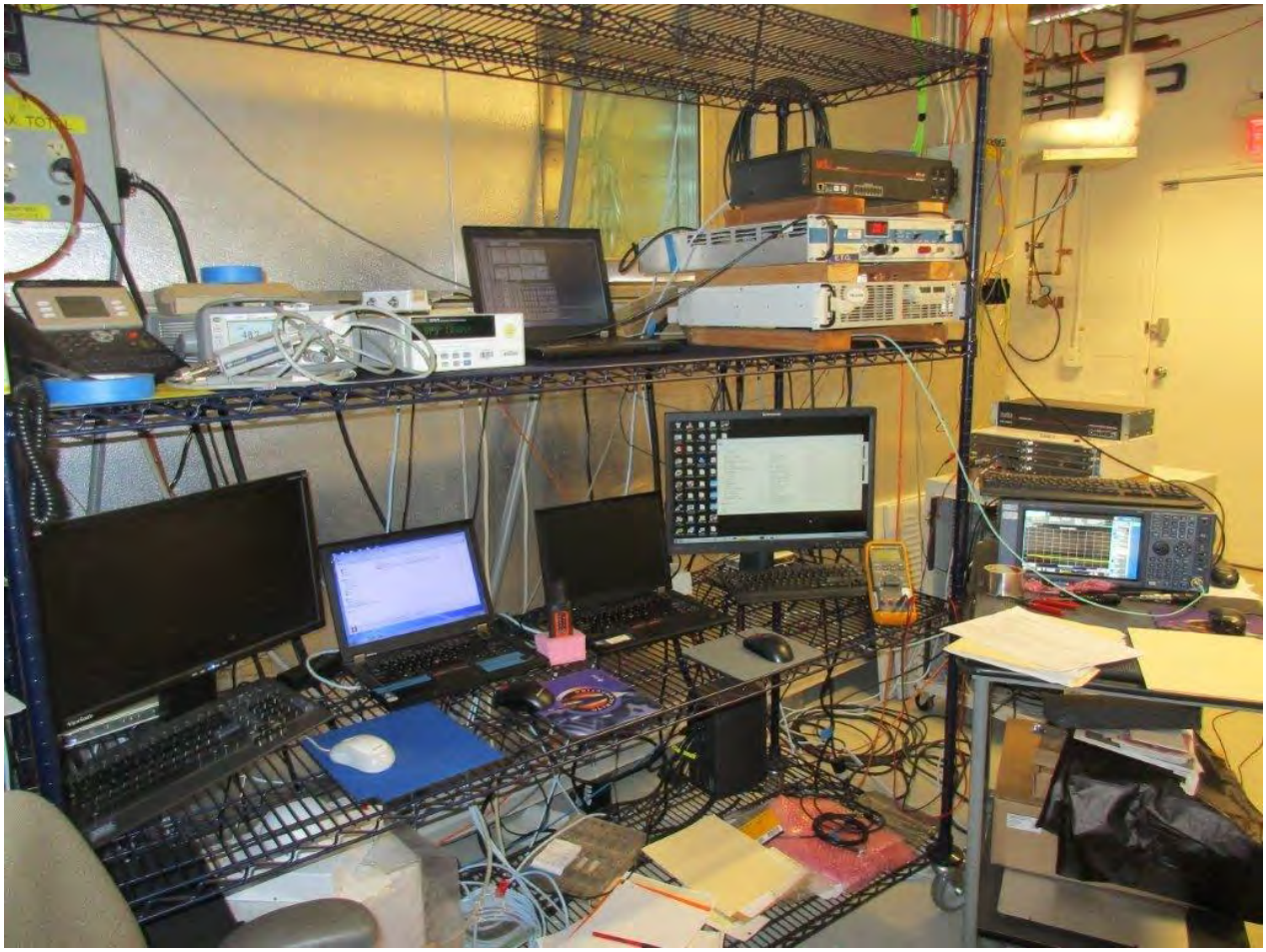
Photographs of the Frequency Stability test setups are below and are also in the filing exhibits.

Frequency Stability Unit Under Test

Frequency Stability Unit Under Test in Chamber

Frequency Stability Radio Under Test and Horn Antenna (inside of thermal chamber)

Frequency Stability Test Measurement Equipment Setup



4.9 FACILITIES AND ACCREDITATION

Measurement facilities at Nokia, Global Product Compliance Laboratory (GPCL) a member of the Nokia family of companies, was used to collect the measurement data in the test report. The laboratory, which is part of Nokia Bell Labs, is located at 600-700 Mountain Avenue, Murray Hill, New Jersey 07974-0636 USA.

The field strength measurements of radiated spurious emissions were made in a FCC registered three meter semi-anechoic chamber AR-8, (FCC Registration Number: 395774) **NVLAP** Lab Code: 100275-0 and IC (Filing Number: 6933F-8) which is maintained by Nokia Bell Labs in Murray Hill, New Jersey. The sites were constructed and are continuously in conformance with the requirements of ANSI C63.4 and CISPR Publication 22.

Nokia Global Product Compliance Laboratory FCC OET Accredited Test Firm Scope List is accessible at:

https://apps.fcc.gov/oetcf/eas/reports/ViewTestFirmAccredScopes.cfm?calledFromFrame=N&RequestTimeout=500&regnum_specified=N&test_firm_id=7007

and is as listed in the Table below.

OET Accredited Test Firm Scope List

Test Firm: Nokia, Global Product Compliance Lab

Scope	FCC Rule Parts	Maximum Assessed Frequency, MHz	Status	Expiration Date	Recognition Date
Unintentional Radiators	FCC Part15, Subpart B	40000	Approved	9/30/2019	7/6/2017
Intentional Radiators	FCC Part 15 Subpart C	40000	Approved	9/30/2019	6/5/2018
U-NII without DFS Intentional Radiators	FCC Part 15, Subpart E	40000	Approved	9/30/2019	6/5/2018
U-NII with DFS Intentional Radiators	FCC Part 15, Subpart E	40000	Approved	9/30/2019	6/5/2018
Commercial Mobile Services	Part 22 (cellular), Part 24, Part 25 (below 3 GHz), Part 27	40000	Approved	9/30/2019	6/5/2018
General Mobile Radio Services	Part 22 (non-cellular), Part 90 (below 3 GHz), Part 95 (below 3 GHz), Part 97 (below 3 GHz), Part 101 (below 3 GHz)	40000	Approved	9/30/2019	6/5/2018
Citizens Broadband Radio Services	Part 96	40000	Approved	9/30/2019	7/6/2017
Microwave and Millimeter Bands Radio Services	Part 25, Part30, Part 74, Part 90 (90M DSRC, Y, Z), Part 95 (M & L), Part 101	200000	Approved	9/30/2019	7/6/2017

Nokia Global Product Compliance Laboratory is accredited with the US Department of Commerce National Institute of Standards and Technology's National Voluntary Laboratory Accreditation Program (NVLAP) for satisfactory compliance with criteria established in Title 15, Part 7 Code of Federal Regulations for offering test services for selected test methods in Electromagnetic Compatibility; Voluntary Control Council for Interference (VCCI), Japan; Australian Communications and Media Authority (ACMA). The laboratory is ISO 9001:2008 Certified.

United States Department of Commerce
National Institute of Standards and Technology

NVLAP®

Certificate of Accreditation to ISO/IEC 17025:2005

NVLAP LAB CODE: 100275-0

Nokia, Global Product Compliance Lab
Murray Hill, NJ

is accredited by the National Voluntary Laboratory Accreditation Program for specific services, listed on the Scope of Accreditation, for:

Electromagnetic Compatibility & Telecommunications

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

2018-09-05 through 2019-09-30
Effective Dates

DEPARTMENT OF COMMERCE · UNITED STATES OF AMERICA

For the National Voluntary Laboratory Accreditation Program

5. APPENDIX A - CALIBRATION CERTIFICATES.

The attached Calibration certificates represent the Harmonic Downconverters used in this testing.

Radiometer Physics
A Rohde & Schwarz Company

Calibration Certificate
Kalibrierschein

Certificate Number 24-0060-100977-01
Zertifikatsnummer

Unit Data

Item
Gegenstand
Harmonic Mixer, 40 GHz to 60 GHz

Manufacturer
Hersteller
RPG

Type
Typ
RPG FS-Z60

Material Number
Materialnummer
1048.0171.02

Serial Number
Seriennummer
100977

Asset Number
Inventarnummer

Order Data

Customer
Auftraggeber

Order Number
Bestellnummer

Date of Receipt
Eingangsdatum

Performance

Place and Date of Calibration
Ort und Datum der Kalibrierung
Meckenheim, 2017-12-21

Scope of Calibration
Umfang der Kalibrierung
Standard Calibration

Statement of Compliance (Incoming)
Konformitätsaussage (Anlieferung)
New device

Statement of Compliance (Outgoing)
Konformitätsaussage (Auslieferung)
All measured values are within the data sheet specifications.

Extend of Calibration Documents
Umfang des Kalibrierdokuments
2 pages Calibration Certificate
5 pages Outgoing Results

This calibration certificate documents, that the named item is tested and measured against defined specifications. Measurement results are located usually in the corresponding interval with a probability of approx. 95% (coverage factor k = 2). Calibration is performed with test equipment and standards directly or indirectly traceable by means of approved calibration techniques to the PTB/DKD or other national/international standards, which realize the physical units of measurement according to the International System of Units (SI). In all cases where no standards are available, measurements are referenced to standards of the R&S laboratories. Principles and methods of calibration correspond with EN ISO/IEC 17025. This calibration certificate may not be reproduced other than in full. Calibration certificates without signatures are not valid. The user is obliged to have the object recalibrated at appropriate intervals.

Dieser Kalibrierschein dokumentiert, dass der genannte Gegenstand nach festgelegten Vorgaben geprüft und gemessen wurde. Die Messwerte lagen im Regelfall mit einer Wahrscheinlichkeit von annähernd 95% im zugeordneten Werteintervall (Erweiterte Messunsicherheit mit k = 2). Die Kalibrierung erfolgte mit Messmitteln und Normalen, die direkt oder indirekt durch Ableitung mittels anerkannter Kalibriertechniken rückgeführt sind auf Normale der PTB/DKD oder anderer nationaler/internationaler Standards zur Darstellung der physikalischen Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI). Wenn keine Normale existieren, erfolgt die Rückführung auf Bezugsnormale der R&S-Laboratorien. Grundsätze und Verfahren der Kalibrierung beziehen sich auf EN ISO/IEC 17025. Dieser Kalibrierschein darf nur vollständig und unverändert weiterverbreitet werden. Kalibrierscheine ohne Unterschriften sind ungültig. Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.

Radiometer Physics GmbH; Meckenheim

Date of Issue
Ausstellungsdatum
2017-12-21

Head of Laboratory
Laborleitung
Schulze

Person Responsible
Bearbeiter
Wildfang

Radiometer Physics GmbH ● Werner-von-Siemens-Str. 4 ● 53340 Meckenheim ● Telephone national: 02225/99981-0 international: 0049 2225-99981-0
Fax: 02225/99981-99 ● Managing Director: Achim Walber, Dr. Thomas Rose ● Company's Place of Business: Meckenheim
Commercial Register No.: Bonn, HRB 10291 ● VAT Identification No.: DE 123 377 395

Calibration Method
Kalibrieranweisung

RPG-PAQA-TN-2014-002

Relative Humidity **20 % - 80 %**
Relative Luftfeuchte

Ambient Temperature
Umgebungstemperatur

(23 $^{+7}_{-3}$) °C

Working standards used (having a significant effect on the accuracy)
Verwendete Gebrauchsnormale (mit signifikantem Einfluss auf die Genauigkeit)

Item Gegenstand	**Type** Typ	**Serial Number** Seriennummer	**Calibration Certificate Number** Kalibrierscheinnummer	**Cal. Due** Kalibr. bis
Vector Network Analyzer	R&S® ZVA67	101097	20-300432406	2020-07-21
Powersensor	R&S® NRP-Z55	140093	20-300426315	2018-05-17
Powersensor	R&S® NRP-Z57	101423	20-541799	2019-04-27

UGB1 **A compliance statement may be possible where a confidence level of less than 95 % is acceptable.**
Die Bestätigung der Konformität ist möglich, sofern ein Grad des Vertrauens von weniger als 95 % akzeptabel ist.

UGB2 **A non-compliance statement may be possible where a confidence level of less than 95 % is acceptable.**
Die Bestätigung der Nicht-Konformität ist möglich, sofern ein Grad des Vertrauens von weniger als 95 % akzeptabel ist.

Ref.: ILAC-G8:03/2009 'Guidelines on the Reporting of Compliance with Specification'.

Notes
Anmerkungen

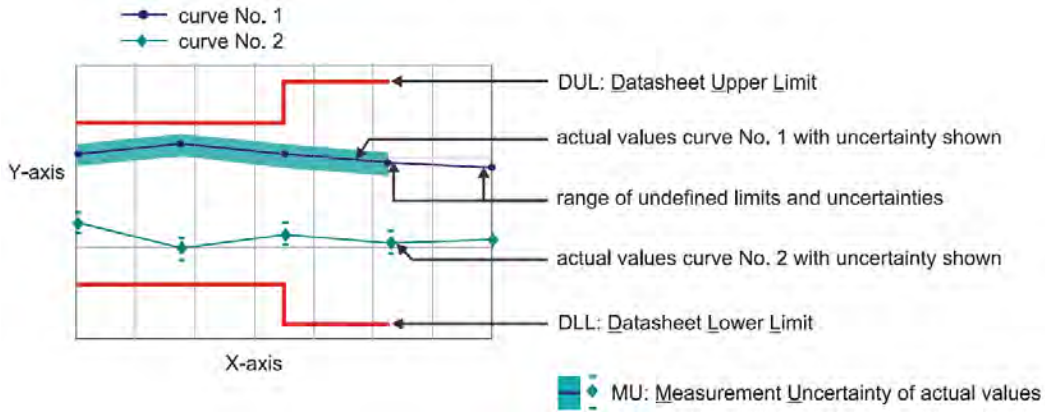
If the new product is stored under the climate conditions as specified in the data sheet upon delivery, the product's accuracy is not significantly affected within 12 month after its calibration in our factory. In this case, the recommended calibration interval starts on the date when the product is actually put into operation.

Outgoing Results

The following abbreviations may be used in this document

{a}	No measurement uncertainty stated because the errors always add together. So it is sure that a measurement result evaluated as "PASS" is pass.
{b}	The measurement uncertainty depends on the measurement result. The stated measurement uncertainty is valid for the close area around the specification. Measurement results outside the close area have a higher measurement uncertainty but are within the specification.
{c}	Functional test, therefore no measurement uncertainty is stated.
{d}	Typical value, refer to performance test.
{e}	The measurement uncertainty is taken into account when setting the measuring system.
DL or DT	Data Limit for symmetrical tolerance limits
DLL	Datasheet Lower Limit
DUL	Datasheet Upper Limit
MU	Measurement Uncertainty
MLL or MLV	Measurement Uncertainty Lower Value
MUL or MUV	Measurement Uncertainty Upper Value
Nom.	Nominal Value
Dev.	Deviation
MErr.	Measurement Error
Act.	Actual Value
UGB	Uncertainty Guard Band: Measuring uncertainty violates the data (spec.) limit.
UGB1	Measurement results marked as UGB1 show conformity with a probability of >50 %and <95 %.
UGB2	Measurement results marked as UGB2 show non-conformity with a probability of >50 %and <95 %.
DU	Datasheet Uncertainty

Explanation of charts

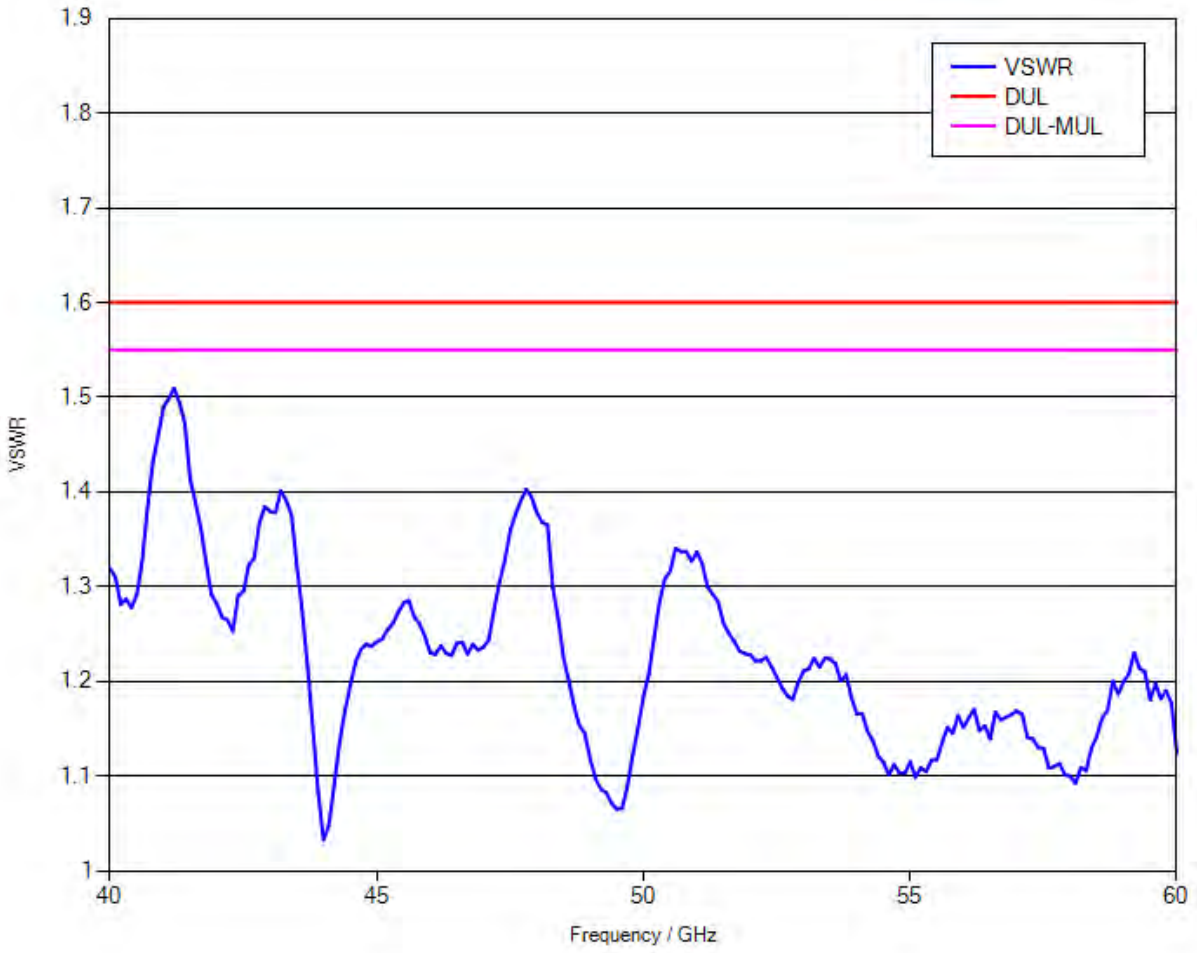


Software used for measurement

Item Type	Version	Remark
Measurement Studio Professional Edition	2013	
MixerCertification	7_07	

1.1 RF Input – VSWR

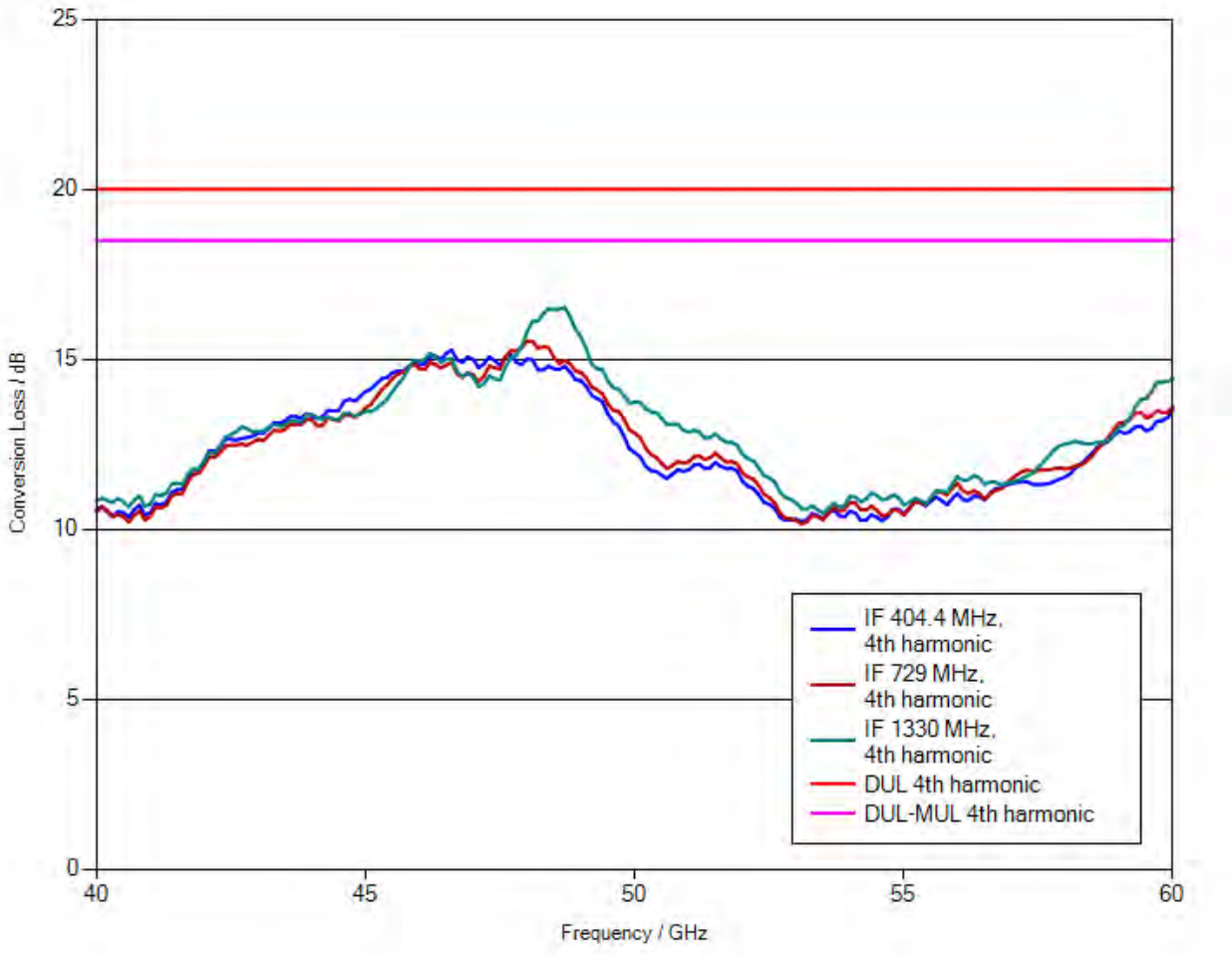
Measurement uncertainty: 0.05 (VSWR)



1.2 Conversion loss

LO level +13 dBm nominal
Bias 0 A

Measurement uncertainty: 1.5 dB



Note: Numeric calibration data can be found attached to the PDF file of the calibration certificate. Click the "paper clip" symbol to display the file.

The file has been renamed for safety reasons.
When downloading the file onto your PC, please delete the ".file" extension and unzip the data.

1.3 Frequency response within 1 GHz

	DUL	Actual (worst case)	Evaluation
IF = 404.4 MHz, 4th harmonic	4 dB	2.02 dB	PASS
IF = 729 MHz, 4th harmonic	4 dB	1.78 dB	PASS
IF = 1330 MHz, 4th harmonic	4 dB	2.35 dB	PASS

ROHDE&SCHWARZ

Calibration Certificate
Kalibrierschein

Certificate Number 24-0090-101719-01
Zertifikatsnummer

Unit Data

Item
Gegenstand
Harmonic Mixer, 60 GHz to 90 GHz

Manufacturer
Hersteller
ROHDE & SCHWARZ

Type
Typ
R&S® FS-Z90

Material Number
Materialnummer
1048.0371.02

Serial Number
Seriennummer
101719

Asset Number
Inventarnummer

Order Data

Customer
Auftraggeber

Order Number
Bestellnummer

Date of Receipt
Eingangsdatum

Performance

Place and Date of Calibration
Ort und Datum der Kalibrierung
Meckenheim, 2017-08-09

Scope of Calibration
Umfang der Kalibrierung
Standard Calibration

Statement of Compliance (Incoming)
Konformitätsaussage (Anlieferung)
New device

Statement of Compliance (Outgoing)
Konformitätsaussage (Auslieferung)
All measured values are within the data sheet specifications.

Extend of Calibration Documents
Umfang des Kalibrierdokuments
2 pages Calibration Certificate
5 pages Outgoing Results

This calibration certificate documents, that the named item is tested and measured against defined specifications. Measurement results are located usually in the corresponding interval with a probability of approx. 95% (coverage factor k = 2). Calibration is performed with test equipment and standards directly or indirectly traceable by means of approved calibration techniques to the PTB/DKD or other national/international standards, which realize the physical units of measurement according to the International System of Units (SI). In all cases where no standards are available, measurements are referenced to standards of the R&S laboratories. Principles and methods of calibration correspond with EN ISO/IEC 17025. This calibration certificate may not be reproduced other than in full. Calibration certificates without signatures are not valid. The user is obliged to have the object recalibrated at appropriate intervals.

Dieser Kalibrierschein dokumentiert, dass der genannte Gegenstand nach festgelegten Vorgaben geprüft und gemessen wurde. Die Messwerte lagen im Regelfall mit einer Wahrscheinlichkeit von annähernd 95% im zugeordneten Werteintervall (Erweiterte Messunsicherheit mit k = 2). Die Kalibrierung erfolgte mit Messmitteln und Normalen, die direkt oder indirekt durch Ableitung mittels anerkannter Kalibriertechniken rückgeführt sind auf Normale der PTB/DKD oder anderer nationaler/internationaler Standards zur Darstellung der physikalischen Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI). Wenn keine Normale existieren, erfolgt die Rückführung auf Bezugsnormale der R&S-Laboratorien. Grundsätze und Verfahren der Kalibrierung beziehen sich auf EN ISO/IEC 17025. Dieser Kalibrierschein darf nur vollständig und unverändert weiterverbreitet werden. Kalibrierscheine ohne Unterschriften sind ungültig. Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.

Radiometer Physics GmbH; Meckenheim

Date of Issue
Ausstellungsdatum
2017-08-11

Head of Laboratory
Laborleitung
Ceru

Person Responsible
Bearbeiter
Heinze

Vers2010-05-05/
RPG2014-02-28

Radiometer Physics GmbH ● Werner-von-Siemens-Str. 4 ● 53340 Meckenheim ● Telephone national: 02225/99981-0 international: 0049 2225-99981-0
Fax: 02225/99981-99 ● Managing Director: Achim Walber, Dr. Thomas Rose ● Company's Place of Business: Meckenheim
Commercial Register No.: Bonn, HRB 10291 ● VAT Identification No.: DE 123 377 395

Calibration Method
Kalibrieranweisung

RPG-PAQA-TN-2014-002

Relative Humidity **20 % - 80 %**
Relative Luftfeuchte

Ambient Temperature
Umgebungstemperatur

(23 $^{+7}_{-3}$) °C

Working standards used (having a significant effect on the accuracy)
Verwendete Gebrauchsnormale (mit signifikantem Einfluss auf die Genauigkeit)

Item Gegenstand	**Type** Typ	**Serial Number** Seriennummer	**Calibration Certificate Number** Kalibrierscheinnummer	**Cal. Due** Kalibr. bis
Vector Network Analyzer	R&S® ZVA67	101097	20-300432406	2020-07-21
Powersensor	R&S® NRP-Z55	140093	20-300426315	2018-05-17
Powersensor	R&S® NRP-Z58	101063	20-611482	2018-07-21
Calibration kit	WR12	E10001	RPG-PAQA-TN-2014-005	2019-02-01

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Die Bestätigung der Konformität ist möglich, sofern ein Grad des Vertrauens von weniger als 95 % akzeptabel ist.

UGB2 **A non-compliance statement may be possible where a confidence level of less than 95 % is acceptable.**
Die Bestätigung der Nicht-Konformität ist möglich, sofern ein Grad des Vertrauens von weniger als 95 % akzeptabel ist.

Ref.: ILAC-G8:03/2009 'Guidelines on the Reporting of Compliance with Specification'.

Notes
Anmerkungen

If the new product is stored under the climate conditions as specified in the data sheet upon delivery, the product's accuracy is not significantly affected within 12 month after its calibration in our factory. In this case, the recommended calibration interval starts on the date when the product is actually put into operation.

Outgoing Results

The following abbreviations may be used in this document

{a}	No measurement uncertainty stated because the errors always add together. So it is sure that a measurement result evaluated as "PASS" is pass.
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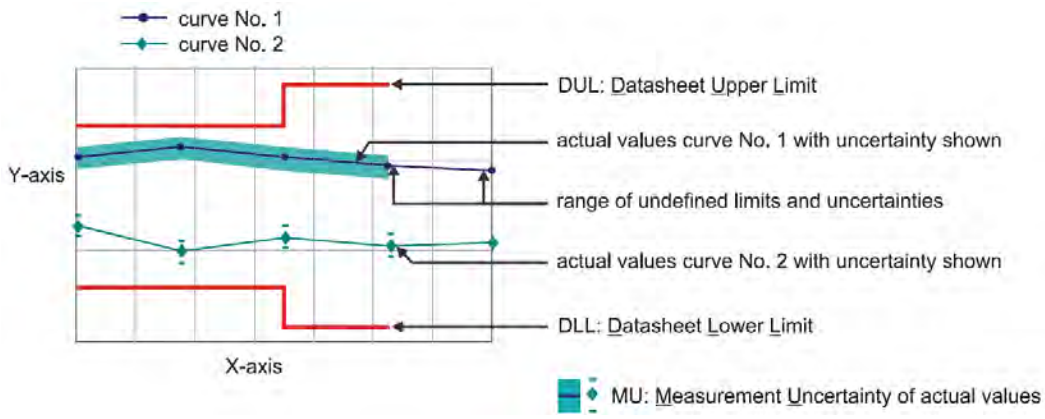
DL or DT	Data Limit for symmetrical tolerance limits
DLL	Datasheet Lower Limit
DUL	Datasheet Upper Limit
MU	Measurement Uncertainty
MLL or MLV	Measurement Uncertainty Lower Value
MUL or MUV	Measurement Uncertainty Upper Value
Nom.	Nominal Value
Dev.	Deviation
MErr.	Measurement Error
Act.	Actual Value
UGB	Uncertainty Guard Band: Measuring uncertainty violates the data (spec.) limit.
UGB1	Measurement results marked as UGB1 show conformity with a probability of >50 %and <95 %.
UGB2	Measurement results marked as UGB2 show non-conformity with a probability of >50 %and <95 %.
DU	Datasheet Uncertainty

Explanation of charts

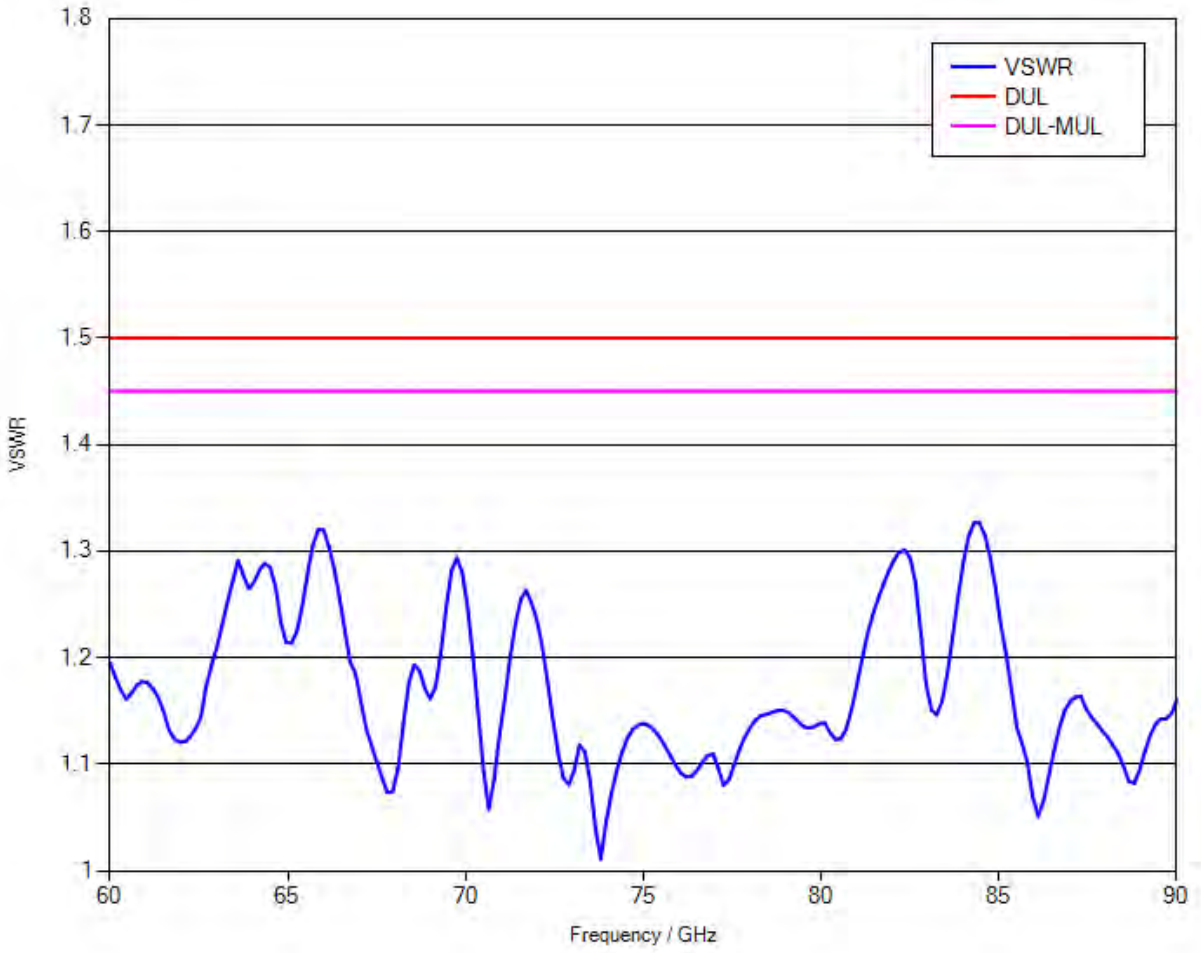


Software used for measurement

Item Type	Version	Remark
Measurement Studio Professional Edition	2013	
MixerCertification	only	

1.1 RF Input – VSWR

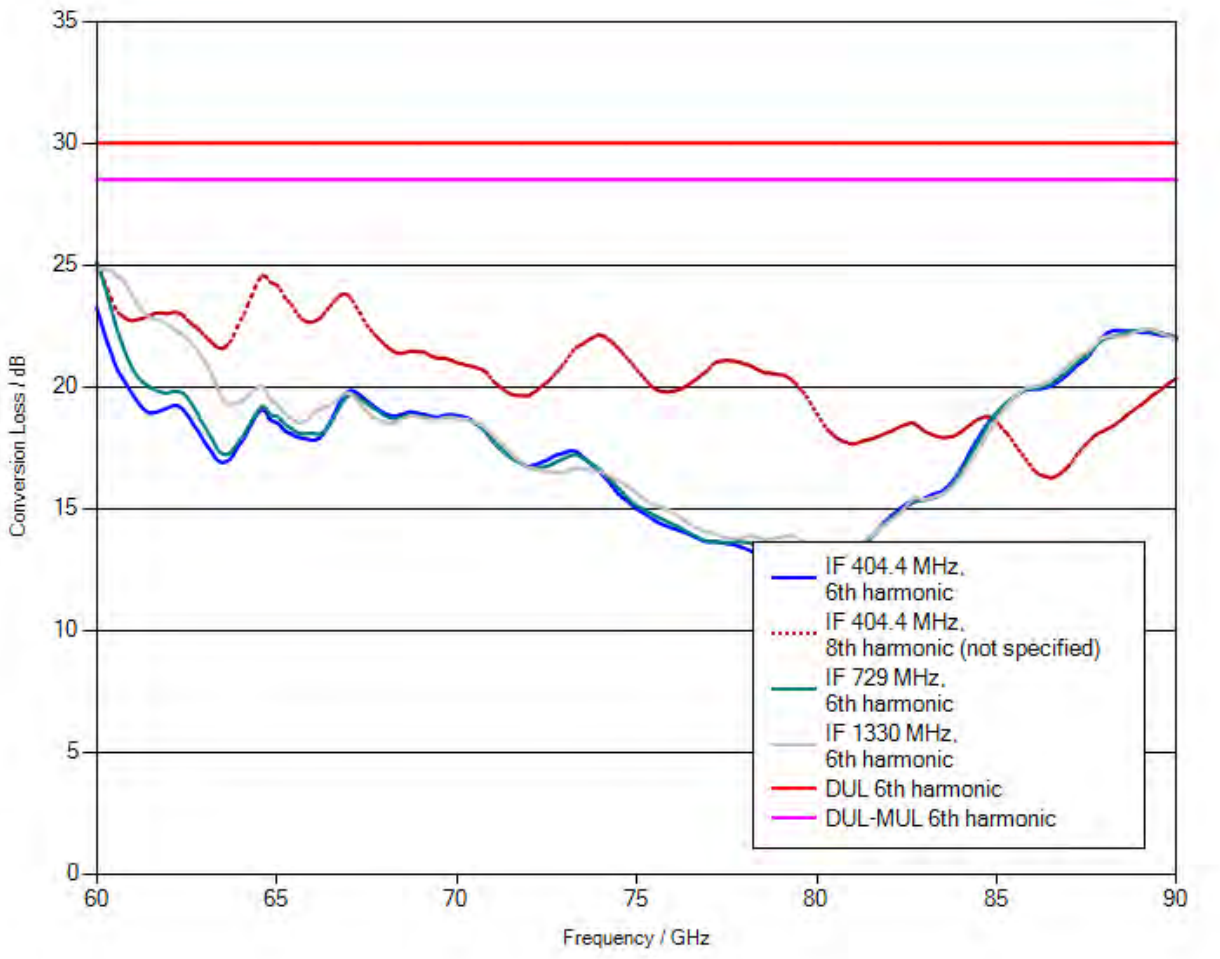
Measurement uncertainty: 0.05 (VSWR)



1.2 Conversion loss

LO level +14 dBm nominal
Bias 0 A

Measurement uncertainty: 1.5 dB



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1.3 Frequency response within 1 GHz

	DUL	Actual (worst case)	Evaluation
IF = 404.4 MHz, 6th harmonic	6 dB	3.33 dB	PASS
IF = 404.4 MHz, 8th harmonic	not specified	2.73 dB	not specified
IF = 729 MHz, 6th harmonic	6 dB	4.12 dB	PASS
IF = 1330 MHz, 6th harmonic	6 dB	2.32 dB	PASS

Radiometer Physics
A Rohde & Schwarz Company

Calibration Certificate
Kalibrierschein

Certificate Number 24-0140-101008-01
Zertifikatsnummer

Unit Data

Item
Gegenstand
Harmonic Mixer, 90 GHz to 140 GHz

Manufacturer
Hersteller
RPG

Type
Typ
RPG FS-Z140

Material Number
Materialnummer
3622.0708.02

Serial Number
Seriennummer
101008

Asset Number
Inventarnummer

Order Data

Customer
Auftraggeber

Order Number
Bestellnummer

Date of Receipt
Eingangsdatum

Performance

Place and Date of Calibration
Ort und Datum der Kalibrierung
Meckenheim, 2017-04-06

Scope of Calibration
Umfang der Kalibrierung
Standard Calibration

Statement of Compliance (Incoming)
Konformitätsaussage (Anlieferung)
New device

Statement of Compliance (Outgoing)
Konformitätsaussage (Auslieferung)
All measured values are within the data sheet specifications.

Extend of Calibration Documents
Umfang des Kalibrierdokuments
2 pages Calibration Certificate
5 pages Outgoing Results

This calibration certificate documents, that the named item is tested and measured against defined specifications. Measurement results are located usually in the corresponding interval with a probability of approx. 95% (coverage factor k = 2). Calibration is performed with test equipment and standards directly or indirectly traceable by means of approved calibration techniques to the PTB/DKD or other national/international standards, which realize the physical units of measurement according to the International System of Units (SI). In all cases where no standards are available, measurements are referenced to standards of the R&S laboratories. Principles and methods of calibration correspond with EN ISO/IEC 17025. This calibration certificate may not be reproduced other than in full. Calibration certificates without signatures are not valid. The user is obliged to have the object recalibrated at appropriate intervals.

Dieser Kalibrierschein dokumentiert, dass der genannte Gegenstand nach festgelegten Vorgaben geprüft und gemessen wurde. Die Messwerte lagen im Regelfall mit einer Wahrscheinlichkeit von annähernd 95% im zugeordneten Werteintervall (Erweiterte Messunsicherheit mit k = 2). Die Kalibrierung erfolgte mit Messmitteln und Normalen, die direkt oder indirekt durch Ableitung mittels anerkannter Kalibriertechniken rückgeführt sind auf Normale der PTB/DKD oder anderer nationaler/internationaler Standards zur Darstellung der physikalischen Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI). Wenn keine Normale existieren, erfolgt die Rückführung auf Bezugsnormale der R&S-Laboratorien. Grundsätze und Verfahren der Kalibrierung beziehen sich auf EN ISO/IEC 17025. Dieser Kalibrierschein darf nur vollständig und unverändert weiterverbreitet werden. Kalibrierscheine ohne Unterschriften sind ungültig. Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.

Radiometer Physics GmbH; Meckenheim

Date of Issue
Ausstellungsdatum
2017-04-07

Head of Laboratory
Laborleitung
Ceru

Person Responsible
Bearbeiter
Heinze

Vers2010-05-05/
RPG2014-02-28

Radiometer Physics GmbH ● Werner-von-Siemens-Str. 4 ● 53340 Meckenheim ● Telephone national: 02225/99981-0 international: 0049 2225-99981-0
Fax: 02225/99981-99 ● Managing Director: Achim Walber, Dr. Thomas Rose ● Company's Place of Business: Meckenheim
Commercial Register No.: Bonn, HRB 10291 ● VAT Identification No.: DE 123 377 395

Calibration Method
Kalibrieranweisung

RPG-PAQA-TN-2014-002

Relative Humidity **20 % - 80 %**
Relative Luftfeuchte

Ambient Temperature
Umgebungstemperatur

(23 $^{+7}_{-3}$) °C

Working standards used (having a significant effect on the accuracy)
Verwendete Gebrauchsnormale (mit signifikantem Einfluss auf die Genauigkeit)

Item Gegenstand	**Type** Typ	**Serial Number** Seriennummer	**Calibration Certificate Number** Kalibrierscheinnummer	**Cal. Due** Kalibr. bis
Vector Network Analyzer	R&S® ZVA67	101097	10-300319061	2017-08-06
Powersensor	R&S® NRP-Z55	140093	20-541556	2017-05-12

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Notes
Anmerkungen

Outgoing Results

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Nom.	Nominal Value
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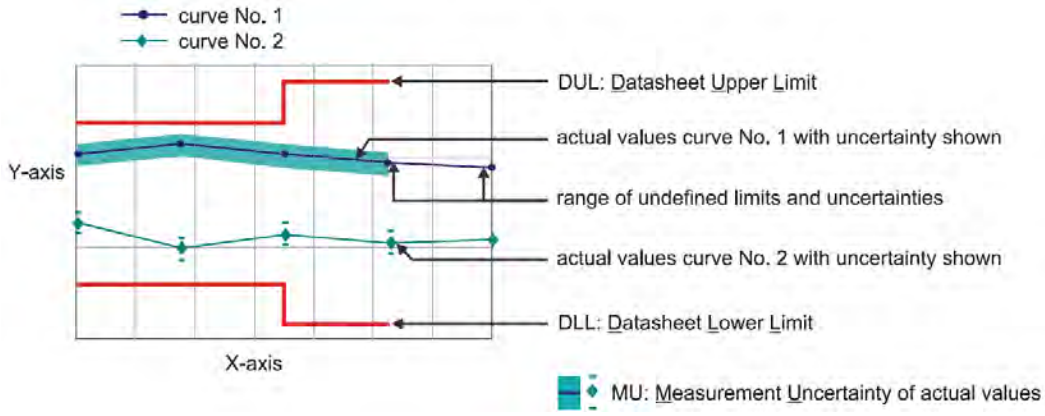
DU	Datasheet Uncertainty

Explanation of charts

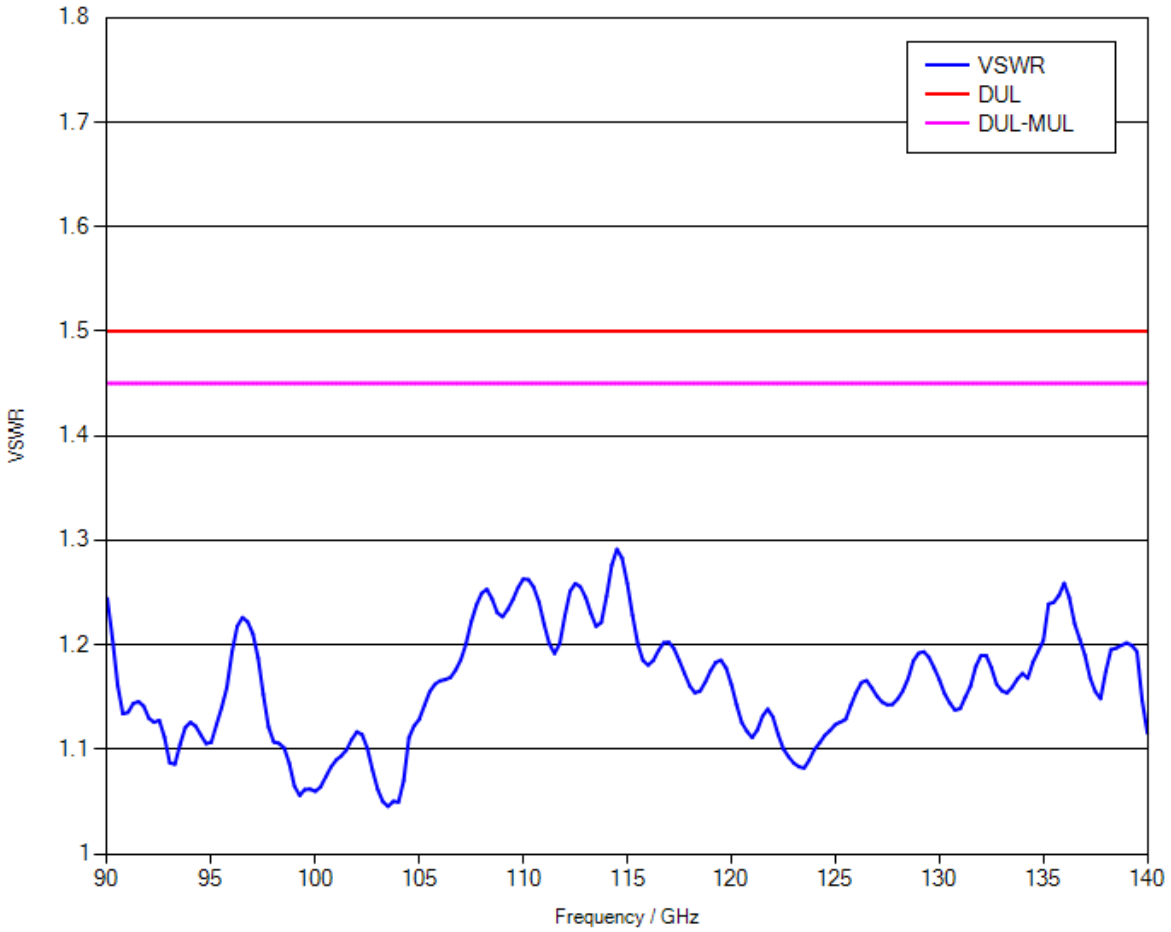


Software used for measurement

Item Type	Version	Remark
Measurement Studio Professional Edition	2013	
MixerCertification	7_04	

1.1 RF Input – VSWR

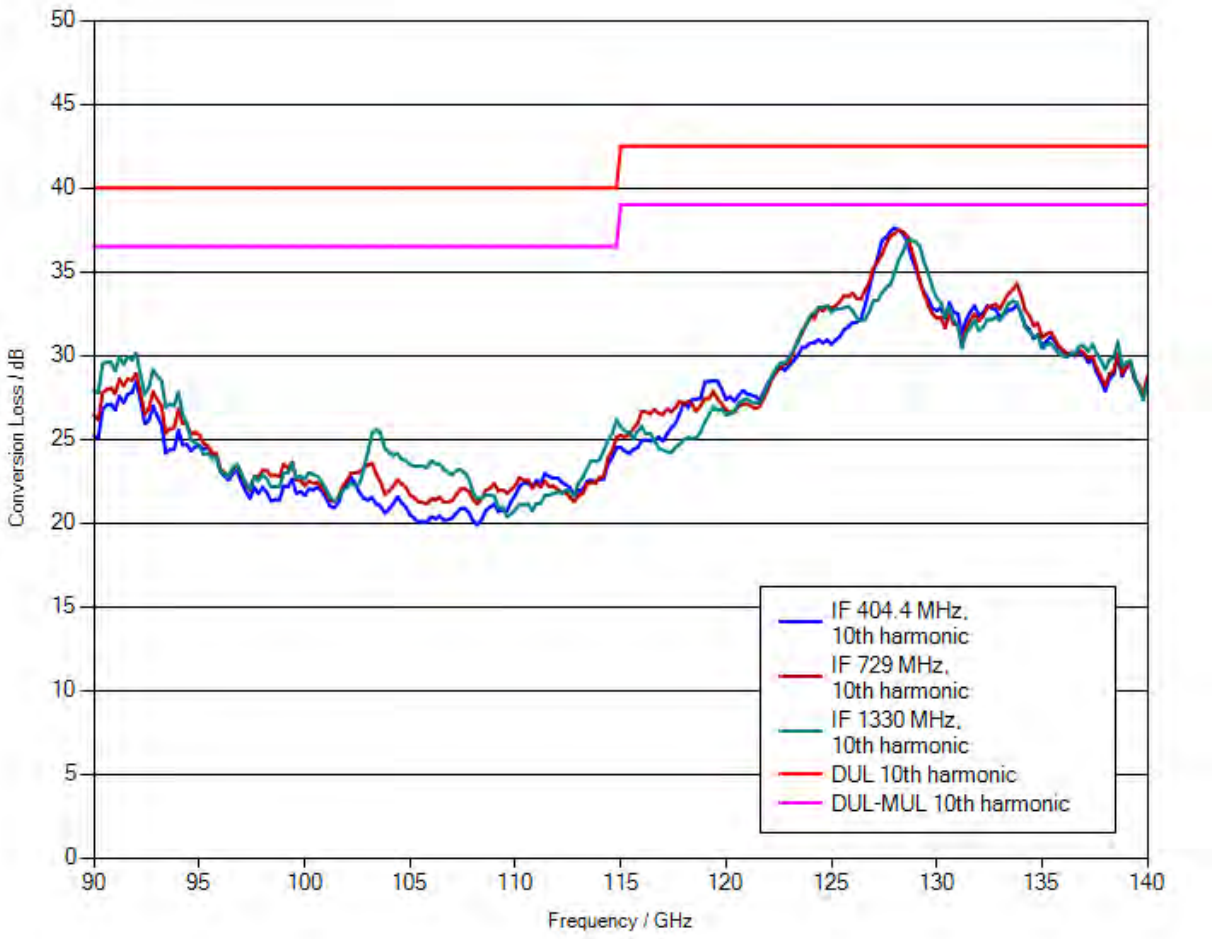
Measurement uncertainty: 0.05 (VSWR)



1.2 Conversion loss

LO level +14 dBm nominal
Bias 0 A

Measurement uncertainty: 3.5 dB



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1.3 Frequency response within 1 GHz

	DUL	Actual (worst case)	Evaluation
IF = 404.4 MHz, 10th harmonic	6 dB	3.86 dB	PASS
IF = 729 MHz, 10th harmonic	6 dB	3.48 dB	PASS
IF = 1330 MHz, 10th harmonic	6 dB	3.19 dB	PASS

Radiometer Physics
A Rohde & Schwarz Company

Calibration Certificate
Kalibrierschein

Certificate Number 24-0220-100960-01
Zertifikatsnummer

Unit Data

Item
Gegenstand
Harmonic Mixer, 140 GHz to 220 GHz

Manufacturer
Hersteller
RPG

Type
Typ
RPG FS-Z220

Material Number
Materialnummer
3593.3250.02

Serial Number
Seriennummer
100960

Asset Number
Inventarnummer

Order Data

Customer
Auftraggeber

Order Number
Bestellnummer

Date of Receipt
Eingangsdatum

Performance

Place and Date of Calibration
Ort und Datum der Kalibrierung
Meckenheim, 2018-01-17

Scope of Calibration
Umfang der Kalibrierung
Standard Calibration

Statement of Compliance (Incoming)
Konformitätsaussage (Anlieferung)
New device

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Radiometer Physics GmbH; Meckenheim

Date of Issue
Ausstellungsdatum
2018-01-19

Head of Laboratory
Laborleitung
Ceru

Person Responsible
Bearbeiter
Dick

Radiometer Physics GmbH ● Werner-von-Siemens-Str. 4 ● 53340 Meckenheim ● Telephone national: 02225/99981-0 international: 0049 2225-99981-0
Fax: 02225/99981-99 ● Managing Director: Achim Walber, Dr. Thomas Rose ● Company's Place of Business: Meckenheim
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Calibration Method
Kalibrieranweisung

RPG-PAQA-TN-2014-002

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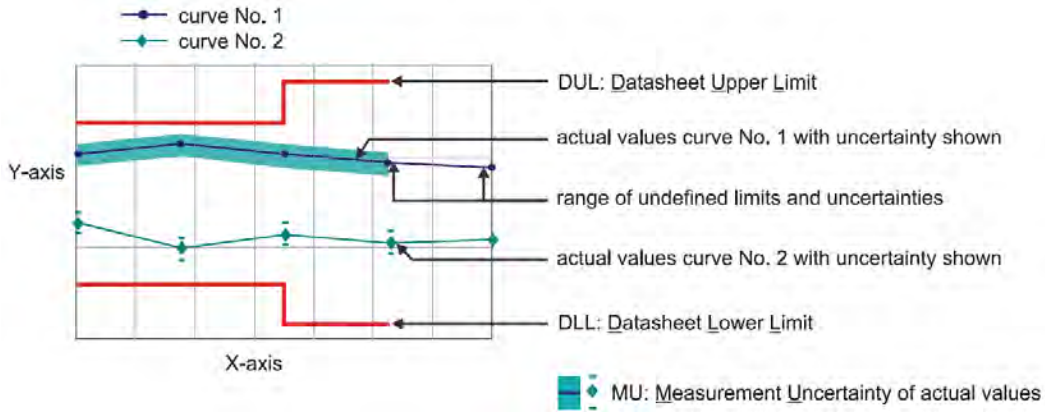

Software used for measurement

Item Type	Version	Remark
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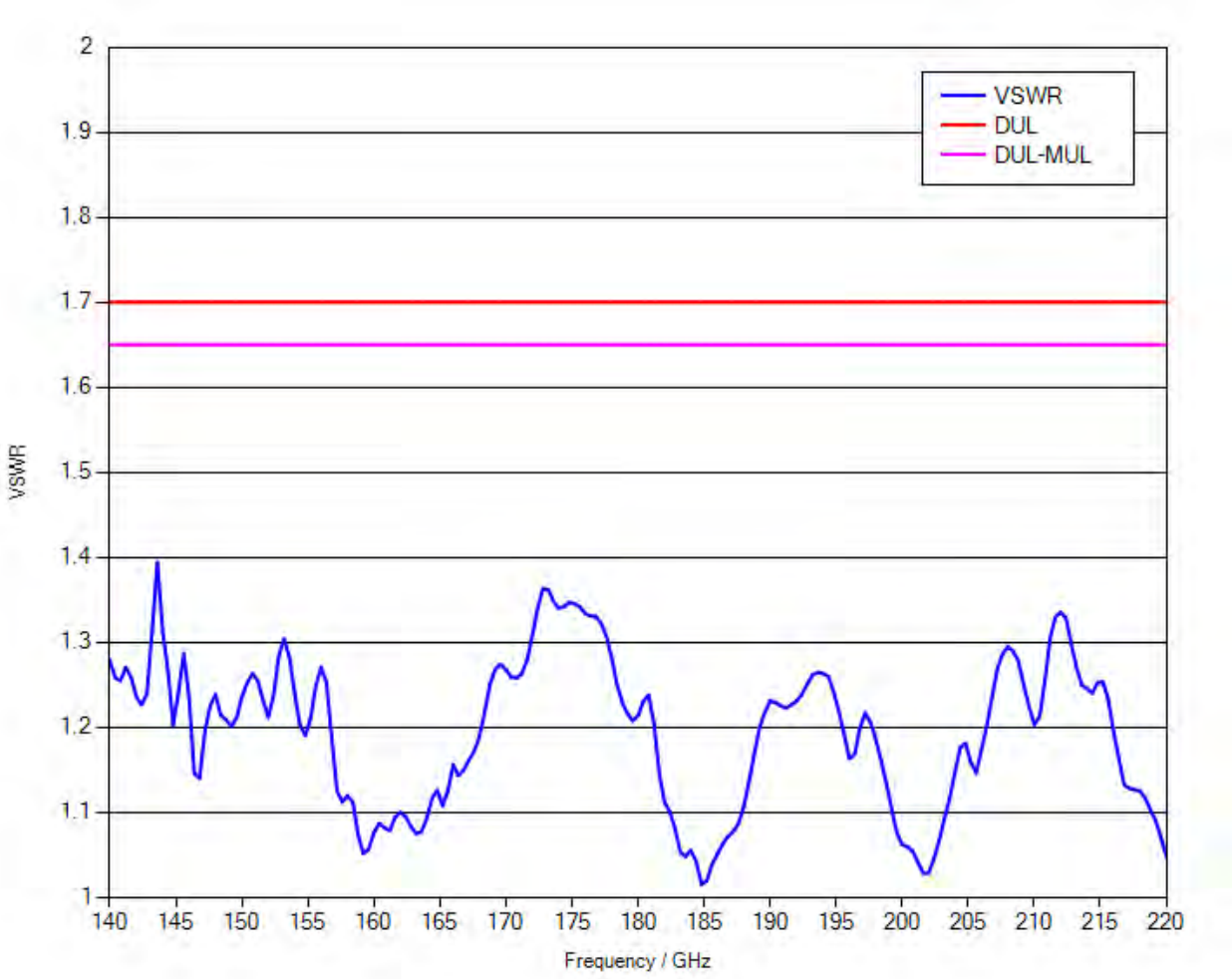
MixerCertification	7_08	

1.1 RF Input – VSWR

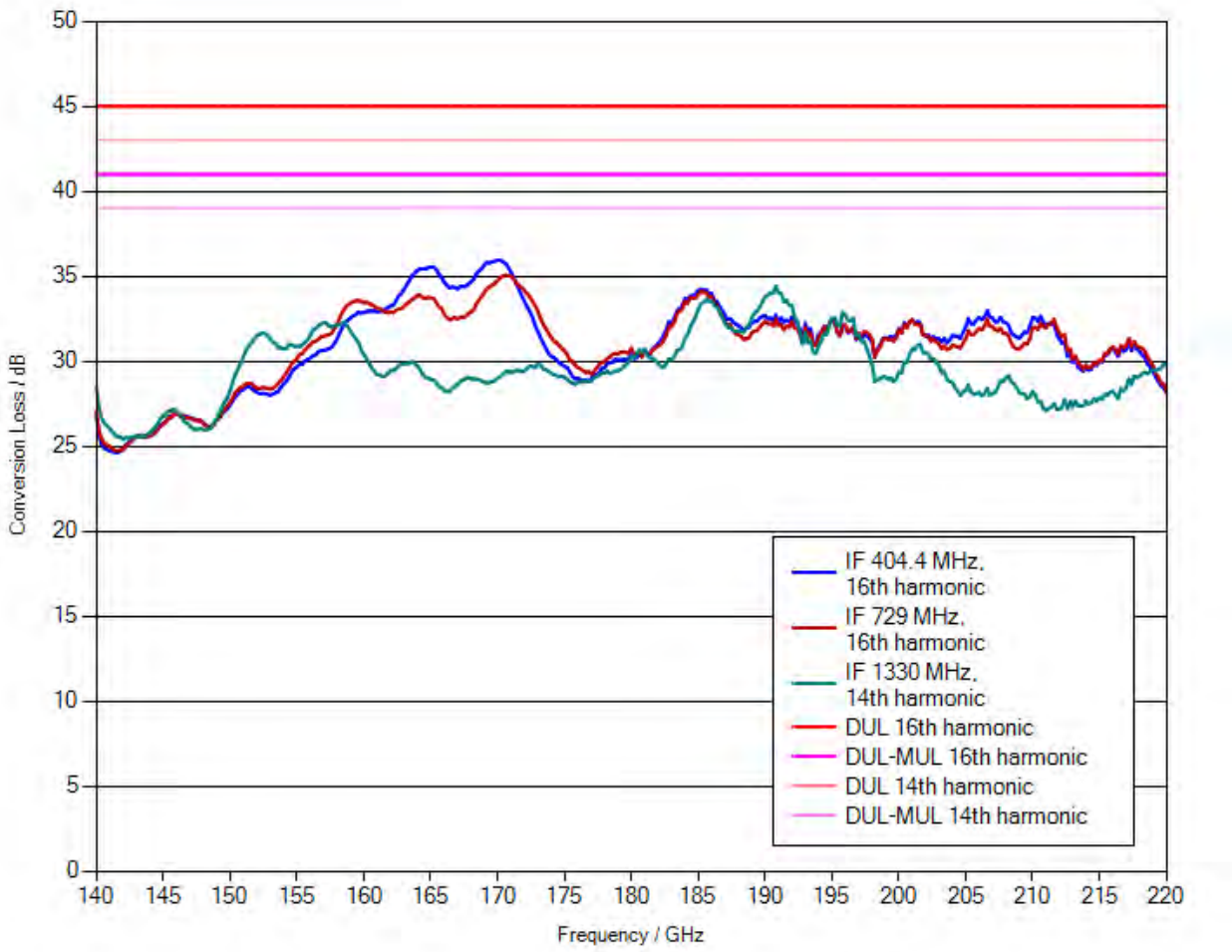
Measurement uncertainty: 0.05 (VSWR)



1.2 Conversion loss

LO level +13 dBm nominal
Bias 0 A

Measurement uncertainty: 4 dB



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1.3 Frequency response within 1 GHz

	DUL	Actual (worst case)	Evaluation
IF = 404.4 MHz, 16th harmonic	6 dB	2.1 dB	PASS
IF = 729 MHz, 16th harmonic	6 dB	2.05 dB	PASS
IF = 1330 MHz, 14th harmonic	6 dB	2.48 dB	PASS