

Annex 201:

Measurement diagrams 24-1-0014701T010_TR1-A201-R01

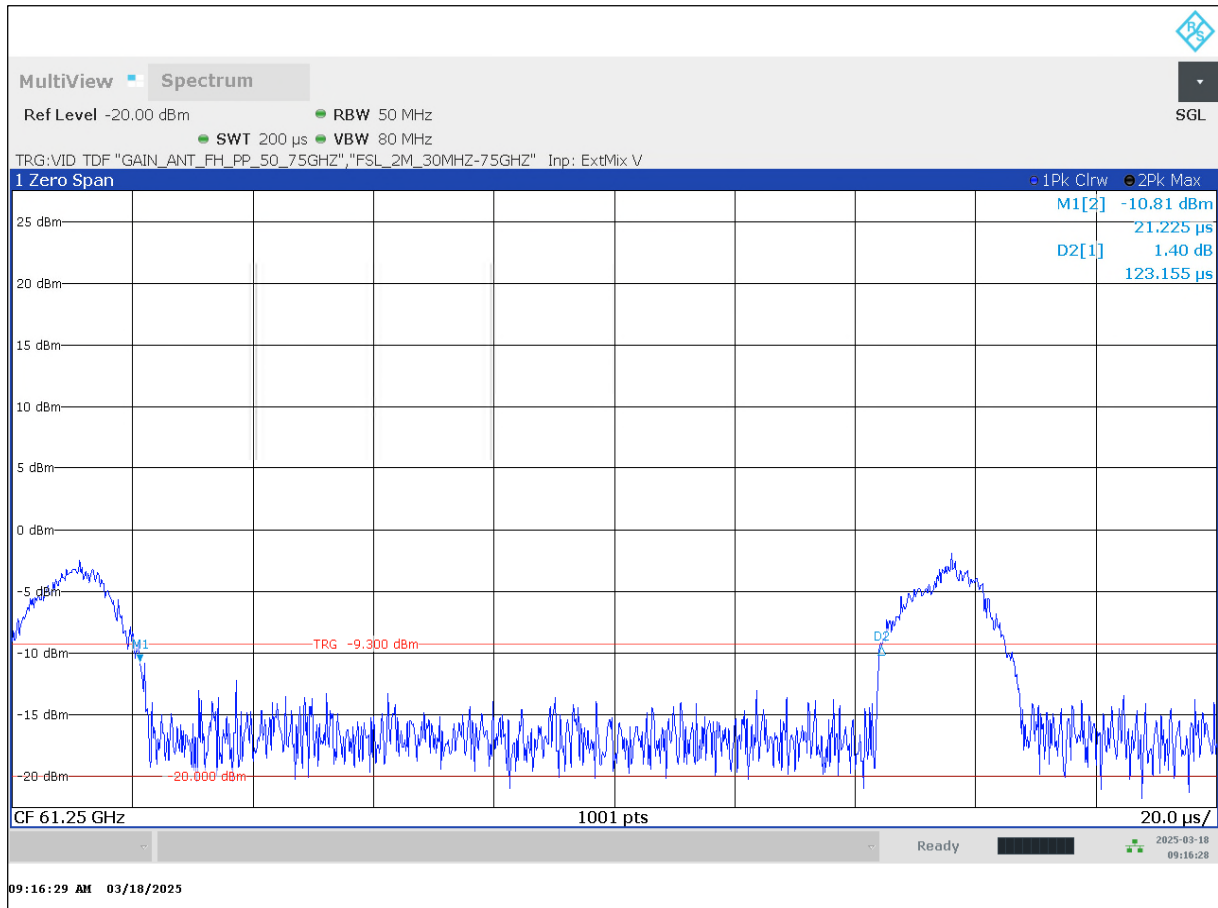
Number of pages:	67	Date of Report:	2025-May-20
Testing company:	cetecom advanced GmbH Untertuerkheimer Str. 6-10 66117 Saarbruecken GERMANY	Applicant:	Abel Sensors
Product: Model:	Fill Level Sensor RAD-SEN-05		
FCC ID:	2BN57-RADSEN05	IC: PMN HVIN	33673-RADSEN05 SMARTSILO rad7972
Testing has been carried out in accordance with:	FCC - Title 47 of the Code of Federal Regulations Chapter I; Part 15 - Radio frequency devices, §15.255 RSS-210, Issue 11: Licence-Exempt Radio Apparatus: Category I Equipment Annex J: Devices operating in the band 57-71 GHz		

1	Measurement diagrams.....	3
1.1	Cycle-Time of transmissions	3
1.2	Desentization.....	7
1.2.1	Measurement antenna horizontal	7
1.2.2	Measurement antenna vertical.....	10
1.3	Occupied bandwidth (99%)	13
1.3.1	T _{nom} , V _{nom}	13
1.3.2	T _{nom} , V _{MIN} to V _{MAX}	14
1.3.3	V _{nom} , T _{MIN} to T _{MAX}	16
1.4	Channel AV-power.....	23
1.5	Radiated power limits outside 61-61.5GHz (but inside 57-71GHz)	24
1.5.1	Antenna horizontal	24
1.5.2	Antenna vertical.....	28
1.6	Radiated emissions according §15.209	32
1.6.1	Frequency range: 9kHz to 30MHz.....	32
1.6.2	Frequency range: 30MHz to 1GHz	34
1.6.3	Frequency range: 1GHz to 12.4GHz	38
1.6.4	Frequency range: 12.4GHz to 18GHz	41
1.6.5	Frequency range: 18GHz to 30GHz	47
1.6.1	Frequency range: 30GHz to 40GHz	51
1.6.2	Frequency range: 40GHz to 50GHz	53
1.6.3	Frequency range: 50GHz to 75GHz	55
1.6.4	Frequency range: 75GHz to 110GHz	60
1.6.5	Frequency range: 110GHz to 140GHz	63
1.6.6	Frequency range: 140GHz to 200GHz	65

1 Measurement diagrams

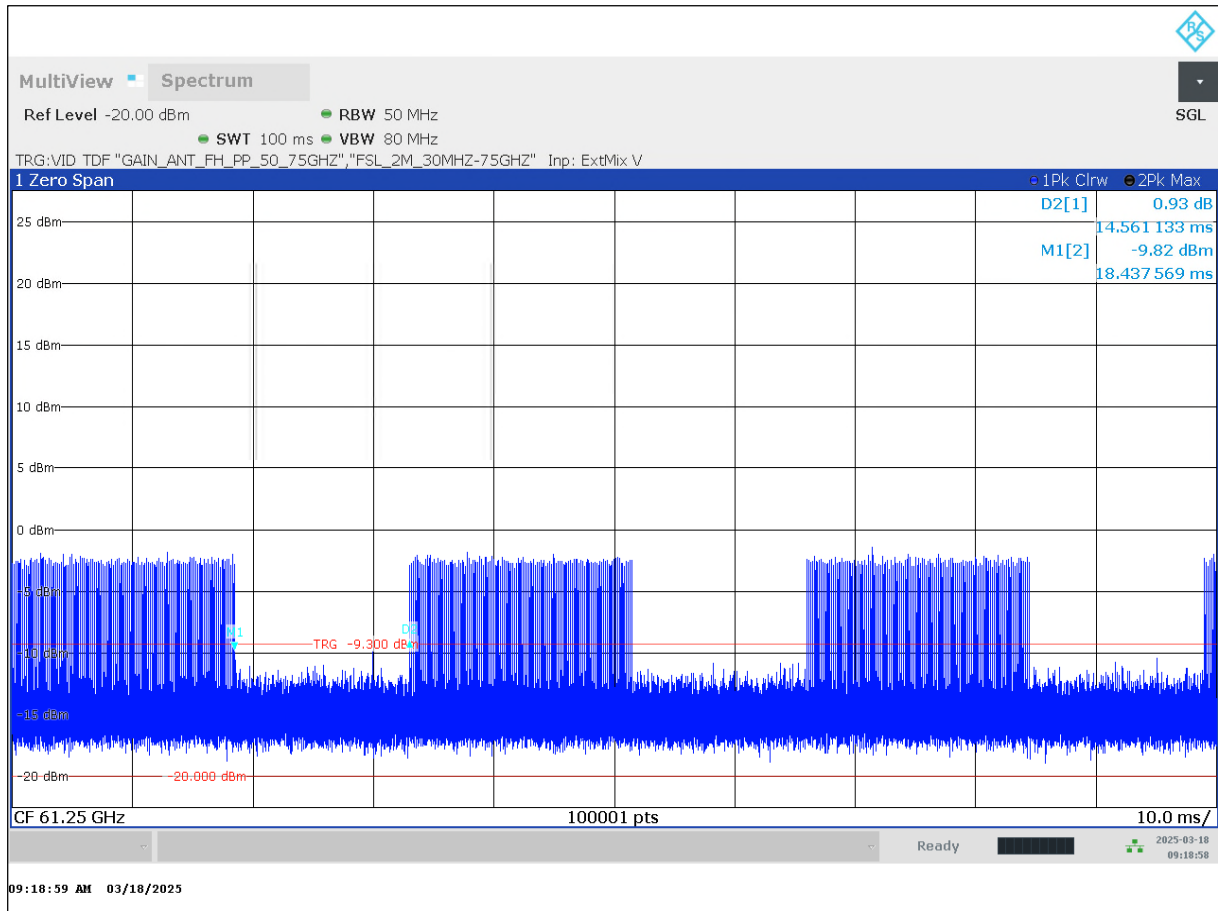
1.1 Cycle-Time of transmissions

TID001a_01_Cycle-Time_Pulse_Individual_Anth



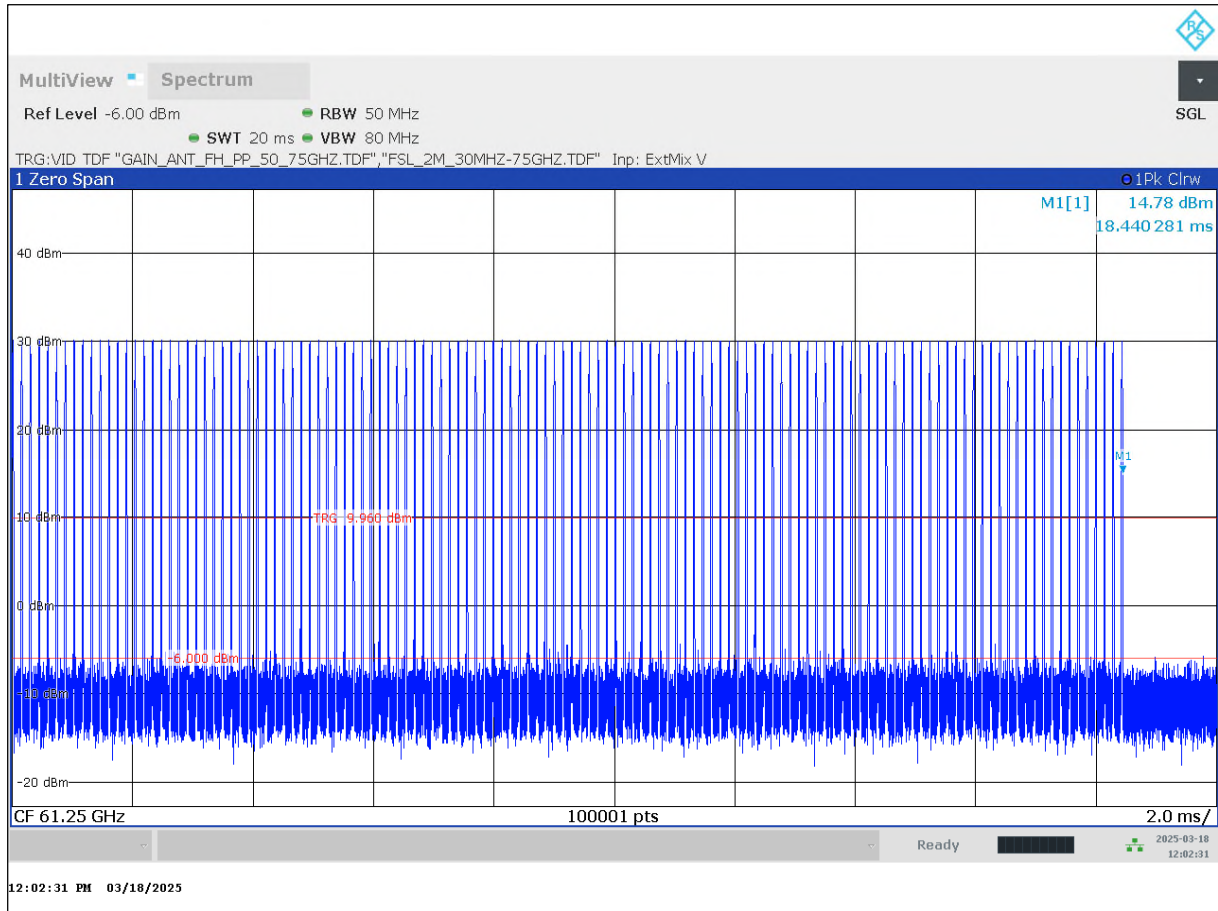
Chirp width: 21.225us

TID001a_03_Cycle-Time_Pulse_Train_Cycle_Anth

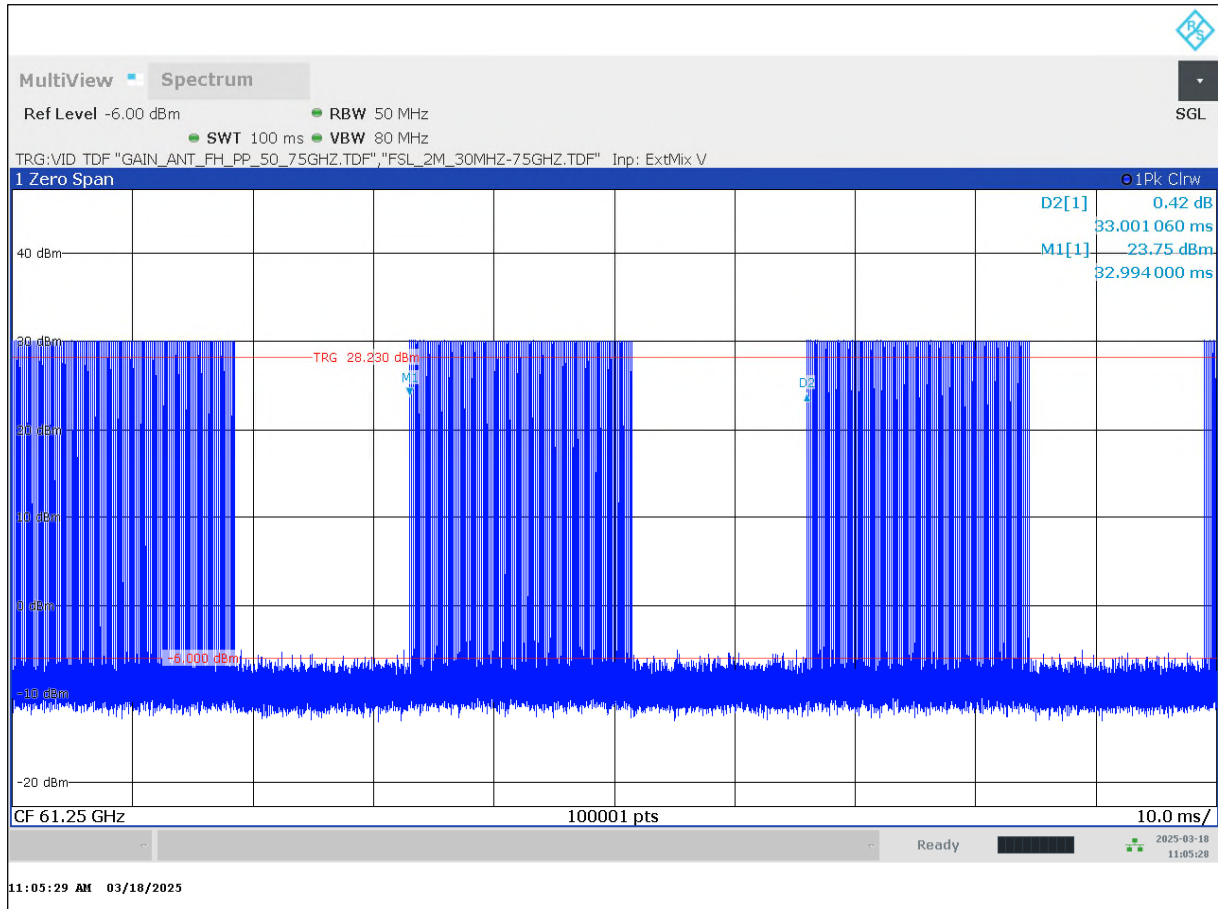


TX:off time: 14.56ms

TID001b_01_Pulse_Train_Length_Am5deg_E90deg_AntV



Tx-on time: 18.44ms

TID001b_Cycle-Time_Pulse_Train_Cycle_Am5deg_E90deg_AntV


Cycle-Time: 33ms

Duty-Cycle of transmissions:

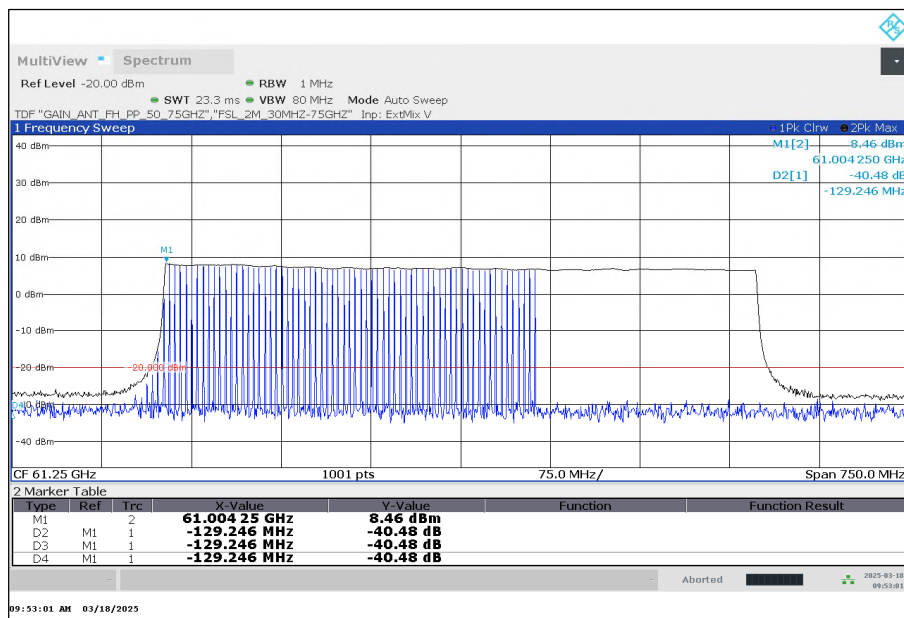
$$DC|_{\%} = 18.44\text{ms} / 32.994\text{ms} = 55.88\%$$

$$DC|_{\text{dB}} = 10 \cdot \log_{10}(1 / DC|_{\%}) = 10 \cdot \log_{10}(1 / 0.5588) = 2.52\text{dB}$$

1.2 Desentization

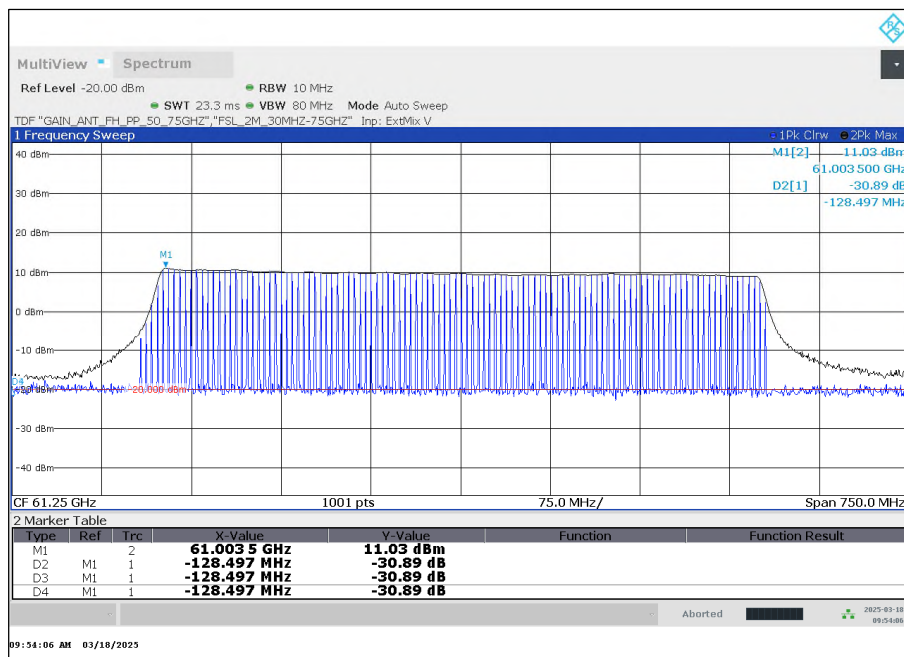
1.2.1 Measurement antenna horizontal

TID003a_Desentization_RBW_1MHz_S08-long-range_Am4deg_E90deg_AntH



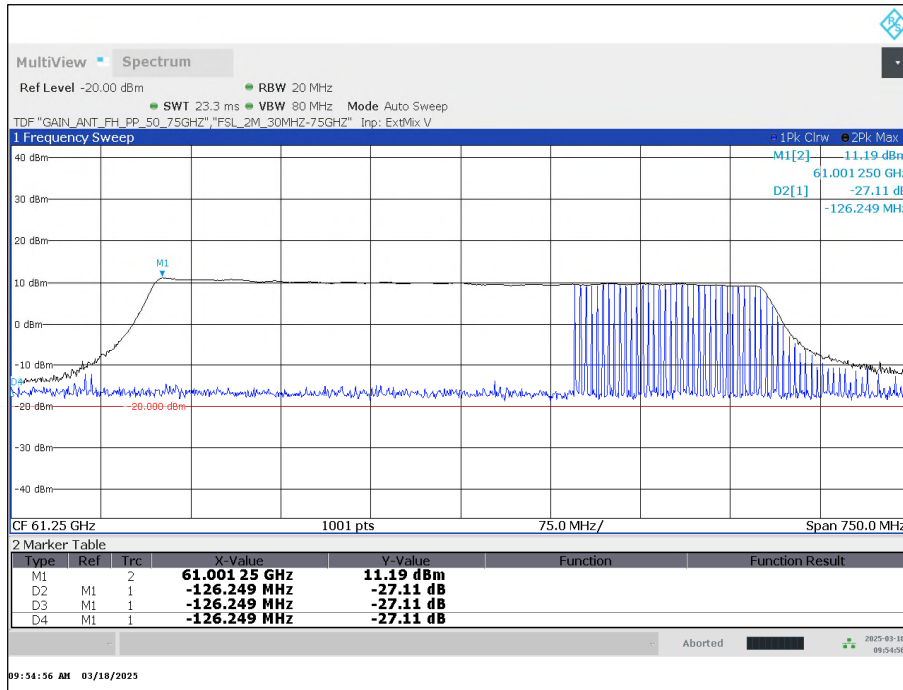
Max-peak value: 8.46dBm EIRP

TID003a_01_Desentization_RBW_10MHz_S08-long-range_Am4deg_E90deg_AntH



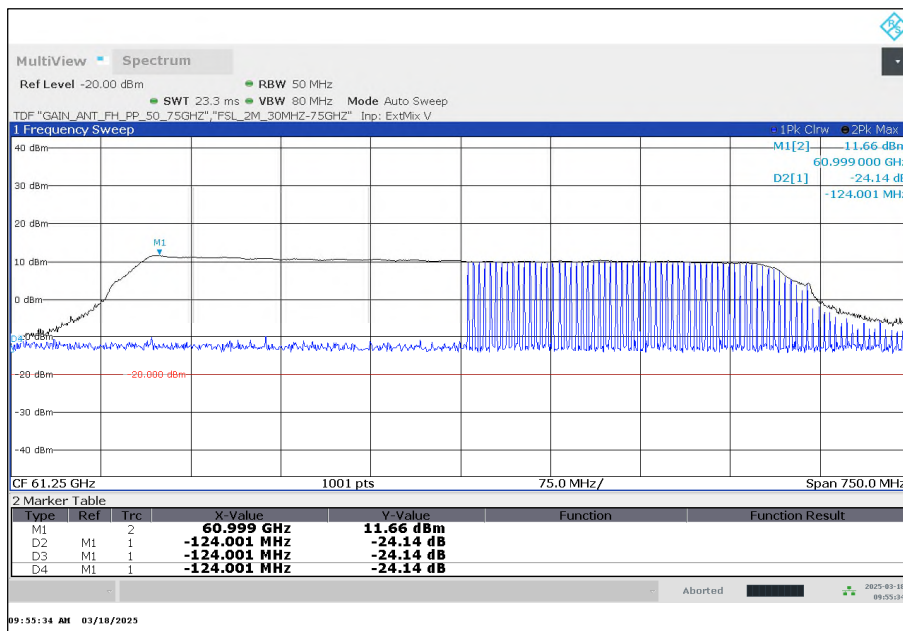
Max-peak value: 11.03 dBm EIRP

TID003a_02_Desentization_RBW_20MHz_S08-long-range_Am4deg_E90deg_AntH

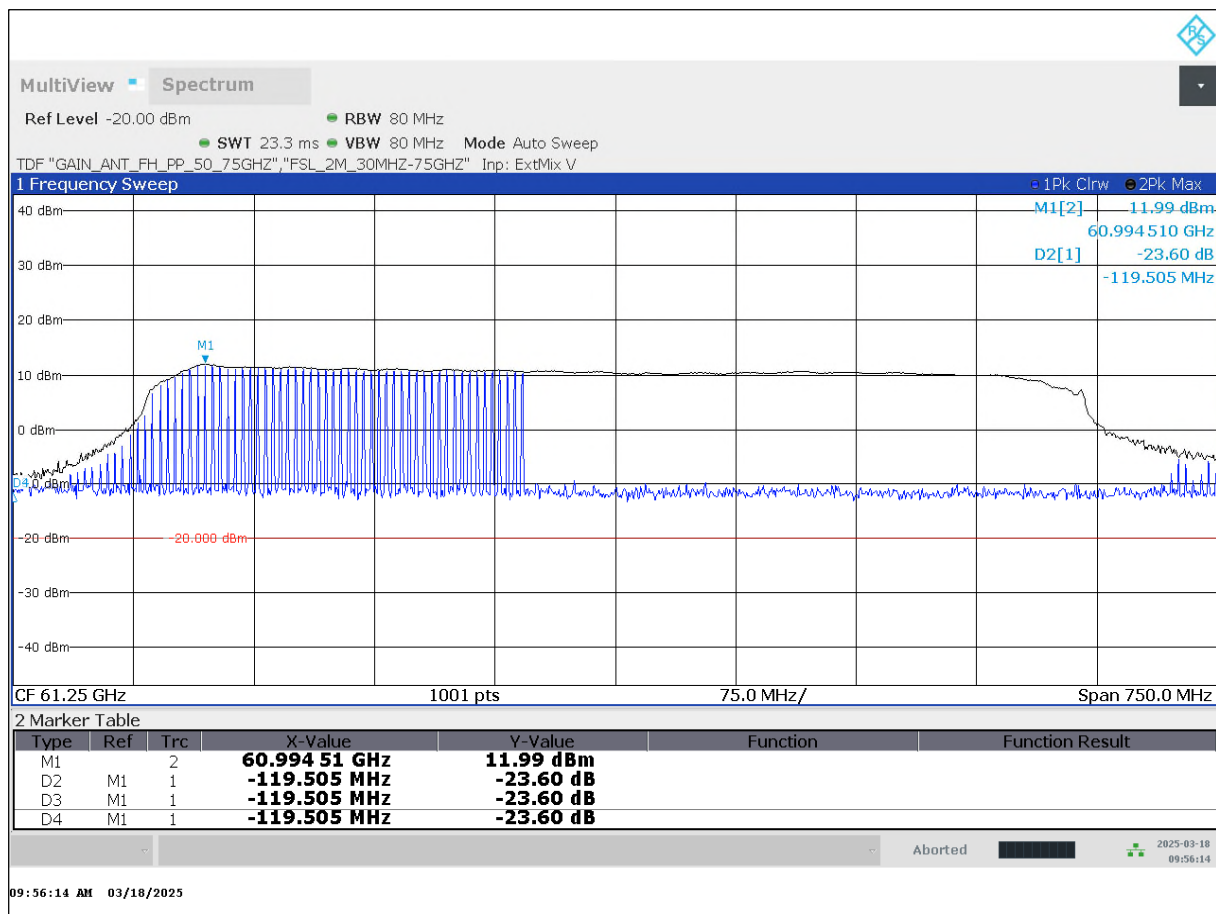


Max-peak value: 11.19 dBm EIRP

TID003a_03_Desentization_RBW_50MHz_S08-long-range_Am4deg_E90deg_AntH



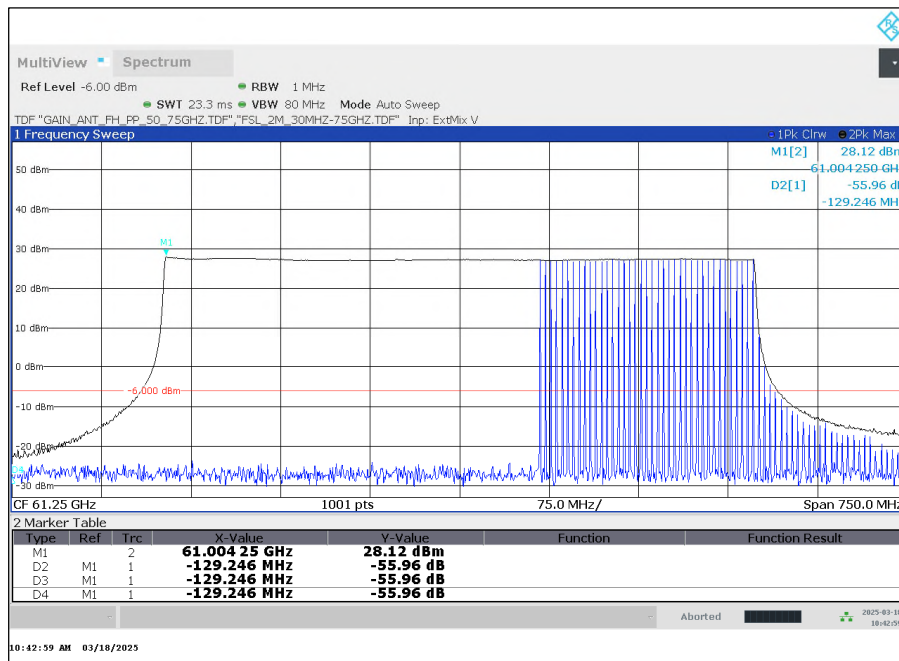
Max-peak value: 11.66 dBm EIRP

TID003a_04_Desentization_RBW_80MHz_S08-long-range_Am4deg_E90deg_AnH


Max-peak value: 11.99 dBm EIRP

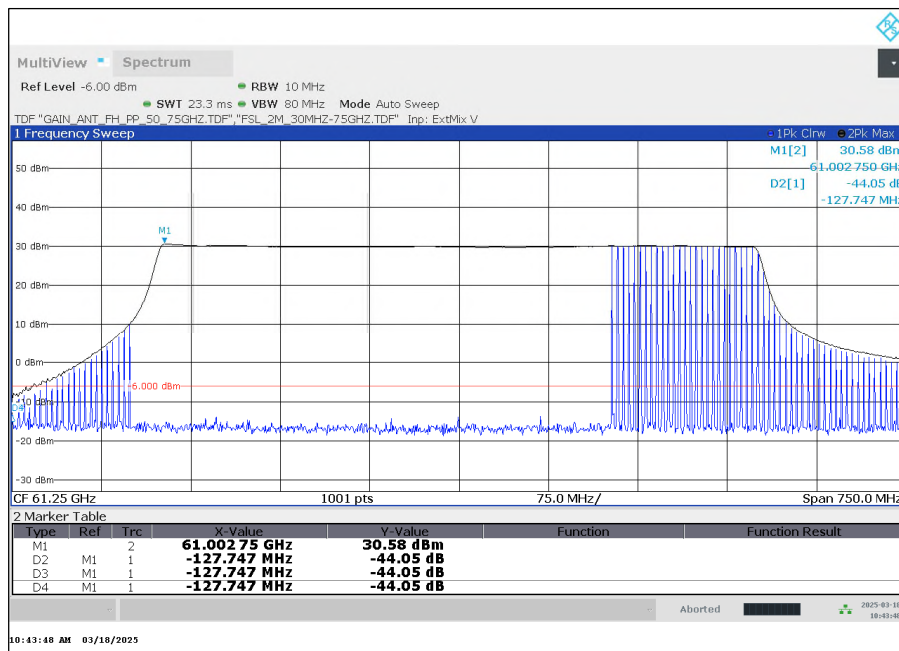
1.2.2 Measurement antenna vertical

TID003b_Desentization_RBW_1MHz_S08-long-range_Am5deg_E90deg_AntV



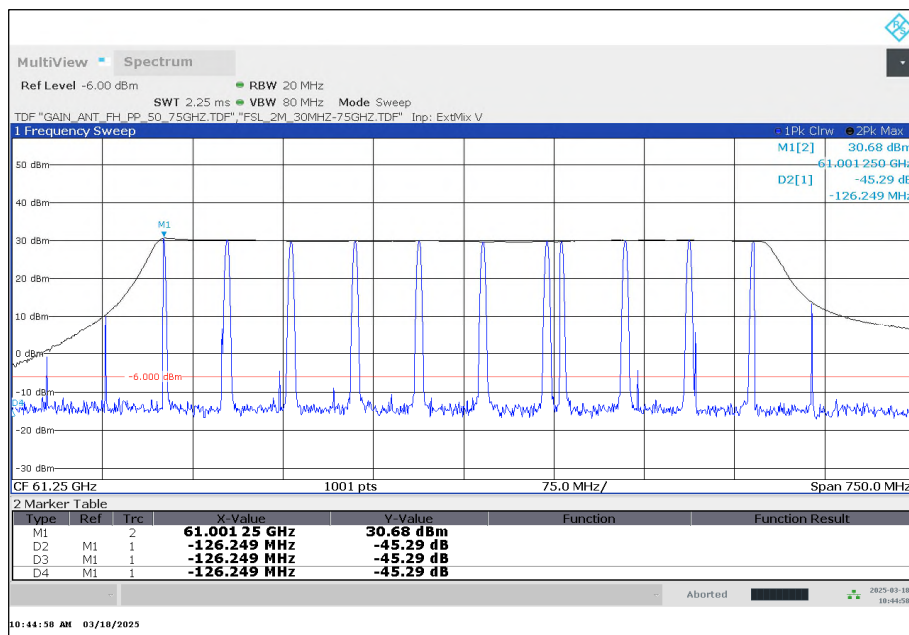
Max-peak value: 28.12 dBm EIRP

TID003b_01_Desentization_RBW_10MHz_S08-long-range_Am5deg_E90deg_AntV



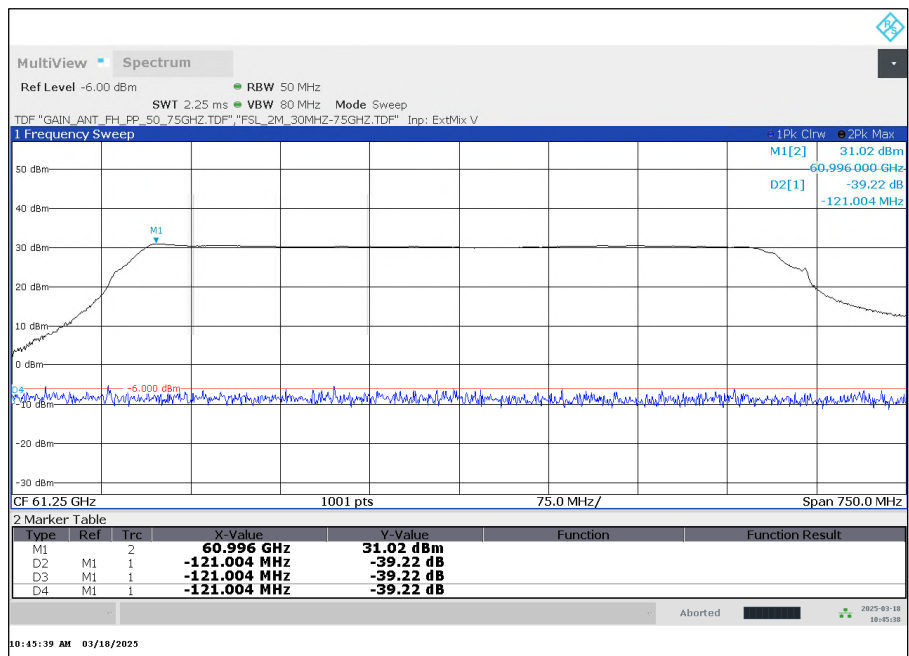
Max-peak value: 30.58dBm EIRP

TID003b_02_Desentization_RBW_20MHz_S08-long-range_Am5deg_E90deg_AntV



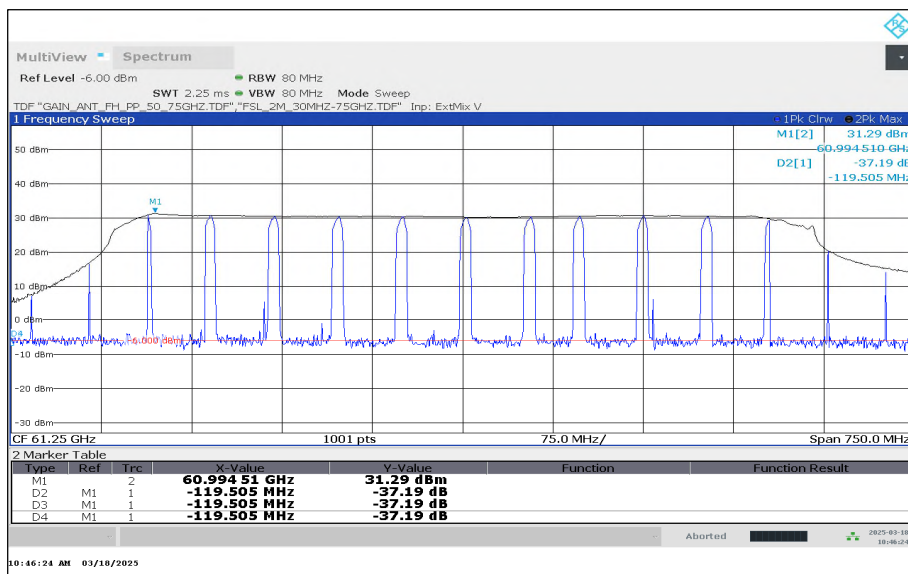
Max-peak value: 30.68 dBm EIRP

TID003b_03_Desentization_RBW_50MHz_S08-long-range_Am5deg_E90deg_AntV



Max-peak value: 31.02dBm EIRP

TID003b_04_Desentization_RBW_80MHz_S08-long-range_Am5deg_E90deg_AntV

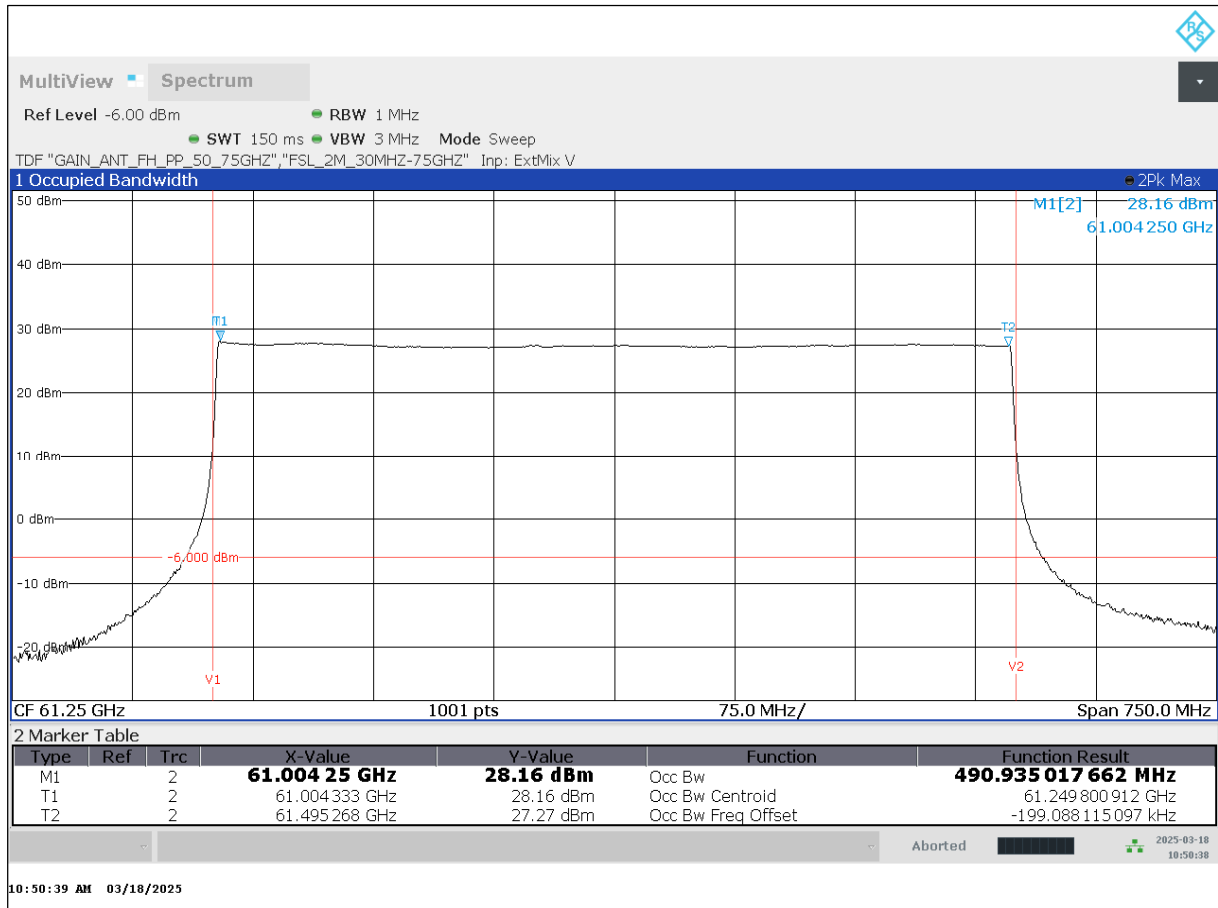


Max-peak value: 31.29dBm EIRP

1.3 Occupied bandwidth (99%)

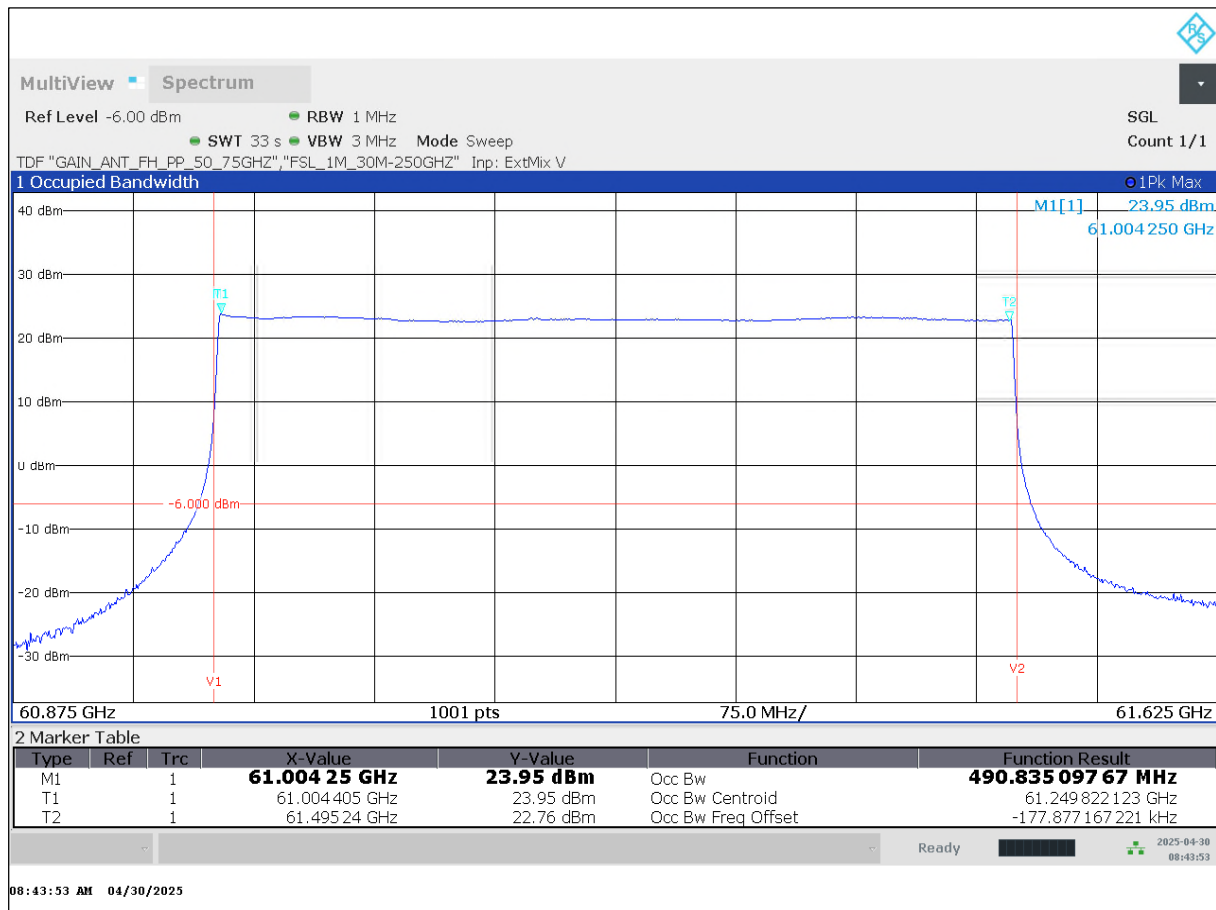
1.3.1 Tnom,Vnom

TID004b_OBW_RBW_1MHz_S08-long-range_Am5deg_E90deg_AntV

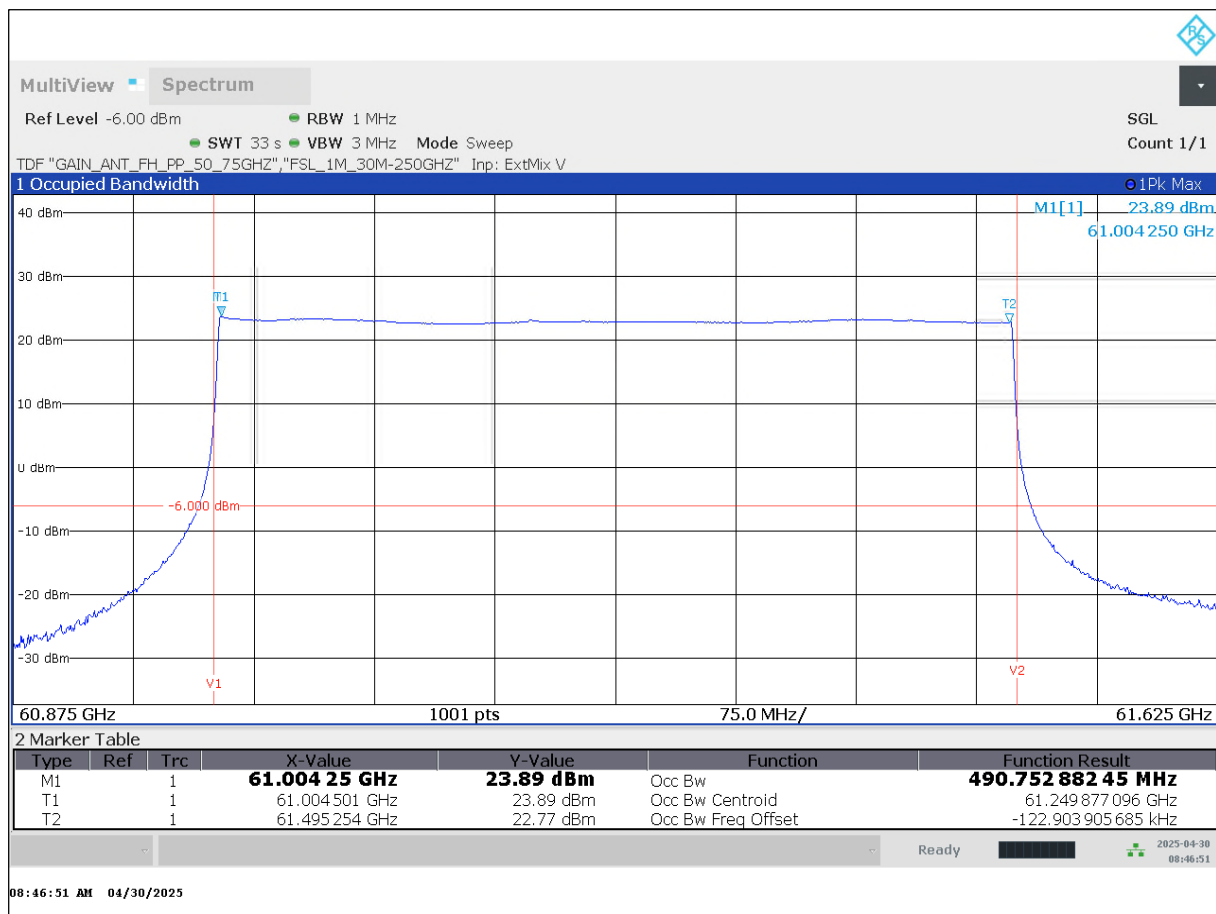


1.3.2 Tnom, V_{MIN} to V_{MAX}

TID004b_08_OBW_Tnom_U3_3V_S08-long-range_AntV

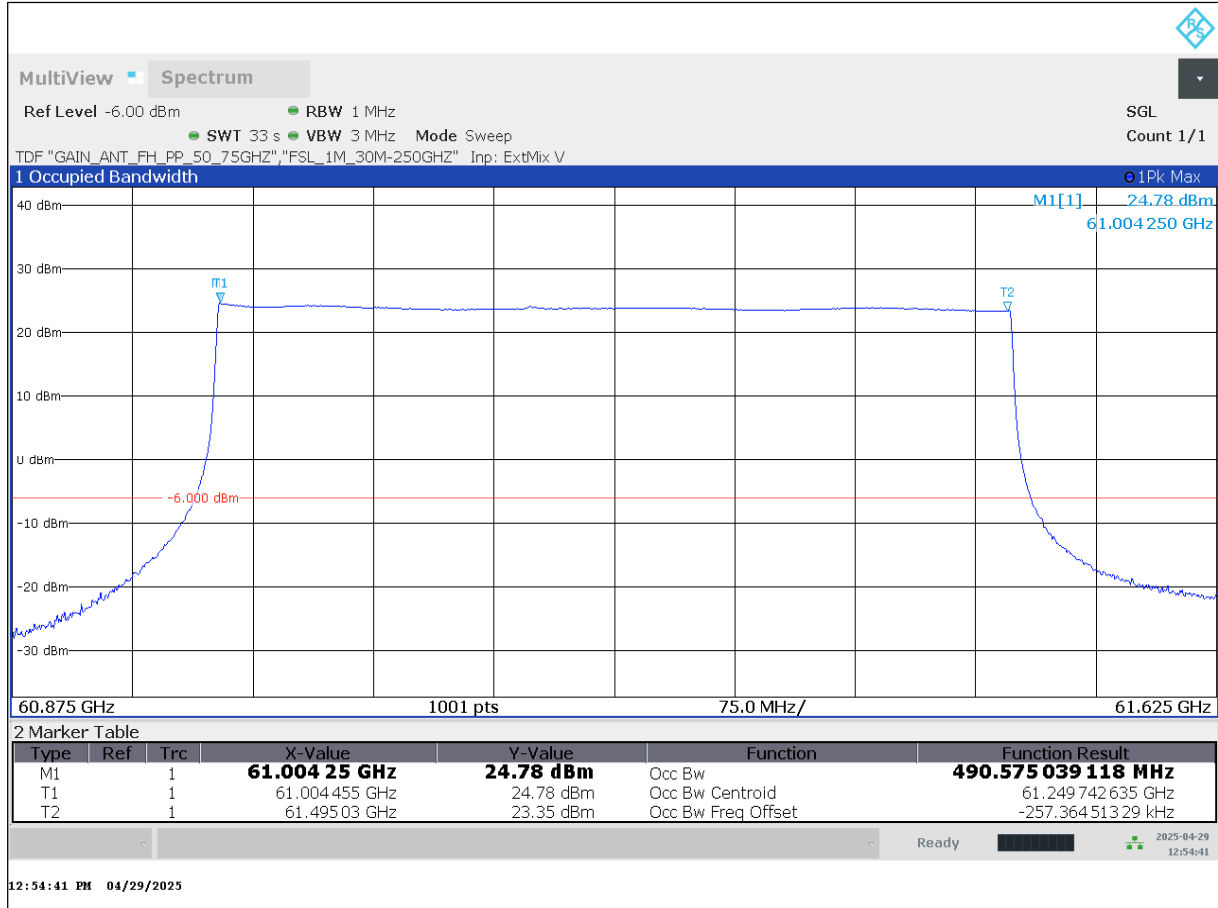


TID004b_09_OBW_Tnom_U3_8V_S08-long-range_AntV

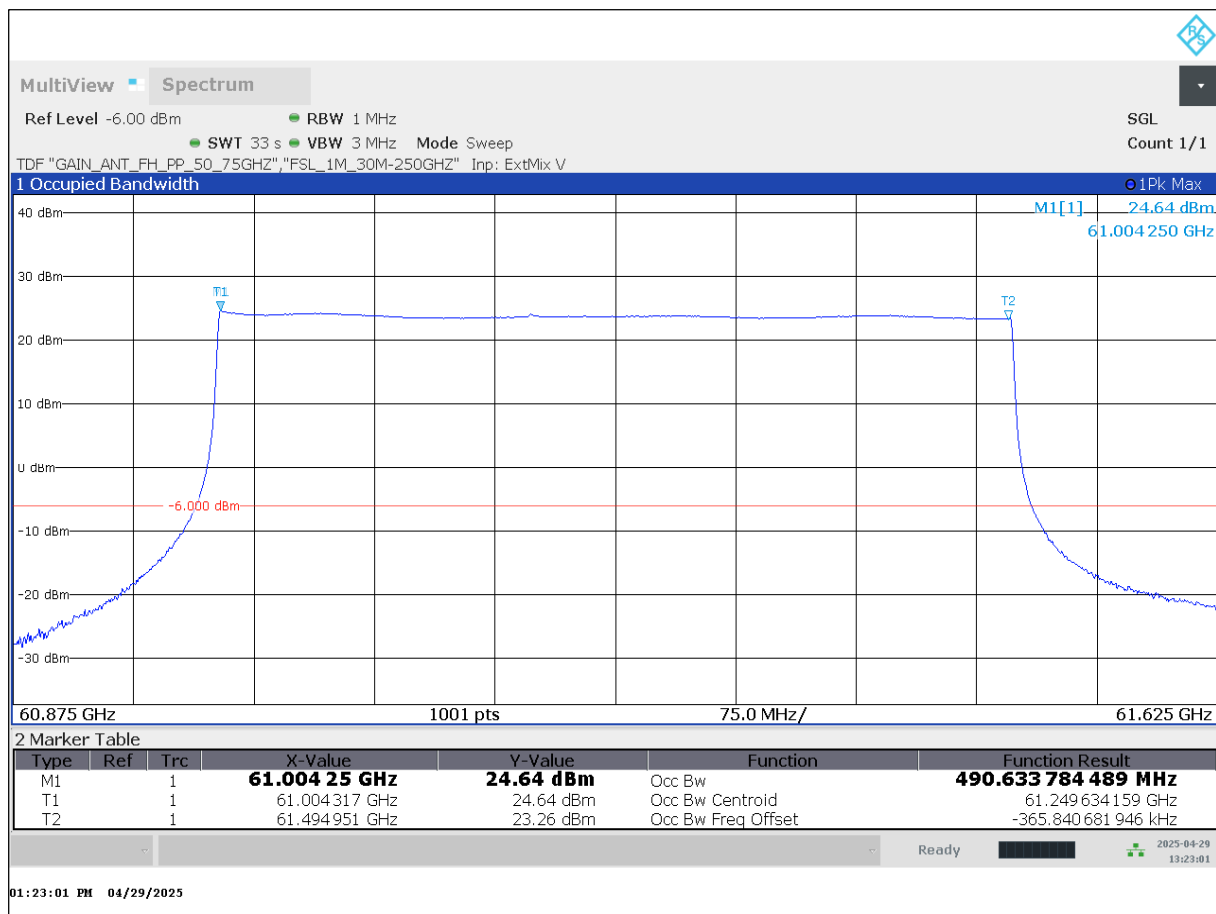


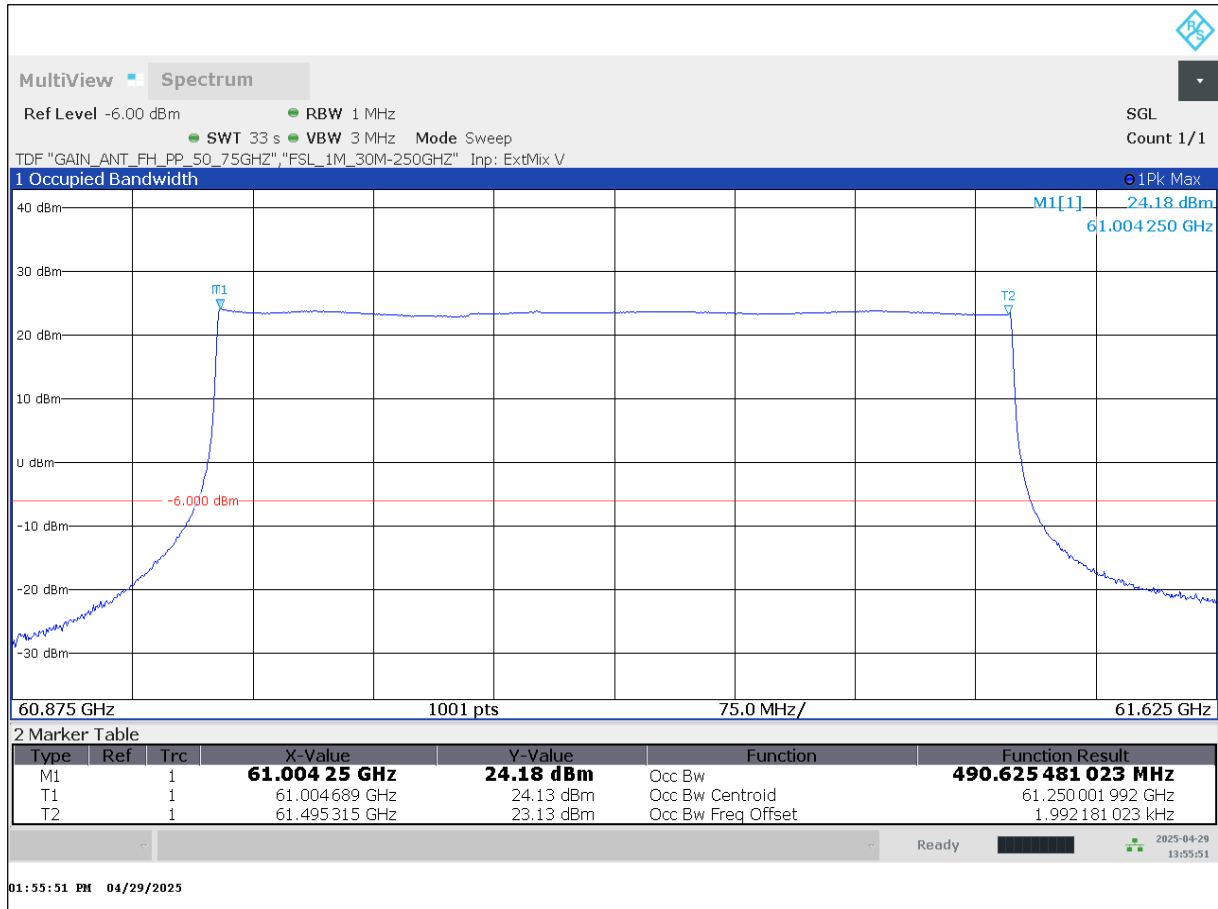
1.3.3 Vnom, T_{MIN} to T_{MAX}

TID004b_01_OBW_T50degree_U3_6V_S08-long-range_AntV

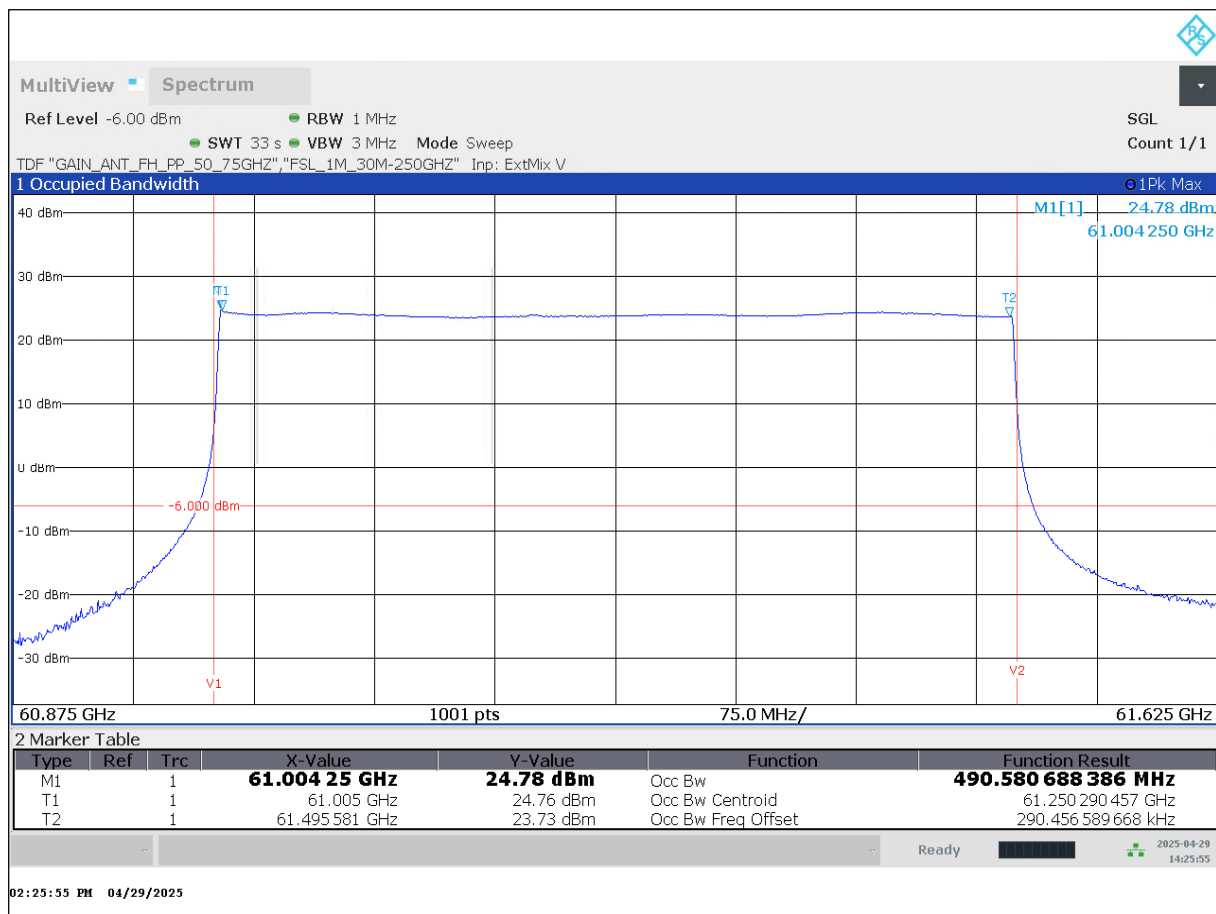


TID004b_02_OBW_T40degree_U3_6V_S08-long-range_AntV

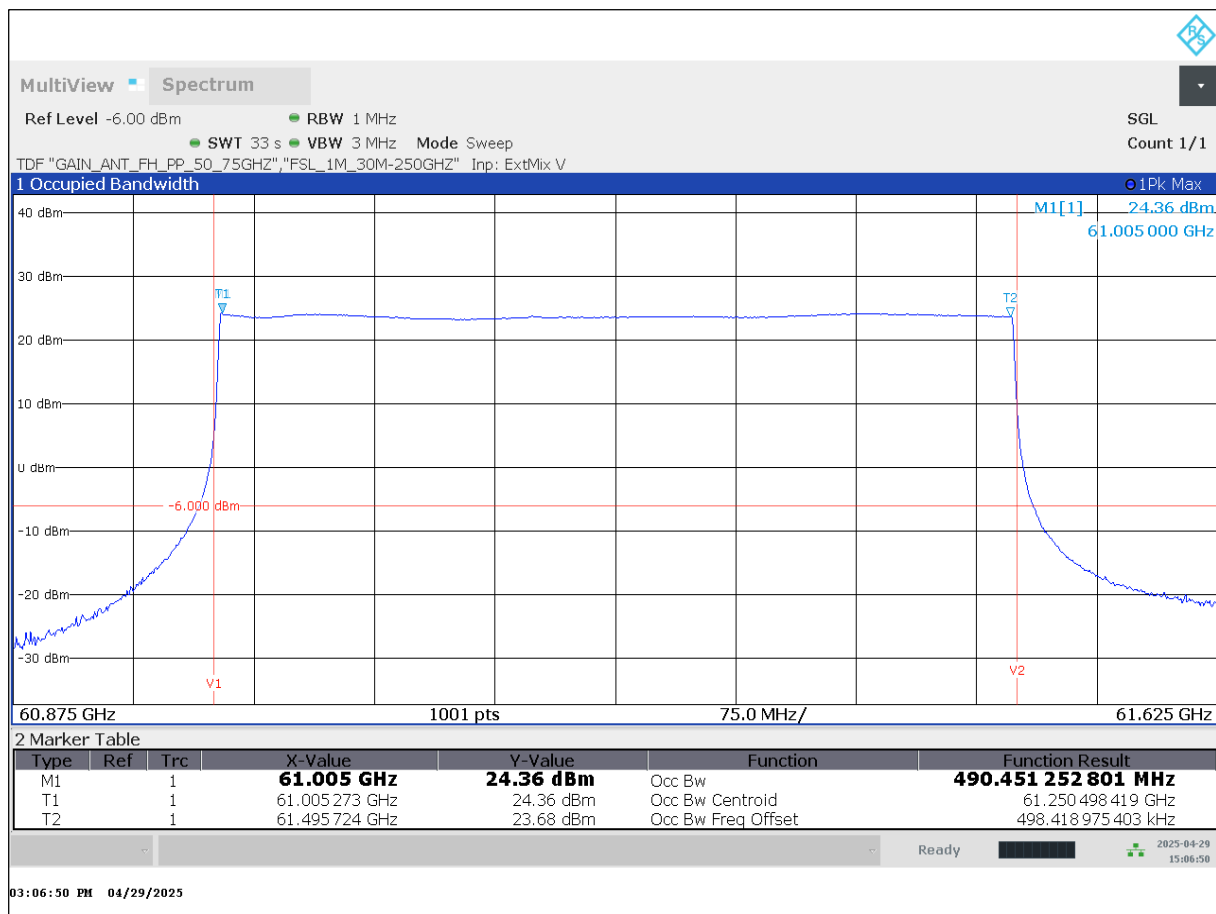


TID004b_03_OBW_T30degree_U3_6V_S08-long-range_AntV


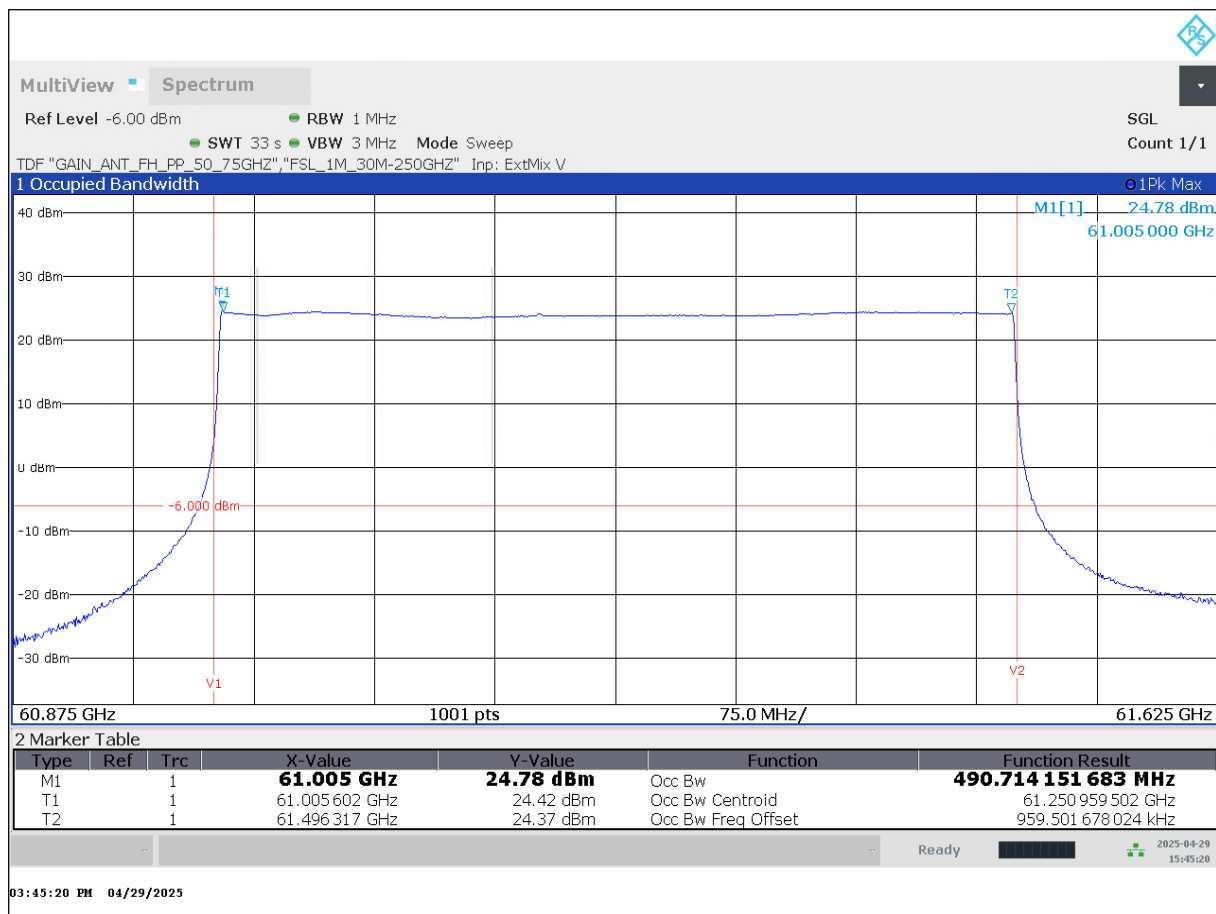
TID004b_04_OBW_T10degree_U3_6V_S08-long-range_AntV



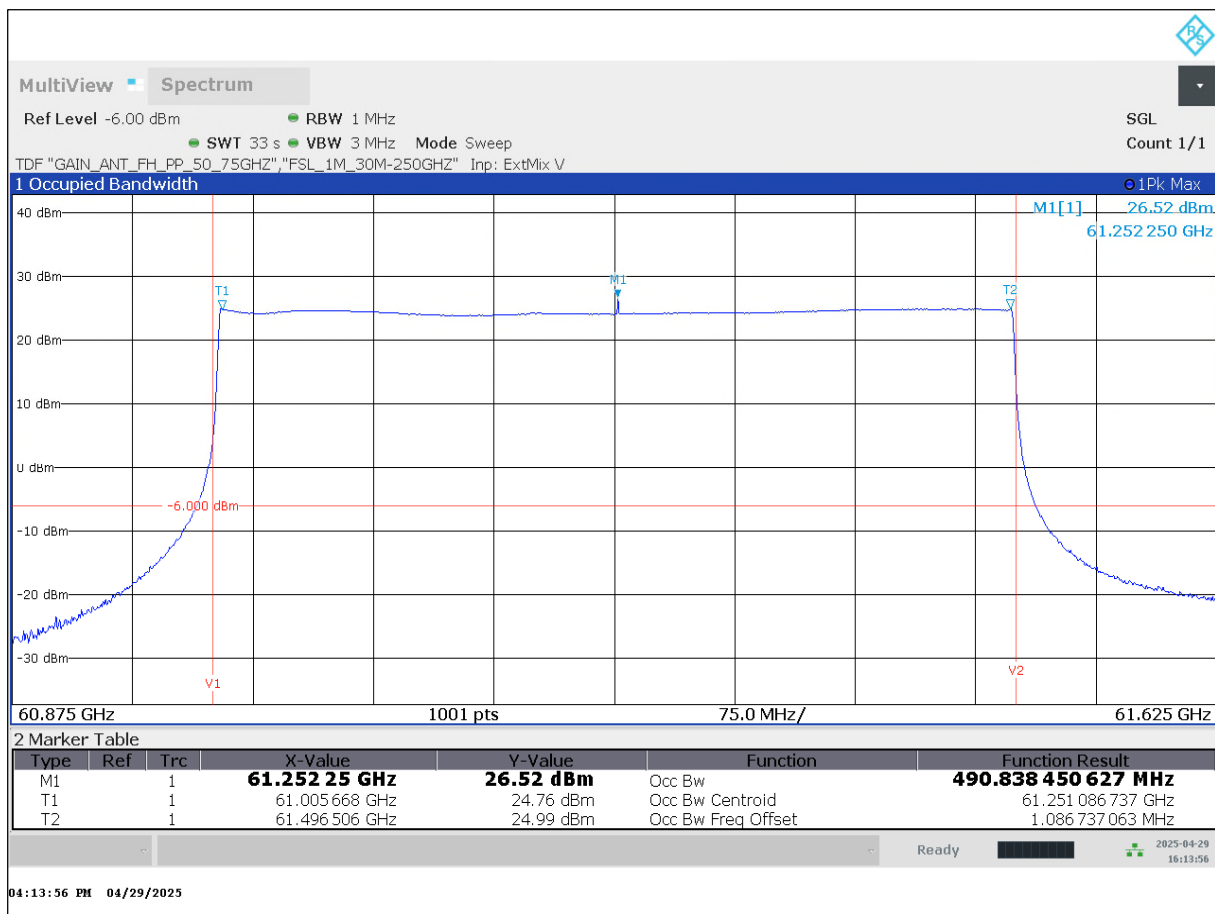
TID004b_05_OBW_T0degree_U3_6V_S08-long-range_AntV



TID004b_06_OBW_T_m10degree_U3_6V_S08-long-range_AntV

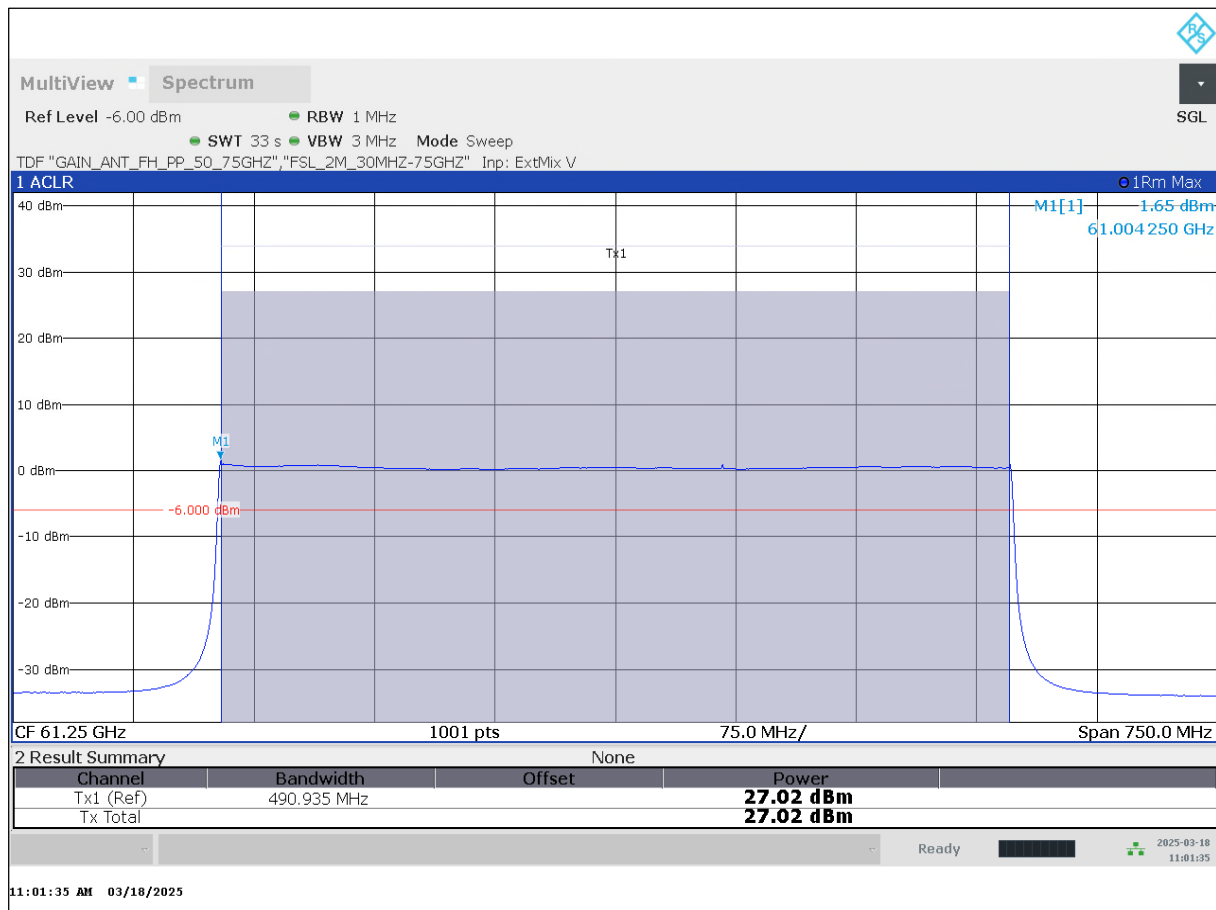


TID004b_07_OBW_T_m20degree_U3_6V_S08-long-range_AntV



1.4 Channel AV-power

TID005b_ChPWR_RBW_1MHz_S08-long-range_Am5deg_E90deg_AntV



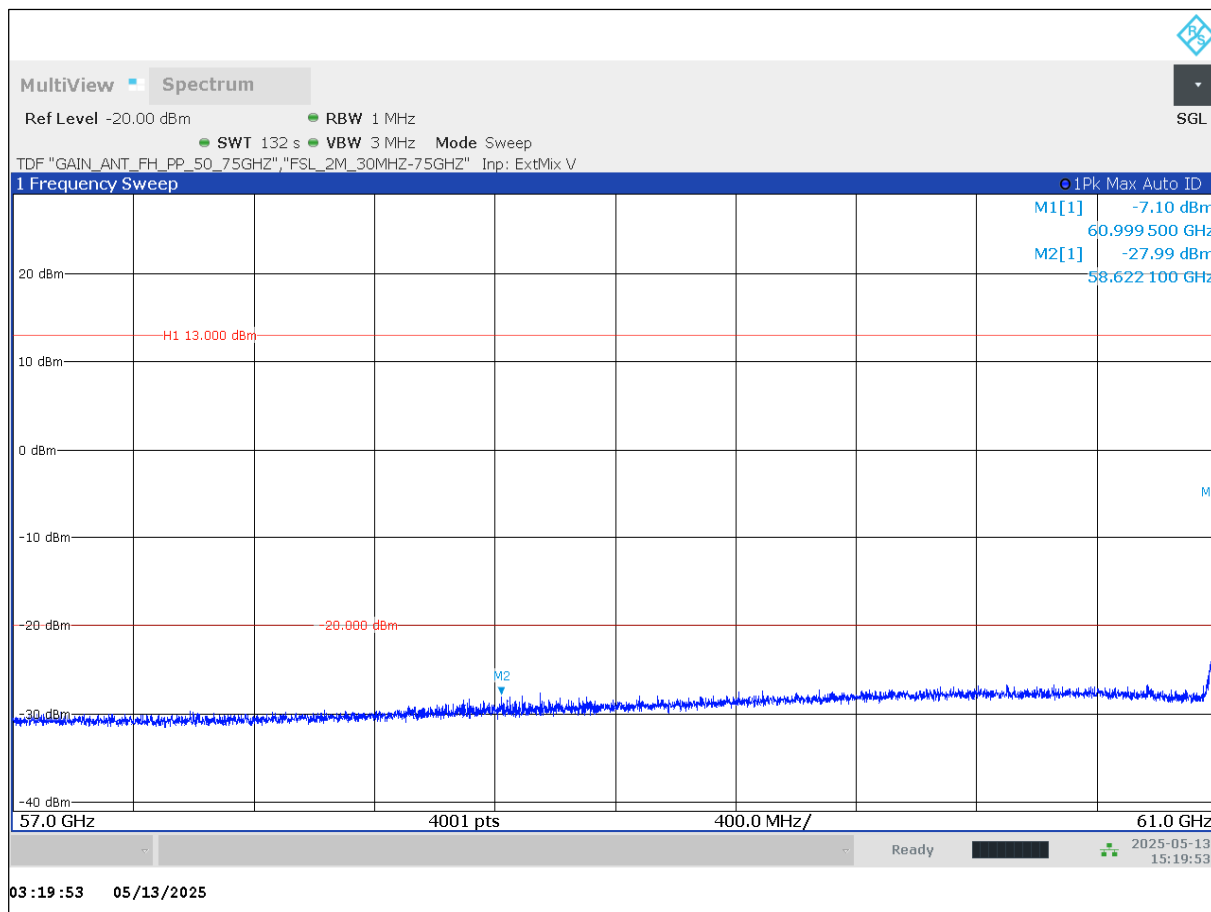
Measurement antenna vertical for worst-case: 27.02dBm

1.5 Radiated power limits outside 61-61.5GHz (but inside 57-71GHz)

1.5.1 Antenna horizontal

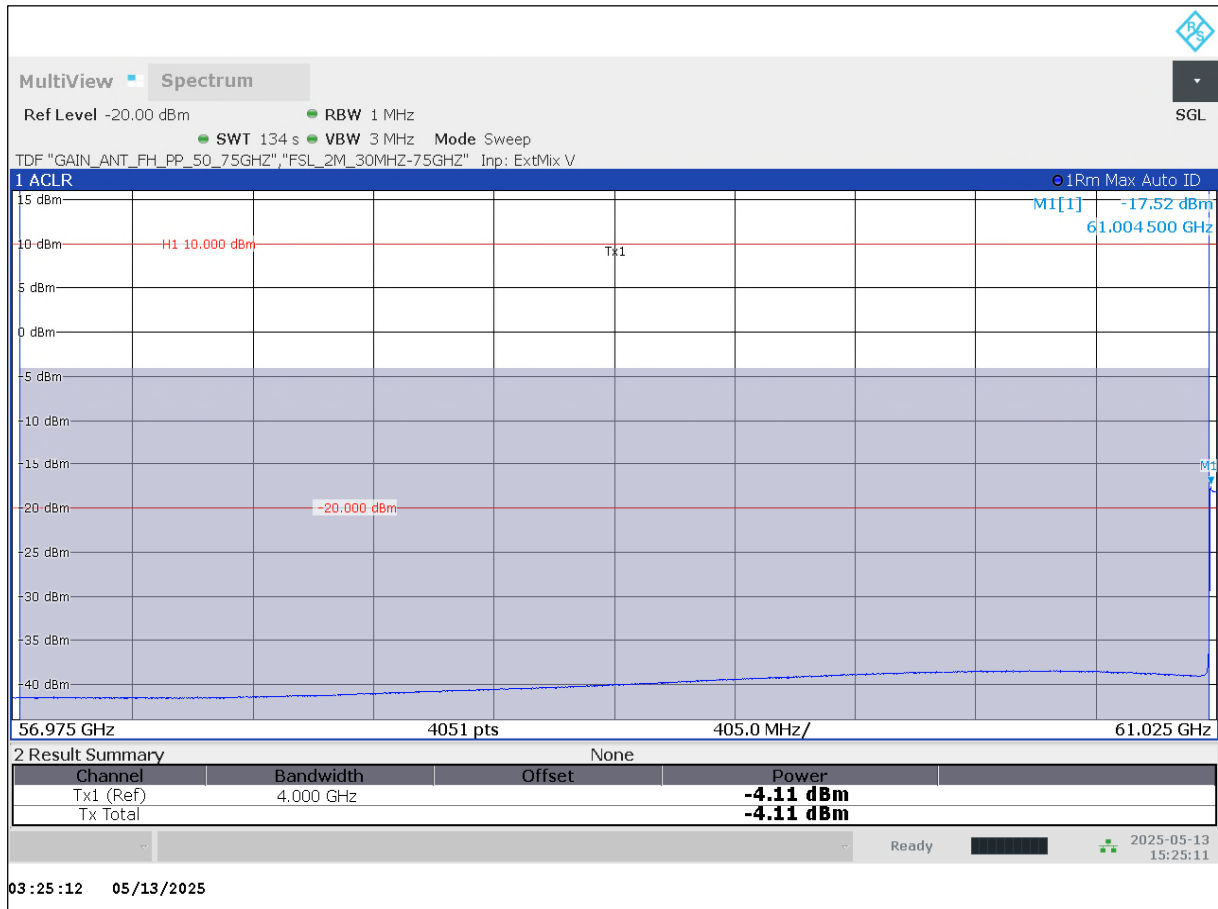
TID007a_01_RSE_PK_InBand_57-

61GHz_RBW_1MHz_HighRange_S08_Am3deg_E90deg__Anth

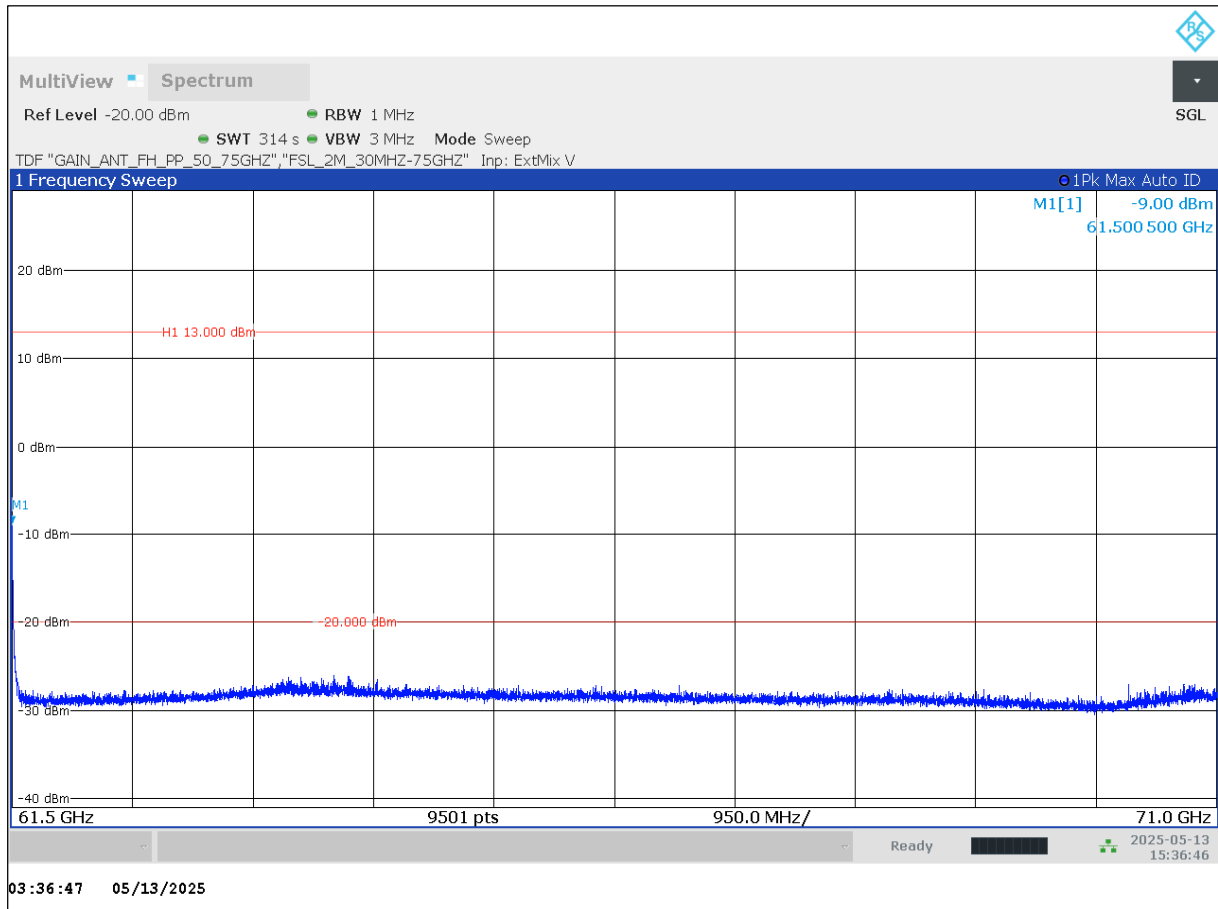


TID007a_02_RSE_AV_InBand_57-

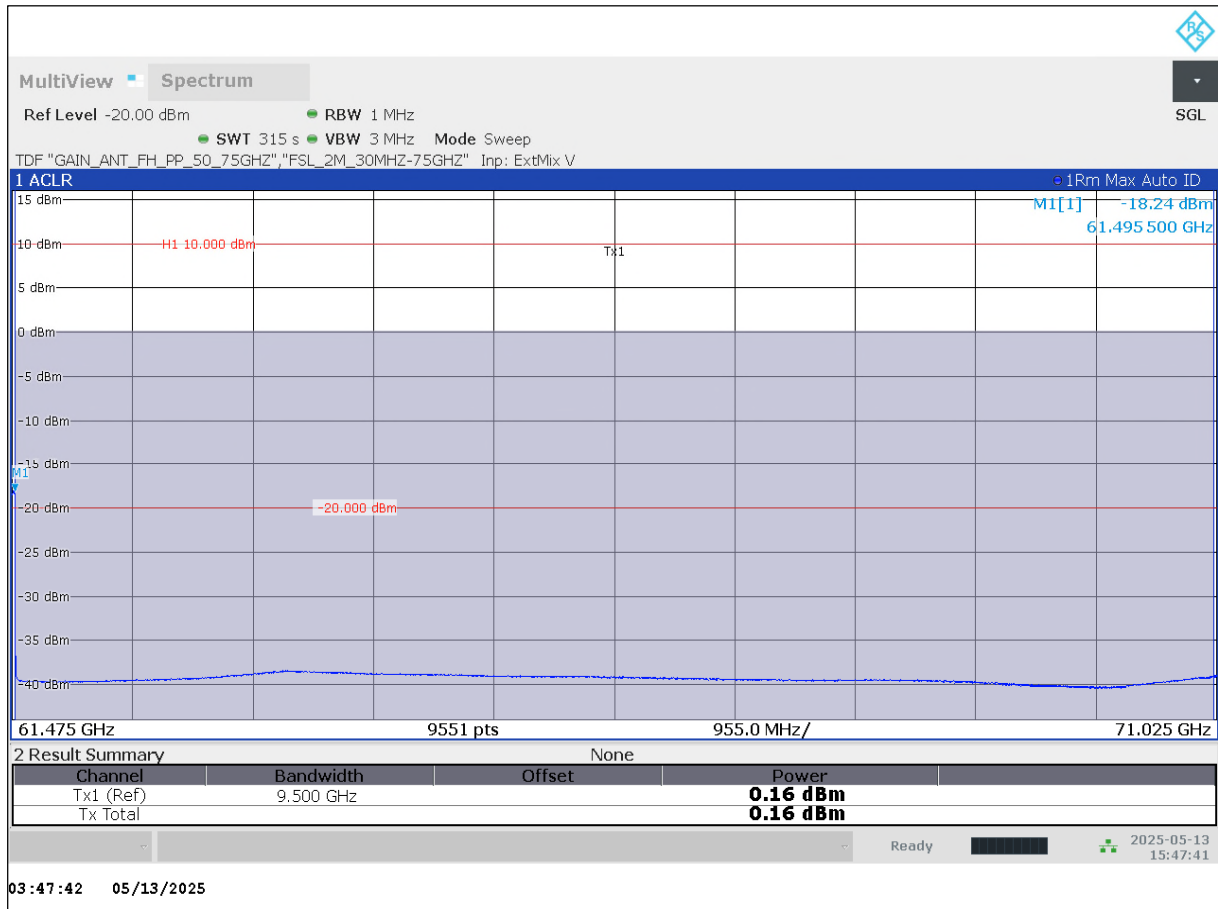
61.0GHz_RBW_1MHz_HighRange_S08_Am3deg_E90deg__AntH



TID007a_03_RSE_PK_InBand_61.5-
71GHz_RBW_1MHz_HighRange_S08_Am3deg_E90deg__AntH

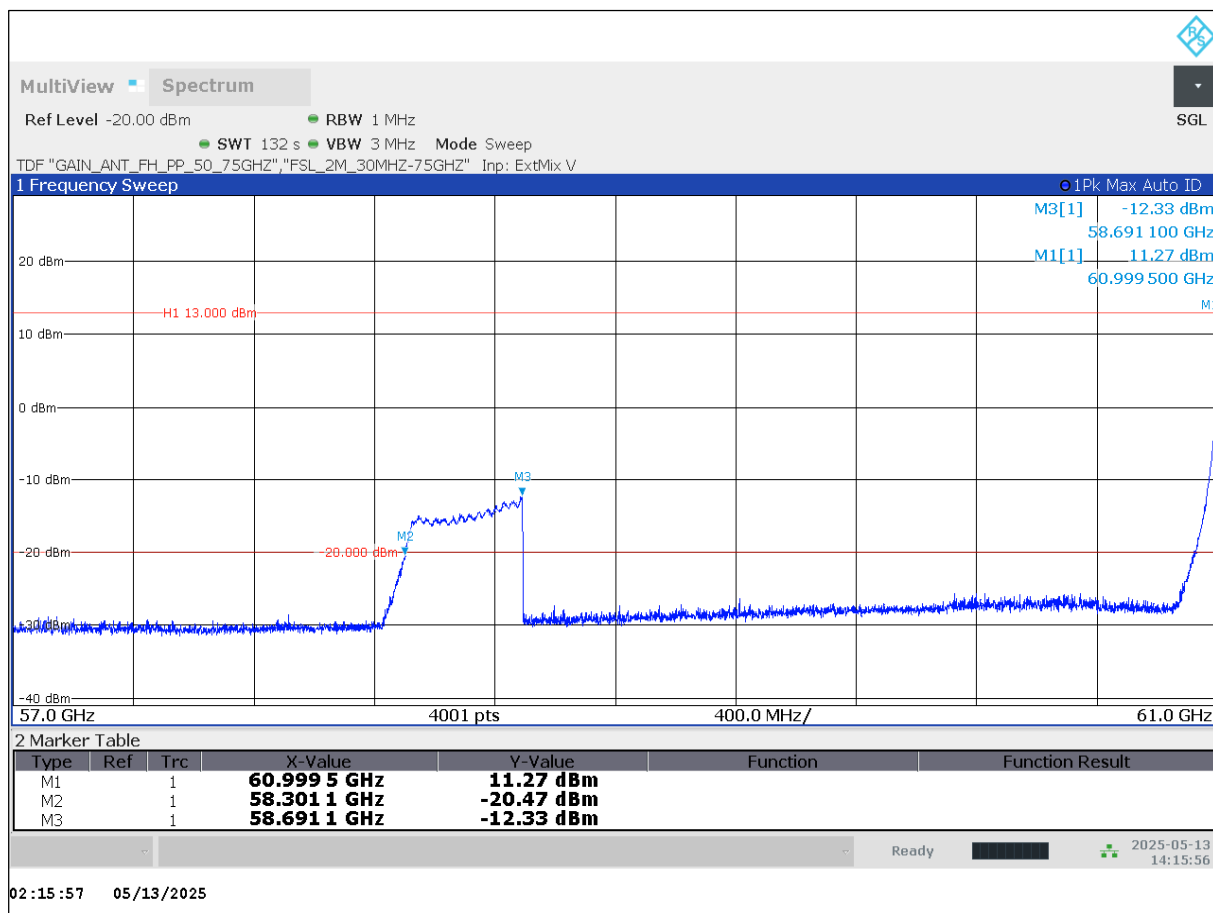


TID007a_04_RSE_AV_InBand_61.5-
71GHz_RBW_1MHz_HighRange_S08_Am3deg_E90deg__Anth



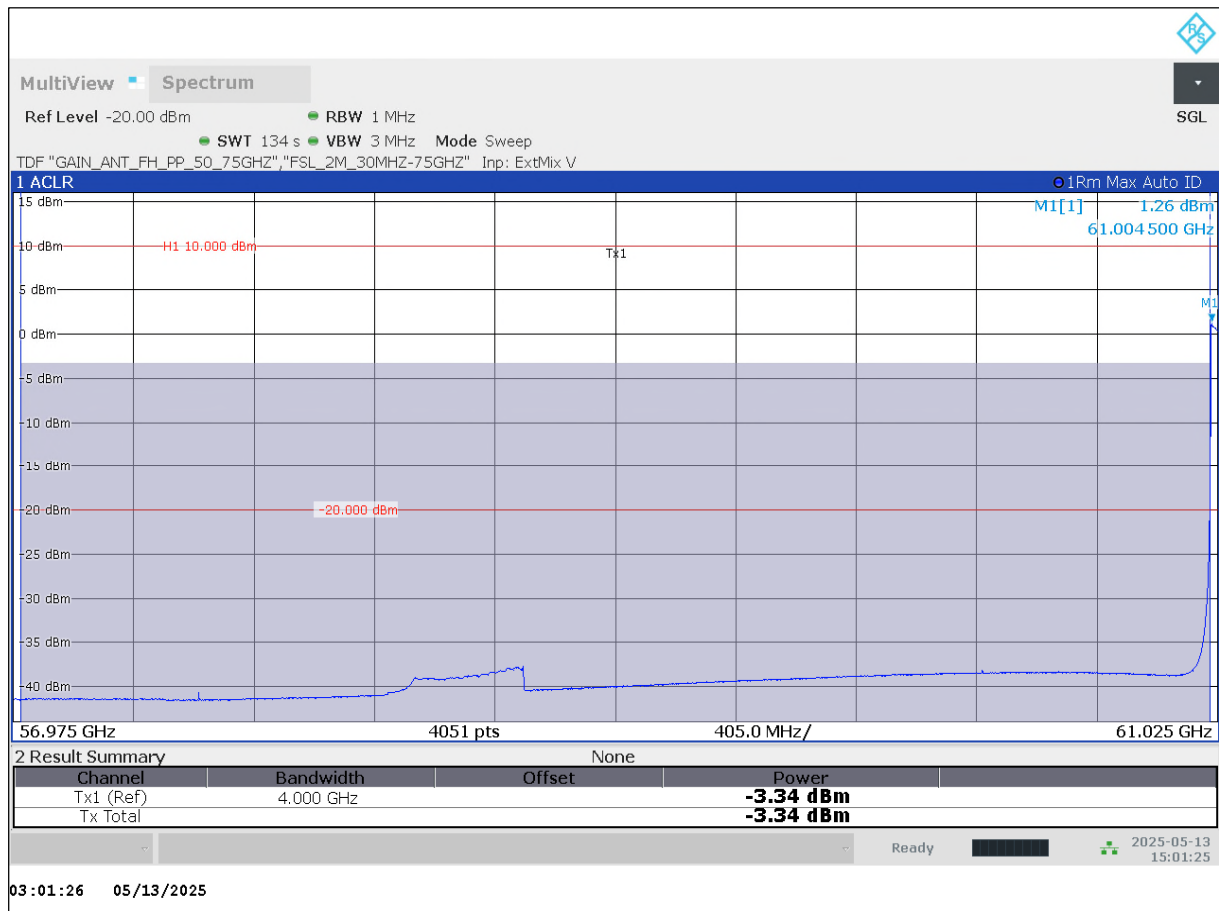
1.5.2 Antenna vertical

TID007b_04_RSE_PK_InBand_57-
61.0GHz_RBW_1MHz_HighRange_S08_Am5deg_E90deg__AntV

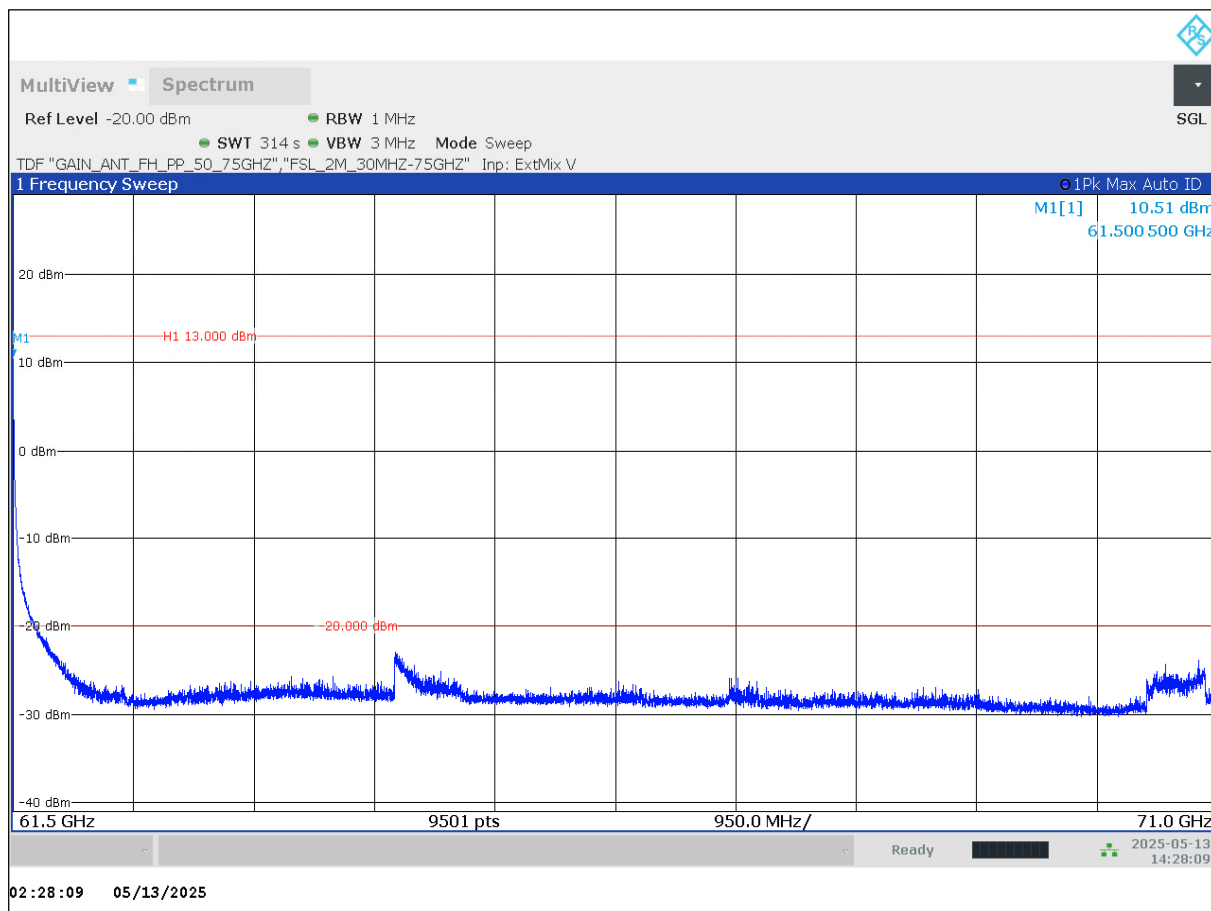


TID007b_05_RSE_AV_InBand_57-

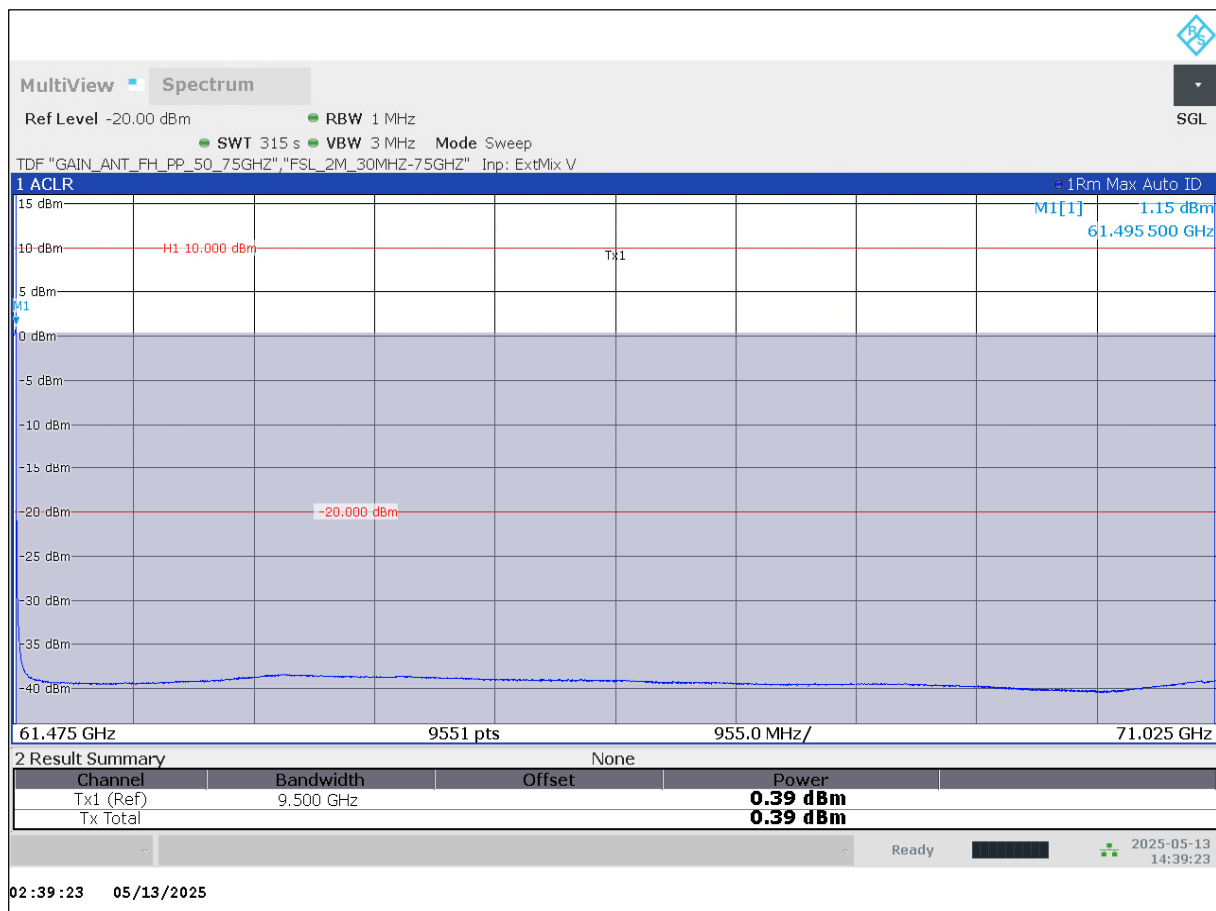
61.0GHz_RBW_1MHz_HighRange_S08_Am5deg_E90deg__AntV



TID007b_06_RSE_PK_InBand_61.5-
71GHz_RBW_1MHz_HighRange_S08_Am5deg_E90deg__AntV



TID007b_07_RSE_AV_InBand_61.5-
71GHz_RBW_1MHz_HighRange_S08_Am5deg_E90deg__AntV



1.6 Radiated emissions according §15.209

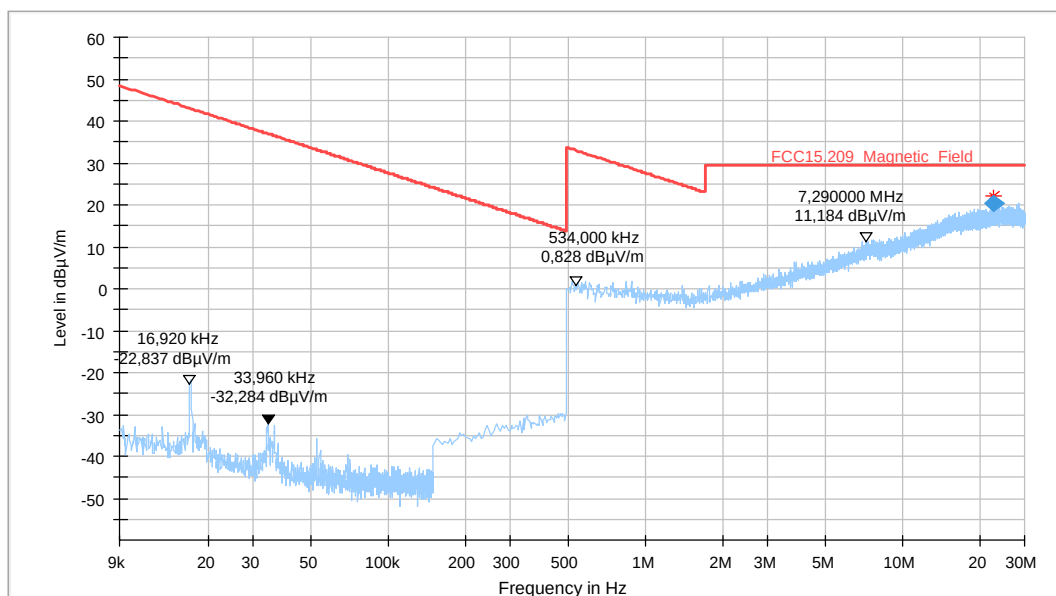
1.6.1 Frequency range: 9kHz to 30MHz

TID015_01_RSE_9kHz-30MHz_EUT_standing

Common Information

Test description:	Magnetic Field Strength Measurement related to 30/300 m distance
Test Site Location:	Ref.-Nr. 441 Semi Anechoic Chamber (SAC1) with 3 m measurement distance
Version of Testsoftware:	EMC32 V10.60.20
Distance correction:	used accord. table, pls. see test report
Technical Data:	Please see page 2 for detailed data of measurement setup
Rec. antenna (pre-scan):	height 1.00 m, parallel and 90° to EUT polarisation
Used filter:	bypass
Test Standard:	FCC 15.205 § 15.209; RSS-Gen: Issue 5
Operator:	Lor
Operating Mode:	RADAR long-Range
Power during tests:	3.6V DC
Comment 1:	Nominal Channel
Comment 2:	EUT standing
Environmental Conditions:	Tnom,Vnom=3.6V
EUT Setup:	1
Verdict:	Passed

Full Spectrum



Final Result

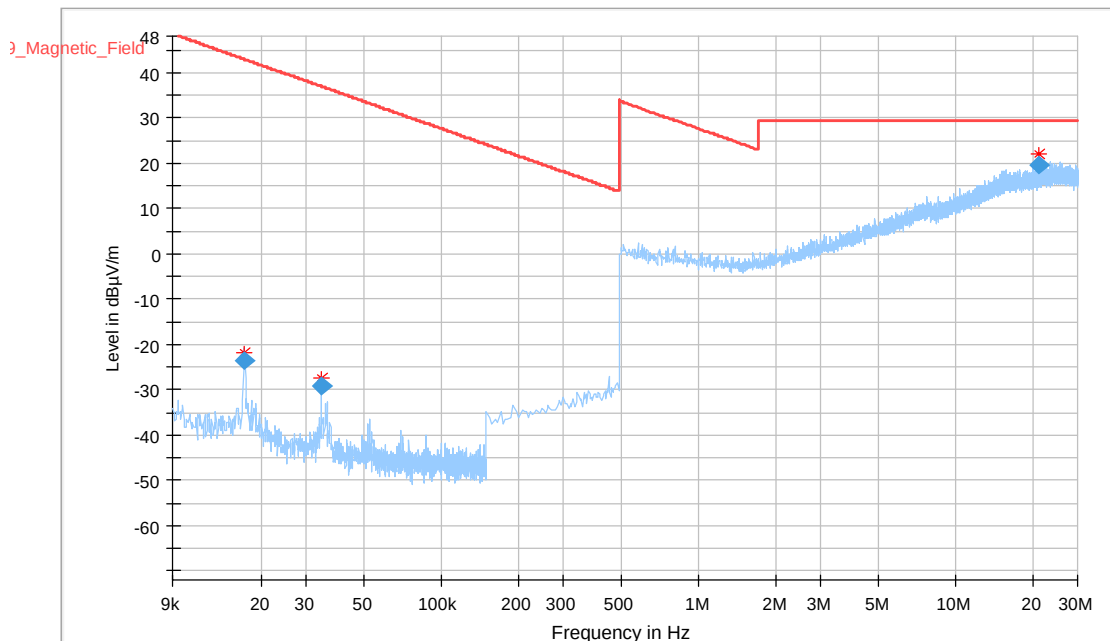
Frequency (MHz)	MaxPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Pol	Azimuth (deg)	Corr. (dB/m)	Comment
22.842000	20.25	29.54	9.29	9.000	H	199.0	1.8	14:09:23 - 27.03.2025

TID015_02_RSE_9kHz-30MHz_EUT_laying

Common Information

Test description:	Magnetic Field Strength Measurement related to 30/300 m distance
Test Site Location:	Ref.-Nr. 441 Semi Anechoic Chamber (SAC1) with 3 m measurement distance
Version of Testsoftware:	EMC32 V10.60.20
Distance correction:	used accord. table, pls. see test report
Technical Data:	Please see page 2 for detailed data of measurement setup
Rec. antenna (pre-scan):	height 1.00 m, parallel and 90° to EUT polarisation
Used filter:	bypass
Test Standard:	FCC 15.205 § 15.209; RSS-Gen: Issue 5
Operator:	Lor
Operating Mode:	RADAR long-Range
Power during tests:	3.6V DC
Comment 1:	Nominal Channel
Comment 2:	EUT laying
Environmental Conditions:	Tnom,Vnom=3.6V
EUT Setup:	1
Verdict:	Passed

Full Spectrum



Final Result

Frequency (MHz)	MaxPeak (dBµV /m)	Limit (dBµV /m)	Margin (dB)	Bandwidth (kHz)	Pol	Azimuth (deg)	Corr. (dB/m)	Comment
0.017080	-23.66	42.95	66.61	0.200	H	330.0	-59.2	15:46:02 - 27.03.2025
0.034280	-29.08	36.90	65.97	0.200	H	308.0	-60.1	15:43:30 - 27.03.2025
21.086000	19.52	29.54	10.02	9.000	H	174.0	1.4	15:40:46 - 27.03.2025

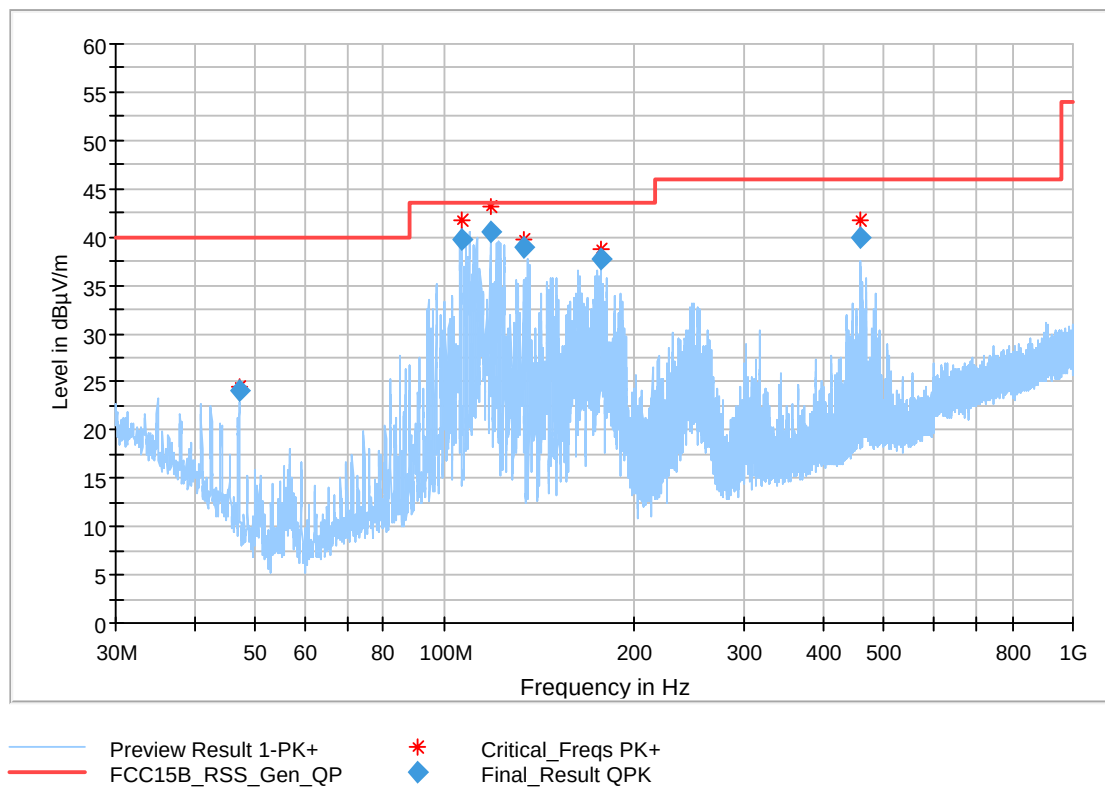
1.6.2 Frequency range: 30MHz to 1GHz

Diagram TID014_01

Common Information

Test Description:	Date: 25.03.2025
Test Site:	Electric Field Strength Measurement
Test Location:	Semi Anechoic Chamber 1 (SAC1)
Version of Testsoftware:	cetecom advanced GmbH, Essen
Test Specification:	EMC32 V10.60.20
Operating Mode:	FCC 15.209 / RSS-Gen
Used Filter:	Long Range
Measured side(s):	none
Distance correction:	front, right, rear, left
Environmental conditions:	no
Operator:	Humidity: 25%rH; Temperature: 21.8°C
Comments:	Lor
	S08 (EUT-standing)

Full Spectrum



Test Receiver/Spectrum Analyzer Settings

Final_Result

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Preamplifier (dB)	Trd Corr. (dB/m)	Raw Rec (dBµV)
47.112000	24.12	40.00	15.88	120.000	135.0	V	3.0	10	0	9	14
106.328000	39.81	43.50	3.69	120.000	257.0	H	4.0	12	0	11	28
118.196000	40.60	43.50	2.90	120.000	263.0	H	5.0	13	0	12	27
133.732000	38.85	43.50	4.65	120.000	176.0	H	14.0	12	0	10	27
177.820000	37.70	43.50	5.80	120.000	103.0	V	221.0	12	0	10	26
460.260000	39.96	46.00	6.04	120.000	149.0	H	245.0	18	0	15	22

EMI Auto Test Template: 01 - ESR7 RE FCC15B Class B 30M-1GHz 3m

Hardware Setup: ESR7 FCC 3m dbuV
 Measurement Type: Open-Area-Test-Site (SAC/FAR)
 Frequency Range: 30 MHz - 1 GHz
 Graphics Level Range: 25 dBμV/m - 65 dBμV/m

Preview Measurements:
 Scan Test Template: ESR7 EMI Scan_Fast_FCC_30M-1G_PK_3m

Subrange	Step Size	Detectors	IF BW	Meas. Time	Preamp
Receiver: [ESU 40] 30 MHz - 1 GHz	40 kHz	PK+	120 kHz	0,0001 s	20 dB

Frequency Zoom:
 Zoom Scan Template: ESR7 EMI Scan_Zoom_FCC_30M-1G_PK_3m

Adjustment:
 Template for Single Meas.: ESR7 EMI Scan_Search_FCC_30M-1G_PK_3m

Final Measurements:
 Template for Single Meas.: ESR7 EMI Scan_Final_FCC_30M-1G_PK_3m

Subrange	Step Size	Detectors	IF BW	Meas. Time	Preamp
Receiver: [ESU 40] 30 MHz - 1 GHz	40 kHz	QPK	120 kHz	1 s	20 dB

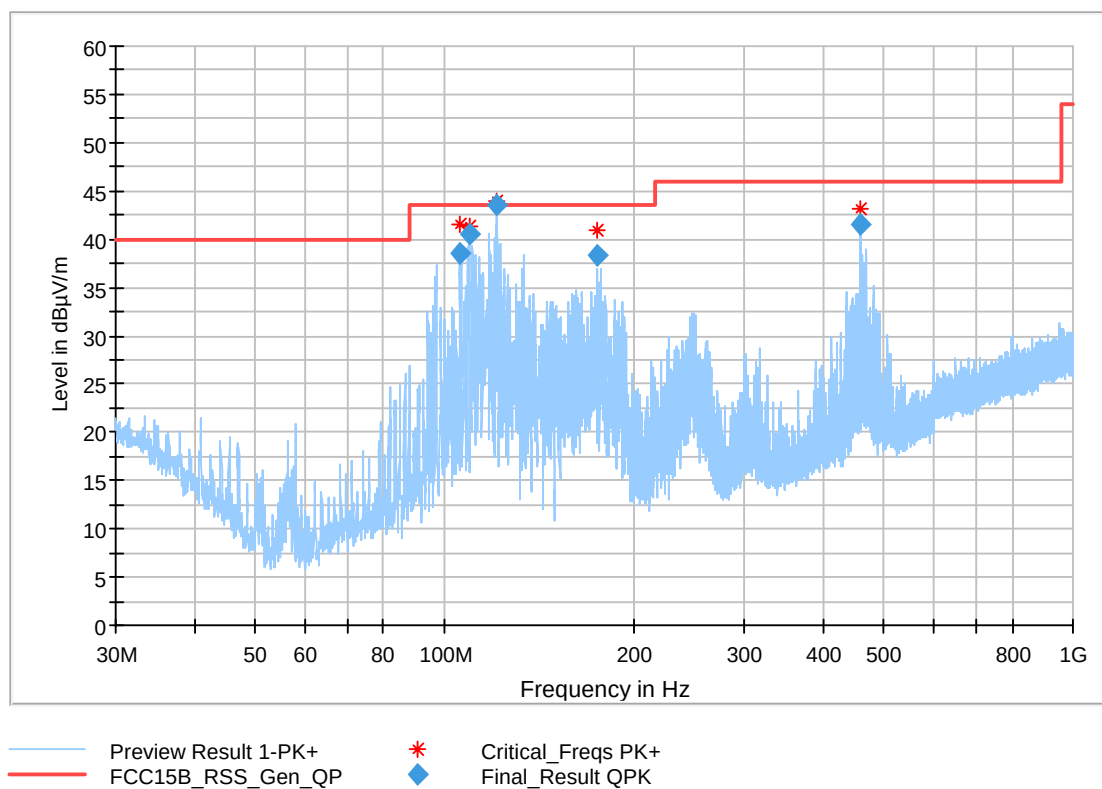
Diagram TID014_02_Laying

Common Information

Test Description:	Date: 25.03.2025
Test Site:	Electric Field Strength Measurement
Test Location:	Semi Anechoic Chamber 1 (SAC1)
Version of Testsoftware:	cetecom advanced GmbH, Essen
Test Specification:	EMC32 V10.60.20
Operating Mode:	FCC 15.209 / RSS-Gen
Used Filter:	Long Range
Measured side(s):	none
Distance correction:	top, under, left, right
Environmental conditions:	no
Operator:	Humidity: 25%rH; Temperature: 21.8°C
Comments:	Lor
	S08 (EUT-lying)

Test Receiver/Spectrum Analyzer Settings

Full Spectrum



EMI Auto Test Template: 01 - ESR7 RE FCC15B Class B 30M-1GHz 3m

Hardware Setup:	ESR7 FCC 3m dbuV
Measurement Type:	Open-Area-Test-Site (SAC/FAR)
Frequency Range:	30 MHz - 1 GHz
Graphics Level Range:	25 dBµV/m - 65 dBµV/m

Preview Measurements:	
Scan Test Template:	ESR7 EMI Scan_Fast_FCC_30M-1G_PK_3m

Subrange	Step Size	Detectors	IF BW	Meas. Time	Preamp
Receiver: [ESU 40]					

30 MHz - 1 GHz 40 kHz PK+ 120 kHz 0,0001 s 20 dB

Frequency Zoom:

Zoom Scan Template: ESR7 EMI Scan_Zoom_FCC_30M-1G_PK_3m

Adjustment:

Template for Single Meas.: ESR7 EMI Scan_Search_FCC_30M-1G_PK_3m

Final Measurements:

Template for Single Meas.: ESR7 EMI Scan_Final_FCC_30M-1G_PK_3m

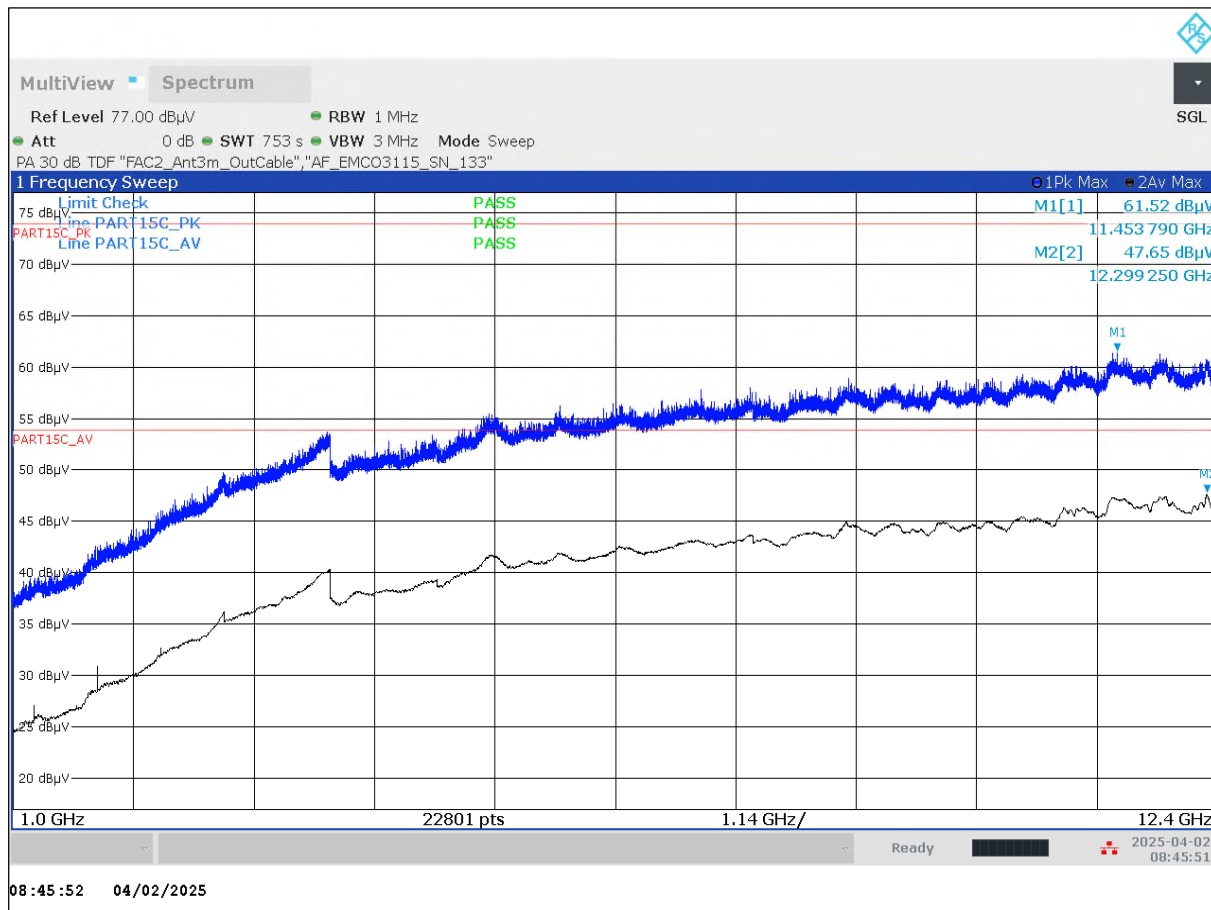
Subrange	Step Size	Detectors	IF BW	Meas. Time	Preamp
Receiver: [ESU 40]					
30 MHz - 1 GHz	40 kHz	QPK	120 kHz	1 s	20 dB

Final_Result

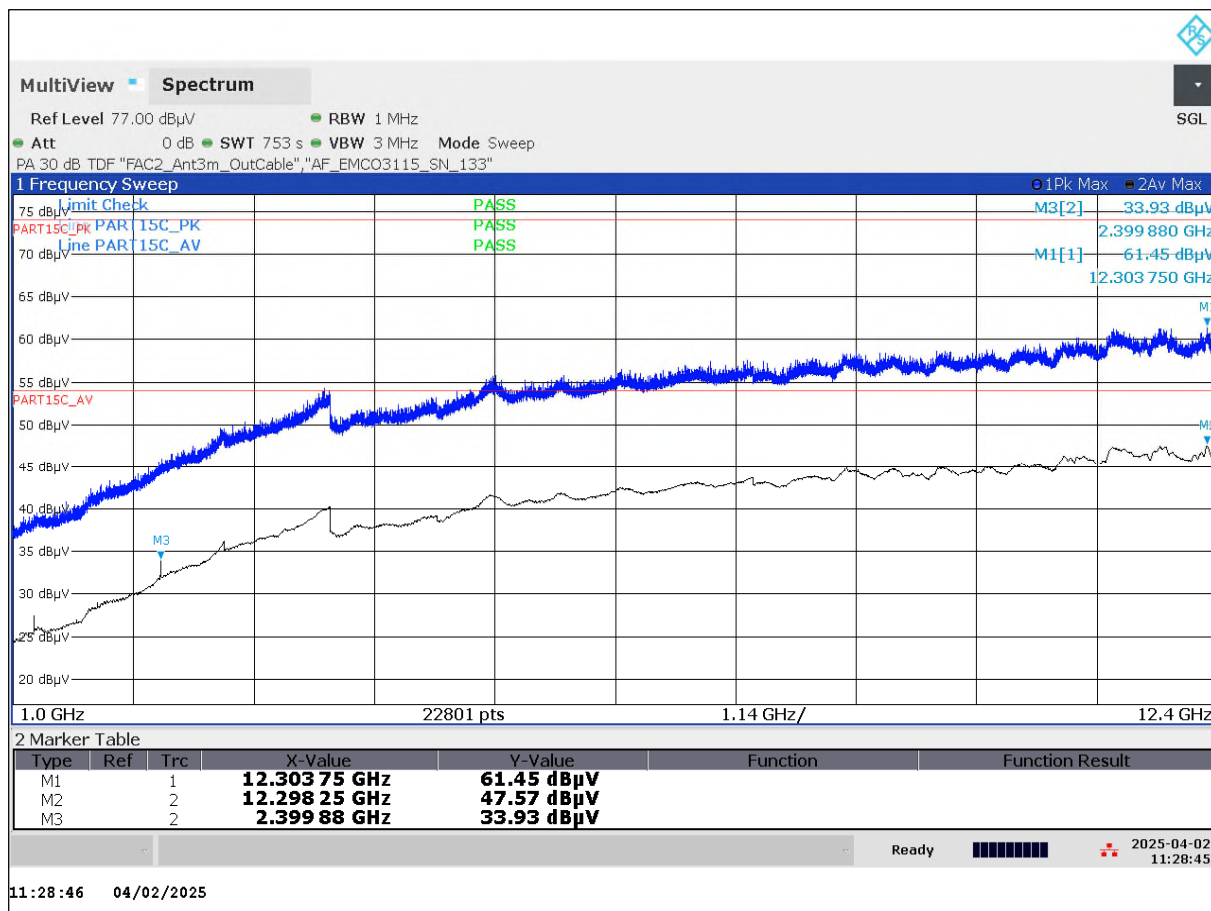
Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)	Preamplifier (dB)	Trd Corr. (dB/m)	Raw Rec (dBµV)
105.956000	38.56	43.50	4.94	120.000	263.0	H	6.0	12	0	11	26
109.316000	40.49	43.50	3.01	120.000	252.0	H	149.0	12	0	11	28
121.412000	43.48	43.50	0.02	120.000	279.0	H	9.0	13	0	12	31
174.488000	38.41	43.50	5.09	120.000	123.0	H	19.0	13	0	12	25
459.512000	41.50	46.00	4.50	120.000	103.0	V	169.0	18	0	15	23

1.6.3 Frequency range: 1GHz to 12.4GHz

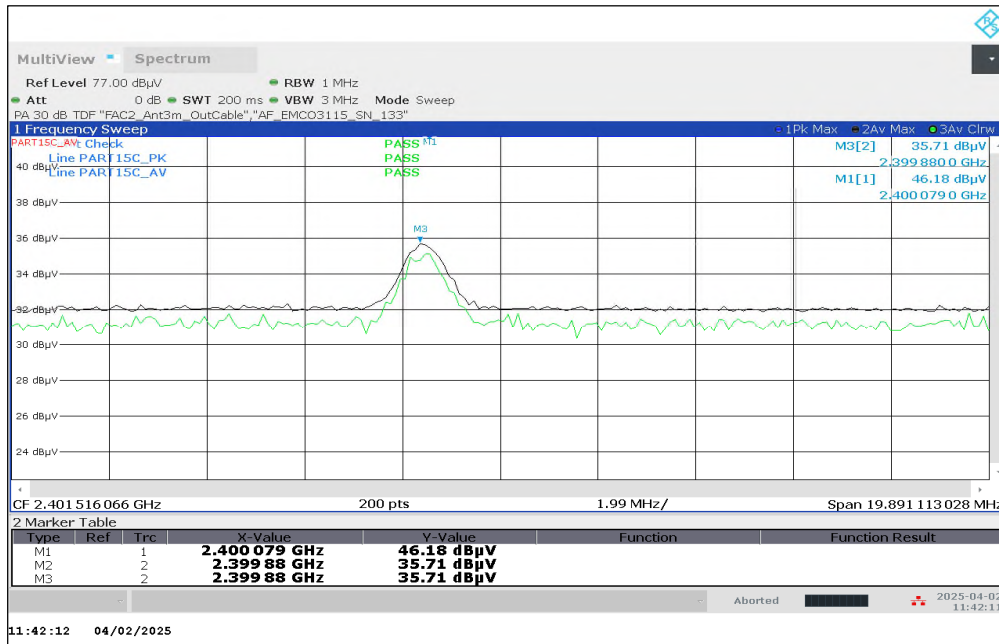
TID016a_01_RSE_OpMode_LongRange_1G-12.4GHz_S08_EUT_AntH



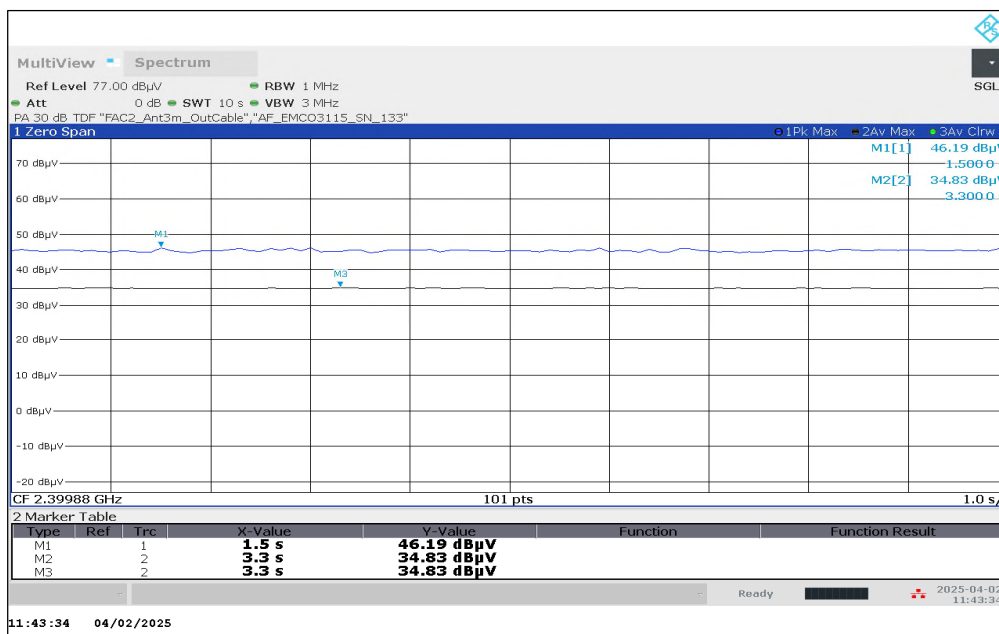
TID016b_01_RSE_OpMode_LongRange_1G-12.4GHZ_S08_EUT_AntV



TID016b_02_f1_2.3998GHz_OpMode_LongRange_S08_EUT_Maximization_A42deg_E78deg_AntV



TID016b_03_f1_2.3998GHz_OpMode_LongRange_S08_EUT_ZeroSpan_A42deg_E78deg_AntV

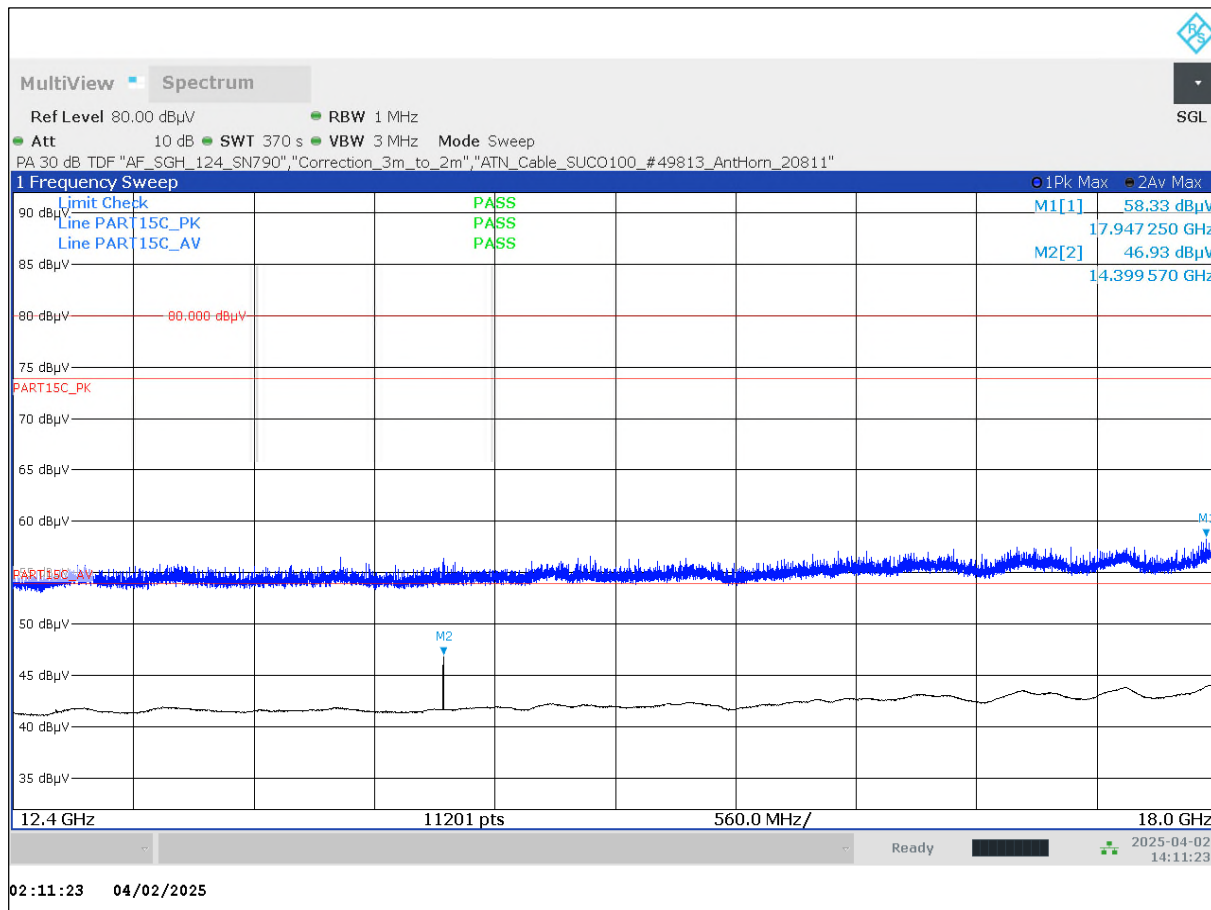


PK-Value: 46.19dBuV/m

AV-Value: 34.83 dBuV/m

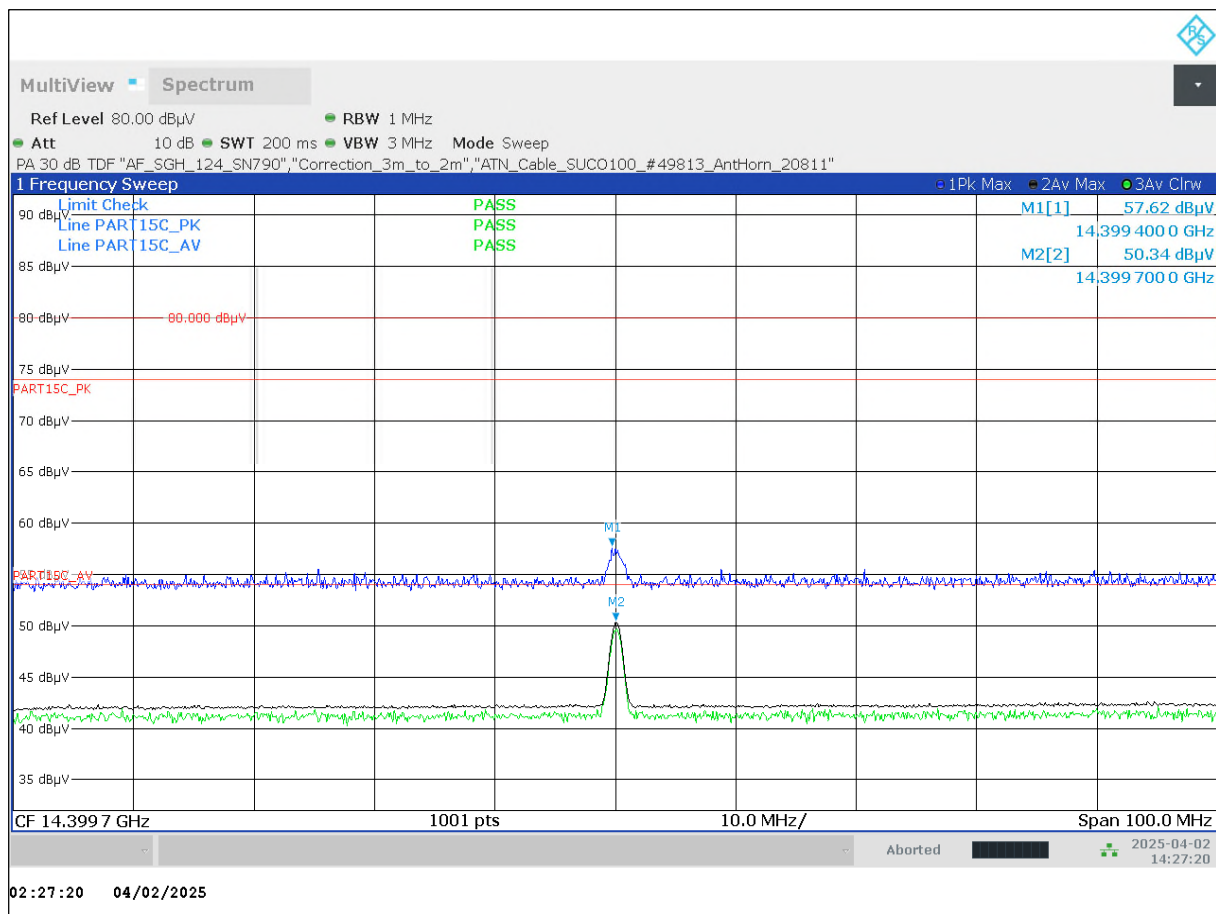
1.6.4 Frequency range: 12.4GHz to 18GHz

TID017a_04_RSE_OpMode_LongRange_12.4G-18GHZ_S08_EUT_AntH

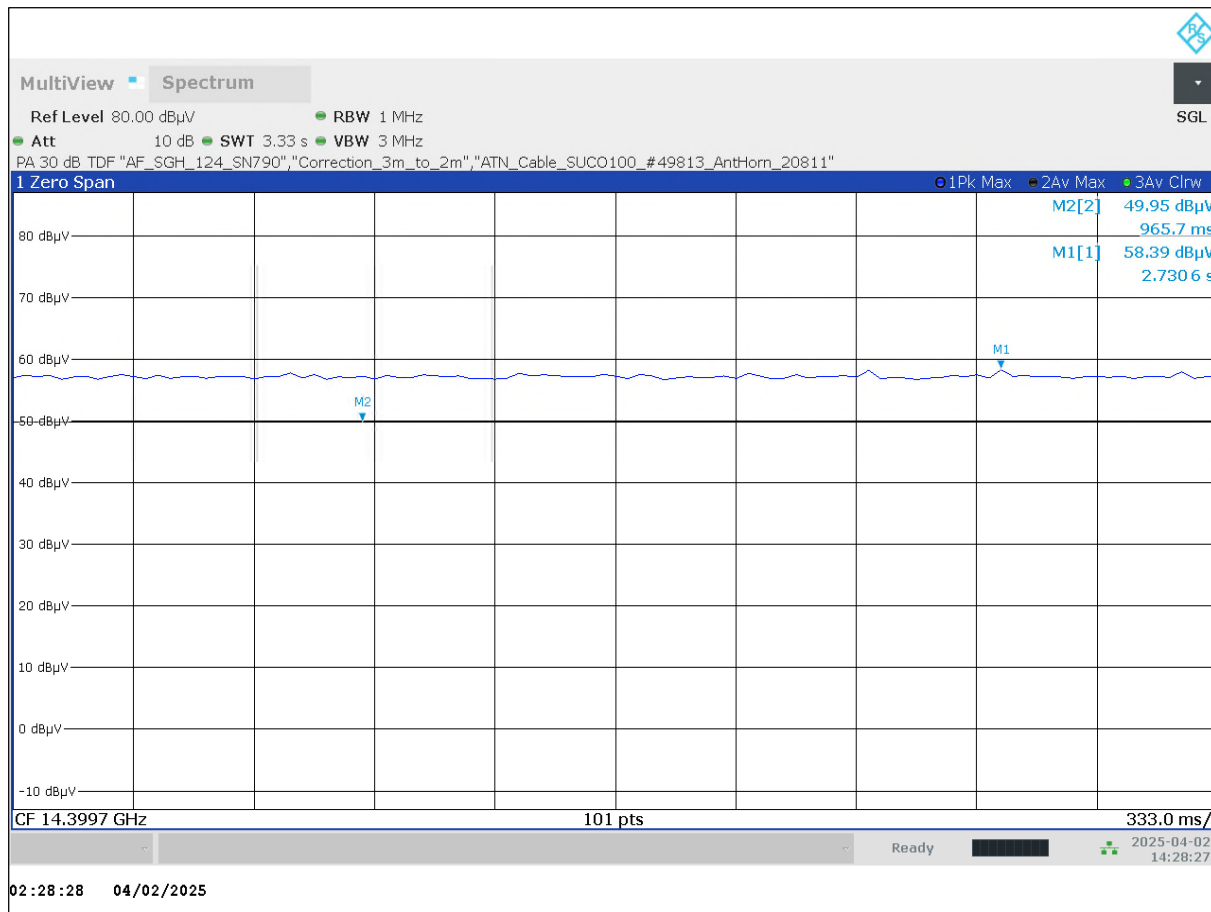


Critical frequency at Marker-2

TID017a_05_f1_14.4GHz_OpMode_LongRange_S08_Maximization_A304deg_E86deg_AntH



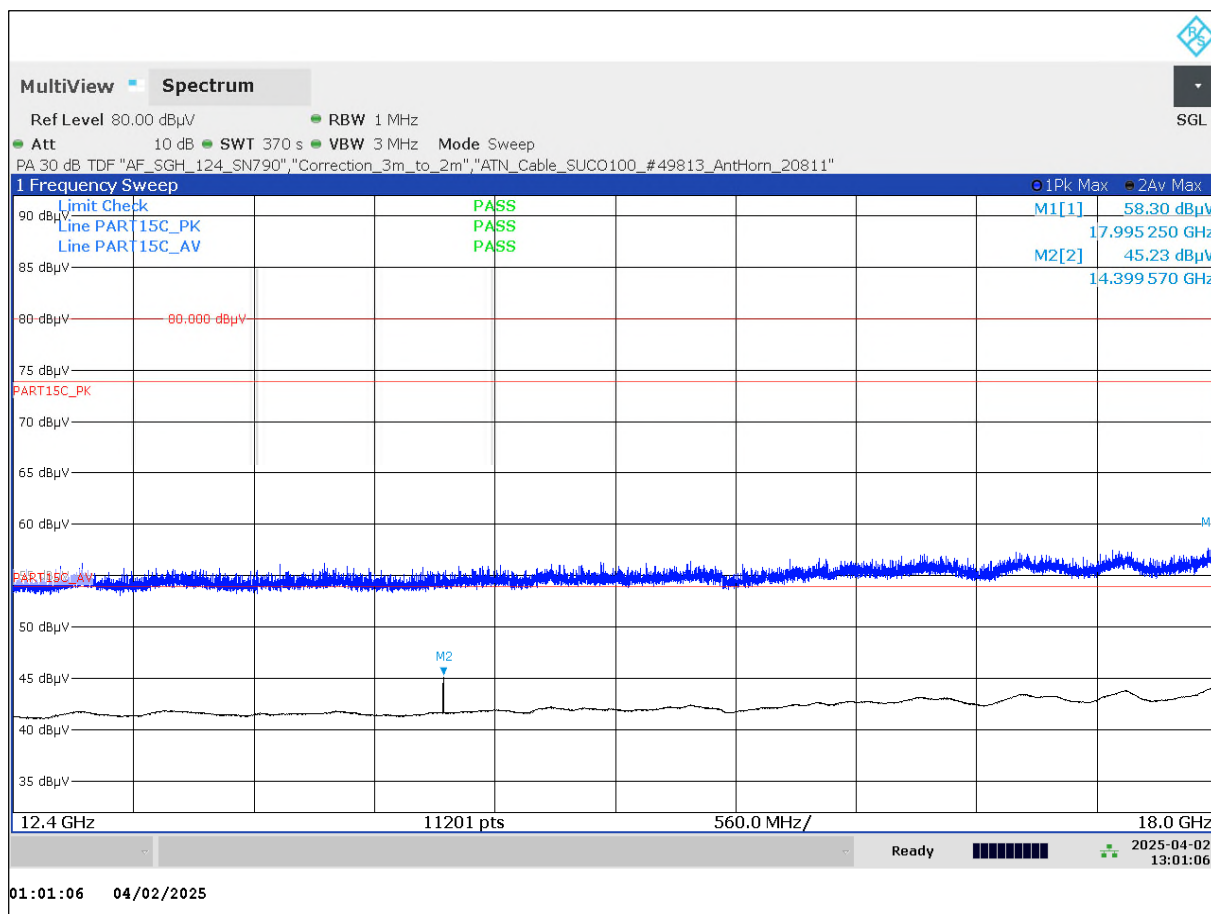
Maximization of emission

TID017a_06_f1_14.4GHz_OpMode_LongRange_S08_ZeroSpan_A304deg_E86deg_AntH


PK-Value: 58.39dBuV/m

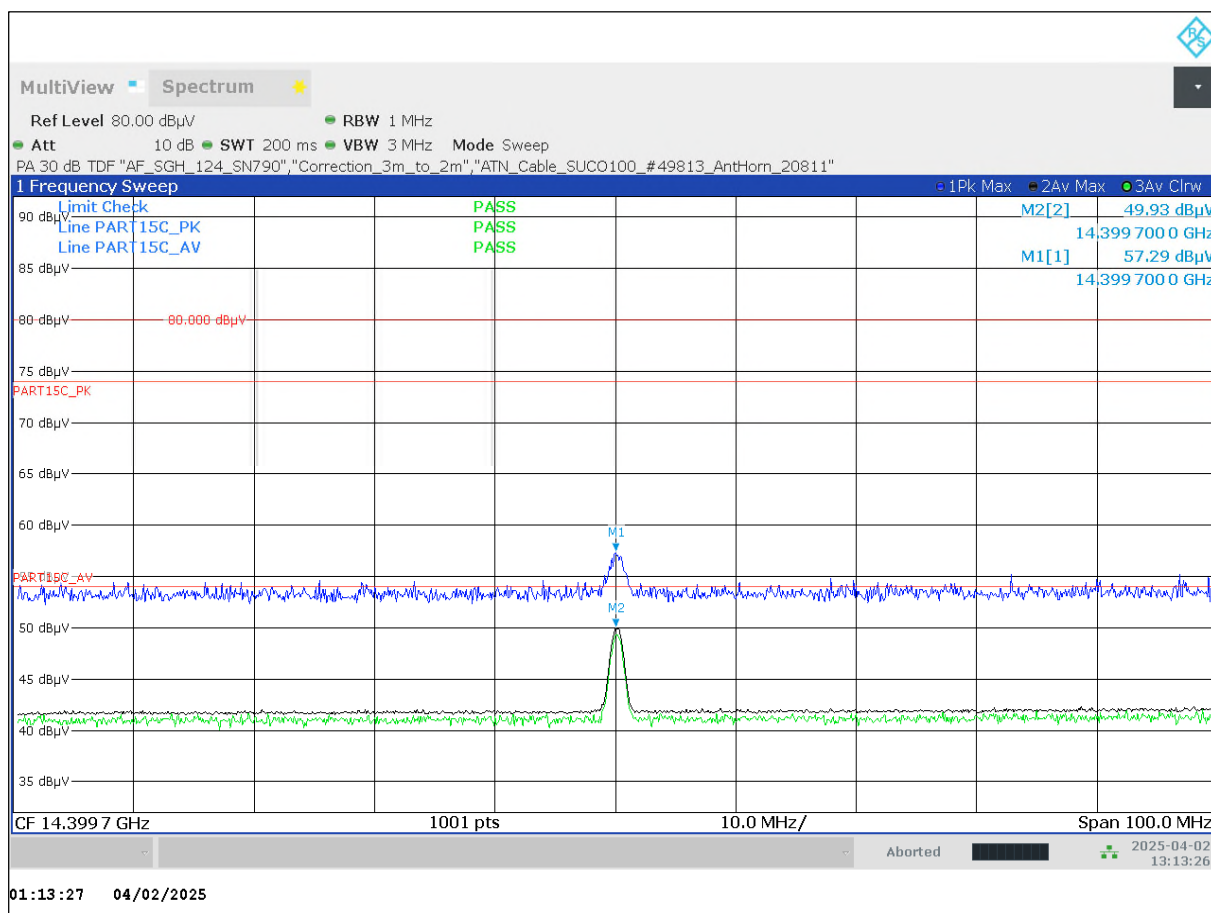
AV-Value: 49.95dBuV/m

TID017b_01_RSE_OpMode_LongRange_12.4G-18GHZ_S08_EUT_AntV

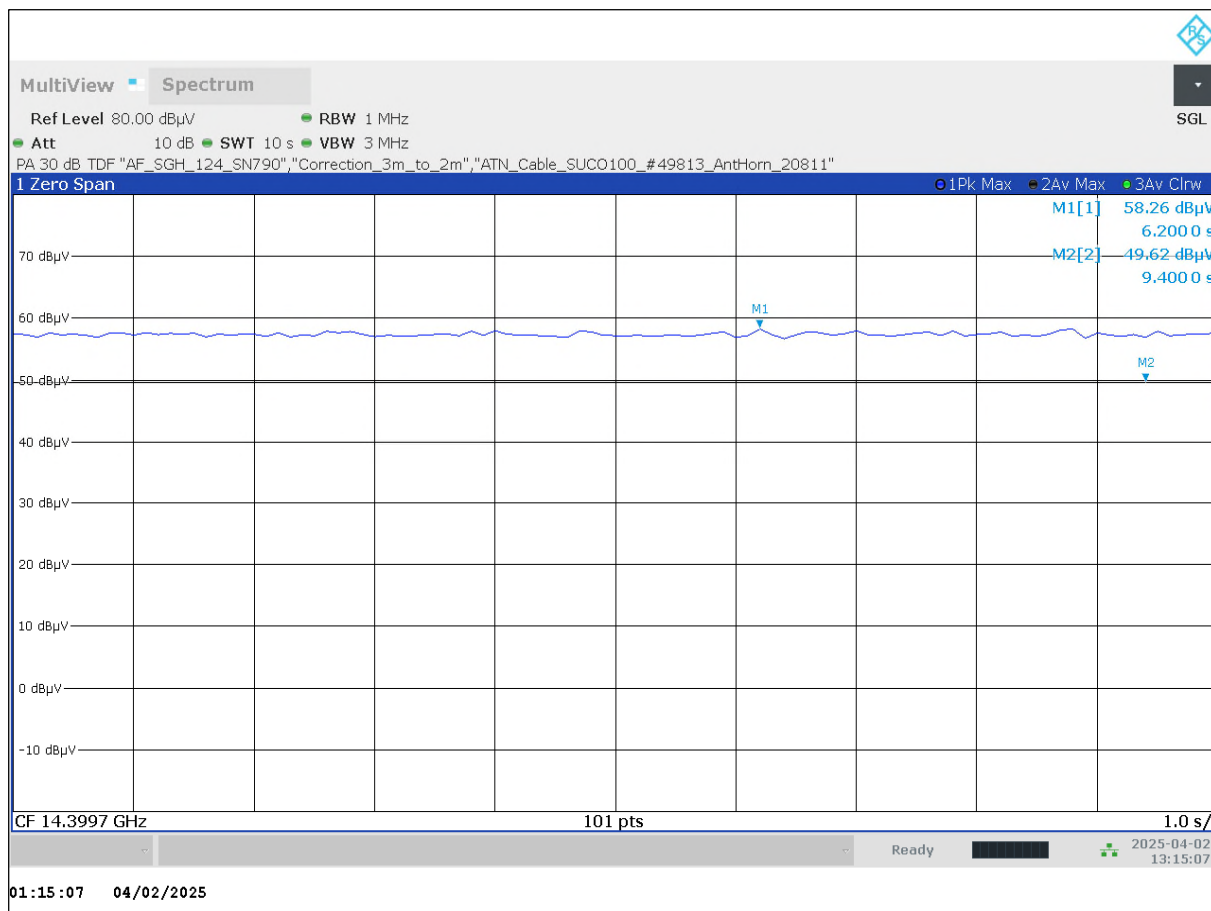


Critical frequency at Marker-2

TID017b_02_f1_14.4GHz_OpMode_LongRange_S08_Maximization_A142deg_E172deg_AntV



Maximization of emission

TID017b_03_f1_14.4GHz_OpMode_LongRange_S08_ZeroSpan_A142deg_E172deg_AntV


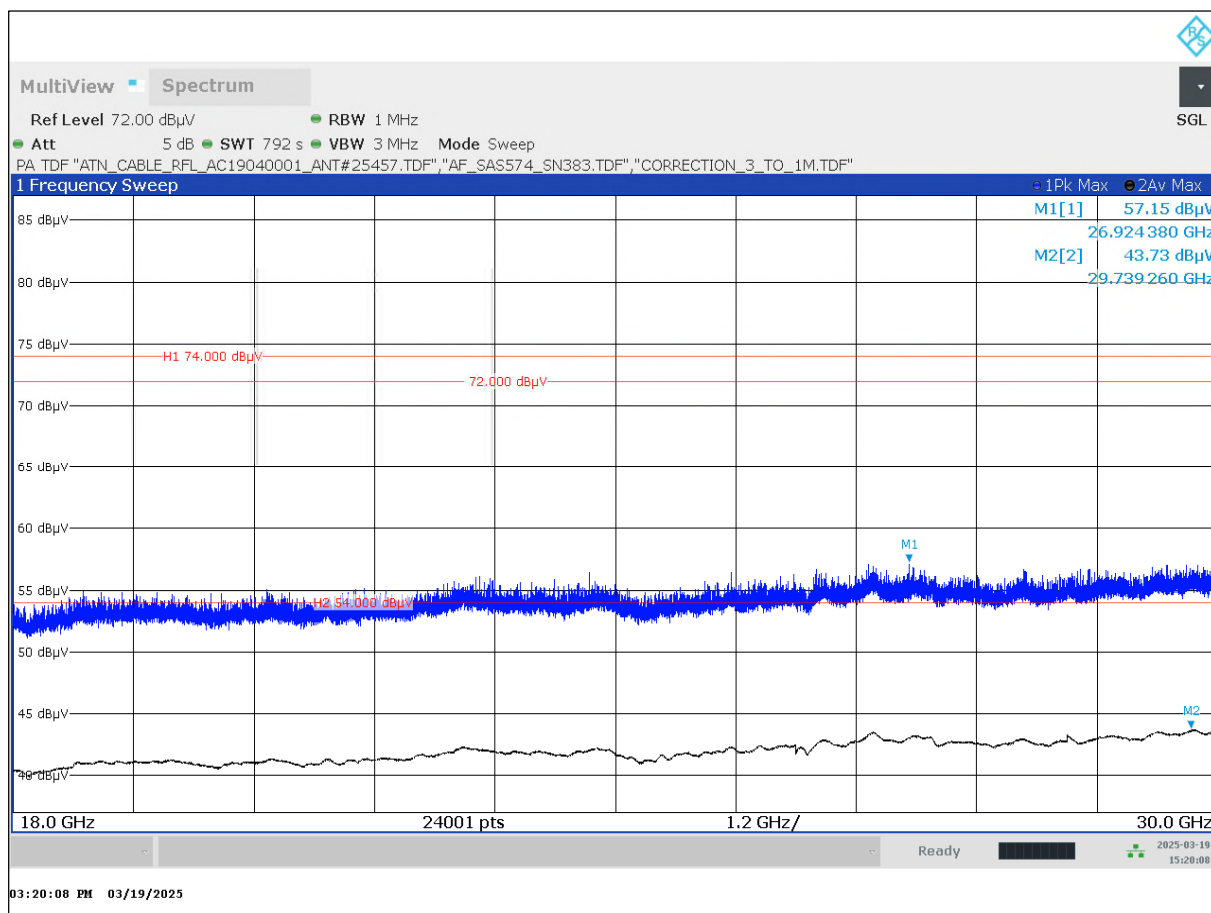
PK-Value: 58.26 dBuV/m

AV-value: 49.62 dBuV/m

1.6.5 Frequency range: 18GHz to 30GHz

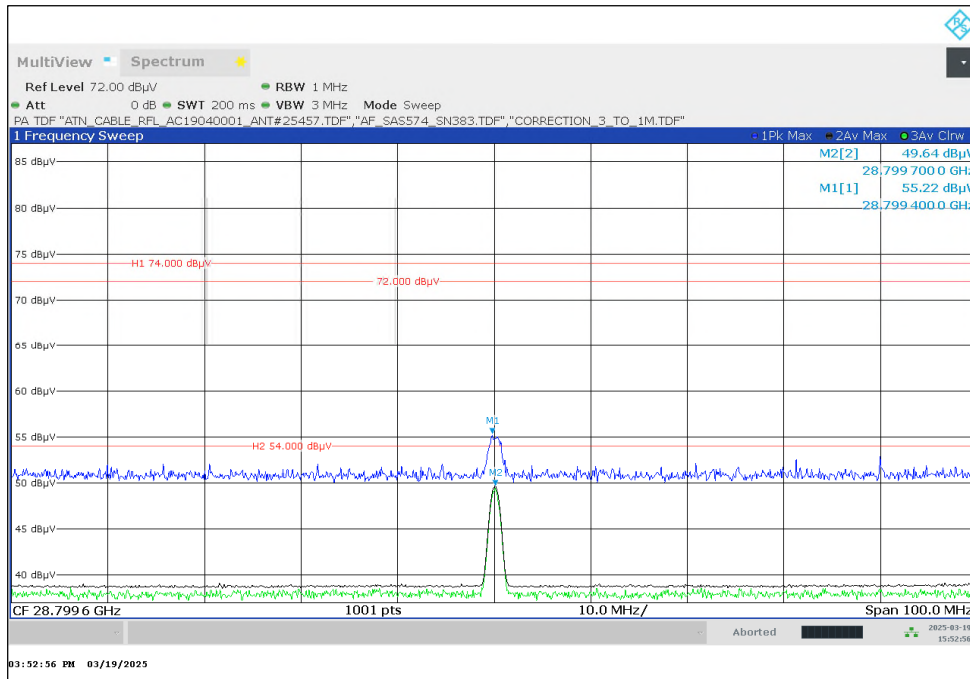
Due critical emission at 28.8GHz a microwave foam was installed into the device (see photos Annex 102). **Only this hardware change can ensure compliance.**

TID013a_RSE_Overview_S08-long-range_A164deg_AntH



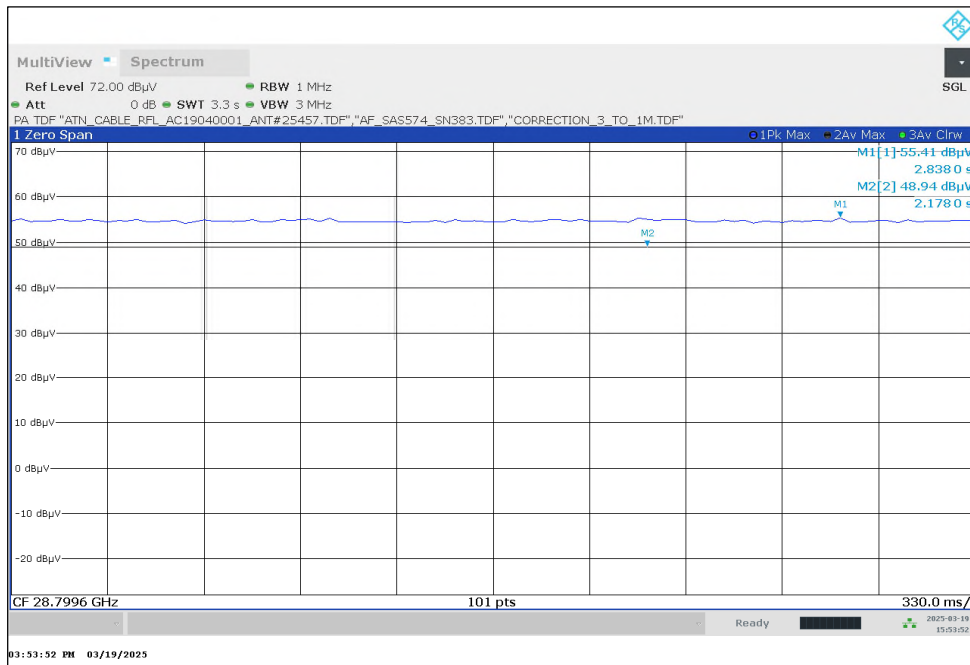
Emission to be investigated: 28.8GHz

TID013a_01_f1_28.8GHz_S08-long-range_MaxSearch_A232_E52_AnTH



Maximization of emission

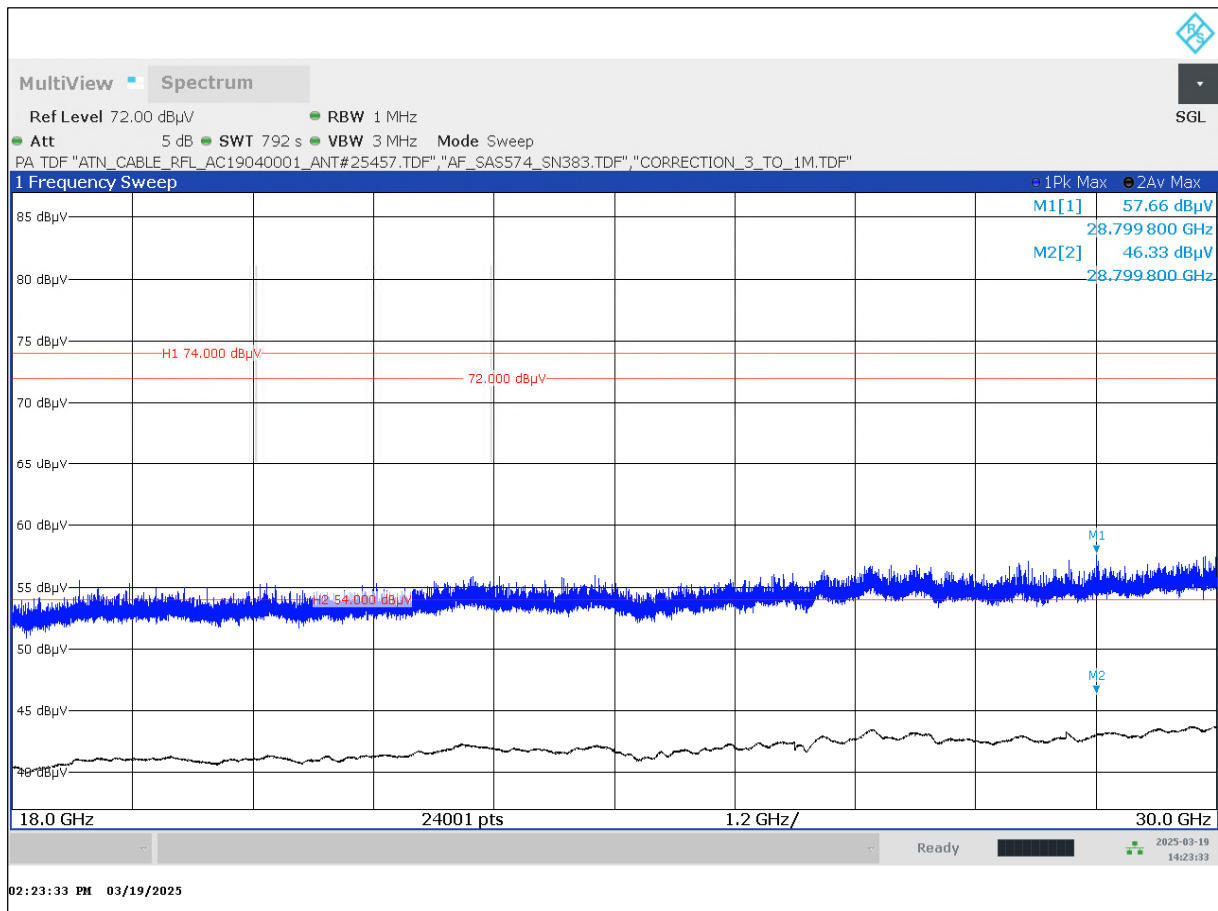
TID013a_02_f1_28.8GHz_S08-long-range_ZeroSpan_A232_E52_AnTH



Pk-Value: 55.41 dBuV/m

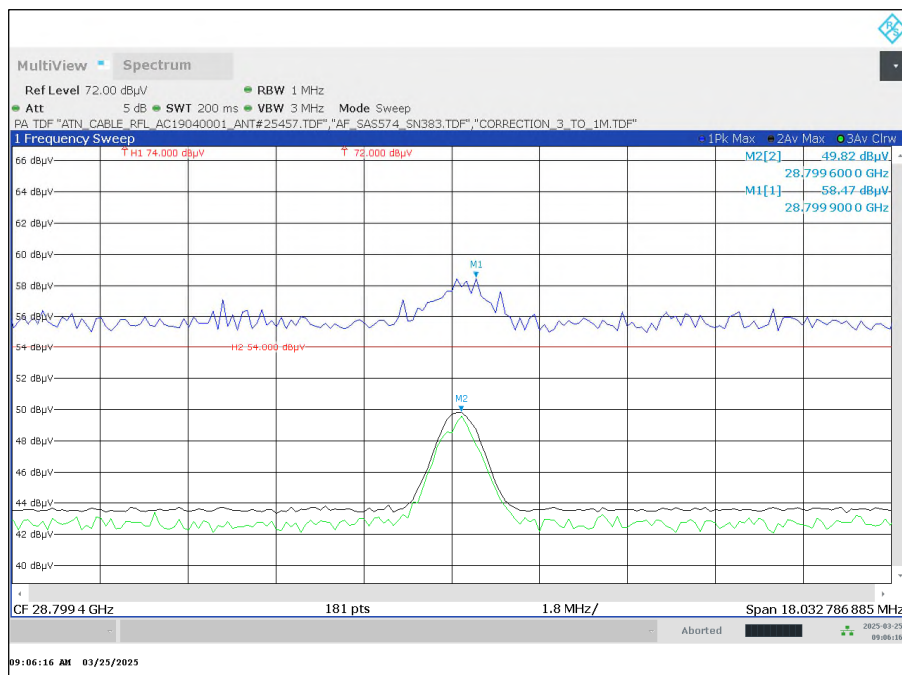
AV-Value: 48.94 dBuV/m

TID013b_RSE_Overview_18-30GHz_S08-long-range_AntV



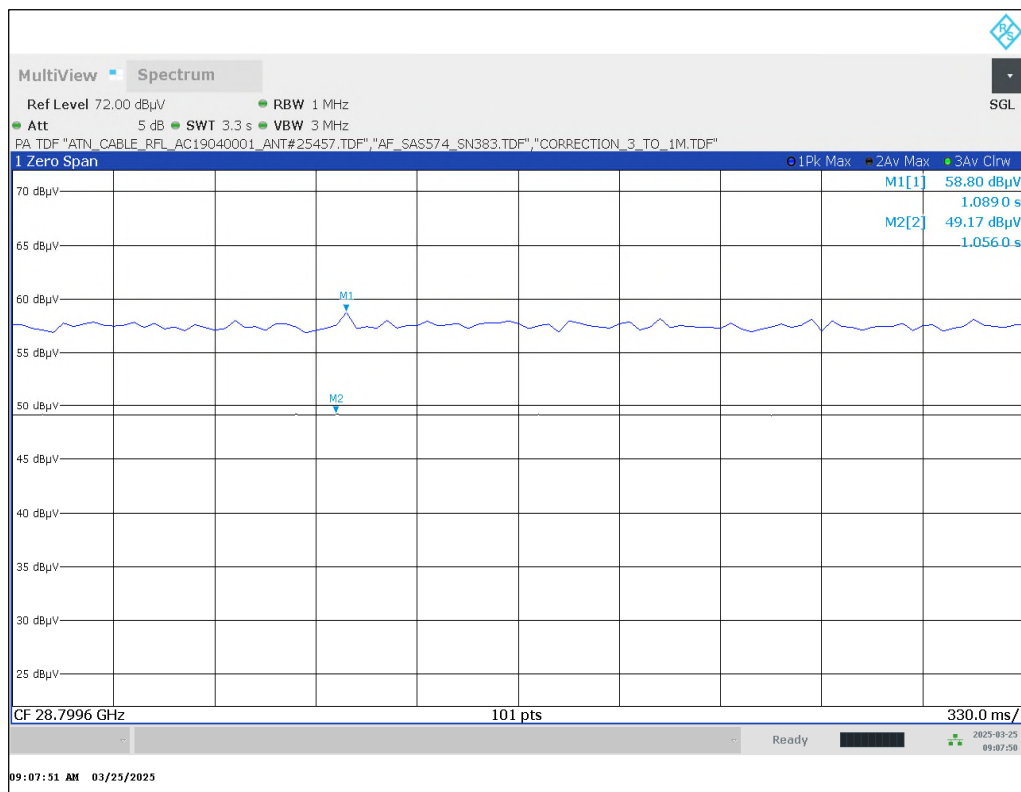
Critical emission at Marker-2

TID013b_03_f1_28.8GHz_S08-long-range_HWC02_A347deg_E97deg_AntH



Maximization of emission

TID013b_04_f1_28.8GHz_S08-long-range_HWC02_ZeroSpan_A347deg_E97deg_AntH

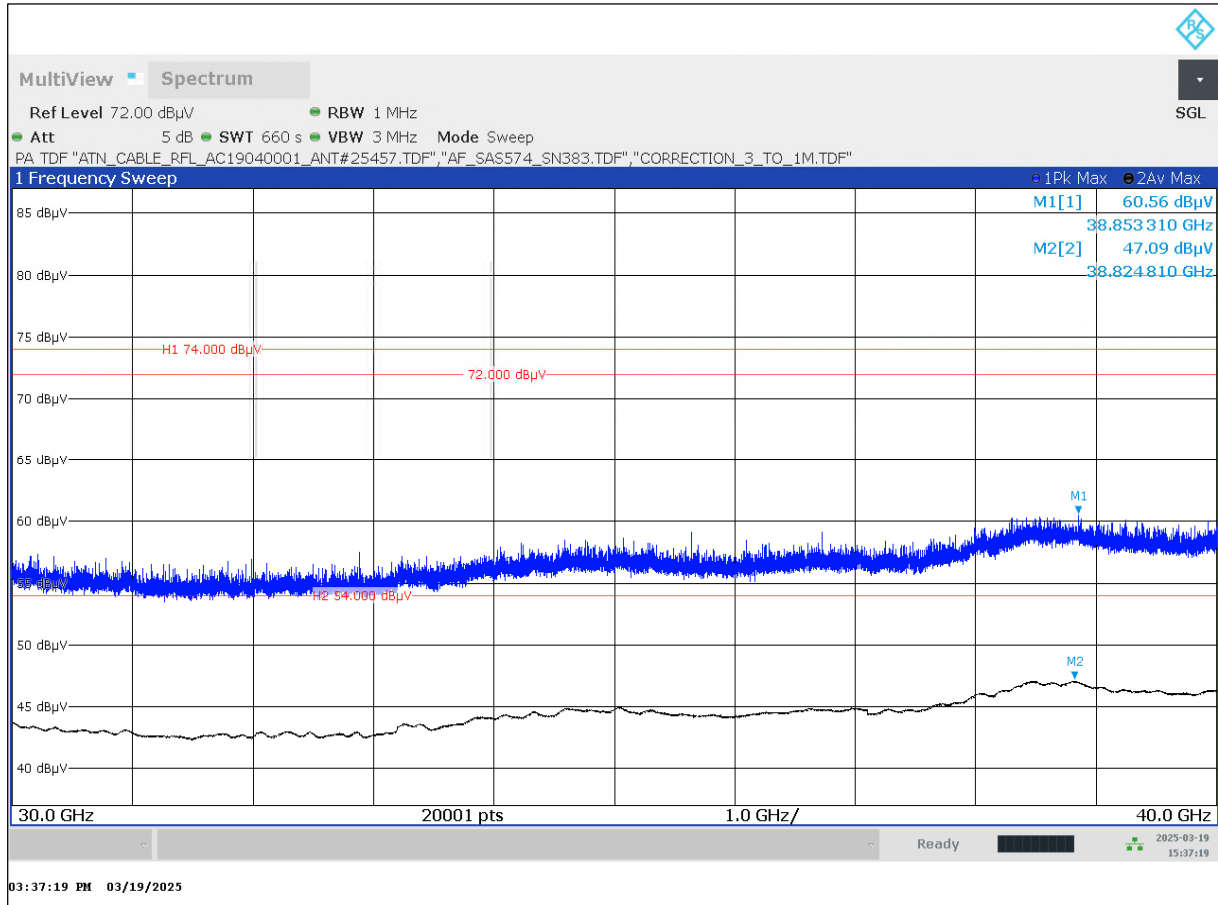


Pk-Value: 58.8 dBuV/m

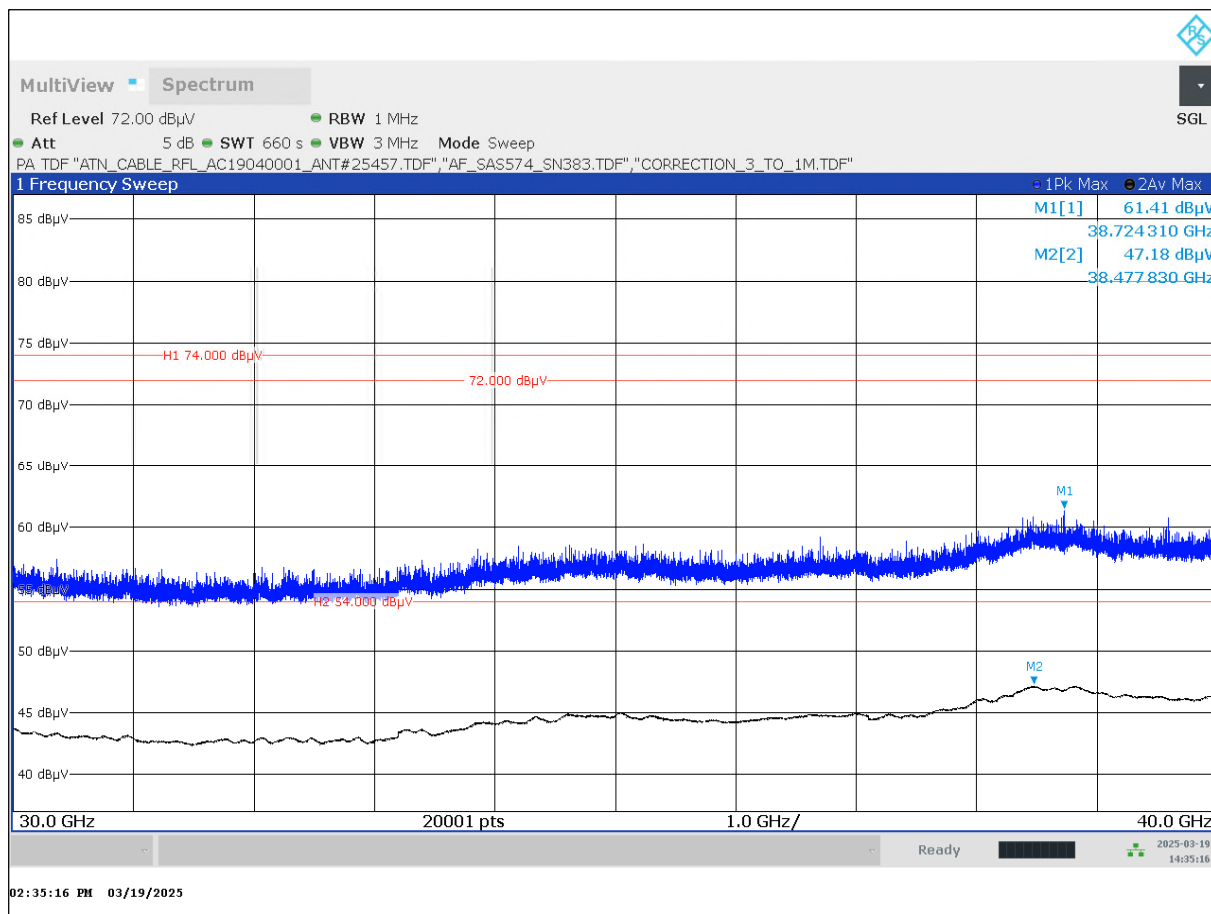
AV-Value: 49.17 dBuV/m

1.6.1 Frequency range: 30GHz to 40GHz

TID012a_RSE_Overview_30-40GHz_S08-long-range_AntH

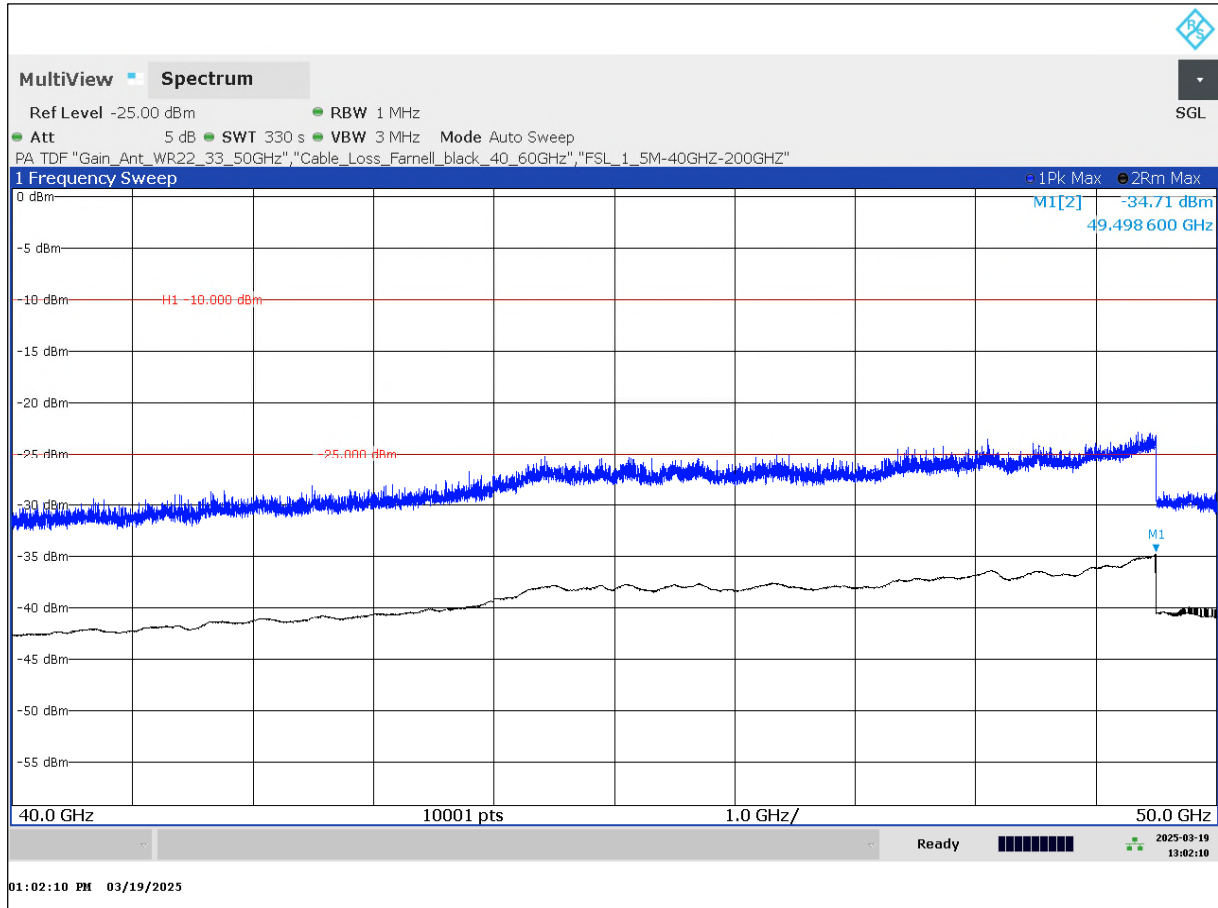


TID012b_RSE_Overview_30-40GHz_S08-long-range_AntV



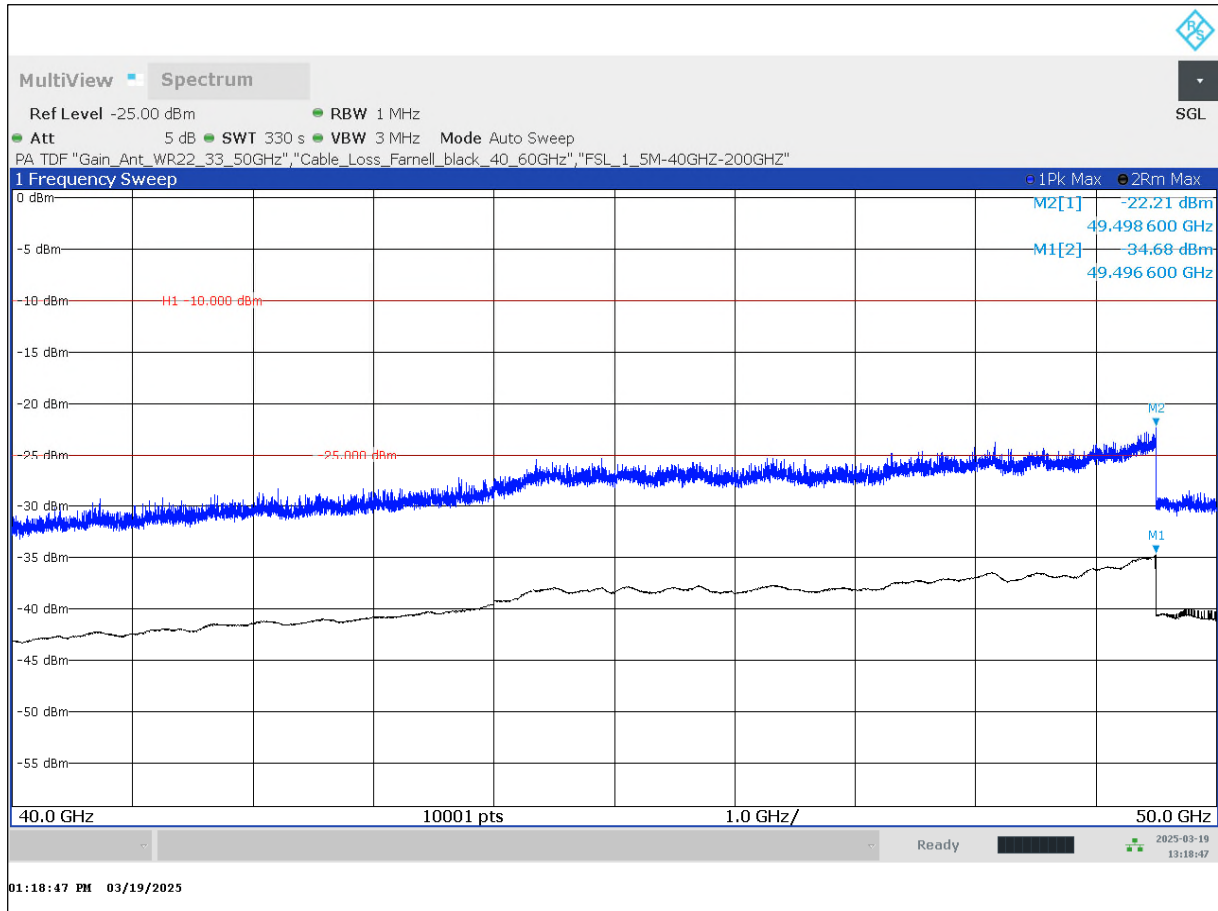
1.6.2 Frequency range: 40GHz to 50GHz

TID011a_RSE_Overview_40G-50GHz_S08-long-range_AntH



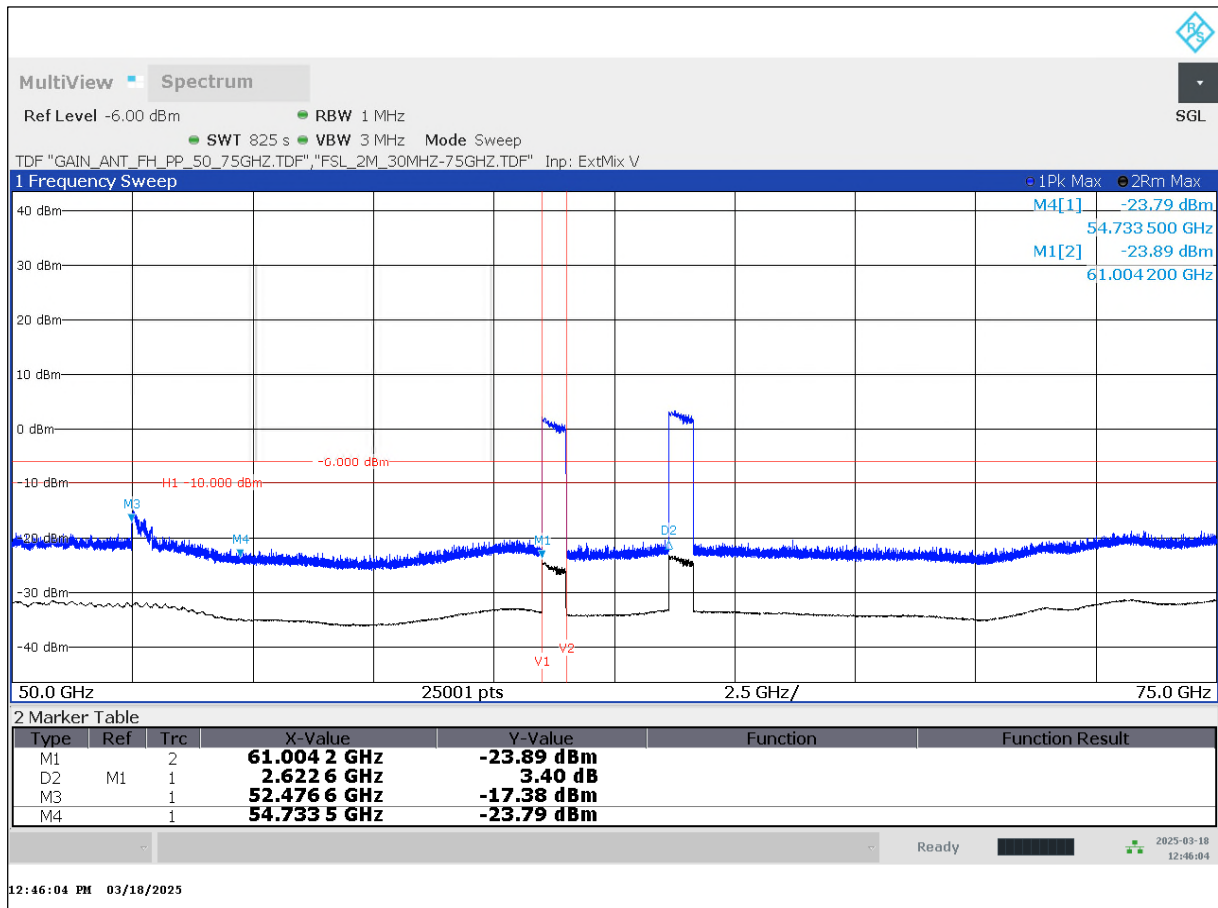
Peak trace for information only

TID011b_RSE_Overview_40G-50GHz_S08-long-range_AntV



1.6.3 Frequency range: 50GHz to 75GHz

TID007a_RSE_Overview_50G-75GHz_S08-long-range_Am4deg_E90deg_AntH

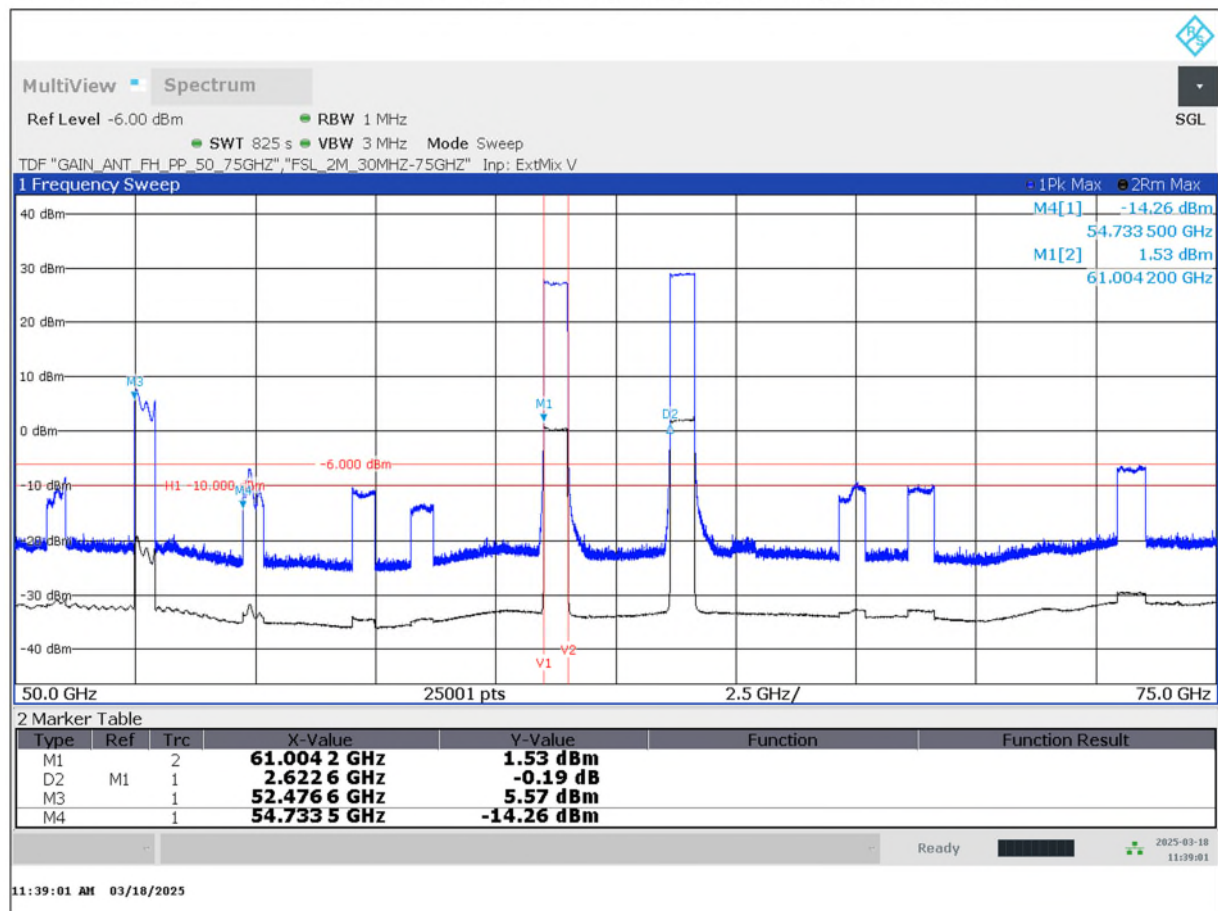


Peak trace (blue) for information only

Wanted signal between V1 and V2

D2 Marker denotes Image signal

TID007b_RSE_Overview_50G-75GHz_S08-long-range_Am5deg_E90deg_AntV

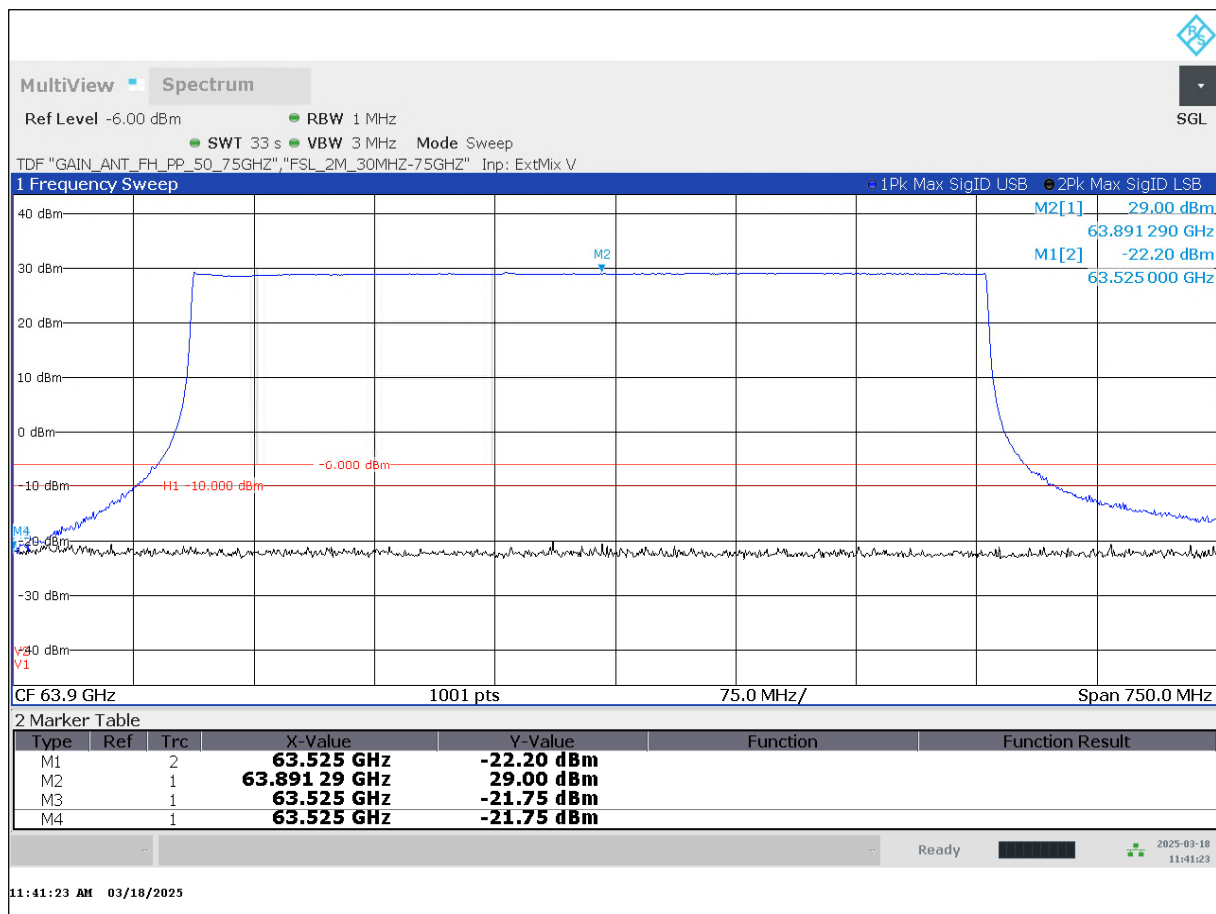


Peak trace (blue) for information only

Wanted signal between V1 and V2

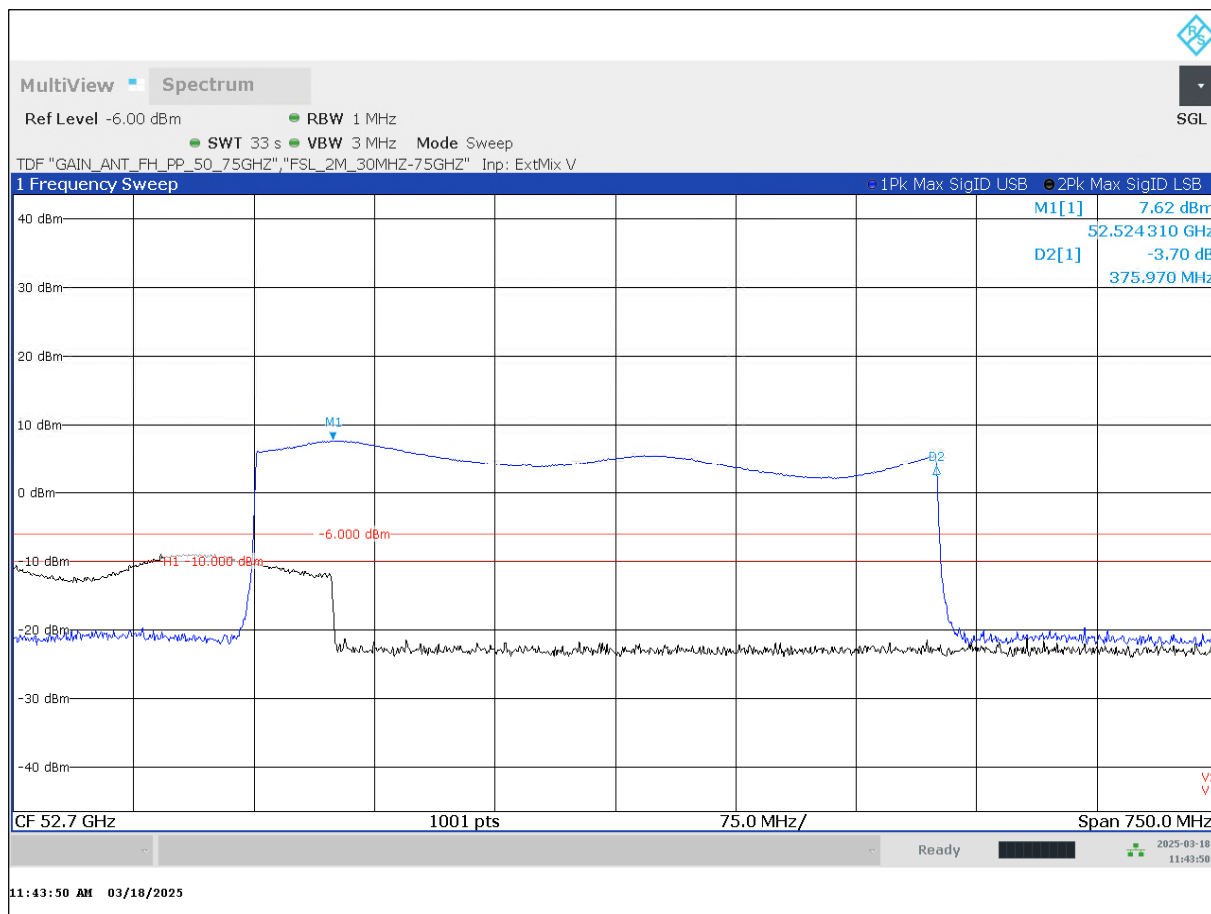
D2 Marker denotes Image signal

TID007b_01_f1_63.9GHz_Ghost_S08-long-range_Am5deg_E90deg_AntV



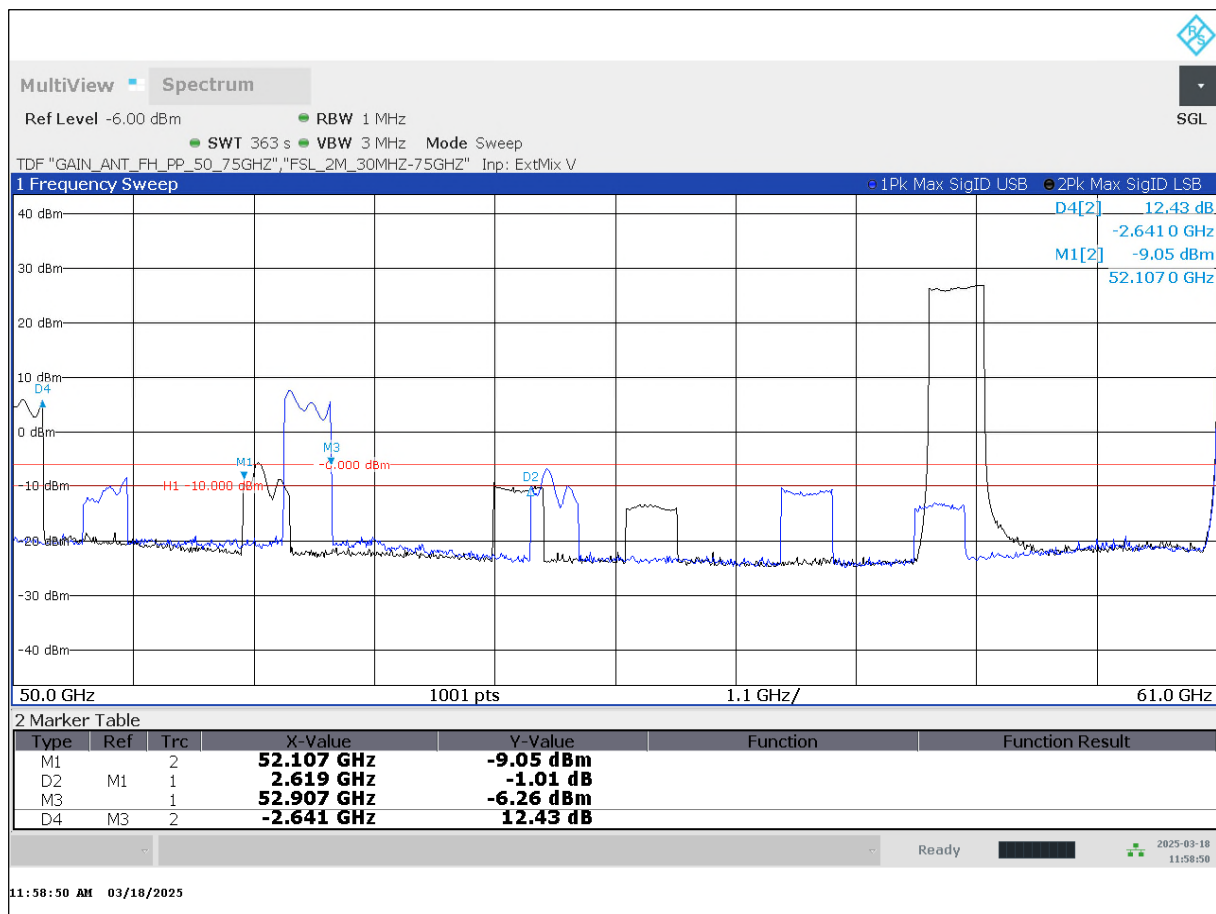
Ghost frequency

TID007b_02_f2_52.7GHz_Ghost_S08-long-range_Am5deg_E90deg_AntV



Ghost frequency

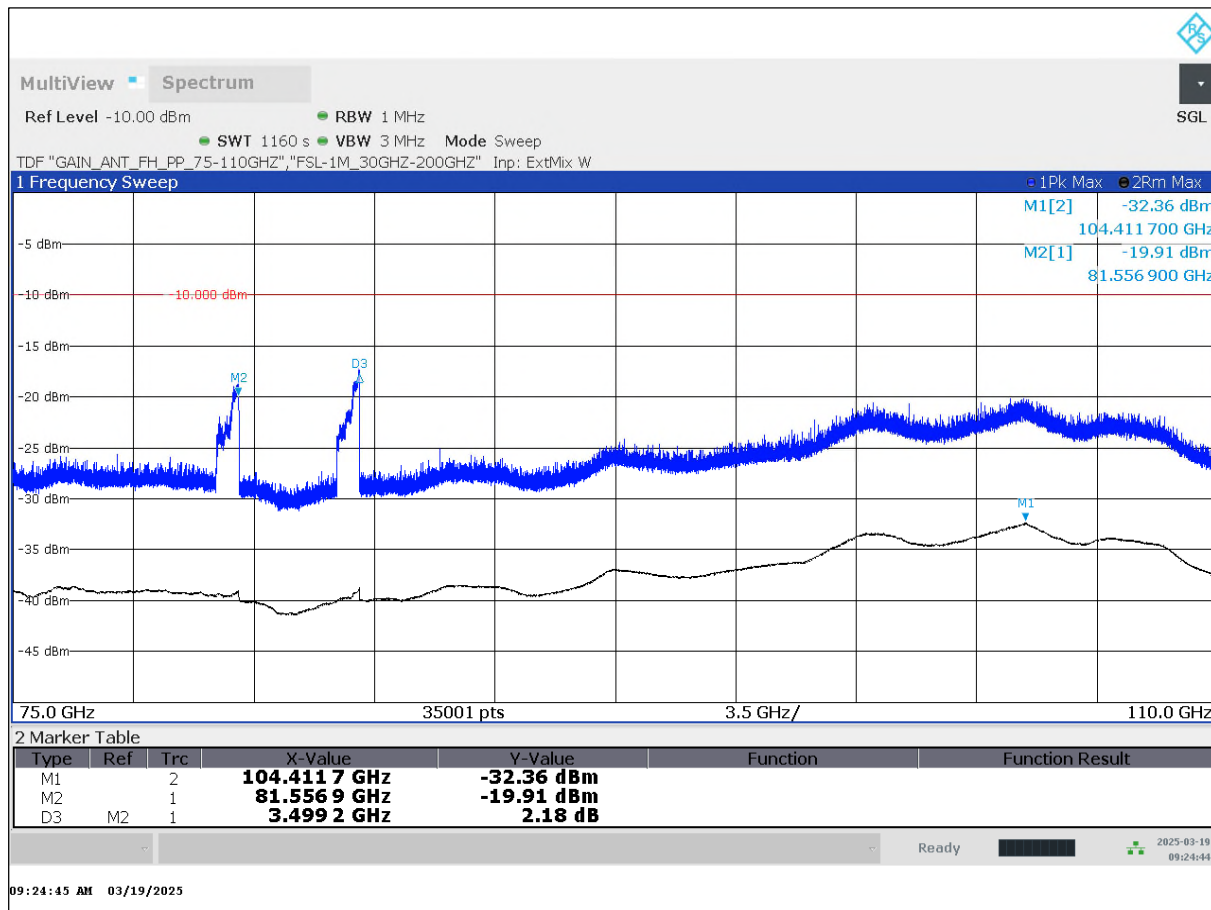
TID007b_03_RSE_Overview2_S08-long-range_Am5deg_E90deg_AntV



Ghost frequencies

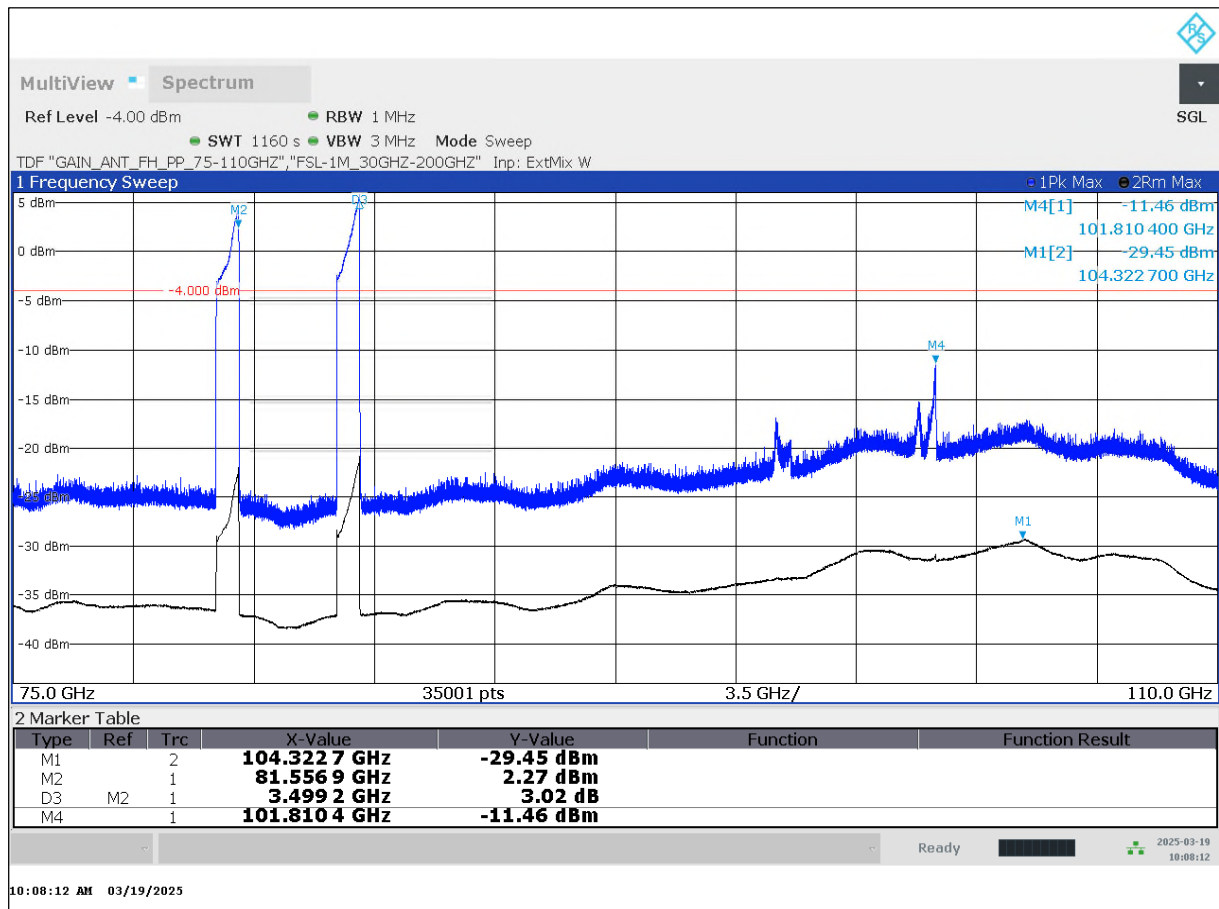
1.6.4 Frequency range: 75GHz to 110GHz

TID008a_RSE_Overview_75G-110GHz_S08-long-range_AntH



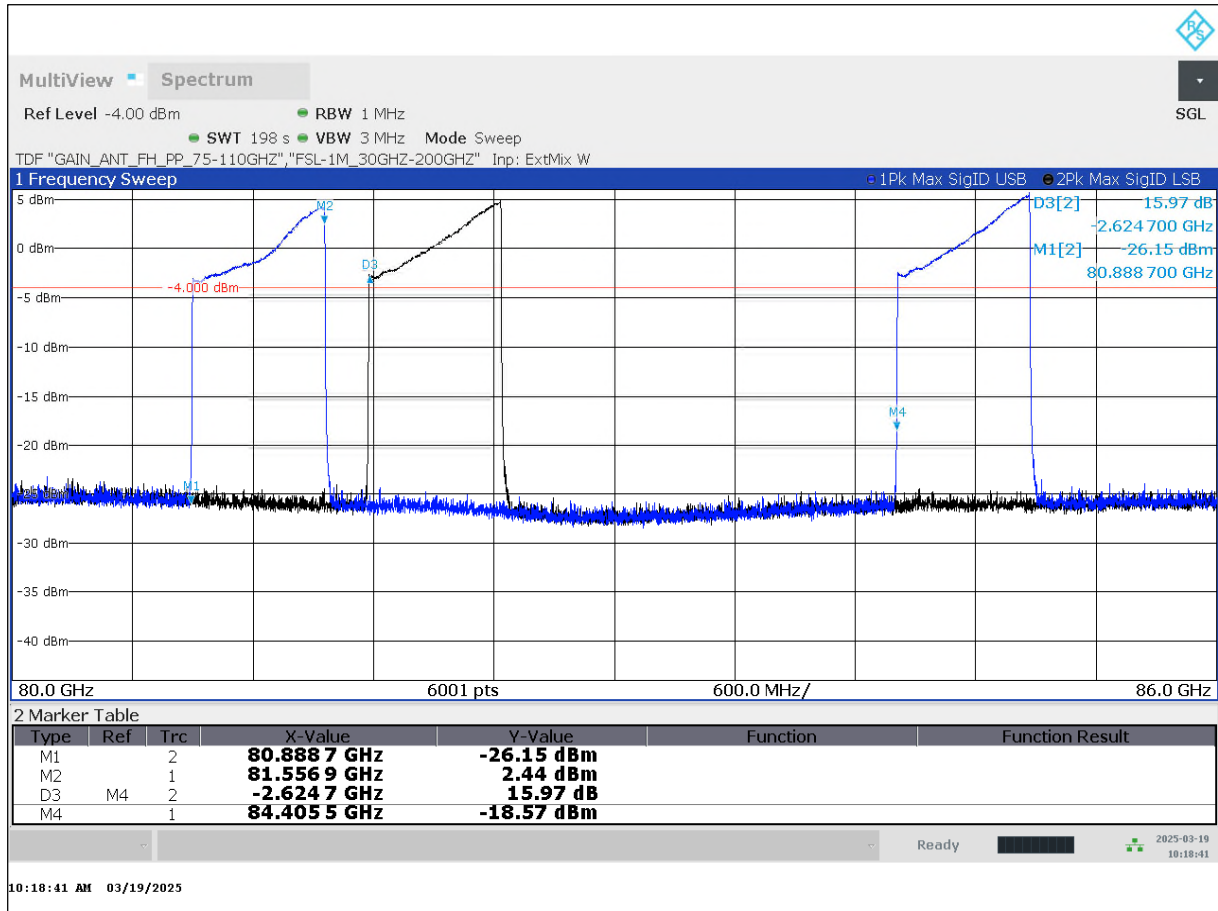
Peak trace (blue) for information only

TID008b_RSE_Overview_75G-110GHz_S08-long-range_AntV



Peak trace (blue) for information only

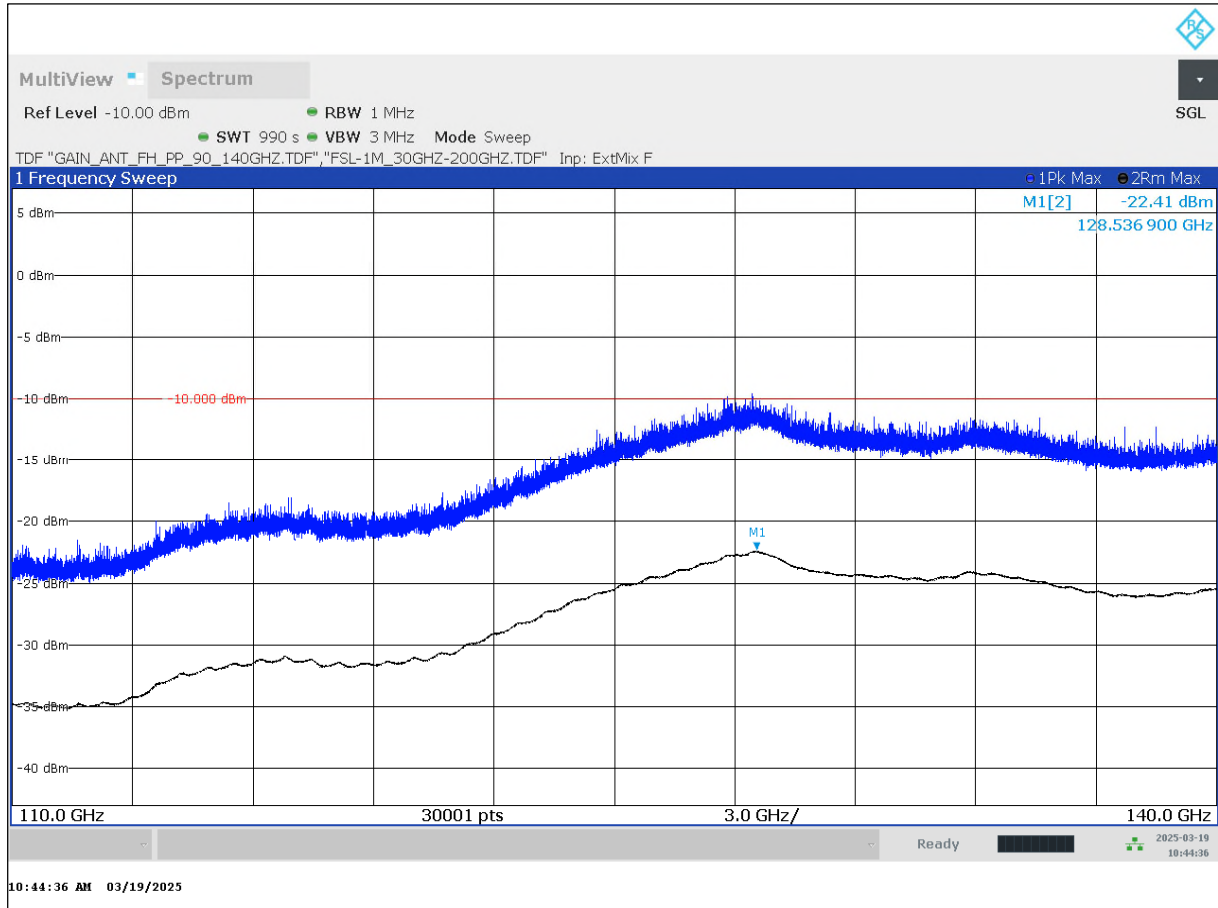
TID008b_01_Ghost-frequencies_80G-86GHz_S08-long-range_AntV



Ghost frequencies, not critical

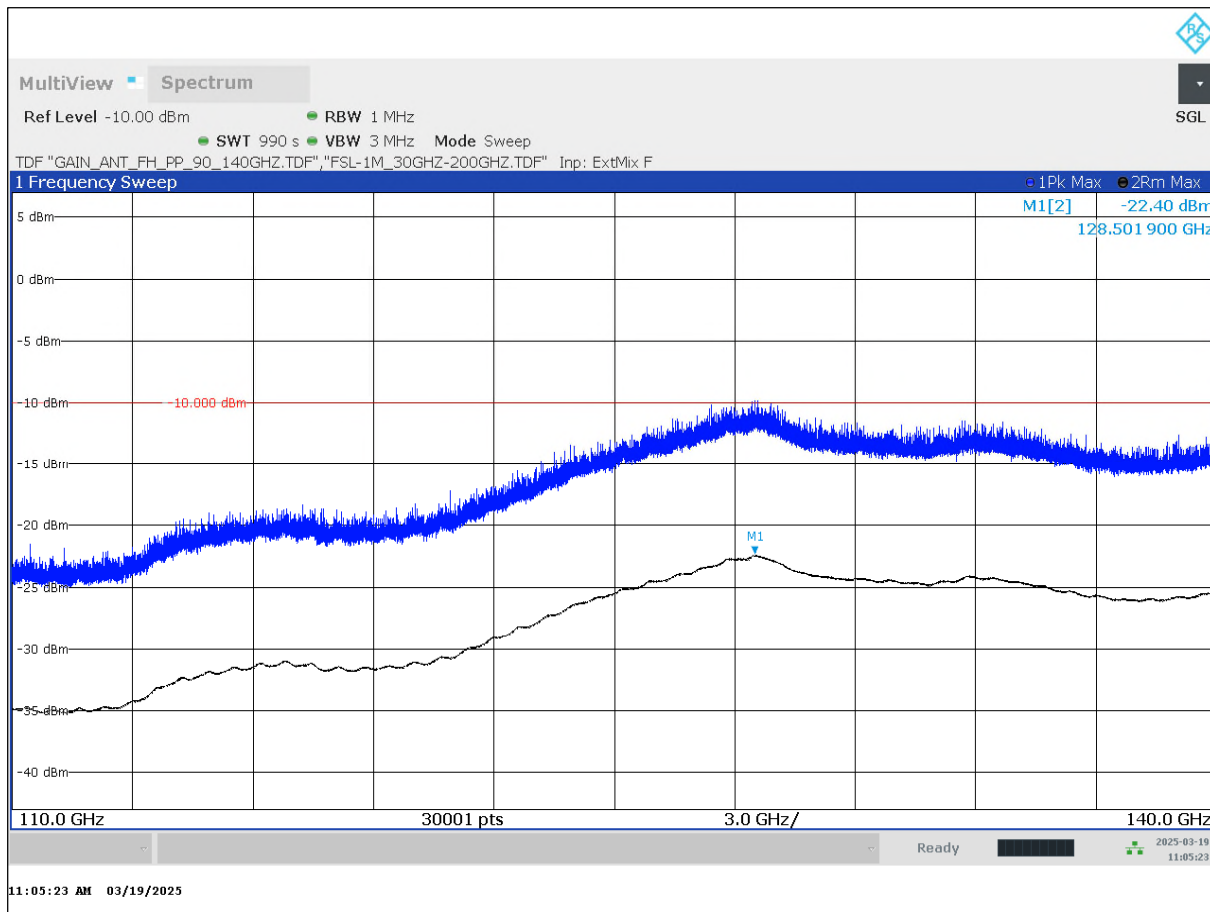
1.6.5 Frequency range: 110GHz to 140GHz

TID009a_RSE_Overview_110G-140GHz_S08-long-range_AntH



Peak trace for information only

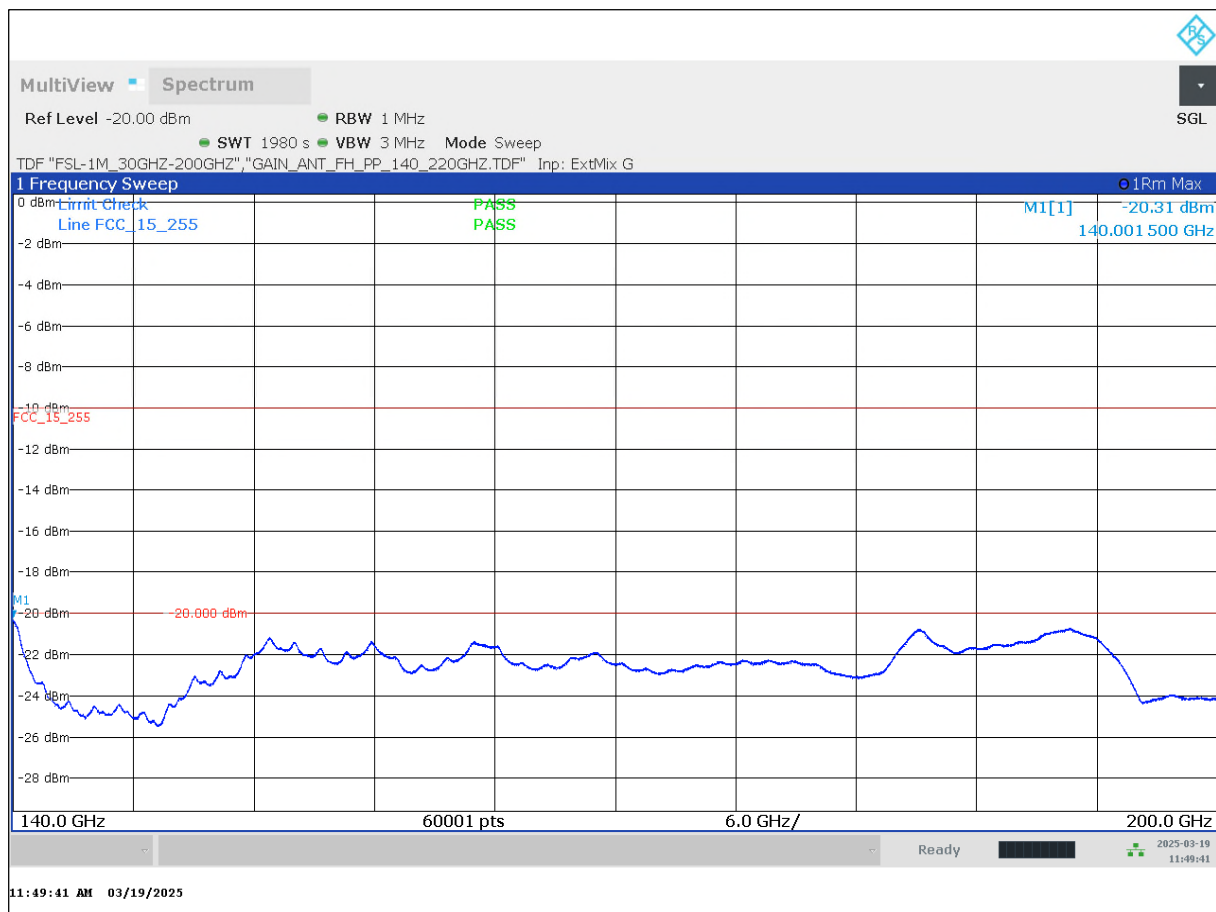
TID009b_RSE_Overview_110G-140GHz_S08-long-range_AntV



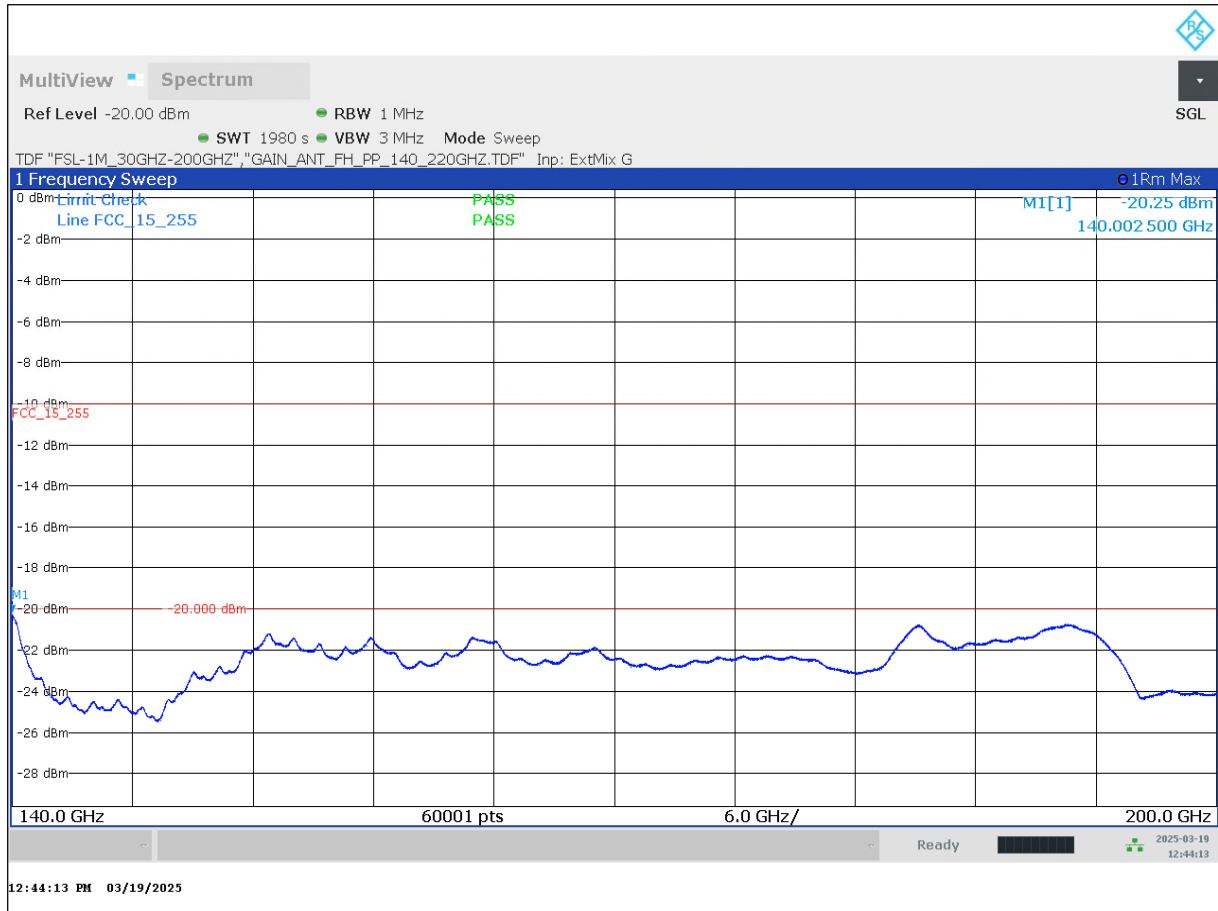
Peak trace for information only

1.6.6 Frequency range: 140GHz to 200GHz

TID010a_RSE_Overview_140G-200GHz_S08-long-range_AntH



TID010b_RSE_Overview_140G-200GHz_S08-long-range_AntV



End Of Annex 201