



Test Report Serial Number:

45461681 R2.0

Test Report Date:

1 September 2021

Project Number:

1547

EMC Test Report - New Certification

Applicant:



Zenner USA
15280 Addison Rs
Suite 240
Addison, TX, 75001, USA

FCC ID:

2ACOA-GM3

Product Model Number / HVIN

100-0027-001

100-0028-001

IC Registration Number

26631-GM3

Product Marketing Name / PMN

Stealth Reader

In Accordance With:

CFR Title 47, Part 15 Subpart C (§15.247), Part 15 Subpart B

Digital Transmission System (DTS)

RSS-Gen, RSS-247 Issue 2

Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices

Approved By:

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Canada



Test Lab Certificate: 2470.01



**Industry
Canada**

IC Registration 3874A



FCC Registration: CA3874

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Table of Contents

1.0 DOCUMENT CONTROL.....	5
2.0 CLIENT AND DUT INFORMATION	6
3.0 SCOPE.....	7
4.0 TEST SUMMARY.....	8
5.0 NORMATIVE REFERENCES	10
6.0 FACILITIES AND ACCREDITATIONS	11
7.0 OCCUPIED BANDWIDTH	12
8.0 DTS BANDWIDTH	26
9.0 20DB BANDWIDTH	31
10.0A ANTENNA PORT CONDUCTED POWER, (DTS)	42
10.0B ANTENNA PORT CONDUCTED POWER, (DSS)	48
11.0 POWER SPECTRAL DENSITY.....	59
12.0 FHSS NUMBER OF HOPPING CHANNELS.....	64
13.0 FHSS CHANNEL SEPARATION	72
14.0 FHSS TIME OF OCCUPANCY.....	77
15.0 CONDUCTED SPURIOUS EMISSIONS -BAND EDGE.....	85
16.0 CONDUCTED SPURIOUS EMISSIONS	95
17.0 RADIATED TX SPURIOUS EMISSIONS, RESTRICTED BAND	97
18.0 RADIATED RX SPURIOUS EMISSIONS	99
APPENDIX A – TEST SETUP DRAWINGS	101
APPENDIX B – EQUIPMENT LIST AND CALIBRATION.....	105
APPENDIX C – MEASUREMENT INSTRUMENT UNCERTAINTY.....	106
END OF REPORT.....	106
APPENDIX D – CONDUCTED SPURIOUS EMISSIONS MEASUREMENT PLOTS	107
APPENDIX E – RADIATED TX EMISSIONS (RESTRICTED BAND) MEASUREMENT PLOTS.....	107
APPENDIX F – RADIATED RX EMISSIONS MEASUREMENT PLOTS	107

Table of Figures

Figure A.1 – Test Setup – Conducted Measurements.....	101
Figure A.2 – Test Setup Radiated Measurements 9kHzMHz – 30MHz	102
Figure A.3 – Test Setup Radiated Measurements 30MHz – 1GHz.....	103
Figure A.4 – Test Setup Radiated Measurements 30MHz – 1GHz, Signal Substitution	103
Figure A.5 – Test Setup Radiated Measurements 1 – 18GHz,	104
Figure A.6 – Test Setup Radiated Measurements 18 – 26.5GHz,	104

Table of Plots

<i>Plot 7.1 – Occupied Bandwidth, MESH, Ch 1</i>	13
<i>Plot 7.2 – Occupied Bandwidth, MESH, Ch 26</i>	14
<i>Plot 7.3 – Occupied Bandwidth, MESH, Ch 0</i>	15
<i>Plot 7.4 – Occupied Bandwidth, Drive-By, Ch 1</i>	16
<i>Plot 7.5 – Occupied Bandwidth, Drive-By, Ch 26</i>	17
<i>Plot 7.6 – Occupied Bandwidth, Drive-By, Ch 0</i>	18
<i>Plot 7.7 – Occupied Bandwidth, LoRa (FHSS), Ch 0</i>	19
<i>Plot 7.8 – Occupied Bandwidth, LoRa (FHSS), Ch 31</i>	20
<i>Plot 7.9 – Occupied Bandwidth, LoRa (FHSS), Ch 63</i>	21
<i>Plot 7.10 – Occupied Bandwidth, LoRa (DTS), Ch 0</i>	22
<i>Plot 7.11 – Occupied Bandwidth, LoRa (DTS), Ch 3</i>	23
<i>Plot 7.12 – Occupied Bandwidth, LoRa (DTS), Ch 7</i>	24
<i>Plot 8.1 – 6dB DTS Bandwidth, LoRa DTS Ch 0</i>	27
<i>Plot 8.2 – 6dB DTS Bandwidth, LoRa DTS Ch 3</i>	28
<i>Plot 8.3 – 6dB DTS Bandwidth, LoRa DTS Ch 7</i>	29
<i>Plot 9.1 – 20dB Bandwidth, MESH Ch 1</i>	32
<i>Plot 9.2 – 20dB Bandwidth, MESH Ch 26</i>	33
<i>Plot 9.3 – 20dB Bandwidth, MESH Ch 0</i>	34
<i>Plot 9.4 – 20dB Bandwidth, Drive-By Ch 1</i>	35
<i>Plot 9.5 – 20dB Bandwidth, Drive-By Ch 26</i>	36
<i>Plot 9.6 – 20dB Bandwidth, Drive-By Ch 0</i>	37
<i>Plot 9.7 – 20dB Bandwidth, Lora (FHSS) Ch 0</i>	38
<i>Plot 9.8 – 20dB Bandwidth, Lora (FHSS) Ch 31</i>	39
<i>Plot 9.9 – 20dB Bandwidth, Lora (FHSS) Ch 63</i>	40
<i>Plot 10A.1 – Conducted Power, Lora (DTS) Ch 0</i>	44
<i>Plot 10A.2 – Conducted Power, Lora (DTS) Ch 3</i>	45
<i>Plot 10A.3 – Conducted Power, Lora (DTS) Ch 7</i>	46
<i>Plot 10B.1 – Conducted Power, MESH Ch 1</i>	49
<i>Plot 10B.2 – Conducted Power, MESH Ch 26</i>	50
<i>Plot 10B.3 – Conducted Power, MESH Ch 0</i>	51
<i>Plot 10B.4 – Conducted Power, Drive-By Ch 1</i>	52
<i>Plot 10B.5 – Conducted Power, Drive-By Ch 26</i>	53
<i>Plot 10B.6 – Conducted Power, Drive-By Ch 0</i>	54
<i>Plot 10B.7 – Conducted Power, Lora DSS Ch 0</i>	55
<i>Plot 10B.8 – Conducted Power, Lora DSS Ch 31</i>	56
<i>Plot 10B.9 – Conducted Power, Lora DSS Ch 63</i>	57
<i>Plot 11.1 – Power Spectral Density, LoRa (DTS) Ch 0</i>	60
<i>Plot 11.2 – Power Spectral Density, LoRa (DTS) Ch 3</i>	61
<i>Plot 11.3 – Power Spectral Density, LoRa (DTS) Ch 7</i>	62
<i>Plot 12.1 – Number of Hopping Channels, MESH, Part 1</i>	65
<i>Plot 12.2 – Number of Hopping Channels, MESH, Part 2</i>	66
<i>Plot 12.3 – Number of Hopping Channels, Drive-By, Part 1</i>	67
<i>Plot 12.4 – Number of Hopping Channels, Drive-By, Part 2</i>	68
<i>Plot 12.5 – Number of Hopping Channels, LoRa (DSS), Part 1</i>	69
<i>Plot 12.6 – Number of Hopping Channels, LoRa (DSS), Part 2</i>	70

<i>Plot 13.1 – Channel Separation, MESH.....</i>	<i>73</i>
<i>Plot 13.2 – Channel Separation, Drive-By</i>	<i>74</i>
<i>Plot 13.3 – Channel Separation, LoRa (DSS).....</i>	<i>75</i>
<i>Plot 14.1 – Time of Occupancy, Dwell Time, MESH.....</i>	<i>78</i>
<i>Plot 14.2 – Time of Occupancy, Occupancy, MESH</i>	<i>79</i>
<i>Plot 14.3 – Time of Occupancy, Dwell Time, Drive-By.....</i>	<i>80</i>
<i>Plot 14.4 – Time of Occupancy, Occupancy, Drive-By.....</i>	<i>81</i>
<i>Plot 14.5 – Time of Occupancy, Dwell Time, LoRa (DSS)</i>	<i>82</i>
<i>Plot 14.6 – Time of Occupancy, Occupancy, LoRa (DSS)</i>	<i>83</i>
<i>Plot 15.1 – Conducted Spurious Emissions, Lower Band Edge, MESH Ch1.....</i>	<i>86</i>
<i>Plot 15.2 – Conducted Spurious Emissions, Upper Band Edge, MESH Ch0.....</i>	<i>87</i>
<i>Plot 15.3 – Conducted Spurious Emissions, Lower Band Edge, Drive-By Ch1</i>	<i>88</i>
<i>Plot 15.4 – Conducted Spurious Emissions, Upper Band Edge, Drive-By Ch0</i>	<i>89</i>
<i>Plot 15.5 – Conducted Spurious Emissions, Lower Band Edge, Lora (DSS) Ch0</i>	<i>90</i>
<i>Plot 15.6 – Conducted Spurious Emissions, Upper Band Edge, Lora (DSS) Ch63</i>	<i>91</i>
<i>Plot 15.7 – Conducted Spurious Emissions, Lower Band Edge, LoRa (DTS) Ch0.....</i>	<i>92</i>
<i>Plot 15.8 – Conducted Spurious Emissions, Upper Band Edge, LoRa (DTS) Ch7</i>	<i>93</i>

Table of Tables

<i>Table 7.1 – Summary of Occupied Bandwidth Measurements.....</i>	<i>25</i>
<i>Table 8.1 – Summary of 6dB DTS Bandwidth Measurements</i>	<i>30</i>
<i>Table 9.1 – Summary of 20dB Bandwidth Measurements,</i>	<i>41</i>
<i>Table 10A.1 – Summary of Conducted Power Measurements.....</i>	<i>47</i>
<i>Table 10B.1 – Summary of Conducted Power Measurements, (DSS).....</i>	<i>58</i>
<i>Table 11.1 – Summary of Power Spectral Density Measurements, (DTS)</i>	<i>63</i>
<i>Table 12.2 – Summary of FHSS Number of Hopping Channels</i>	<i>71</i>
<i>Table 13.1 – Summary of FHSS Channel Separation</i>	<i>76</i>
<i>Table 14.1 – Summary of FHSS Time of Occupancy.....</i>	<i>84</i>
<i>Table 15.1 – Summary of Conducted Spurious Emission Measurements – Band Edge,</i>	<i>94</i>
<i>Table 16.1 – Summary of Conducted Spurious Emissions, (DTS).....</i>	<i>96</i>
<i>Table 17.1 – Summary of Radiated Tx Spurious Emissions, Restricted Band.....</i>	<i>98</i>
<i>Table 19.1 – Summary of Radiated Rx Spurious Emissions</i>	<i>100</i>
<i>Table A.1 – Conducted Measurement Setup.....</i>	<i>101</i>
<i>Table A.2 – Radiated Emissions Measurement Equipment</i>	<i>102</i>
<i>Table B.1 – Equipment Calibration Information</i>	<i>105</i>

1.0 DOCUMENT CONTROL

Revision History					
Samples Tested By:		Art Voss, P.Eng.	Date(s) of Evaluation:		5 July - 25 Aug, 2021
Report Prepared By:		Art Voss, P.Eng.	Report Reviewed By:		Ben Hewson
Report Revision	Description of Revision		Revised Section	Revised By	Revision Date
0.1	Initial Draft Release		n/a	Art Voss	27 August 2021
1.0	Initial Release		n/a	Art Voss	30 August 2021
2.0	Corrected LORA DSS Ch 63 Frequency		All	Art Voss	1 September 2021

2.0 CLIENT AND DUT INFORMATION

Client Information	
Applicant Name	Zenner USA
Applicant Address	15280 Addison Rd, Suite 240
	Addison, TX, 75001
	USA
DUT Information	
Device Identifier(s):	FCC ID: 2ACOA-GM3
	ISED ID: 26631-GM3
Device Model(s) / HVIN:	100-0027-001
	100-0028-001
Device Marketing Name / PMN:	Stealth Reader
Test Sample Serial No.:	9999005
Device Type:	Digital Transceiver
FCC Equipment Class:	Digital Transmission System (DTS)
	Spread Spectrum Transmitter (DSS)
ISED Equipment Class:	Spread Spectrum/Digital Device (902-928MHz)
Transmit Frequency Range:	MESH Mode (DSS): 902-928MHz
	Drive-By Mode (DSS): 902-928MHz
	Lora Mode (DSS): 902-915MHz
	Lora Mode (DTS): 902-915MHz
Manuf. Max. Rated Output Power:	MESH Mode (DSS): 500mW (27dBm)
	Drive-By Mode (DSS): 500mW (27dBm)
	Lora Mode (DSS): 500mW (27dBm)
	Lora Mode (DTS): 100mW (20dBm)
Antenna Type and Gain:	0dBi Max*, Helical
Modulation:	FSK
DUT Power Source:	3.6 VDC Li-Metal
DUT Dimensions [LxWxH] (cm)	H x W x D: 13X13X4.5
Deviation(s) from standard/procedure:	None
Modification of DUT:	None

* Information regarding antenna type and gain provided by applicant.

3.0 SCOPE

Preface:

This Certification Report was prepared on behalf of:

Zenner USA

,(the '*Applicant*'), in accordance with the applicable Federal Communications Commission (FCC) CFR 47 and Innovation, Scientific and Economic Development (ISED) Canada rules parts and regulations (the '*Rules*'). The scope of this investigation was limited to only the equipment, devices and accessories (the '*Equipment*') supplied by the *Applicant*. The tests and measurements performed on this *Equipment* were only those set forth in the applicable *Rules* and/or the Test and Measurement Standards they reference. The *Rules* applied and the Test and Measurement Standards used during this evaluation appear in the Normative References section of this report. The limits set forth in the technical requirements of the applicable *Rules* were applied to the measurement results obtained during this evaluation and ,unless otherwise noted, these limits were used as the Pass/Fail criteria. The Pass/Fail statements made in this report apply to only the tests and measurements performed on only the *Equipment* tested during this evaluation. Where applicable and permissible, information including test and measurement data and/or results from previous evaluations of same or similar equipment, devices and/or accessories may be cited in this report.

Device Operation:

The Zenner USA Model/HVIN: 100-0027-001 & 100-0028-001 (GM3) are utility meter (gas meter) digital data transceivers operating in the 902-928MHz band. The GM3 is a hybrid device consisting of three (3) modes of Digital Spread Spectrum and one (1) mode of Digital Transmitter System. The DSS modes are MESH, Drive-By and Long Range (LoRa) operating with 20dB bandwidths of 230kHz, 400kHz and 150kHz, respectively. The MESH and Drive-By modes transmit on 50 hopping channels between 902 and 928MHz. The LoRa mode transmits on 64 hopping channels between 902 and 915MHz. The DTS mode is also a LoRa transmitter operating with a DTS bandwidth in excess of 500kHz between 902 and 915MHz. All modes modulate using FSK. Both model variants are identical with the exception of the interface cable used to connect to the metering equipment.

Requirement:

The transceivers of this *equipment* are subject to emissions evaluation in accordance with FCC: 47 CFR 2, 15C, ISED: RSS-Gen, and RSS-247. As per FCC 47 CFR §2.1093 and Health Canada Safety Code 6, an RF Exposure (MPE) evaluation is required for this *Equipment* and the results of the RF Exposure (MPE) evaluation appear in a separate report.

Application:

This is an application for a New Certification.

Scope:

The scope of this investigation is limited to the evaluation and reporting of the wanted and unwanted spurious emissions in accordance with the rule parts cited in Normative References section of this report.

4.0 TEST SUMMARY

TEST SUMMARY						
Section	Description of Test	Procedure Reference	Applicable Rule Part(s) FCC	Applicable Rule Part(s) ISCED	Test Date	Result
7.0	Occupied Bandwidth	ANSI C63.10-2013 KDB 558074 D01v05	§2.1049	RSS-Gen (6.7)	12 Aug 2021 25 Aug 2021	Pass
8.0	DTS Bandwidth	ANSI C63.10-2013 KDB 558074 D01v05	§15.247(a)(2)	RSS-Gen (6.7) RSS-247 (5.2)(a)	12 Aug 2021	Pass
9.0	20dB Bandwidth	ANSI C63.10-2013 KDB 558074 D01v05	§15.247(a)(1)(i)	RSS-Gen (6.7) RSS-247 (5.1)(c)	12 Aug 2021 25 Aug 2021	Pass
10.0	Conducted Power (Fundamental)	ANSI C63.10-2013 KDB 558074 D01v05 KDB 558074 D01v05	§2.1046 §15.247(b)(2) §15.247(b)(3)	RSS-Gen (6.12) RSS-247 (5.4)(a) RSS-247 (5.4)(d)	13 Aug 2021	Pass
11.0	Power Spectral Density	ANSI C63.10-2013 KDB 558074 D01v05	§15.247(e)	RSS-247 (5.2)(b)	13 Aug 2021	Pass
12.0	FHSS Hopping Characteristics	ANSI C63.4-2014 KDB 558074 D01v05	§15.247(a)(1)(iii)	RSS-247 (5.1)(d)	24 Aug 2021	Pass
13.0	FHSS Channel Separation	ANSI C63.4-2014 KDB 558074 D01v05	§15.247(a)(1)	RSS-247 (5.1)(b)	24 Aug 2021	Pass
14.0	FHSS Time of Occupancy	ANSI C63.4-2014 KDB 558074 D01v05	§15.247(a)(1)(iii)	RSS-247 (5.1)(d)	24 Aug 2021	Pass
15.0	Conducted Tx Spurious Emissions Band Edge	ANSI C63.10-2013 KDB 558074 D01v05	§2.1051 §15.247(d)	RSS-Gen (6.13) RSS-247 (5.5)	24 Aug 2021	Pass
16.0	Conducted Tx Spurious Emissions	ANSI C63.10-2013 KDB 558074 D01v05	§2.1051 §15.247(d)	RSS-Gen (6.13) RSS-247 (5.5)	24 Aug 2021	Pass
17.0	Radiated Tx Spurious Emissions And Restricted Band	ANSI C63.4-2014 KDB 558074 D01v05	§15.109 §15.247(d)	RSS-Gen (6.13)	5 July 2021	Pass
18.0	Radiated Rx Spurious Emissions	ANSI C63.4-2014 KDB 558074 D01v05	§15.109	RSS-Gen (7.4) ICES-003(6.2)	5 July 2021	Pass

Test Station Day Log					
Date	Ambient Temp (°C)	Relative Humidity (%)	Barometric Pressure (kPa)	Test Station	Tests Performed Section(s)
5 July 2021	24.0	47	101.4	OATS	17, 18
12 Aug 2021	25.6	18	101.9	EMC	7, 8, 9
13 Aug 2021	25.6	18	102.0	EMC	10, 11
24 Aug 2021	23.2	14	102.1	EMC	12, 13, 14, 15, 16
25 Aug 2021	22.9	15	101.7	EMC	7, 9

EMC - EMC Test Bench

OATS - Open Area Test Site

LISN - LISN Test Area

IMM - Immunity Test Area

SAC - Semi-Anechoic Chamber

TC - Temperature Chamber

ESD - ESD Test Bench

RI - Radiated Immunity Chamber

I attest that the data reported herein is true and accurate within the tolerance of the Measurement Instrument Uncertainty; that all tests and measurements were performed in accordance with accepted practices or procedures; and that all tests and measurements were performed by me or by trained personnel under my direct supervision. The results of this investigation are based solely on the test sample(s) provided by the client which were not adjusted, modified or altered in any manner whatsoever, except as required to carry out specific tests or measurements. This test report has been completed in accordance with ISO/IEC 17025.



Art Voss, P.Eng.
Technical Manager
Celltech Labs Inc.

24 August 2021
Date



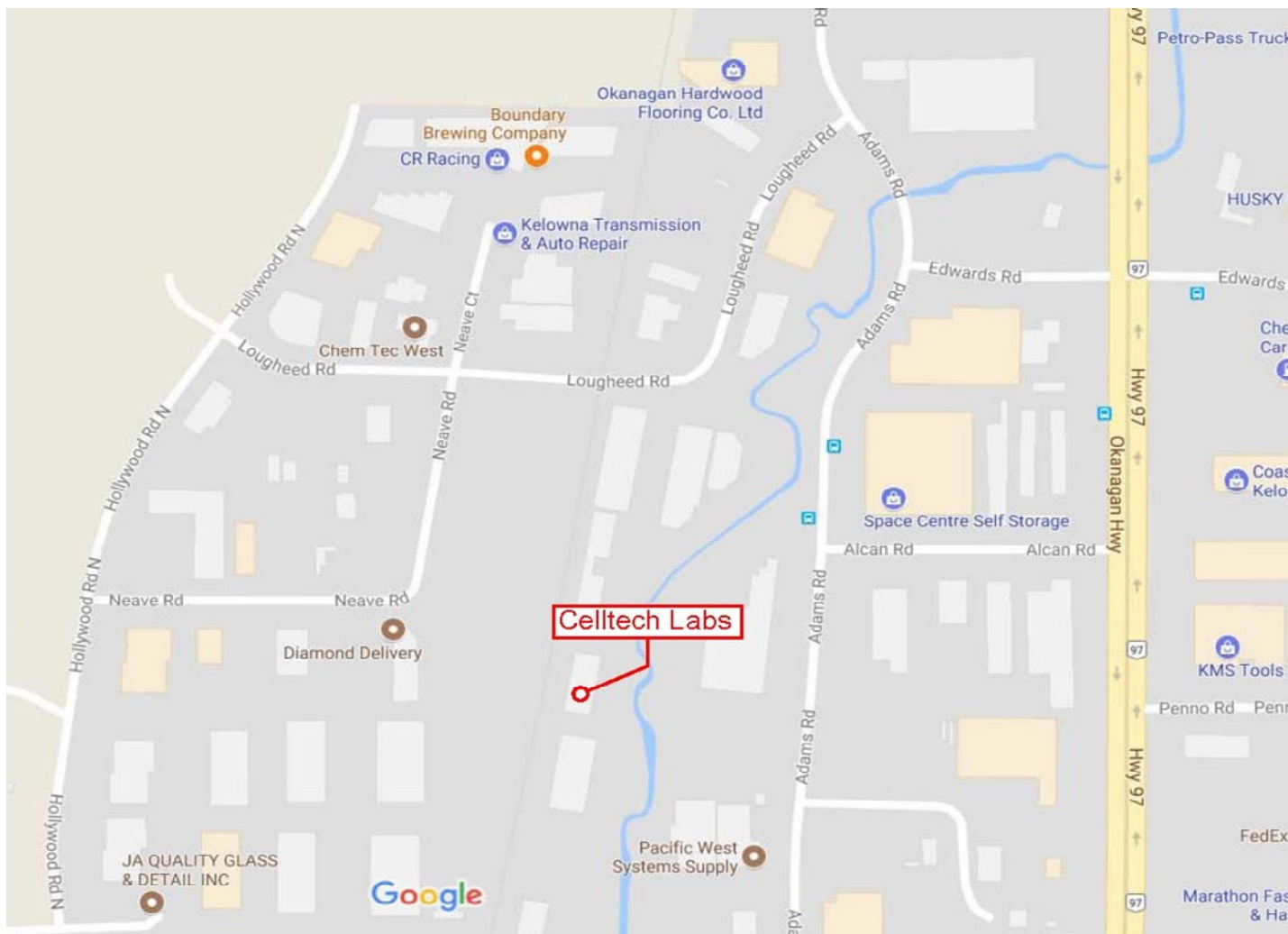
5.0 NORMATIVE REFERENCES

Normative References	
ISO/IEC 17025:2017	General requirements for the competence of testing and calibration laboratories
ANSI C63.4-2014	American National Standard of Procedures for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electric and Electronic Equipment in the Range of 9kHz to 40GHz
ANSI C63.10-2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
CFR	Code of Federal Regulations Title 47: Telecommunication Part 2: Frequency Allocations and Radio Treaty Matters; General Rules and Regulations
CFR	Code of Federal Regulations Title 47: Telecommunication Part 15: Radio Frequency Devices Sub Part C (15.247) Intentional Radiators
ISED	Innovation, Science and Economic Development Canada RSS-Gen Issue 5A1: Spectrum Management and Telecommunications Radio Standards Specification March 2019 General Requirements and Information for the Certification of Radiocommunication Equipment
ISED	Innovation, Science and Economic Development Canada Spectrum Management and Telecommunications Radio Standards Specification RSS-247 Issue 2: Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) February 2017 and Licensed-Exempt Local Area Network (LE_LAN) Devices
FCC KDB 558074 D01v05r02	OET Major Guidance Publications, Knowledge Data Base Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under Section 15.247

6.0 FACILITIES AND ACCREDITATIONS

Facility and Accreditation:

The facilities used to evaluate this device outlined in this report are located at 21-364 Lougheed Road, Kelowna, British Columbia, Canada V1X 7R8. The radiated emissions site (OATS) conforms to the requirements set forth in ANSI C63.4 and is filed and listed with the FCC under Test Firm Registration Number CA3874 and Innovation, Science and Economic Development Canada under Test Site File Number ISED 3874A. Celltech is accredited to ISO 17025, through accrediting body A2LA and with certificate 2470.01.



7.0 OCCUPIED BANDWIDTH

Test Procedure

Normative	FCC 47 CFR §2.1046, §15.247(b)(3), RSS-Gen (6.1.2), RSS-247 (5.4)(d),
Reference	KDB 558074 (8.3.2.1), ANSI C63.10 (6.9.3)

General Procedure

KDB 558074 (8.3.2.1)	8.3.2.1 General Section 15.247 permits the maximum conducted (average) output power to be measured as an alternative to the maximum peak conducted output power for demonstrating compliance to the limit. When this option is exercised, the measured power is to be referenced to the OBW rather than the DTS bandwidth.
C63.10 (6.9.3)	6.9.3 Occupied bandwidth—power bandwidth (99%) measurement procedure The occupied bandwidth is the frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers are each equal to 0.5% of the total mean power of the given emission. The following procedure shall be used for measuring 99% power bandwidth: - The instrument center frequency is set to the nominal EUT channel center frequency. The frequency span for the spectrum analyzer shall be between 1.5 times and 5.0 times the OBW. - The nominal IF filter bandwidth (3 dB RBW) shall be in the range of 1% to 5% of the OBW, and VBW shall be approximately three times the RBW, unless otherwise specified by the applicable requirement. - Set the reference level of the instrument as required, keeping the signal from exceeding the maximum input mixer level for linear operation. In general, the peak of the spectral envelope shall be more than $[10 \log (OBW/RBW)]$ below the reference level. Specific guidance is given in 4.1.5.2. - Step a) through step c) might require iteration to adjust within the specified range. - Video averaging is not permitted. Where practical, a sample detection and single sweep mode shall be used. Otherwise, peak detection and max hold mode (until the trace stabilizes) shall be used. - Use the 99% power bandwidth function of the instrument (if available) and report the measured bandwidth.

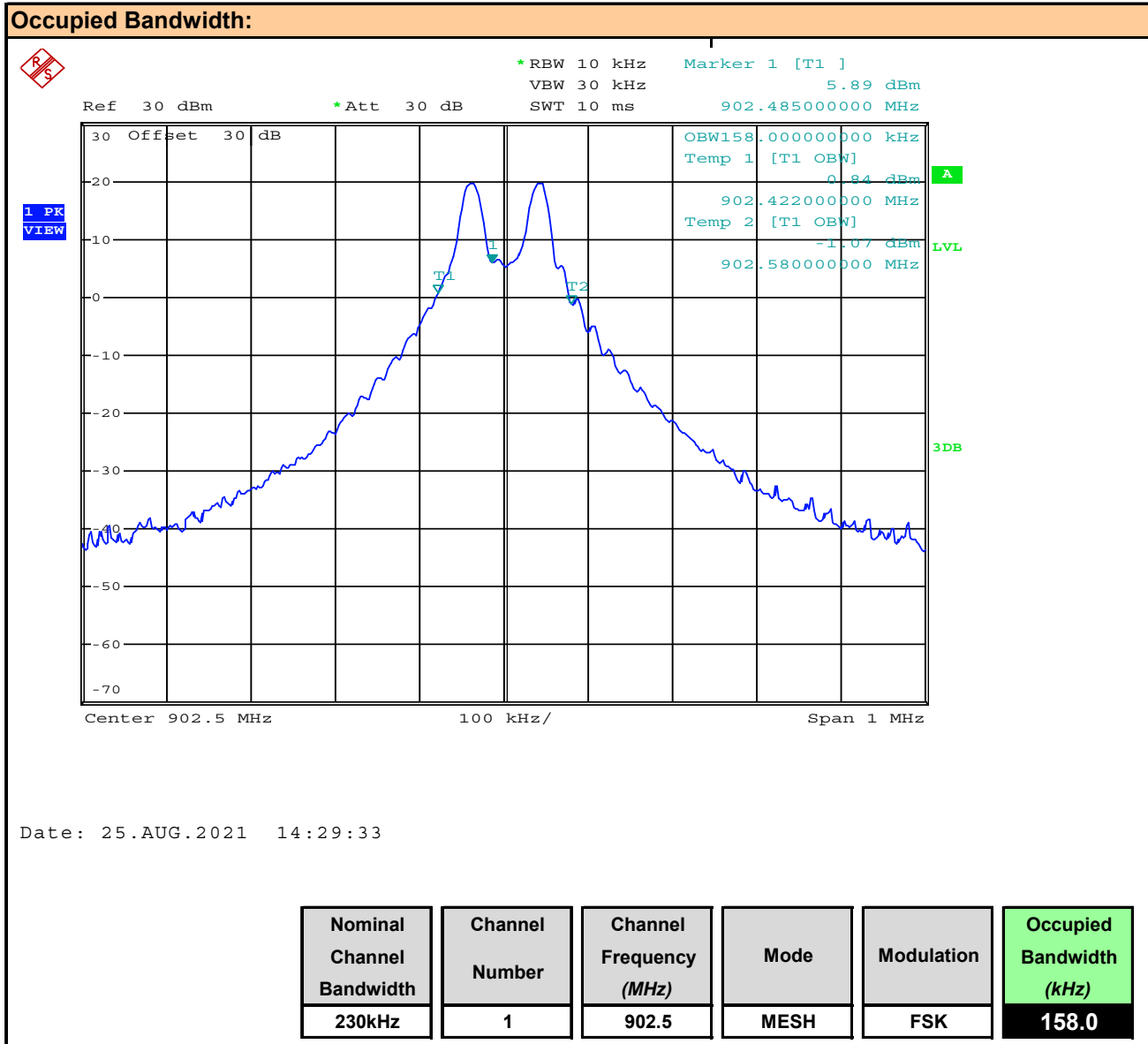
Test Setup

Appendix A - Figure A.1

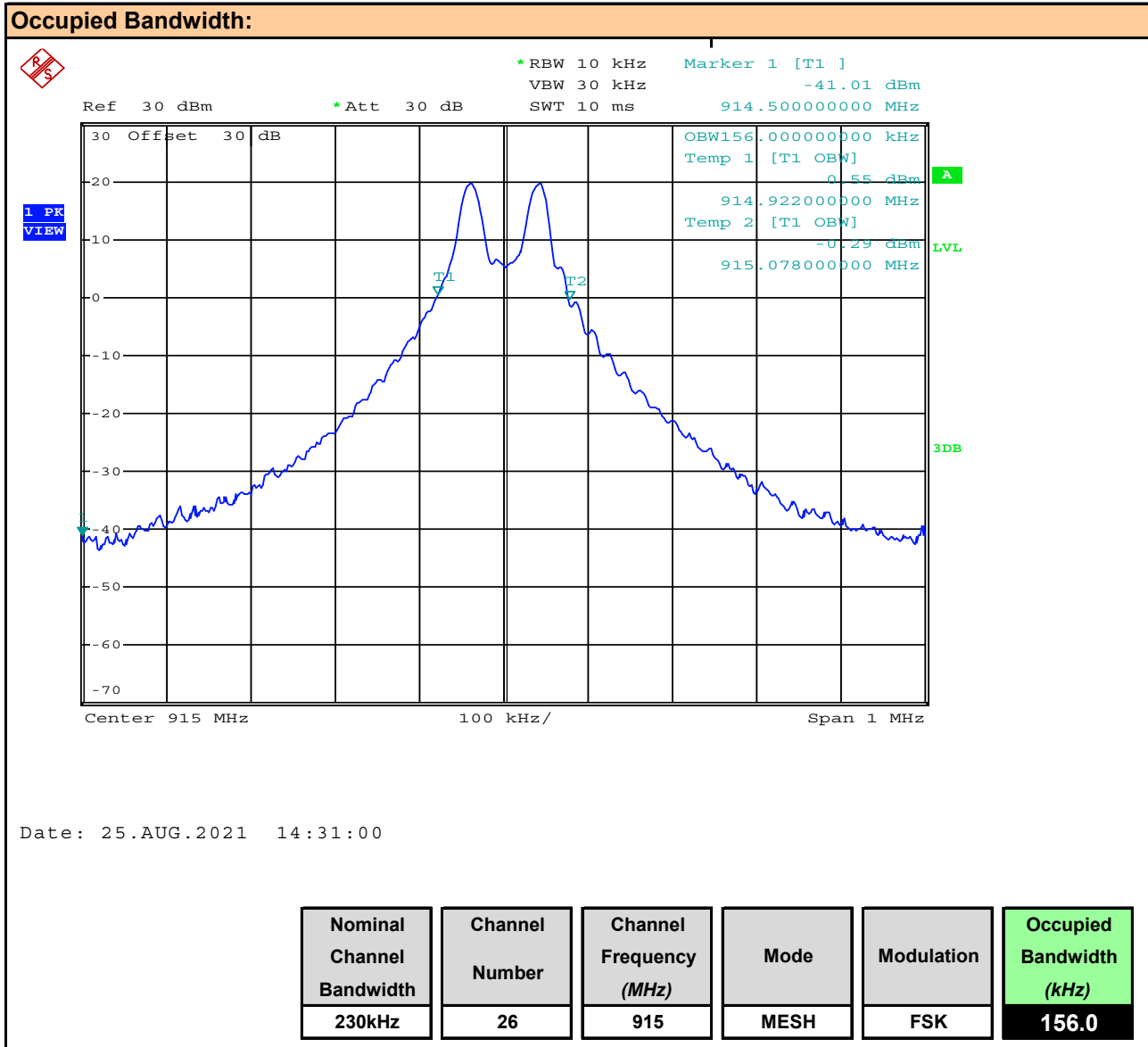
Measurement Procedure

The DUT was connected to a Spectrum Analyzer (SA) via a 30dB attenuator connected to the DUT's antenna port. The SA was configured as described above using the 99% Occupied Bandwidth function. The output power of the DUT was set to the manufacturer's highest output power setting at the Low, Mid and High frequency channels as permitted by the device. The DUT was set to transmit at its maximum Duty Cycle. The 99% Occupied Bandwidth was measured and recorded and used for the basis for measuring the Conducted Output Power (See Section 10.0) and Power Spectral Density (See Section 11.0).

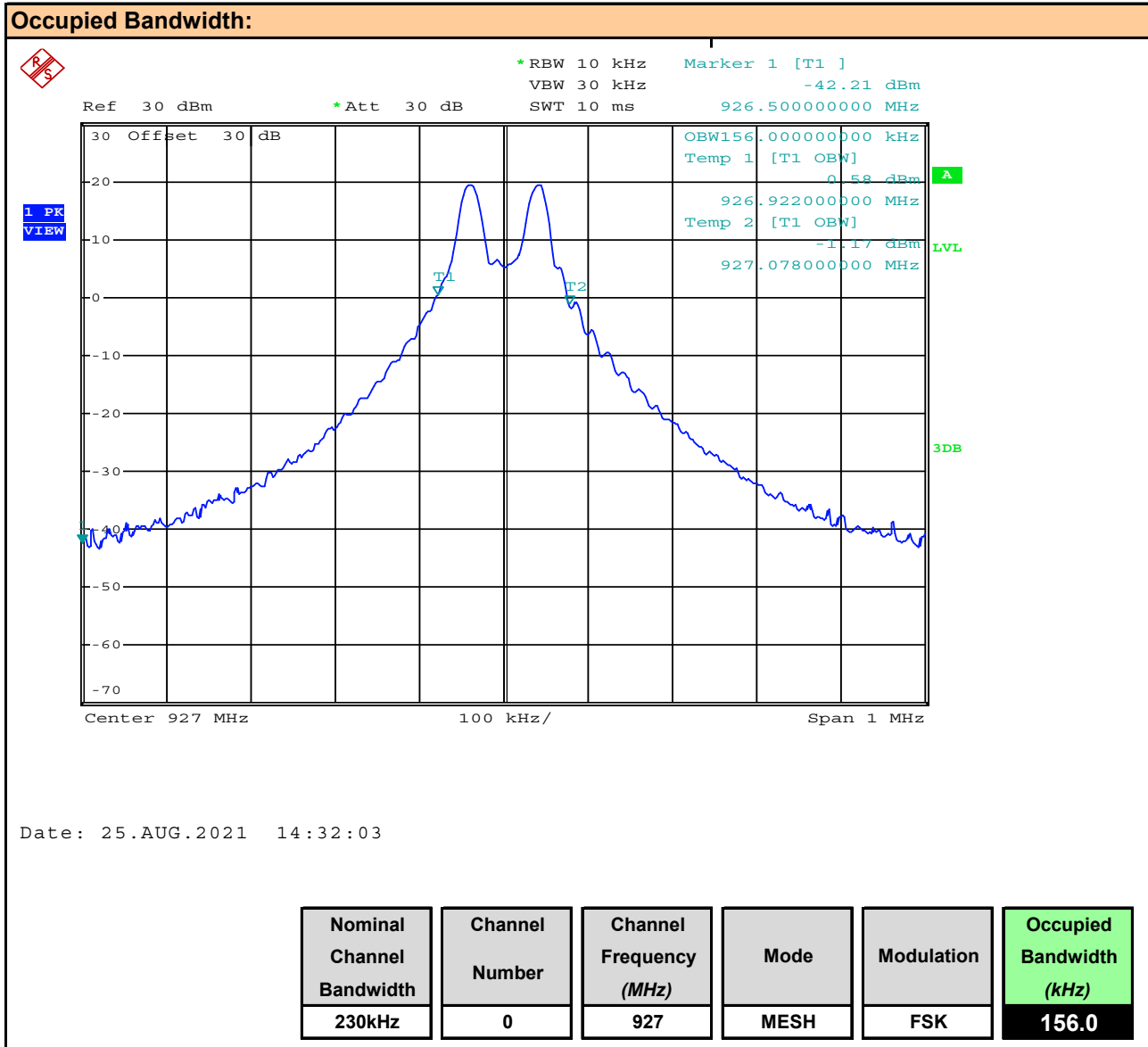
Plot 7.1 – Occupied Bandwidth, MESH, Ch 1



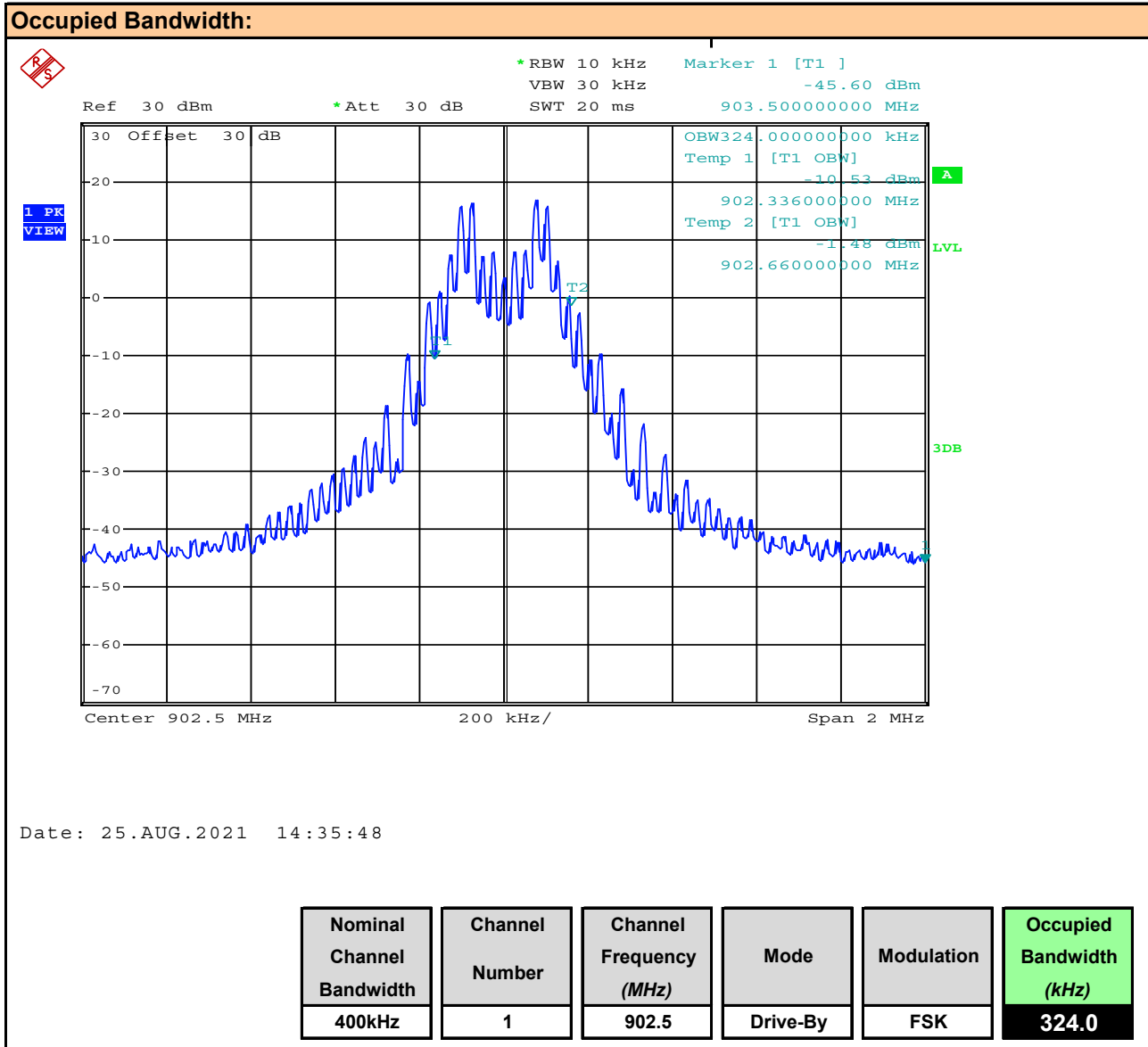
Plot 7.2 – Occupied Bandwidth, MESH, Ch 26



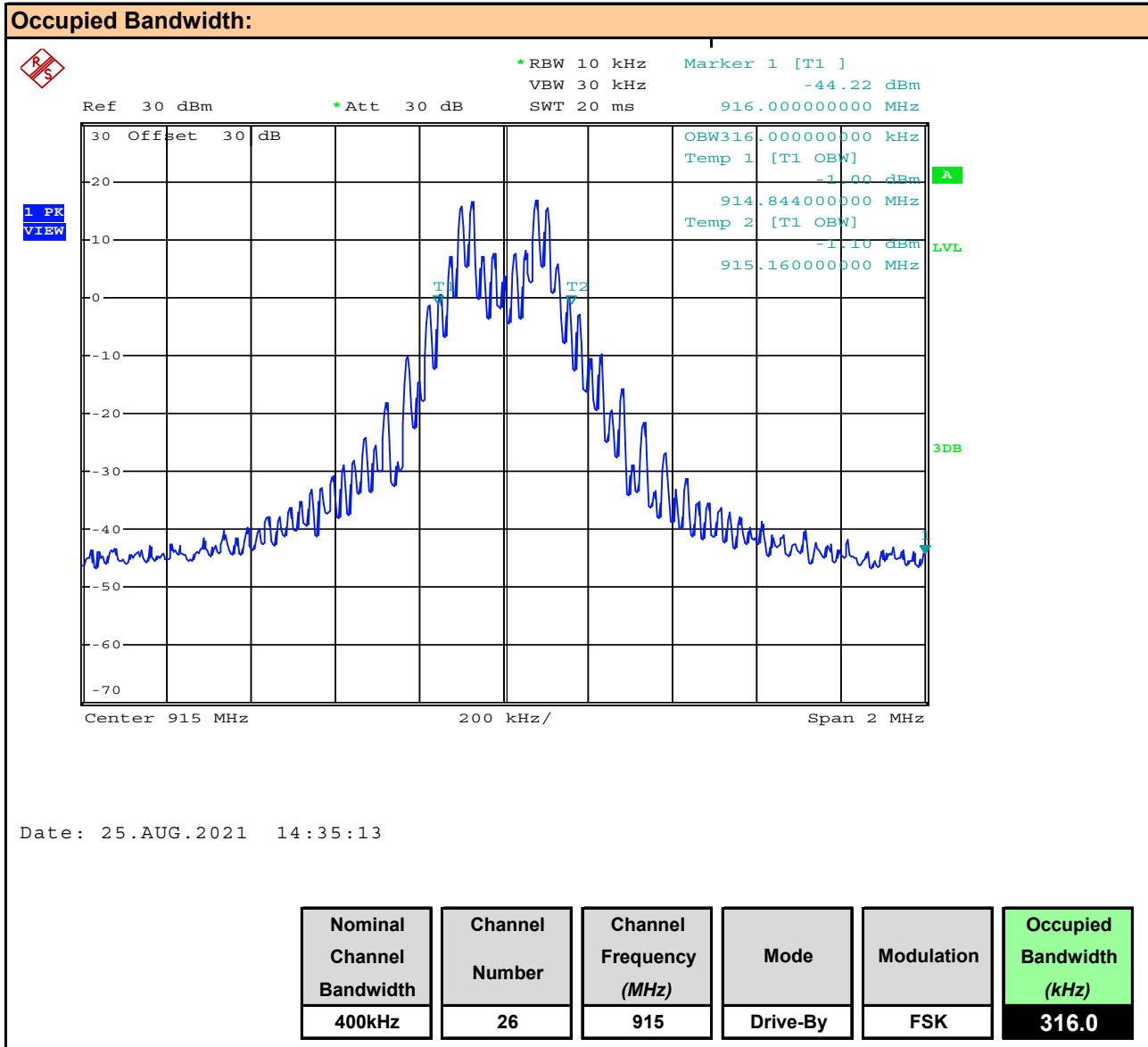
Plot 7.3 – Occupied Bandwidth, MESH, Ch 0



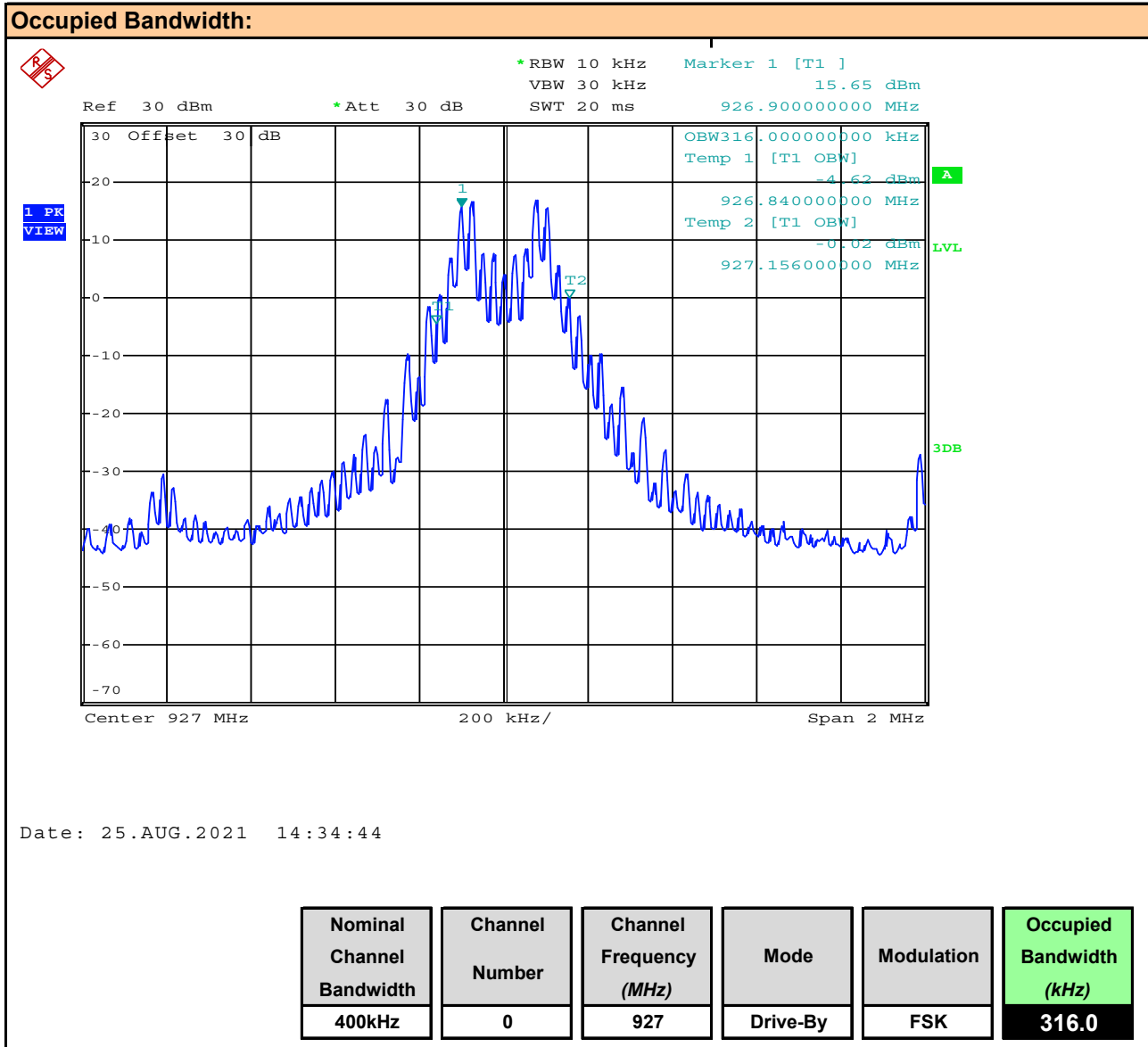
Plot 7.4 – Occupied Bandwidth, Drive-By, Ch 1



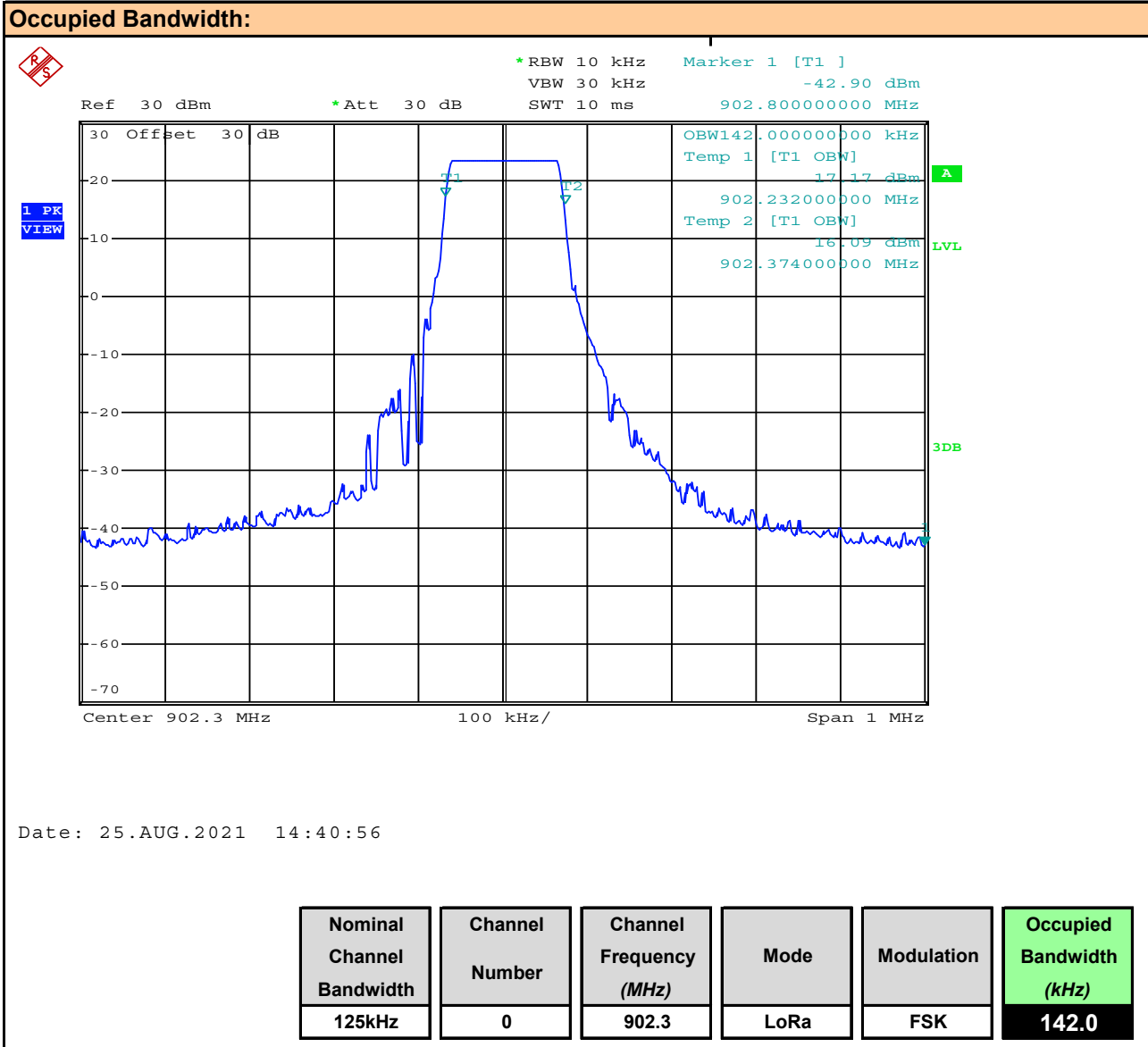
Plot 7.5 – Occupied Bandwidth, Drive-By, Ch 26



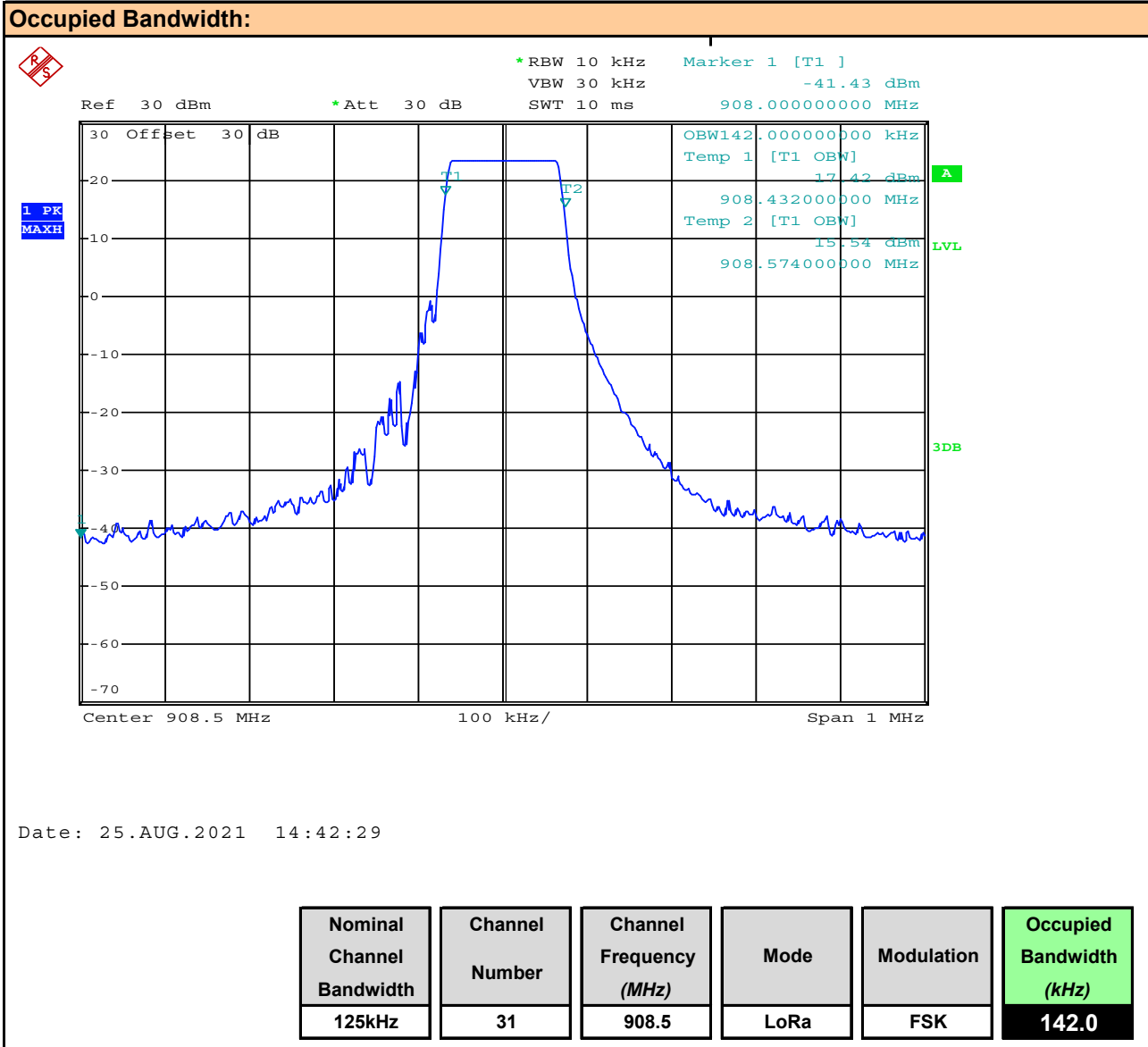
Plot 7.6 – Occupied Bandwidth, Drive-By, Ch 0



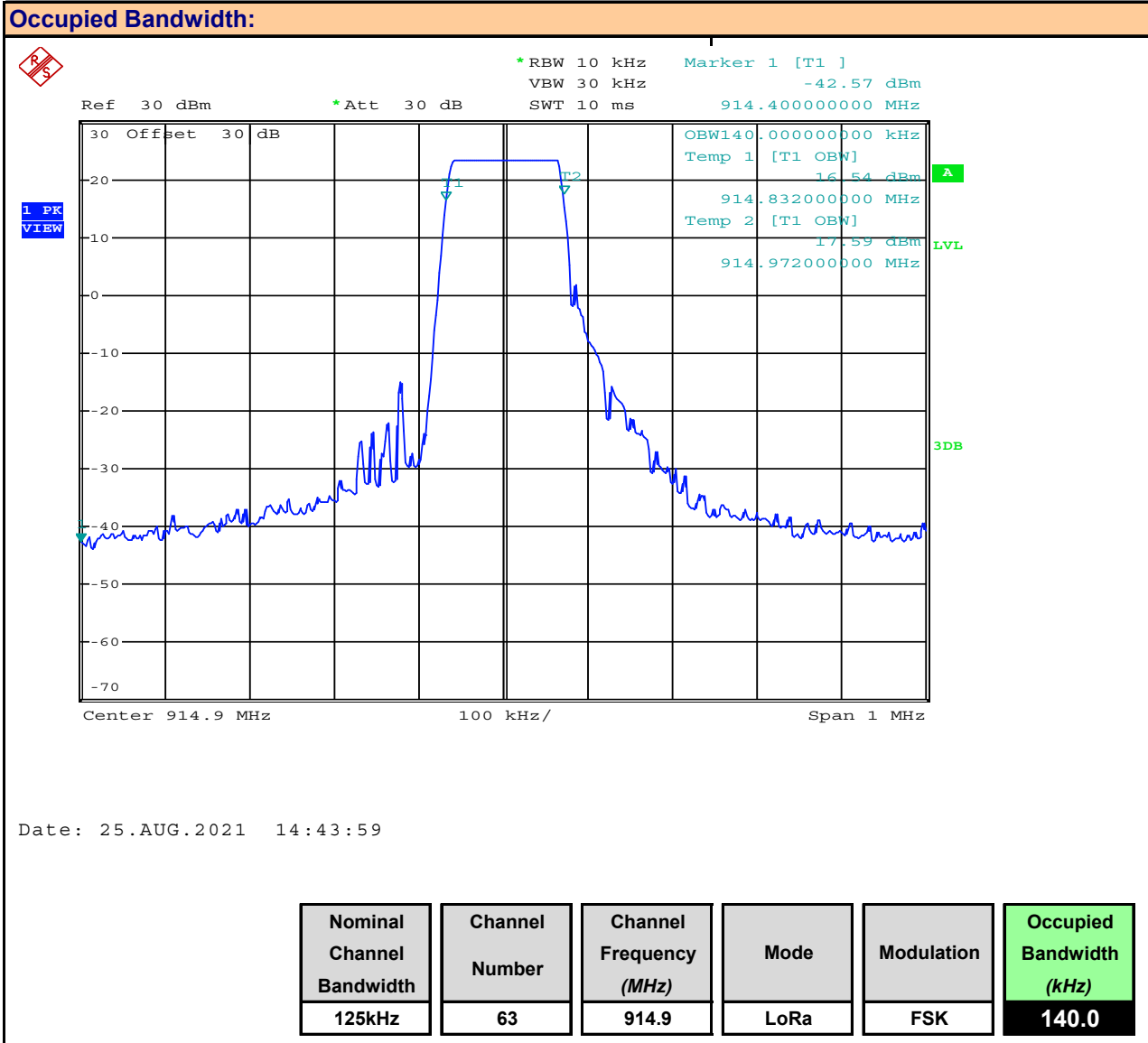
Plot 7.7 – Occupied Bandwidth, LoRa (FHSS), Ch 0



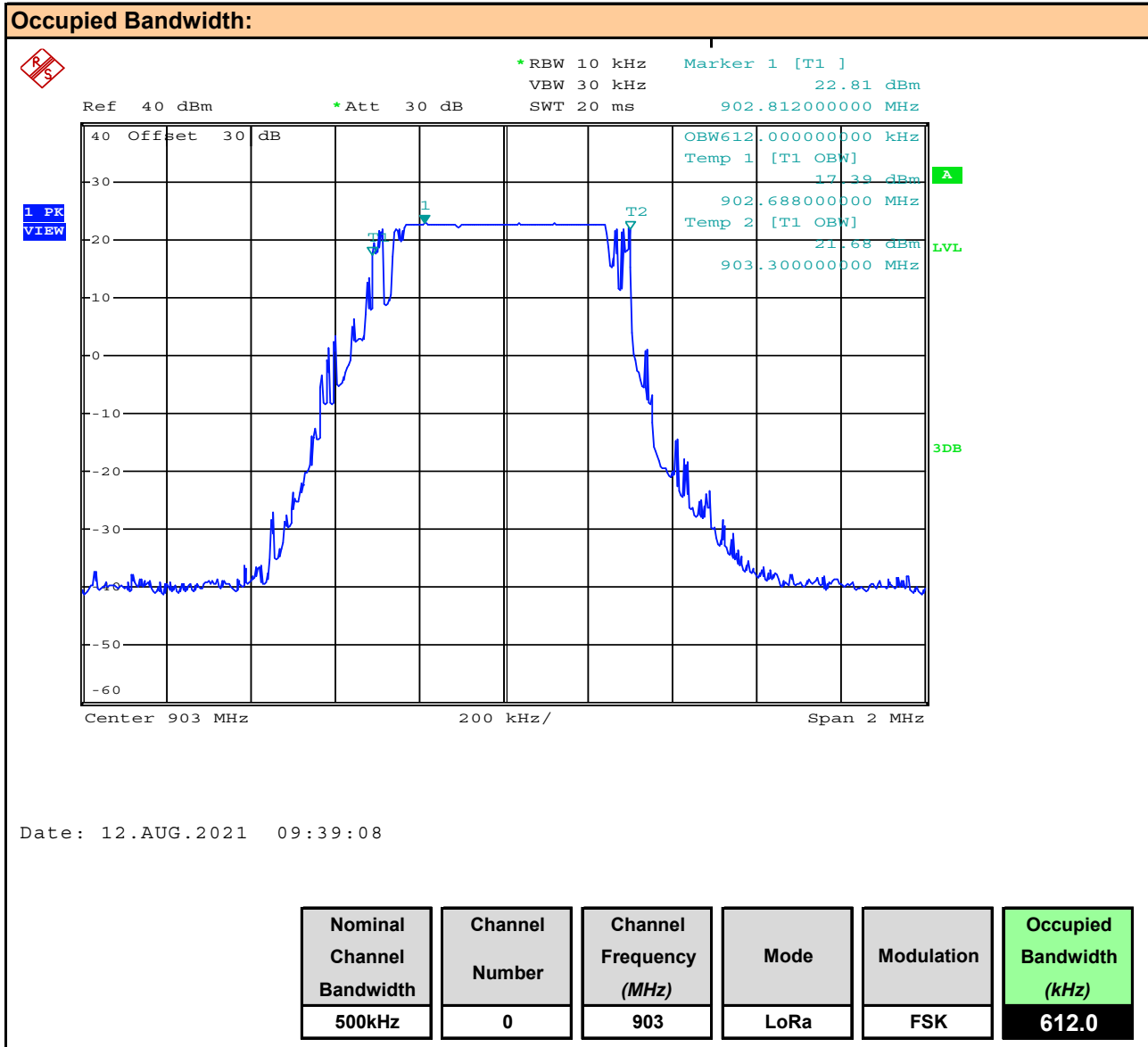
Plot 7.8 – Occupied Bandwidth, LoRa (FHSS), Ch 31



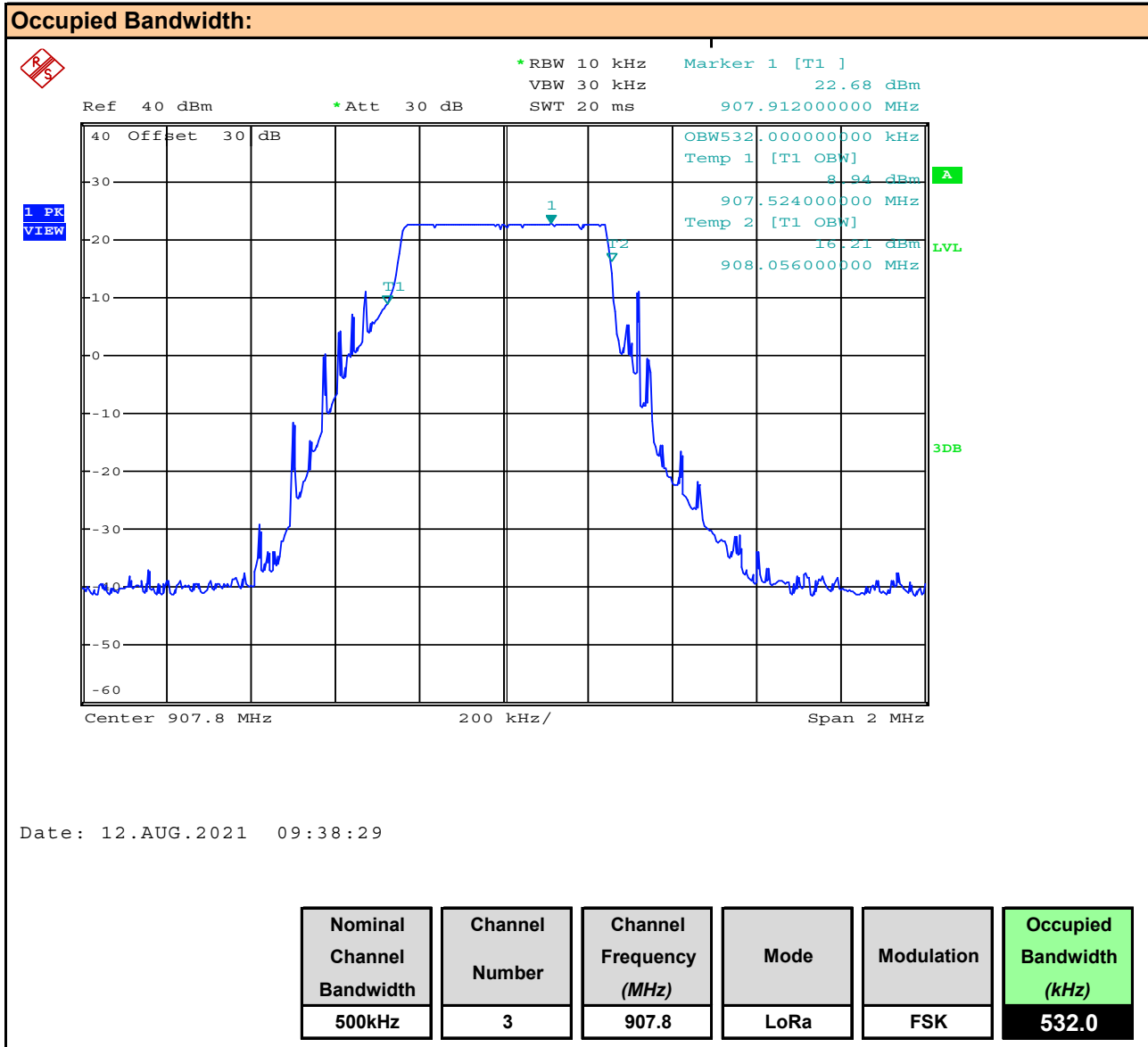
Plot 7.9 – Occupied Bandwidth, LoRa (FHSS), Ch 63



Plot 7.10 – Occupied Bandwidth, LoRa (DTS), Ch 0



Plot 7.11 – Occupied Bandwidth, LoRa (DTS), Ch 3



Plot 7.12 – Occupied Bandwidth, LoRa (DTS), Ch 7

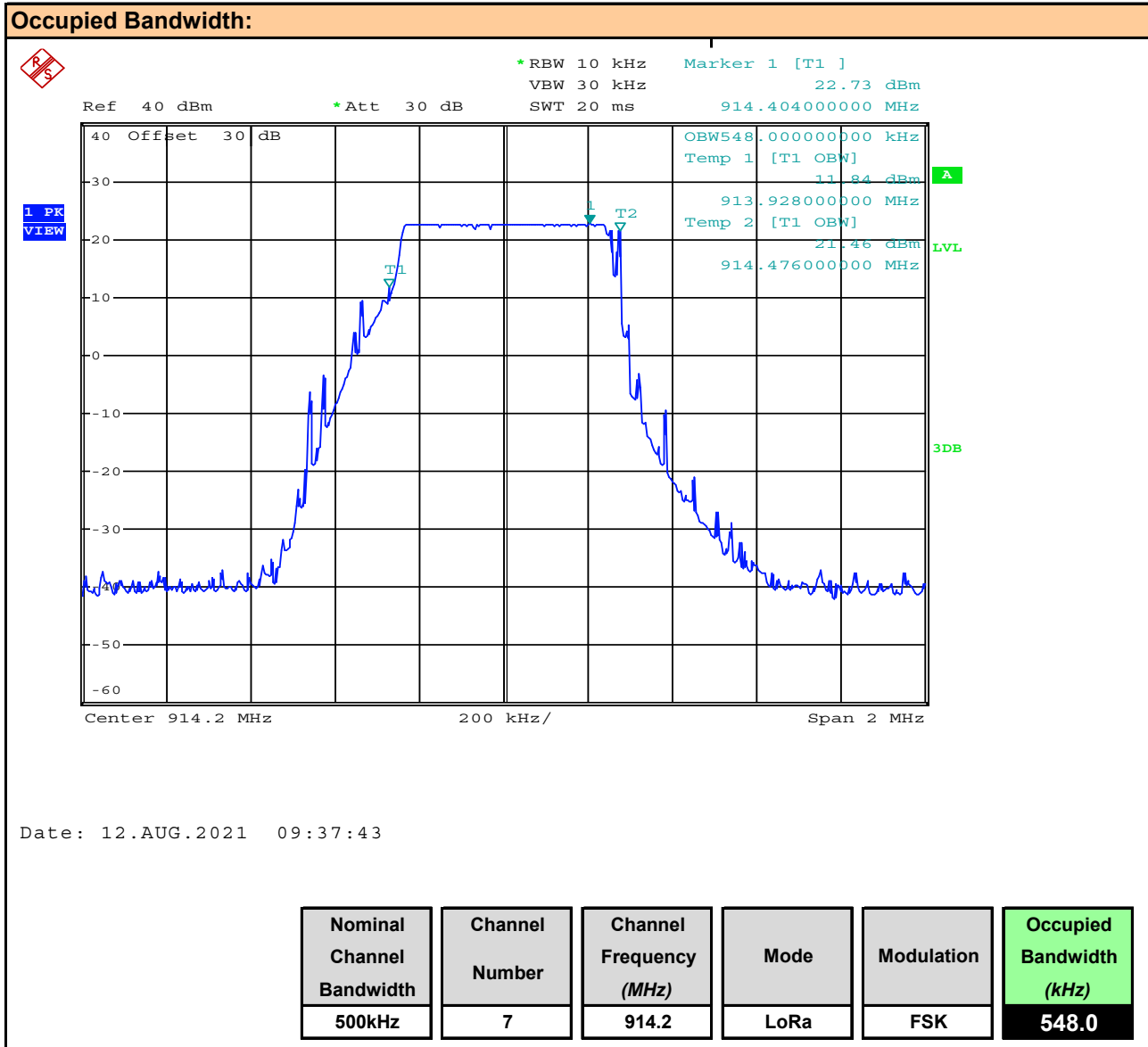


Table 7.1 – Summary of Occupied Bandwidth Measurements

Occupied Bandwidth Measurement Results:							
Mode	Equipment Class	Channel Number	Channel Frequency (MHz)	Modulation	Nominal Channel Bandwidth (kHz)	Measured Occupied Bandwidth (kHz)	Emission Designator
MESH	DSS	1	902.5	FSK	230kHz	158.0	158KF1D
		26	915.0			156.0	156KF1D
		0	927.0			156.0	156KF1D
Drive-By		1	902.5		400kHz	324.0	324KF1D
		26	915.0			316.0	316KF1D
		0	927.0			316.0	316KF1D
LoRa		0	902.3		125kHz	142.0	142KF1D
		31	908.5			142.0	142KF1D
		63	914.9			140.0	140KF1D
LoRa	DTS	0	903.0		500kHz	612.0	612KF1D
		3	907.8			532.0	532KF1D
		7	914.2			548.0	548KF1D
Result:						Complies	

8.0 DTS BANDWIDTH

Test Procedure

Normative Reference	FCC 47 CFR §2.1049, §15.247(a)(2), RSS-Gen (6.7), RSS-247 (5.2)(a), KDB 558074 (8.2), ANSI C63.10 (11.8.2)
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Limits

47 CFR §15.247(a)(2)	(a) Operation under the provisions of this Section is limited to frequency hopping and digitally modulated intentional radiators that comply with the following provisions: (2) Systems using digital modulation techniques may operate in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.
RSS-247 (5.2)(a)	5.2 Digital transmission systems DTSs include systems that employ digital modulation techniques resulting in spectral characteristics similar to direct sequence systems. The following applies to the bands 902-928 MHz and 2400 - 2483.5 MHz: a) The minimum 6 dB bandwidth shall be 500 kHz.

General Procedure

KDB 558074 (8.2) C63.10 (11.8.2)	11.8.2 Option 2 The automatic bandwidth measurement capability of an instrument may be employed using the X dB bandwidth mode with X set to 6 dB, if the functionality described above (i.e., RBW = 100 kHz, VBW ≥ 3 X RBW, peak detector with maximum hold) is implemented by the instrumentation function. When using this capability, care shall be taken so that the bandwidth measurement is not influenced by any intermediate power nulls in the fundamental emission that might be ≥ 6 dB.
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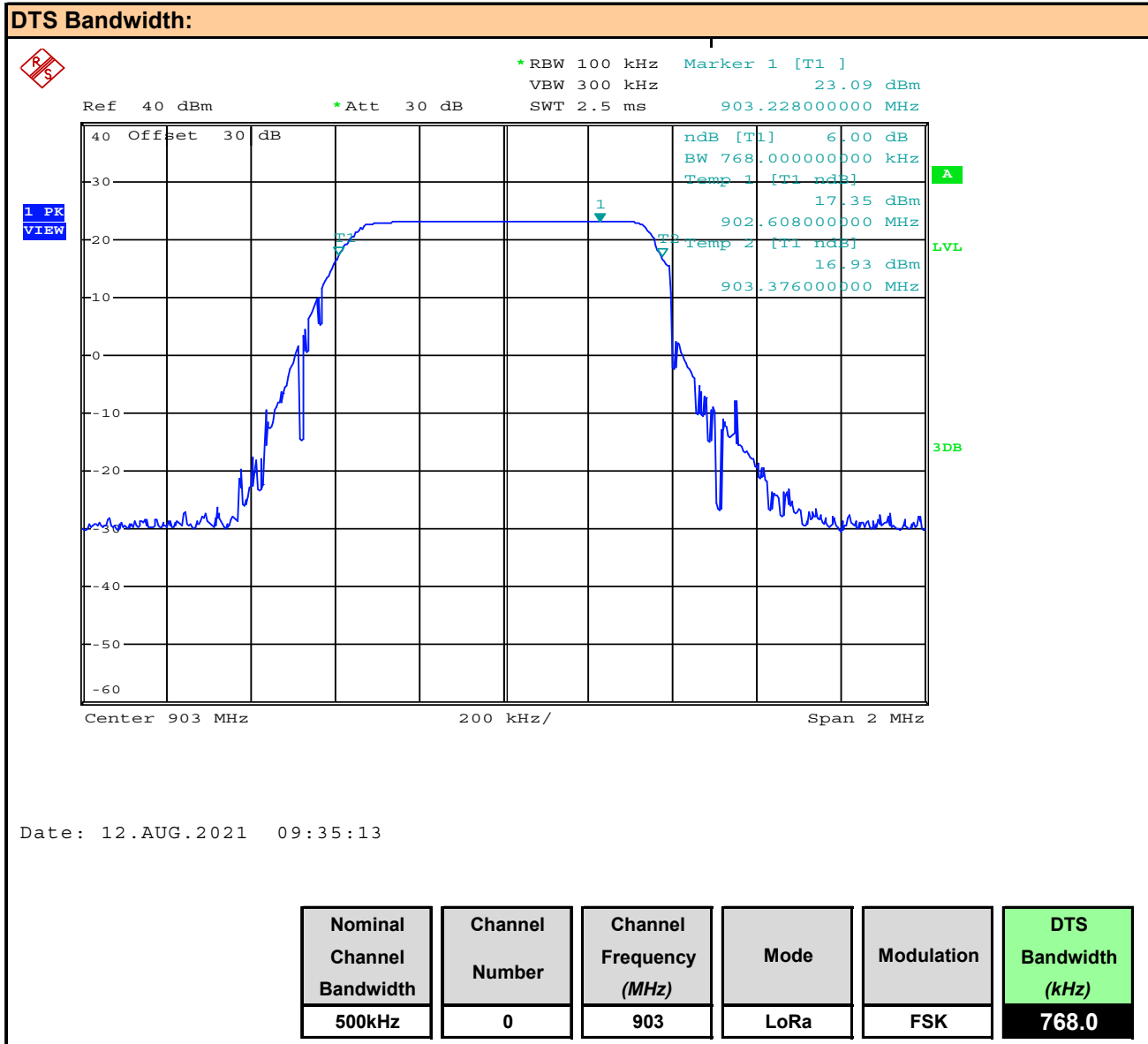
Test Setup

Appendix A - Figure A.1

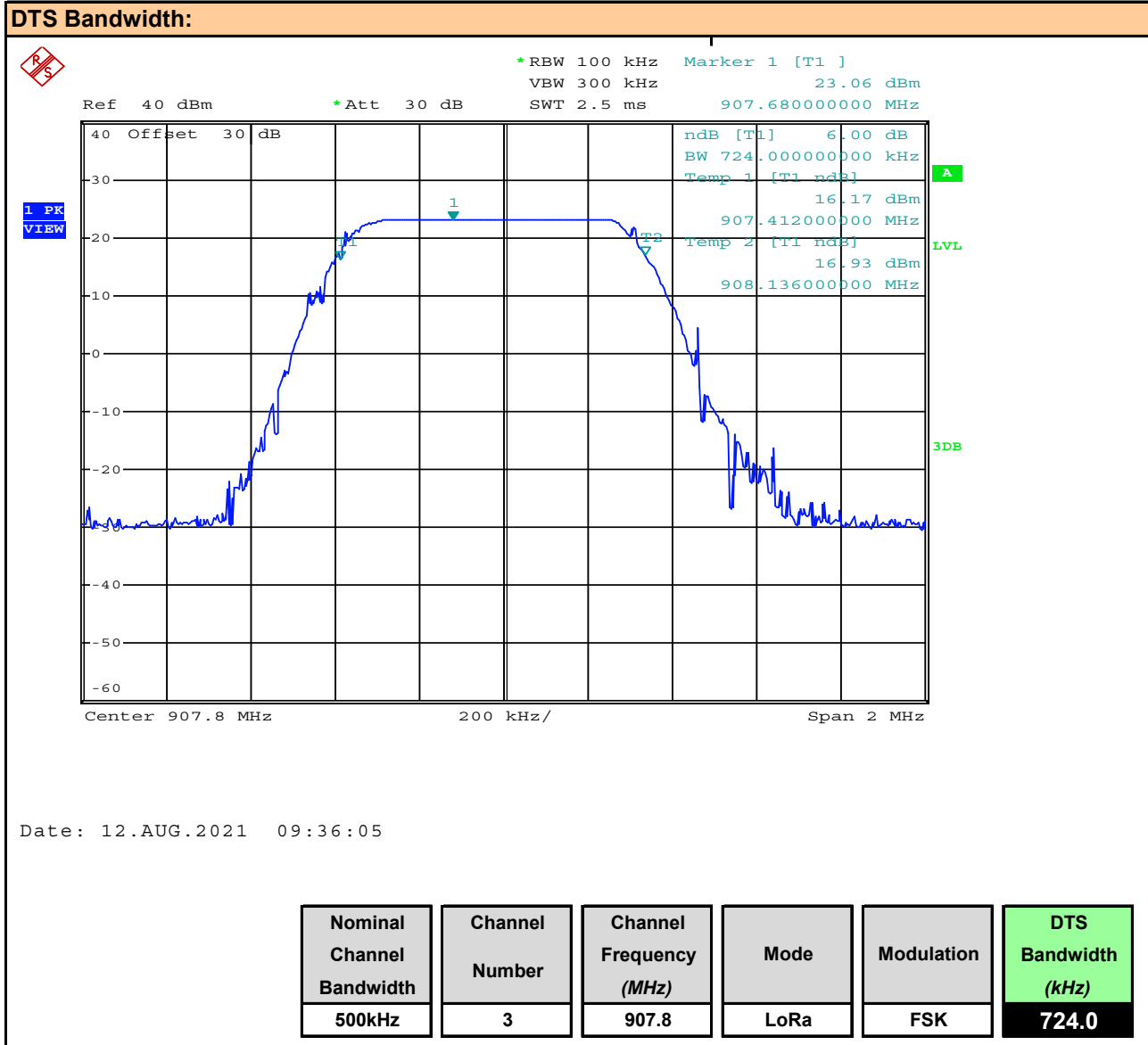
Measurement Procedure

The DUT was connected to a Spectrum Analyzer (SA) via a 30dB attenuator connected to the DUT's antenna port. The SA was configured as above using the Automatic 6dB Cursor Bandwidth measurement. The output power of the DUT was set to the manufacturer's highest output power setting at the Low, Mid and High frequency channels as permitted by the device. The DUT was set to transmit at its maximum Duty Cycle.

Plot 8.1 – 6dB DTS Bandwidth, LoRa DTS Ch 0



Plot 8.2 – 6dB DTS Bandwidth, LoRa DTS Ch 3



Plot 8.3 – 6dB DTS Bandwidth, LoRa DTS Ch 7

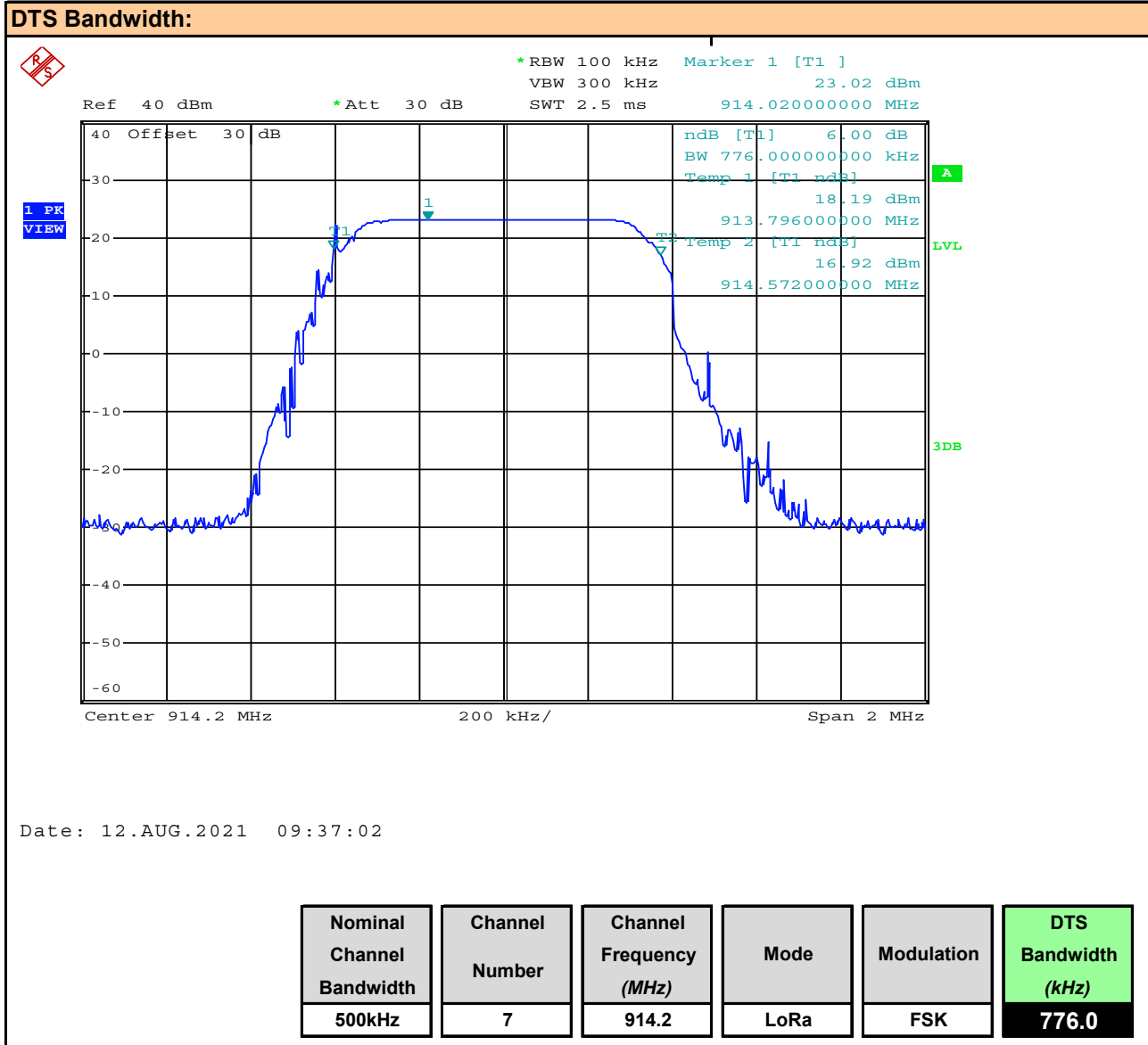


Table 8.1 – Summary of 6dB DTS Bandwidth Measurements

DTS Bandwidth Measurement Results:						
Mode	Equipment Class	Channel Number	Channel Frequency (MHz)	Modulation	Nominal Channel Bandwidth (kHz)	Measured DTS Bandwidth (kHz)
LoRa	DTS	0	903.0	FSK	500kHz	768.0
		3	907.8			724.0
		7	914.2			776.0
Result:						Complies

9.0 20DB BANDWIDTH

Test Procedure

Normative Reference	FCC 47 CFR §2.1049, §15.247(a)(1)(i), RSS-Gen (6.7), RSS-247 (5.2)(c), KDB 558074 (8.2), ANSI C63.10 (11.8.2)
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Limits

§15.247(a)(1) (i)	(a) Operation under the provisions of this Section is limited to frequency hopping and digitally modulated intentional radiators that comply with the following provisions: (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 and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period; if the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 10 second period. The maximum allowed 20 dB bandwidth of the hopping channel is 500 kHz.
RSS-247 (5.2)(c)	5.2 Digital transmission systems DTSS include systems that employ digital modulation techniques resulting in spectral characteristics similar to direct sequence systems. The following applies to the bands 902-928 MHz and 2400 - 2483.5 MHz: c) For FHSs in the band 902-928 MHz: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping channels and the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 20-second period. If the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping channels and the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 10-second period. The maximum 20 dB bandwidth of the hopping channel shall be 500 kHz.

General Procedure

KDB 558074 (8.2) C63.10 (11.8.2)	11.8.2 Option 2 The automatic bandwidth measurement capability of an instrument may be employed using the X dB bandwidth mode with X set to 6 dB, if the functionality described above (i.e., RBW = 100 kHz, VBW ≥ 3 X RBW, peak detector with maximum hold) is implemented by the instrumentation function. When using this capability, care shall be taken so that the bandwidth measurement is not influenced by any intermediate power nulls in the fundamental emission that might be ≥ 6 dB.
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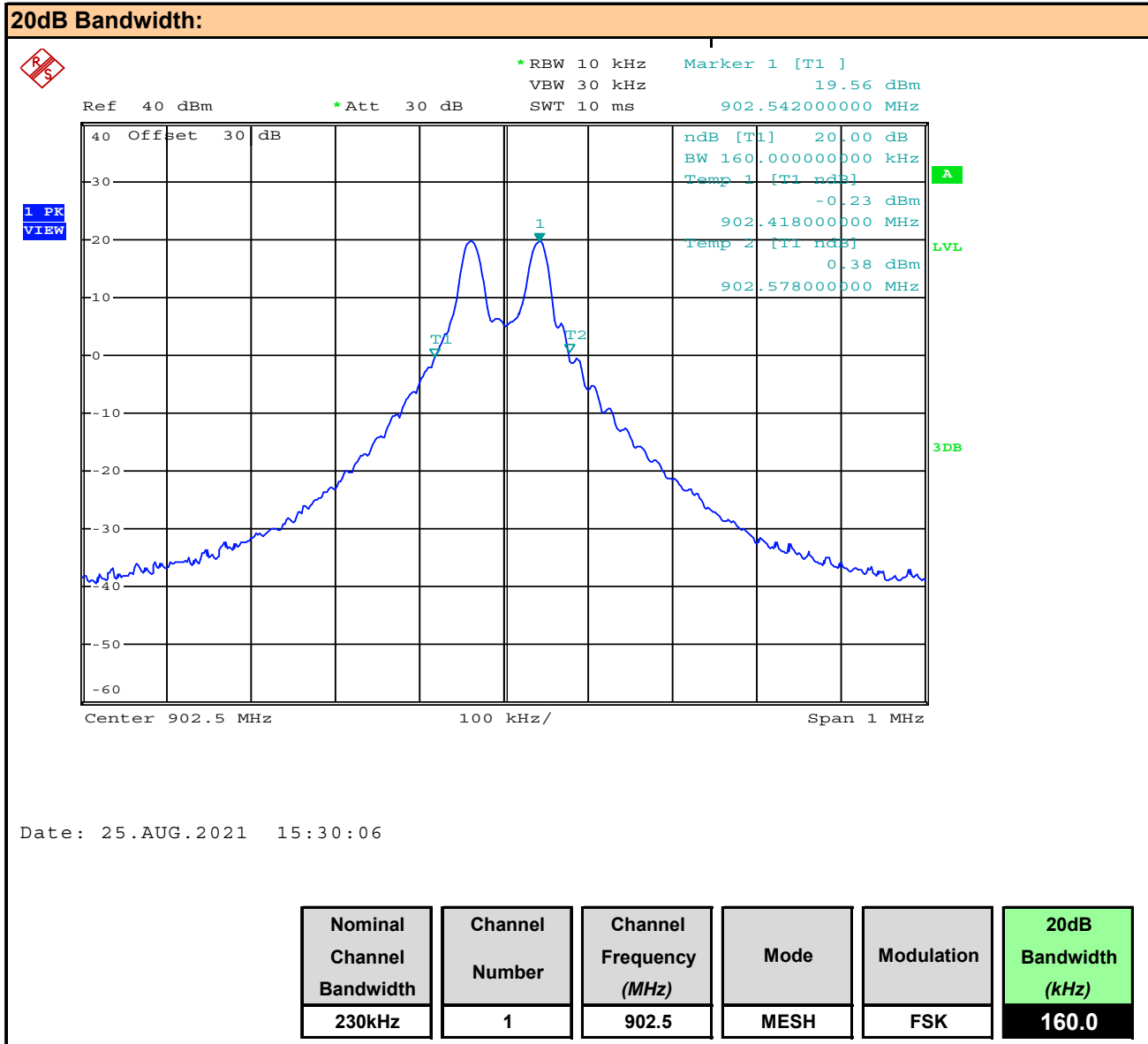
Test Setup

Appendix A - Figure A.1

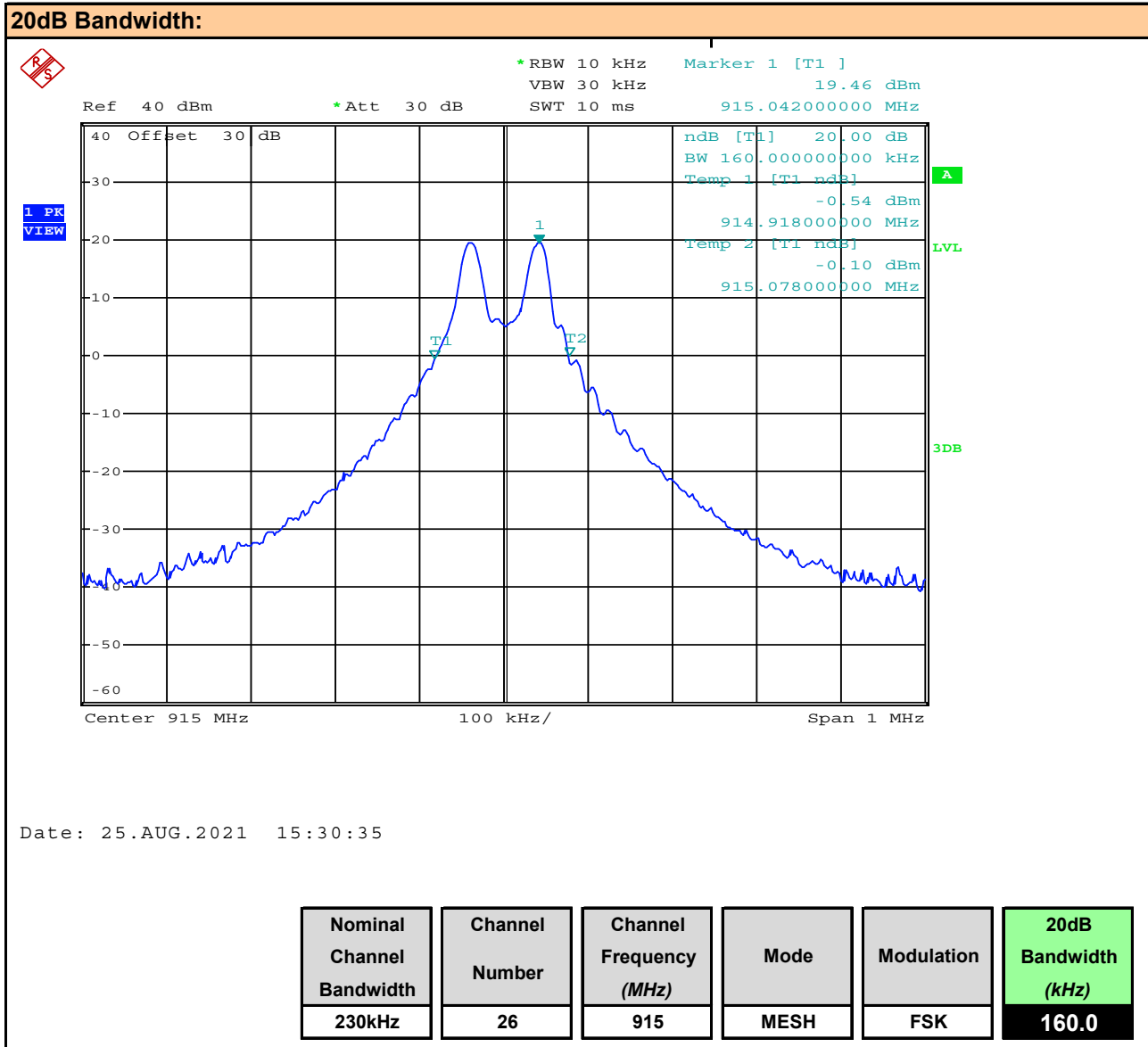
Measurement Procedure

The DUT was connected to a Spectrum Analyzer (SA) via a 30dB attenuator connected to the DUT's antenna port. The SA was configured as above using the Automatic 6dB Cursor Bandwidth measurement. The output power of the DUT was set to the manufacturer's highest output power setting at the Low, Mid and High frequency channels as permitted by the device.

Plot 9.1 – 20dB Bandwidth, MESH Ch 1



Plot 9.2 – 20dB Bandwidth, MESH Ch 26



20dB Bandwidth:

1 PK

VIEW

Ref 40 dBm

*Att 30 dB

SWT 10 ms

*RBW 10 kHz

VBW 30 kHz

Marker 1 [T1]

927.042000000 MHz

19.42 dBm

40

Offset 30 dB

30

20

10

0

-10

-20

-30

-40

-50

-60

Center 927 MHz

100 kHz/

Span 1 MHz

ndB [T1] 20.00 dB

BW 160.000000000 kHz

Temp 1 [T1 ndB]

926.918000000 MHz

-0.45 dBm

Temp 2 [T1 ndB]

927.078000000 MHz

-0.94 dBm

A

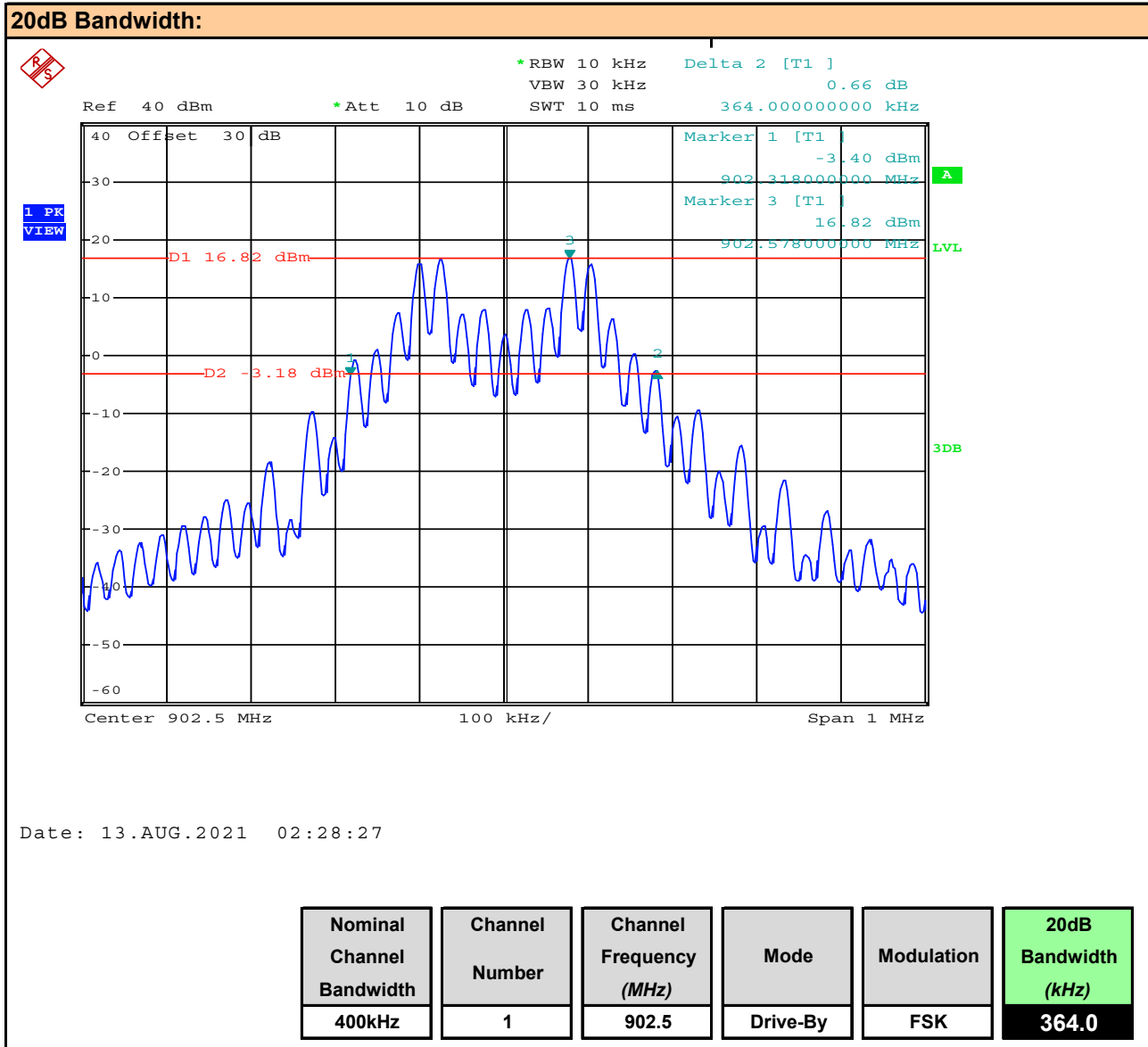
LVL

3DB

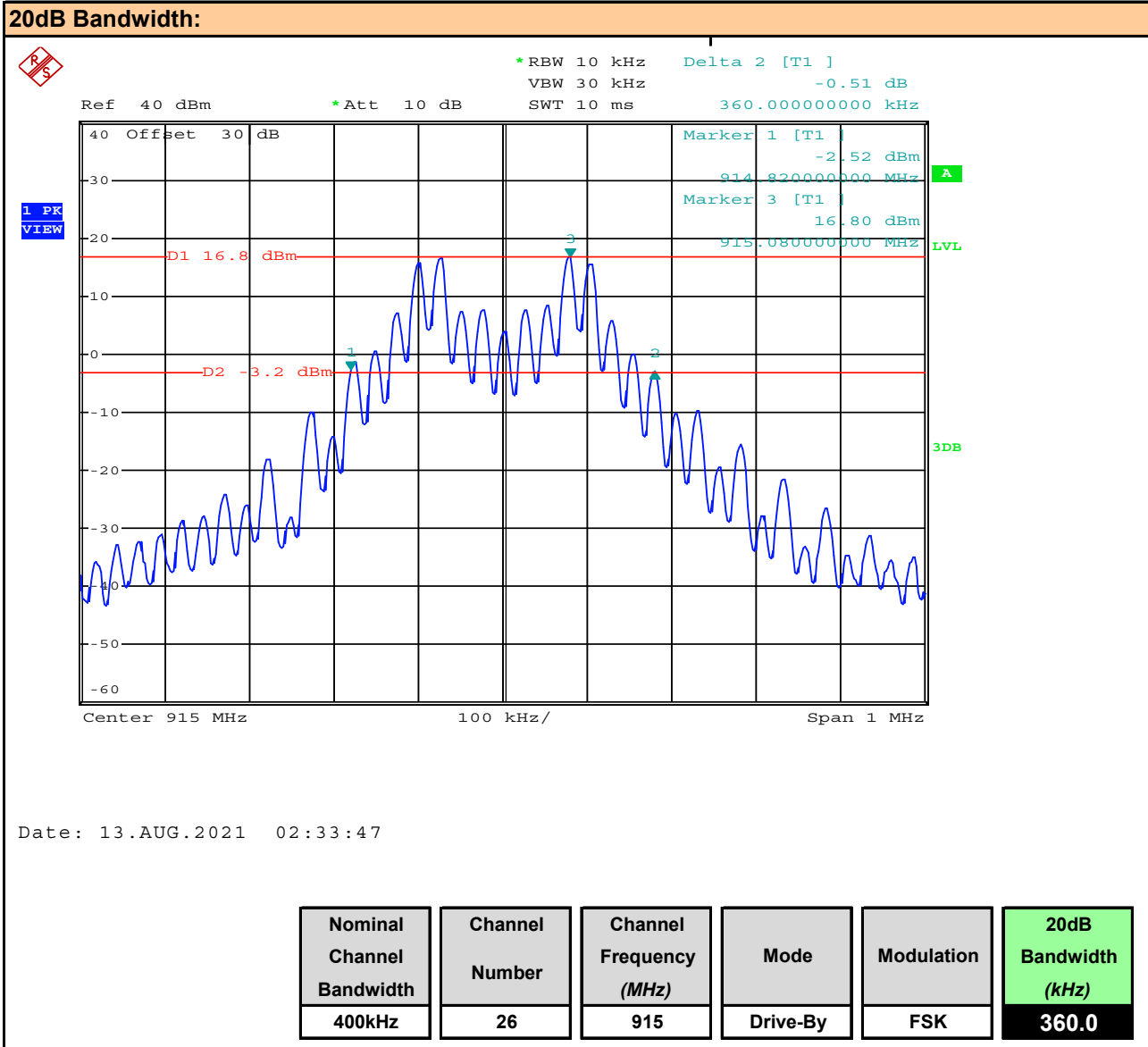
Date: 25.AUG.2021 15:31:09

Nominal Channel Bandwidth	Channel Number	Channel Frequency (MHz)	Mode	Modulation	20dB Bandwidth (kHz)
230kHz	0	927	MESH	FSK	160.0

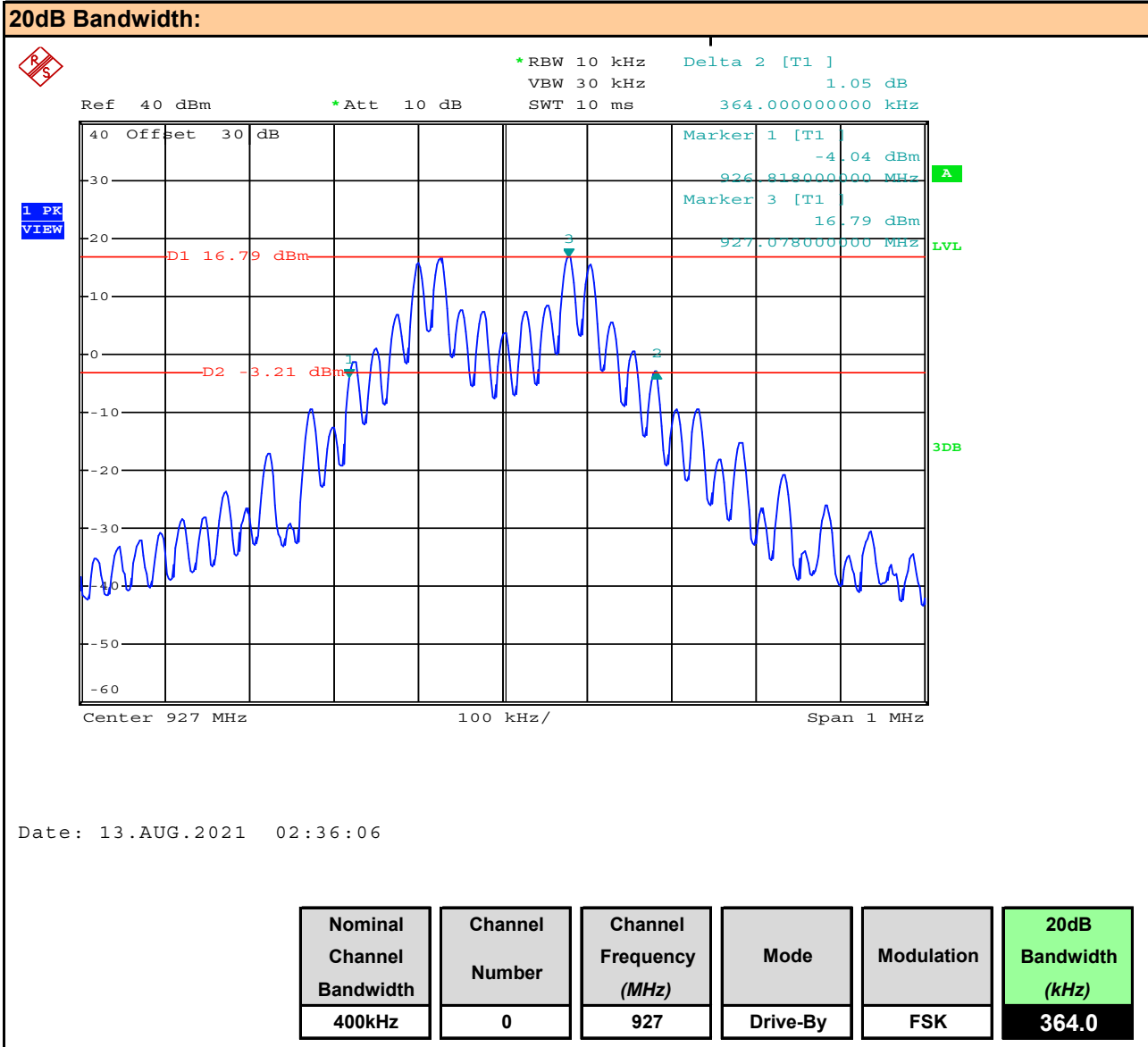
Plot 9.4 – 20dB Bandwidth, Drive-By Ch 1



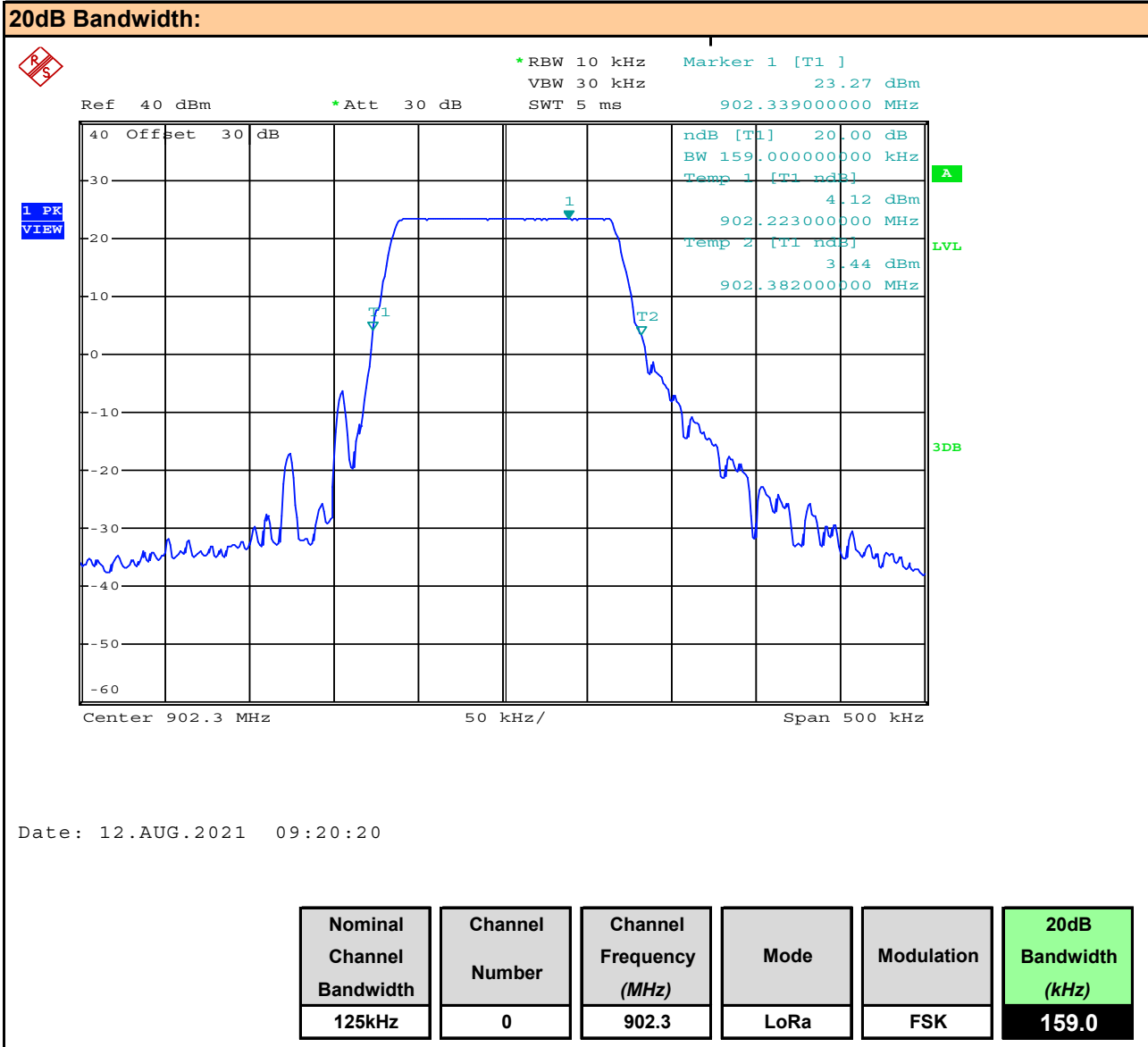
Plot 9.5 – 20dB Bandwidth, Drive-By Ch 26



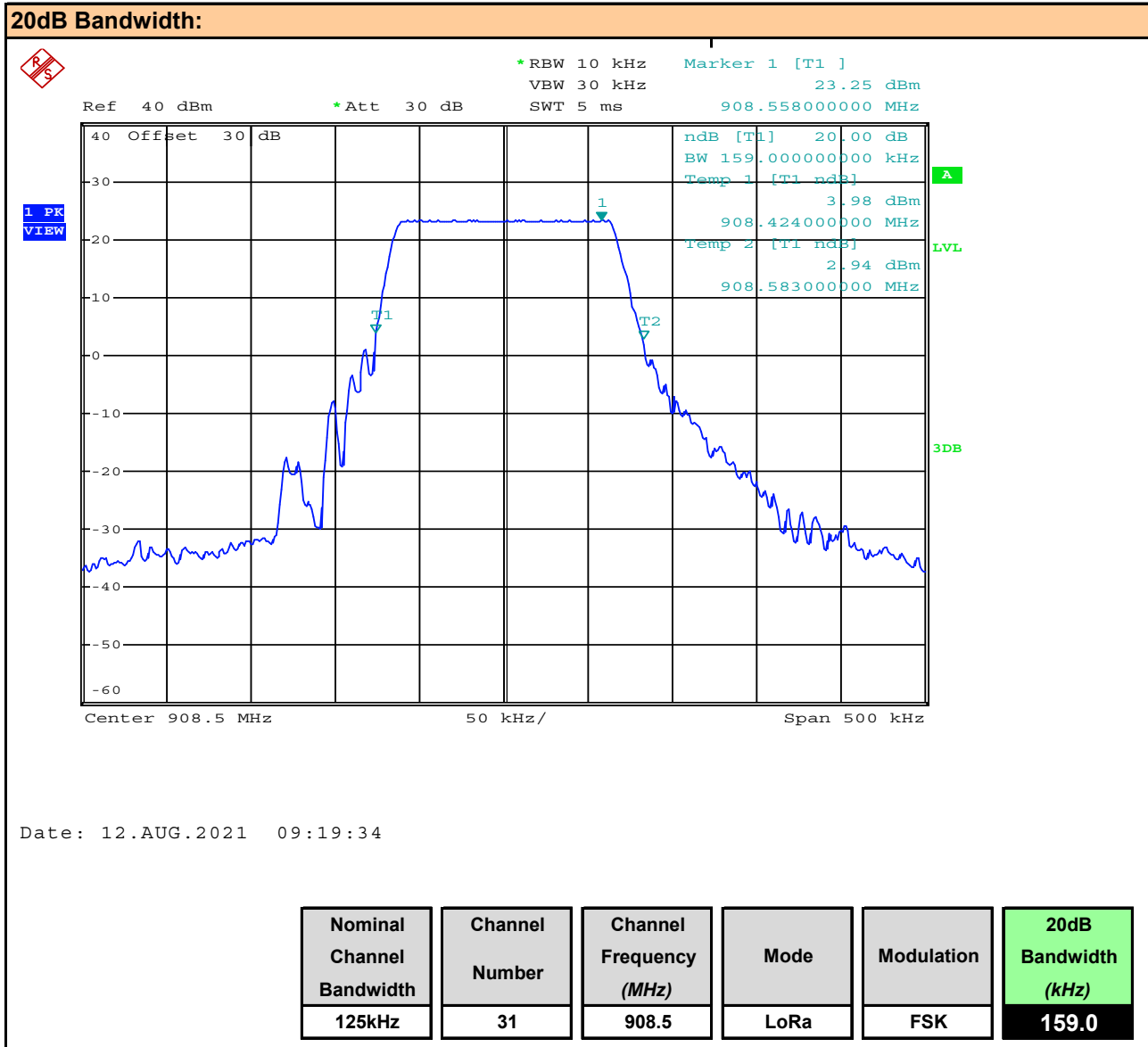
Plot 9.6 – 20dB Bandwidth, Drive-By Ch 0



Plot 9.7 – 20dB Bandwidth, Lora (FHSS) Ch 0

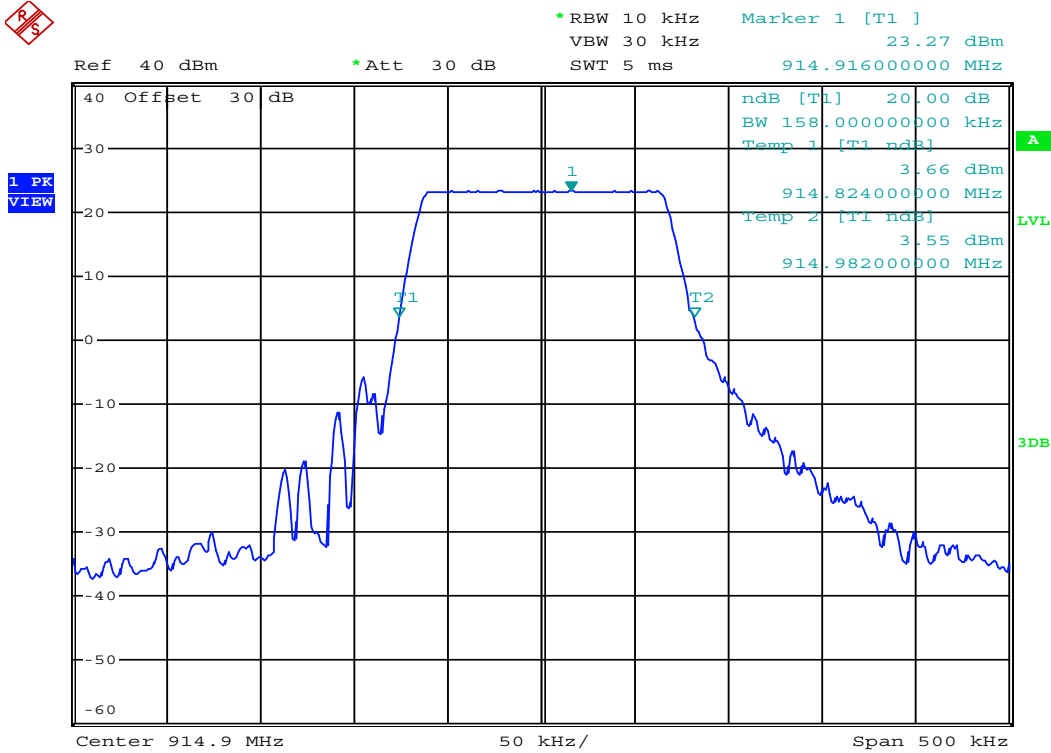


Plot 9.8 – 20dB Bandwidth, Lora (FHSS) Ch 31



Plot 9.9 – 20dB Bandwidth, Lora (FHSS) Ch 63

20dB Bandwidth:



Date: 12.AUG.2021 09:18:47

Nominal Channel Bandwidth	Channel Number	Channel Frequency (MHz)	Mode	Modulation	20dB Bandwidth (kHz)
125kHz	63	914.9	LoRa	FSK	158.0

Table 9.1 – Summary of 20dB Bandwidth Measurements,

20dB Bandwidth Measurement Results:						
Mode	Equipment Class	Channel Number	Channel Frequency (MHz)	Modulation	Nominal Channel Bandwidth (kHz)	Measured 20dB Bandwidth (kHz)
MESH	DSS	1	902.5	FSK	230kHz	162.0
		26	915.0			160.0
		0	927.0			160.0
Drive-By		1	902.5		400kHz	364.0
		26	915.0			360.0
		0	927.0			364.0
LoRa		0	902.3		150kHz	159.0
		31	908.5			159.0
		63	914.9			158.0
Result:						Complies

10.0A ANTENNA PORT CONDUCTED POWER, (DTS)

Test Procedure

Normative Reference	FCC 47 CFR §2.1046, §15.247(b)(3), RSS-Gen (6.1.2), RSS-247 (5.4)(d), KDB 558074 (8.3.2), ANSI C63.10 (11.9.2.2.2)
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Limits

47 CFR §15.247(b)(3)	(b) The maximum peak conducted output power of the intentional radiator shall not exceed the following: (3) For systems using digital modulation in the 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz bands: 1 Watt. As an alternative to a peak power measurement, compliance with the one Watt limit can be based on a measurement of the maximum conducted output power.
RSS-247 (5.4)(d)	5.4 Transmitter output power and equivalent isotropically radiated power (e.i.r.p.) Devices shall comply with the following requirements, where applicable: d) For DTSs employing digital modulation techniques operating in the bands 902-928 MHz and 2400-2483.5 MHz, the maximum peak conducted output power shall not exceed 1W. The e.i.r.p. shall not exceed 4 W, except as provided in section 5.4(e). As an alternative to a peak power measurement, compliance can be based on a measurement of the maximum conducted output power.

Test Procedure

Normative Reference	FCC 47 CFR §2.1046, §15.247(b)(3), RSS-Gen (6.1.2), RSS-247 (5.4)(d), KDB 558074 (8.3.2), ANSI C63.10 (11.9.2.2.2)
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General Procedure

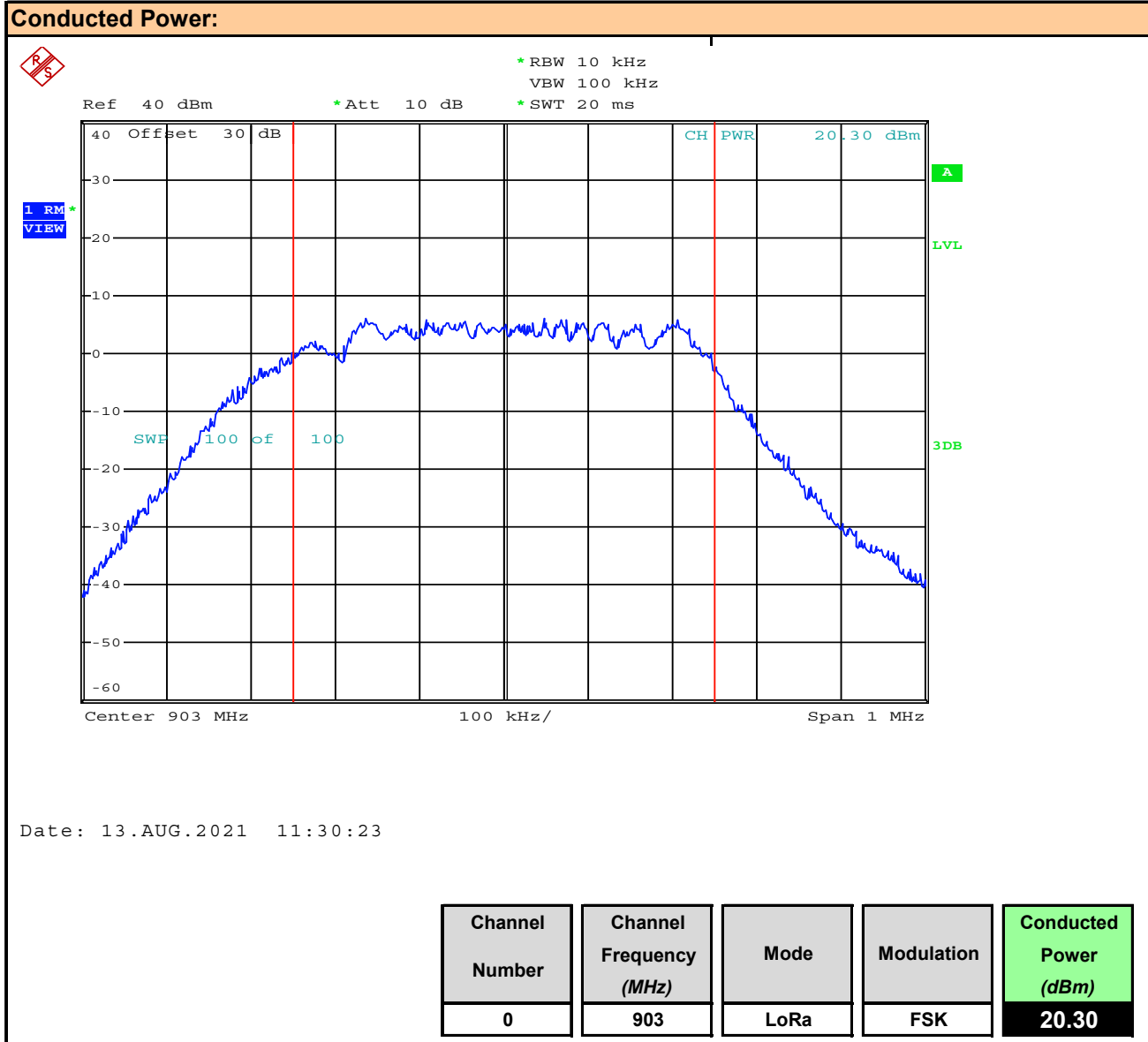
KDB 558074 (8.3.2.1)	8.3.2.1 General Section 15.247 permits the maximum conducted (average) output power to be measured as an alternative to the maximum peak conducted output power for demonstrating compliance to the limit. When this option is exercised, the measured power is to be referenced to the OBW rather than the DTS bandwidth.
C63.10 (11.9.2.2.2)	Method AVGSA-1 (trace averaging with the EUT transmitting at full power throughout each a) Set span to at least 1.5 X OBW. b) Set RBW = 1 % to 5 % of the OBW, not to exceed 1 MHz. c) Set VBW $\geq 3 \times$ RBW. d) Number of points in sweep $\geq 2 \times$ span / RBW. e) Sweep time = auto. f) Detector = RMS g) If the EUT transmits continuously (i.e., with no off intervals) or at duty cycle $\geq 98 \%$, and if each transmission is entirely at the maximum power control level, then the trigger shall be set to "free run". h) Trace average at least 100 traces in power averaging i) Compute power by integrating the spectrum across the OBW of the signal using the instrument's band power measurement function, with band limits set equal to the OBW band edges.

Test Setup	Appendix A - Figure A.1
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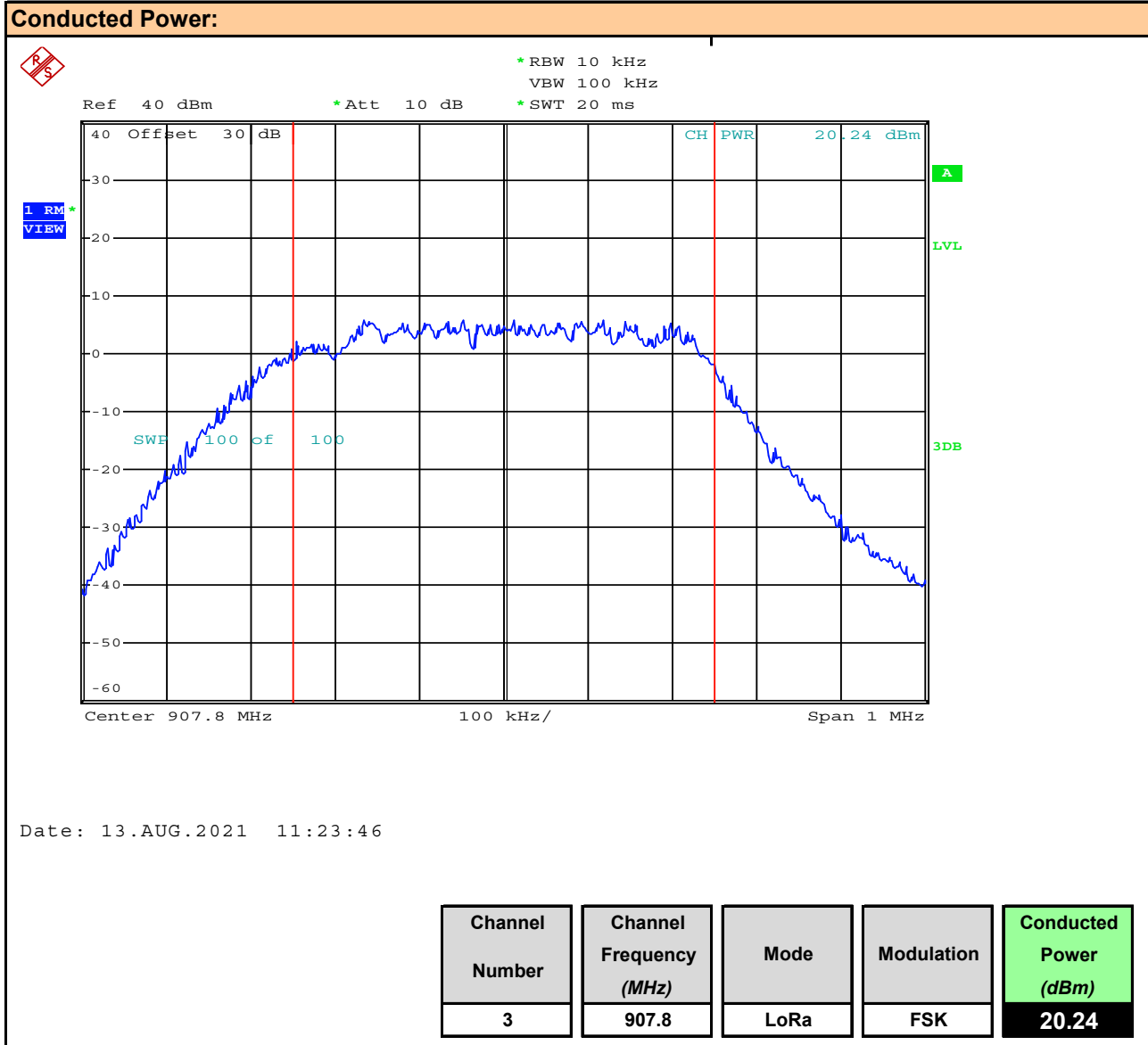
Measurement Procedure

The DUT was connected to a Spectrum Analyzer (SA) via a 30dB attenuator connected to the DUT's antenna port. The SA was configured as described above. Number of Sweep Points $\geq 2 \times$ Span / RBW = $2 \times (4\text{MHz} / 30\text{kHz}) = 267$, the SA was configured for 501 Points. The output power of the DUT was set to the manufacturer's highest output power setting at the Low, Mid and High frequency channels as permitted by the device. The DUT was set to transmit at 100% Duty Cycle. The Channel Bandwidth was set to the measured 99% Occupied Bandwidth (See Section 9.0). The Band Channel Power was measured and recorded.

Plot 10A.1 – Conducted Power, Lora (DTS) Ch 0



Plot 10A.2 – Conducted Power, Lora (DTS) Ch 3



Plot 10A.3 – Conducted Power, Lora (DTS) Ch 7

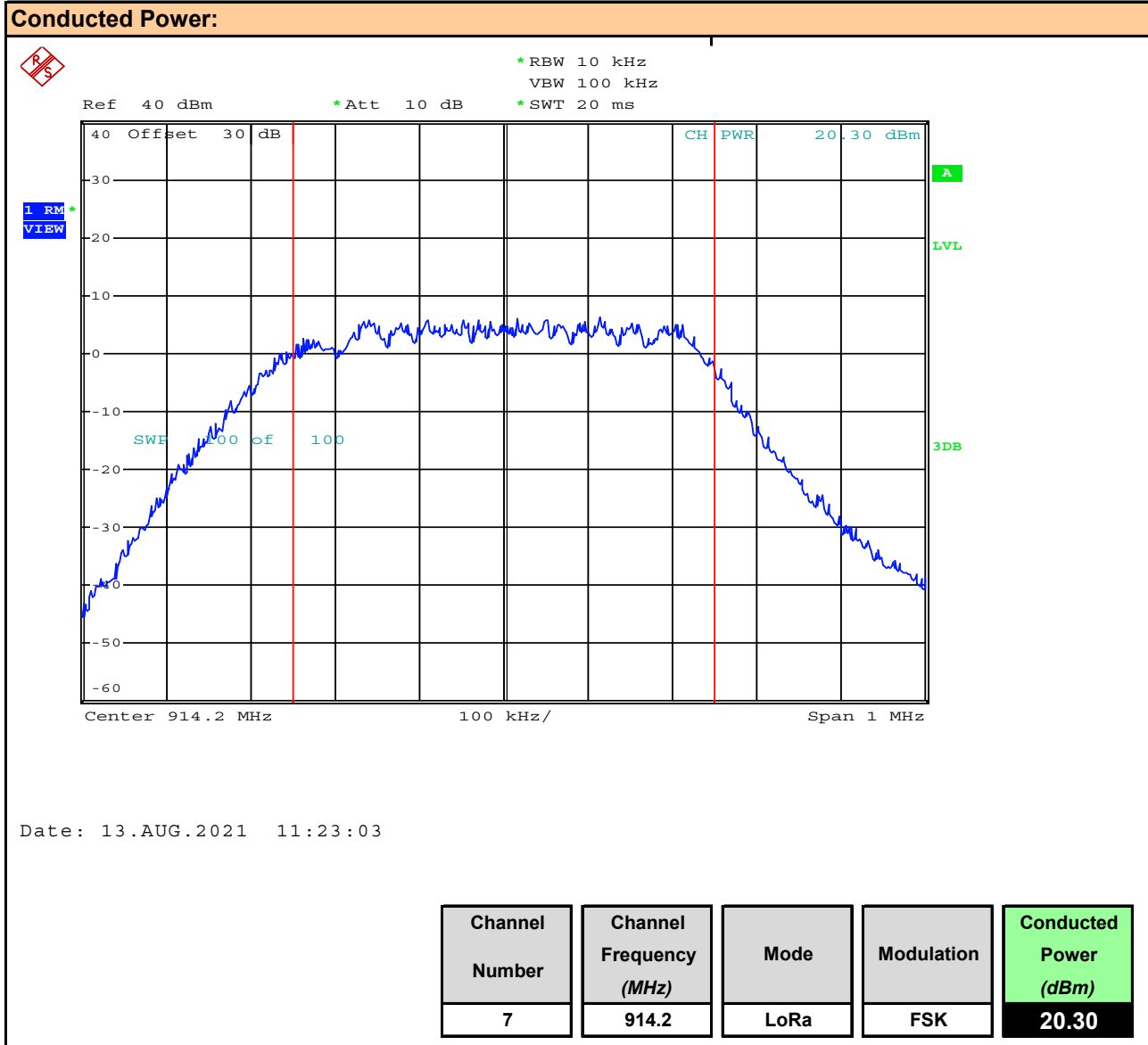


Table 10A.1 – Summary of Conducted Power Measurements

Conducted Power Measurement Results:											
Mode	Channel Number	Frequency (MHz)	Equipment Class	Modulation	Measured Power [P _{Meas}] (dBm)	Conducted Limit [P _{Lim}] (dBm)	Conducted Margin (dB)	Antenna Gain (dBi)	EIRP [E _{Meas}] (dBm)	EIRP Limit [E _{Lim}] (dBm)	EIRP Margin (dB)
LoRa	0	903.00	DTS	FSK	20.300	30	9.7	0	20.30	36	36.0
	3	907.80			20.240		9.8		20.24		36.0
	7	914.20			20.300		9.7		20.30		36.0
Result:										Complies	

Conducted Margin = $P_{\text{Limit}} - P_{\text{Meas}}$

EIRP Margin = $E_{\text{Limit}} - E_{\text{Meas}}$

10.0B ANTENNA PORT CONDUCTED POWER, (DSS)

Test Procedure

Normative	FCC 47 CFR §2.1046, §15.247(b)(2), RSS-Gen (6.1.2), RSS-247 (5.4)(d),
Reference	KDB 558074 (8.3.2), ANSI C63.10 (11.9.1.1)

Limits

47 CFR §15.247(b)(2)	(b) The maximum peak conducted output power of the intentional radiator shall not exceed the following: (2) For frequency hopping systems operating in the 902-928 MHz band: 1 watt for systems employing at least 50 hopping channels; and, 0.25 watts for systems employing less than 50 hopping channels, but at least 25 hopping channels, as permitted under paragraph (a)(1)(i) of this section.
RSS-247 (5.4)(d)	5.4 Transmitter output power and equivalent isotropically radiated power (e.i.r.p.) Devices shall comply with the following requirements, where applicable: a) For FHSs operating in the band 902-928 MHz, the maximum peak conducted output power shall not exceed 1.0 W, and the e.i.r.p. shall not exceed 4 W if the hopset uses 50 or more hopping channels; the maximum peak conducted output power shall not exceed 0.25 W and the e.i.r.p. shall not exceed 1 W if the hopset uses less than 50 hopping channels.

General Procedure

KDB 558074 (8.3.2.1)	8.3.2.1 General Section 15.247 permits the maximum conducted (average) output power to be measured as an alternative to the maximum peak conducted output power for demonstrating compliance to the limit. When this option is exercised, the measured power is to be referenced to the OBW rather than the DTS bandwidth.
C63.10 (11.9.1.1)	11.9.1.1 RBW ≥ DTS bandwidth The following procedure shall be used when an instrument with a resolution bandwidth that is greater than the DTS bandwidth is available to perform the measurement: a) Set the RBW ≥ DTS bandwidth. b) Set VBW ≥ [3 × RBW]. c) Set span ≥ [3 × RBW]. d) Sweep time = auto couple. e) Detector = peak. f) Trace mode = max hold. g) Allow trace to fully stabilize. h) Use peak marker function to determine the peak amplitude level.

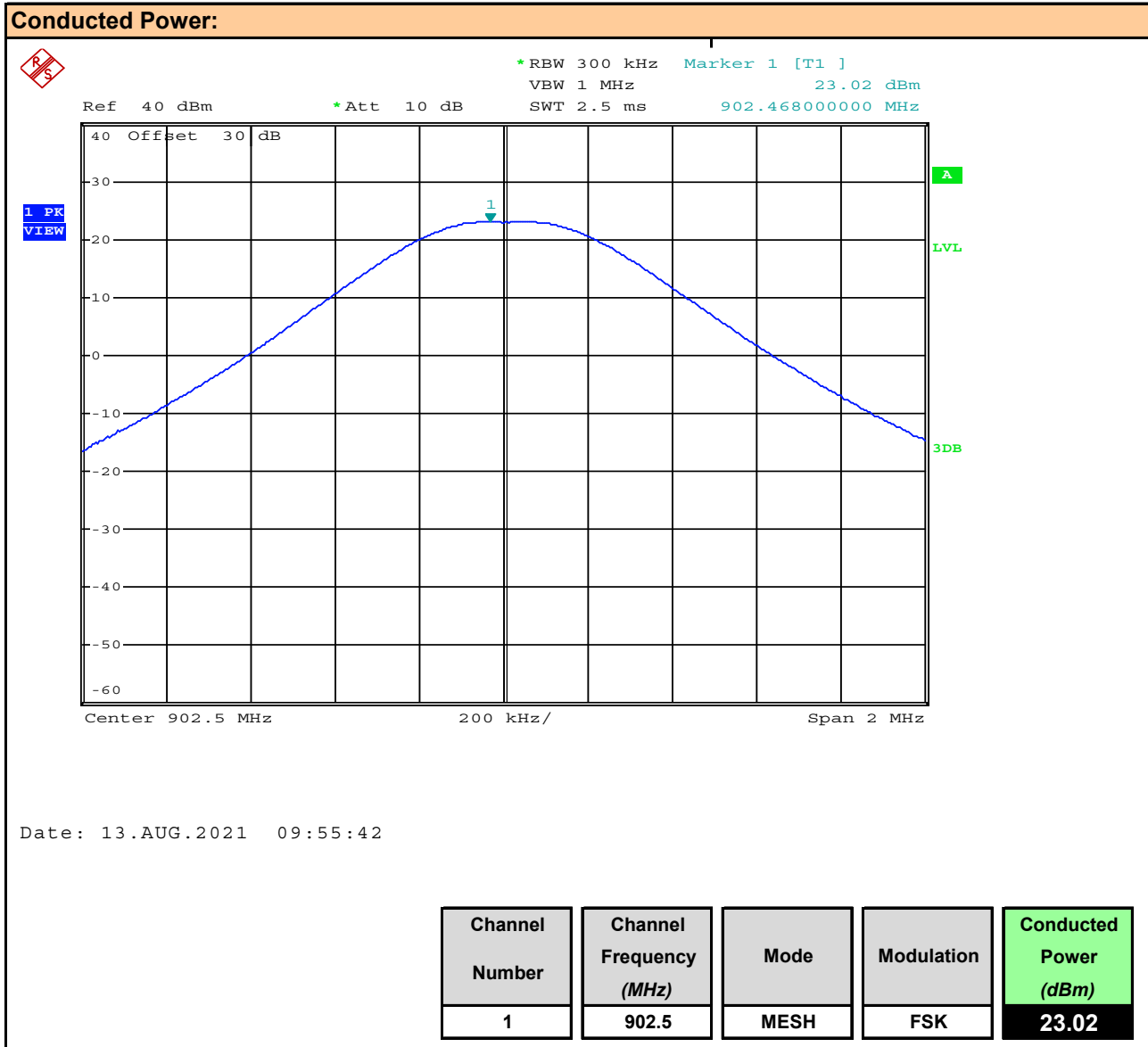
Test Setup

Appendix A - Figure A.1

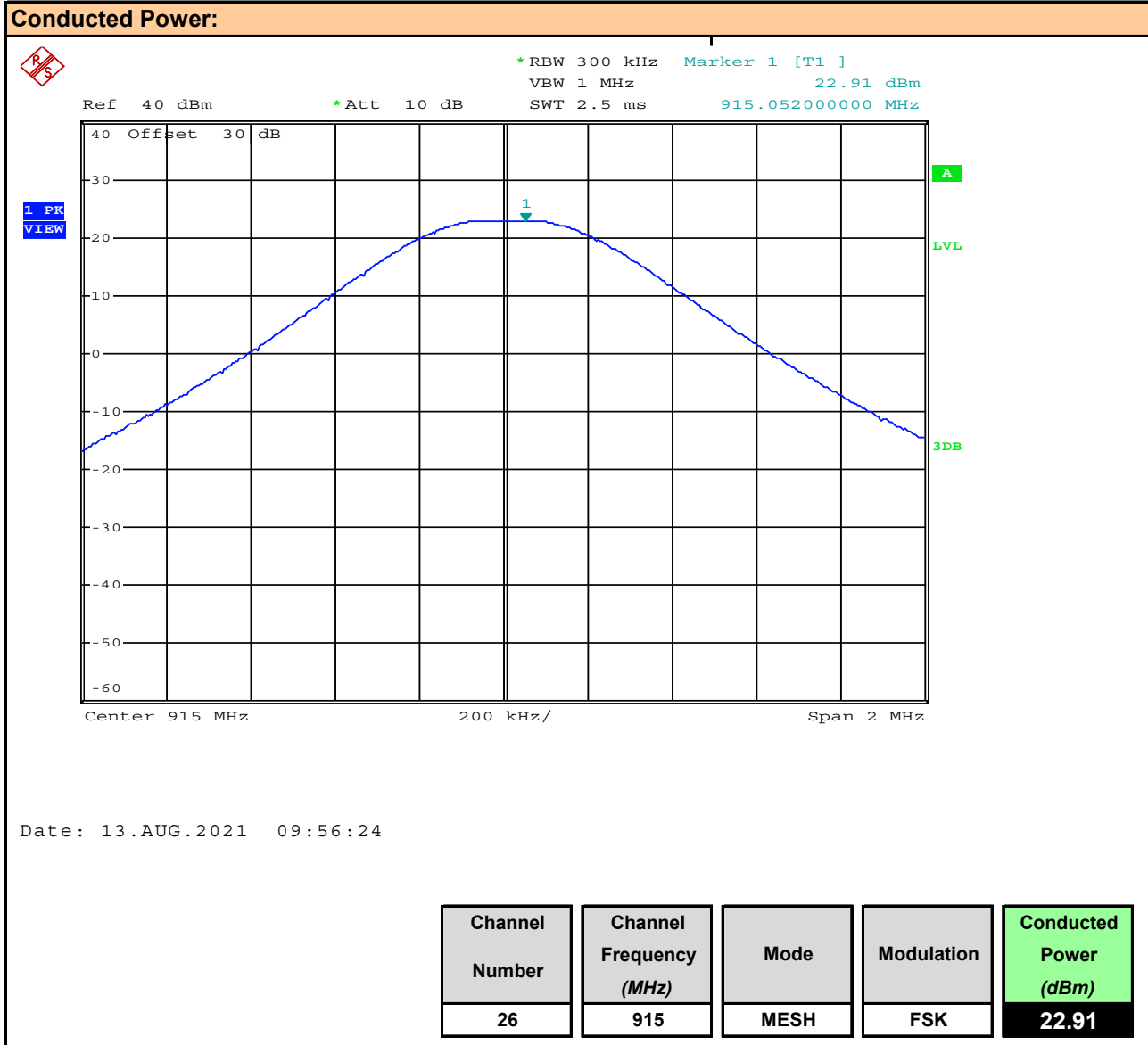
Measurement Procedure

The DUT was connected to a Spectrum Analyzer (SA) via a 30dB attenuator connected to the DUT's antenna port. The SA was configured as described above. The Power was measured and recorded.

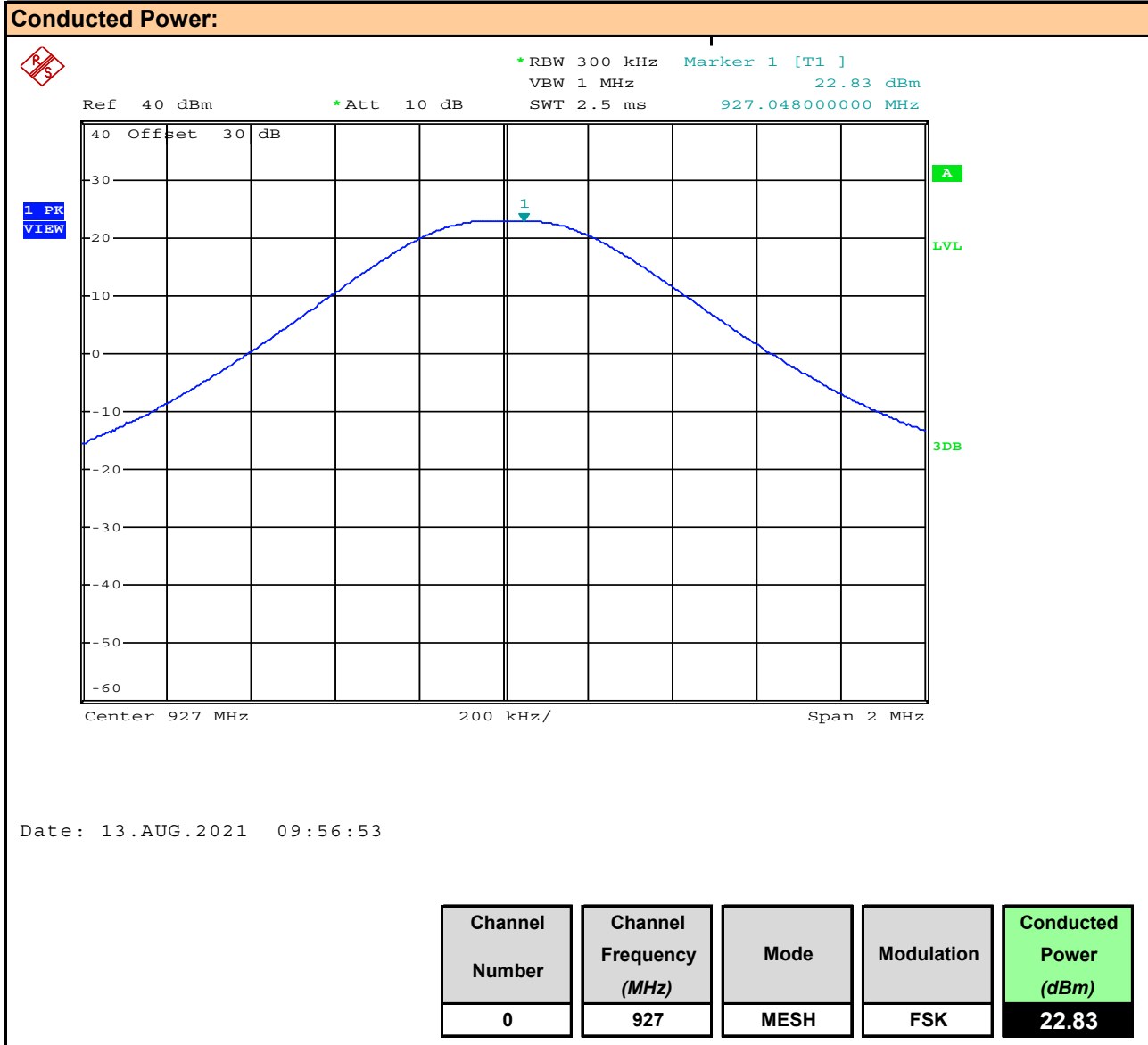
Plot 10B.1 – Conducted Power, MESH Ch 1



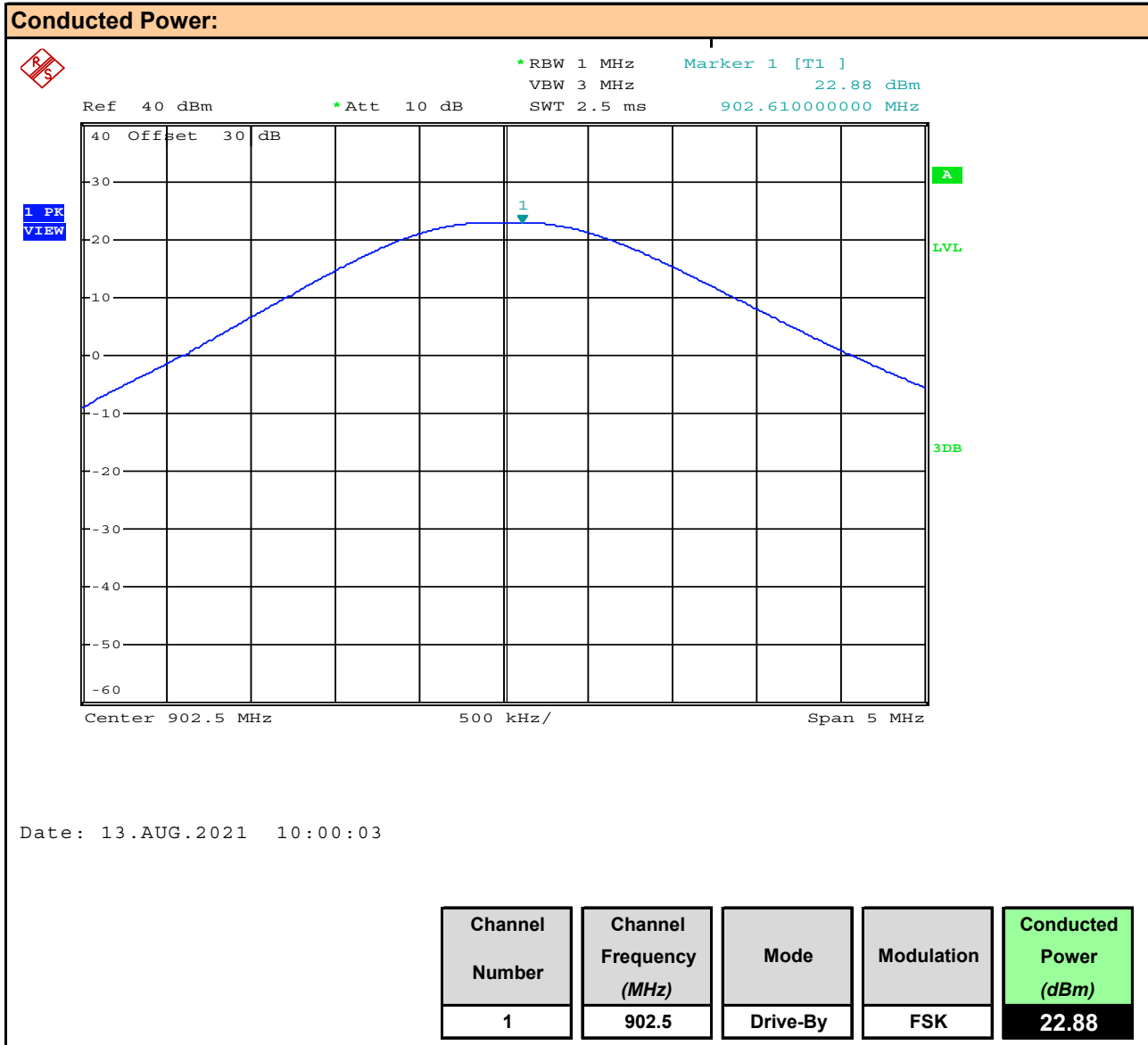
Plot 10B.2 – Conducted Power, MESH Ch 26



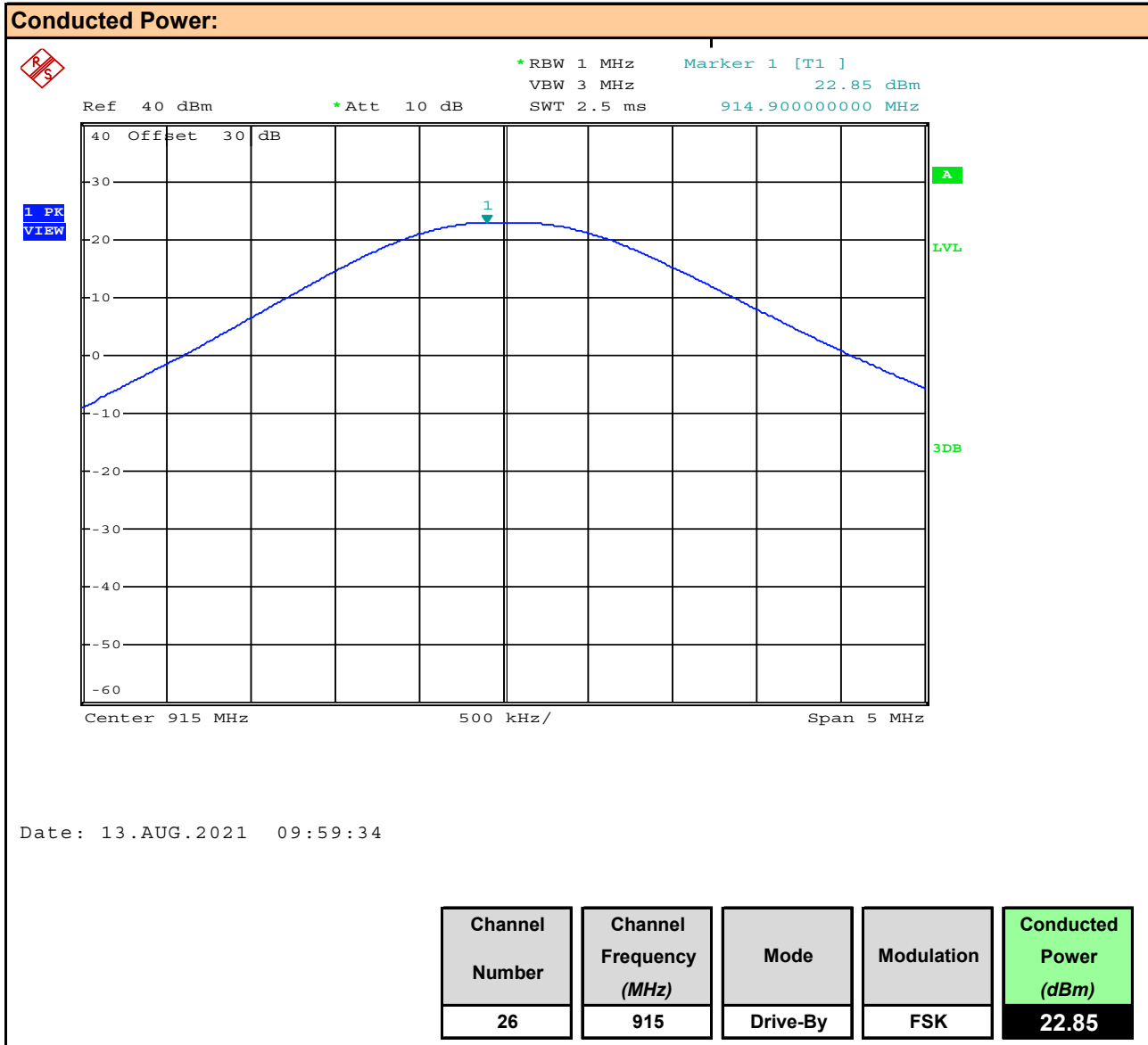
Plot 10B.3 – Conducted Power, MESH Ch 0



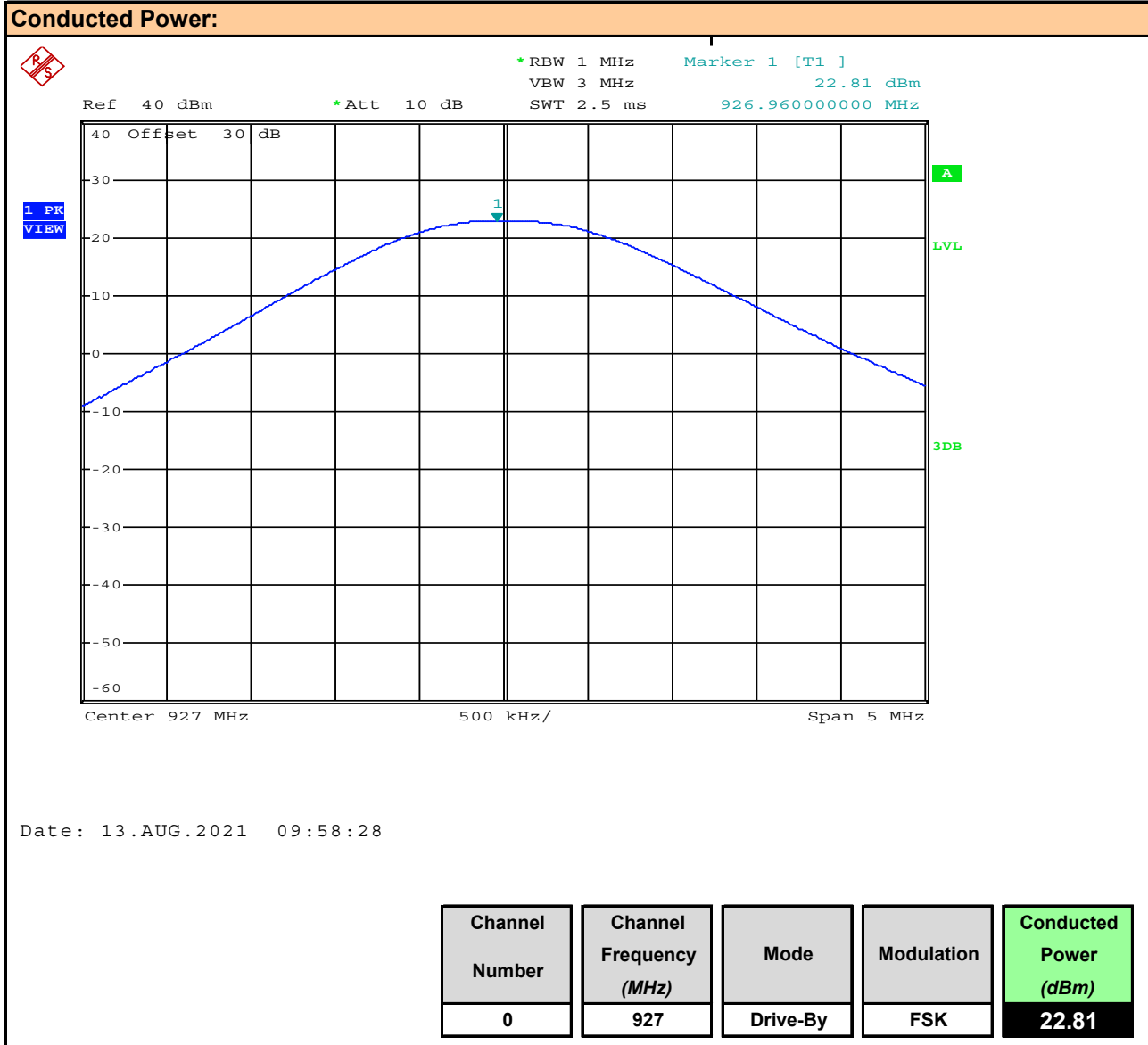
Plot 10B.4 – Conducted Power, Drive-By Ch 1



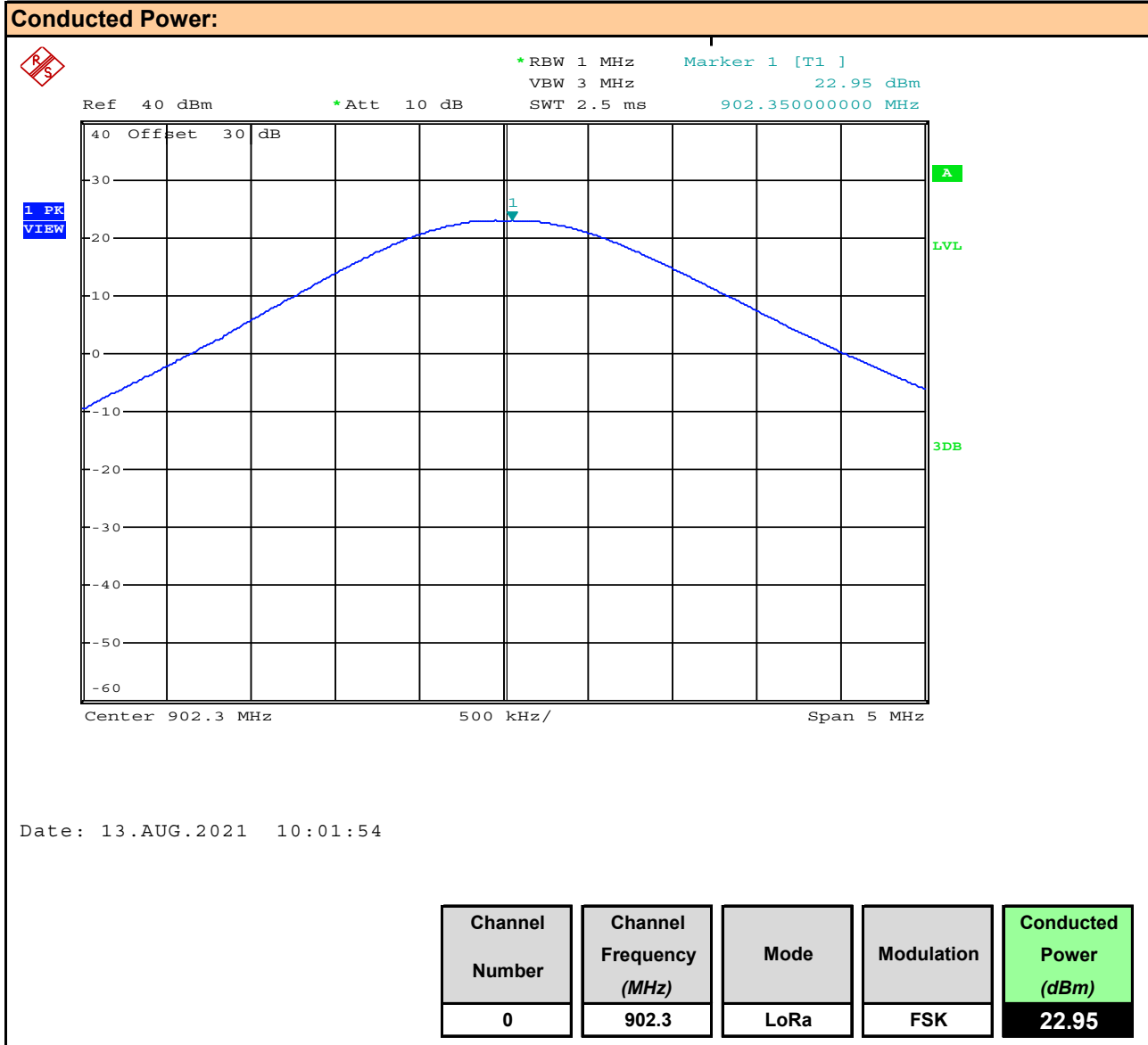
Plot 10B.5 – Conducted Power, Drive-By Ch 26



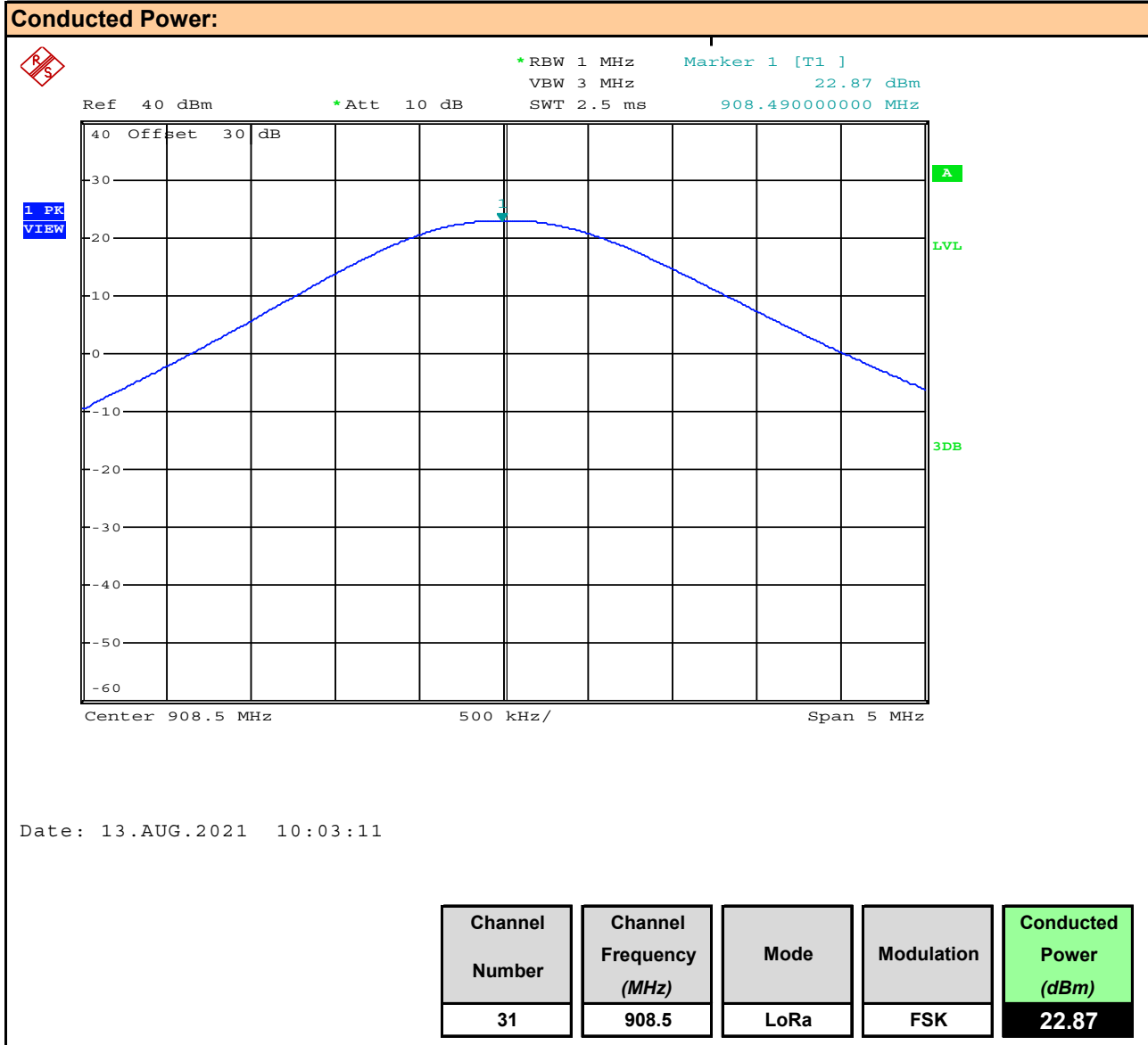
Plot 10B.6 – Conducted Power, Drive-By Ch 0



Plot 10B.7 – Conducted Power, Lora DSS Ch 0



Plot 10B.8 – Conducted Power, Lora DSS Ch 31



Plot 10B.9 – Conducted Power, Lora DSS Ch 63

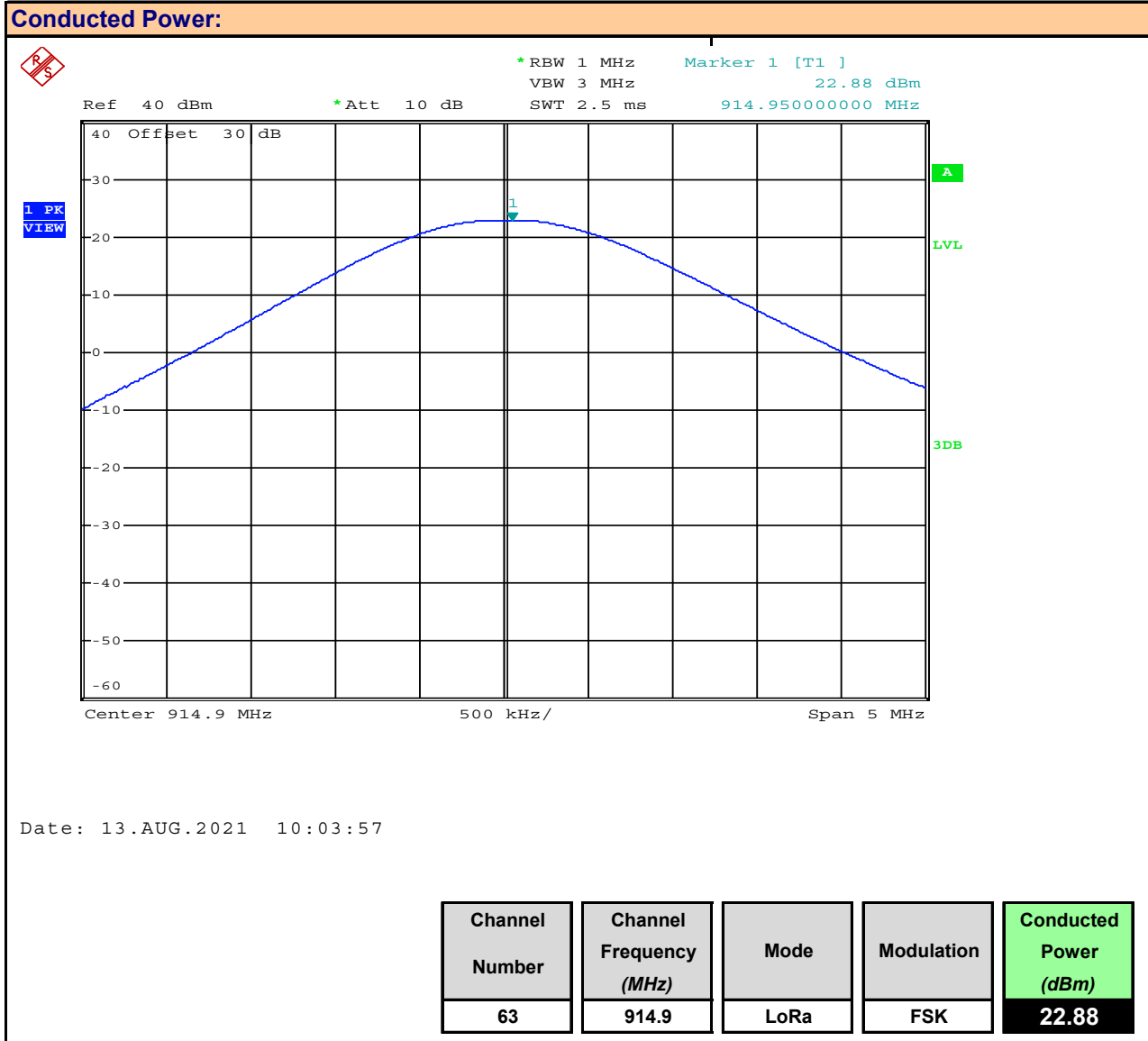


Table 10B.1 – Summary of Conducted Power Measurements, (DSS)

Conducted Power Measurement Results:											
Mode	Channel Number	Frequency (MHz)	Equipment Class	Modulation	Measured Power [P _{Meas}] (dBm)	Conducted Limit [P _{Lim}] (dBm)	Conducted Margin (dB)	Antenna Gain (dBi)	EIRP [E _{Meas}] (dBm)	EIRP Limit [E _{Lim}] (dBm)	EIRP Margin (dB)
MESH	1	902.50	DSS	FSK	23.020	30	7.0	0	23.02	36	13.2
	26	915.00			22.910		7.1		22.91		13.1
	0	927.00			22.830		7.2		22.83		13.1
Drive-By	1	902.50			22.880		7.1		22.88		13.1
	26	915.00			22.850		7.2		22.85		15.7
	0	927.00			22.810		7.2		22.81		15.8
LoRa	0	902.30			22.950		7.1		22.95		15.7
	31	908.50			22.870		7.1		22.87		36.0
	63	914.90			22.880		7.1		22.88		36.0
Result:										Complies	

Conducted Margin = $P_{\text{Limit}} - P_{\text{Meas}}$

EIRP Margin = $E_{\text{Limit}} - E_{\text{Meas}}$

11.0 POWER SPECTRAL DENSITY

Test Procedure

Normative Reference	FCC 47 CFR §15.247(e), RSS-247 (5.2)(b), KDB 558074 (10.3), ANSI C63.10 (11.10.3)
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Limits

47 CFR §15.247(e)	(e) For digitally modulated systems, the power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. This power spectral density shall be determined in accordance with the provisions of paragraph (b) of this section. The same method of determining the conducted output power shall be used to determine the power spectral density.
RSS-247 (5.2)(b)	b) The transmitter power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. This power spectral density shall be determined in accordance with the provisions of section 5.4(d), (i.e. the power spectral density shall be determined using the same method as is used to determine the conducted output power).
KDB 558074 (10.3) C63.10 (11.10.3)	Method AVGPS-1 (trace averaging with EUT transmitting at full power throughout each sweep) This procedure may be used when the maximum (average) conducted output power was used to demonstrate compliance to the output power limit. This is the baseline method for determining the maximum (average) conducted PSD level. If the instrument has an RMS power averaging detector, it must be used; otherwise, use the sample detector. The EUT must be configured to transmit continuously (duty cycle $\geq 98\%$); otherwise sweep triggering/signal gating must be implemented to ensure that measurements are made only when the EUT is transmitting at its maximum power control level (no transmitter off time is to be considered). a) Set instrument center frequency to DTS channel center frequency. b) Set span to at least $1.5 \times \text{OBW}$. c) Set RBW to: $3 \text{ kHz} \leq \text{RBW} \leq 100 \text{ kHz}$. d) Set VBW $\geq 3 \times \text{RBW}$. e) Detector = RMS f) Ensure that the number of measurement points in the sweep $\geq 2 \times \text{span/RBW}$. g) Sweep time = auto couple. h) Employ trace averaging (RMS) mode over a minimum of 100 traces. i) Use the peak marker function to determine the maximum amplitude level. j) If measured value exceeds limit, reduce RBW (no less than 3 kHz) and repeat (note that this may require zooming in on the emission of interest and reducing the span in order to meet the minimum measurement point requirement as the RBW is reduced).
Test Setup	Appendix A Figure A.1

Measurement Procedure

The DUT was connected to a Spectrum Analyzer (SA) via a 30dB attenuator connected to the DUT's antenna port. The SA was configured as described above. Number of Sweep Points $\geq 2 \times \text{Span} / \text{RBW} = 2 \times (1.5\text{MHz} / 3\text{kHz}) = 1000$, the SA was configured for 1001 Points. The output power of the DUT was set to the manufacturer's highest output power setting at the Low, Mid and High frequency channels as permitted by the device. The DUT was set to transmit at 100% Duty Cycle. The Power Spectral Density was measured and recorded.

Power Spectral Density:

RS

1 RM*

VIEW

Ref 40 dBm

*Att 10 dB

*RBW 10 kHz

VBW 100 kHz

*SWT 20 ms

Marker 1 [T1]

5.39 dBm

903.048000000 MHz

Offset 30 dB

SWR 100 of 100

Center 903 MHz

100 kHz/

Span 1 MHz

40

30

20

10

0

-10

-20

-30

-40

-50

-60

A

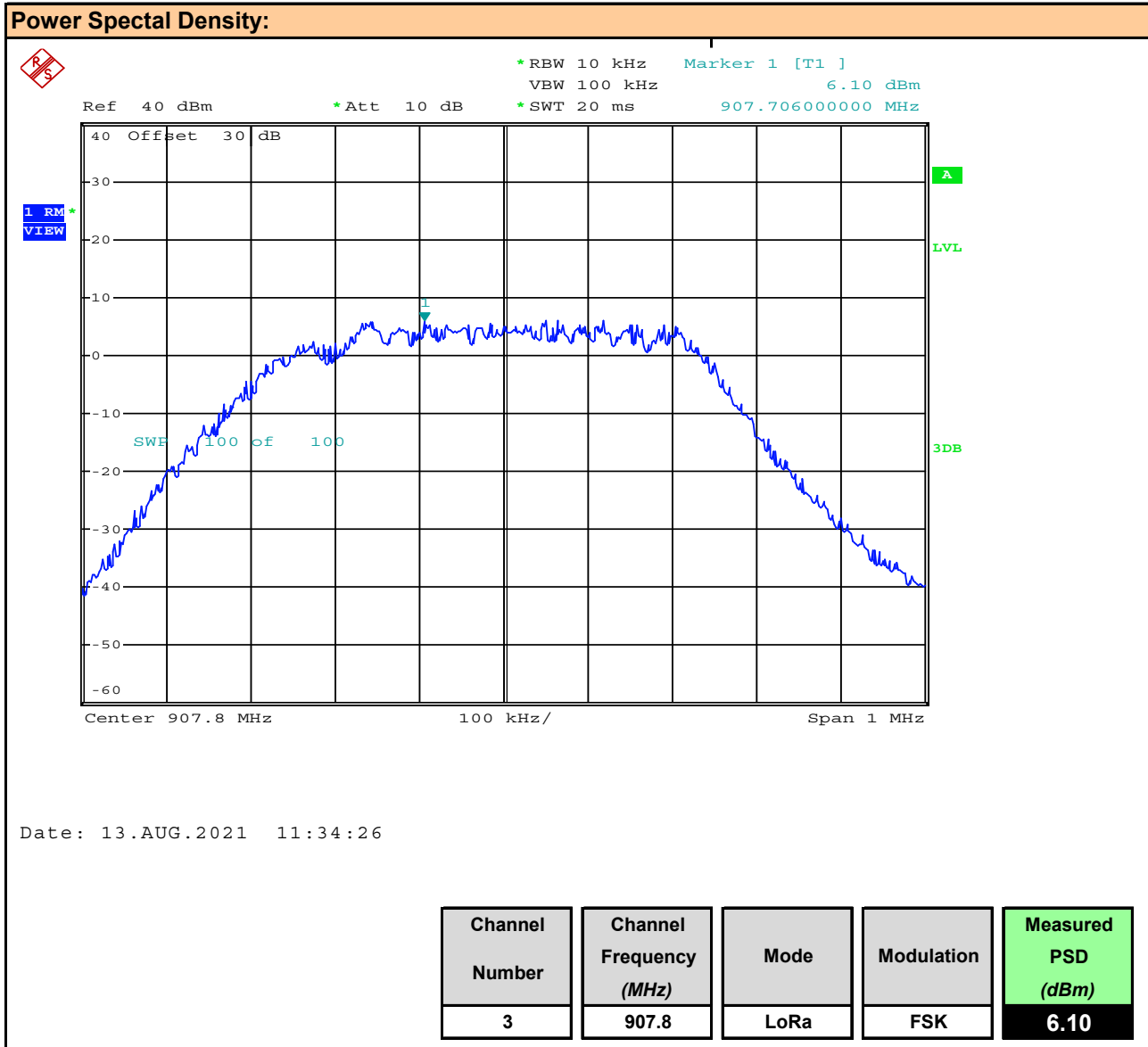
LVL

3DB

Date: 13.AUG.2021 11:33:35

Channel Number	Channel Frequency (MHz)	Mode	Modulation	Measured PSD (dBm)
0	903	LoRa	FSK	5.39

Plot 11.2 – Power Spectral Density, LoRa (DTS) Ch 3



Plot 11.3 – Power Spectral Density, LoRa (DTS) Ch 7

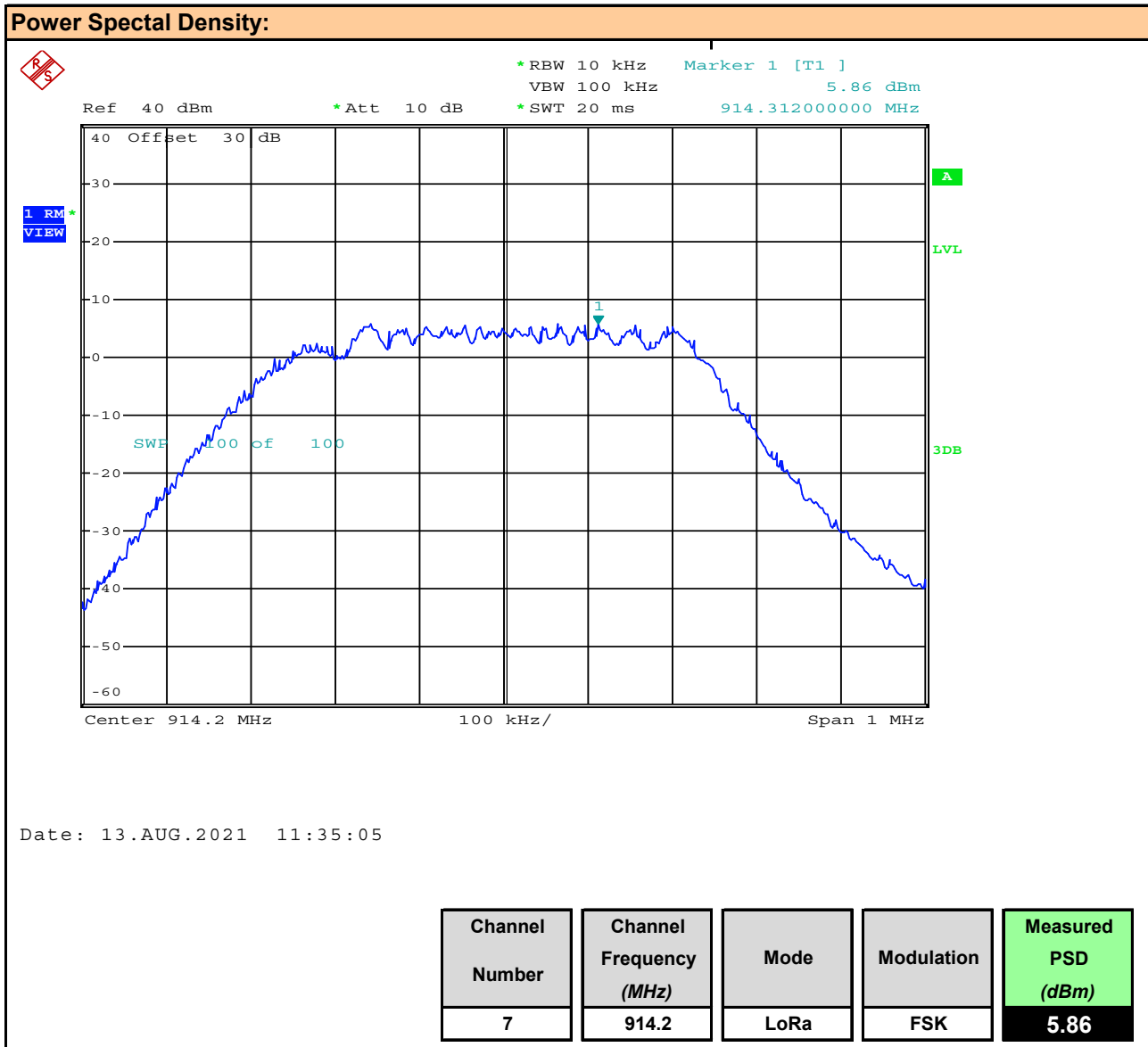


Table 11.1 – Summary of Power Spectral Density Measurements, (DTS)

Power Spectral Density Measurement Results: DTS						
Mode	Channel Number	Frequency (MHz)	Modulation	Measured PSD [P _{Meas}] (dBm)	PSD Limit [P _{Lim}] (dBm)	Conducted Margin (dB)
Lora	0	903.0	FSK	5.39	8	2.6
	3	907.8		6.10	8	1.9
	7	914.2		5.86	8	2.1
Result:					Complies	

$$\text{Margin} = P_{\text{Limit}} - P_{\text{Meas}}$$

12.0 FHSS NUMBER OF HOPPING CHANNELS

Test Procedure

Normative Reference	FCC 47 CFR §2.1049, §15.247(a)(1)(i), RSS-Gen (6.7), RSS-247 (5.2)(c), KDB 558074 (8.2), ANSI C63.10 (11.8.2)
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Limits

§15.247(a)(1) (i)	(a) Operation under the provisions of this Section is limited to frequency hopping and digitally modulated intentional radiators that comply with the following provisions: (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 and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period; if the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 10 second period. The maximum allowed 20 dB bandwidth of the hopping channel is 500 kHz.
RSS-247 (5.2)(c)	5.2 Digital transmission systems DTSS include systems that employ digital modulation techniques resulting in spectral characteristics similar to direct sequence systems. The following applies to the bands 902-928 MHz and 2400 - 2483.5 MHz: c) For FHSs in the band 902-928 MHz: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping channels and the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 20-second period. If the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping channels and the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 10-second period. The maximum 20 dB bandwidth of the hopping channel shall be 500 kHz.

General Procedure

KDB 558074 (8.2) C63.10 (11.8.2)	11.8.2 Option 2 The automatic bandwidth measurement capability of an instrument may be employed using the X dB bandwidth mode with X set to 6 dB, if the functionality described above (i.e., RBW = 100 kHz, VBW ≥ 3 X RBW, peak detector with maximum hold) is implemented by the instrumentation function. When using this capability, care shall be taken so that the bandwidth measurement is not influenced by any intermediate power nulls in the fundamental emission that might be ≥ 6 dB.
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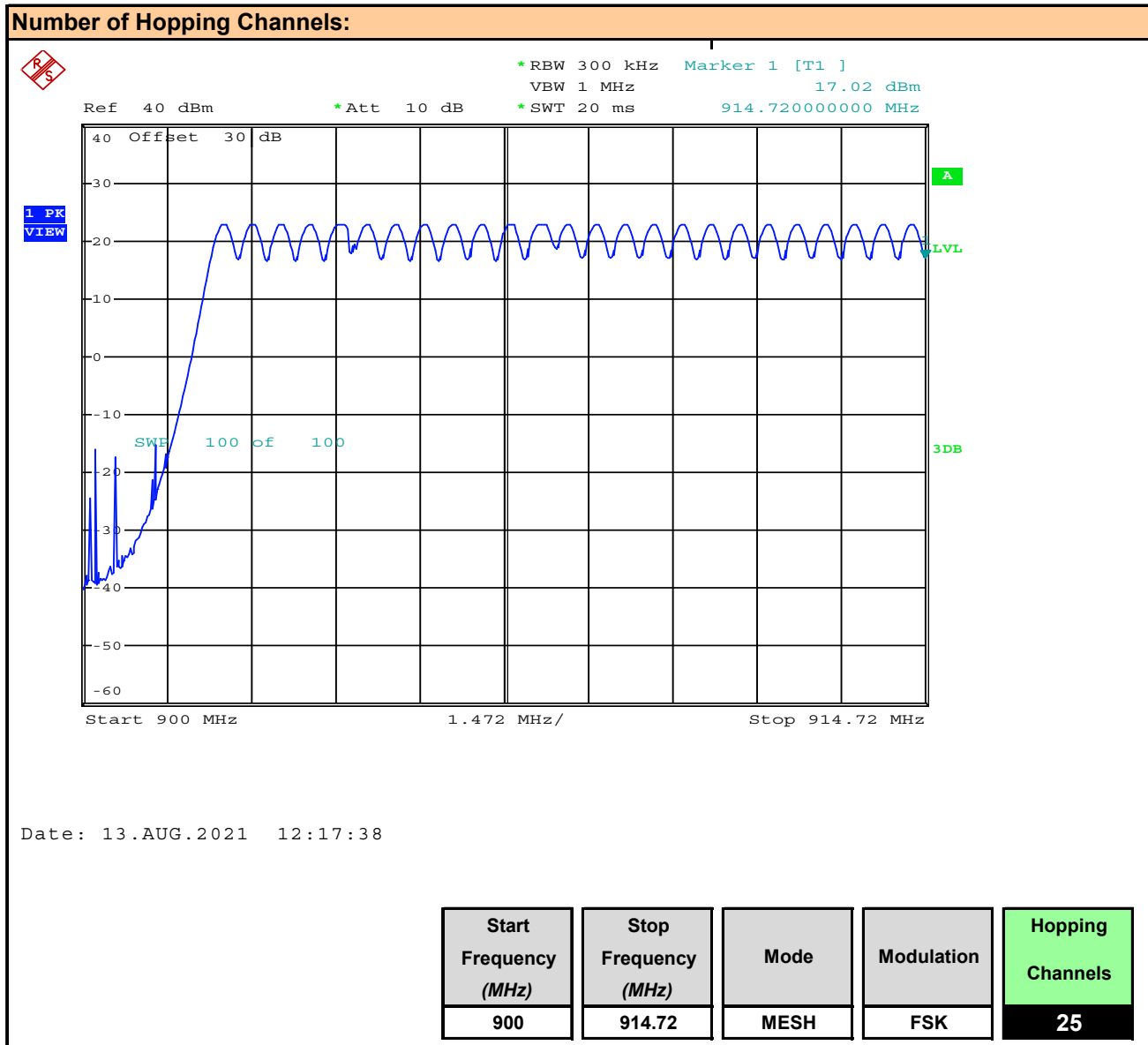
Test Setup

Appendix A - Figure A.1

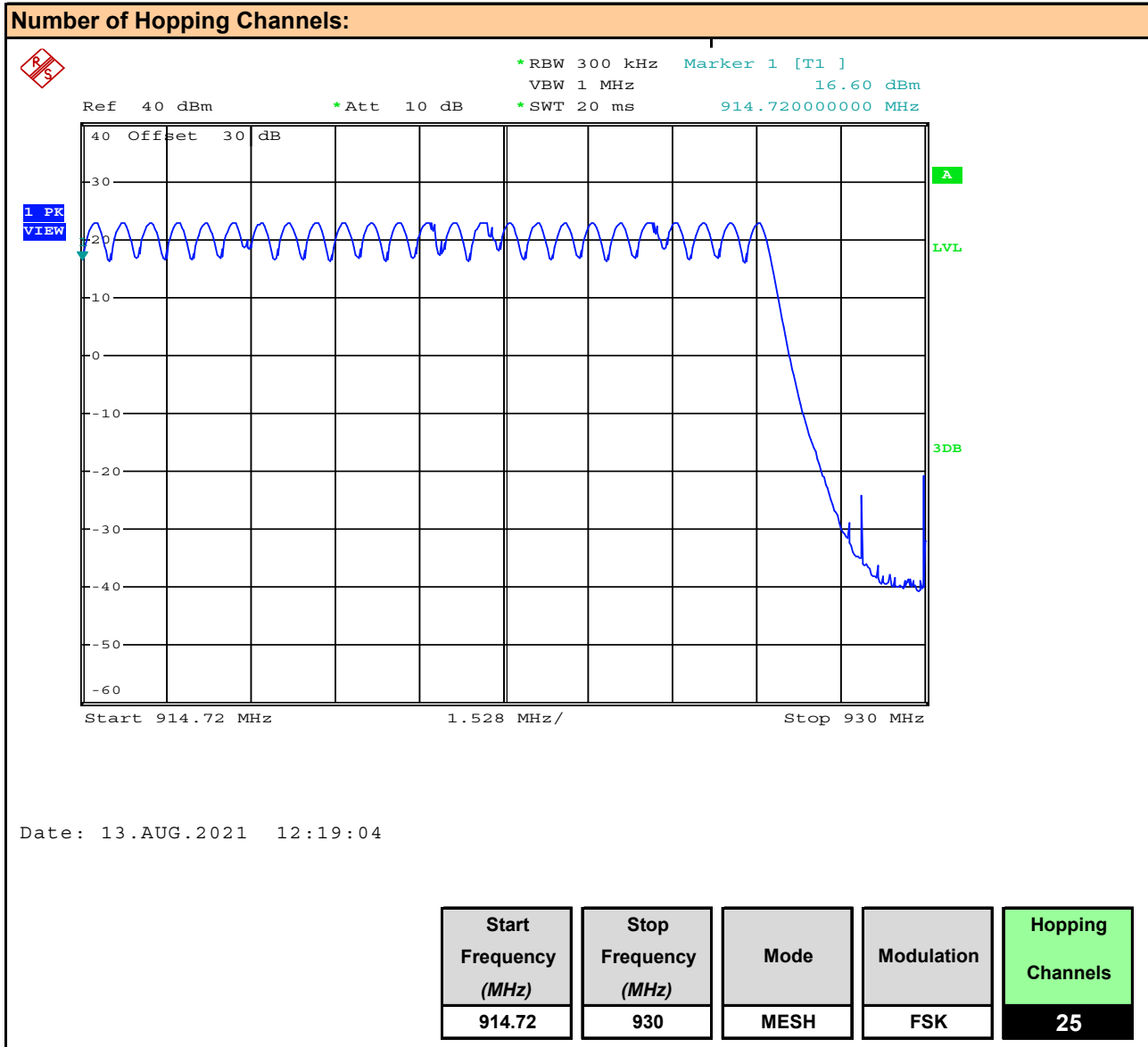
Measurement Procedure

The DUT was connected to a Spectrum Analyzer (SA) via a 30dB attenuator connected to the DUT's antenna port. The SA was configured as above using the Automatic 6dB Cursor Bandwidth measurement. The output power of the DUT was set to the manufacturer's highest output power setting at the Low, Mid and High frequency channels as permitted by the device.

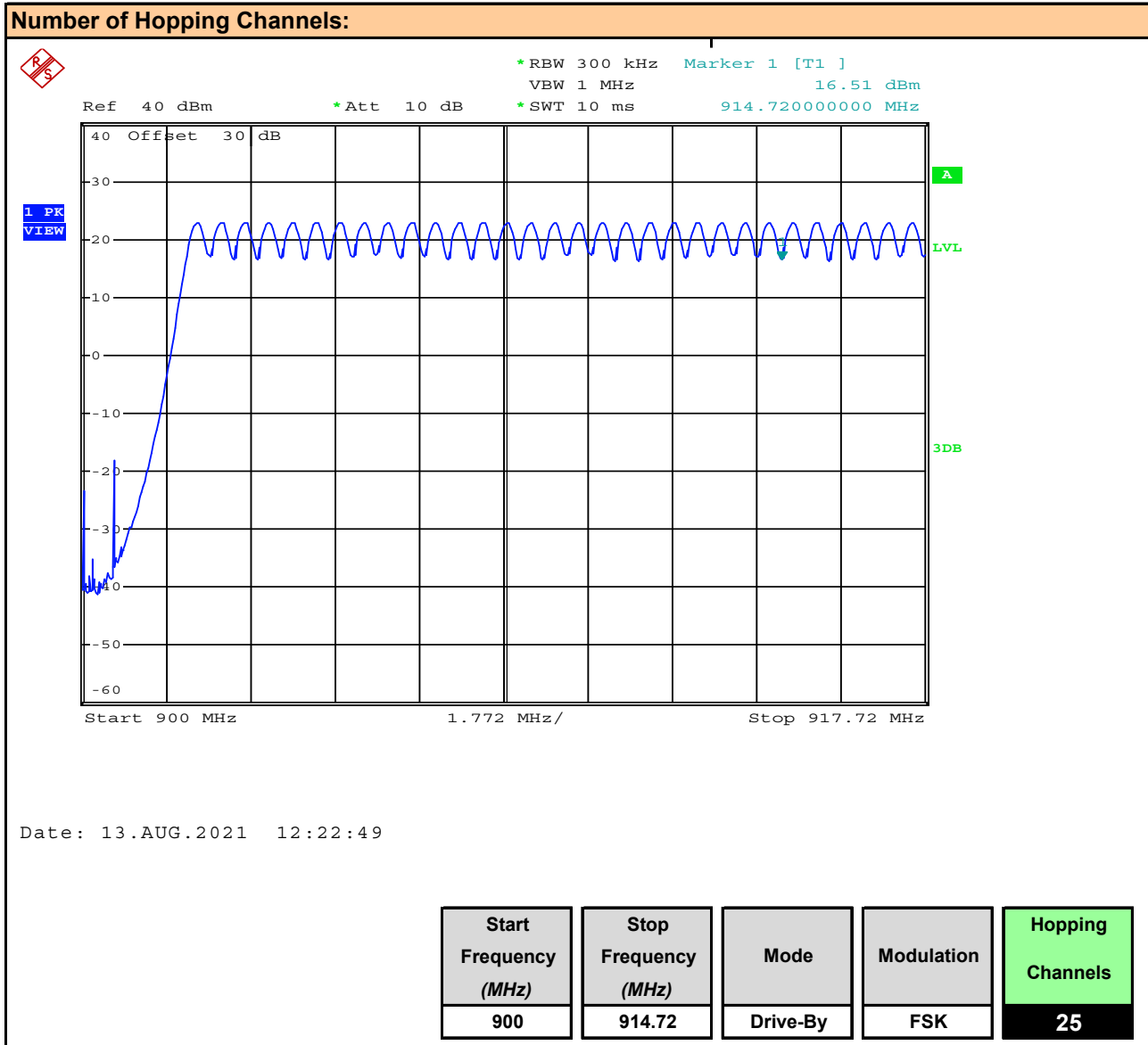
Plot 12.1 – Number of Hopping Channels, MESH, Part 1



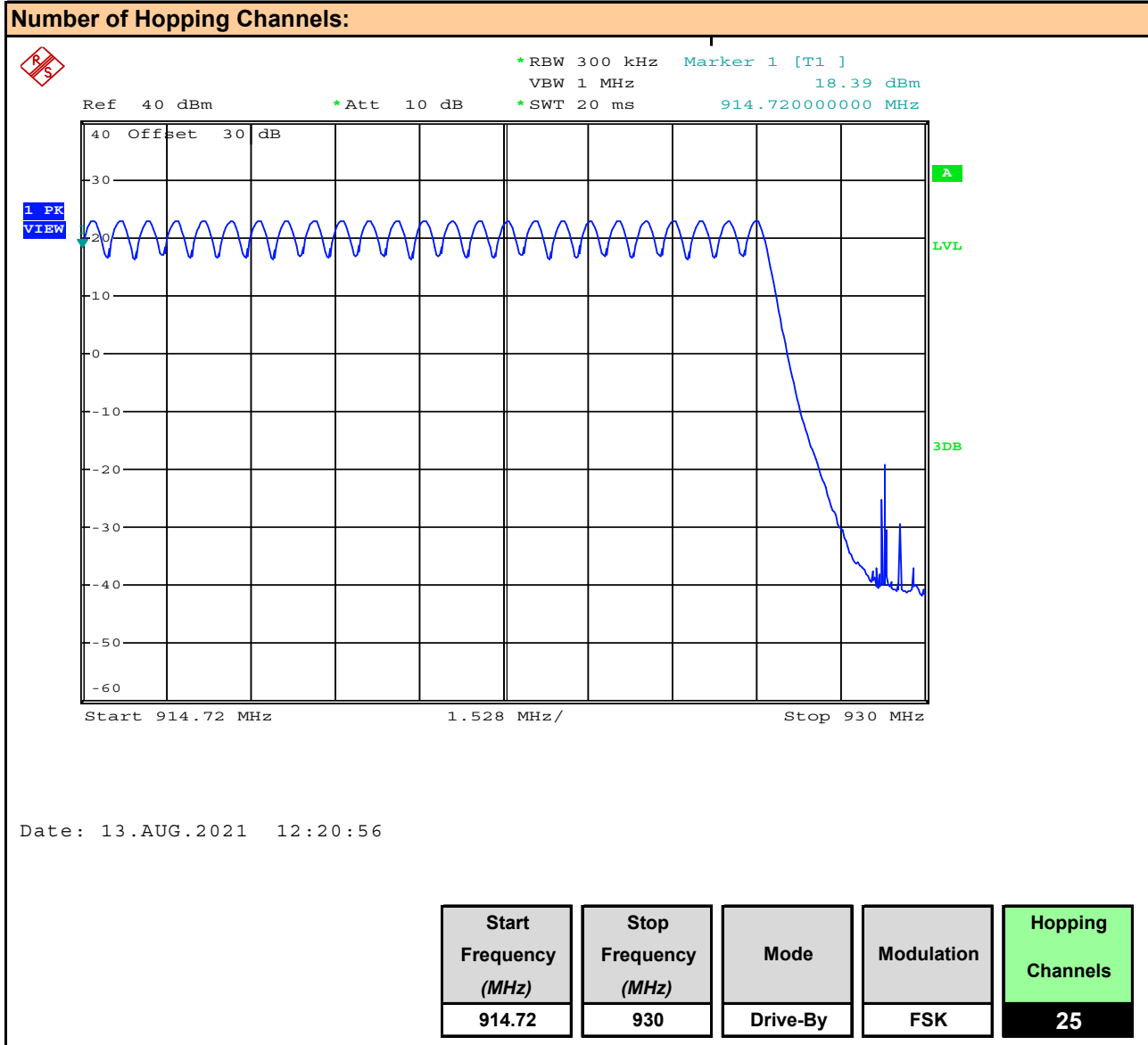
Plot 12.2 – Number of Hopping Channels, MESH, Part 2



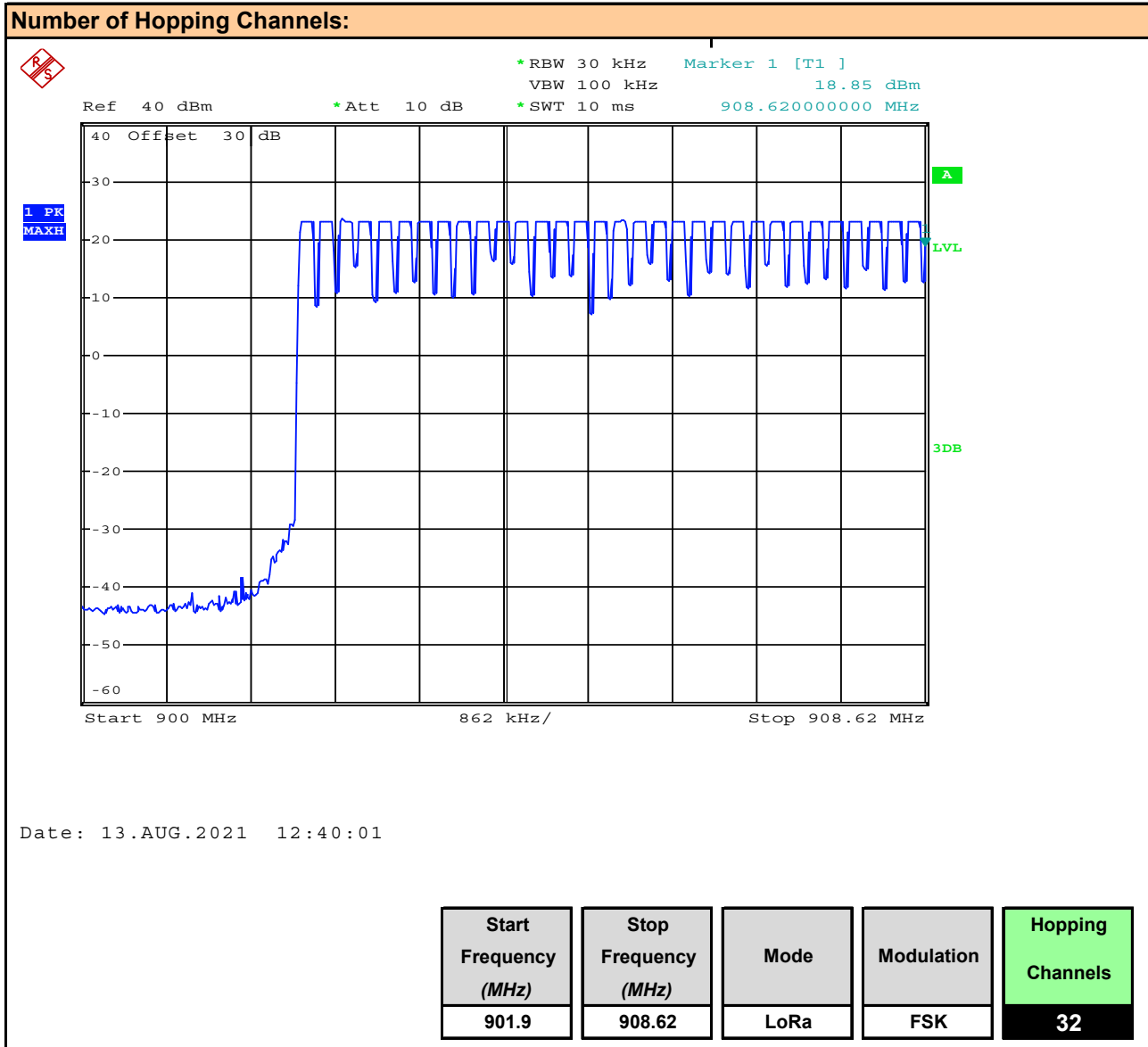
Plot 12.3 – Number of Hopping Channels, Drive-By, Part 1



Plot 12.4 – Number of Hopping Channels, Drive-By, Part 2



Plot 12.5 – Number of Hopping Channels, LoRa (DSS), Part 1



Plot 12.6 – Number of Hopping Channels, LoRa (DSS), Part 2

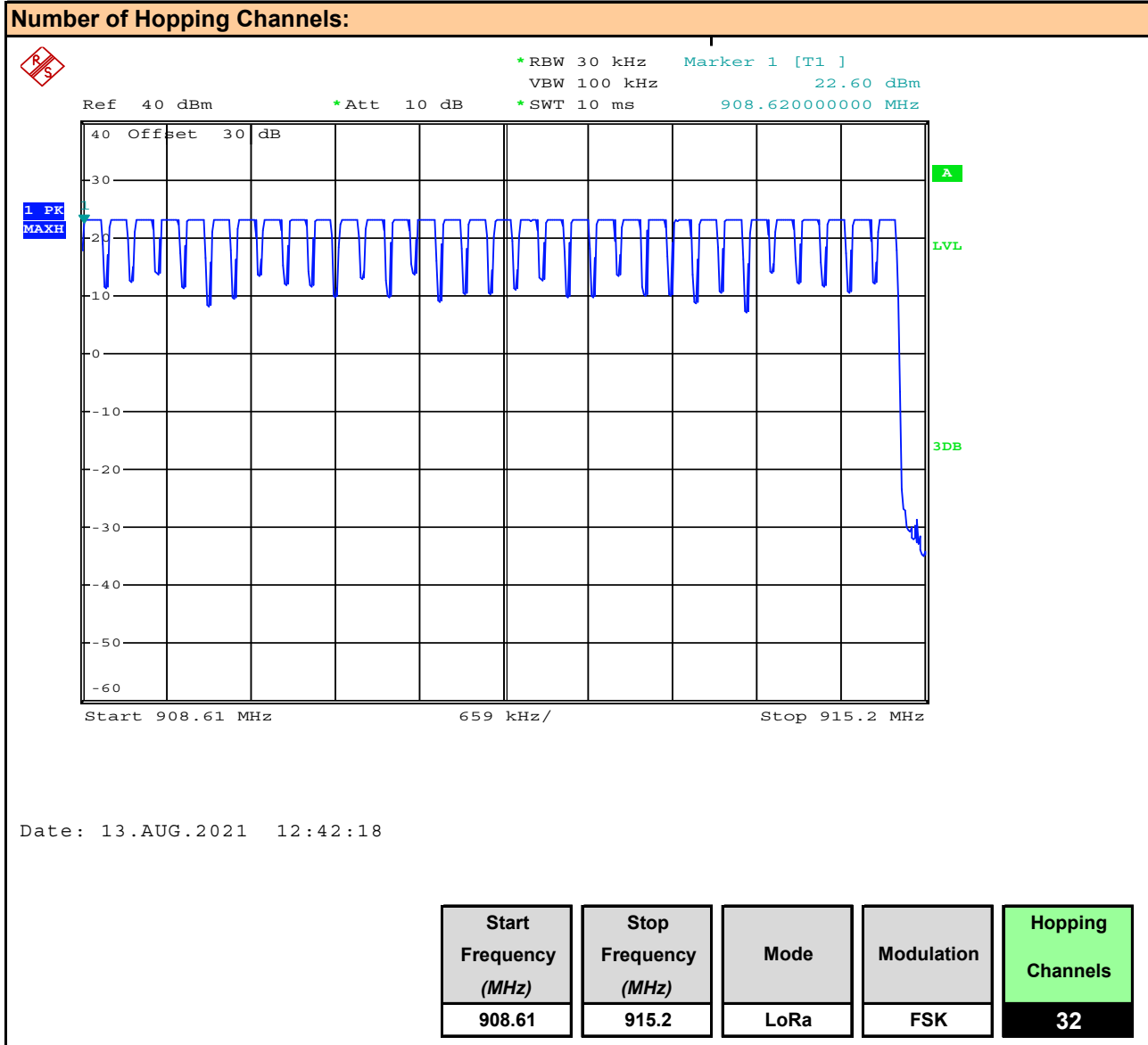


Table 12.2 – Summary of FHSS Number of Hopping Channels

Hopping Channel Results DSS			
Frequency Range (MHz)	Mode	Modulation	Number of Hopping Channels
900-914.7	MESH	FSK	25
914.7-930			25
Total:			50
900-914.7	Drive-By	FSK	25
914.7-930			25
Total:			50
901.9-908.6	LoRa	FSK	32
908.6-915			32
Total:			64
Result:			Complies

13.0 FHSS CHANNEL SEPARATION

Test Procedure

Normative Reference	FCC 47 CFR §2.1049, §15.247(a)(1)(i), RSS-Gen (6.7), RSS-247 (5.2)(c), KDB 558074 (8.2), ANSI C63.10 (11.8.2)
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Limits

§15.247(a)(1) (i)	(a) Operation under the provisions of this Section is limited to frequency hopping and digitally modulated intentional radiators that comply with the following provisions: (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 and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period; if the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 10 second period. The maximum allowed 20 dB bandwidth of the hopping channel is 500 kHz.
RSS-247 (5.2)(c)	5.2 Digital transmission systems DTSS include systems that employ digital modulation techniques resulting in spectral characteristics similar to direct sequence systems. The following applies to the bands 902-928 MHz and 2400 - 2483.5 MHz: c) For FHSs in the band 902-928 MHz: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping channels and the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 20-second period. If the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping channels and the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 10-second period. The maximum 20 dB bandwidth of the hopping channel shall be 500 kHz.

General Procedure

KDB 558074 (8.2) C63.10 (11.8.2)	11.8.2 Option 2 The automatic bandwidth measurement capability of an instrument may be employed using the X dB bandwidth mode with X set to 6 dB, if the functionality described above (i.e., RBW = 100 kHz, VBW ≥ 3 X RBW, peak detector with maximum hold) is implemented by the instrumentation function. When using this capability, care shall be taken so that the bandwidth measurement is not influenced by any intermediate power nulls in the fundamental emission that might be ≥ 6 dB.
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Test Setup

Appendix A - Figure A.1

Measurement Procedure

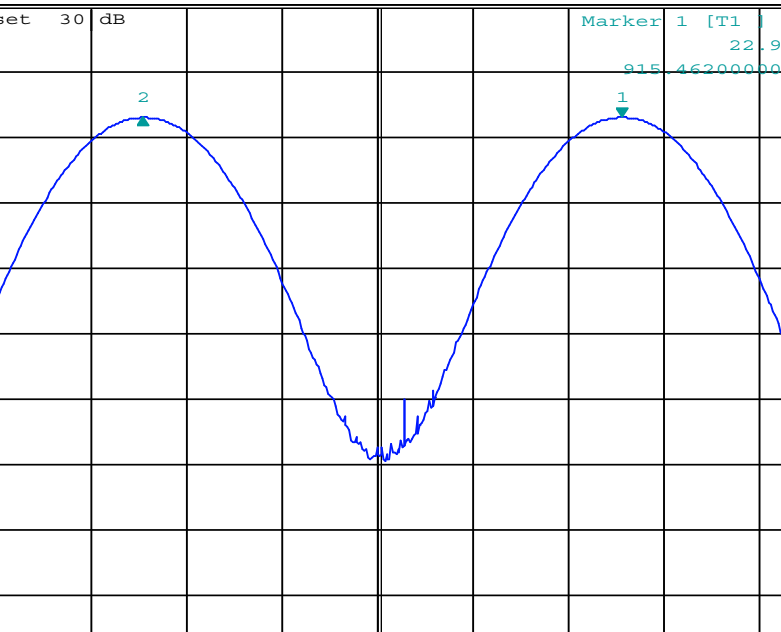
The DUT was connected to a Spectrum Analyzer (SA) via a 30dB attenuator connected to the DUT's antenna port. The SA was configured as above using the Automatic 6dB Cursor Bandwidth measurement. The output power of the DUT was set to the manufacturer's highest output power setting at the Low, Mid and High frequency channels as permitted by the device.

Hopping Channel Separation:

 *RBW 100 kHz Delta 2 [T1]
VBW 300 kHz -0.00 dB
*Att 10 dB *SWT 10 ms -502.00000000 kHz

Ref 40 dBm Offset 30 dB

1 PK VIEW



Marker 1 [T1]
22.96 dBm
915.463000000 MHz

2

1

LVL

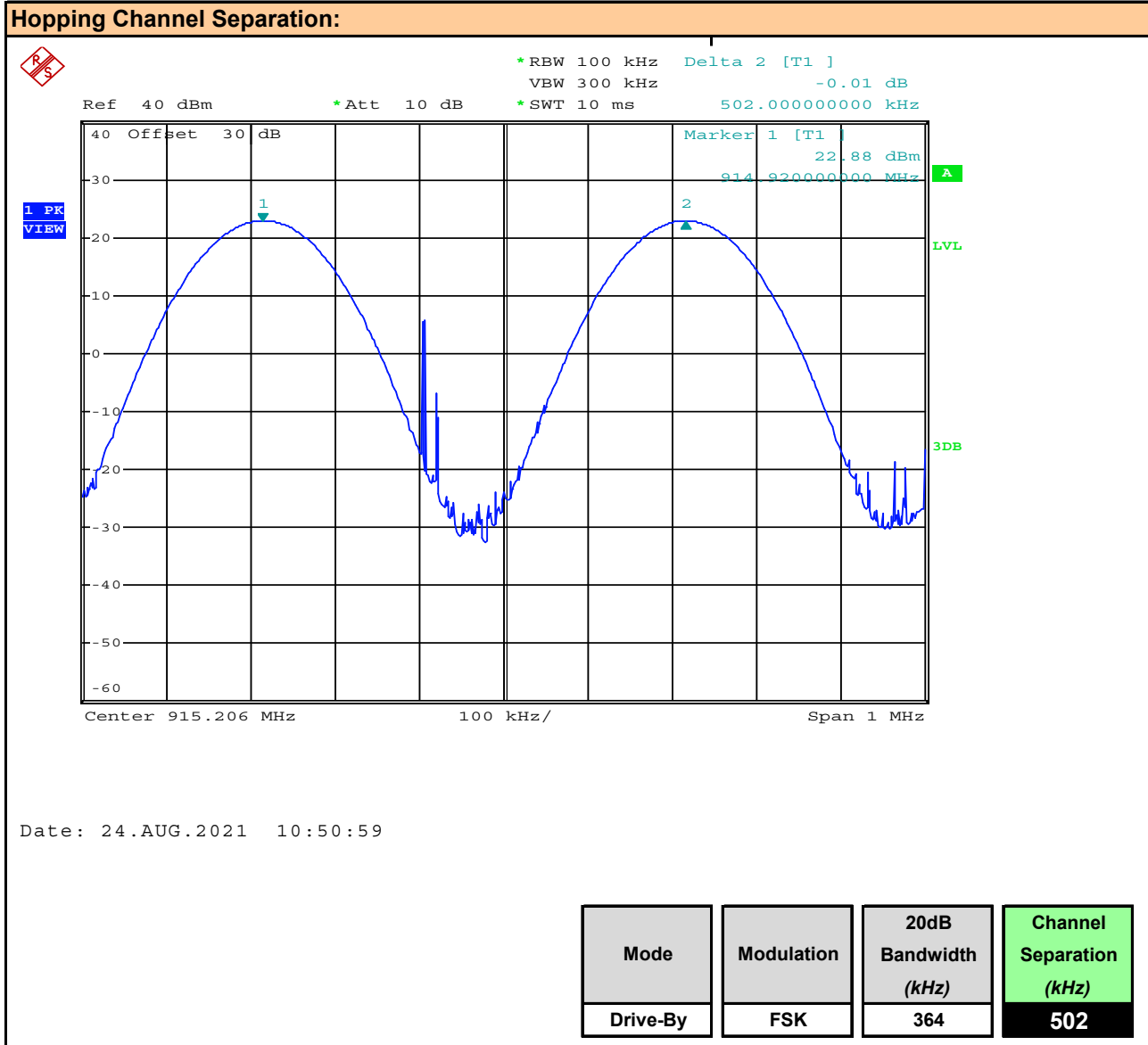
3DB

Center 915.206 MHz 100 kHz/ Span 1 MHz

Date: 24.AUG.2021 10:49:06

Mode	Modulation	20dB Bandwidth (kHz)	Channel Separation (kHz)
MESH	FSK	162	502

Plot 13.2 – Channel Separation, Drive-By



Plot 13.3 – Channel Separation, LoRa (DSS)

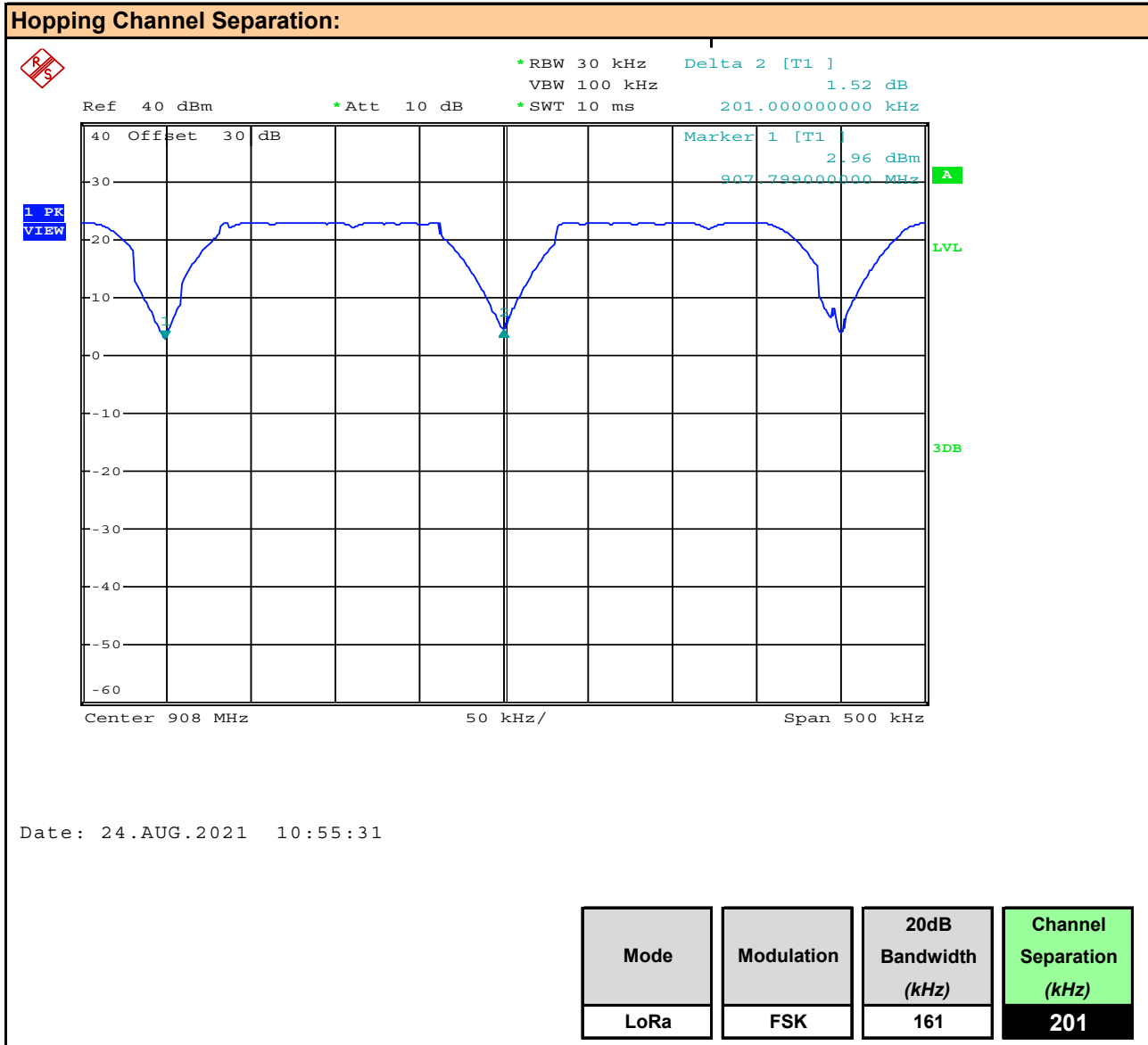


Table 13.1 – Summary of FHSS Channel Separation

Hopping Channel Separation Results DSS				
Mode	Modulation	Channel Separation (kHz)	20dB BW (kHz)	Margin (kHz)
MESH	FSK	502	162.000	340.000
Drive-By		502	364.000	138.000
Lora		201	159.000	42.000
Result:				Complies

Margin = Channel Separation - Minimum Bandwidth

14.0 FHSS TIME OF OCCUPANCY

Test Procedure

Normative	FCC 47 CFR §2.1049, §15.247(a)(1)(i), RSS-Gen (6.7), RSS-247 (5.2)(c),
Reference	KDB 558074 (8.2), ANSI C63.10 (11.8.2)

Limits

§15.247(a)(1) (i)	(a) Operation under the provisions of this Section is limited to frequency hopping and digitally modulated intentional radiators that comply with the following provisions: (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 and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period; if the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 10 second period. The maximum allowed 20 dB bandwidth of the hopping channel is 500 kHz.
RSS-247 (5.2)(c)	5.2 Digital transmission systems DTSS include systems that employ digital modulation techniques resulting in spectral characteristics similar to direct sequence systems. The following applies to the bands 902-928 MHz and 2400 - 2483.5 MHz: c) For FHSs in the band 902-928 MHz: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping channels and the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 20-second period. If the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping channels and the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 10-second period. The maximum 20 dB bandwidth of the hopping channel shall be 500 kHz.

General Procedure

KDB 558074 (8.2) C63.10 (11.8.2)	11.8.2 Option 2 The automatic bandwidth measurement capability of an instrument may be employed using the X dB bandwidth mode with X set to 6 dB, if the functionality described above (i.e., RBW = 100 kHz, VBW ≥ 3 X RBW, peak detector with maximum hold) is implemented by the instrumentation function. When using this capability, care shall be taken so that the bandwidth measurement is not influenced by any intermediate power nulls in the fundamental emission that might be ≥ 6 dB.
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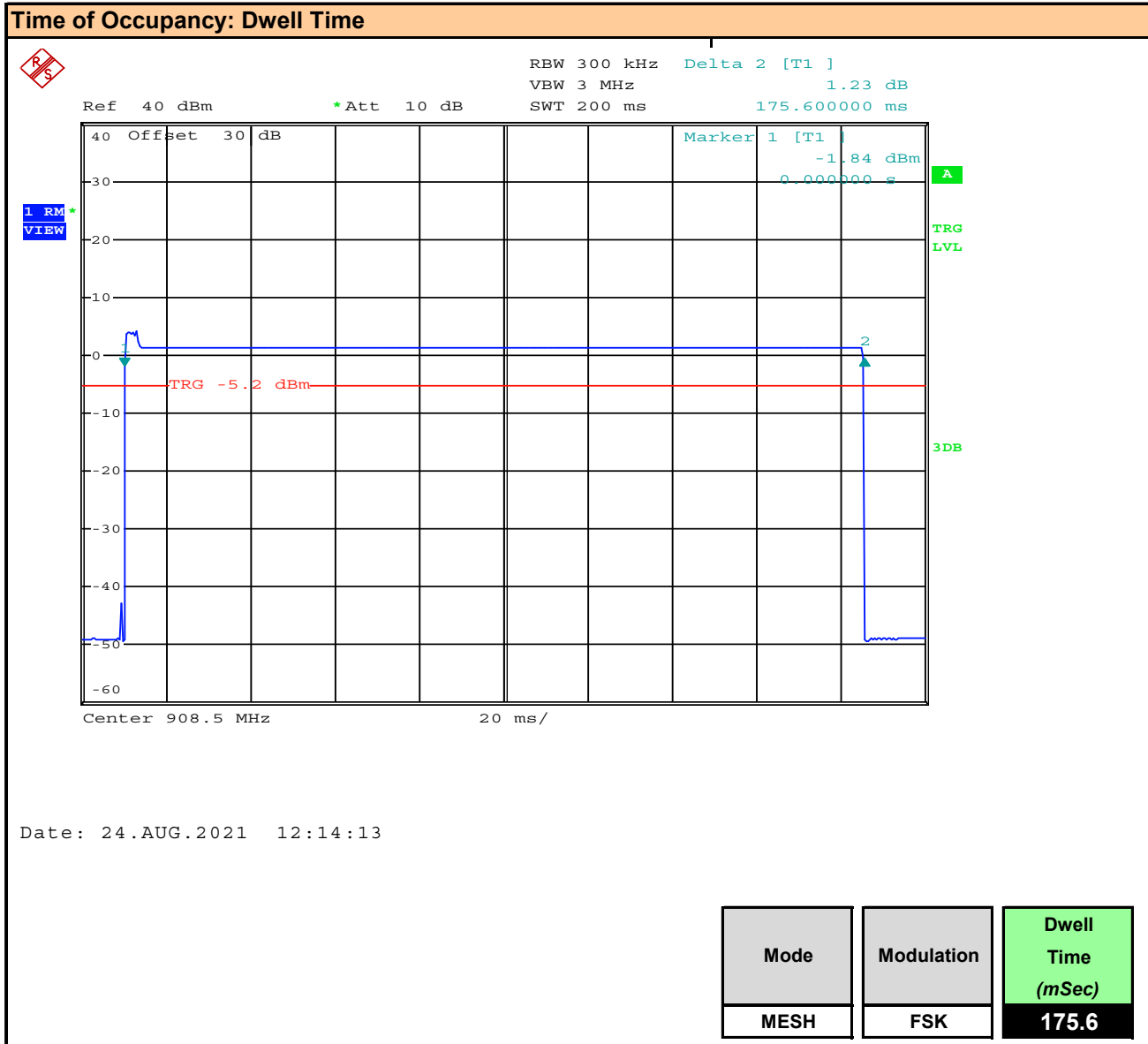
Test Setup

Appendix A - Figure A.1

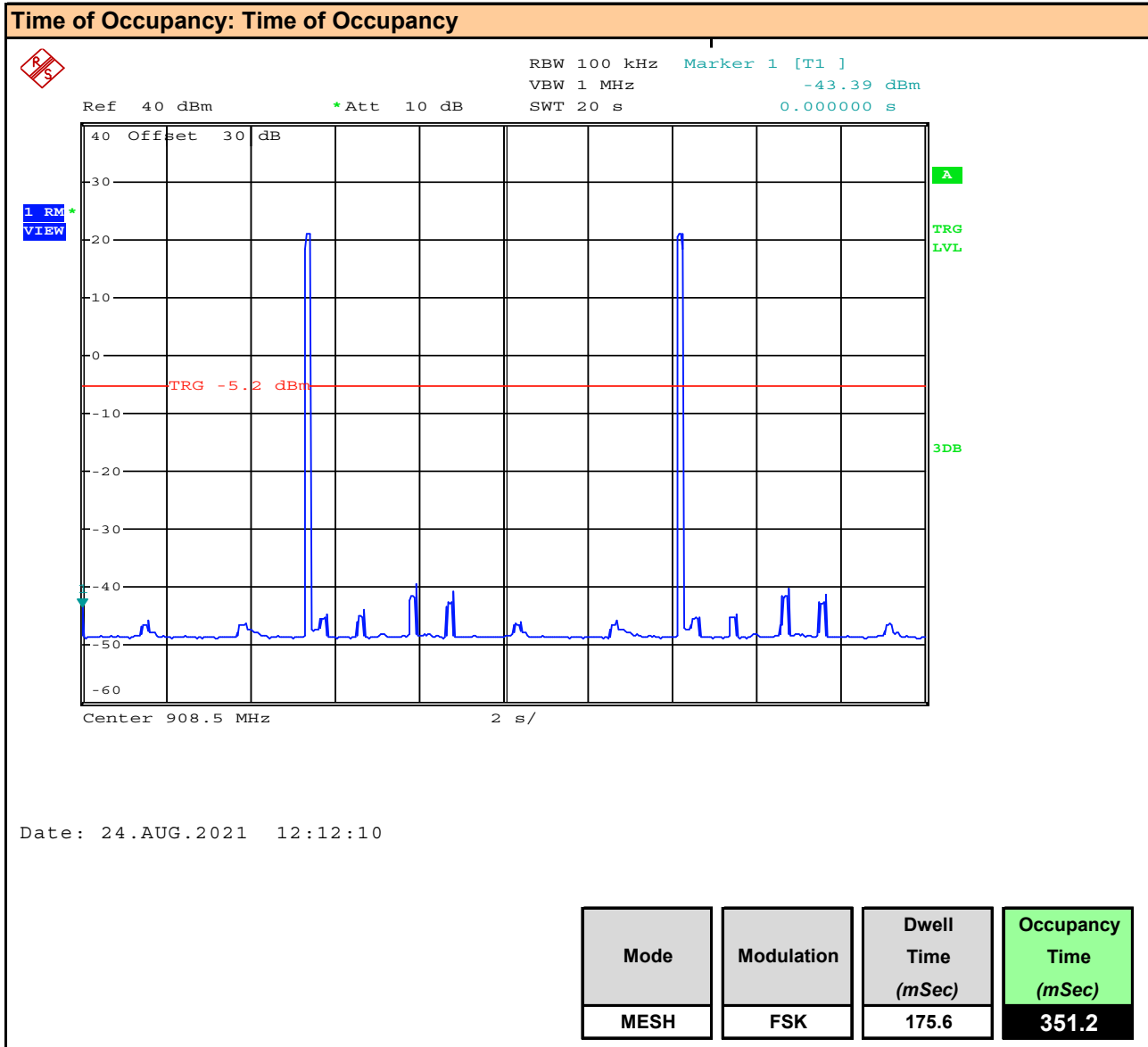
Measurement Procedure

The DUT was connected to a Spectrum Analyzer (SA) via a 30dB attenuator connected to the DUT's antenna port. The SA was configured as above using the Automatic 6dB Cursor Bandwidth measurement. The output power of the DUT was set to the manufacturer's highest output power setting at the Low, Mid and High frequency channels as permitted by the device.

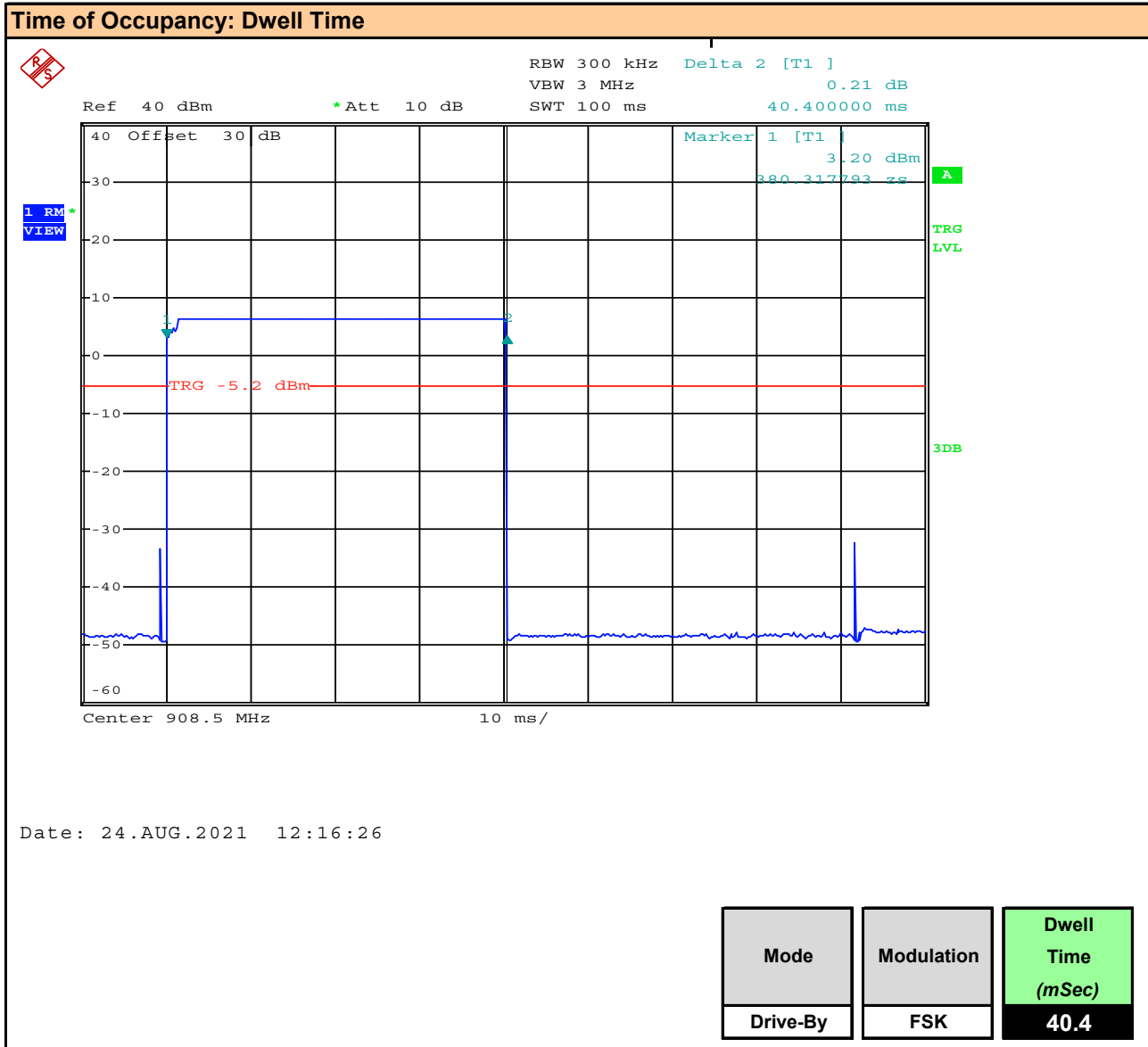
Plot 14.1 – Time of Occupancy, Dwell Time, MESH



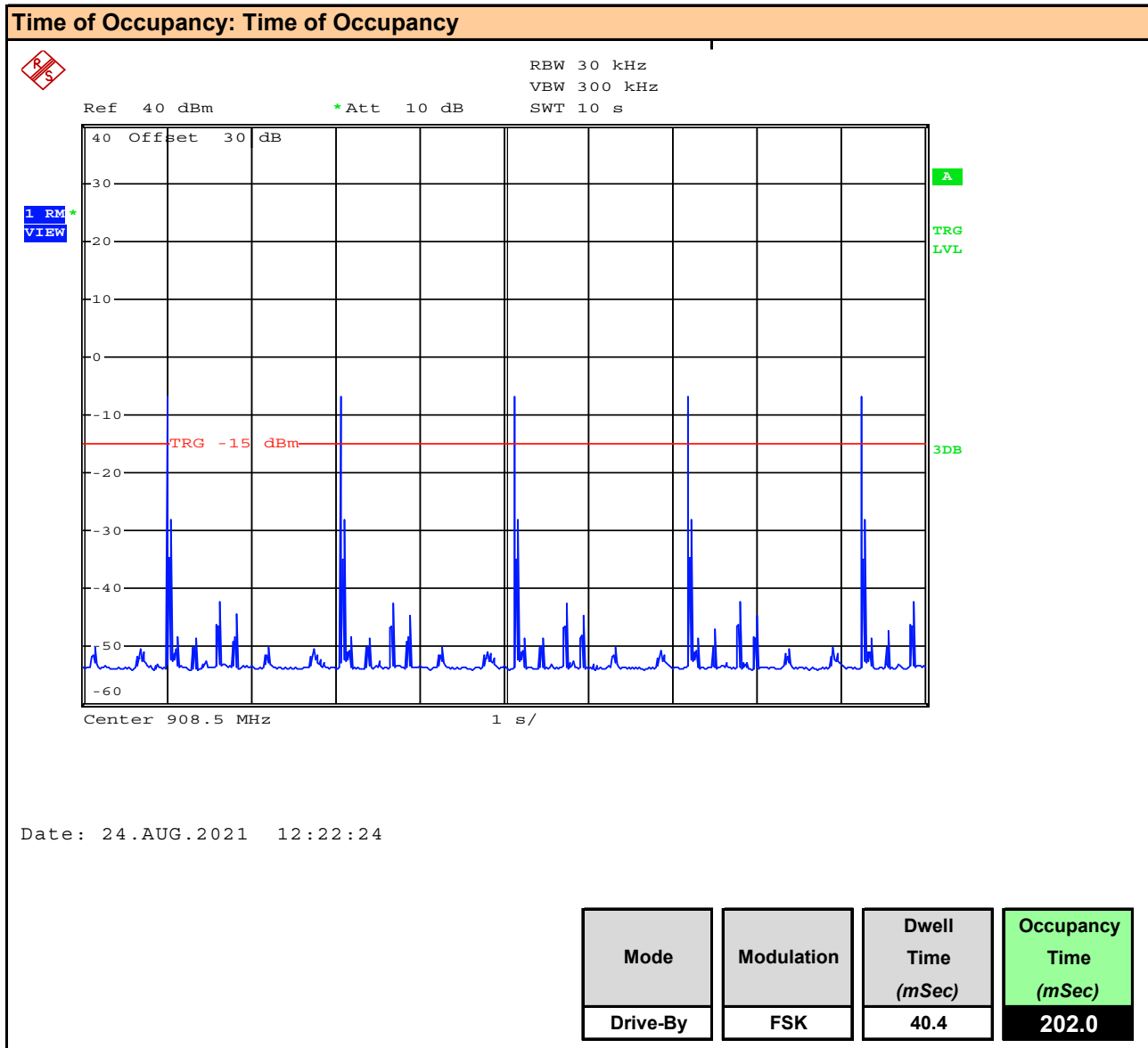
Plot 14.2 – Time of Occupancy, Occupancy, MESH



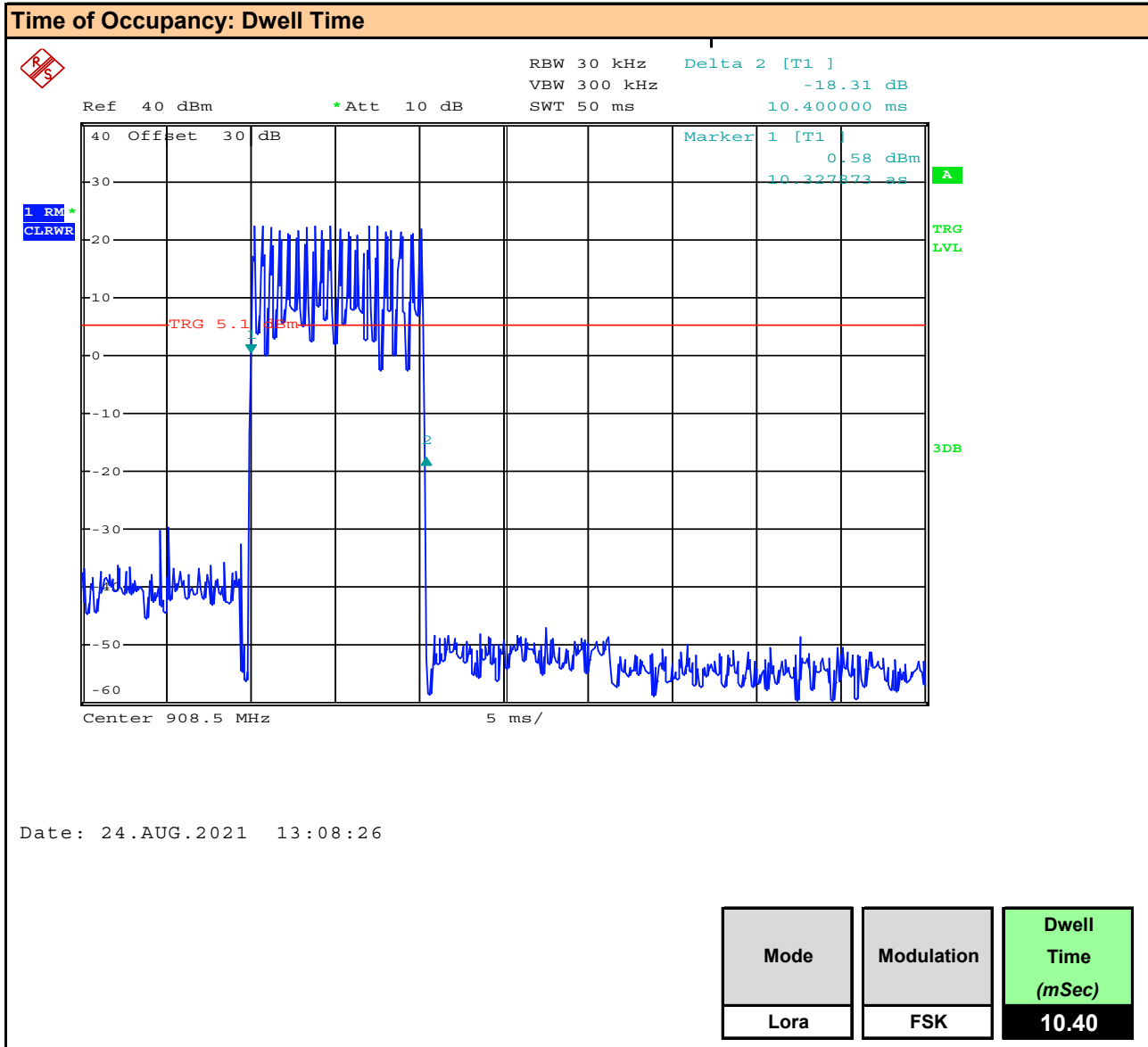
Plot 14.3 – Time of Occupancy, Dwell Time, Drive-By



Plot 14.4 – Time of Occupancy, Occupancy, Drive-By



Plot 14.5 – Time of Occupancy, Dwell Time, LoRa (DSS)



Plot 14.6 – Time of Occupancy, Occupancy, LoRa (DSS)

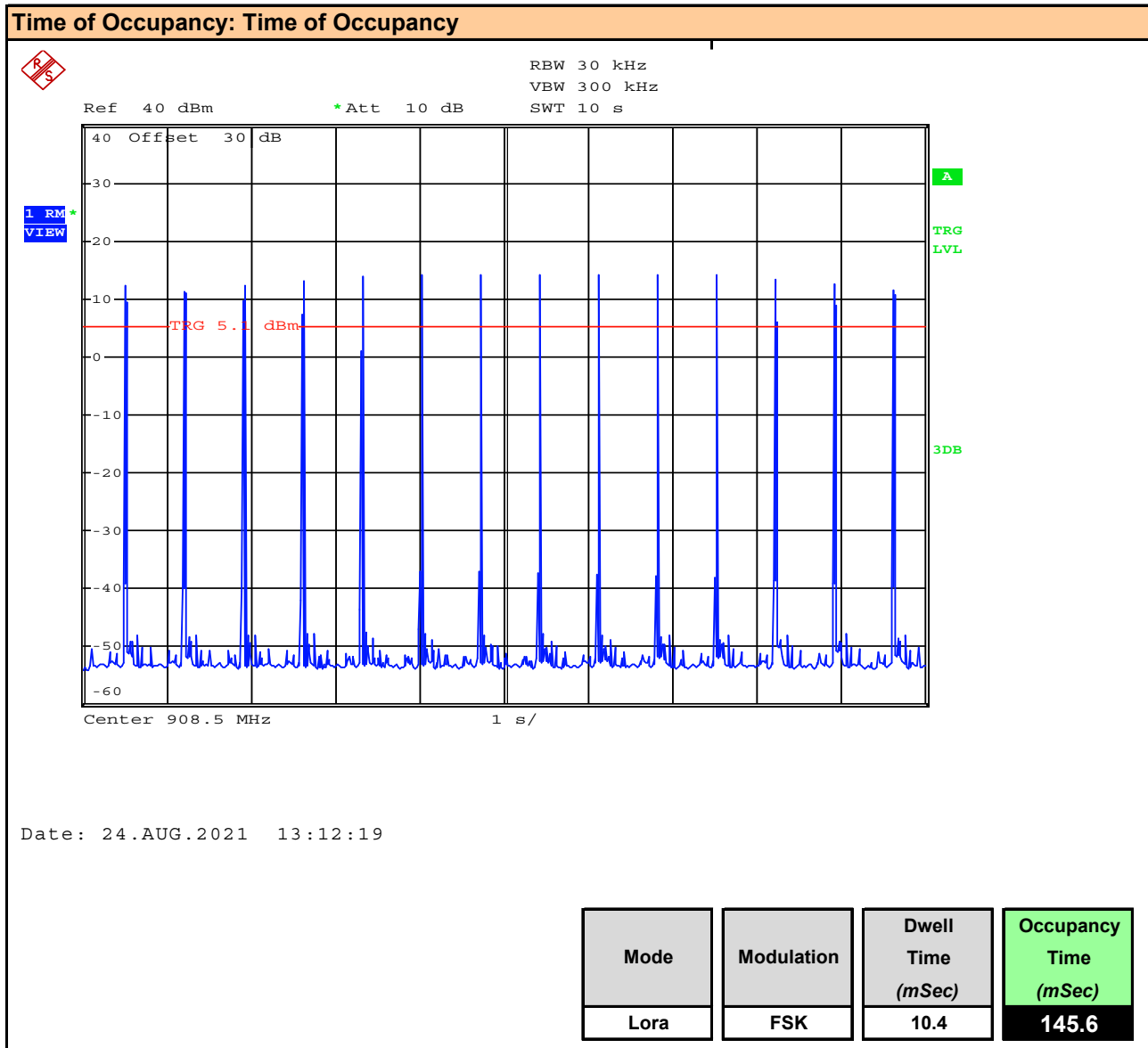


Table 14.1 – Summary of FHSS Time of Occupancy

Hopping Channel Time of Occupancy DSS										
Mode	Modulation	Channel On Time (Dwell) [t _{on}] (mSec)	Number of Period Transmits [N _{Period}]	Observation Period [T _{Period}] (Sec)	Time of Period Occupancy [T _{Occ}] (mSec)	Total Observation Period [TT _{Period}] (mSec)	Accumulated Time of Occupancy [TT _{Occ}] (mSec)	Number of Hopping Channels [N _{Hop}]	Limit [Limit] (mSec)	Margin (mSec)
MESH	FSK	175.6	2	20	351.2	20	351.20	50	400	49
Drive-By		40.4	5	10	202.0	10	202.00	50	400	198
LoRa		10.4	14	10	145.6	20	291.20	64	400	109
									Result:	Complies

Time of Occupancy within the measurement (Observation) period [T_{Occ}] = On Time [T_{on}] X Number of Transmits within the Observation Period [N_{period}]

Total Observation Period [TT_{Period}] = 15mSec X Number of Hopping Channels = 15mSec X [N_{Hop}]

Accumulated Time of Occupancy [TT_{Occ}] = Time of Occupancy [T_{Occ}] X Total Observation Period [TT_{Period}] / Observation Period [T_{Period}]

Margin = Limit - TT_{Occ}

15.0 CONDUCTED SPURIOUS EMISSIONS -BAND EDGE

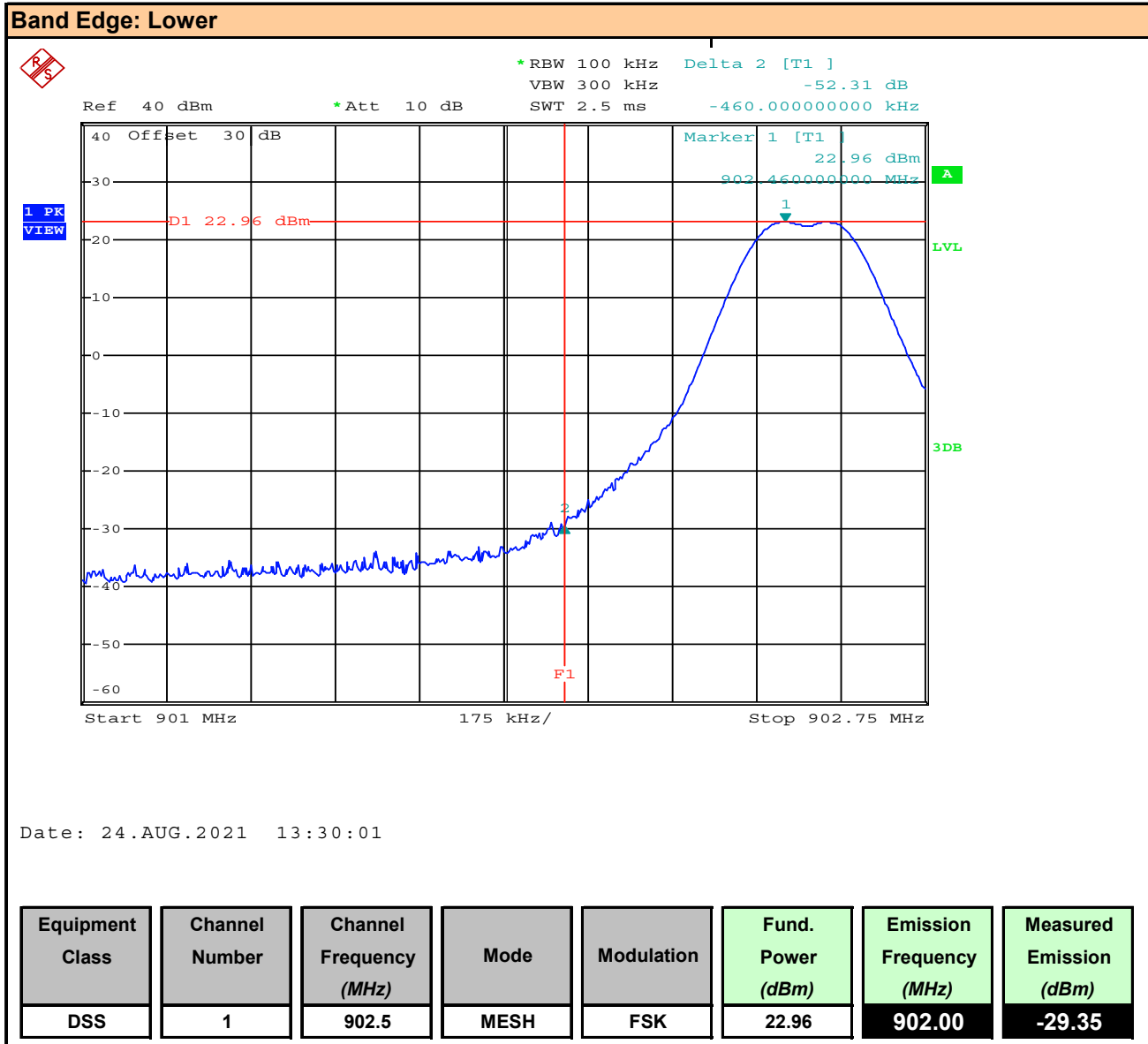
Test Procedure

Normative Reference	FCC 47 CFR §2.1051, §15.247(d), RSS-Gen (6.13), RSS-247 (5.5), KDB 558074 (11.3), ANSI C63.10 (11.11.3)
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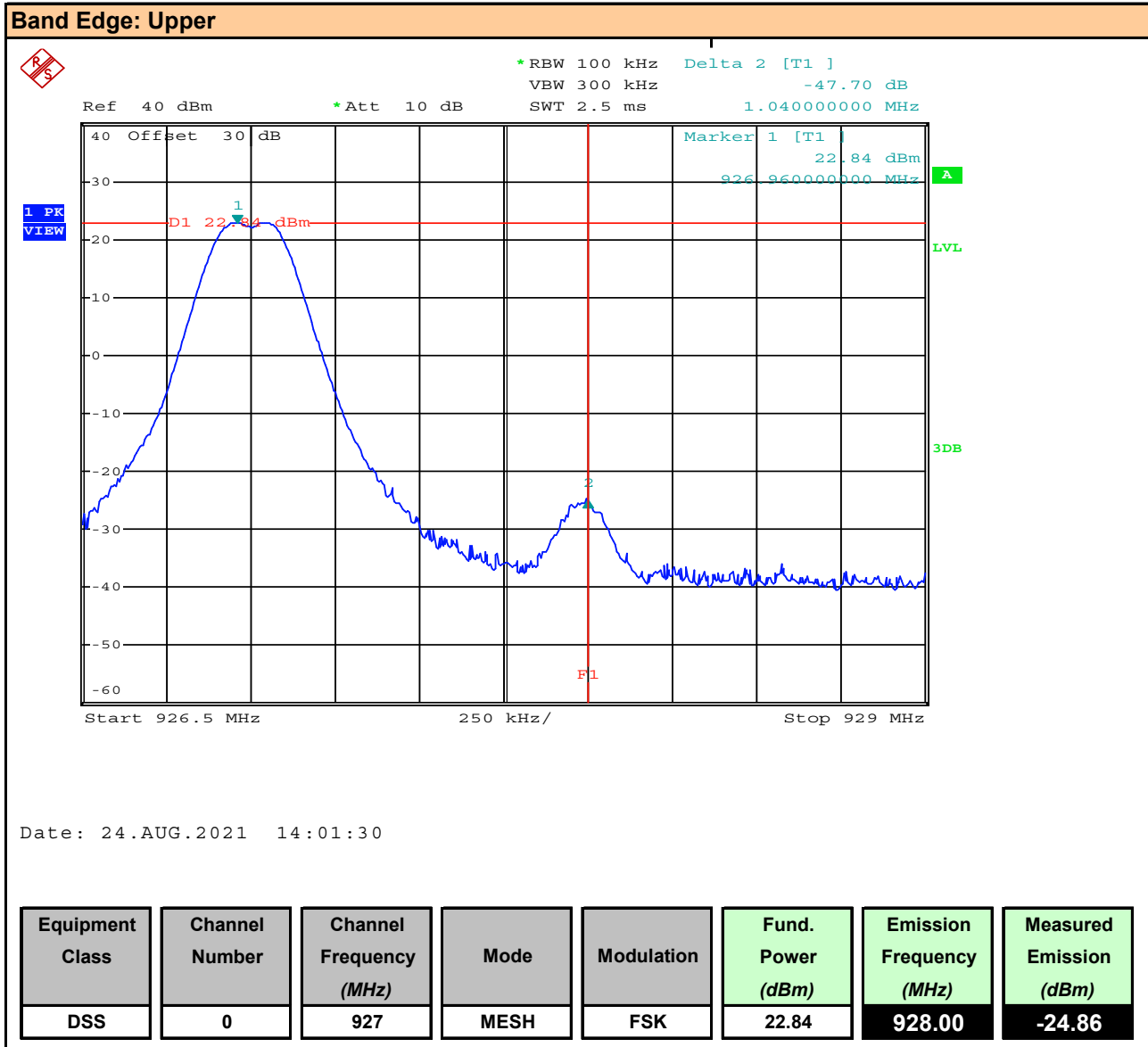
Limits

47 CFR §15.247(d)	(d) In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required.
RSS-247 (5.5)	5.5 Unwanted emissions In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required. d) For DTSs employing digital modulation techniques operating in the bands 902-928 MHz and 2400-2483.5 MHz, the maximum peak conducted output power shall not exceed 1W. The e.i.r.p. shall not exceed 4 W, except as provided in section 5.4(e). As an alternative to a peak power measurement, compliance can be based on a measurement of the maximum conducted output power.
KDB 558074 (11.3) C63.10 (11.11.3)	11.1 General The DTS rules specify that in any 100 kHz bandwidth outside of the authorized frequency band, the power shall be attenuated according to the following conditions: b) If maximum conducted (average) output power was used to demonstrate compliance as described in 9.2, then the peak power in any 100 kHz bandwidth outside of the authorized frequency band shall be attenuated by at least 30 dB relative to the maximum in-band peak PSD level in 100 kHz (i.e., 30 dBc). 11.2 Reference level measurement a) Set instrument center frequency to DTS channel center frequency. b) Set the span to $\geq 1.5 \times DTS \text{ bandwidth}$. c) Set the RBW = 100 kHz. d) Set the VBW $\geq 3 \times RBW$. e) Detector = peak. f) Sweep time = auto couple. g) Trace mode = max hold. h) Allow trace to fully stabilize. i) Use the peak marker function to determine the maximum PSD level. Note that the channel found to contain the maximum PSD level can be used to establish the reference

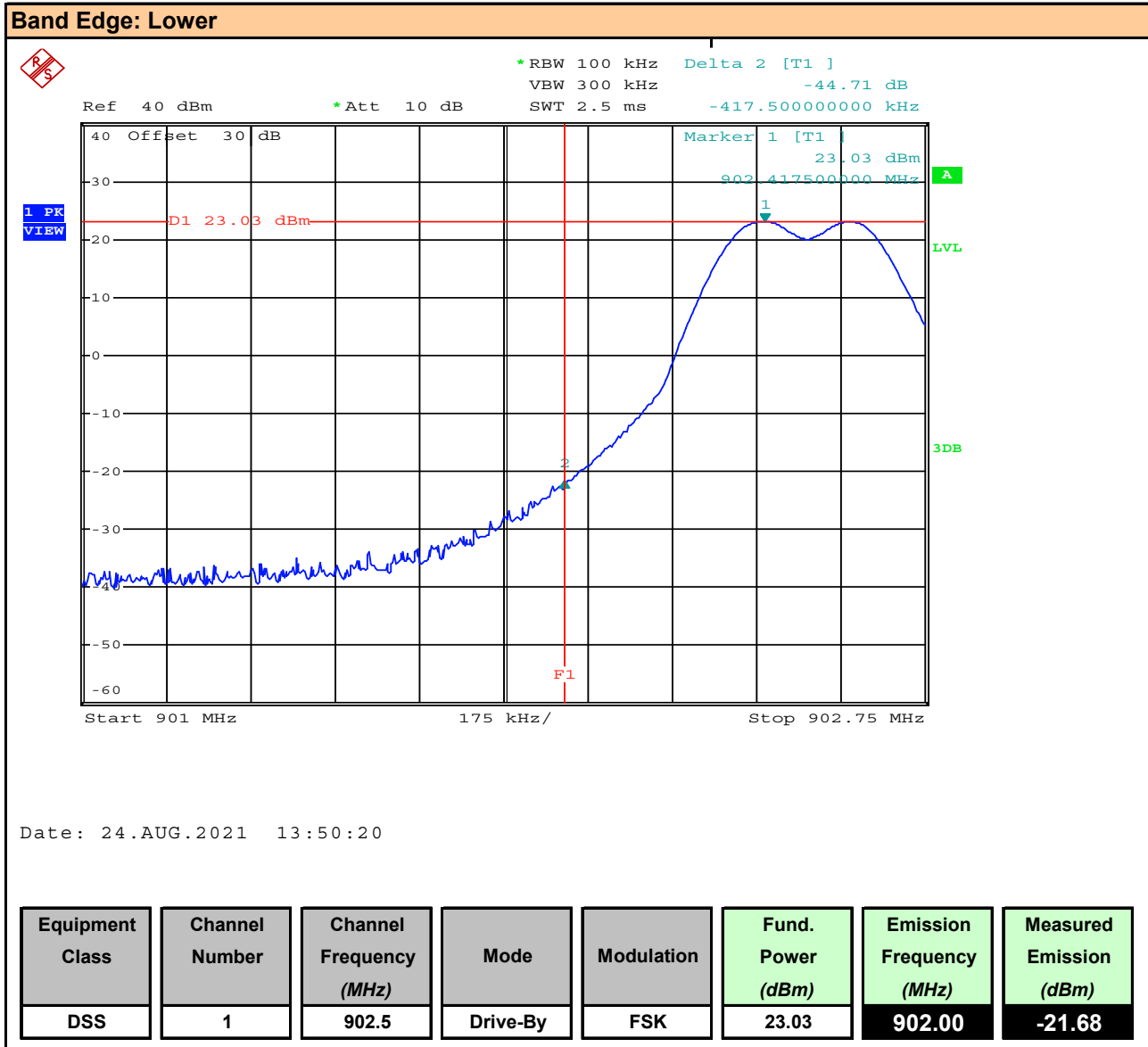
Plot 15.1 – Conducted Spurious Emissions, Lower Band Edge, MESH Ch1



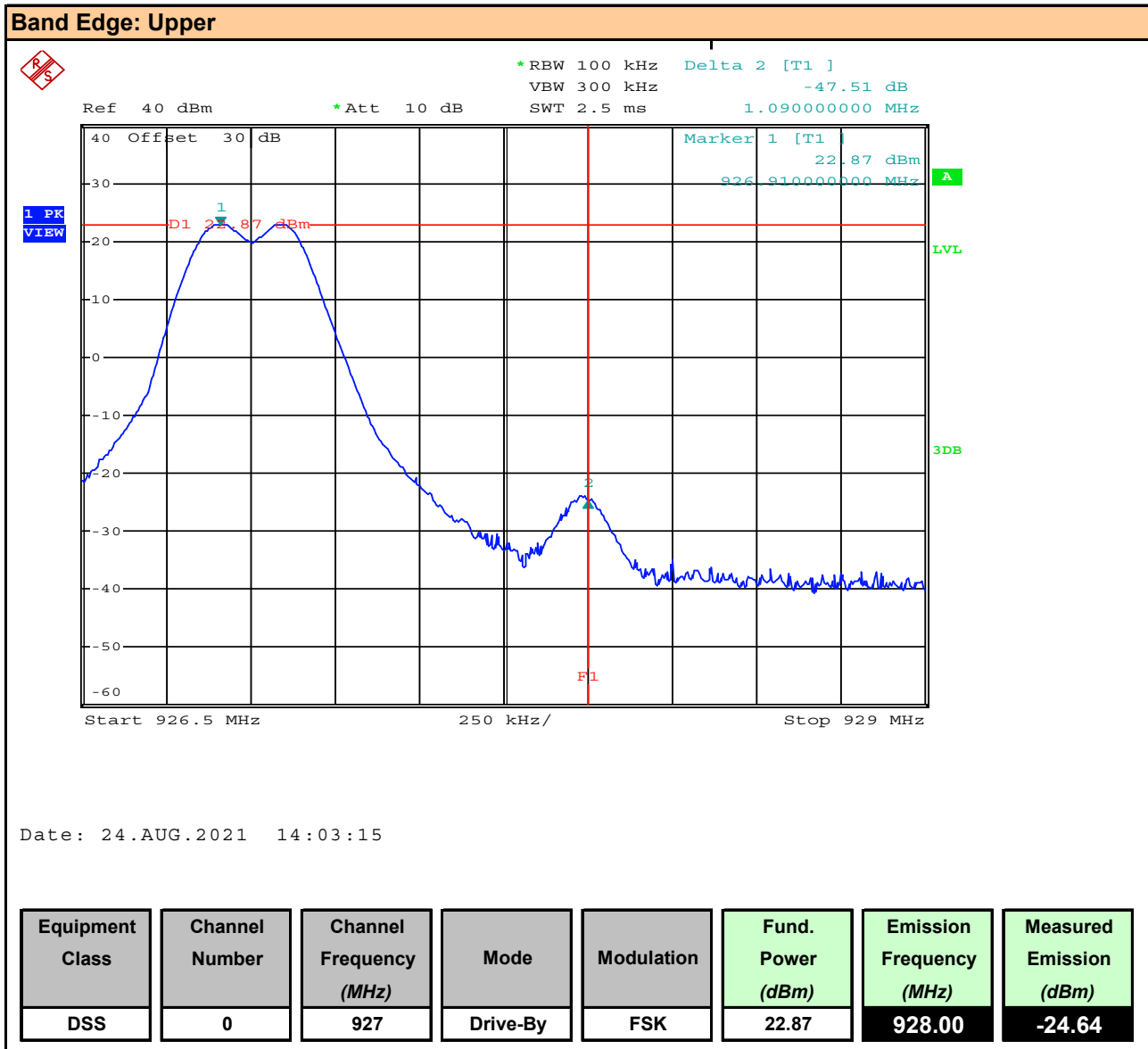
Plot 15.2 – Conducted Spurious Emissions, Upper Band Edge, MESH Ch0



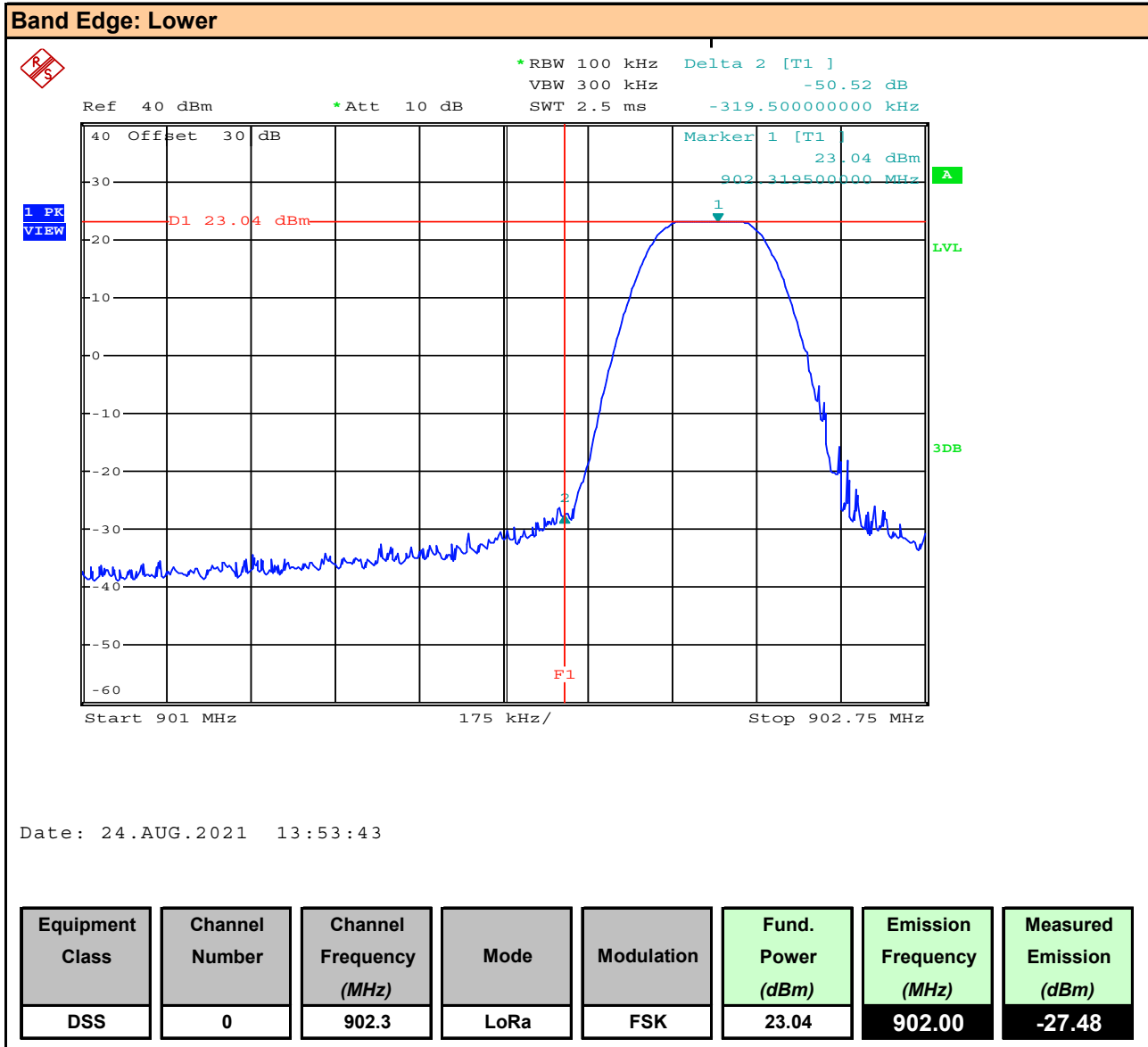
Plot 15.3 – Conducted Spurious Emissions, Lower Band Edge, Drive-By Ch1



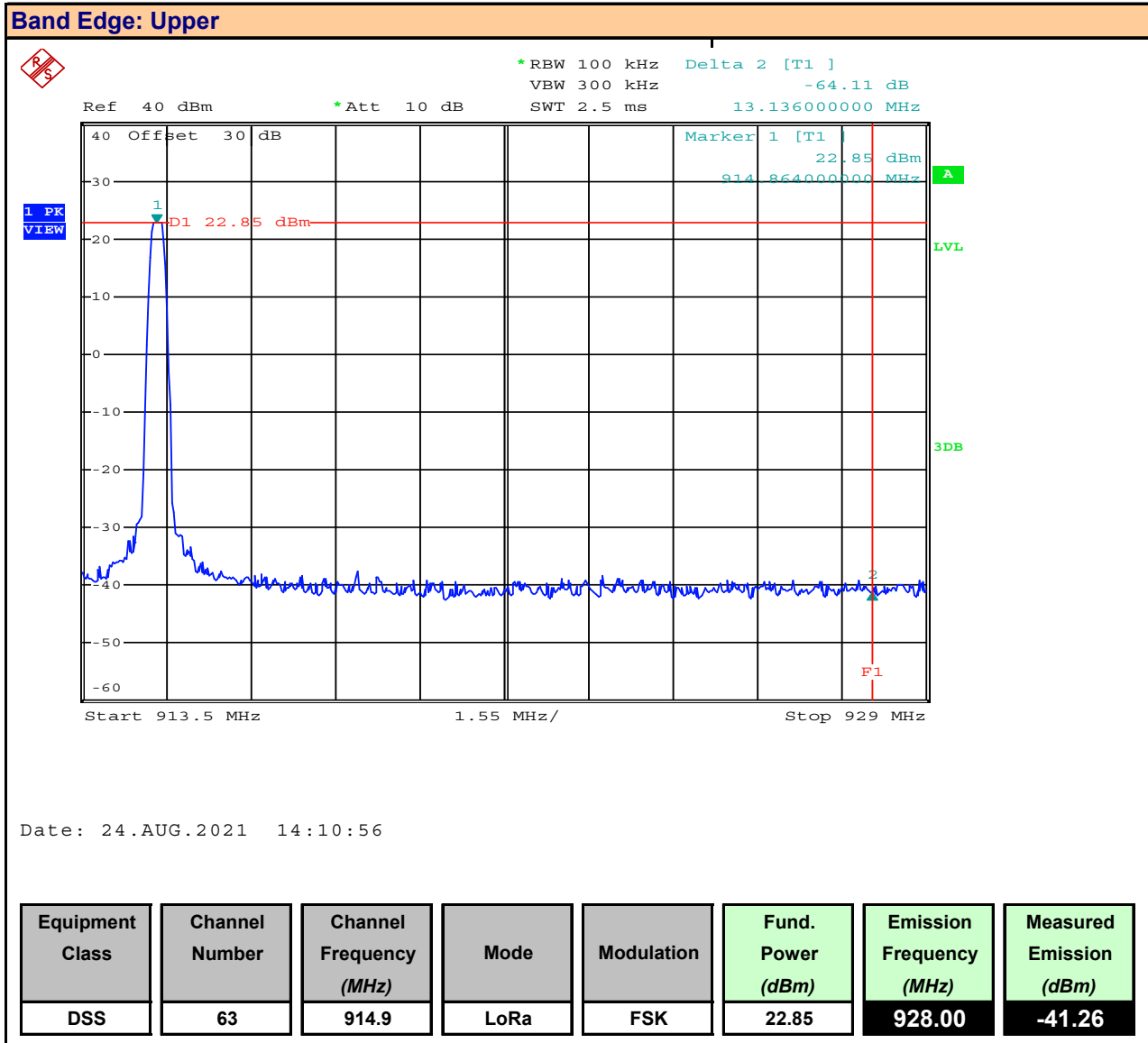
Plot 15.4 – Conducted Spurious Emissions, Upper Band Edge, Drive-By Ch0



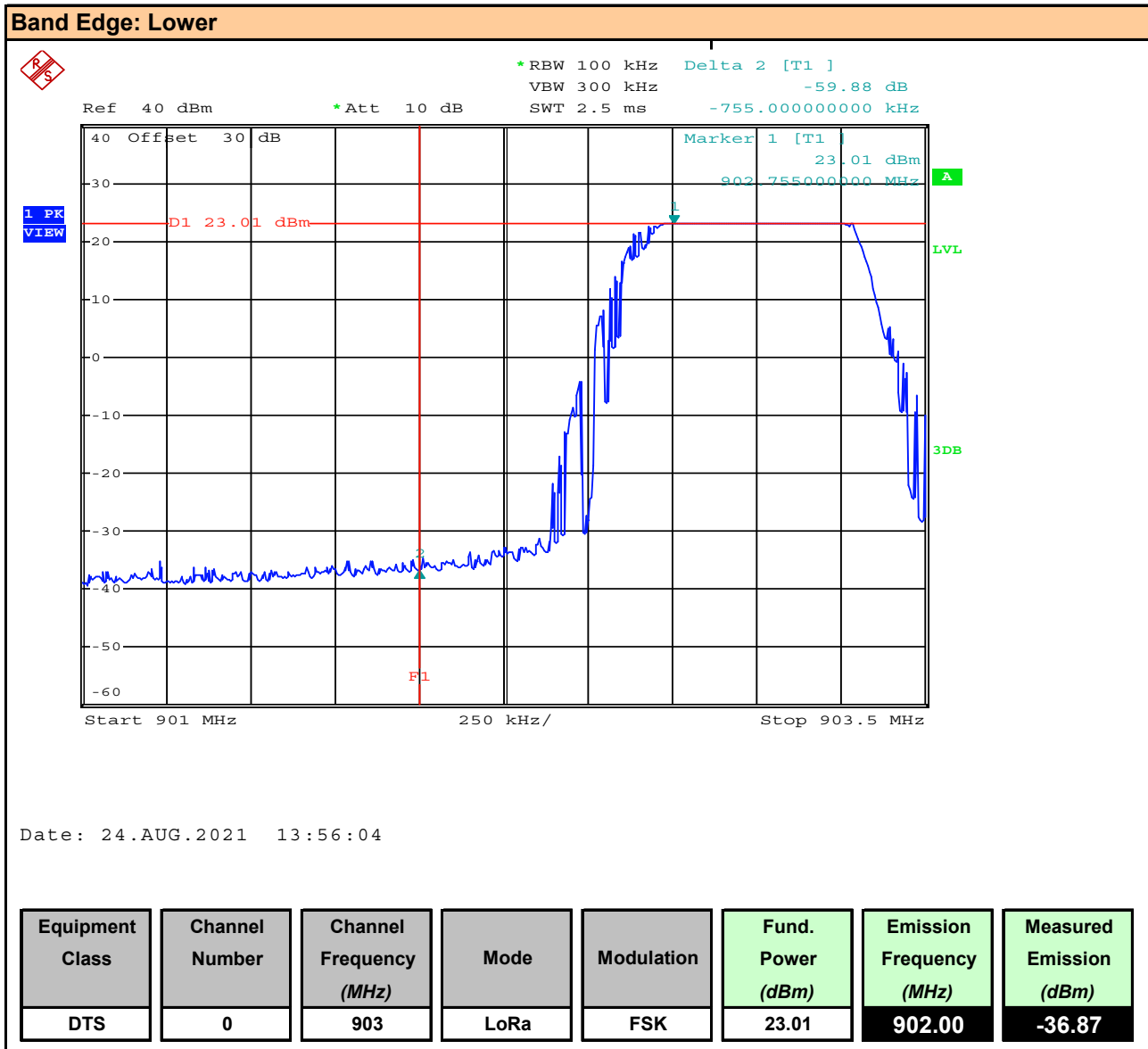
Plot 15.5 – Conducted Spurious Emissions, Lower Band Edge, Lora (DSS) Ch0



Plot 15.6 – Conducted Spurious Emissions, Upper Band Edge, Lora (DSS) Ch63



Plot 15.7 – Conducted Spurious Emissions, Lower Band Edge, LoRa (DTS) Ch0



Plot 15.8 – Conducted Spurious Emissions, Upper Band Edge, LoRa (DTS) Ch7

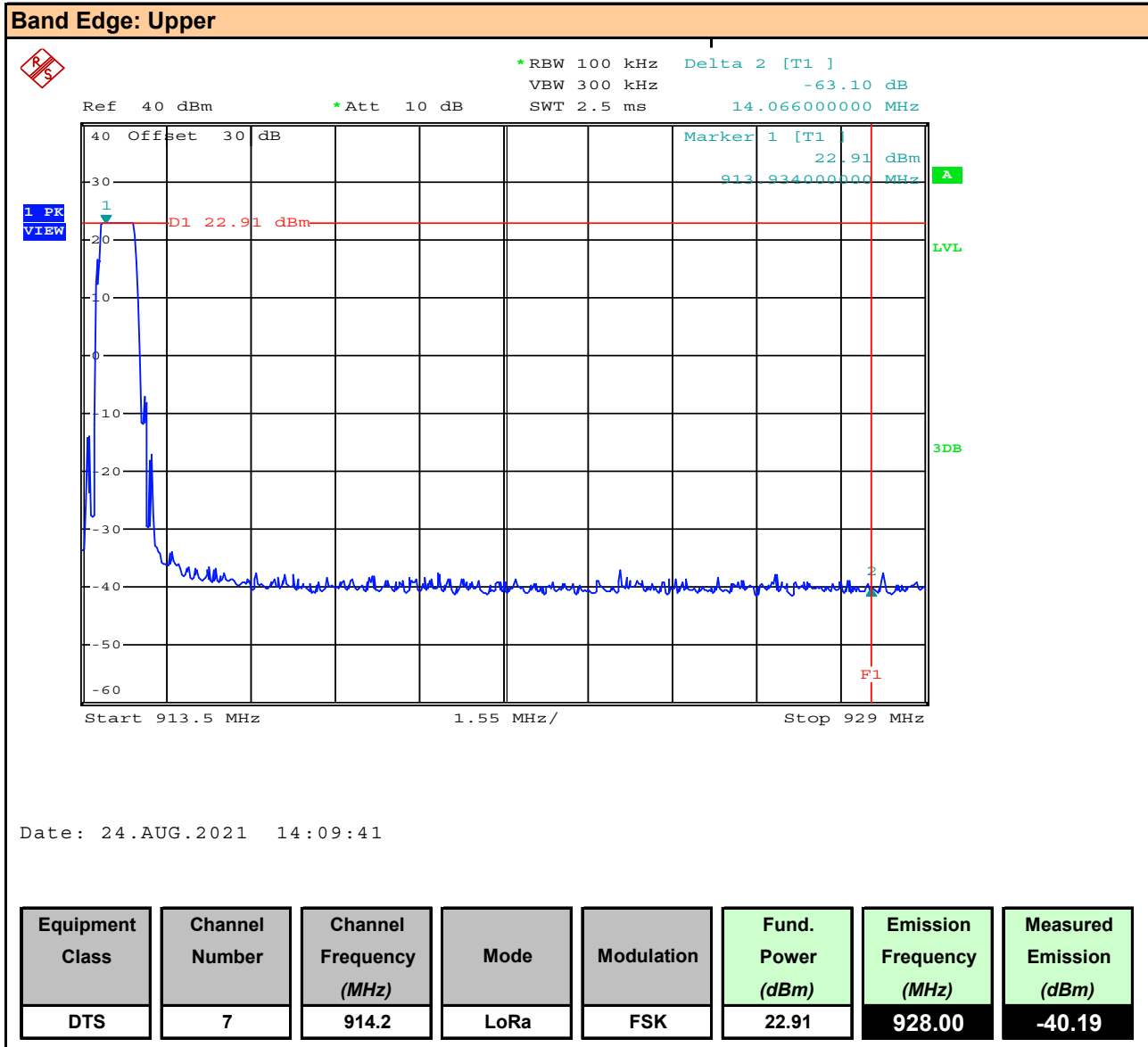


Table 15.1 – Summary of Conducted Spurious Emission Measurements – Band Edge,

Unwanted Emissions Measurement Results: Band Edge										
Mode	Channel Number	Channel Frequency (MHz)	Equipment Class	Modulation	Fundamental Power [P _{Fund}] (dBm)	Emission Frequency (MHz)	Measured Emission [P _{Meas}] (dBm)	Attenuation [Att] (dBm)	Limit (dB)	Margin (dB)
MESH	1	902.5	DSS	FSK	22.96	902.0	-29.35	52.31	20	32.3
	0	927.0			22.84	928.0	-24.86	47.70		27.7
Drive-By	1	902.5			23.03	902.0	-21.68	44.71		24.7
	0	927.0			22.87	928.0	-24.64	47.51		27.5
LoRa	0	902.3			23.04	902.0	-27.48	50.52		30.5
	63	914.9			22.85	928.0	-41.26	64.11		44.1
LoRa	0	903.0	DTS		23.01	902.0	-36.87	59.88	30	29.9
	7	914.2			22.91	928.0	-40.19	63.10		33.1
									Result:	Complies

Attenuation [Att] = Fundamental Power [P_{Fund}] - Measured Emission [P_{meas}]

Margin = [Att] - Limit

16.0 CONDUCTED SPURIOUS EMISSIONS

Test Procedure	
Normative Reference	FCC 47 CFR §2.1051, §15.247(d), RSS-Gen (6.13), RSS-247 (5.5), KDB 558074 (11.3), ANSI C63.10 (11.11.3)
Limits	
47 CFR §15.247(d)	(d) In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required.
RSS-247 (5.5)	5.5 Unwanted emissions In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required. d) For DTSs employing digital modulation techniques operating in the bands 902-928 MHz and 2400-2483.5 MHz, the maximum peak conducted output power shall not exceed 1W. The e.i.r.p. shall not exceed 4 W, except as provided in section 5.4(e). As an alternative to a peak power measurement, compliance can be based on a measurement of the maximum conducted output power.
KDB 558074 (11.3) C63.10 (11.11.3)	11.1 General The DTS rules specify that in any 100 kHz bandwidth outside of the authorized frequency band, the power shall be attenuated according to the following conditions: b) If maximum conducted (average) output power was used to demonstrate compliance as described in 9.2, then the peak power in any 100 kHz bandwidth outside of the authorized frequency band shall be attenuated by at least 30 dB relative to the maximum in-band peak PSD level in 100 kHz (i.e., 30 dBc). 11.2 Reference level measurement a) Set instrument center frequency to DTS channel center frequency. b) Set the span to $\geq 1.5 \times \text{DTS bandwidth}$. c) Set the RBW = 100 kHz. d) Set the VBW $\geq 3 \times \text{RBW}$. e) Detector = peak. f) Sweep time = auto couple. g) Trace mode = max hold. h) Allow trace to fully stabilize. i) Use the peak marker function to determine the maximum PSD level. Note that the channel found to contain the maximum PSD level can be used to establish the reference

Table 16.1 – Summary of Conducted Spurious Emissions, (DTS)

See Appendix D for Measurement Plots

Conducted Spurious Emissions Measurement Results:										
Mode	Channel Number	Channel Frequency (MHz)	Equipment Class	Modulation	Fundamental Power [P _{Fund}] (dBm)	Emission Frequency (MHz)	Measured Emission [P _{Meas}] (dBm)	Attenuation [Att] (dBm)	Limit (dB)	Margin (dB)
MESH	0	927.0	DSS	FSK	21.85	980.2	-37.84	59.69	20.0	39.7
					21.85	1852.0	-34.28	56.13		36.1
					21.85	8950.0	-32.82	54.67		34.7
					21.85	1852.0	-32.94	54.79		34.8
Drive-By	0	927.0			21.85	963.0	-37.25	59.10		39.1
					21.85	1856.0	-34.05	55.90		35.9
					21.85	9760.0	-32.19	54.04		34.0
					21.85	1854.0	-33.21	55.06		35.1
LoRa	63	914.6			23.01	977.3	-37.52	60.53		40.5
					23.01	1832.0	-33.77	56.78		36.8
					23.01	3154.0	-32.70	55.71		35.7
					23.01	1830.0	-33.04	56.05		36.1
LoRa	7	914.2	DTS		22.82	981.0	-37.81	60.63	30.0	30.6
					22.82	1828.0	-34.72	57.54		27.5
					22.82	3000.0	-38.15	60.97		31.0
					22.82	1829.0	-33.89	56.71		26.7
Result:									Complies	

Attenuation [Att] = Fundamental Power [P_{Fund}] - Measured Emission [P_{meas}]

Margin = [Att] - Limit

17.0 RADIATED TX SPURIOUS EMISSIONS, RESTRICTED BAND

Test Procedure

Normative Reference	FCC 47 CFR §2.1051, §15.247(d), §15.205(a), §15.205(c), §15.209(a)
	KDB 558074 (8.6), ANSI C63.10 (11.12)

Limits

47 CFR §15.247(d)	(d) In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).																
47 CFR §15.209(a)	§15.209 Radiated emission limits; general requirements. (a) Except as provided elsewhere in this subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table: <table border="1"> <thead> <tr> <th>Frequency (MHz)</th><th>Field Strength (microvolts/meter)</th></tr> </thead> <tbody> <tr> <td>0.009 - 0.490</td><td>2400/F (kHz) @300m</td></tr> <tr> <td>0.490 - 1.705</td><td>24000/F (kHz) @30m</td></tr> <tr> <td>1.705 - 30</td><td>30 @ 30m</td></tr> <tr> <td>30 - 88</td><td>100 @3m</td></tr> <tr> <td>88 - 216</td><td>150 @3m</td></tr> <tr> <td>216 - 960</td><td>200 @3m</td></tr> <tr> <td>Above 960</td><td>500 @3m</td></tr> </tbody> </table>	Frequency (MHz)	Field Strength (microvolts/meter)	0.009 - 0.490	2400/F (kHz) @300m	0.490 - 1.705	24000/F (kHz) @30m	1.705 - 30	30 @ 30m	30 - 88	100 @3m	88 - 216	150 @3m	216 - 960	200 @3m	Above 960	500 @3m
Frequency (MHz)	Field Strength (microvolts/meter)																
0.009 - 0.490	2400/F (kHz) @300m																
0.490 - 1.705	24000/F (kHz) @30m																
1.705 - 30	30 @ 30m																
30 - 88	100 @3m																
88 - 216	150 @3m																
216 - 960	200 @3m																
Above 960	500 @3m																

Table 17.1 – Summary of Radiated Tx Spurious Emissions, Restricted Band

See Appendix E for Measurement Plots

Summary of Radiated Tx Emissions (Restricted Band)										
Measured Frequency Range (MHz)	Channel Frequency (MHz)	Antenna Polarization	Emission Frequency	Measured Emission [E _{Meas}] (dBuV)	Antenna ACF [ACF] (dB)	Cable Loss [L _C] (dB)	Amplifier Gain [G _A] (dB)	Corrected Emission [E _{Corr}] (dBuV/m)	Limit (dBuV)	Margin (dB)
9kHz - 30MHz	916.0	Front	ND	ND (1)	0.00	0.00	0.00 (3)	ND (2)	n/a	n/a
9kHz - 30MHz	916.0	Side	ND	ND (1)	0.00	0.00	0.00 (3)	ND (2)	n/a	n/a
30-1000MHz	916.0	Horizontal	96.69MHz	23.9	0.00	0.00	0.00 (3)	23.9 (2)	43.5	19.6
30-1000MHz	916.0	Horizontal	105.06MHz	25.6	0.00	0.00	0.00 (3)	25.6 (2)	43.5	17.9
30-1000MHz	916.0	Horizontal	142.05MHz	26.4	0.00	0.00	0.00 (3)	26.4 (2)	43.5	17.1
30-1000MHz	916.0	Horizontal	464.5MHz	33.5	0.00	0.00	0.00 (3)	33.5 (2)	46.0	12.5
1 - 3GHz	916.0	Horizontal	ND	ND (1)	27.40	4.58	0.00 (3)	ND	60.0	n/a
1 - 3GHz	916.0	Vertical	ND	ND (1)	27.40	4.58	0.00 (3)	ND	60.0	n/a
3-10GHz	916.0	Horizontal	ND	ND (1)	36.76	9.86	0.00 (3)	ND	60.0	n/a
3-10GHz	916.0	Vertical	ND	ND (1)	36.76	9.86	0.00 (3)	ND	60.0	n/a
Results:									Complies	

(1) No Emissions Detected (ND) above ambient or within 20dB of the limit

(2) Antenna ACF, Cable Loss and Amplifier Gain corrected in Spectrum Analyzer Transducer Factor

(3) External Amplifier not used

$$E_{\text{Corr}} = E_{\text{Meas}} + \text{ACF} + L_C - G_A$$

18.0 RADIATED RX SPURIOUS EMISSIONS

Test Procedure

Normative Reference	FCC 47 CFR §15.109, ICES-003(6.2) ANSI C63.4:2014
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Limits

47 CFR §15.109	(a) Except for Class A digital devices, the field strength of radiated emissions from unintentional radiators at a distance of 3 meters shall not exceed the following values: 30-88MHz: 40dBuV/m 88-216MHz: 43.5dBuV/m 216-960MHz: 46dBuV/m > 960MHz: 54dBuV/m
ICES-003(6.2.1)	6.2.1 - Radiated Emissions Limits Below 1 GHz Class B: ITE that does not meet the conditions for Class A operation shall comply with the Class B radiated limits set out in Table 5 determined at a distance of 3 metres. 30-88MHz: 40dBuV/m 88-216MHz: 43.5dBuV/m 216-960MHz: 46dBuV/m > 960MHz: 54dBuV/m

Test Setup	Appendix A Figure A.2
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Measurement Procedure

The DUT was set up as per ANSI C63.4:2014. Emissions were scanned between 30MHz and 1000MHz. The turntable was rotated 360 degrees and the antenna was elevated to 4m to optimize the measured emissions.

Table 19.1 – Summary of Radiated Rx Spurious Emissions

See Appendix F for Measurement Plots

Measurement Results				
Frequency Range	Antenna Polarization	Measured Emission [E _{Meas}] (dBm)	Limit e.r.p./e.r.i.p. [A _L] (dBuV/m)	Margin (dB)
30-1000MHz	Horizontal	ND	49.5	n/a
1 - 3GHz		ND	60.0	n/a
3 - 10GHz		ND	60.0	n/a
30-1000MHz	Vertical	ND	49.5	n/a
1 - 3GHz		ND	60.0	n/a
3 - 10GHz		ND	60.0	n/a
Results:			Complies	

ND: No emissions detected above ambient or within 20dB of the limit

APPENDIX A – TEST SETUP DRAWINGS

Table A.1 – Conducted Measurement Setup

Equipment List				
Asset Number	Manufacturer	Model Number	Serial Number	Description
00241	R&S	FSU40	100500	Spectrum Analyzer
00263	Koaxis	KP10-1.00M-TD	263	1m Armoured Cable

Figure A.1 – Test Setup – Conducted Measurements

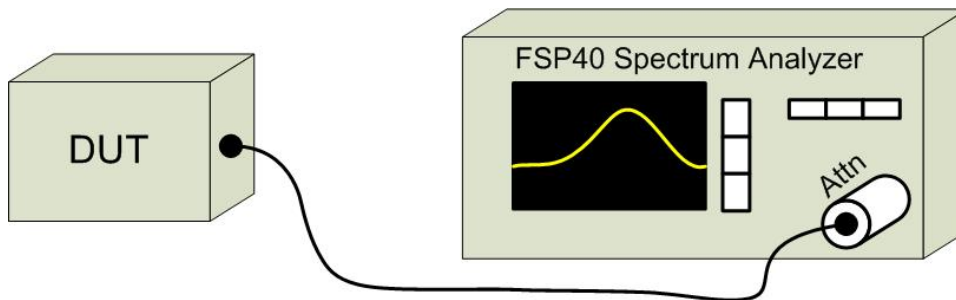


Table A.2 – Radiated Emissions Measurement Equipment

Equipment List				
Asset Number	Manufacturer	Model Number	Serial Number	Description
00050	Chase	CBL-6111A	1607	Bilog Antenna
00034	ETS	3115	6267	Double Ridged Guide Horn
00035	ETS	3115	6276	Double Ridged Guide Horn
00085	EMCO	6502	9203-2724	Loop Antenna
00161	Waveline Inc.	889		Standard Gain Horn 18-26GHz
00162	Waveline Inc.	889		Standard Gain Horn 18-26GHz
00165	Waveline Inc.	801-KF		Waveguide Adapter 18-26GHz
00166	Waveline Inc.	801-KF		Waveguide Adapter 18-26GHz
00333	HP	85685A	3010A01095	RF Preselector
00049	HP	85650A	2043A00162	Quasi-peak Adapter
00051	HP	8566B	2747A05510	Spectrum Analyzer
00241	R&S	FSU40	100500	Spectrum Analyzer
00265	Miteq	JS32-00104000-58-5P	1939850	Microwave L/N Amplifier
00071	EMCO	2090	9912-1484	Multi-Device Controller
00072	EMCO	2075	0001-2277	Mini-mast
00073	EMCO	2080	0002-1002	Turn Table
00263	Koaxis	KP10-1.00M-TD	263	1m Armoured Cable
00263B	Koaxis	KP10-1.00M-TD	263B	1m Armoured Cable
00275	TMS	LMR400	n/a	25m Cable
00278	TILE	34G3	n/a	TILE Test Software

Figure A.2 – Test Setup Radiated Measurements 9kHzMHz – 30MHz

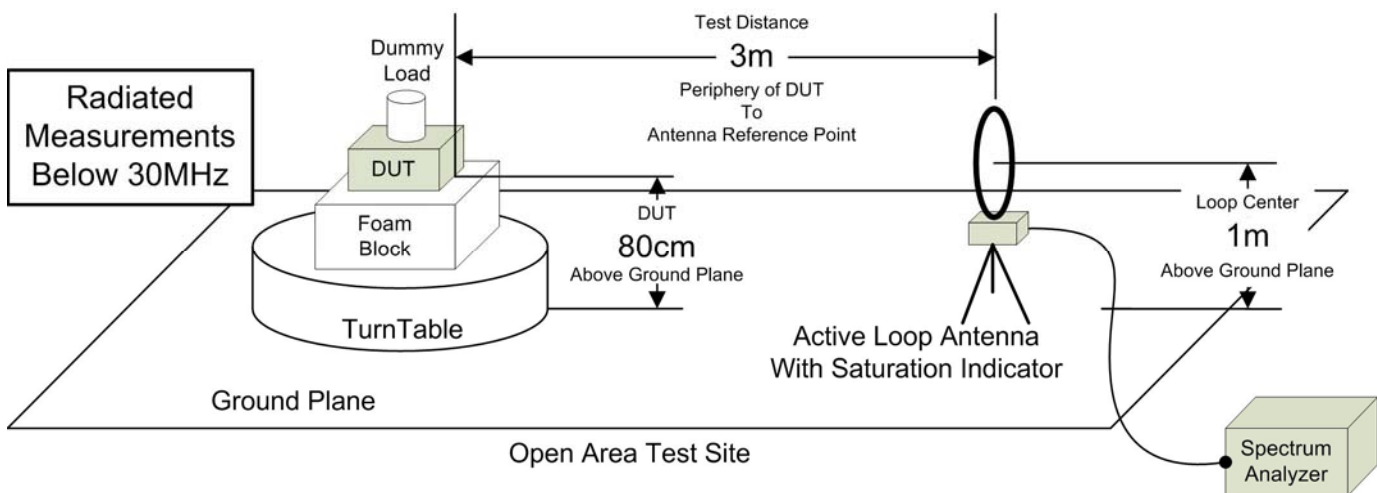


Figure A.3 – Test Setup Radiated Measurements 30MHz – 1GHz

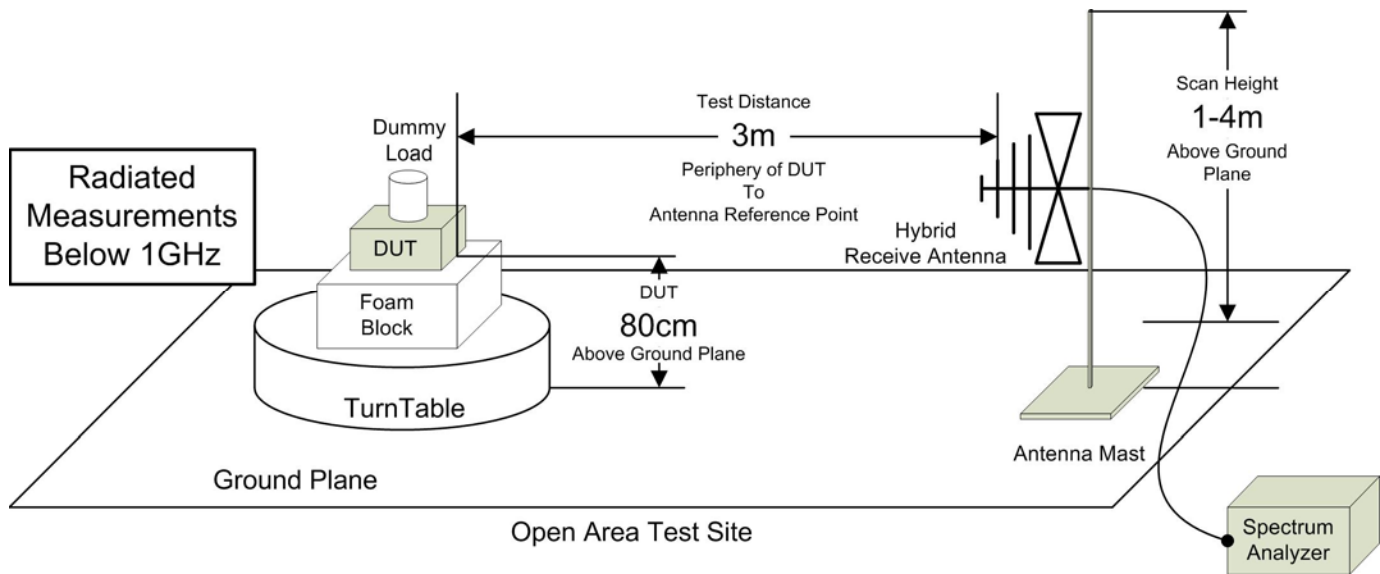


Figure A.4 – Test Setup Radiated Measurements 30MHz – 1GHz, Signal Substitution

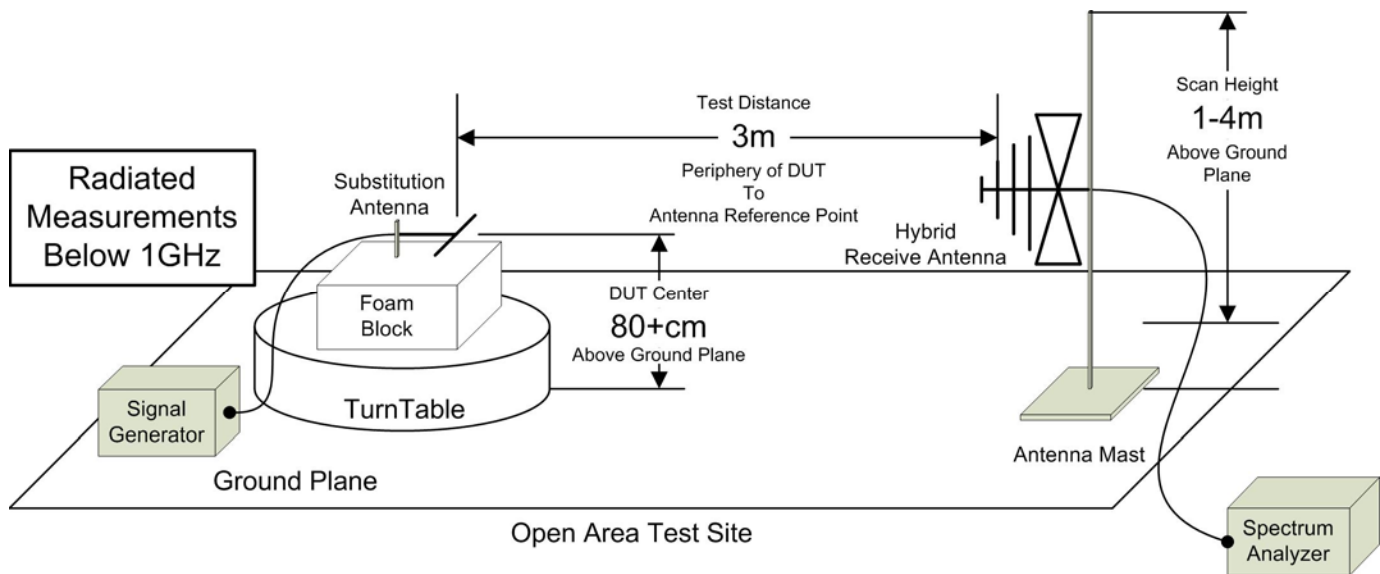


Figure A.5 – Test Setup Radiated Measurements 1 – 18GHz,

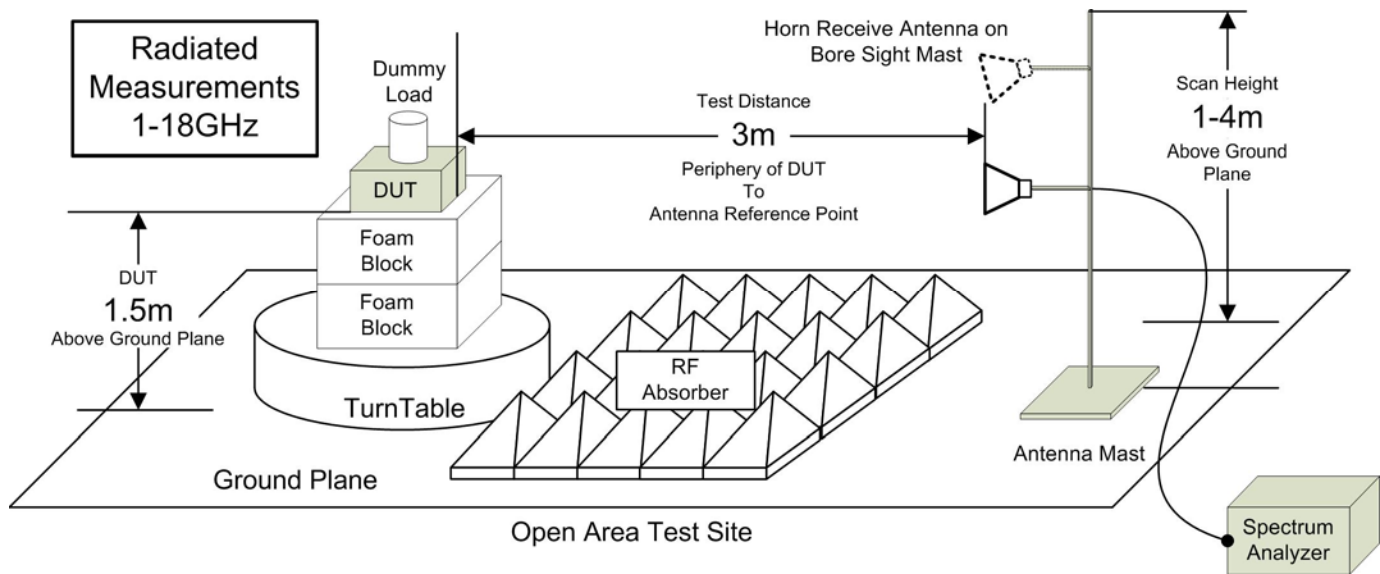
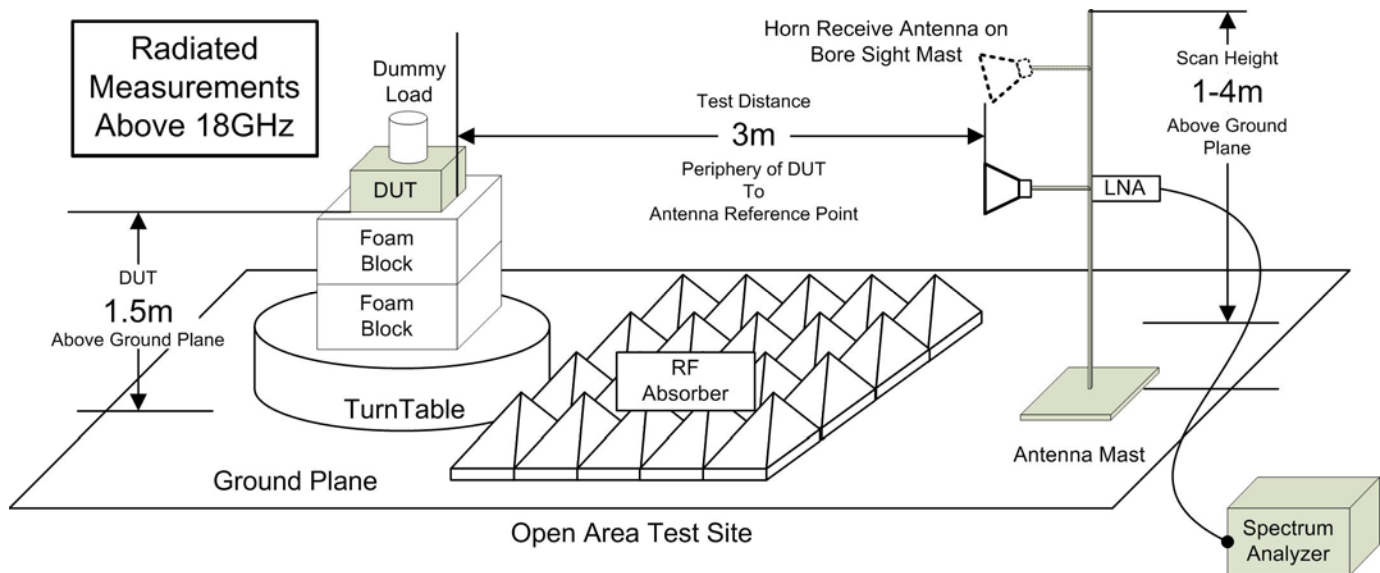


Figure A.6 – Test Setup Radiated Measurements 18 – 26.5GHz,



APPENDIX B – EQUIPMENT LIST AND CALIBRATION

Table B.1 – Equipment Calibration Information

Equipment List							
Asset Number	Manufacturer	Model Number	Serial Number	Description	Last Calibrated	Calibration Interval	Calibration Due
00050	Chase	CBL-6111A	1607	Bilog Antenna	3 Jan 2019	Triennial	3 Jan 2022
00034	ETS	3115	6267	Double Ridged Guide Horn	26 Nov 2018	Triennial	26 Nov 2021
00035	ETS	3115	6276	Double Ridged Guide Horn	22 Mar 2019	Triennial	21 Mar 2022
00085	EMCO	6502	9203-2724	Loop Antenna	11 Jun 2019	Triennial	11 Jun 2022
00333	HP	85685A	3010A01095	RF Preselector	23 Jun 2020	Triennial	30 Jun 2023
00049	HP	85650A	2043A00162	Quasi-peak Adapter	23 Jun 2020	Triennial	23 Jun 2023
00051	HP	8566B	2747A05510	Spectrum Analyzer	23 Jun 2020	Triennial	23 Jun 2023
00223	HP	8901A	3749A07154	Modulation Analyzer	27 Dec 2017	Triennial	27 Dec 2020
00241	R&S	FSU40	100500	Spectrum Analyzer	10 Aug 2021	Triennial	10 Aug 2024
00071	EMCO	2090	9912-1484	Multi-Device Controller	n/a	n/a	n/a
00072	EMCO	2075	0001-2277	Mini-mast	n/a	n/a	n/a
00073	EMCO	2080	0002-1002	Turn Table	n/a	n/a	n/a
00275	TMS	LMR400	n/a	25m Cable	COU	n/a	COU
00276	TMS	LMR400	n/a	4m Cable	COU	n/a	COU
00277	TMS	LMR400	n/a	4m Cable	COU	n/a	COU
00278	TILE	34G3	n/a	TILE Test Software	NCR	n/a	NCR

NCR: No Calibration Required

COU: Calibrate On Use

APPENDIX C – MEASUREMENT INSTRUMENT UNCERTAINTY

CISPR 16-4 Measurement Uncertainty (U_{LAB})

This uncertainty represents an expanded uncertainty expressed at approximately the 95% confidence interval using a coverage factor of $k=2$

Radiated Emissions 30MHz - 200MHz

$U_{LAB} = 5.14\text{dB}$ $U_{CISPR} = 6.3\text{dB}$

Radiated Emissions 200MHz - 1000MHz

$U_{LAB} = 5.90\text{dB}$ $U_{CISPR} = 6.3\text{dB}$

Radiated Emissions 1GHz - 6GHz

$U_{LAB} = 4.80\text{dB}$ $U_{CISPR} = 5.2\text{dB}$

Radiated Emissions 6GHz - 18GHz

$U_{LAB} = 5.1\text{dB}$ $U_{CISPR} = 5.5\text{dB}$

Power Line Conducted Emissions 9kHz to 150kHz

$U_{LAB} = 2.96\text{dB}$ $U_{CISPR} = 3.8\text{dB}$

Power Line Conducted Emissions 150kHz to 30MHz

$U_{LAB} = 3.12\text{dB}$ $U_{CISPR} = 3.4\text{dB}$

If the calculated uncertainty U_{lab} is **less** than U_{CISPR} then:

- | | |
|---|---|
| 1 | Compliance is deemed to occur if NO measured disturbance exceeds the disturbance limit |
| 2 | Non-Compliance is deemed to occur if ANY measured disturbance EXCEEDS the disturbance limit |

If the calculated uncertainty U_{lab} is **greater** than U_{CISPR} then:

- | | |
|---|--|
| 3 | Compliance is deemed to occur if NO measured disturbance, increased by ($U_{lab} - U_{CISPR}$), exceeds the disturbance limit |
| 4 | Non-Compliance is deemed to occur if ANY measured disturbance, increased by ($U_{lab} - U_{CISPR}$), EXCEEDS the disturbance limit |

Other Measurement Uncertainties (U_{LAB})

RF Conducted Emissions 9kHz - 40GHz

$U_{LAB} = 1.0\text{dB}$ $U_{CISPR} = \text{n/a}$

Frequency/Bandwidth 9kHz - 40GHz

$U_{LAB} = 0.1\text{ppm}$ $U_{CISPR} = \text{n/a}$

Temperature

$U_{LAB} = 1^{\circ}\text{C}$ $U_{CISPR} = \text{n/a}$

END OF REPORT

APPENDIX D – CONDUCTED SPURIOUS EMISSIONS MEASUREMENT PLOTS

APPENDIX E – RADIATED TX EMISSIONS (RESTRICTED BAND) MEASUREMENT PLOTS

APPENDIX F – RADIATED RX EMISSIONS MEASUREMENT PLOTS