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Test Report

Prepared for:	**701x**
Address:	**700 Main Avenue** **Fargo, North Dakota 58103**
Product:	**xTAG**
FCC ID:	**2AZT3-701XT1**
Test Report No:	**R2010414-20-E1A**
Approved by:	 **Nic S. Johnson, NCE** **Technical Manager** **iNARTE Certified EMC Engineer #EMC-003337-NE**
DATE:	**24 August 2021**
Total Pages:	**40**

REVISION PAGE

Rev. No.	Date	Description
0	30 July 2021	Original – NJohnson Prepared by FLane
A	19 August 2021	Added FCC ID Added conducted power values Updated description in output power plots

CONTENTS

1.0 SUMMARY OF TEST RESULTS

The EUT has been tested according to the following specifications:

(1) US Code of Federal Regulations, Title 47, Part 15
(2) ISED RSS-Gen, Issue 5
(3) ISED RSS-247, Issue 2

SUMMARY			
Standard Section	**Test Type and Limit**	**Result**	**Remark**
FCC 15.203	Unique Antenna Requirement	Pass	PCB antenna
FCC 15.209 RSS-Gen, 7.1	Receiver Radiated Emissions	Pass	Meets the requirement of the limit.
FCC 15.247(a)(1)(i) RSS-247, 5.1(c)	Minimum Bandwidth, Limit: Max. 250kHz	Pass	Meets the requirement of the limit.
FCC 15.247(b)(1) RSS-247, 5.1	Maximum Peak Output Power, Limit: Max. 30 dBm	Pass	Meets the requirement of the limit.
FCC 15.209 RSS-Gen, 8.9 RSS-247, 5.5	Transmitter Radiated Emissions	Pass	Meets the requirement of the limit.
FCC 15.247(a) (1) (i) RSS-247, 5.1(c)	Frequency hopping system, Channel Dwell Time Limit: Max. 0.4 Seconds in 20 Second Period	Pass	Meets the requirement of the limit.
FCC 15.209, 15.205 RSS-Gen, 8.9 RSS-247, 5.5	Band Edge Measurement, Limit: 20dB less than the peak value of fundamental frequency	Pass	Meets the requirement of the limit.
FCC 15.205(a) FCC 15.247(d)	Restricted Band Edge Measurement, Limit: FCC 15.209 Limits in restricted bands	Pass	Meets the requirement of the limit.
FCC 15.207 RSS-Gen. 8.8	Conducted AC Emissions	NA	Battery Powered.

2.0 EUT DESCRIPTION

2.1 EQUIPMENT UNDER TEST

The Equipment Under Test (EUT) was a wireless FHSS transmitter.

EUT	Cattle Tracker
EUT Received	7/7/2021
EUT Tested	7/7/2021 - 7/8/2021
Serial No.	001 (assigned by lab)
Operating Band	902.0 – 928.0 MHz
Device Type	FHSS
Power Supply	Internal Battery

NOTE: For more detailed features description, please refer to the manufacturer's specifications or user's manual.

2.2 DESCRIPTION OF TEST MODES

The EUT operates on, and was tested at the frequencies below:

Channel	Frequency
Low	902.2
Middle	915.0
High	927.8

These are the only three representative channels tested in the frequency range according to FCC Part 15.31 and RSS-Gen Table A1. See the operational description for a list of all channel frequency and designations.

This EUT was set to transmit in a worse-case scenario with modulation on. The manufacturer modified the unit to transmit continuously on the lowest, highest and one channel in the middle.

2.3 DESCRIPTION OF SUPPORT UNITS

None

3.0 LABORATORY DESCRIPTION

3.1 LABORATORY DESCRIPTION

All testing was performed at the following Facility:

The Nebraska Center for Excellence in Electronics (NCEE Labs)
4740 Discovery Drive
Lincoln, NE 68521

A2LA Certificate Number:	1953.01
FCC Accredited Test Site Designation No:	US1060
Industry Canada Test Site Registration No:	4294A-1
CAB MRA Recognition Identification No:	US0177

Environmental conditions varied slightly throughout the tests:
Relative humidity of 35 ± 4%
Temperature of 22 ± 3° Celsius

3.2 TEST PERSONNEL

No.	PERSONNEL	TITLE	ROLE
1	Nic Johnson	Technical Manager	Review of Results
2	Fox Lane	EMC Test Engineer	Testing and Report
3	Karthik Vepuri	EMC Test Engineer	Testing

Notes:
All personnel are permanent staff members of NCEE Labs. No testing or review was sub-contracted or performed by sub-contracted personnel.

3.3 TEST EQUIPMENT

DESCRIPTION AND MANUFACTURER	MODEL NO.	SERIAL NO.	LAST CALIBRATION DATE	CALIBRATION DUE DATE
Keysight MXE Signal Analyzer (26.5GHz)**	N9038A	MY56400083	May 5, 2020	May 5, 2022
SunAR RF Motion	JB1	A082918-1	August 17, 2020	August 17, 2021
EMCO Horn Antenna**	3115	6415	March 16, 2020	March 16, 2022
Rohde & Schwarz Preamplifier*	TS-PR18	3545700803	April 14, 2020	April 14, 2022
Trilithic High Pass Filter*	6HC330	23042	April 14, 2020	April 14, 2022
MiniCircuits High Pass Filter*	VHF-1320+	15542	April 14, 2020	April 14, 2022
RF Cable (preamplifier to antenna)*	MFR-57500	01-07-002	April 14, 2020	April 14, 2022
TDK Emissions Lab Software	V11.25	700307	NA	NA

*Internal Characterization
**2 Year Calibration Cycle

Notes:
All equipment is owned by NCEE Labs and stored permanently at NCEE Labs facilities.

3.4 GENERAL TEST PROCEDURE AND SETUP FOR RADIO MEASUREMNTS

Measurement type presented in this report (Please see the checked box below):

Conducted ☐

The conducted measurements were performed by connecting the output of the transmitter directly into a spectrum analyzer using an impedance matched cable and connector soldered to the EUT in place of the antenna. The information regarding resolution bandwidth, video bandwidth, span and the detector used can be found in the graphs provided in the Appendix C. All the radio measurements were performed using the sections from ANSI C63.10, details about the section used can be found in the spectrum analyzer titles on the graph.

Figure 1 - Bandwidth Measurements Test Setup

Radiated ☒

All the radiated measurements were taken at a distance of 3m from the EUT. The information regarding resolution bandwidth, video bandwidth, span and the detector used can be found in the graphs provided in the Appendix C. All the radio measurements were performed using the sections from ANSI C63.10, details about the section used can be found in the spectrum analyzer titles on the graph.

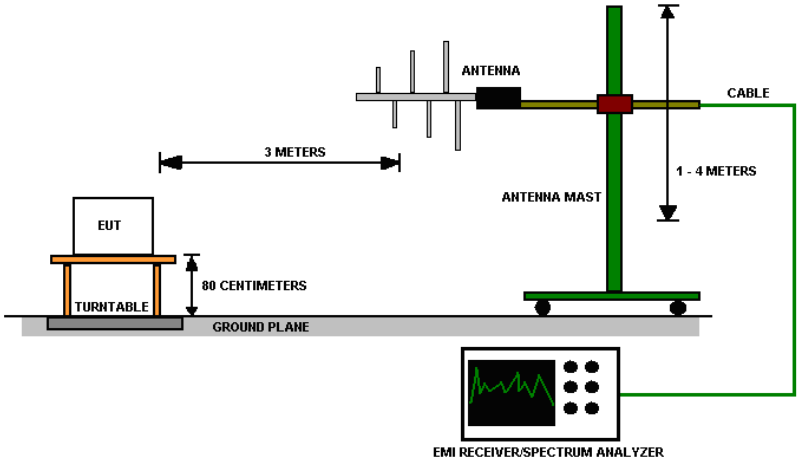


Figure 2 - Radiated Emissions Test Setup

4.0 DETAILED RESULTS

Radio Measurements								
CHANNEL	Transmitter	Occupied Bandwidth (kHz)	20 dB Bandwidth (kHz)	PEAK OUTPUT POWER EIRP (dBm)	PEAK OUTPUT POWER Conducted (dBm)	RESULT	No. of Hoping Channels	Time of Occupancy (msec)
							129	368
Low	Continuous	94.78	103.00	17.854	15.654	PASS	Frequency Separation (kHz)	
Mid	Continuous	92.91	102.40	13.301	11.101	PASS		
High	Continuous	94.30	101.60	16.128	13.928	PASS	201.075	

*Measurements were taken while EUT was transmitting continuously modulated with a duty cycle of >99%

Peak Output Power EIRP = SA Reading + Transducer + Cable + 107 – 95.23

*Conducted measurements = EIRP – antenna gain

Antenna gain = 2.2 dBi

4.1 DUTY CYCLE

Test Method: NA

4.2 RADIATED EMISSIONS

Test Method: ANSI C63.10-2013, Section 6.5, 6.6

Limits for radiated emissions measurements:

Emissions radiated outside of the specified bands shall be applied to the limits in 15.209 as followed:

FREQUENCIES (MHz)	FIELD STRENGTH (μV/m)	MEASUREMENT DISTANCE (m)
0.009-0.490	2400/F(kHz)	300
0.490-1.705	24000/F(kHz)	30
1.705-30.0	30	3
30-88	100	3
88-216	150	3
216-960	200	3
Above 960	500	3

NOTE:
1. The lower limit shall apply at the transition frequencies.
2. Emission level (dBuV/m) = 20 * log * Emission level (μV/m).
3. As shown in 15.35(b), for frequencies above 1000MHz, the field strength limits are based on average detector, however, the peak field strength of any emission shall not exceed the maximum permitted average limits by more than 20dB under any condition of modulation.

Test procedures:

a. The EUT was placed on the top of a rotating table above the ground plane in a 10 meter semi-anechoic chamber. The table was rotated 360 degrees to determine the position of the highest radiation. The table was 0.8m high for measurements form 30MHz-1GHz and 1.5m for measurements from 1GHz to 10 GHz.

b. The EUT was set 3 meters away from the interference-receiving antenna, which was mounted on the top of a variable-height antenna tower.

c. The antenna was a broadband antenna, and its height is varied from one meter to four meters above the ground to determine the maximum value of the field strength. Both horizontal and vertical polarizations of the antenna are used to make the measurement.

d. For each suspected emission, the EUT was arranged to maximize its emissions and then the antenna height was varied from 1 meter to 4 meters and the rotating table was turned from 0 degrees to 360 degrees to find the maximum emission reading.

e. The test-receiver system was set to use a peak detector with a specified resolution bandwidth. For spectrum analyzer measurements, the composite maximum of several analyzer sweeps was used for final measurements.

f. If the emission level of the EUT in peak mode was 10dB lower than the limit specified, then testing could be stopped and the peak values of the EUT would be reported. Otherwise, the emissions that did not have 10 dB margin would be re-tested one by one using peak, quasi-peak or average method as specified and then reported in a data sheet.

g. The EUT was maximized in all 3 orthogonal positions. The results are presented for the axis that had the highest emissions.

h. The EUT was tested during the preview scan with all radios transmitting simultaneously. If any intermodulation products were measured withing the laboratory's measurement sensitivity, they were recorded in the results.

NOTE:
1. The resolution bandwidth and video bandwidth of test receiver/spectrum analyzer is 120kHz for Peak detection (PK) and Quasi-peak detection (QP) at frequencies below 1GHz.

2. The resolution bandwidth 1 MHz for all measurements and at frequencies above 1GHz, A peak detector was used for all measurements above 1GHz. Measurements were made with an EMI Receiver.

Deviations from test standard:

No deviation.

Test setup:

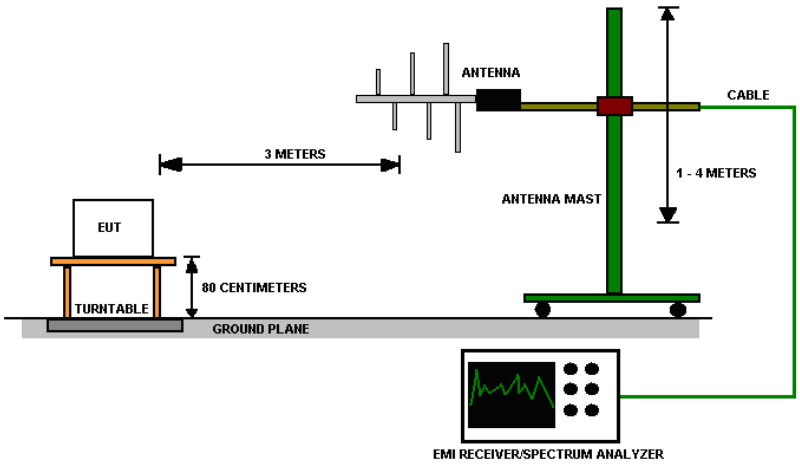


Figure 3 - Radiated Emissions Test Setup

EUT operating conditions
The EUT was powered by 5 VDC unless specified and set to transmit continuously on the lowest frequency channel, highest frequency channel and one in the middle of its operating range.

Test results:

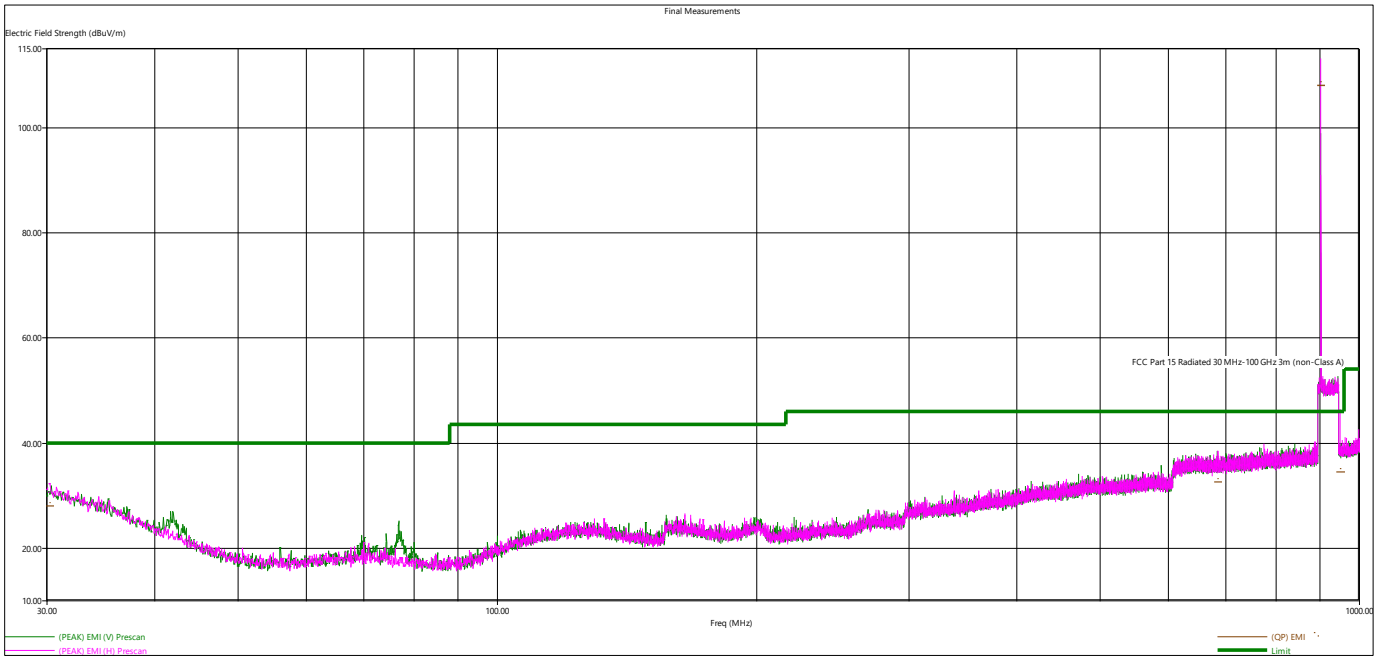


Figure 4 - Radiated Emissions Plot, Low Channel

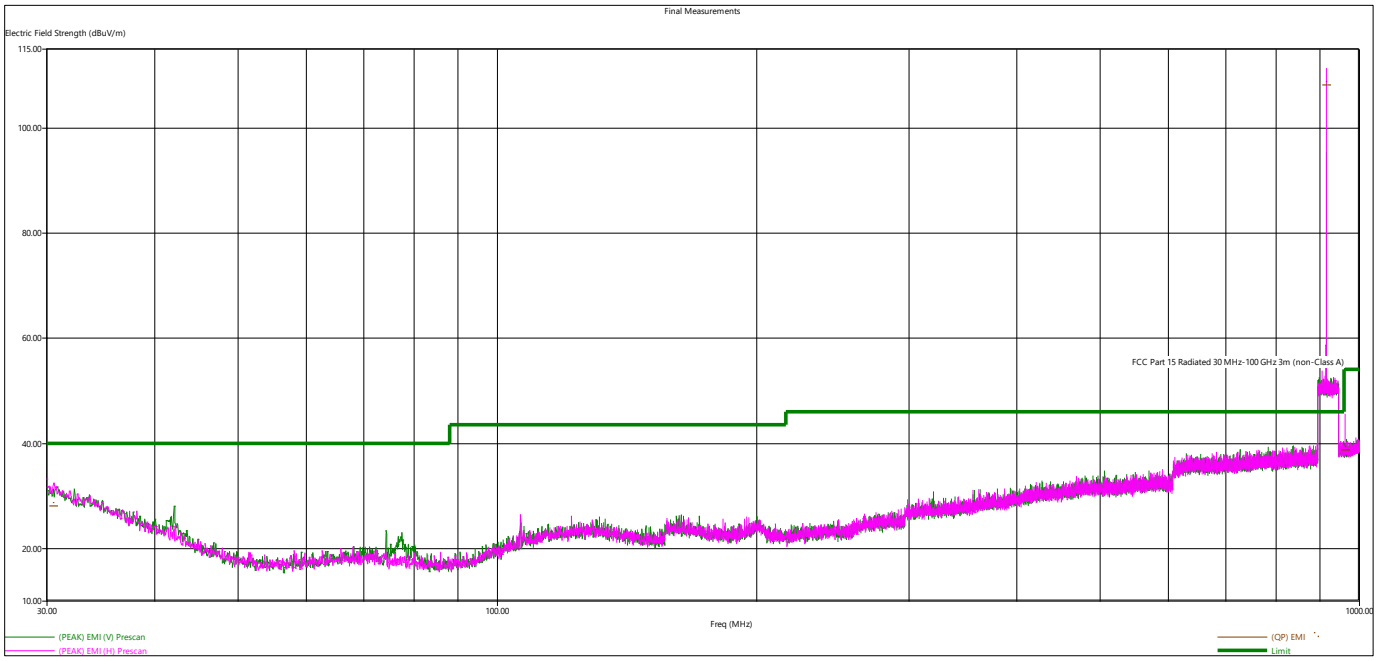


Figure 5 - Radiated Emissions Plot, Mid Channel

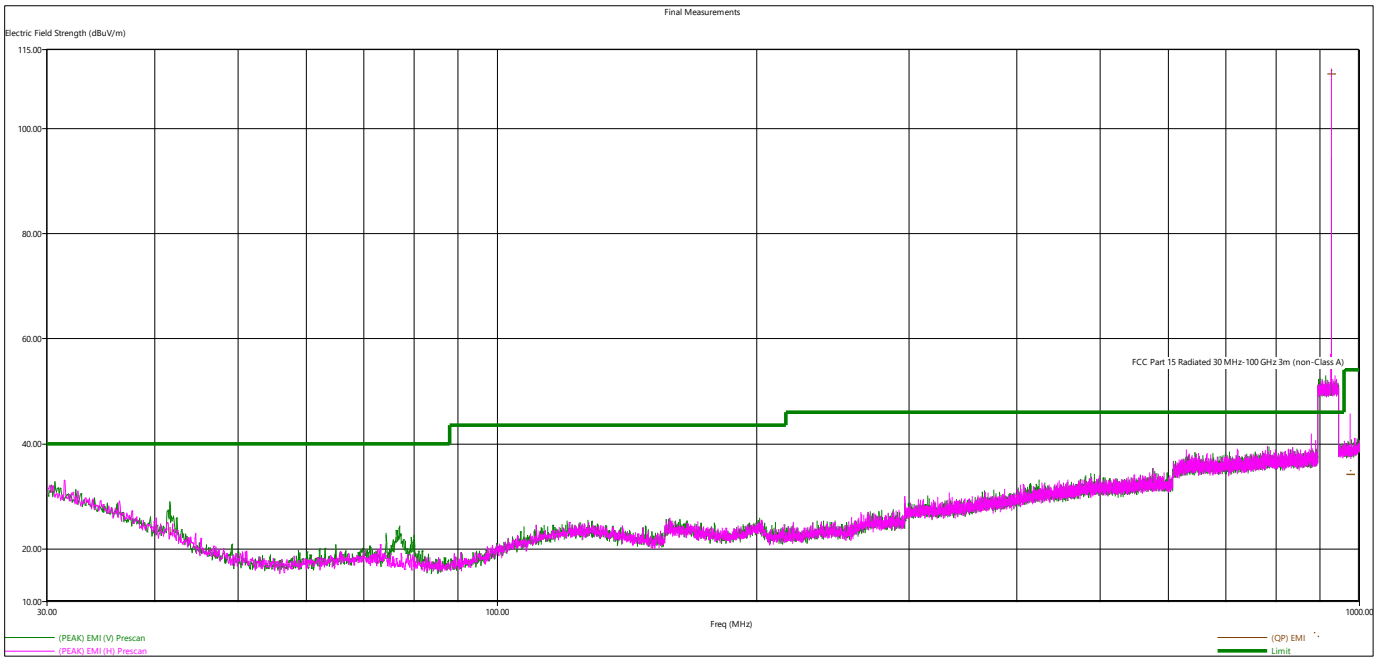


Figure 6 - Radiated Emissions Plot, High Channel

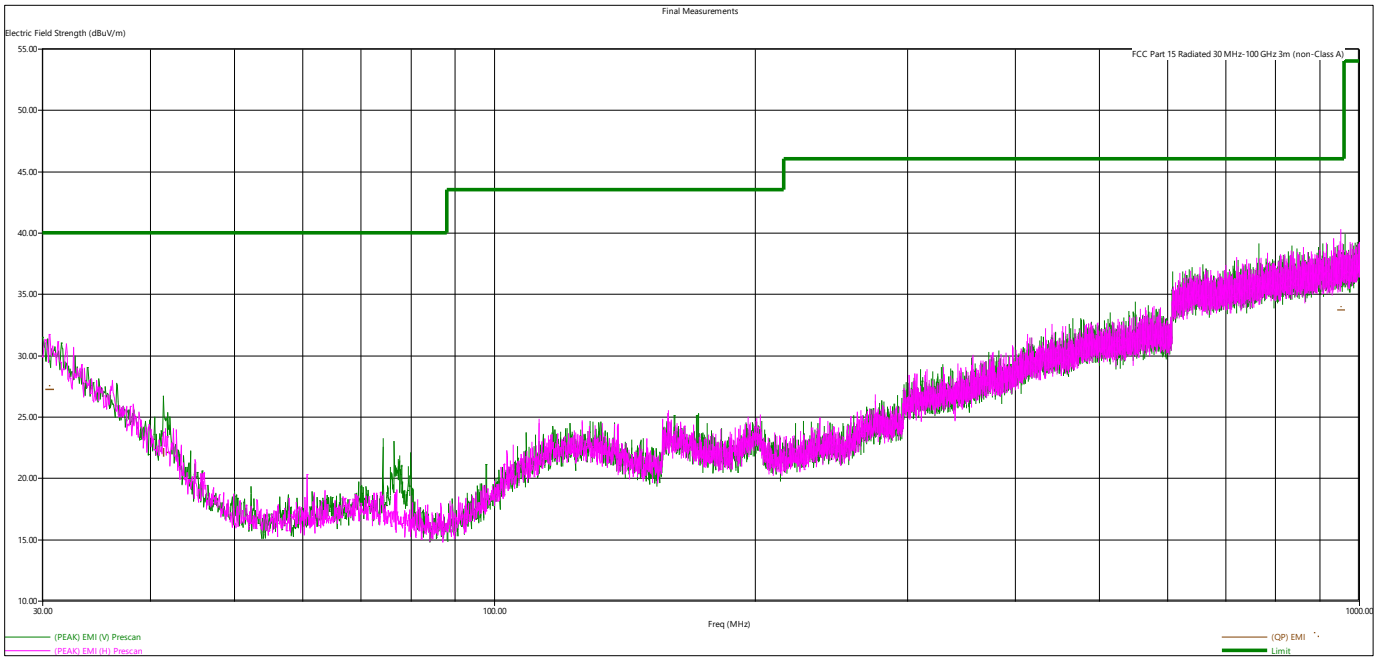


Figure 7 - Radiated Emissions Plot, Receive Mode

Figure 8 - Radiated Emissions Plot, Receive Channel

Quasi-Peak Measurements							
Frequency	**Level**	**Limit**	**Margin**	**Height**	**Angle**	**Pol**	**Channel**
MHz	**dBµV/m**	**dBµV/m**	**dB**	**cm.**	**deg.**		
30.241200	27.90	40.00	12.10	268.00	249.00	H	Low
685.924800	32.38	46.02	13.64	141.00	278.00	H	Low
902.165440	107.88	NA	NA	103.00	116.00	H	Low
950.047920	34.35	46.02	11.67	103.00	79.00	H	Low
30.529920	27.88	40.00	12.12	356.00	58.00	H	Mid
914.986720	108.05	NA	NA	100.00	58.00	H	Mid
962.962320	38.52	53.98	15.46	108.00	50.00	H	Mid
41.699760	23.26	40.00	16.74	110.00	342.00	V	High
927.812320	110.17	NA	NA	103.00	298.00	H	High
975.625920	34.09	53.98	19.89	398.00	85.00	H	High
30.454080	27.16	40.00	12.84	184.00	221.00	H	Receive
951.826080	33.65	46.02	12.37	236.00	182.00	H	Receive
41.357520	22.07	40.00	17.93	130.00	4.00	V	Receive

*Measurements taken with EUT in CW mode

Module Verification of Cellular Module (FCC ID: XMR201912BG77) investigated and found to be within 2dB of previous certification.

Peak Measurements							
Frequency	**Level**	**Limit**	**Margin**	**Height**	**Angle**	**Pol**	**Channel**
MHz	**dBµV/m**	**dBµV/m**	**dB**	**cm.**	**deg.**		
1804.36	60.31	93.084	13.67	149	47	H	Low
2706.37	44.75	73.98	29.23	122	184	H	Low
4511.088	53.55	73.98	20.43	383	122	V	Low
1830.018	55.15	88.531	18.83	145	205	H	Mid
2744.93	47.28	73.98	26.7	295	313	H	Mid
4574.938	54.16	73.98	19.82	375	304	V	Mid
5489.948	48.81	88.531	25.17	158	164	V	Mid
6405.038	47.83	88.531	26.15	179	187	V	Mid
1855.556	58.67	91.358	15.31	138	209	H	High
2783.334	48.65	73.98	25.33	461	64	H	High
4639.064	51.6	73.98	22.38	479	308	V	High
5566.65	48.43	91.358	25.55	159	169	V	High
6494.398	47.52	91.358	26.46	115	175	V	High

*Measurements taken with EUT in CW mode

Average Measurements							
Frequency	**Level**	**Limit**	**Margin**	**Height**	**Angle**	**Pol**	**Channel**
MHz	**dBµV/m**	**dBµV/m**	**dB**	**cm.**	**deg.**		
1804.36	59.76	NA	NA	149	47	H	Low
2706.37	39.79	53.98	14.19	122	184	H	Low
4511.088	50.72	53.98	3.26	383	122	V	Low
1830.018	54.26	NA	NA	145	205	H	Mid
2744.93	44.18	53.98	9.8	295	313	H	Mid
4574.938	52.12	53.98	1.86	375	304	V	Mid
5489.948	41.66	NA	NA	158	164	V	Mid
6405.038	41.23	NA	NA	179	187	V	Mid
1855.556	58.09	NA	NA	138	209	H	High
2783.334	46.01	53.98	7.97	461	64	H	High
4639.064	48.59	53.98	5.39	479	308	V	High
5566.65	40.24	NA	NA	159	169	V	High
6494.398	41.05	NA	NA	115	175	V	High

Measurements taken with average detector and EUT in CW mode

REMARKS:

1. Emission level (dBuV/m) = Raw Value (dBuV) + Correction Factor (dB)
2. Correction Factor (dB/m) = Antenna Factor (dB/m) + Cable Factor (dB)
3. The other emission levels were very low against the limit.
4. Margin value = Limit Value – Emission Level.
5. The EUT was measured in all 3 orthogonal axes. See the test setup photo exhibit for details on the orientations.

4.3 PEAK OUTPUT POWER

Test Method: ANSI C63.10, Section(s) 7.8.5

Limits of output power measurements:

§15.247 Operation within the bands 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz

For frequency hopping systems operating in the 902-928 MHz band: 1 watt for systems employing at least 50 hopping channels.

Test procedures:
Spectrum analyzer was set with a resolution bandwidth greater than occupied bandwidth and centered on the operating channel.

Deviations from test standard:
No deviation.

Test setup:
Details can be found in section 3.4 of this report.

EUT operating conditions:
Details can be found in section 2.1 of this report.

Test results:

Pass

Comments:

1. All the output power plots can be found in the Appendix C.
2. All data is in the table in results section 4.0.
3. All the measurements were found to be compliant.

4.4 BANDWIDTH

Test Method: ANSI C63.10, Section(s) 6.9.2

Limits of bandwidth measurements:

§15.247 Operation within the bands 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz

For frequency hopping systems operating in the 902-928 MHz band: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period.

Test procedures:
The bandwidth of the fundamental frequency was measured by spectrum analyzer with 3 kHz RBW and 30 kHz VBW.

The 20 dB bandwidth is defined as the bandwidth of which is higher than peak power minus 20dB. The 99% bandwidth is defined as the bandwidth that contains 99% of the power.

Deviations from test standard:
No deviation.

Test setup:
Details can be found in section 3.4 of this report.

EUT operating conditions:
Details can be found in section 2.1 of this report.

Test results:

Pass

Comments:
1. All the bandwidth plots can be found in the Appendix C.
2. All data is in the table in results section 4.0.
3. All the measurements were found to be compliant.

4.5 BANDEDGES

Test Method: ANSI C63.10, Section(s) 6.10.6

Limits of band edge measurements:

§15.247 Operation within the bands 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz

For emissions outside of the allowed band of operation (902 – 928MHz), the emission level needs to be 20dB under the maximum fundamental field strength. However, if the emissions fall within one of the restricted bands from 15.205 the field strength levels need to be under that of the limits in 15.209.

Test procedures:
The EUT was tested in the same method as described in section *4.4 - Bandwidth*. The resolution bandwidth was set to 100kHz and the EMI receiver was used to scan from the band edge to the fundamental frequency with a quasi-peak detector. The highest emissions level beyond the band edge was measured and recorded. For restricted band edge measurements, the unit was tested to the same method as section 4.2 of this report.

Deviations from test standard:
No deviation.

Test setup:
Details can be found in section 3.4 of this report.

EUT operating conditions:
Details can be found in section 2.1 of this report.

Test results:

Pass

Comments:

1. All the band edge plots can be found in the Appendix C.
2. All data is in the table in results section 4.0.
3. If the device falls under FCC Part 15.247 (Details can be found in summary of test results), compliance is shown in the unrestricted band edges by showing minimum delta of 20 dB between peak and the band edge.
4. The restricted band edge compliance is shown by comparing to the general limit defined in Part 15.209. The limit shown in the graph accounts for the antenna gain of the device.

4.6 CARRIER FREQUENCY SEPARATION, NUMBER OF HOPPING CHANNELS, TIME OF OCCUPANCY

Test Method: ANSI C63.10, Section 7.8.2, 7.8.3, 7.8.4

Limits for Time of Occupancy:

§15.247 Operation within the bands 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz

(1)(i) Average time of occupancy on any frequency, not to exceed 0.4 seconds within a 10 second period.

Limits for Time of Number of Hopping Channels:

§15.247 Operation within the bands 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz

(1)(i) For frequency hopping systems operating in the 902-928 MHz band: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping frequencies

Limits for Carrier Frequency Separation:

§15.247 Operation within the bands 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz

(1) Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater.

Test procedures:
The method from KDB 558074 D01 v05

Test setup:
Details can be found in section 3.4 of this report.

EUT operating conditions:
Details can be found in section 2.1 of this report.

.

Test results:

Pass

Comments:

1. All the plots can be found in the Appendix C.
2. All the measurements were found to be compliant.
3. The measurements are reported on the graph.

APPENDIX A: SAMPLE CALCULATION

Field Strength Calculation

The field strength is calculated by adding the Antenna Factor and Cable Factor, and subtracting the Amplifier Gain (if any) from the measured reading. The basic equation with a sample calculation is as follows:
FS = RA + AF – (-CF + AG) + AV

where FS = Field Strength

RA = Receiver Amplitude

AF = Antenna Factor

CF = Cable Attenuation Factor

AG = Amplifier Gain

AV = Averaging Factor (if applicable)

Assume a receiver reading of 55 dBμV is obtained. The Antenna Factor of 12 and a Cable Factor of 1.1 is added. The Amplifier Gain of 20 dB is subtracted, giving a field strength of 48.1 dBμV/m.

FS = 55 + 12 – (-1.1 + 20) + 0 = 48.1 dBμV/m

The 48.1 dBμV/m value can be mathematically converted to its corresponding level in μV/m.

Level in μV/m = Common Antilogarithm [(48.1 dBμV/m)/20]= 254.1 μV/m

AV is calculated by the taking the 20*log(T_{on}/100) where T_{on} is the maximum transmission time in any 100ms window.

EIRP Calculations

In cases where direct antenna port measurement is not possible or would be inaccurate, output power is measured in EIRP. The maximum field strength is measured at a specified distance and the EIRP is calculated using the following equation;

EIRP (Watts) = [Field Strength (V/m) x antenna distance (m)]^2 / 30

Power (watts) = 10^[Power (dBm)/10] / 1000

Voltage (dBµV) = Power (dBm) + 107 (for 50Ω measurement systems)

Field Strength (V/m) = 10^[Field Strength (dBµV/m) / 20] / 10^6

Gain = 1 (numeric gain for isotropic radiator)

Conversion from 3m field strength to EIRP (d=3):

EIRP = [FS(V/m) x d^2]/30 = FS [0.3] for d = 3

EIRP(dBm) = FS(dBµV/m) – 10(log 10^9)+ 10log[0.3] = FS(dBµV/m) - 95.23

10log(10^9) is the conversion from micro to milli

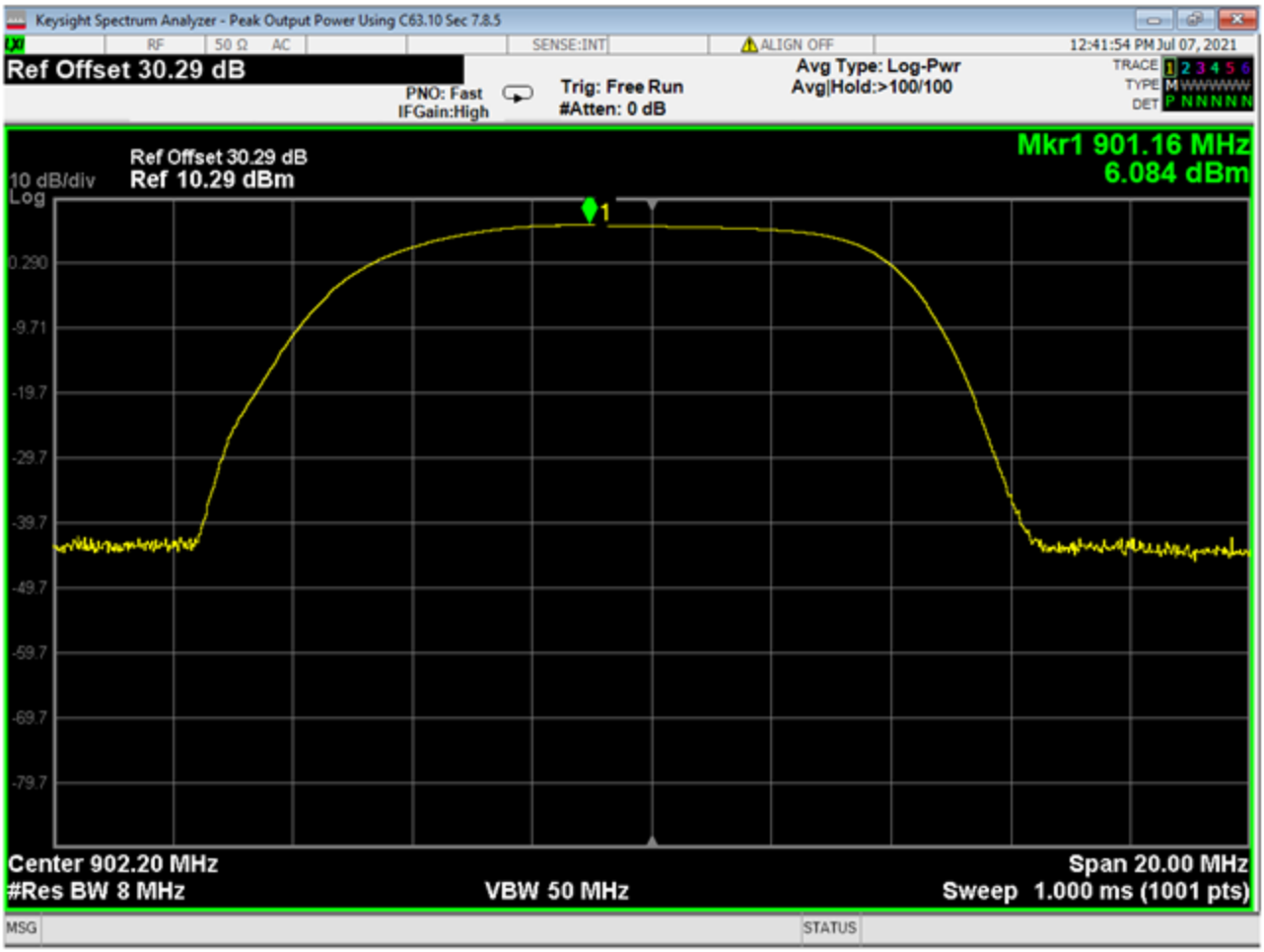
APPENDIX B – MEASUREMENT UNCERTAINTY

Where relevant, the following measurement uncertainty levels have been for tests performed in this test report:

Test	Frequency Range	Uncertainty Value (dB)
Radiated Emissions, 3m	30MHz - 1GHz	3.82
Radiated Emissions, 3m	1GHz - 18GHz	4.44
Emissions limits, conducted	30MHz – 18GHz	±3.30 dB

Expanded uncertainty values are calculated to a confidence level of 95%.

APPENDIX C – GRAPHS AND TABLES

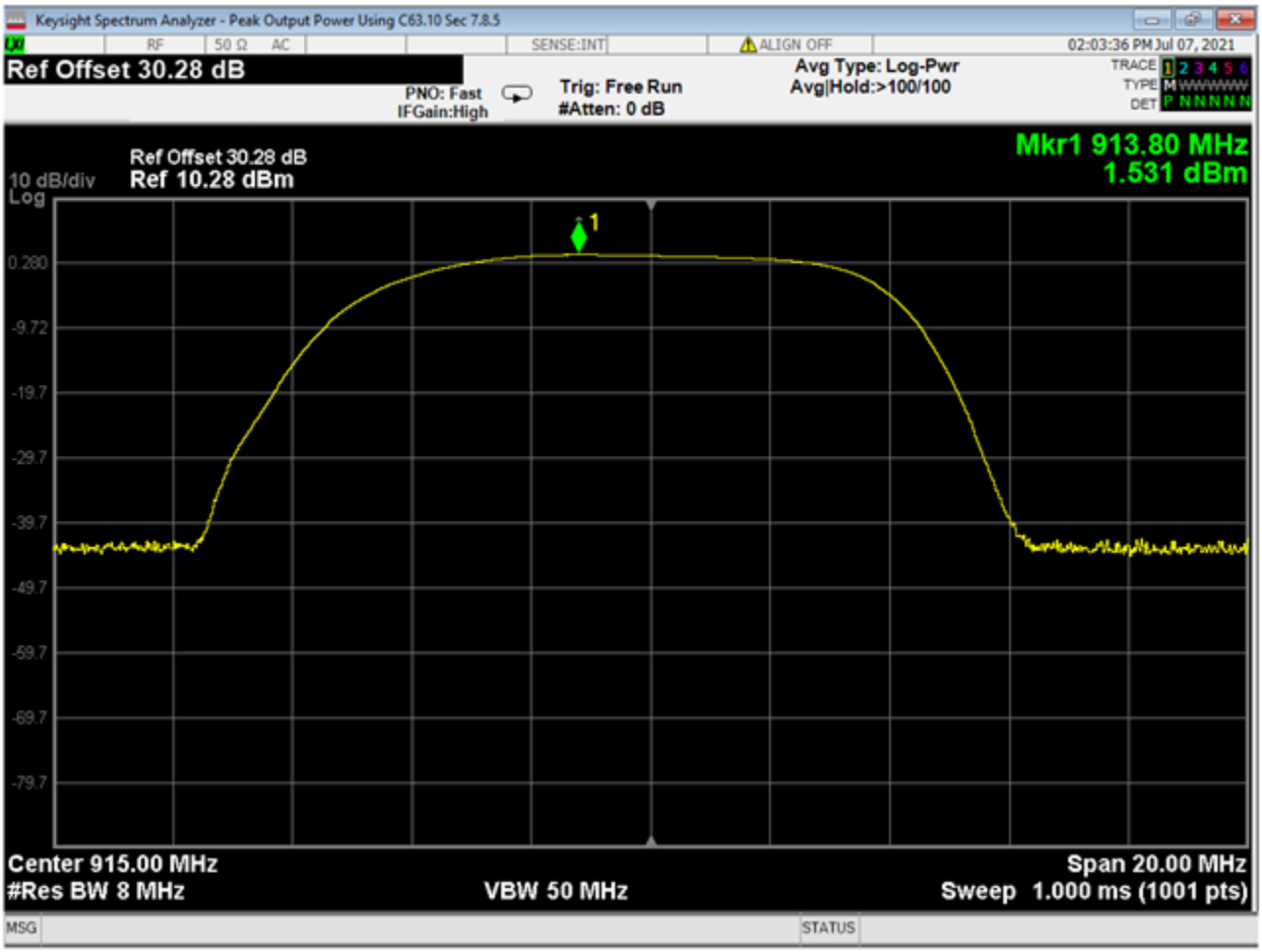


01 Peak Output Power, Low

Transducer and Cable Corrections included in Ref Offset

Plots show corrected Radiated Field Strength measurement taken at 3m test distance

Peak Output Power EIRP = Field Strength + 107 – 95.23

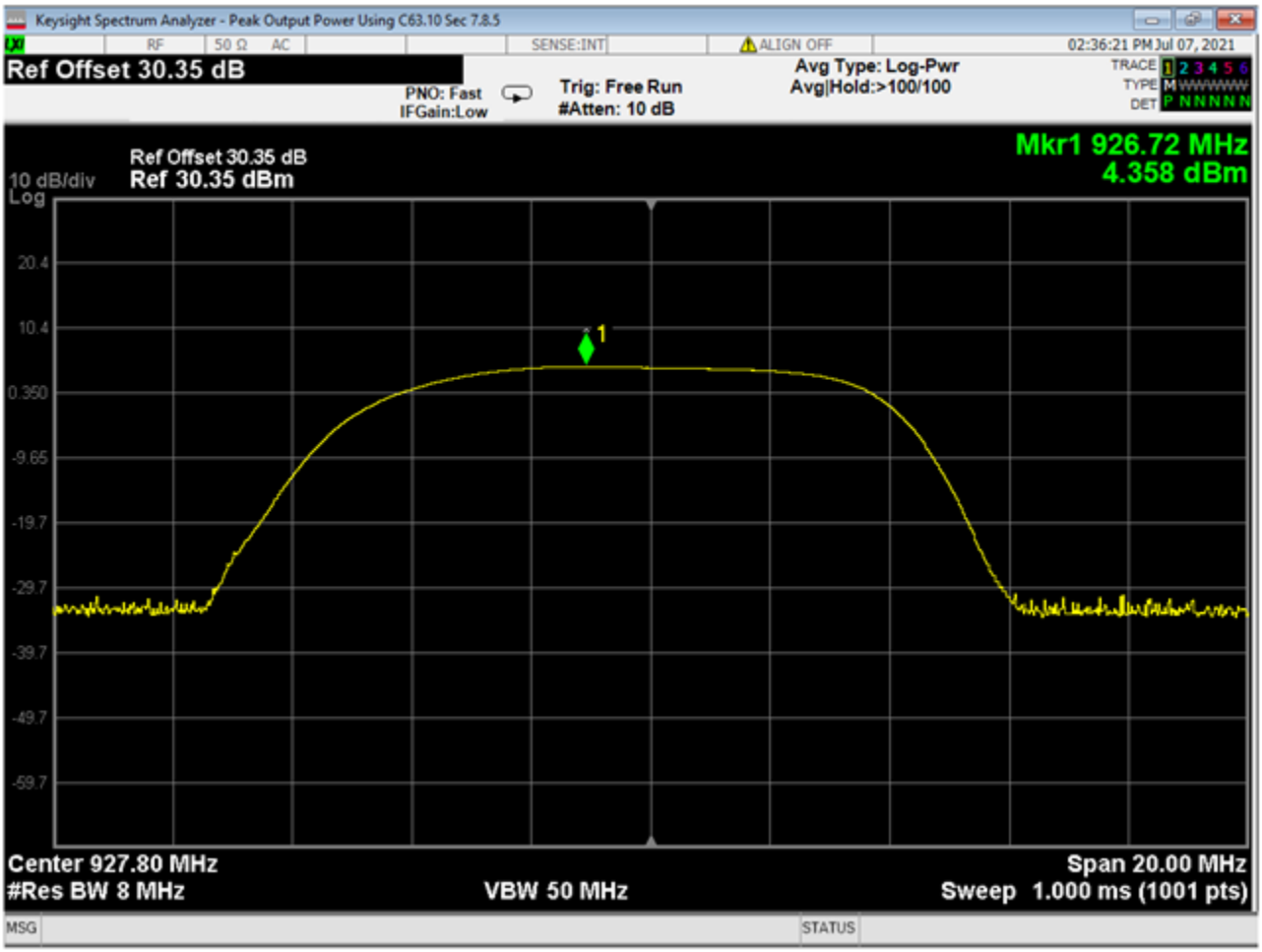


02 Peak Output Power, Mid

Transducer and Cable Corrections included in Ref Offset

Plots show corrected Radiated Field Strength measurement taken at 3m test distance

Peak Output Power EIRP = Field Strength + 107 – 95.23

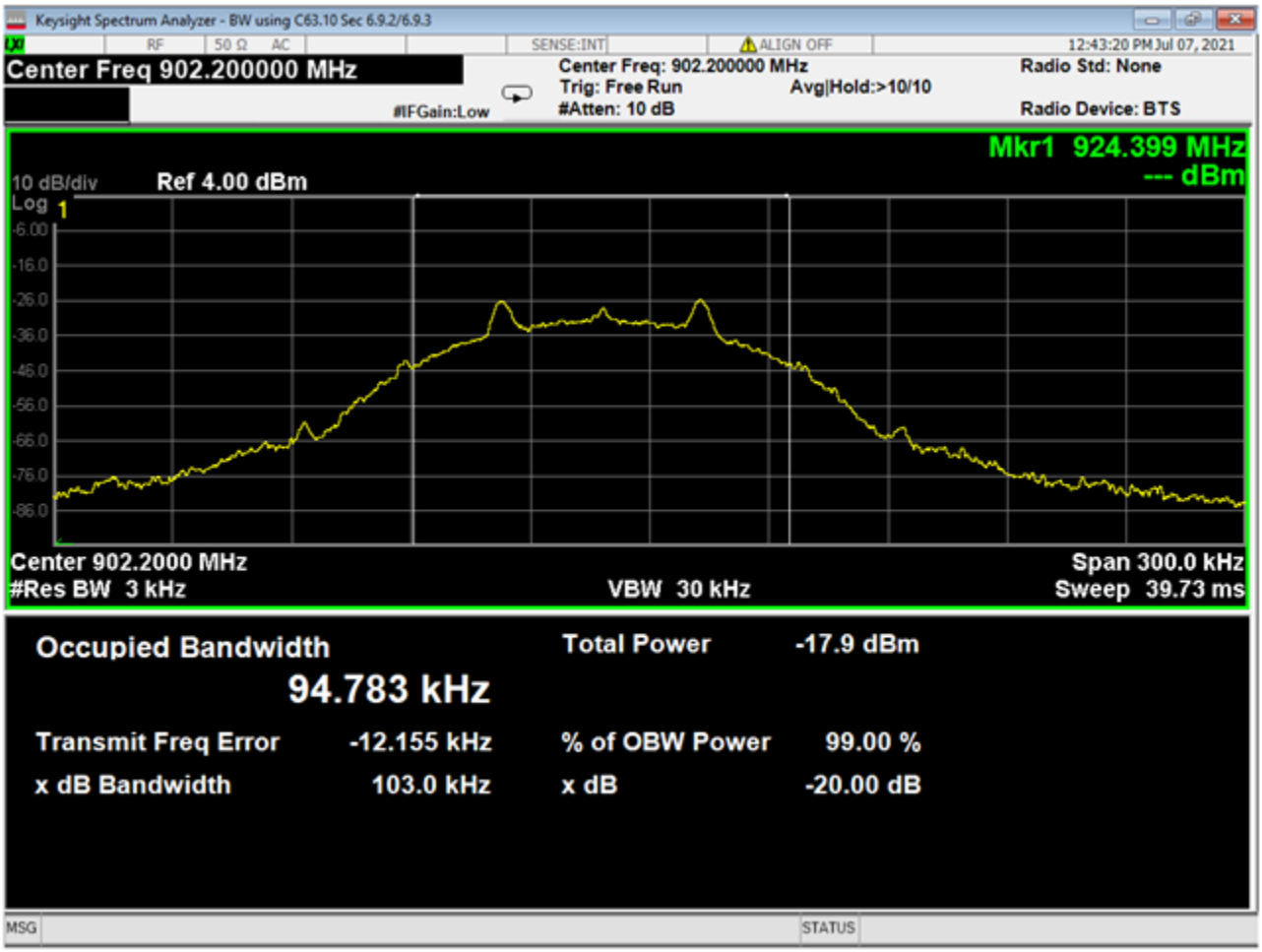


03 Peak Output Power, High

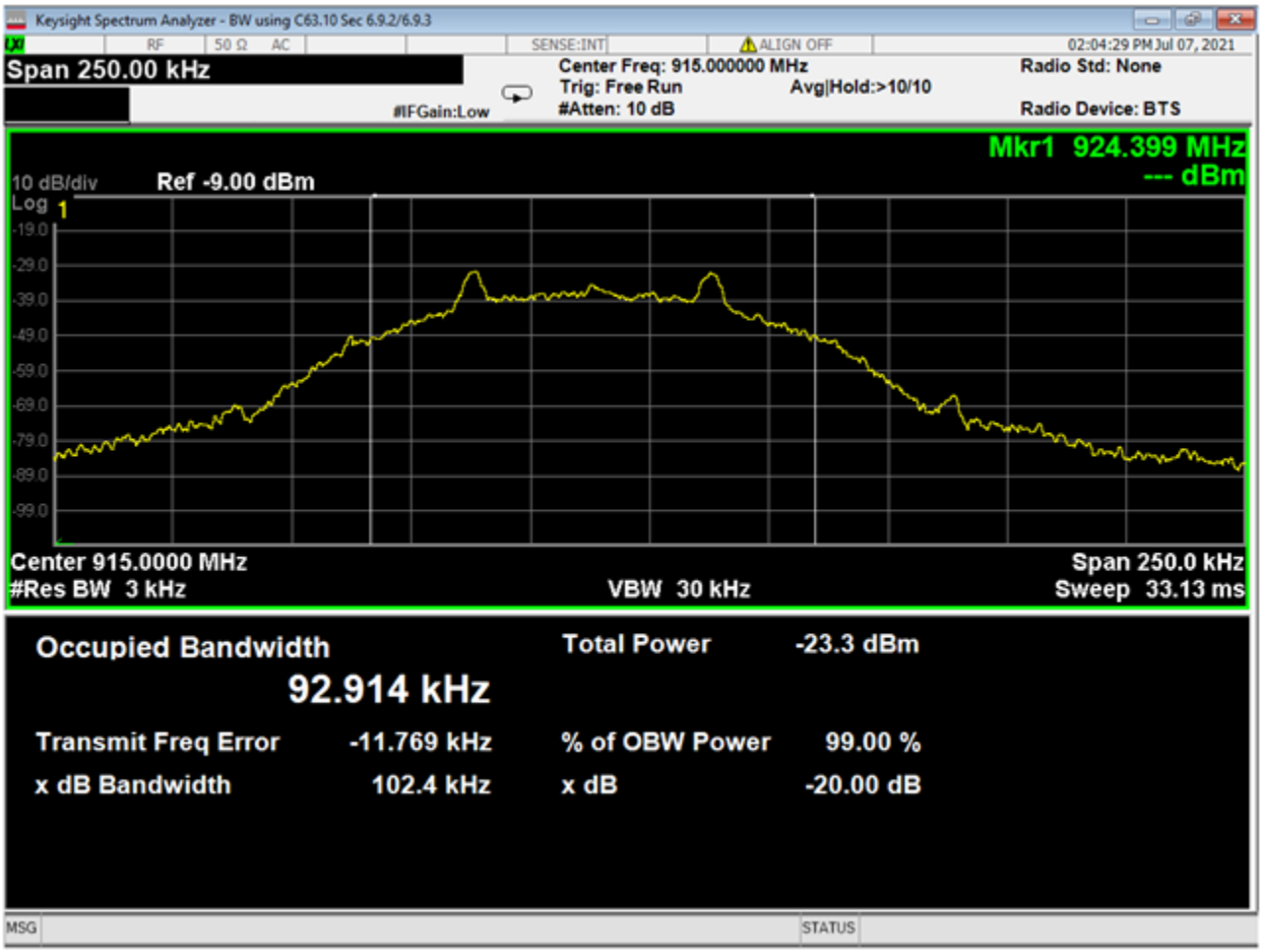
Transducer and Cable Corrections included in Ref Offset

Plots show corrected Radiated Field Strength measurement taken at 3m test distance

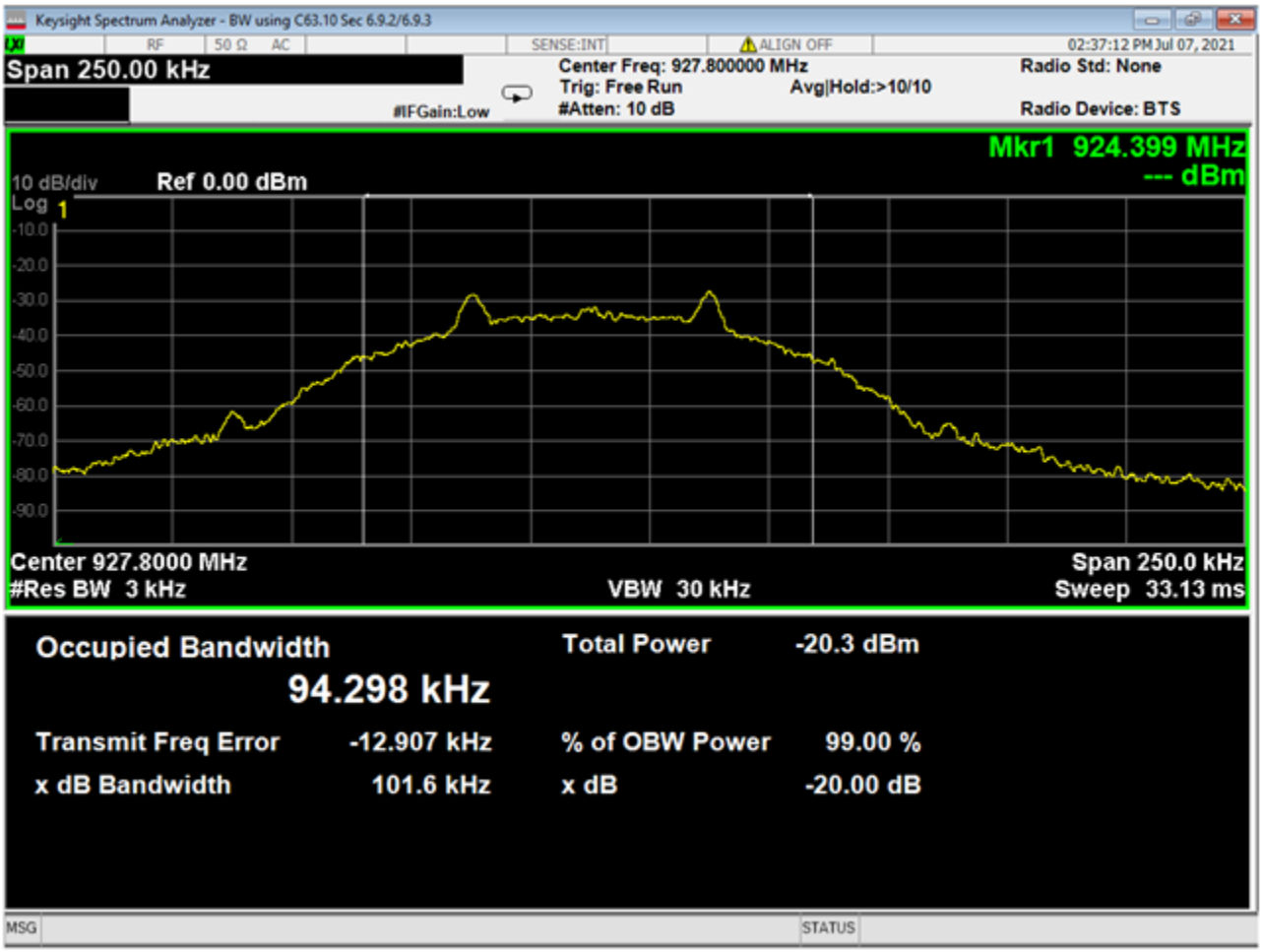
Peak Output Power EIRP = Field Strength + 107 – 95.23



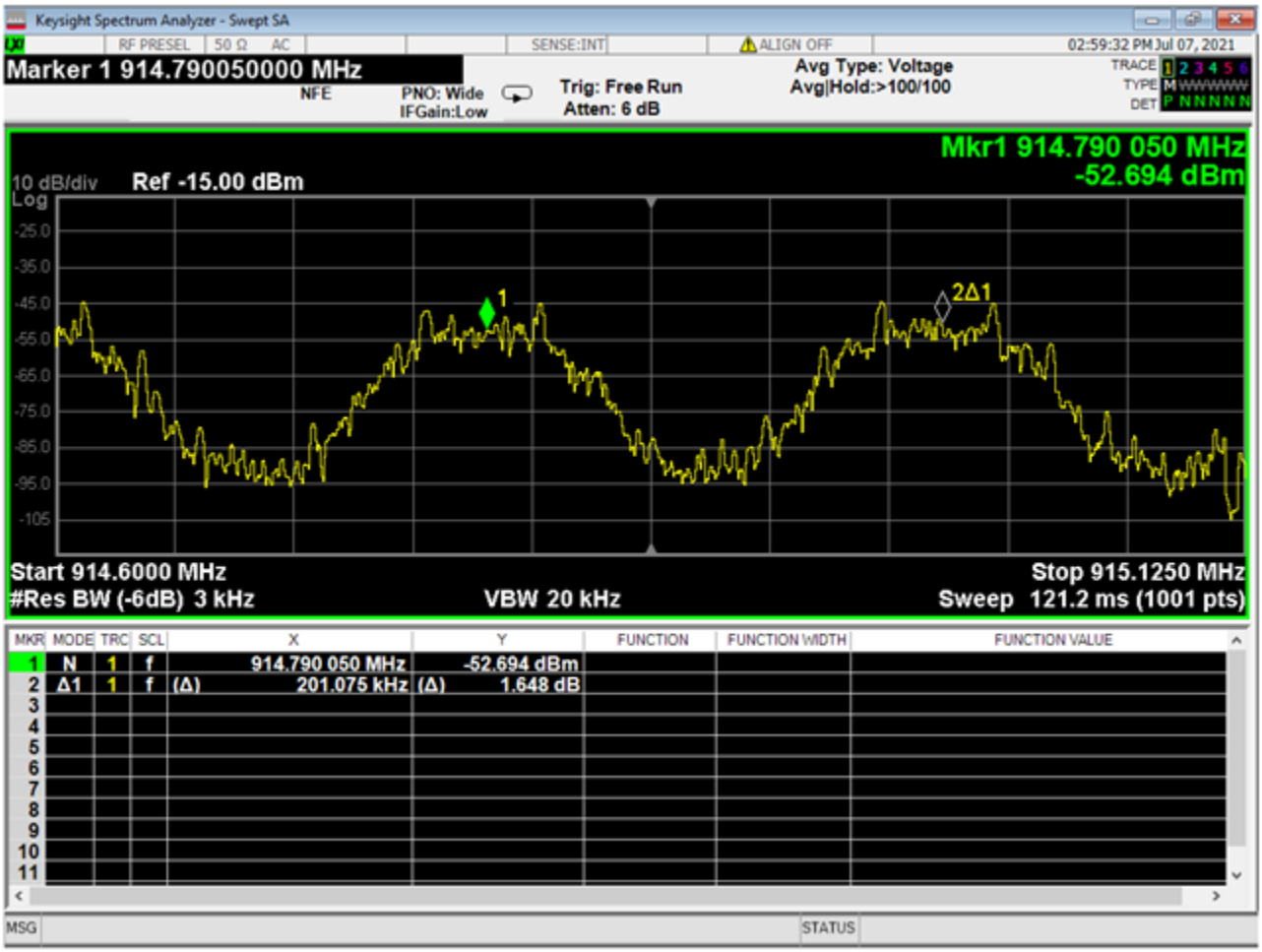
04 OBW-20dB, Low



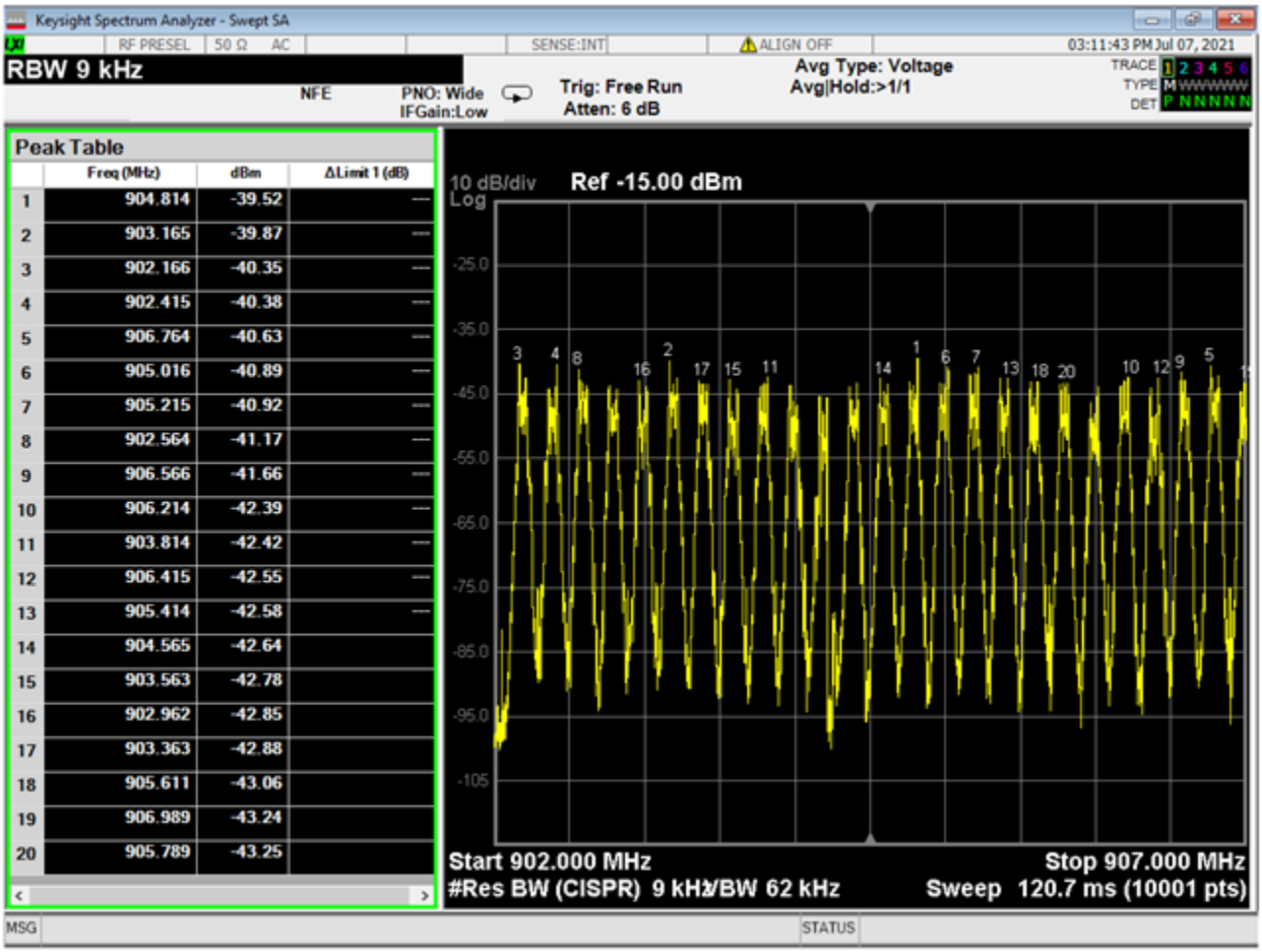
05 OBW-20dB, Mid



06 OBW-20dB, High

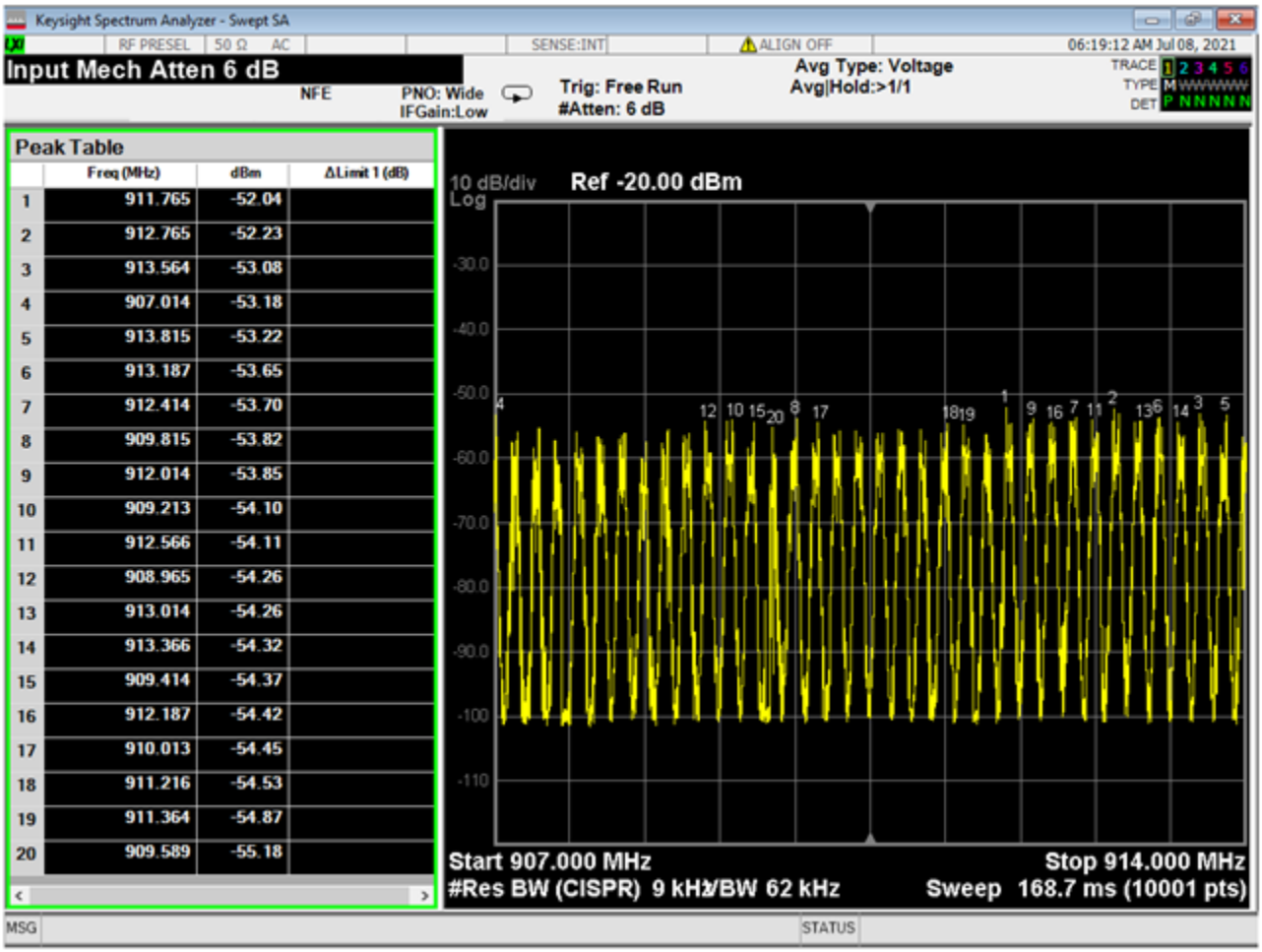


07 Channel Separation



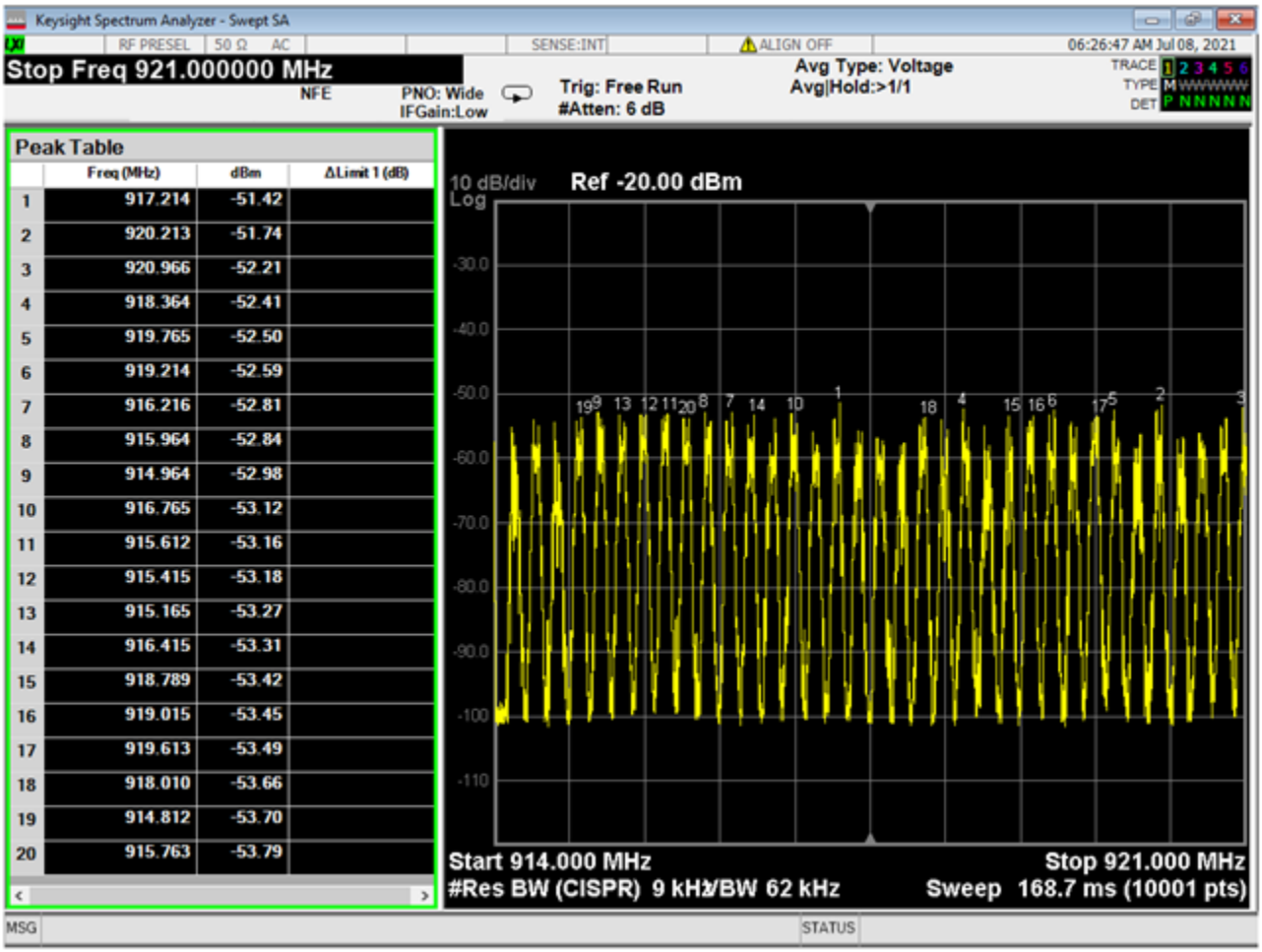
08 Number of Channels 902 - 907, 25 channels

Incomplete list of channels please see other pictures in Appendix C



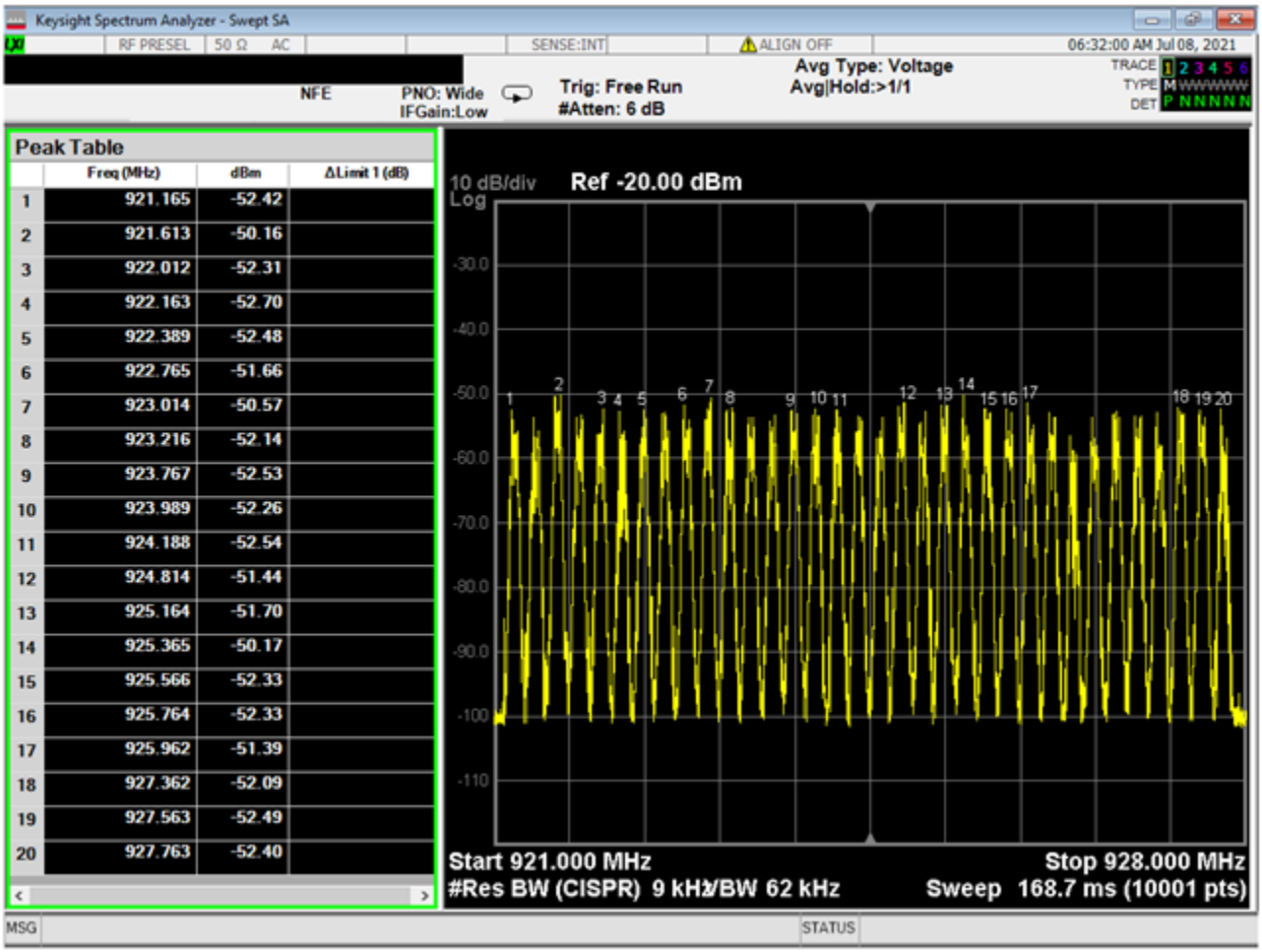
09 Number of Channels 907 - 914, 35 channels

Incomplete list of channels please see other pictures in Appendix C



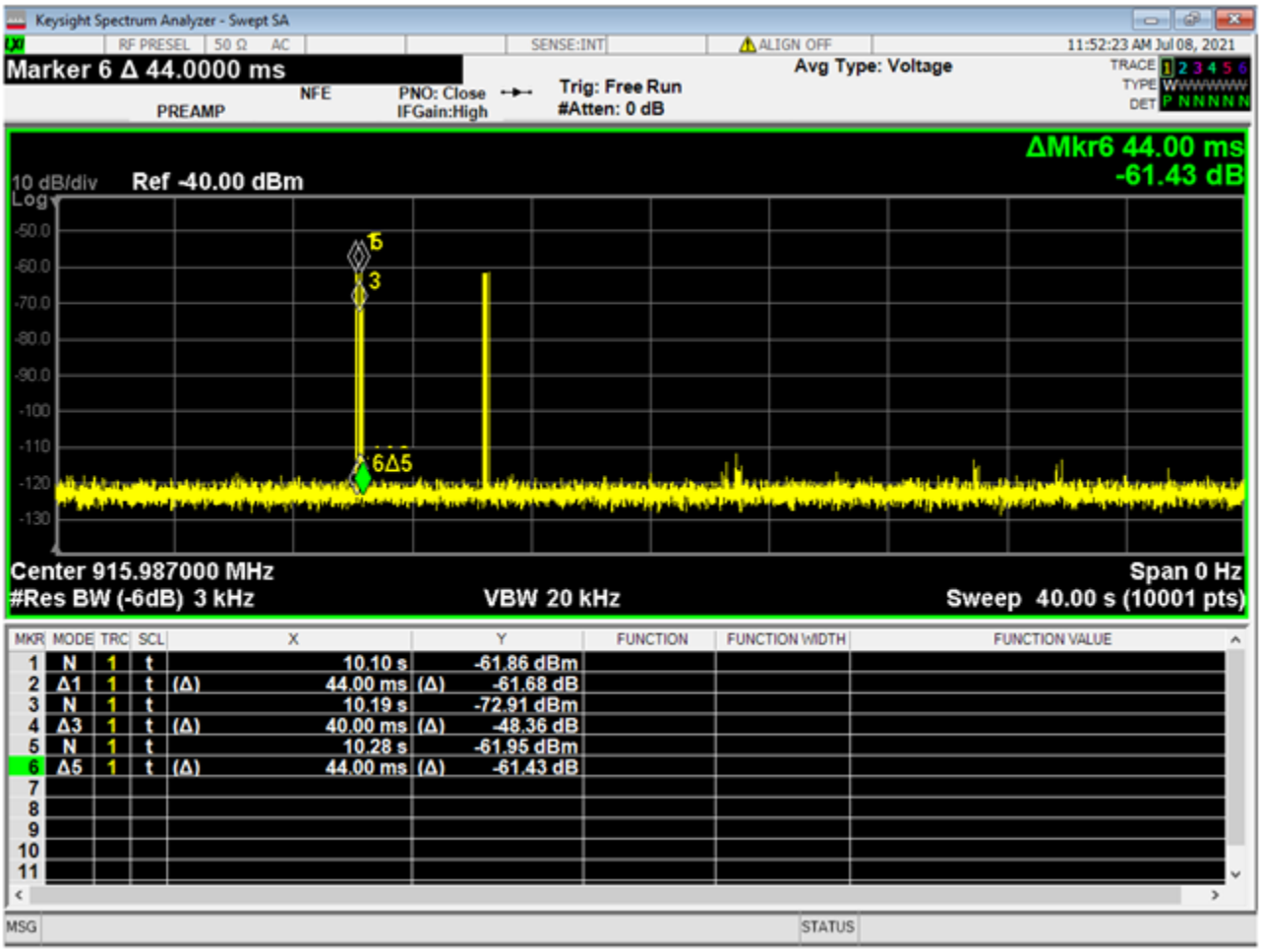
10 Number of Channels 914 - 921, 35 channels

Incomplete list of channels please see other pictures in Appendix C

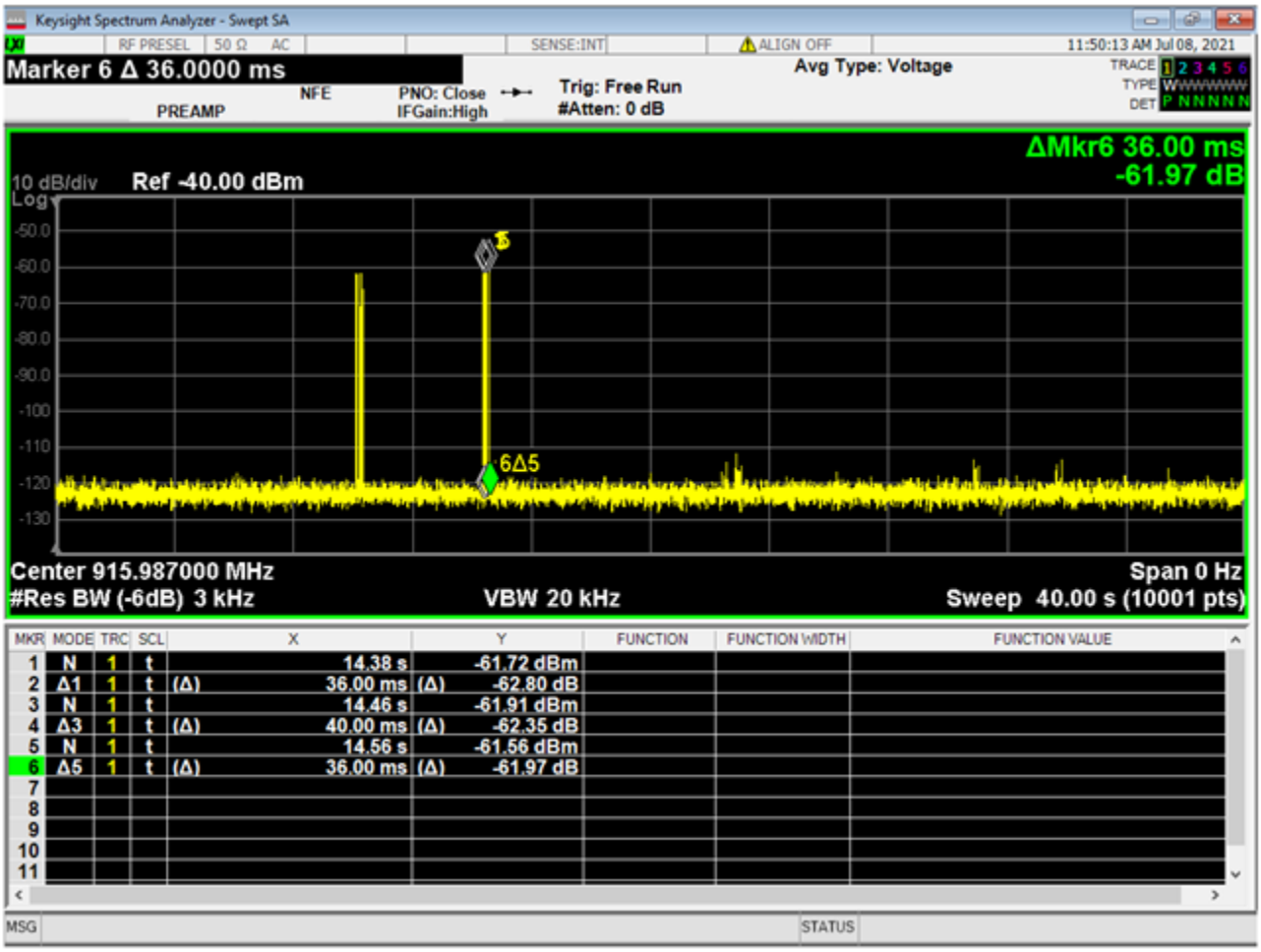


11 Number of Channels 921 - 928, 34 channels

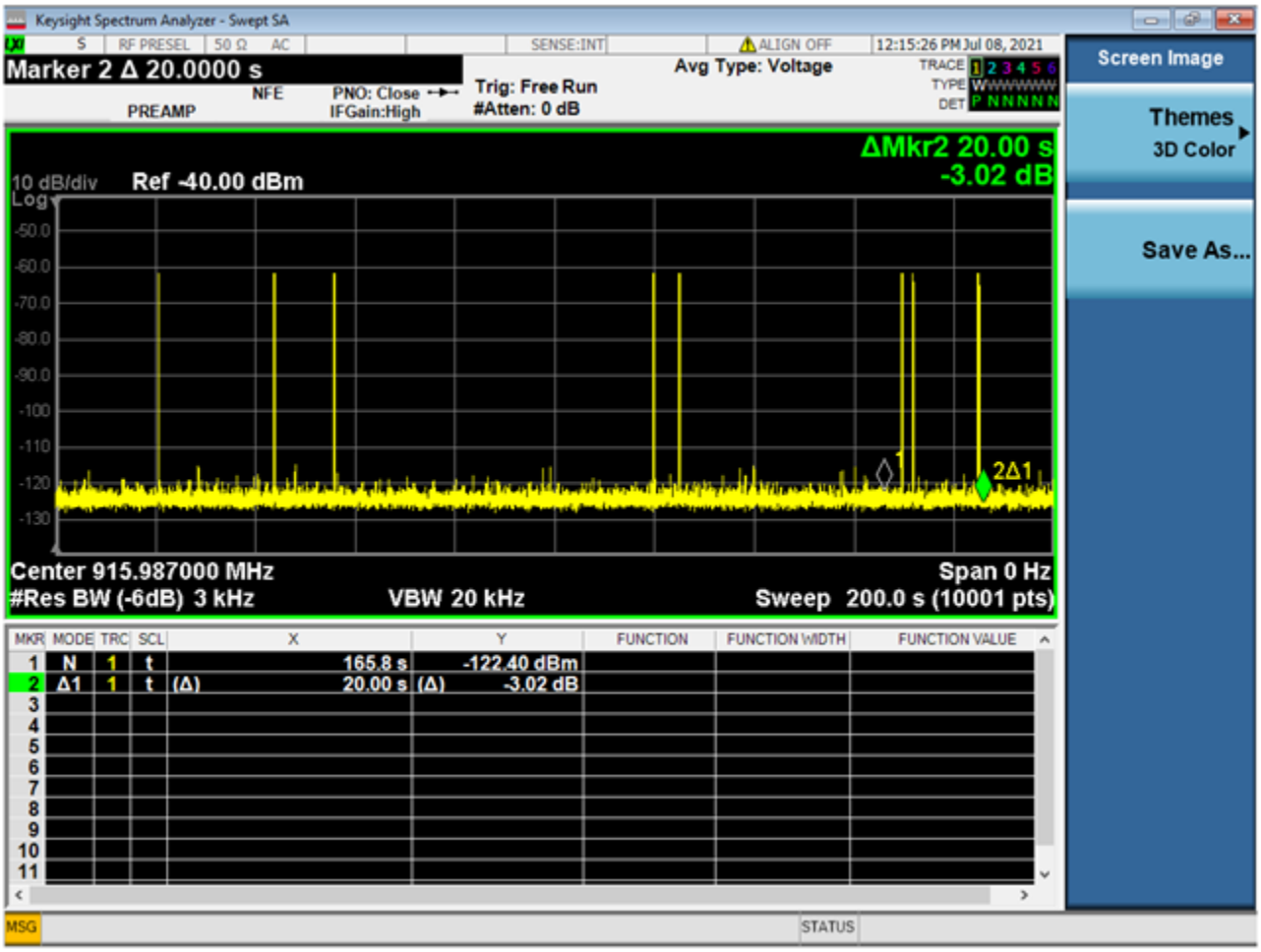
Incomplete list of channels please see other pictures in Appendix C



12 Time of Occupancy 40 Seconds (1)



13 Time of Occupancy 40 Seconds (2)



14 200s dwell time, 3 Signals within 20 Secs

Total dwell time was taken using worst case signal ON time.

REPORT END