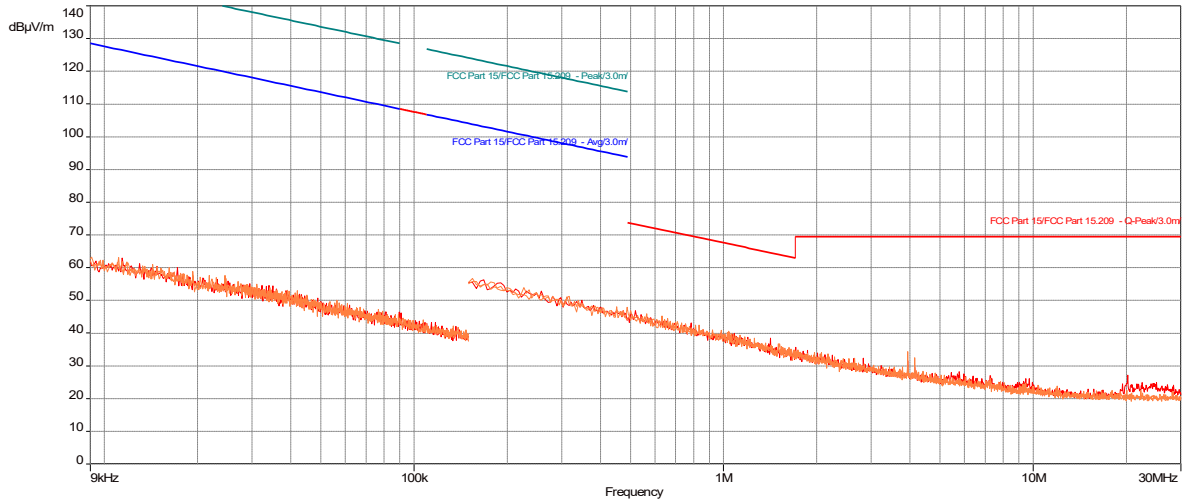
9.5 Plots/Data:

Powered from 120VAC 60Hz, 9kHz-30 MHz

Test Information:

Date and Time	6/26/2023 9:30:32 PM
Client and Project Number	Liberty Defense_G105270120
Engineer	Randi Torres
Temperature	23C
Humidity	52%
Atmospheric Pressure	1001mbars
Comments	Scan16_RE 9kHz-30MHz Loop antenna, Electric Field, 3M Location (FCC 15.209)

Graph:



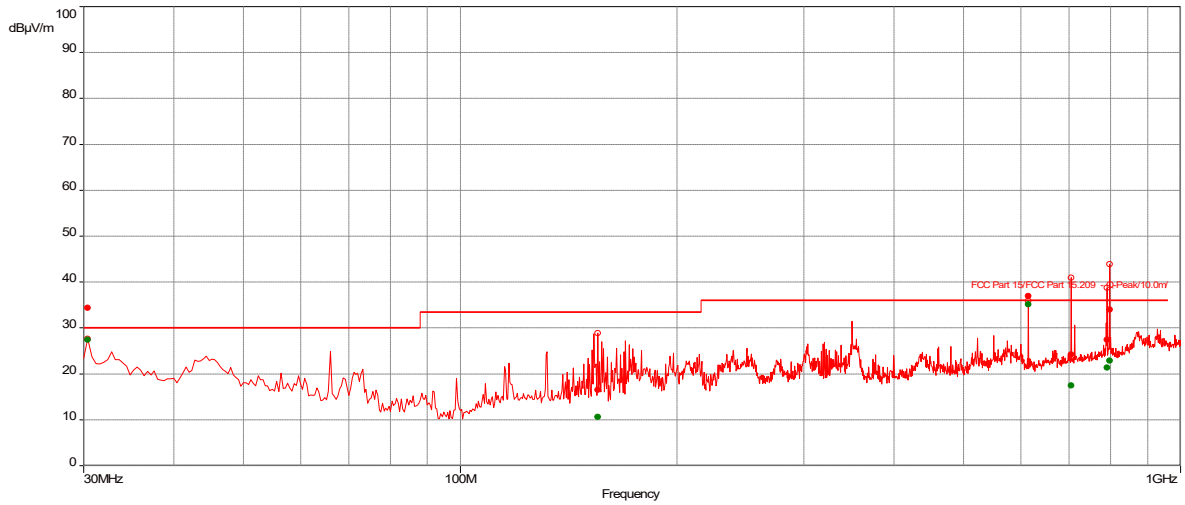
Results: No emissions were detected.

Powered from 120VAC 60Hz, 30 – 1000 MHz

Test Information:

Date and Time	6/26/2023 11:31:15 AM
Client and Project Number	Liberty Defense_G105270120
Engineer	Randi Torres
Temperature	23C
Humidity	52%
Atmospheric Pressure	1001mbars
Comments	Scan4_RE 30-1000MHz SA mode

Graph:



Results:

QuasiPeak (PASS) (6)

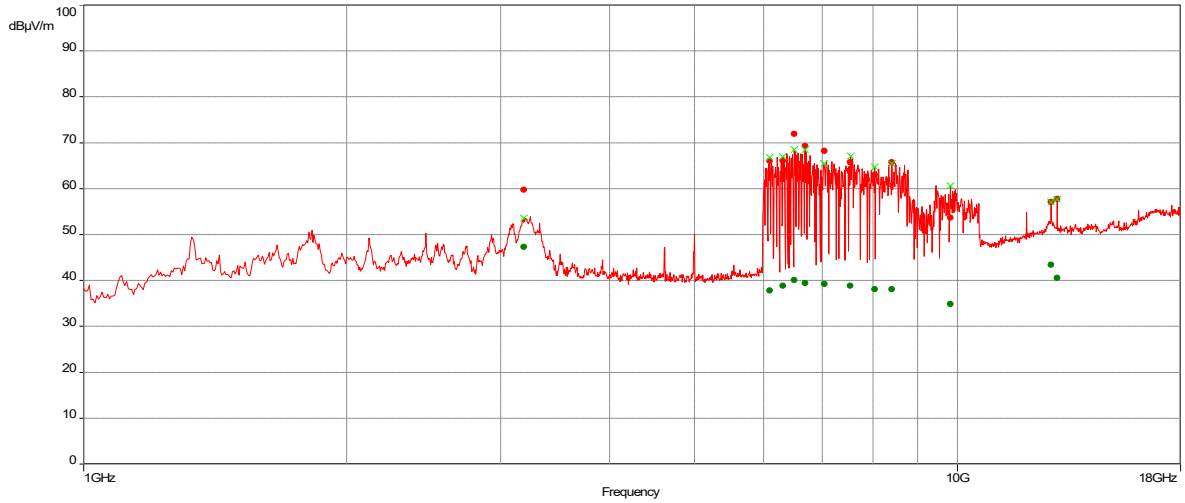
Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Azimuth (°)	Height (m)	Pol.	RBW	Correction (dB)
30.34736842	27.47	30.00	-2.53	257.00	1.57	Vertical	120k	-12.75
155.2	10.65	33.50	-22.85	316.00	2.00	Vertical	120k	-19.98
614.4	35.21	36.00	-0.79	227.00	1.00	Horizontal	120k	-11.49
704.7368421	17.48	36.00	-18.52	247.00	1.76	Vertical	120k	-9.50
790.3052632	21.37	36.00	-14.63	133.00	3.13	Horizontal	120k	-7.97
796.9894737	22.91	36.00	-13.09	341.00	2.76	Vertical	120k	-7.71

Powered from 120VAC 60Hz, 1-18 GHz

Test Information:

Date and Time	7/13/2023 3:05:05 PM
Client and Project Number	Liberty Defense
Engineer	Kouma Sin
Temperature	26 C
Humidity	39 %
Atmospheric Pressure	1002 mbar
Comments	Scan 3: 2nd Modification, RE 1 to 18 GHz SA mode

Graph:



Results:

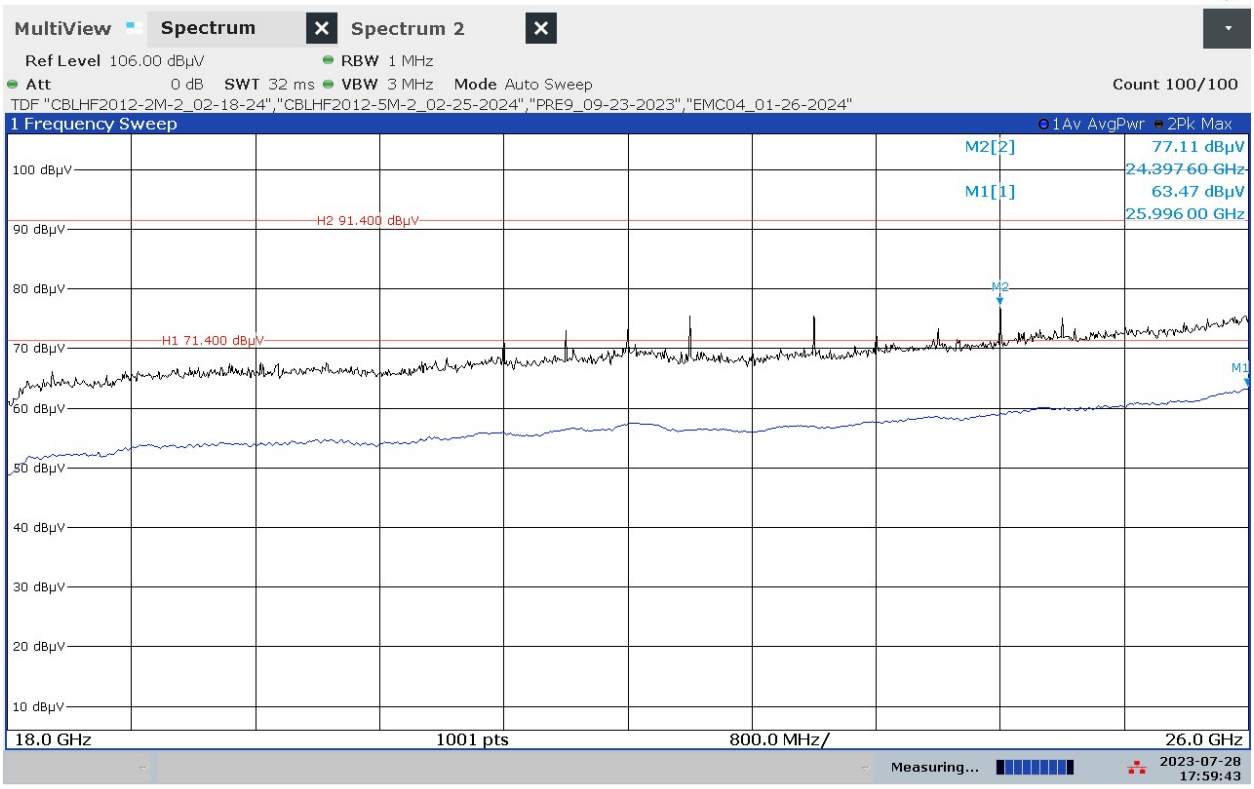
Average (12)

Frequency (MHz)	Field Strength Level (dBµV/m)	EIRP Level (dBm)	EIRP Limit (dBm)	Margin (dB)	Azimuth (°)	Height (m)	Pol.	RBW	Correction (dB)
3188.947368	47.38	-47.82	-41.3	-6.52	240.00	1.78	Horizontal	1M	5.70
6101.315789	37.85	-57.35	-41.3	-16.05	45.00	1.38	Horizontal	1M	2.24
6308.157895	38.93	-56.27	-41.3	-14.97	324.00	1.14	Horizontal	1M	2.89
6499.473684	40.09	-55.11	-41.3	-13.81	10.00	1.74	Horizontal	1M	3.10
6689.736842	39.41	-55.79	-41.3	-14.49	340.00	1.38	Horizontal	1M	3.11
7038.684211	39.31	-55.89	-41.3	-14.59	22.00	1.21	Horizontal	1M	3.37
7540.263158	38.91	-56.29	-41.3	-14.99	8.00	3.02	Horizontal	1M	3.92
8037.894737	38.15	-57.05	-41.3	-15.75	8.00	2.25	Vertical	1M	4.90
8415.789474	38.13	-57.07	-41.3	-15.77	351.00	1.27	Horizontal	1M	5.91
9812.105263	34.92	-60.28	-41.3	-18.98	86.00	1.41	Horizontal	1M	5.83
12799.21053	43.45	-51.75	-51.3	-0.45	240.00	3.22	Horizontal	1M	13.81
13000.78947	40.56	-54.64	-51.3	-3.34	135.00	1.07	Horizontal	1M	13.27

Notes:

EIRP Level (dBm) = Field Strength Level (dBuV/m) + 20*log(d) - 104.7
EIRP Level (dBm) = Field Strength Level (dBuV/m) – 95.2, at 3 meters
EIRP Limit per FCC Part 15 Subpart F Section 15.511(c)

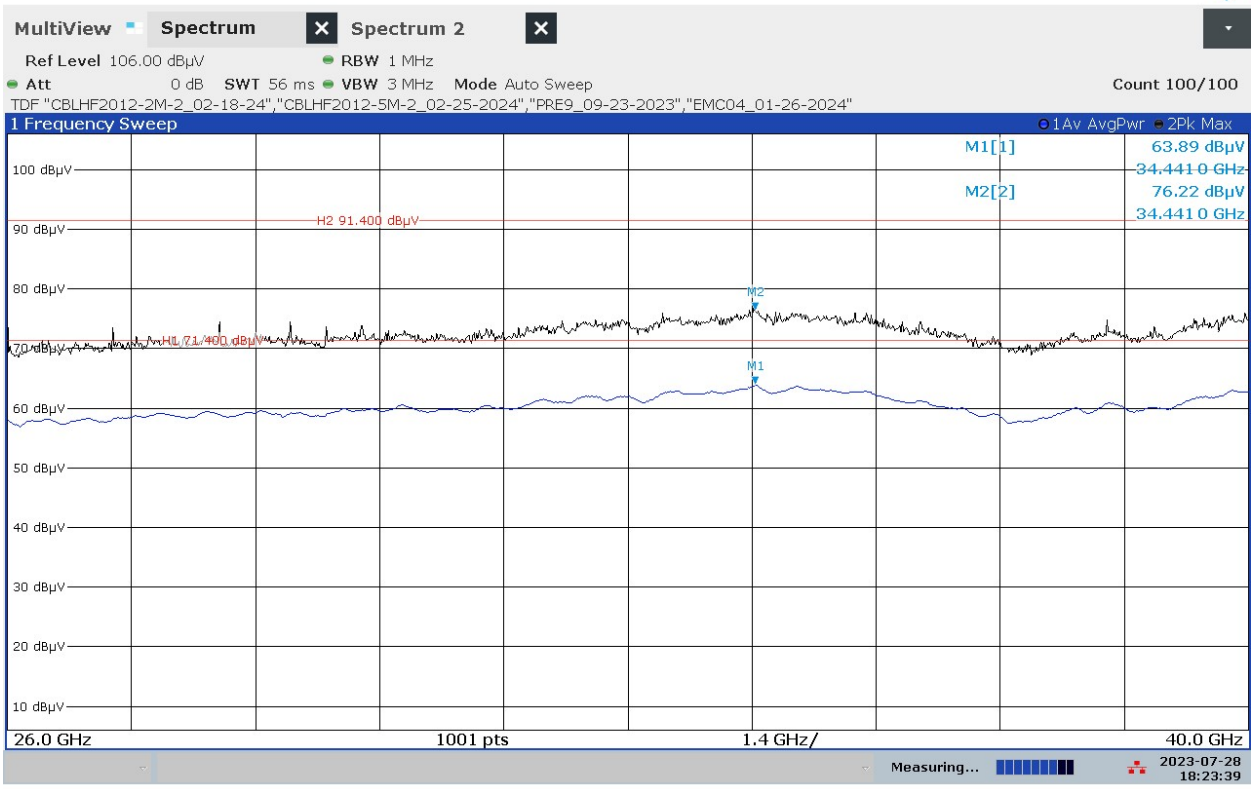
Powered from 120VAC 60Hz, 18-26 GHz



05:59:43 PM 07/28/2023

Note: The antenna factor, cable loss, and pre-amp gain were internally compensated as TDF. Testing was performed with antenna located at 10 cm from the EUT.

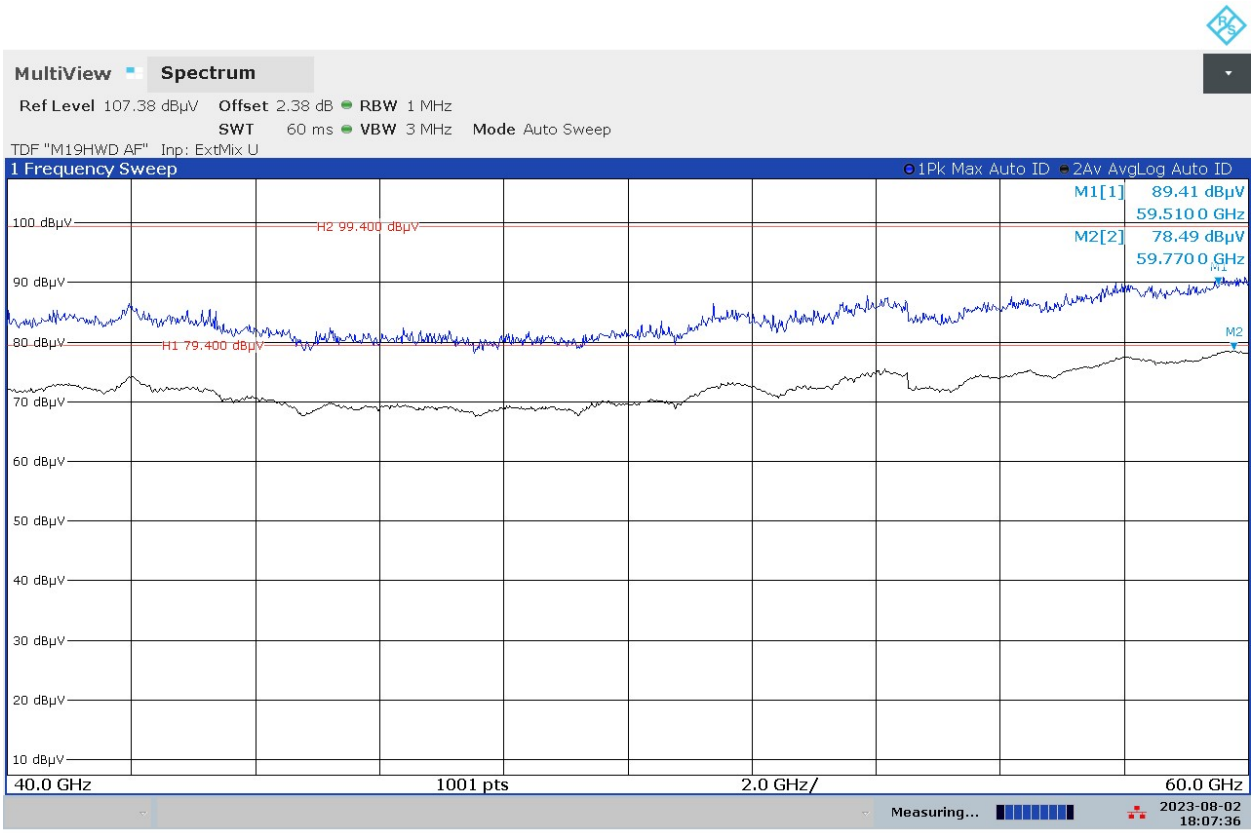
Powered from 120VAC 60Hz, 26-40 GHz



06:23:39 PM 07/28/2023

Note: The antenna factor, cable loss, and pre-amp gain were internally compensated as TDF. Testing was performed with antenna located at 10 cm from the EUT.

Powered from 120VAC 60Hz, 40-60 GHz



06:07:36 PM 08/02/2023

Note: Antenna factor and cable loss were internally compensated as TDF and dB-ffset. Testing was performed with antenna located at 5 cm from EUT. No emissions were detected above the measuring equipment noise floor.

Sample calculation:

Example:

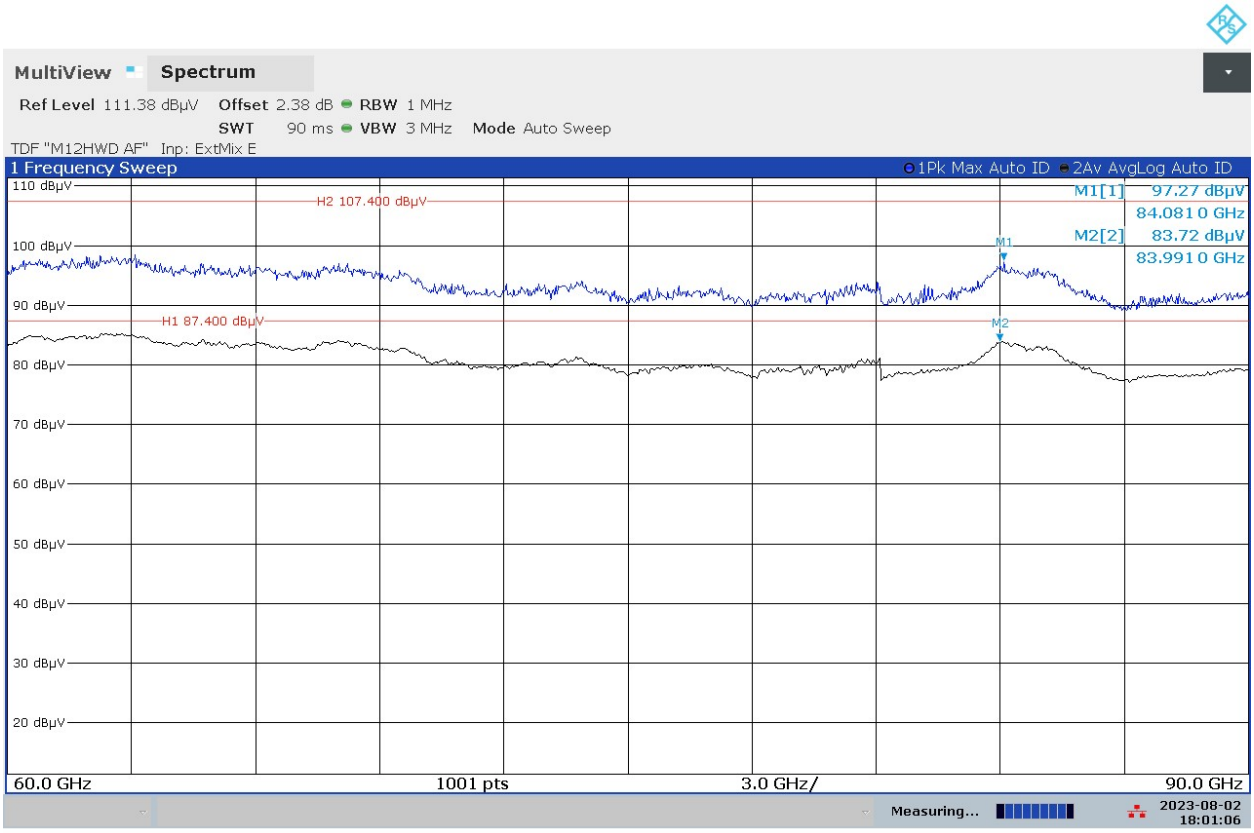
FS = RA + AF + CF + CL

Where FS = Field Strength in dBµV/m
RA = Receiver Amplitude (including preamplifier) in dBµV
CF = Cable Attenuation Factor in dB
AF = Antenna Factor in dB/m
L.O = (RF+IF)/4
RF = 59.51 GHz
IF = 1.33 GHz
Cable Factor (CF) = 2.2 dB
Conversion Loss (CL) = 29.68 dB, internally compensated

RA = 15.84 dB(uV/m)
AF = 41.69 dB/m

FS = 15.84 + 41.69 + 2.2 + 29.68 = 89.41 dB(uV/m)

Powered from 120VAC 60Hz, 60-90 GHz



06:01:06 PM 08/02/2023

Note: Antenna factor and cable loss were internally compensated as TDF and dB-ffset. Testing was performed with antenna located at 2 cm from EUT. No emissions were detected above the measuring equipment noise floor.

Sample calculation:

Example:

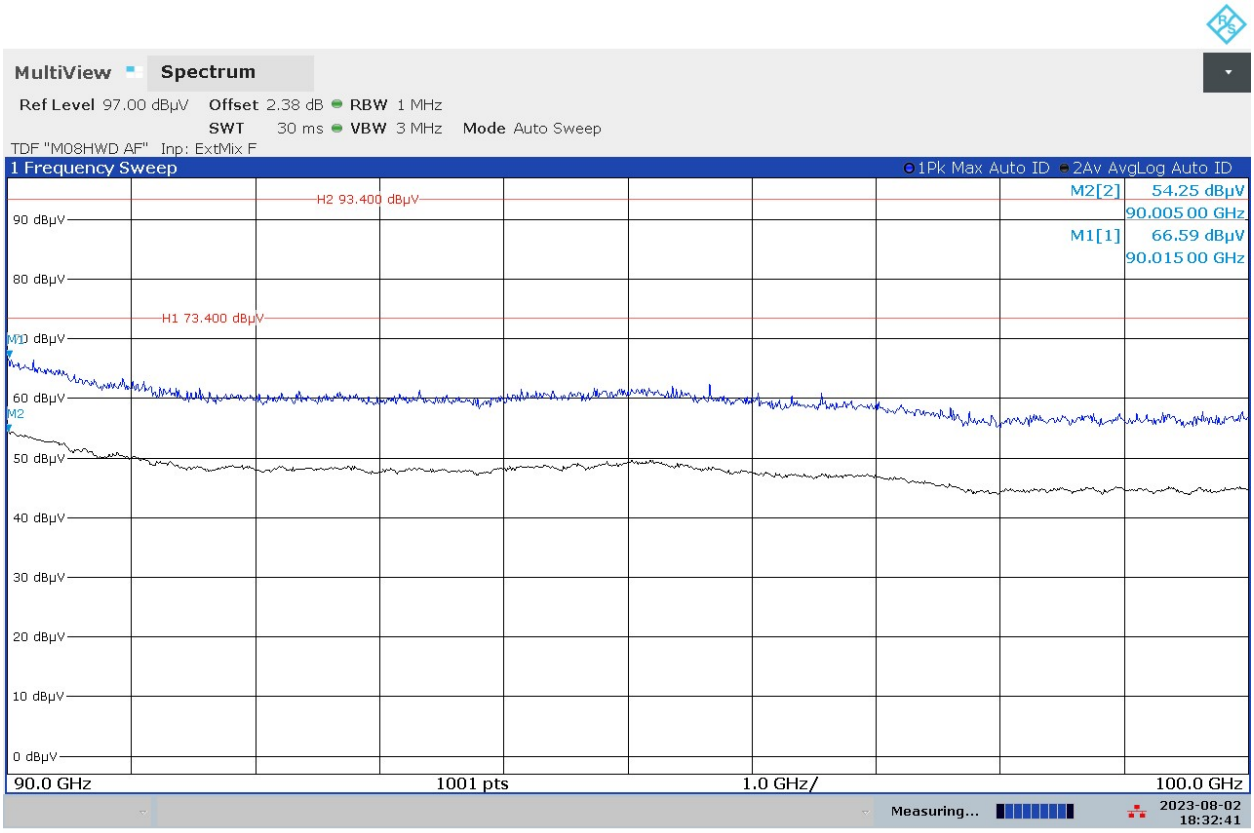
FS = RA + AF + CF + CL

Where FS = Field Strength in dBµV/m
RA = Receiver Amplitude (including preamplifier) in dBµV
CF = Cable Attenuation Factor in dB
AF = Antenna Factor in dB/m
L.O = (RF+IF)/6
RF = 84.08 GHz
IF = 1.33 GHz
Cable Factor (CF) = 2.2 dB
Conversion Loss (CL) = 31.7 dB, internally compensated

RA = 18.8 dB(uV/m)
AF = 44.57 dB/m

FS = 18.8 + 44.57 + 2.2 + 31.7 = 97.27 dB(uV/m)

Powered from 120VAC 60Hz, 90-100 GHz



06:32:42 PM 08/02/2023

Note: Antenna factor and cable loss were internally compensated as TDF and dB-ffset. Testing was performed with antenna located at 10 cm from EUT. No emissions were detected above the measuring equipment noise floor.

Sample calculation:

Example:

FS = RA + AF + CF + CL

Where FS = Field Strength in dBµV/m
RA = Receiver Amplitude (including preamplifier) in dBµV
CF = Cable Attenuation Factor in dB
AF = Antenna Factor in dB/m
L.O = (RF+IF)/10
RF = 90.005 GHz
IF = 1.33 GHz
Cable Factor (CF) = 2.2 dB
Conversion Loss (CL) = 42.01 dB, internally compensated

RA = -22.69 dB(uV/m)
AF = 45.07 dB/m

FS = -22.69 + 45.07 + 2.2 + 42.01 = 66.59 dB(uV/m)

	Product Standard: FCC Part 15, Subpart F, RSS-220 §15.511 and FCC Waver DA-22-133A1-c3			Limit applied: per §15.511, RSS-220 and FCC Waver DA-22-133A1-c3 Pretest Verification w/BB source: Yes			
Test Date	Test Personnel/ Initials	Supervising Engineer/ Initials	Input Voltage	Mode	Atmospheric Data		
					Temp C°	Relative Humidity %	Atmospheric Pressure mbar
06/26/2023	Vathana Ven	N/A	120VAC 60Hz	Continuous sweep	23	52	1001
06/26/2023	Randi Torres RT	N/A	120VAC 60Hz	Continuous sweep	23	52	1001
07/13/2023	Kouma Sinn	N/A	120VAC 60Hz	Continuous sweep	26	39	1002
07/28/2023	Vathana Ven	N/A	120VAC 60Hz	Continuous sweep	25	35	1007
08/02/2023	Vathana Ven	N/A	120VAC 60Hz	Continuous sweep	25	35	1007

Deviations, Additions, or Exclusions: None

10 AC Mains Conducted Emissions

10.1 Method

Tests are performed in accordance with ANSI C63.4.

TEST SITE: EMC Lab

The EMC Lab has one Semi-anechoic Chamber and one Shielded Chamber. AC Mains Power is available at 120, 230, and 277 Single Phase; 208, 400, and 480 3-Phase. Large reference ground-planes are installed in the general lab area to facilitate EMC work not requiring a shielded environment.

Measurement Uncertainty

Measurement	Frequency Range	Expanded Uncertainty (k=2)	Ucispr
AC Line Conducted Emissions	150 kHz - 30 MHz	1.2 dB	3.4 dB
Telco Port Emissions	150 kHz - 30 MHz	2.8 dB	5.0 dB

As shown in the table above our conducted emissions U_{lab} is less than the corresponding U_{CISPR} reference value in CISPR 16-4-2 Table 1, hence the compliance of the product is only based on the measured value, and no measurement uncertainty correction is required, based on CISPR 22 and CISPR 11 (for 2006 and later revisions) Clause 11.

Sample Calculations

The following is how net line-conducted readings were determined:

NF = RF + LF + CF + AF
Where NF = Net Reading in dBμV
RF = Reading from receiver in dBμV
LF = LISN or ISN Correction Factor in dB
CF = Cable Correction Factor in dB

AF = Attenuator Loss Factor in dB

To convert from dBμV to μV or mV the following was used:

$UF = 10^{(NF / 20)}$ where UF = Net Reading in μV
NF = Net Reading in dBμV

Example:
NF = RF + LF + CF + AF = 28.5 + 0.2 + 0.4 + 20.0 = 49.1 dBμV
$UF = 10^{(49.1\ dB\mu V / 20)}$ = 285.1 μV/m

Alternately, when BAT-EMC Emission Software is used, the “Level” includes all losses and gains and is compared directly in the “Margin” column to the “Limit”. The “Correction” includes Antenna Factor, Preamp, and Cable Loss. These are already accounted for in the “Level” column.

10.2 Test Equipment Used:

Asset	Description	Manufacturer	Model	Serial	Cal Date	Cal Due
NAR006'	EMI CISPR Receiver	NARDA	PMM 9010	696WW30303	03/08/2023	03/08/2024
DAV005'	Weather Station	Davis	6250	MS191218083	02/21/2023	02/21/2024
WEI23'	Attenuator 20dB 2 watt	Weinschel	WA18-20	1001015N0010001	08/25/2022	08/25/2023
CBL041'	3ft BNC to BNC Cable	Hoswell	Coax RG-58	CBL041	01/26/2023	01/26/2024
147324'	Signal Generator 9kHz-2GHz	Hewlett Packard	8648B	3642U00875	02/17/2023	02/17/2024
FCC9'	Coupling, Decoupling Network	Fischer Custom Commu	FCC-801-AF2	71	09/02/2022	09/02/2023
LISN30'	LISN - CISPR16 Compliant 9kHz-30MHz	Com-Power	LI-215A	191961	09/27/2022	09/27/2023

Software Utilized:

Name	Manufacturer	Version
BAT-EMC	Nexio	2022.0.27.0

10.3 Results:

The sample tested was found to Comply.

10.4 Setup Photographs:

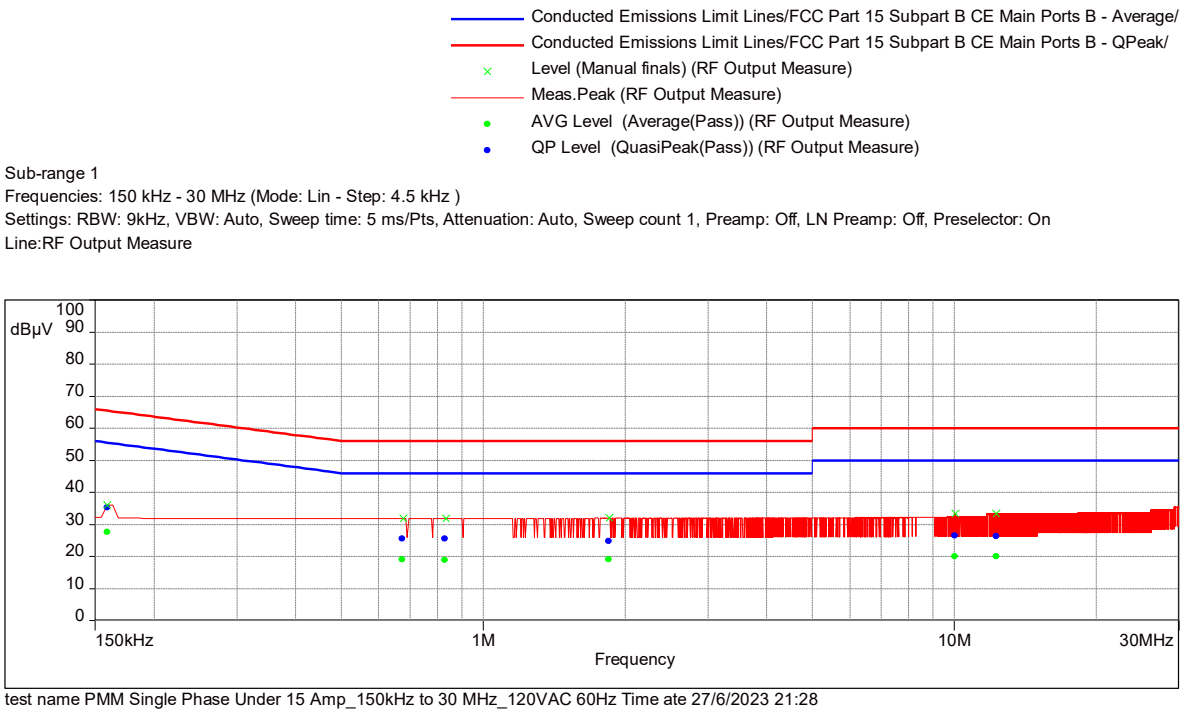
10.5 Plots/Data:

EUT Powered From 120VAC 60Hz, FCC Part 15.207(a)

Test Information:

Date and Time	6/27/2023 9:15:34 PM
Client and Project Number	Liberty Defense_G105270120
Engineer	Vathana Ven
Temperature	23 Deg C
Humidity	43 %
Atmospheric Pressure	1010 mbar
Comments	PMM Single Phase Under 15 Amp_150kHz to 30 MHz_120VAC 60Hz

Graph:



test name PMM Single Phase Under 15 Amp_150kHz to 30 MHz_120VAC 60Hz Time ate 27/6/2023 21:28

Results:

QuasiPeak(Pass) (6)

Frequency (MHz)	QP Level (dBµV)	QP Limit (dBuV)	QP Margin (dB)	Position	RBW (Hz)	Correction (dB)
0.1606	35.20	65.52	-30.32	Neutral	9000.00	20.10
0.6715001	25.58	56.00	-30.42	Neutral	9000.00	19.84
0.8292002	25.49	56.00	-30.51	Neutral	9000.00	19.86
1.8462	24.85	56.00	-31.15	Neutral	9000.00	19.93
10.0405	26.55	60.00	-33.45	Neutral	9000.00	20.32
12.2729	26.32	60.00	-33.68	Neutral	9000.00	20.35

Average(Pass) (6)

Frequency (MHz)	AVG Level (dBµV)	AVG Limit (dBuV)	AVG Margin (dB)	Position	RBW (Hz)	Correction (dB)
0.1606	27.69	55.52	-27.83	Neutral	9000.00	20.10
0.6715001	19.05	46.00	-26.95	Neutral	9000.00	19.84
0.8292002	18.96	46.00	-27.04	Neutral	9000.00	19.86
1.8462	19.16	46.00	-26.84	Neutral	9000.00	19.93
10.0405	20.07	50.00	-29.93	Neutral	9000.00	20.32
12.2729	20.10	50.00	-29.90	Neutral	9000.00	20.35

	Product Standard: FCC Part 15, Subpart B, FCC 15.207(a), RSS-GEN			Limit applied: Class B Pretest Verification w/BB source: Yes			
Test Date	Test Personnel/ Initials	Supervising Engineer/ Initials	Input Voltage	Mode	Atmospheric Data		
					Temp C°	Relative Humidity %	Atmospheric Pressure mbar
06/27/2023	Vathana Ven	N/A	120VAC 60Hz	Continuous sweep	23	43	1010

Deviations, Additions, or Exclusions: None

11 Appendix A - FCC Waver DA-22-133A1-c3

Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Liberty Defense Holdings, Ltd.	)	ET Docket No. 19-217
d/b/a Liberty Defense Technologies	)	
	)	
Request for Waiver of Sections 15.31(c), 15.503(d),	)	
15.511(b), 15.511(f) and 15.521(d) of the	)	
Commission's Rules	)	

ORDER

Adopted: February 9, 2022 **Released: February 9, 2022**

By the Acting Chief, Office of Engineering and Technology:

I. INTRODUCTION

1. By this Order, we grant a request by Liberty Defense Holdings, Ltd. d/b/a Liberty Defense Technologies (Liberty), for a waiver of our rules governing unlicensed ultra-wideband (UWB) devices to permit the certification and marketing of its threat detection imaging system. We find that opening a path for the sale and operation of this equipment will allow this system to be deployed to protect Americans against threats in public venues and other high-traffic areas, in furtherance of the public interest, and that operation of this device under the specified waiver conditions poses no greater risk of causing harmful interference to communication services than those devices already permitted under the existing rules.

II. BACKGROUND

2. On May 8, 2019, Liberty filed a request for waiver of the Commission's Part 15 rules to allow the marketing and operation of its surveillance system known as the HEXWAVE.[1] Liberty states that the system uses active three-dimensional imaging to detect weapons, explosives, and other threats using UWB technology, and that the HEXWAVE will enable law enforcement and security professionals to engage a target before a situation can escalate into an attack.[2]

3. The HEXWAVE is a UWB device that is designed to operate in the 6-10.6 GHz band by sweeping through its frequency range in 200-megahertz blocks. UWB devices are low-power radio frequency devices that operate under Part 15 Subpart F of the Commission's rules without individual licenses from the Commission.[3] UWB transmitters use narrow or short duration pulses that result in transmissions over very large bandwidths. Surveillance systems such as the HEXWAVE are a particular

[1] Liberty Defense Holdings, Ltd. Request for Waiver, ET Docket No. 19-217 (filed May 8, 2019) (Liberty Waiver Request).

[2] *Id.* at 5.

[3] 47 CFR §§ 15.501-15.525.

type of UWB imaging device that are designed to operate as "security fences" by establishing a stationary RF perimeter field and detecting the intrusion by persons or objects in that field.[4]

4. Liberty seeks waiver of the following sections of the Commission's rules: Section 15.503(d), which requires that a UWB transmitter at any point in time have a fractional bandwidth equal to or greater than 0.20 or a UWB bandwidth equal to or greater than 500 megahertz, regardless of the fractional bandwidth; Section 15.31(c), which requires measurements to be made with the frequency sweep stopped; and Section 15.521(d), requires that that if pulse gating is employed where the transmitter is quiescent for intervals that are long compared to the nominal pulse repetition interval, measurements shall be made with the pulse train gated on.[5] Liberty also seeks a waiver of Section 15.511's use limitations to allow for the use of HEXWAVE devices by private security personnel.[6] The three paragraphs of Section 15.511 subject to Liberty's waiver request relate to eligibility requirements for the operation of such surveillance systems to law enforcement, fire or emergency rescue organizations, or by manufacturers licensees, petroleum licensees or power licensees; require that operation must be coordinated with the Federal government; and specify that surveillance systems must bear the statement that: "Operation of this device is restricted to law enforcement, fire and rescue officials, public utilities, and industrial entities."[7]

5. The Office of Engineering and Technology (OET) sought comment on Liberty's waiver request.[8] While no party filed comments specifically addressing technical concerns regarding the waiver request, Liberty's request was cited in a letter that Cisco Systems, Inc. and Hewlett Packard Enterprise Company filed in multiple proceedings asking that the Commission evaluate the UWB rules as part of a comprehensive proceeding.[9]

III. DISCUSSION

6. We are authorized to grant a waiver under Section 1.3 of the Commission's rules if the petitioner demonstrates good cause for such action.[10] Good cause, in turn, may be found "where

[4] *See Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*, ET Docket No. 98-153, Order, 17 FCC Rcd 13522 (2002).

[5] 47 CFR §§ 15.503(d), 15.31(c), and 15.521(d), respectively.

[6] *See* Letter from Aman Bhardwaj, President, Liberty Defense Holdings to Marlene H. Dortch, Secretary, Federal Communications Commission, ET Docket No. 19-217 (filed Oct. 2, 2019) (defining "private security personnel" to mean individuals and organizations (other than public law enforcement personnel and agencies) that primarily are engaged in the detection of crime and threats to people and property at sites at which people aggregate, including providers of (i) proprietary or contractual guard and screening services, (ii) electronic security systems integration and management services, and (iii) security consulting services).

[7] 47 CFR § 15.511(b) introductory text, (b)(2), and (f). The specific Federal Government coordination procedures, detailed in Section 15.525, require users to disclose operational areas and other information to the Commission's Office of Engineering and Technology, which coordinates with the Federal government through the National Telecommunications and Information Administration (NTIA).

[8] *Office of Engineering and Technology Seeks Comment on Liberty Defense Holdings, LTD. Request for Waiver of Certain Part 15 Ultra-Wideband (UWB) Rules*, Public Notice, DA 19-706 (OET 2019); *Office of Engineering and Technology Extends Comment Cycle Deadlines on Liberty Defense Holdings, LTD. Request for Waiver of Certain Part 15 Ultra-Wideband (UWB) Rules*, Public Notice, DA 19-217 (OET 2019).

[9] Letter from Mary L. Brown, Cisco, and Chuck Lukaszewski, Hewlett Packard, to Marlene H. Dortch, Secretary, Federal Communications Commission, in various dockets including ET Docket No. 19-217, (filed Nov. 13, 2019) (Cisco/HPE UWB Letter).

[10] 47 CFR § 1.3. *See also ICO Global Communications (Holdings) Limited v. FCC*, 428 F.3d 264 (D.C. Cir. 2005); *Northeast Cellular Telephone Co. v. FCC*, 897 F.2d 1164 (D.C. Cir. 1990); *WAIT Radio v. FCC*, 418 F.2d 1153 (D.C. Cir. 1969).

particular facts would make strict compliance inconsistent with the public interest."[11] To make this public interest determination, the waiver cannot undermine the purpose of the rule, and there must be a stronger public interest benefit in granting the waiver than in applying the rule.[12] The UWB standards in Part 15 were adopted to ensure that UWB devices, including surveillance devices, do not cause harmful interference to authorized radio services, including those operated by the Federal Government.[13] As discussed below, we find that, with appropriate operational and technical limitations, granting Liberty's request for waiver poses no greater risk of causing harmful interference to radio communications services than any other surveillance device operating under our rules. In addition, we find that there is a stronger public interest benefit in granting this waiver than in strictly applying the rules. HEXWAVE devices can provide protection and safety to the American public by passively detecting weapons and other threats in public venues. Thus, we find that the waiver standard has been met.

A. Waiver of the UWB definition in Section 15.503(d)

7. Section 15.503(d) of the Commission's rules defines a UWB transmitter as a device that "at any point in time" has an UWB bandwidth equal to or greater than 500 megahertz or a fractional bandwidth equal to or greater than 0.20.[14] Liberty describes the HEXWAVE as using a set of "chirplets."[15] It sweeps a continuous waveform signal through a 200-megahertz block of spectrum, followed by a 100 nanosecond quiet period. The device then sweeps through the next 200-megahertz block of spectrum. These chirplets are grouped together in sets of three, spanning a total of 600 megahertz.[16] Each of these individual transmissions is less than 500 megahertz in bandwidth "at any point in time" and Liberty's device does not have a 0.20 or greater fractional bandwidth. Thus, even though the device has a total bandwidth that exceeds 500 megahertz, it would not meet the definitional requirement for operation under the UWB rules because of the quiet period between each chirplet.[17]

8. The UWB imaging rules were designed to accommodate devices that emit impulsive or transient-like signals that are spread across a very wide bandwidth to produce an image of objects within the ground or other materials.[18] The primary difference between the Liberty device and other UWB surveillance systems devices provided for in the rules is that the HEXWAVE uses an array of closely spaced transmitting/receiving antennas that transmit sequentially over a large band of spectrum to gather all the needed data. This modulation scheme is functionally equivalent to other types of UWB imaging devices in that it uses transient-like signals spread across a wide bandwidth. The risk of interference is no

[11] *Northeast Cellular*, 897 F.2d at 1166; *see also ICO Global Communications*, 428 F.3d at 269 (quoting *Northeast Cellular*); *WAIT Radio*, 418 F.2d at 1157-59.

[12] *See, e.g.*, *WAIT Radio*, 418 F.2d at 1157 (stating that even though the overall objectives of a general rule have been adjudged to be in the public interest, it is possible that application of the rule to a specific case may not serve the public interest if an applicant's proposal does not undermine the public interest policy served by the rule); *Northeast Cellular*, 897 F.2d at 1166 (stating that in granting a waiver, an agency must explain why deviation from the general rule better serves the public interest than would strict adherence to the rule).

[13] *Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*, ET Docket No. 98-153, First Report and Order, 17 FCC Rcd 7435 (2002) (*UWB First R&O*); *see also*, 47 CFR §§ 15.501-15.525.

[14] 47 CFR §15.503(d).

[15] Liberty Waiver Request at 6.

[16] *Id.*

[17] Stepped and swept frequency devices like Liberty's have a difficult time meeting the rule's technical specifications because the large bandwidth is achieved by stepping or sweeping a narrow signal through the broader frequency range, and therefore won't be instantaneously wide enough to meet the rules' specific requirements.

[18] *See UWB First R&O*, 17 FCC Rcd at 7437-7440, 7450, 7476 and 7494.

greater than that from other such UWB surveillance systems, and so a waiver in this case will not undermine the intent of our rule.

B. Waiver of the measurement procedures in Sections 15.31(c) and 15.521(d)

9. Section 15.31(c) of the Commission's rules sets forth the measurement standards for unlicensed devices to demonstrate compliance with applicable emissions limits.[19] This rule requires swept frequency equipment measurements to be made with the frequency sweep stopped. Section 15.521(d) sets forth the measurement procedures for UWB devices to demonstrate compliance with applicable emissions limits.[20] For emissions above 960 MHz, this rule requires that, if pulse gating is used and the transmitter is quiescent for longer intervals than the nominal pulse repetition interval, measurements are made with the pulse train gated on. Liberty observes that, since this rule was adopted, the Commission has permitted other UWB transmitters operating above 960 MHz that use frequency stepping techniques to be measured using an average detector with the transmitter operating in its normal mode, *i.e.*, with the sweeping function active.[21] Liberty claims that the HEXWAVE will meet all other emission limits and technical requirements under the UWB rules when measured with the sweeping function active.[22]

10. We recognized in prior orders granting waivers of the measurement procedures for UWB transmitters, where emissions were permitted to be measured with the transmitter operating in its normal transmission mode, that the interference aspects of a transmitter employing frequency hopping, frequency stepping, or gating are quite similar, as viewed by a receiver.[23] That is because transmitters using these burst formats appear to the receiver to emit for a short period of time followed by a quiet period.[24] We concluded that "any requirement to stop the frequency hopping, band sequencing, or system gating serves only to add another unnecessary level of conservatism to already stringent UWB standards."[25] In conjunction with NTIA, we have further determined that allowing stepped frequency devices to be measured with the stepping function on would not increase the interference potential of the device above that of impulse UWB devices if all other emission limits and technical requirements are met.[26] Liberty's request represents an analogous situation. We find that permitting Liberty to demonstrate compliance with the UWB surveillance systems emission limits under a waiver of the measurement procedures in Sections 15.31(c) and 15.521(d) poses no greater risk of causing harmful interference to radio communications services than any other UWB imaging system operating under our rules, and therefore will not undermine the purpose of these rules.[27]

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[19] 47 CFR §15.31(c).

[20] 47 CFR §15.521(d).

[21] Liberty Waiver Request at 8-9 (citing waiver requests by the Multi-band OFDM Alliance Special Interest Group, Curtiss-Wright Controls, and Kyma Medical Technologies Ltd.).

[22] *Id.* at 15.

[23] *See, e.g., Petition for Waiver of the Part 15 UWB Regulations Filed by the Multi-band OFDM Alliance Special Interest Group*, ET Docket No. 04-352, Order, 20 FCC Rcd 5528 (2005) (MBOA-SIG Waiver Order).

[24] *Id.*, 20 FCC Rcd at 5535.

[25] *Id.*, 20 FCC Rcd at 5534.

[26] *See Curtiss-Wright Controls Inc. Request for Waiver of Part 15 of the Commission's Rules Applicable to Ultra-Wideband Devices*, ET Docket No. 10-167, Order, 27 FCC Rcd 234 at 242 (OET 2012) (CWCI Waiver Order). *See also* MBOA-SIG Waiver Order, 20 FCC Rcd at 5531-5536.

[27] Our reliance on the MBOA-SIG Waiver Order and the CWCI Waiver Order in this instance only relates to the measurement procedures in Section 15.521(d).

C. Waiver of the eligibility, operational, and disclosure requirements in Section 15.511

11. Section 15.511(b) includes eligibility requirements and coordination requirements with the Federal Government under section 15.525 applicable to UWB surveillance systems.[28] The eligibility requirements limit the use of fixed surveillance systems to applications associated with law enforcement, firefighting, emergency rescue, manufacturers licensees, petroleum licensees, or power licensees. This provision is intended to ensure that surveillance systems are used infrequently with a low proliferation rate to avoid causing harmful interference to authorized users.[29] Section 15.511(f) mandates that a surveillance system carry a statement that the operation of the system is restricted to law enforcement, fire and rescue, public utilities, and industrial entities.[30]

12. In its waiver request, Liberty argues that while the list of eligible users does not include private security professionals, reliance on such private security teams is an important component of efforts to protect vulnerable facilities and public gatherings nationwide.[31] A waiver of the eligibility requirements set forth in the introductory text of Section 15.511(b) would permit security professionals that do not qualify under the law enforcement provision to operate HEXWAVE devices. We find that Liberty has made a persuasive case that use under the requested waiver will be sufficiently limited so as not to undermine the purpose of the rule, and that grant of a waiver of this section would be consistent with our prior decisions. The HEXWAVE is intended for use by trained security professionals in limited locations. According to Liberty, HEXWAVE's price point will have the practical effect of limiting deployment to high priority events.[32] In addition, the use scenario – detection of concealed weapon detection – is exactly the type of targeted law enforcement use that would already be permissible under Section 15.511(b), but for the fact that the HEXWAVE operators may not themselves be law enforcement officers. Moreover, grant of a limited waiver in this instance is consistent with precedent, where we found that expanding eligibility requirements to permit a narrow and specific application was justified where such use would be infrequent and with a low proliferation rate.[33]

13. Therefore, for purposes of this waiver, we adopt a narrowly tailored definition of "private security personnel" suggested by Liberty in its waiver petition,[34] to mean individuals and organizations (other than public law enforcement personnel and agencies) that primarily are engaged in the detection of crime and threats to people and property at sites at which people aggregate, including providers of (i) proprietary or contractual guard and screening services, (ii) electronic security systems integration and management services, and (iii) security consulting services, which could include security staff who also hold private security licenses or adhere to federal, state, or local private security laws. This definition is designed to ensure that eligibility to use the HEXWAVE is not extended to members of the general public who are not otherwise involved in security-related activities.

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[28] 47 CFR §15.511(b) introductory text and (b)(2).

[29] *UWB First R&O*, 17 FCC Rcd at 7499-7504, paras. 185-201 (2002). Private security firms did not request to be included in the original list of permissible uses during the rulemaking and the Commission did not discuss private security firm users in its decision.

[30] 47 CFR §15.511(f).

[31] Liberty Waiver Request at 10.

[32] *Id.* at 10-11.

[33] *See Headsight, Inc. Request for waiver of Part 15 of the Commission's Rules Applicable to Ultra-Wide Band Devices*, ET Docket No. 16-44, Order, 32 FCC Rcd 1511 at 1514 (OET 2017) (allowing use of a UWB device mounted on farming machinery operated in fields that are located in rural or predominantly agricultural areas by parties eligible for licensing under the Part 90 rules).

[34] *See supra* note 6.

14. To further ensure that the purpose of the rule is not undermined, we will limit the number of devices that may be deployed under this waiver to 100 in the first year following the effective date of this Order, to an additional 200 in the second year, and to an additional 300 in the third year for a total of 600 devices at the end of the third year.[35] In the fourth year and all subsequent years, Liberty may deploy up to 300 additional devices per year. Our decision to limit the number of devices and to allow for their gradual deployment is a cautious approach, so that harmful interference issues can be identified and addressed in the extremely unlikely event that they were to occur. If no interference issues arise, starting in the fourth year the FCC, in coordination with NTIA, would consider a request by Liberty to increase the number of devices that may be deployed each year. Devices deployed under the terms of this waiver may continue to operate after the three-year deployment period ends, provided there is no harmful interference to authorized operations.[36] As an additional precautionary measure, Liberty has agreed to limit the parameters for the HEXWAVE system to those described in its *Ex Parte* presentation.[37] More specifically Liberty on its own motion has agreed to limit the total transmit time of the HEXWAVE system during a cycle to less than 54 milliseconds and each cycle will be repeated with a period of no less than 100 milliseconds. This will ensure that the total transmit time will be kept to a minimum.

15. We also find that a waiver of the Section 15.511(b)(2) coordination requirement, with appropriate conditions, is warranted. The HEXWAVE will be limited in number and only used in specialized settings (e.g., hotels, schools, and sporting venues). As noted in the *Kyma Medical Order*, the coordination process for UWB devices was primarily put into place to keep track of ground penetrating radars that would potentially be used for extended periods in outdoor locations.[38] Unlike the HEXWAVE, ground penetrating radars are prolific commercial devices that are widely deployed throughout the United States. In addition, Liberty has agreed to operational restrictions to protect certain Federal government operations. The 7.145-7.235 GHz and 8.4-8.5 GHz bands are allocated to the space research service and are used to receive low-power signals from space by NASA and radio astronomers. To protect these operations, Liberty has agreed that operations of HEXWAVE devices should be prohibited in certain locations and should require coordination with either NASA or radio astronomy at other locations.

16. To satisfy Federal government coordination interests, we will require Liberty to create and maintain a record of installations of all devices operating under this waiver, including the identity of the customer, the type of installation (e.g., airport or government building, commercial venue), and street address and/or geographical coordinates, and must maintain a record of any instances of harmful interference caused to Federal government operations. Liberty must make this information available to the Commission and/or NTIA upon request. Liberty must also inform purchasers that HEXWAVE devices may not be resold to third parties for use at another installation in the United States without prior notice and unless arrangements are made for the third-party buyer to meet all the waiver conditions. We will also require Liberty to actively maintain location information, have the capability of detecting any abnormal operation, and possess the ability to remotely cease transmission of a HEXWAVE system upon notice of interference.[39] These requirements are consistent with those suggested by Liberty and will assist it and the

[35] This matches the deployment numbers that Liberty has endorsed in the record. *See* Letter from Aman Bhardwaj, President, Liberty Defense Holdings to Marlene H. Dortch, Secretary, Federal Communications Commission, ET Docket No. 19-217 (filed Apr. 24, 2020).

[36] Liberty must file a modification of its waiver to deploy more than 600 devices or to extend the deployment period beyond three years.

[37] *See* Liberty *Ex Parte* Notice filed September 11, 2019, at 2.

[38] *See Kyma Medical Technologies Ltd. Request for Waiver of Part 15 of the Commission's Rules Applicable to Ultra-Wideband Devices*, ET Docket No. 15-119, Order, 31 FCC Rcd 9705, 9710 (OET 2016).

[39] *See* Liberty *Ex Parte* filed December 7, 2021.

Commission in addressing questions that may arise regarding the deployment and operation of HEXWAVE devices.[40]

17. We also grant a waiver of Section 15.511(f), to properly reflect the waiver of Section 15.511(b) by requiring a modified statement of who may operate the HEXWAVE system. Each HEXWAVE device will be required to bear the following (or a substantially similar) statement in a conspicuous location on the device: "Operation of this device is restricted to law enforcement, fire and rescue officials, private security personnel, public utilities, and industrial entities. Operation by any other party is a violation of 47 U.S.C. 301 and could subject the operator to serious legal penalties."[41]

D. Waiver conditions

18. This waiver is conditioned on Liberty meeting the specified waiver conditions. We further note that Liberty is not requesting a relaxation of the restrictive emission limits that are an integral part of our UWB rules, and which we have acknowledged to be conservative and extremely protective of incumbent services.[42] Because the HEXWAVE must comply with these rules, and because it can operate under a waiver of the four rules we have identified in a manner consistent with the use characteristics associated with other UWB surveillance applications without increasing the potential for harmful interference to authorized users, we find good cause to grant the waiver request. We also find good cause to grant this waiver without first resolving the issues Cisco and Hewlett Packard have raised in their letter.[43] Liberty's request is narrowly tailored, can be granted without raising the potential for causing harmful interference to authorized services, and can help realize important public safety benefits. By contrast, Cisco and Hewlett Packard raise general questions of Commission practice and policy that will remain available for our consideration later and in an appropriate context.

19. Accordingly, pursuant to the delegated authority in Sections 0.31 and 0.241 of the Commission's rules, we waive the requirements of Sections 15.31(c), 15.503(d), the introductory text of 15.511(b), 15.511(b)(2), 15.511(f), and 15.521(d) of our rules to permit the certification and marketing of the HEXWAVE System. This waiver is subject to the following conditions:

1) The HEXWAVE device shall be certified by the Commission and must comply with the technical specifications applicable to operation under Part 15 of 47 CFR, except as permitted below:

   (a) the instantaneous bandwidth requirement in 47 CFR §15.503(d) is waived to permit operation of the swept-frequency UWB surveillance system;

   (b) the measurement requirements in 47 CFR §15.31(c) and 47 CFR § 15.521(d) are waived to permit the HEXWAVE device to be tested with the frequency sweep active, rather than stopped, to demonstrate compliance with the maximum permitted average power in Section 15.511;

   (c) the eligible user requirements specified in the introductory text of 47 CFR §15.511(b) are relaxed to also allow use by private security personnel defined as "Individuals and organizations (other than public law enforcement personnel and agencies) that primarily are engaged in the detection of crime and threats to people and property at sites at which people aggregate, including

[40] *See L-3 Communications Security and Detections Systems, Inc. Request for Waiver of Sections 15.31(c), 15.35(b) and 15.205(a) of the Commission's Rules to Permit the Deployment of Security Screening Portal Devices that Operate in the 20-40 GHz Range*, ET Docket No. 16-45, Order, 31 FCC Rcd 12310 (OET 2016) (mandating a similar detailed recordkeeping requirement as a condition to granting a waiver).

[41] *See* Liberty Waiver Request at Exhibit A.

[42] *See UWB First R&O*, 17 FCC Rcd 7435, 7437, para. 1 (stating that "we are concerned, however, that the standards we are adopting may be overprotective and could unnecessarily constrain the development of UWB technology").

[43] *See* Cisco/HPE UWB Letter, *supra* note 9.

providers of (i) proprietary or contractual guard and screening services, (ii) electronic security systems integration and management services, and (iii) security consulting services";

(d) the coordination requirement of 47 CFR §15.511(b)(2) to coordinate directly with the Commission and NTIA is waived;

(e) in lieu of the labeling requirement of 47 CFR §15.511(f), each HEXWAVE system shall bear the following or substantially similar statement in a conspicuous location on the device: "Operation of this device is restricted to law enforcement, fire and rescue officials, private security personnel, public utilities, and industrial entities. Operation by any other party is a violation of 47 U.S.C. 301 and could subject the operator to serious legal penalties."

(f) Liberty's sale of the HEXWAVE system will be limited to law enforcement, fire, and rescue officials, private security personnel, public utilities, and industrial entities as described in conditions (1)(c) and (1)(e).

2) Liberty shall create and maintain a record of all devices sold under this waiver, which record shall include all information set forth in 47 CFR § 15.525(b) to include latitude and longitude information. This record shall be made available to the Commission and to NTIA upon request.

3) The maximum EIRP of the HEXWAVE system shall not exceed -41.3 dBm/MHz.

4) The intentional emissions generated by the HEXWAVE device must be completely contained within the 6-10.6 GHz frequency range.

5) The total transmit time of the HEXWAVE system during a cycle will be less than 54 milliseconds and each cycle will be repeated with a period of no less than 100 milliseconds.

6) Each HEXWAVE system will be operated such that no two antennas within a single HEXWAVE system will transmit concurrently.

7) This waiver shall apply to the HEXWAVE systems as described herein and provided no changes are made to the transmitter that would increase the system's EIRP.

8) Liberty shall:

a) maintain a database, accessible to the FCC and NTIA upon request, of any instance in which a deployed HEXWAVE system caused harmful interference to federal operations;

b) in every instance know the exact location of the deployment of each HEXWAVE system due to the terms of its customer agreements and its ability to remotely monitor operating HEXWAVE systems, and contractually require Liberty's approval for its customer to move a HEXWAVE system; and

c) maintain remote connectivity to each HEXWAVE to continuously monitor systems operating in the field. Liberty will take corrective action if there is abnormal operation by a HEXWAVE system, including terminating operation in the event of interference.

9) Liberty shall inform purchasers that the HEXWAVE device may not be resold or leased by such purchasers to third parties for use at another installation in the United States without prior notice to Liberty and unless appropriate arrangements are made for the third-party buyer to meet all of the conditions of this waiver.

10) Liberty shall disclose in a manner that would be conspicuous to both initial and subsequent purchasers of HEXWAVE that these devices may only be operated on a non-interference basis to existing and future authorized services and operators of these devices will be required to mitigate any instances of harmful interference that may occur.

11) Liberty shall limit the number of systems installed under this waiver to one hundred (100) installations during the first twelve months following the grant of this waiver and to an additional

two hundred (200) during the second twelve months and to an additional three hundred (300) during the third twelve months, for a total of no more than six hundred (600) systems at the end of three years. In the fourth year and all subsequent years Liberty may install up to three hundred (300) additional systems per year; any request by Liberty to modify this limit may be considered by the FCC in coordination with NTIA.

12) Liberty shall avoid outdoor deployment within 20 km of the sites listed in footnote US 131:

Arecibo Observatory, PR	18° 20' 37" N, 66° 45' 11" W
Green Bank Telescope (GBT), WV	38° 25' 59" N, 79° 50' 23" W
Very Large Array (VLA), Socorro, NM	34° 04' 44" N, 107° 37' 06" W

Very Long Baseline Array (VLBA) Stations:

Brewster, WA	48° 07' 52" N, 119° 41' 00" W
Fort Davis, TX	30° 38' 06" N, 103° 56' 41" W
Hancock, NH	42° 56' 01" N, 71° 59' 12" W
Kitt Peak, AZ	31° 57' 23" N, 111° 36' 45" W
Los Alamos, NM	35° 46' 30" N, 106° 14' 44" W
Mauna Kea, HI	19° 48' 05" N, 155° 27' 20" W
North Liberty, IA	41° 46' 17" N, 91° 34' 27" W
Owens Valley, CA	37° 13' 54" N, 118° 16' 37" W
Pie Town, NM	34° 18' 04" N, 108° 07' 09" W
St. Croix, VI	17° 45' 24" N, 64° 35' 01" W

Coordination is required for outdoor operations within 20 km of the above referenced sites. The following points of contact must be notified for coordination (please cc esm@nsf.gov):

VLA/VLBA:
Dan "Mert" Mertely
nrao-rfi@nrao.edu
phone: (575) 835-7128

Arecibo:
Angel Vazquez
angel@naic.edu
phone: (787) 878-2612 ext.304

Coordination is required for any operations within the National Radio Quiet Zone (NRQZ). The NRQZ and GBT PoC is:

Paulette Woody
nrqz@gb.nrao.edu
Phone: (304) 456-2107 (normal); (615) 796-6395 (Google voice) or 304-456-9951 (H)

Notification to esm@nsf.gov and the VLA/VLBA point of contact is required for any operation/deployment within the geographic area bounded by:

31.367224° N, 109.031505° W
31.367224° N, 103.077521° W
34.386150° N, 103.077521° W
34.386150° N, 109.031505° W

Except for within the city limits of Las Cruces, Alamogordo, Roswell, and Carlsbad in NM, and

El Paso, TX. This would assist radio astronomy operations. NSF may request coordination of operations in the future, as the VLA does make use of the frequency range involved, and such coordination may assist with telescope scheduling.

13) Outdoor deployment shall be avoided within 10 km of the sites listed in Table 1:

Table 1. Exclusion Zone Sites

Location	Latitude (dd mm ss)	Longitude (ddd mm ss)
AK, Anchorage	61 09 24 N	149 59 07 W
AK, Fairbanks	64 51 32 N	147 51 04 W
AK, U of AK	64 51 37 N	147 50 50 W
AK, North Pole	64 48 18 N	147 30 00 W
AK, North Pole West AS4	64 47 37 N	147 32 18 W
AK, North Pole West AS5	64 47 42 N	147 32 18 W
AK, Poker Flat	65 07 00 N	147 27 35 W
CA, Goldstone (DSS-14)	35 25 33 N	116 53 19 W
CA, Goldstone (DSS-24)	35 20 24 N	116 52 29 W
CA, Goldstone (DSS-25)	35 20 15 N	116 52 31 W
CA, Goldstone (DSS-26)	35 20 09 N	116 52 23 W
HI, South Point	19 00 50 N	155 39 47 W
SD, Sioux Falls	43 44 10 N	096 37 21W
VA, Wallops Island	37 55 28 N	075 28 35 W
VA Wallops Island	37 55 35 N	075 28 32 W

The outdoor deployment Coordination Zone Sites that should be subject to a 1.2 km coordination zone are identified in Table 2.

Table 2. Coordination Zone Sites

Location	Latitude (dd mm ss)	Longitude (ddd mm ss)
CA, La Jolla	32 52 11 N	117 15 07 W
CA, Orange	33 47 38 N	117 51 00 W
CA, Pasadena	34 12 06 N	118 10 27 W
CA, Poway	32 56 18 N	117 02 42 W
DE, Newark	39 41 01 N	075 45 18 W
FL, St. Petersburg	27 45 36 N	082 37 55 W
FL, Tallahassee	30 23 10 N	084 13 53 W
HI, Honolulu	21 17 54 N	157 48 59 W
IN, Indianapolis	39 47 42 N	086 03 43 W
IN, Lafayette	40 25 48 N	086 54 54 W
KY, Morehead	38 11 31 N	083 26 20 W
LA, Baton Rouge	30 24 43 N	091 10 44 W

Location	Latitude (dd mm ss)	Longitude (ddd mm ss)
MD, Greenbelt	38 59 57 N	076 51 18 W
MD, Lanham	38 57 40 N	076 50 24 W
MD, Suitland	38 51 07 N	076 56 31 W
MI, Peach Mountain	42 23 56 N	083 56 08 W
MS, Stennis Space Center	30 22 05 N	089 37 01 W
MT, Missoula	46 55 34 N	114 05 35 W
NJ, New Brunswick	40 28 48 N	074 26 13 W
NM, Albuquerque	35 05 02 N	106 37 16 W
NY, New York	40 49 12 N	073 57 00 W
OR, Corvallis	44 34 04 N	123 16 39 W
TX, Austin	30 23 42 N	097 44 06 W
TX, Irving	32 52 41 N	096 59 53 W
UT, Salt Lake City	40 46 00 N	111 53 13 W
WI, Madison	43 04 15 N	089 24 24 W

The point of contact for coordination is Bryan Rhodes NASA, Frequency Assignment Program Manager bryan.a.rhodes@nasa.gov.

14) This waiver and its conditions shall apply only to the UWB devices described herein and are not to be considered to apply generally to any other UWB operations where further analysis would be necessary to assess the potential for impact to other authorized users.

15) A copy of this Order shall be provided with the application for certification of the device.

IV. ORDERING CLAUSES

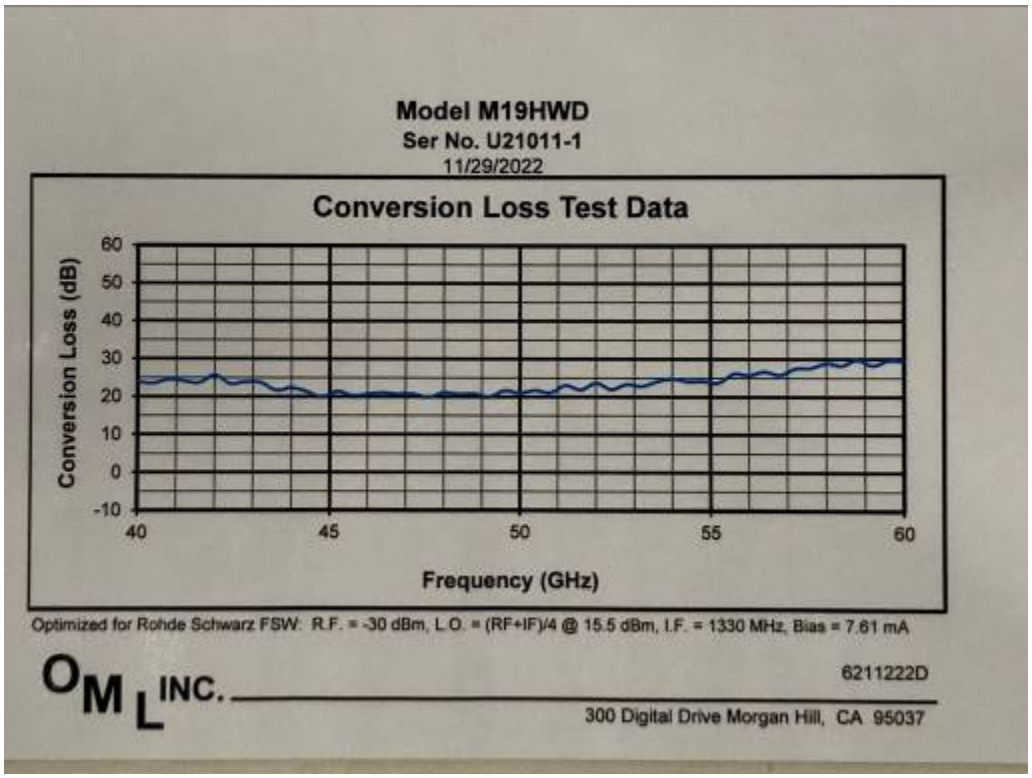
20. Accordingly, pursuant to authority delegated in Sections 0.31 and 0.241 of the Commission's rules, 47 CFR §§ 0.31, 0.241, and Section 1.3 of the Commission's rules, 47 CFR § 1.3, IT IS ORDERED that the Request for Waiver filed by Liberty Defense Holdings, Ltd. on May 8, 2019 IS GRANTED consistent with the terms of this Order. This action is taken pursuant to Sections 4(i), 302, 303(e), and 303(r) of the Communications Act of 1934, as amended, 47 U.S.C. Sections 154(i), 302, 303(e), and 303(r). This action is effective upon release of this Order.

21. IT IS FURTHER ORDERED that, if no applications for review are timely filed, this proceeding SHALL BE TERMINATED and the docket CLOSED.

FEDERAL COMMUNICATIONS COMMISSION

Ronald T. Repasi
Acting Chief
Office of Engineering and Technology

Appendix B - Mixer/Horn Calibration Certificates



Model M19HWD
Ser No. U21011-1
11/29/2022

Conversion Loss Test Data

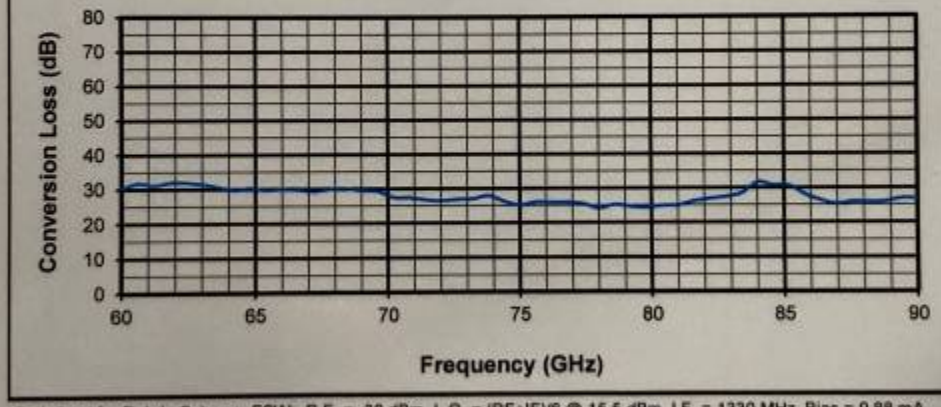
Frequency (GHz)	Conversion Loss (dB)
40.00	**23.89**
40.40	23.47
40.80	24.53
41.20	24.11
41.60	23.64
42.00	25.65
42.40	23.43
42.80	23.88
43.20	23.71
43.60	21.67
44.00	22.34
44.40	21.35
44.80	19.88
45.20	21.43
45.60	20.33
46.00	20.76
46.40	21.09
46.80	20.70
47.20	20.80
47.60	19.89
48.00	21.15
48.40	20.71
48.80	20.83
49.20	20.04
49.60	21.69
50.00	**21.04**
50.40	21.77
50.80	21.13
51.20	23.08
51.60	21.85
52.00	23.74
52.40	22.01
52.80	23.39
53.20	22.83
53.60	24.16
54.00	24.86
54.40	24.11
54.80	24.22
55.20	23.78
55.60	26.23
56.00	25.82
56.40	26.83
56.80	25.91
57.20	27.62
57.60	27.75
58.00	29.03
58.40	28.36
58.80	29.89
59.20	28.40
59.60	29.68
60.00	**29.52**

Traceability only available ≤ 110 GHz

OML INC. 6211222D
300 Digital Drive Morgan Hill, CA 95037

Model M12HWD
Ser No. E21011-1
11/29/2022

Conversion Loss Test Data



Optimized for Rohde Schwarz FSW: R.F. = -30 dBm, L.O. = (RF+IF)/6 @ 15.5 dBm, I.F. = 1330 MHz, Bias = 9.88 mA

6211222C

OML INC. 300 Digital Drive Morgan Hill, CA 95037

Model M12HWD
Ser No. E21011-1
11/29/2022

Conversion Loss Test Data

Frequency (GHz)	Conversion Loss (dB)
60.00	**30.24**
60.60	31.78
61.20	31.14
61.80	31.96
62.40	31.93
63.00	31.45
63.60	30.67
64.20	29.71
64.80	30.29
65.40	29.71
66.00	30.00
66.60	29.77
67.20	29.34
67.80	29.94
68.40	30.17
69.00	29.52
69.60	29.29

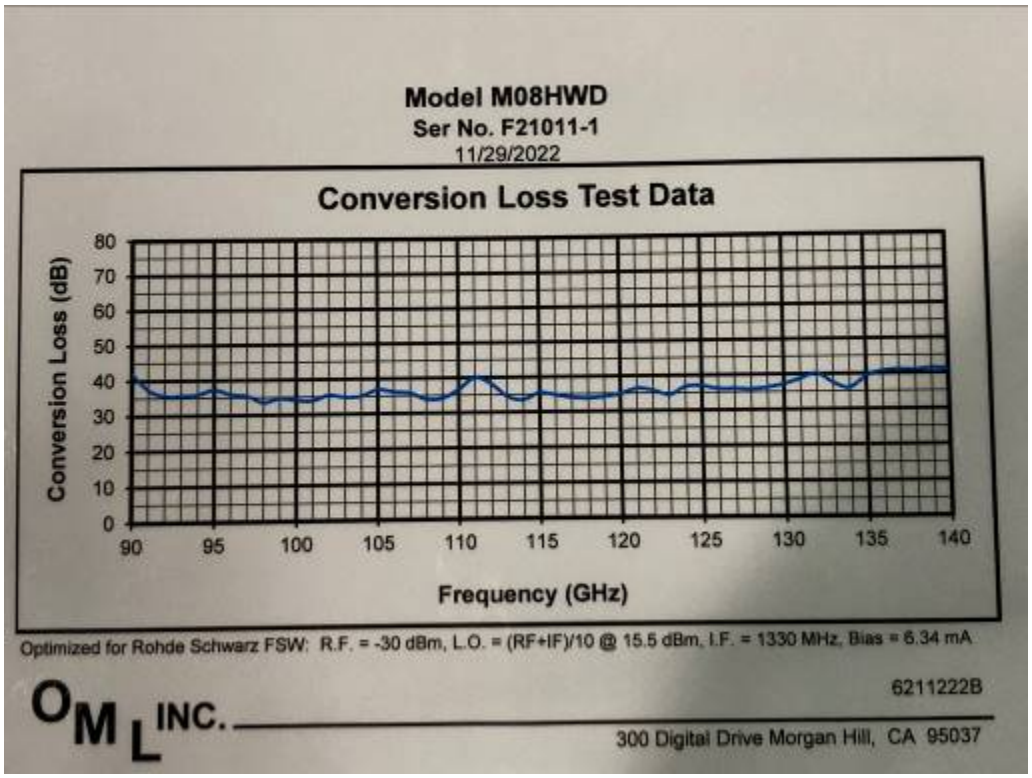
Frequency (GHz)	Conversion Loss (dB)
70.20	27.50
70.80	27.41
71.40	26.78
72.00	26.49
72.60	26.90
73.20	27.00
73.80	27.94
74.40	26.34
75.00	**25.14**
75.60	26.04
76.20	25.96
76.80	25.96
77.40	25.52
78.00	24.24
78.60	25.29
79.20	24.74
79.80	24.40

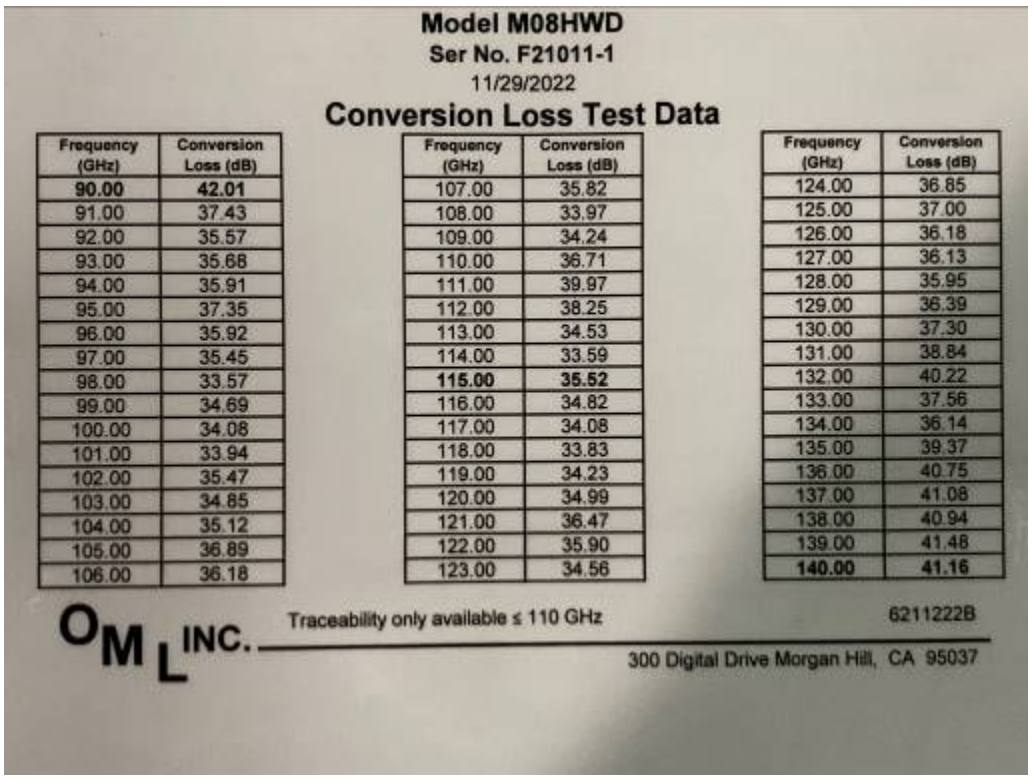
Frequency (GHz)	Conversion Loss (dB)
80.40	24.93
81.00	25.04
81.60	26.22
82.20	26.95
82.80	27.50
83.40	28.46
84.00	31.70
84.60	30.88
85.20	30.73
85.80	28.11
86.40	26.44
87.00	25.39
87.60	26.08
88.20	25.98
88.80	26.12
89.40	27.04
90.00	**26.97**

Traceability only available ≤ 110 GHz

6211222C

OML INC. 300 Digital Drive Morgan Hill, CA 95037





Model M08HWD
Ser No. F21011-1
11/29/2022

Conversion Loss Test Data

Frequency (GHz)	Conversion Loss (dB)
90.00	**42.01**
91.00	37.43
92.00	35.57
93.00	35.68
94.00	35.91
95.00	37.35
96.00	35.92
97.00	35.45
98.00	33.57
99.00	34.69
100.00	34.08
101.00	33.94
102.00	35.47
103.00	34.85
104.00	35.12
105.00	36.89
106.00	36.18

Frequency (GHz)	Conversion Loss (dB)
107.00	35.82
108.00	33.97
109.00	34.24
110.00	36.71
111.00	39.97
112.00	38.25
113.00	34.53
114.00	33.59
115.00	**35.52**
116.00	34.82
117.00	34.08
118.00	33.83
119.00	34.23
120.00	34.99
121.00	36.47
122.00	35.90
123.00	34.56

Frequency (GHz)	Conversion Loss (dB)
124.00	36.85
125.00	37.00
126.00	36.18
127.00	36.13
128.00	35.95
129.00	36.39
130.00	37.30
131.00	38.84
132.00	40.22
133.00	37.56
134.00	36.14
135.00	39.37
136.00	40.75
137.00	41.08
138.00	40.94
139.00	41.48
140.00	**41.16**

Traceability only available ≤ 110 GHz

6211222B

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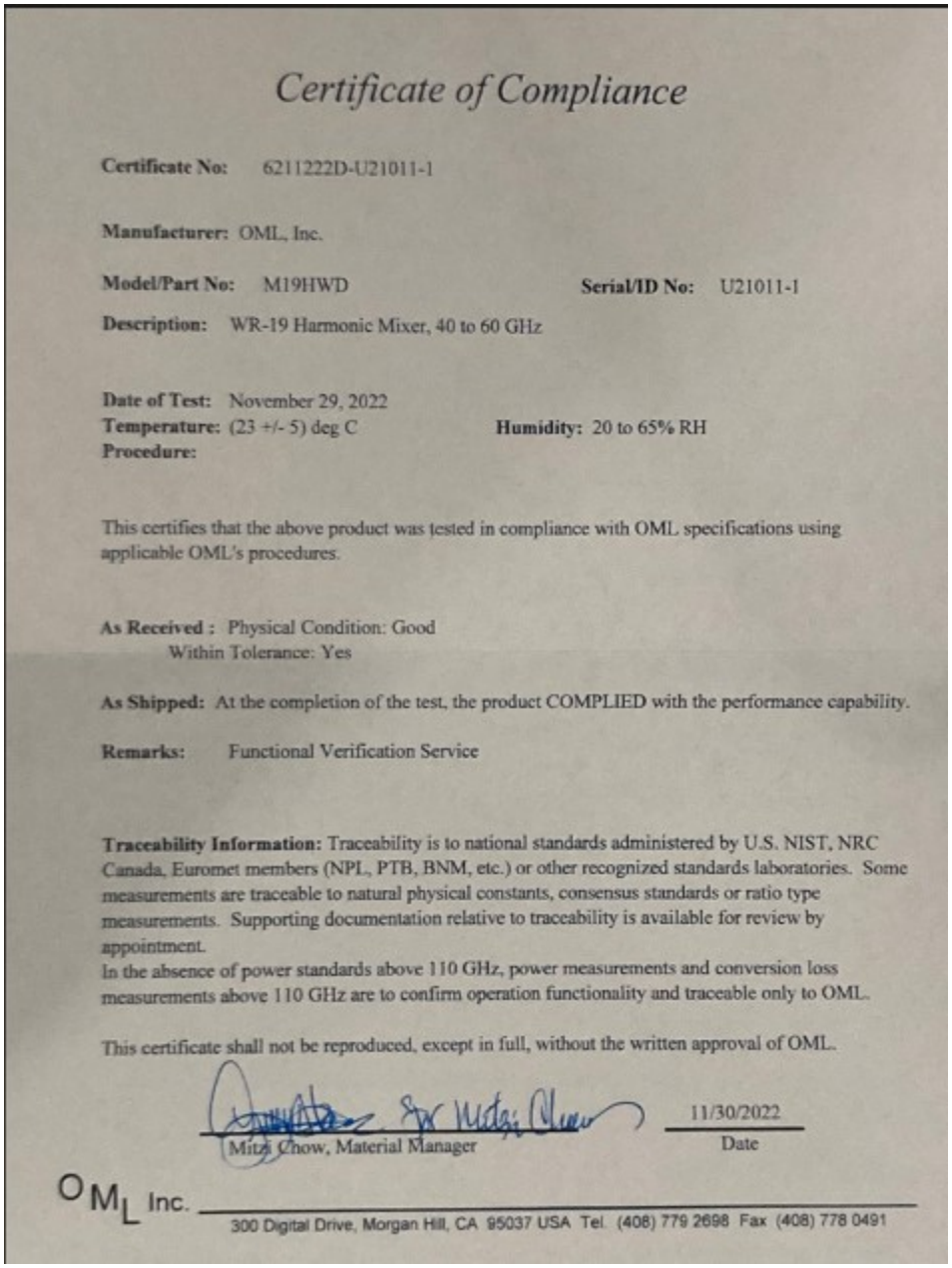
300 Digital Drive Morgan Hill, CA 95037



Certificate of Compliance

Certificate No: 6211222D-U21011-1

Manufacturer: OML, Inc.

Model/Part No: M19HWD **Serial/ID No:** U21011-1

Description: WR-19 Harmonic Mixer, 40 to 60 GHz

Date of Test: November 29, 2022
Temperature: (23 +/- 5) deg C **Humidity:** 20 to 65% RH
Procedure:

This certifies that the above product was tested in compliance with OML specifications using applicable OML's procedures.

As Received : Physical Condition: Good
Within Tolerance: Yes

As Shipped: At the completion of the test, the product COMPLIED with the performance capability.

Remarks: Functional Verification Service

Traceability Information: Traceability is to national standards administered by U.S. NIST, NRC Canada, Euromet members (NPL, PTB, BNM, etc.) or other recognized standards laboratories. Some measurements are traceable to natural physical constants, consensus standards or ratio type measurements. Supporting documentation relative to traceability is available for review by appointment.
In the absence of power standards above 110 GHz, power measurements and conversion loss measurements above 110 GHz are to confirm operation functionality and traceable only to OML.

This certificate shall not be reproduced, except in full, without the written approval of OML.

Mitzi Chow, Material Manager — 11/30/2022 Date

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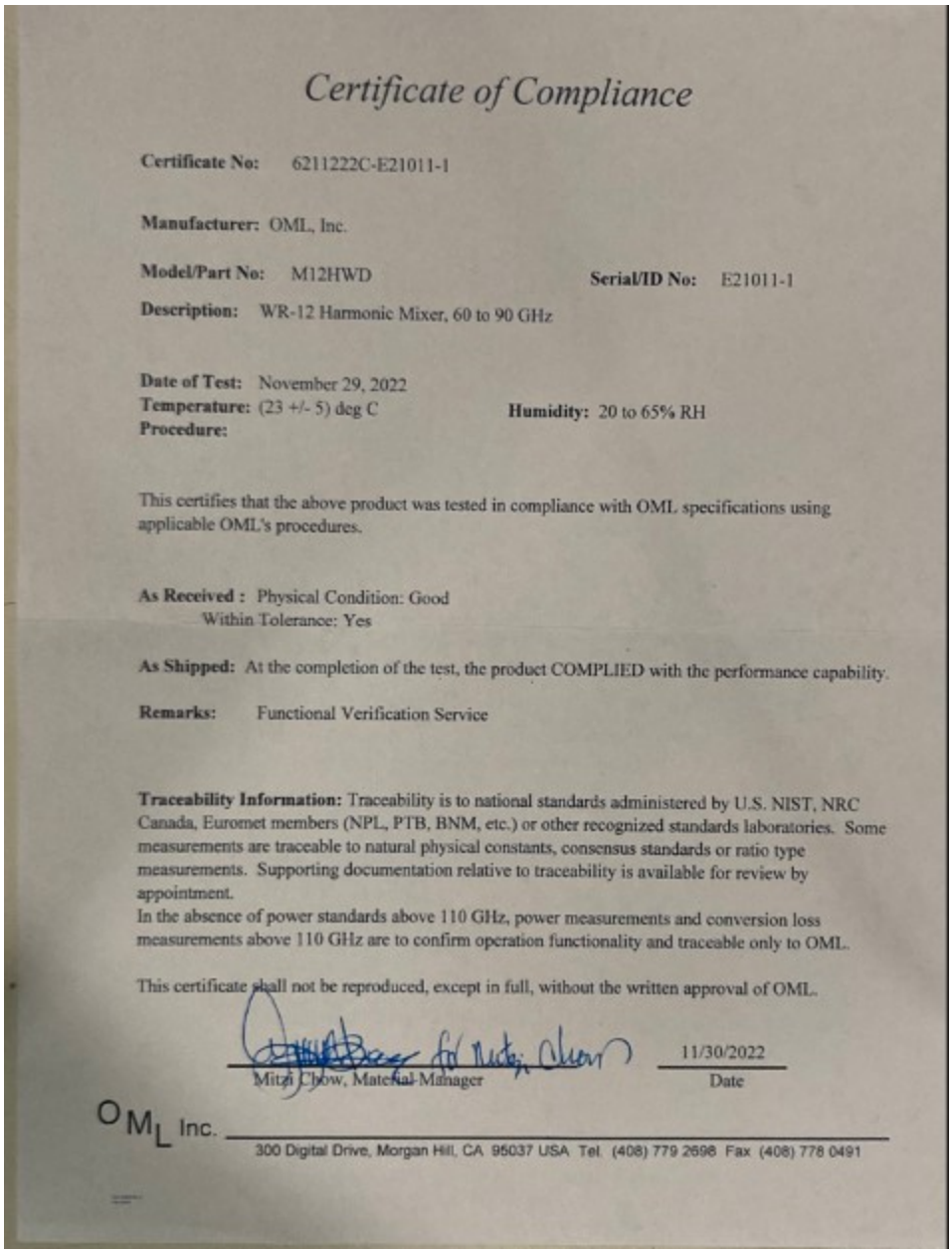

Certificate of Compliance

Certificate No: 6211222C-E21011-1

Manufacturer: OML, Inc.

Model/Part No: M12HWD **Serial/ID No:** E21011-1

Description: WR-12 Harmonic Mixer, 60 to 90 GHz

Date of Test: November 29, 2022
Temperature: (23 +/- 5) deg C **Humidity:** 20 to 65% RH
Procedure:

This certifies that the above product was tested in compliance with OML specifications using applicable OML's procedures.

As Received : Physical Condition: Good
Within Tolerance: Yes

As Shipped: At the completion of the test, the product COMPLIED with the performance capability.

Remarks: Functional Verification Service

Traceability Information: Traceability is to national standards administered by U.S. NIST, NRC Canada, Euromet members (NPL, PTB, BNM, etc.) or other recognized standards laboratories. Some measurements are traceable to natural physical constants, consensus standards or ratio type measurements. Supporting documentation relative to traceability is available for review by appointment.
In the absence of power standards above 110 GHz, power measurements and conversion loss measurements above 110 GHz are to confirm operation functionality and traceable only to OML.

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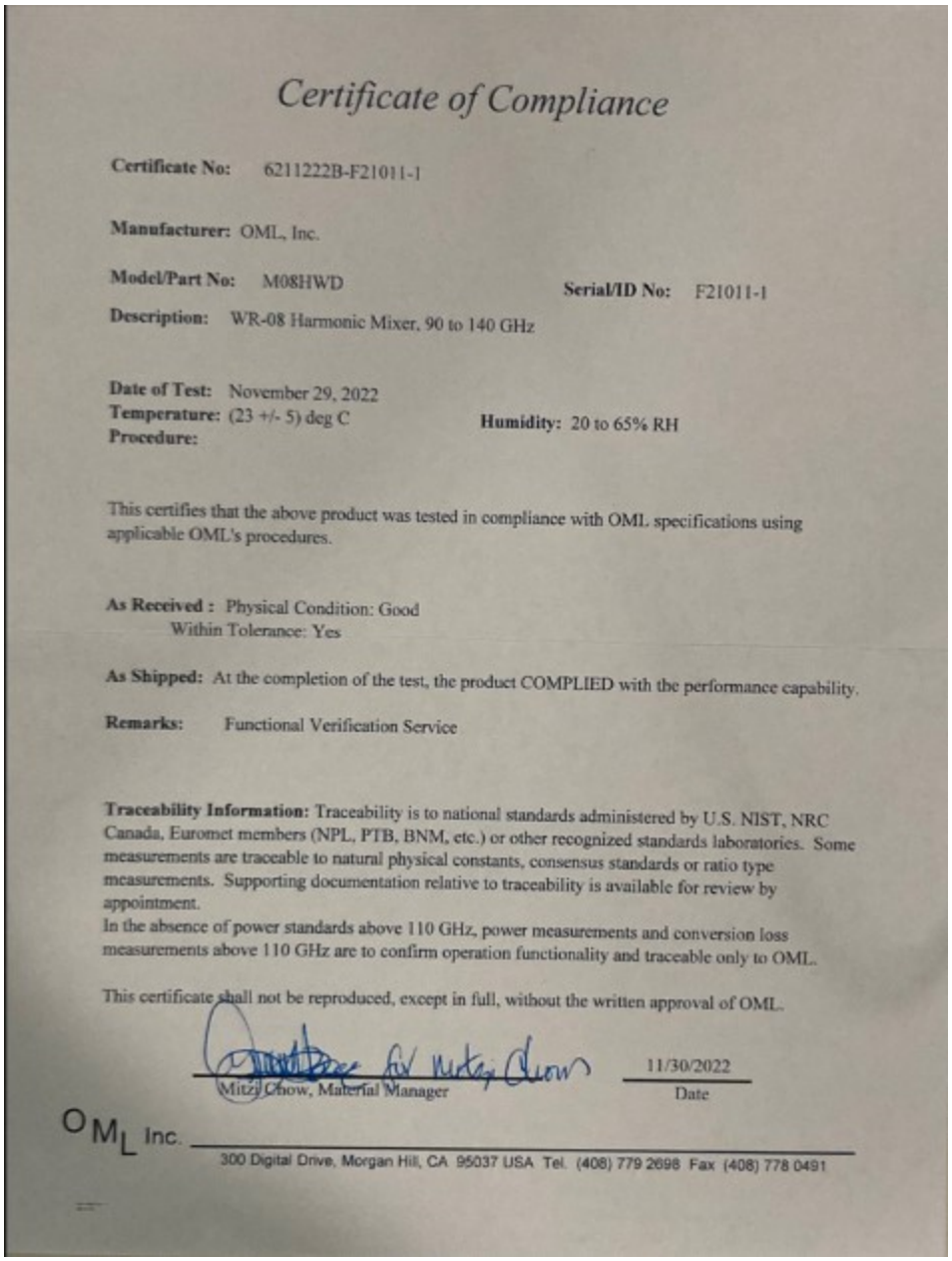

Certificate of Compliance

Certificate No: 6211222B-F21011-1

Manufacturer: OML, Inc.

Model/Part No: M08HWD **Serial/ID No:** F21011-1

Description: WR-08 Harmonic Mixer, 90 to 140 GHz

Date of Test: November 29, 2022
Temperature: (23 +/- 5) deg C **Humidity:** 20 to 65% RH
Procedure:

This certifies that the above product was tested in compliance with OML specifications using applicable OML's procedures.

As Received : Physical Condition: Good
Within Tolerance: Yes

As Shipped: At the completion of the test, the product COMPLIED with the performance capability.

Remarks: Functional Verification Service

Traceability Information: Traceability is to national standards administered by U.S. NIST, NRC Canada, Euromet members (NPL, PTB, BNM, etc.) or other recognized standards laboratories. Some measurements are traceable to natural physical constants, consensus standards or ratio type measurements. Supporting documentation relative to traceability is available for review by appointment.
In the absence of power standards above 110 GHz, power measurements and conversion loss measurements above 110 GHz are to confirm operation functionality and traceable only to OML.

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Mitzi Chow, Material Manager — 11/30/2022 Date

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12 Revision History

Revision Level	Date	Report Number	Prepared By	Reviewed By	Notes
0	08/11/2023	105270120BOX-007	VFV	KPS	Original Issue
1	10/25/2023	105270120BOX-007_R1	VFV	KPS	Addressed TCB reviewer's comments