

Exhibit F – Test Report

The data required by 47 CFR Sections 2.1046 through 2.1057 inclusive, measured in accordance with the procedures set out in Section 2.1041. (2.1033 (c) (14))

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F.1 Test Procedure and Compliance Matrix

This section documents the test procedures and results of tests to demonstrate compliance with the applicable requirements of Parts 2 and 87 of the FCC Rules and Regulations, Code of Federal Regulations (CFR) Title 47.

Tests were conducted on engineering “Red Label” units under configuration management. “Red Label” units are considered to be identical to production “Black Label” units in terms of the performance criteria specified in this section. “Red Label” units are converted to “Black Label” units once FAA Technical Standard Order (TSO) and FCC approval are obtained.

The Table F- below identifies the applicable sections of this document and its relationship between the Parts 2 and 87 requirements. The test results are included within each individual test section.

Table F-1 – Test Requirements Matrix

47 CFR Part 2 Section	47 CFR Part 87 Section	Test Description Summary	Section
2.1047	87.141	Modulation Characteristics	F.2
2.1046	87.131	RF Power Output	F.4
2.1055	87.133	Frequency Stability	F.5
2.1049	87.135	Occupied Bandwidth	F.6
2.1051	87.139	Spurious Emissions at Antenna Terminals	F.7
2.1053	87.139	Field Strength of Spurious Radiation	F.8

F.2 TTR-2100 Modulation Characteristics (2.1047)

Requirement:

47 CFR Section 2.201 – Emission, Modulation, and Transmission Characteristics

47 CFR Section 2.1047(d) states: “A curve or equivalent data which shows that the equipment will meet the modulation requirements of the rules under which the equipment is to be licensed.”

Operation:

The TTR-2100 utilizes rectangular pulses modulated with Binary Phase-Shift Keying (BPSK).

Under the guidelines of Section 2.201 of the CFR the Emissions Designation of the TTR-2100 is as follows:

12M10V1D

Where:

“12M10” - The necessary bandwidth as measured in the Occupied Bandwidth section below.

“V” – A sequence of pulses which is a combination of the foregoing or is produced by other means. In the case of TCAS both phase and amplitude modulation is used.

“1” – A single channel containing quantized or digital information without the use of a modulating sub-carrier, excluding time-division multiplex.

“D” – Type of information to be transmitted – Data transmission, telemetry, telecommand.

The following paragraphs describe the transmitted output waveform and frequency utilization.

F.2.1 Mode C-Only All-Call Interrogation

The TTR-2100 supports two types of modulation. The first is referred to as “Mode C” and utilizes the following waveforms.

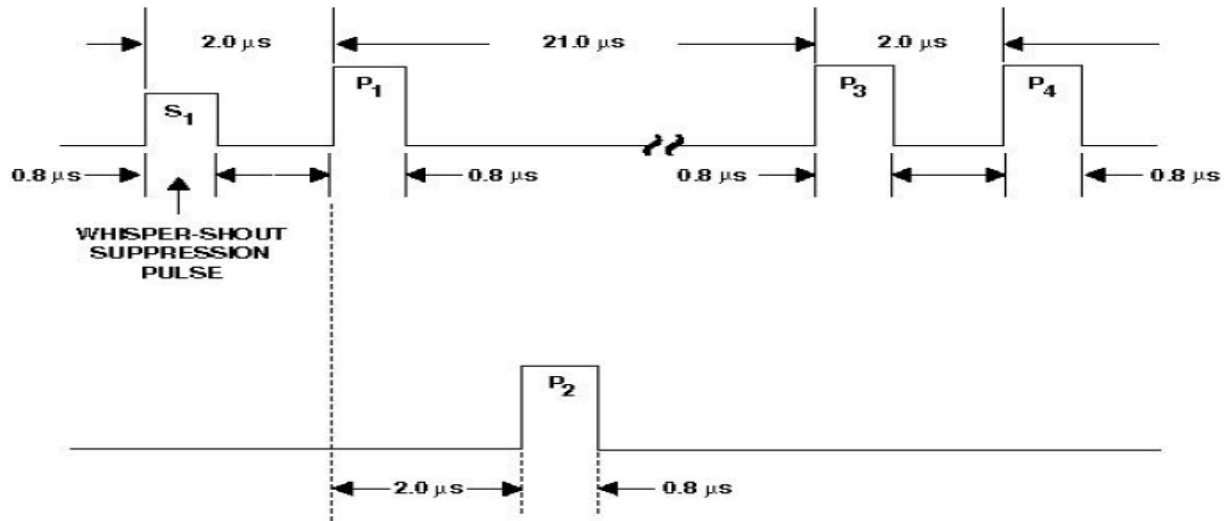


Figure F-1 – Mode C-Only All-Call Interrogation Pulse Sequence

Mode C interrogations from TCAS II equipment employ the “Mode-C-Only All-Call” format which consists of three pulses P1, P3, and P4. This normally is preceded by a Mode C “whisper-shout” suppression pulse designated S1. Sidelobe suppression is accomplished by transmitting a P2 pulse via a separate control pattern. These formats are illustrated in the above figure. The pulses have shapes and spacing as tabulated below. The amplitude of P3 is within 0.5 dB of the amplitude of P1 and the amplitude of P4 is within 0.5 dB of the amplitude of P3. A discussion of Whisper-Shout will follow the wave shapes used.

Table F-2 – Mode-C Pulse Spacing

(All values in microseconds)

Pulse Designator	Pulse Duration	Duration Tolerance	Rise Time		Decay Time	
			Min.	Max.	Min.	Max.
S ₁ , P ₁ , P ₂ , P ₃ , P ₄	0.8	± 0.05	0.05	0.1	0.05	0.2

The pulse spacing tolerances shall be as follows:

- S1 to P1 2 microseconds □ 10 nanoseconds;
- P1 to P2 2 microseconds □ 10 nanoseconds;
- P1 to P3 21 microseconds □ 10 nanoseconds;
- P3 to P4 2 microseconds □ 40 nanoseconds.

F.2.2 Mode-S Interrogation

The second type of modulation supported by the TTR-2100 is “Mode-S”. It is described below.

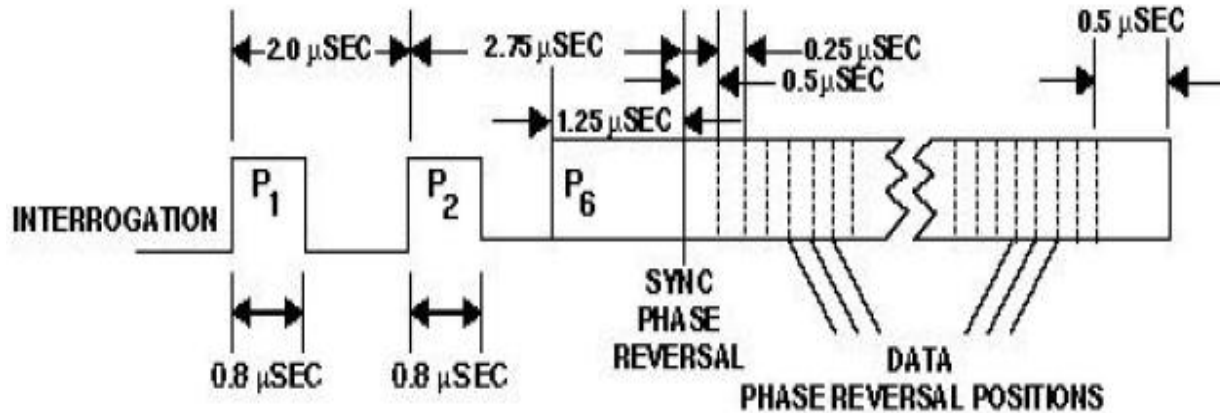


Figure F-2 – Mode-S Interrogation Pulse Sequence

Mode S transmissions shall consist of P1, P2, and P6 pulses as shown in the figure above. The pulses shall have shapes and spacing as tabulated below.

Table F-3 – Mode-S Pulse Spacing

(All values in microseconds)

Pulse Designator	Pulse Duration	Duration Tolerance	Rise Time Min.	Rise Time Max.	Decay Time Min.	Decay Time Max.
P ₁ , P ₂	0.8	± 0.05	0.05	0.1	0.05	0.2
P ₆ (Short)	16.25	± 0.125	0.05	0.1	0.05	0.2
P ₆ (Long)	30.25	± 0.125	0.05	0.1	0.05	0.2

The short 16.25 microsecond and long 30.25 microsecond P6 pulses have internal modulation consisting of possible 180 degree phase reversals of the carrier at designated times. The first phase reversal in the P6 pulse is the sync phase reversal and is always present. The presence or absence of a subsequent phase reversal indicates a one or zero in the transmitted code respectively.

Note 1: The sync phase reversal is the timing reference provided to identify chip positions to Mode S interrogation decoders.

The duration of a phase reversal in P6 is less than 80 nanoseconds as measured between the 10 degree and 170 degree points of the phase transition. The interval between the 80 percent points of the amplitude transient associated with the phase reversal is less than 80 nanoseconds.

The tolerance on the 0 and 180 degree phase relationships in P6 is ± 5 degrees.

The 90-degree point of each data phase reversal in P6 occurs only at a time (N x 0.25) microseconds ± 20 nanoseconds (N .GE. 2) after the 90 degree point of the sync phase reversal.

Note 2: 56 or 112 data phase reversals can occur in the 16.25 and 30.25 microsecond P6 pulses respectively. This results in a 4 Mbit/sec data rate within the P6 pulse.

The spacing from P1 to P2 is 2 μs ± 40 ns between leading edges. The spacing from the leading edge of P2 to the 90 degree point of the sync phase reversal of P6 shall be 2.75 μs ± 40 ns. The sync phase reversal of P6 occurs 1.25 μs ± 40 ns after the leading edge.

Note 3: The P1-P2 pair preceding P6 suppresses replies from ATCRBS transponders to avoid synchronous garble due to random triggering of ATCRBS transponders by Mode S interrogations. A

series of “chips” containing the information within P6 starts 500 nanoseconds after the sync phase reversal. Each chip is of 250 nanosecond duration and is preceded by a possible phase reversal. If preceded by a phase reversal, a chip represents logic “1”. There are either 56 or 112 chips. The last chip is followed by a 500 nanosecond guard interval which prevents the trailing edge of P6 from interfering with the demodulation process.

The radiated amplitudes of P2 and the initial first microsecond of P6 are greater than the radiated amplitude of P1 minus 0.25 dB. The maximum envelope amplitude variations between successive phase modulation chips in P6 are less than 0.25 dB.

F.2.3 Mode-C/Mode-S Interrogation Spectral Mask

The following table provides the spectral mask requirements for TCAS II as defined in RTCA DO-185A. DO-185A is the FAA specified performance requirements that all TCAS II systems must meet.

Table F-4 – Mode-C/Mode-S Interrogation Spectral Mask

Frequency Difference (MHz from 1030 MHz Carrier)	Maximum Relative Power (dB Down From Peak)
Between 4 and 6	6
Between 6 and 8	11
Between 8 and 10	15
Between 10 and 20	19
Between 20 and 30	31
Between 30 and 40	38
Between 40 and 50	43
Between 50 and 60	47
Between 60 and 90	50
Greater Than 90	60

F.2.4 Control of Synchronous Garble with Whisper-Shout

Aircraft equipped with the TCAS II system provide active surveillance of targets-of-interest that support the generation of collision advisory information. When operating far away from heavily congested airspace, en-route, there is a low probability of the generation of garbled communications due to multiple transmitters operating at the same time in the same spectrum. The equipment provides an automated means of controlling ATCRBS synchronous garble to a level that enables TCAS II to achieve the system requirements when operating within heavily congested airspace by reducing operating power output.

ATCRBS synchronous interference can be controlled by the use of a Mode C whisper-shout interrogation sequence and by the use of a directional transmitting antenna. The degree to which synchronous interference can be reduced depends on the ATCRBS transponder density, the resolution of the whisper-shout interrogation sequence and the azimuth directionality of the transmitting antenna. For a given antenna directionality and de-garble performance, the required degree of resolution is directly proportional to the ATCRBS transponder density; i.e., the lower the ATCRBS density the less resolution is required to provide an equivalent reduction in the level of synchronous interference. TCAS II equipment employs at least a four-beam top-mounted directional interrogation antenna. In conjunction with a four-beam antenna, TCAS II uses the Minimum Basic 6-level whisper-shout sequence, the high resolution whisper-shout sequence or a single interrogation according to selection criteria.

To control ATCRBS synchronous interference and also to reduce the severity of multi-path effects on the interrogation link, a sequence of interrogations at different power levels are to be transmitted during each surveillance update period. Each of the interrogations in the sequence, other than the one at lowest power, is to be preceded by a suppression pulse (designated S1) 2 microseconds preceding the P1

pulse. The combination of S1 and P1 serve as a suppression transmission. S1 is to be at a power level lower than that of P1. The minimum time between successive interrogations is 1 millisecond. All interrogations in the sequence are transmitted within a single surveillance update interval.

Because the suppression transmission in each step is always at a lower power level than the following interrogation, this technique is referred to as whisper-shout. The intended mechanism is that each aircraft replies to only one or two of the interrogations in a sequence. The lowest power interrogation is not preceded by an S1 suppression pulse to ensure that each transponder will respond to at least one of the interrogations in the sequence. A typical population of ATCRBS transponders at any given range may have a large spread in effective sensitivity due to variations in receivers, cable losses, and antenna shielding. Typically, each transponder in the population will respond to two interrogations in the sequence, and will be turned off by the higher power suppression transmissions accompanying higher-power interrogations in the sequence. Given a situation in which several aircraft are near enough to each other in range for their replies to synchronously interfere, it is unlikely they would all reply to the same interrogation and, as a result, the severity of synchronous interference is reduced.

F.2.4.1 Minimum Basic Whisper-Shout Sequence

The following figure shows the top antenna forward beam timing for six power steps in the Minimum Basic Whisper-Shout sequence. The first pulse of the interrogation serves as the second pulse of suppression.

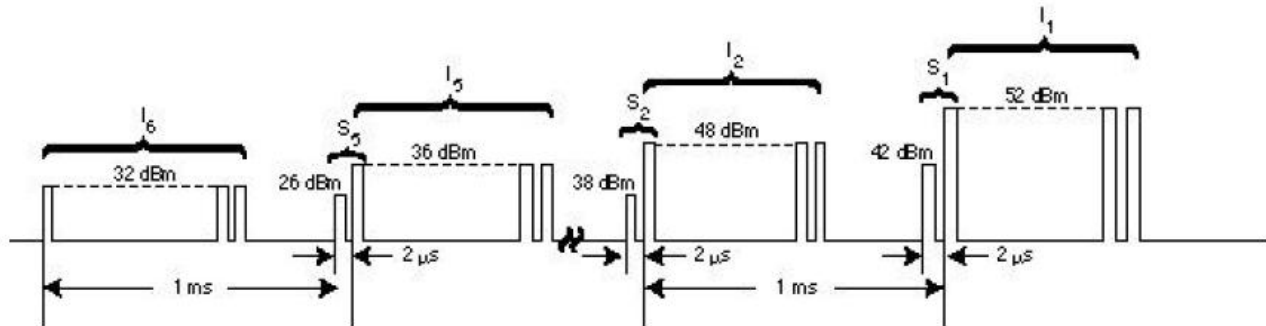


Figure F-3 – Whisper-Shout Minimum Basic Sequence

This design is the shortest whisper-shout sequence that has been developed, tested and shown to be effective, when used with a four-beam top-mounted directional antenna, in providing an acceptable level of de-garbling performance in a moderate ATCRBS transponder density of approximately 0.05 ATCRBS-equipped aircraft per sq. nautical mile. Five distinct sub-sequences are defined for use in the four beams of the top-mounted antenna and for the bottom-mounted Omni-directional antenna. The interrogations may be transmitted in any order.

Note: Most of the interrogations are transmitted from the top antenna because it is less susceptible to multi-path interference from the ground.

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MINIMUM EFFECTIVE RADIATED INTERFERENCE LIMITING

STEP NUMBER	INTERROGATION POWER LEVEL (dBm)	PRIORITY	MTL (-dBm)
1	S.....I 52	<i>Note: Each 1 dB reduction in the sequence follows the priority for the forward beam in Figure 2-9 (e.g. 1,5,9,...etc)</i>	74
2	Top Antenna S.....I 48		74
3	Forward S.....I 44		72
4	Direction S.....I 40		68
5	S.....I 36		64
6	.....I 32		60
7,8	S.....I 48	<i>Note: Each 1 dB reduction in the sequence follows the priority for the right/left beam in Figure 2-9 (e.g. 2/3,6/7...etc)</i>	74
9,10	Top Antenna S.....I 44		72
11,12	Left & Right S.....I 40		68
13,14	Direction S.....I 36		64
15,16	S.....I 32		60
17	S.....I 43	<i>Note: Each 1 dB reduction follows the priority for the aft beam in Fig. 2-9 (e.g. 4,8,12....etc)</i>	71
18	Top Antenna S.....I 39		67
19	Aft Direction S.....I 35		63
20	.....I 31		59
21	S..I 34	<i>Note: Each 1 dB reduction in the sequence follows the priority for the bottom ant in Figure 2-9 (e.g. 80,81,82...etc)</i>	62
22	Bottom Omni S..I 32		60
23	S..I 30		58
24	...I 28		56

Notes: "I" indicates ERP of P_1 , P_3 , and P_4 Interrogation Pulses.

"S" indicates ERP of S_1 Suppression Pulse.

"S.I" means that the S_1 ERP is 2 dB less than the interrogation ERP.

"S..I" means that the S_1 ERP is 3 dB less than the interrogation ERP.

"S.....I" means the S_1 ERP is 10 dB less than the interrogation ERP

In the last steps of each quadrant no S_1 pulses are transmitted.

Figure F-4 – Whisper-Shout Minimum Basic Step Description

F.2.4.2 Higher Capability Whisper-Shout Sequences

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The figures below define the high resolution whisper-shout sequence that's used in conjunction with a four-beam top-mounted directional antenna for high density ATRBS surveillance. This sequence, when used with a top mounted four-beam directional antenna, has been verified to operate successfully in densities up to 0.3 aircraft per square nautical mile. Five distinct sub sequences are defined for use in the four beams of the top-mounted antenna and the bottom-mounted omnidirectional antenna. The interrogations may be transmitted in any order.

STEP NUMBER		MINIMUM EFFECTIVE RADIATED INTERROGATION POWER LEVEL (dBm)	INTERFERENCE LIMITING PRIORITY	MTL (-dBm)
1		S..I	52	74
2	TOP	S.I	51	74
3	ANTENNA	S..I	50	74
4		S.I	49	74
5	FORWARD	S..I	48	74
6	DIRECTION	S.I	47	74
7		S..I	46	74
8		S.I	45	73
9		S..I	44	72
10		S.I	43	71
11		S..I	42	70
12		S.I	41	69
13		S..I	40	68
14		S.I	39	67
15		S..I	38	66
16		S.I	37	65
17		S..I	36	64
18		S.I	35	63
19		S..I	34	62
20		S.I	33	61
21		S..I	32	60
22		S.I	31	59
23		S..I	30	58
24	....I	29	79	57

Notes:

- "I" indicates ERP of P_1 , P_3 , and P_4 Interrogation Pulses.
- "S" indicates ERP of S_1 Suppression Pulse.
- "S.I" means that the S_1 ERP is 2 dB less than the interrogation ERP.
- "S..I" means that the S_1 ERP is 3 dB less than the interrogation ERP.
- In the last steps of each quadrant no S_1 pulses are transmitted.

Figure F-5 – Whisper-Shout High Resolution Step Description

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STEP	MINIMUM EFFECTIVE RADIATED		INTERFERENCE		
NUMBER	INTERROGATION POWER LEVEL		LIMITING	MTL	
		(dBm)	PRIORITY	(-dBm)	
25,26		S..I	48	2,3	74
27,28	TOP	S.I	47	6,7	74
29,30	ANTENNA	S..I	46	10,11	74
31,32		S.I	45	14,15	73
33,34		S..I	44	18,19	72
35,36	LEFT&RIGHT	S.I	43	22,23	71
37,38	DIRECTIONS	S..I	42	26,27	70
39,40		S.I	41	30,31	69
41,42		S..I	40	34,35	68
43,44		S.I	39	38,39	67
45,46		S..I	38	42,43	66
47,48		S.I	37	46,47	65
49,50		S..I	36	50,51	64
51,52		S.I	35	54,55	63
53,54		S..I	34	58,59	62
55,56		S.I	33	62,63	61
57,58		S..I	32	65,66	60
59,60		S.I	31	68,69	59
61,62		S..I	30	71,72	58
63,64		....I	29	74,75	57
65		S.I	43	4	71
66		S..I	42	8	70
67		S..I	41	12	69
68		S..I	40	16	68
69		S.I	39	20	67
70		S..I	38	24	66
71		S.I	37	28	65
72		S..I	36	32	64
73		S.I	35	36	63
74		S..I	34	40	62
75		S.I	33	44	61
76		S..I	32	48	60
77		S.I	31	52	59
78		S..I	30	56	58
79	I	29	60	57

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MIN EFFECTIVE RADIATED POWER LEVEL

(dBm)

Notes: "I" indicates ERP of P_1 , P_3 , and P_4 Interrogation Pulses.
 "S" indicates ERP of S_1 Suppression Pulse.
 "S.I" means that the S_1 ERP is 2 dB less than the interrogation ERP.
 "S..I" means that the S_1 ERP is 3 dB less than the interrogation ERP.
 In the last steps of each quadrant no S_1 pulses are transmitted.

Figure F-6 – Whisper-Shout High Resolution Step Description (cont.)

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STEP NUMBER	MINIMUM EFFECTIVE RADIATED INTERROGATION POWER LEVEL		INTERFERENCE LIMITING PRIORITY	MTL
	(dBm)			(-dBm)
80	S..I		34	62
81	S..I	BOTTOM	32	60
82	S..I	OMNI	30	58
83	..I		28	56

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MIN EFFECTIVE RADIATED POWER LEVEL (dBm)

Notes: "I" indicates ERP of P_1 , P_3 , and P_4 Interrogation Pulses.
 "S" indicates ERP of S_1 Suppression Pulse.
 "S.I" means that the S_1 ERP is 2 dB less than the interrogation ERP.
 "S..I" means that the S_1 ERP is 3 dB less than the interrogation ERP.
 In the last steps of each quadrant no S_1 pulses are transmitted.

Figure F-7 – Whisper-Shout High Resolution Step Description (cont.)

F.3 Special FCC Test Conditions

The equipment provides the following interrogation test modes for use with the bench test procedures.

a. Mode S Test Mode 1

A Mode S interrogation format with a short P6 pulse, but containing a data block whose bit values are all ONE. The interrogation rate shall be 50 per second, nominal.

b. Mode S Test Mode 2

A Mode S interrogation format with a long P6 pulse, but containing a data block whose bit values are all ONE. The interrogation rate shall be 50 per second, nominal.

c. Mode S Test Mode 3

A Mode S interrogation format without the preamble pulses and with a long P6 pulse containing no internal modulation (i.e., a data block whose bit values are all ZERO). The interrogation rate shall be 50 per second, nominal.

d. Mode C Test Mode 1

A standard Mode C only all-call interrogation (see section F.2.1) at a rate of 50 per second, nominal.

e. Whisper-Shout Test Mode 1

A standard minimum basic whisper-shout sequence for the minimum TCAS is defined in subparagraph F.2.8. The interrogation sequence rate shall be 10 per second, nominal.

f. Whisper-Shout Test Mode 2

A standard high resolution whisper-shout sequence for the minimum TCAS is defined in subparagraph F.2.9. The interrogation sequence rate shall be 10 per second, nominal.

g. No-Interrogation Test Mode

A mode in which the TCAS transmitter is programmed to transmit no interrogations but otherwise is active.

Table F-5 lists the Special FCC Test Conditions described above and lists which FCC test paragraphs utilized these conditions.

Table F-5 – Special FCC Test Conditions

47 CFR Part 2 Section	Test Mode(s)	Notes
2.1046 – RF Power Output	Mode C Test Mode 1 Mode S Test Mode 2	Representative Mode C and Mode S waveforms.
2.1049 – Occupied BW	Mode C Test Mode 1 Mode S Test Mode 2	Represents worst case spectrum utilization. Phase transition every bit period.
2.1051 – Spurious Emissions	Mode S Test Mode 2	Represents worst case spectrum utilization. Phase transition every bit period. Only Mode S used.
2.1053 – Spurious Radiation	Normal Operation	Normal operation software used with test system capable of simulating 2 Mode C and 2 Mode S aircraft.
2.1055 – Frequency Stability	Mode S Test Mode 3	Un-modulated Mode S pulse used as it generates the narrowest modulation spectrum and provides the best frequency accuracy.

F.4 RF Power Output (2.1046)

Requirement:

47 CFR Section 2.1046(a) "For transmitters other than single sideband, independent sideband and controlled carrier radiotelephone, power output shall be measured at the RF output terminals when the transmitter is adjusted in accordance with the tune-up procedure to give the value of current and voltage on circuit elements specified in 2.1033 (c)(8). The electrical characteristics of the radio frequency load attached to the output terminals when this test is made shall be stated."

47 CFR Section 2.1033(c)(8) "The dc voltages applied to and dc currents into the several elements of the final radio frequency amplifying device for normal operation over the power range."

47 CFR Section 87.131, Note 7 "Frequency, emission, and maximum power will be determined by appropriate standards during the certification process".

Test Equipment and Setup:

The TTR-2100 unit utilizes a 115 VAC power supply. The power supply boosts the incoming voltage to a high voltage DC rail for hold-up capacitance storage and power factor correction. The supply then converts the high voltage DC rail to +12 VDC for internal distribution to the various assemblies in the unit. The Transceiver assembly then boosts the system +12 VDC to +32 VDC to be applied to the modulator for the RF power amplifier driver and final transistors. The modulator for the power amplifier transistors regulates the +32 VDC rail to a digitally controlled value around 20 VDC in order to prevent transmitter droop. The transistors draw approximately 40 A's peak, and around 800 mA average. Transmitter tuning is not required. The test shall be completed by varying the input power input voltage $\pm 15\%$.

The equipment used for the RF Power Output Test is shown in Table F-6.

Table F-6 – Test Equipment Used for RF Power Output Test

Equipment	Manufacturer/Model Number	Specific Identification
Receiver/Transmitter Module	Rockwell Collins TTR-2100 (822-2911-950R)	S/N 44MCN
Test Harness	Rockwell Collins TTR-2100 Breakout Panel	N/A
SST-2010	Rockwell Collins	N/A
TTR-2100 Antenna Simulator	Rockwell Collins	653-4519-015
8-Way Combiner	Mini-Circuits, ZB8PD-2000-S+	N/A
Spectrum Analyzer	Rohde & Schwarz, FSU	460-0155-003
DC Power Supply	Agilent 6653A	469-0077-760
AC Power Supply	Agilent 6812B	469-0077-787
Attenuator (20 dB)	Weinschel	N/A
Personal Computer	Generic PC	N/A
Ethernet Switch	D-Link DSS-16+	N/A

A functional block diagram of the equipment setup for the RF Power Output Test is shown in Figure F-8.

TTR-2100

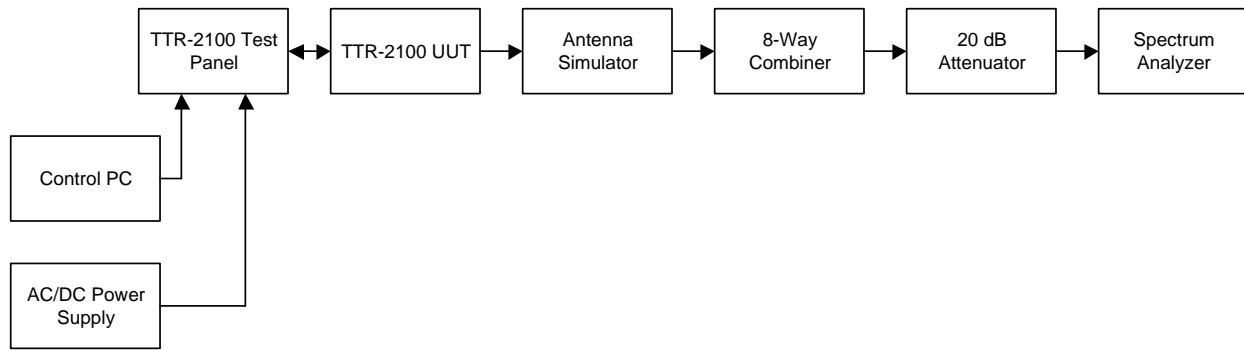


Figure F-8 – RF Power Output Test Equipment Setup Diagram

Test Procedure:

This test shall measure the RF output power while the primary power input varies up to $\pm 15\%$. The RF power output shall be measured using both Mode C Test Mode 1 and Mode S Test Mode 2.

For each voltage specified in Table F-7, set the unit to each of test mode and measure the peak RF output power. The power shall be measured through 20 dB of attenuation to avoid damage to the test equipment.

Test Results:

The measured transmitter power output for each operating frequency versus power supply voltage is contained in Table F-7.

Table F-7 – TTR-2100 RF Power Output

Line Voltage (VAC)	Peak Transmitter Power Output (Watts)	
	Mode C	Mode S
97.8 (115 – 15%)	257	257
103.5 (115 – 10%)	257	251
109.3 (115 – 5%)	257	257
115	269	257
120.8 (115 + 5%)	257	251
126.5 (115 + 10%)	257	251
132.3 (115 + 15%)	257	251

F.5 Frequency Stability (2.1055)

Requirement:

47 CFR Section 2.1055(a)(2) The frequency shall be measured with variation of ambient temperature from -20° to +50° centigrade for equipment licensed for use aboard aircraft in the Aviation Services under part 87 of FCC Code of Federal Regulations Title 47.

47 CFR Section 2.1055(b) The frequency measurement shall be made at the extremes and at intervals of not more than 10° centigrade through the range. A period of time sufficient to stabilize all of the components of the oscillator circuit at each temperature level shall be allowed prior to frequency measurement.

47 CFR Section 2.1055(d)(1)(3) The frequency stability shall be measured with variation of primary supply voltage from 85 to 115 percent of the nominal value. The supply voltage shall be measured at the input to the cable normally provided with the equipment, or at the power supply terminals if cables are not normally provided.

47 CFR Section 87.133 (a) Frequency tolerance for Frequency band (7) 470 to 2450 MHz Aircraft Stations is 20 ppm.

Test Equipment and Setup:

The equipment used for the Frequency Stability tests is shown in Table F-8.

Table F-8 – Equipment Used for Frequency Stability Test

Equipment	Manufacturer/Model Number	Specific Identification
Receiver/Transmitter Module	Rockwell Collins TTR-2100 (822-2911-950R)	S/N 44MCN
Test Harness	Rockwell Collins TTR-2100 Breakout Panel	N/A
SST-2010	Rockwell Collins	N/A
TTR-2100 Antenna Simulator	Rockwell Collins	653-4519-015
8-Way Combiner	Mini-Circuits, ZB8PD-2000-S+	N/A
Spectrum Analyzer	Rohde & Schwarz, FSU	460-0155-003
DC Power Supply	Agilent 6653A	469-0077-760
AC Power Supply	Agilent 6812B	469-0077-787
Attenuator (20 dB)	Weinschel	N/A
Personal Computer	Generic PC	N/A
Ethernet Switch	D-Link DSS-16+	N/A

The test setup for the Frequency Stability test is shown in Figure F-9.

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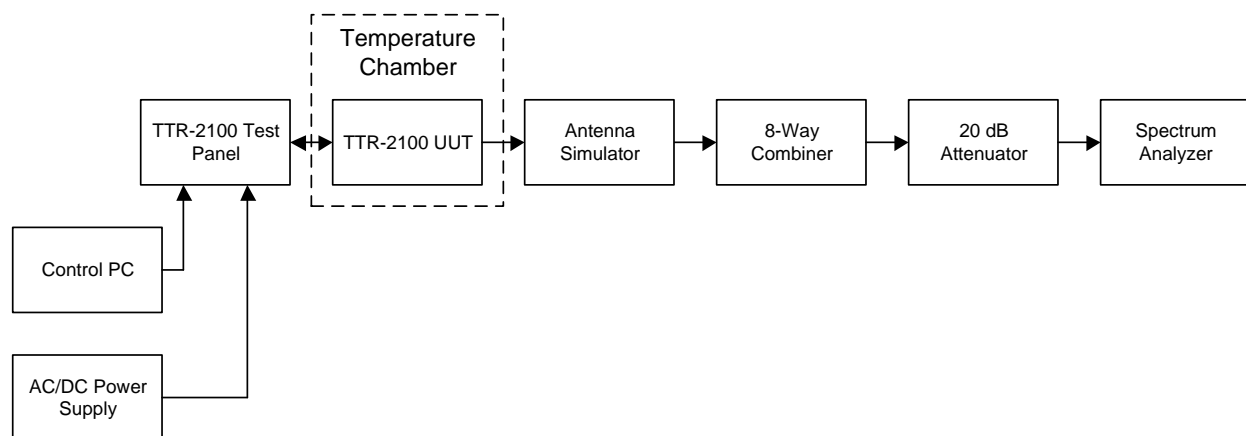


Figure F-9 – Frequency Stability Test Setup Diagram

Test Procedure – Primary Supply Variation:

This test shall measure the RF output frequency while the primary power input varies up to $\pm 15\%$. The test shall be completed at ambient room temperature. The output frequency shall be measured using Mode S Test Mode 3.

For each voltage specified in Table F-9 measure the RF output frequency. The frequency shall be measured through 20 dB of attenuation to avoid damage to the test equipment. The frequency shall be within ± 10.3 kHz of the center frequency of 1030 MHz.

Test Results - Primary Supply Variation:

Frequency Stability vs Line Voltage test results are shown in Table F-9. There were no out of tolerance frequency variations as a result of line voltage variations.

Table F-9 – TTR-2100 Transmitted Frequency vs. Input Voltage

Line Voltage (VAC)	Frequency (Spectrum Analyzer) (MHz)
	Mode S
97.8 (115 – 15%)	1030.000000
103.5 (115 – 10%)	1030.000000
109.3 (115 – 5%)	1030.000000
115	1030.000321
120.8 (115 + 5%)	1030.000321
126.5 (115 + 10%)	1030.000321
132.3 (115 + 15%)	1030.000000

Test Procedure – Temperature Variation:

This test shall measure the RF output frequency while the ambient temperature is varied from -55°C to $+70^{\circ}\text{C}$ in 10°C increments. The test shall be completed at with a nominal input voltage level of 115 VAC. The output frequency shall be measured using Mode S Test Mode 3.

For each temperature step specified in, measure the RF output frequency. The frequency shall be measured through 20 dB of attenuation to avoid damage to the test equipment. The frequency shall be within ± 10.3 kHz of the center frequency of 1030 MHz.

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Test Results – Temperature Variation:

Temperature Test results are shown in Table F-10 and Figure F-10. There were no out of tolerance frequency variations as a result of temperature extremes from -55 °C to +70 °C.

Table F-10 – TTR-2100 Transmitted Frequency vs. Temperature

Temp. (°C)	Frequency (Spectrum Analyzer) (MHz)
	Mode S
-55	1029.997400
-50	1030.001300
-40	1030.000900
-30	1030.000700
-20	1030.000200
-10	1030.000200
0	1030.000200
10	1030.000700
20	1030.000300
30	1030.000000
40	1029.999600
50	1030.000000
60	1029.999900
70	1029.999600

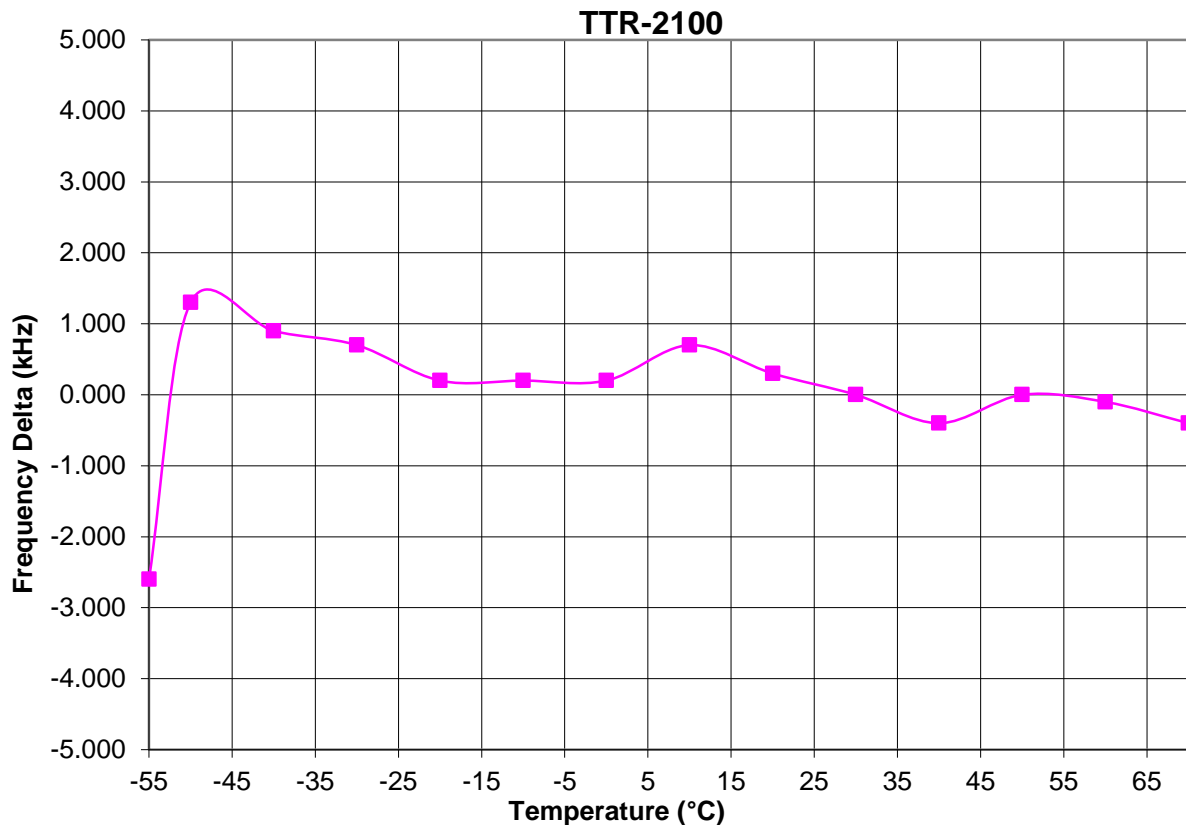


Figure F-10 – TTR-2100 Transmitter Frequency Stability vs. Temperature

F.6 Occupied Bandwidth (2.1049)

Requirement:

47 CFR Section 2.1049 “The occupied bandwidth, that is the frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers radiated are each equal to 0.5 percent of the total mean power radiated by a given emission shall be measured under the following conditions as applicable.”

47 CFR Section 2.1049(i) “Transmitters designed for other types of modulation – when modulated by an appropriate signal of sufficient amplitude to be representative of the type of service in which used. A description of the input signal should be supplied.”

47 CFR Section 87.133 (a) Frequency tolerance for Frequency band (7) 470 to 2450 MHz Aircraft Stations is 20 ppm.

47 CFR Section 87.135

(a) Occupied bandwidth is the width of a frequency band such that, below the lower and above the upper frequency limits, the mean powers emitted are each equal to 0.5 percent of the total mean power of a given emission.

(b) The authorized bandwidth is the maximum occupied bandwidth authorized to be used by a station.

(c) The necessary bandwidth for a given class of emission is the width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions.

Test Equipment and Setup:

The equipment used for the Occupied Bandwidth Test is shown in Table F-11.

Table F-11 – Equipment Used for Occupied Bandwidth Tests

Equipment	Manufacturer/Model Number	Specific Identification
Receiver/Transmitter Module	Rockwell Collins TTR-2100 (822-2911-950R)	S/N 44MCN
Test Harness	Rockwell Collins TTR-2100 Breakout Panel	N/A
SST-2010	Rockwell Collins	N/A
TTR-2100 Antenna Simulator	Rockwell Collins	653-4519-015
8-Way Combiner	Mini-Circuits, ZB8PD-2000-S+	N/A
Spectrum Analyzer	Rohde & Schwarz, FSU	460-0155-003
DC Power Supply	Agilent 6653A	469-0077-760
AC Power Supply	Agilent 6812B	469-0077-787
Attenuator (20 dB)	Weinschel	N/A
Personal Computer	Generic PC	N/A
Ethernet Switch	D-Link DSS-16+	N/A

A functional block diagram of the equipment setup for the Occupied Bandwidth Test is shown in Figure F-11.

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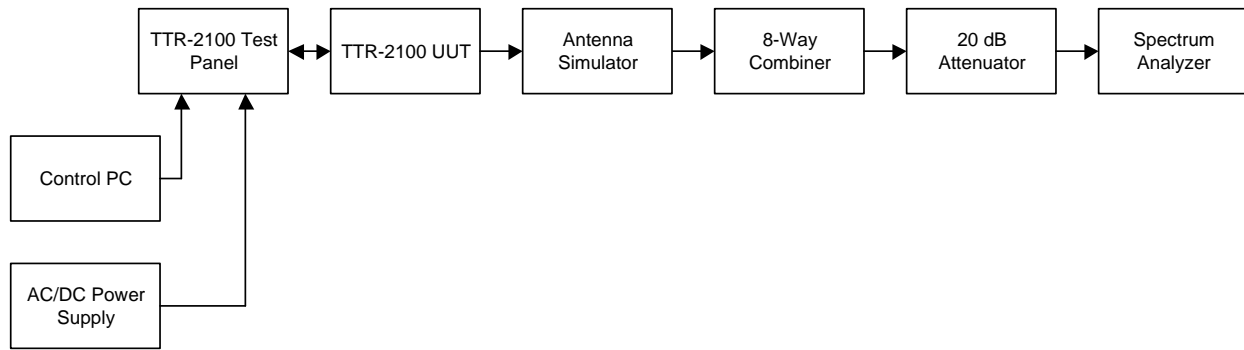


Figure F-11 – Occupied Bandwidth Test Equipment Setup

Test Procedure:

This test shall measure the occupied bandwidth using Mode C Test Mode 1 and Mode S Test Mode 2. The test shall be completed with a nominal input voltage level of 115 VAC. The occupied bandwidth shall be measured through 20 dB of attenuation to avoid damage to the test equipment.

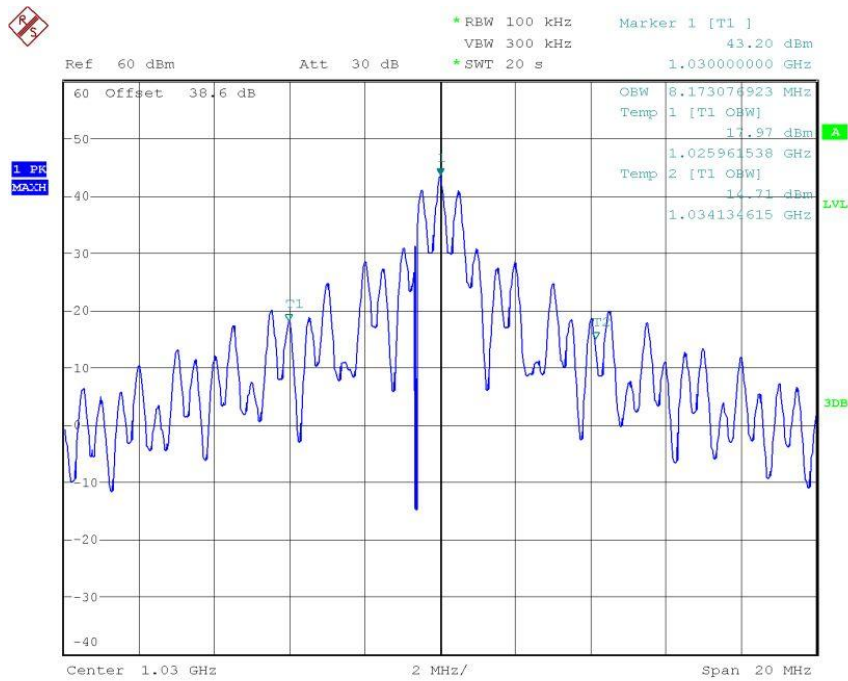
Test Results:

The Rohde & Schwarz FSU spectrum analyzer was set up to automatically measure 99% occupied bandwidth. Table F-12 contains the test result for the Weather plus Turbulence operating mode.

Table F-12 – TTR-2100 Occupied Bandwidth Measurement Results

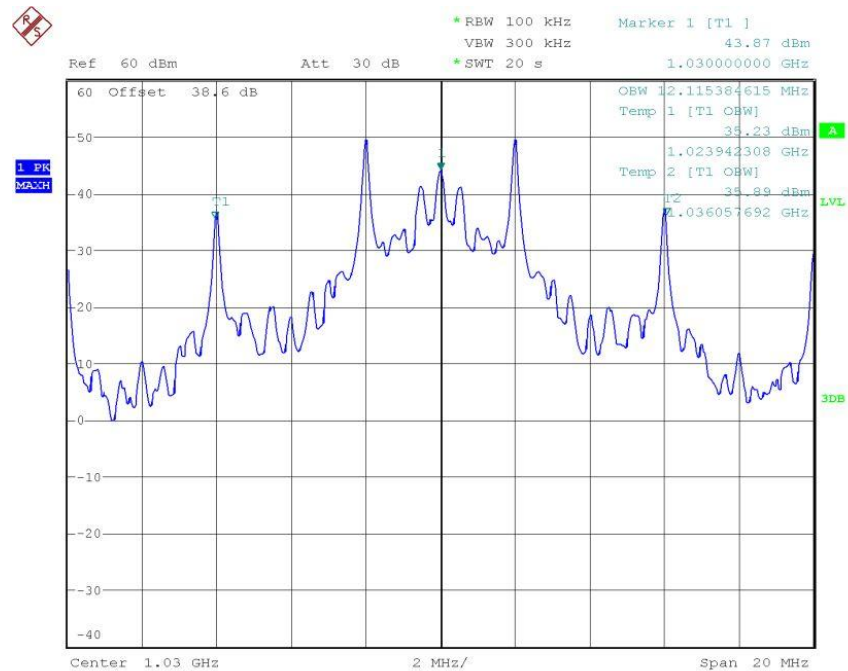
Operational Mode	99% Occupied Bandwidth	Reference Figure
Mode C	8.17 MHz	Figure F-12
Mode S	12.12 MHz	Figure F-13

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Figure F-12 – Occupied Bandwidth Measurement – Mode C



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Figure F-13 – Occupied Bandwidth Measurement – Mode S

F.7 Spurious Emissions at Antenna Terminal (2.1051)

Requirement:

47 CFR Section 2.1051 The radio frequency voltage or powers generated within the equipment and appearing on a spurious frequency shall be checked at the equipment output terminals when properly loaded with a suitable artificial antenna. Curves or equivalent data shall show the magnitude of each harmonic and other spurious emissions that can be detected when the equipment is operated under the conditions specified in Section 2.1049 as appropriate. The magnitude of spurious emissions attenuated more than 20 dB below the permissible values need not be specified.

47 CFR Section 87.139(a) "... the mean power of any emission must be attenuated below the mean power of the transmitter (pY) as follows:

(1) When the frequency is removed from the assigned frequency by more than 50 percent up to and including 100 percent of the authorized bandwidth the attenuation must be at least 25 dB.

(2) When the frequency is removed from the assigned frequency by more than 100 percent up to and including 250 percent of the authorized bandwidth the attenuation must be at least 35 dB.

(3) When the frequency is removed from the assigned frequency by more than 250 percent of the authorized bandwidth the attenuation for aircraft station transmitters must be at least 40 dB; and the attenuation for aeronautical station transmitters must be at least $43 + \log_{10}(pY)$ dB.

Since the TTR-2100 falls under the definition of an aircraft station transmitter defined in Section 87.139(a)(3), the worst case limit is 40 dBc. The Authorized Bandwidth is assumed to be 1020 to 1040 MHz which is the frequency range allocated for TCAS II equipment per FAA guidelines.

The TTR-2100 has a maximum peak power output of 269 Watts. Based on this power level, the absolute limits are calculated as follows using 40 dBc as an example.

$$P_{TX_peak} = 269 \text{ Watts} = 54.3 \text{ dBm}$$

$$\text{FCC Limit} = 40 \text{ dBc}$$

$$\text{Absolute Limit} = P_{TX_peak} (\text{dBm}) - \text{FCC Limit (dBc)} = +14.3 \text{ dBm}$$

Note: The FCC limit is specified in terms of mean power (pY). However, the test equipment utilized for these tests provides peak measurements. Calculation of the FCC limits based on mean power, then converting to peak readings will yield the same limits.

The requirements for the Spurious Emissions Test are contained in Table F-13.

Table F-13 – Spurious Emission Test Requirements (87.139(a)(3))

Frequency Band	Emission Level	Absolute FCC Limit (Peak)
Below 970 MHz	-40 dBc	+14.3 dBm
From 970 MHz to 1000 MHz	-35 dBc	+19.3 dBm
From 1000 MHz to 1010 MHz	-25 dBc	+29.3 dBm
From 1050 MHz to 1060 MHz	-25 dBc	+29.3 dBm
From 1060 MHz to 1090 MHz	-35 dBc	+19.3 dBm
Over 1090 MHz	-40 dBc	+14.3 dBm

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Test Equipment and Setup:

The equipment used for all Spurious Emissions test is shown in Table F-14.

Table F-14 – Equipment Used for Spurious Emissions Tests

Equipment	Manufacturer/Model Number	Specific Identification
Receiver/Transmitter Module	Rockwell Collins TTR-2100 (822-2911-950R)	S/N 44MCN
Test Harness	Rockwell Collins TTR-2100 Breakout Panel	N/A
SST-2010	Rockwell Collins	N/A
TTR-2100 Antenna Simulator	Rockwell Collins	653-4519-015
8-Way Combiner	Mini-Circuits, ZB8PD-2000-S+	N/A
Spectrum Analyzer	Rohde & Schwarz, FSU	460-0155-003
DC Power Supply	Agilent 6653A	469-0077-760
AC Power Supply	Agilent 6812B	469-0077-787
Attenuator (20 dB)	Weinschel	N/A
Personal Computer	Generic PC	N/A
Ethernet Switch	D-Link DSS-16+	N/A

A functional block diagram of the equipment setup for Spurious Emissions at Antenna Terminal test is shown in Figure F-14.

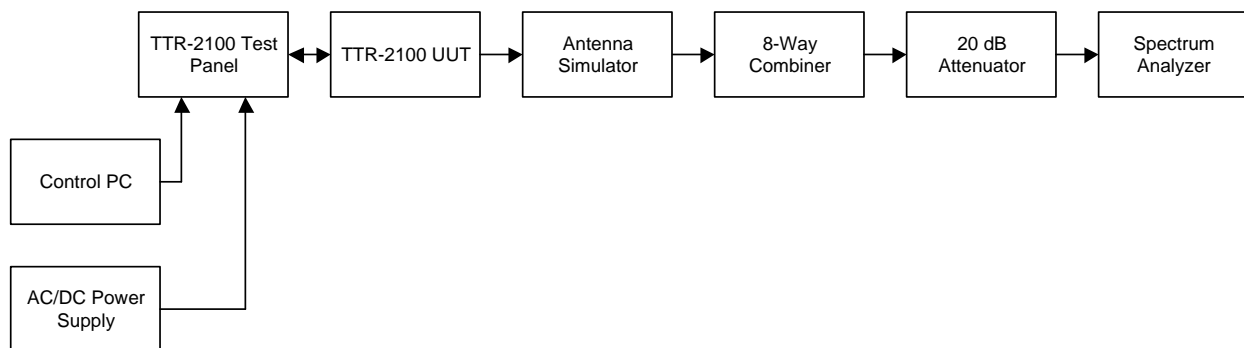


Figure F-14 – Spurious Emissions of Antenna Terminal Test Setup Diagram

Test Procedure:

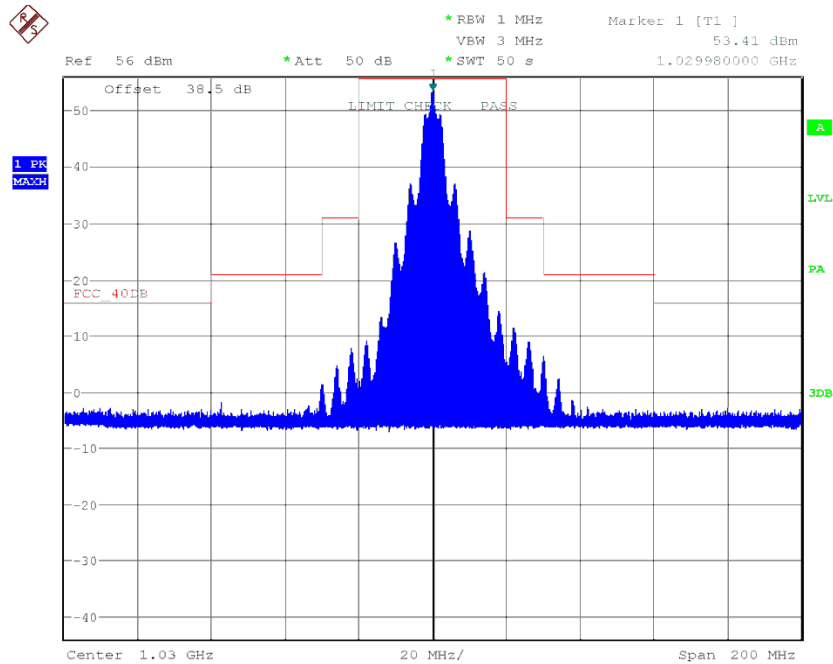
This test shall measure spurious emissions at the antenna terminal using Mode S Test Mode 3. The test shall be completed at with a nominal input voltage level of 115 VAC.

Test Results:

There were no emissions above the FCC Limit of 40 dBc.

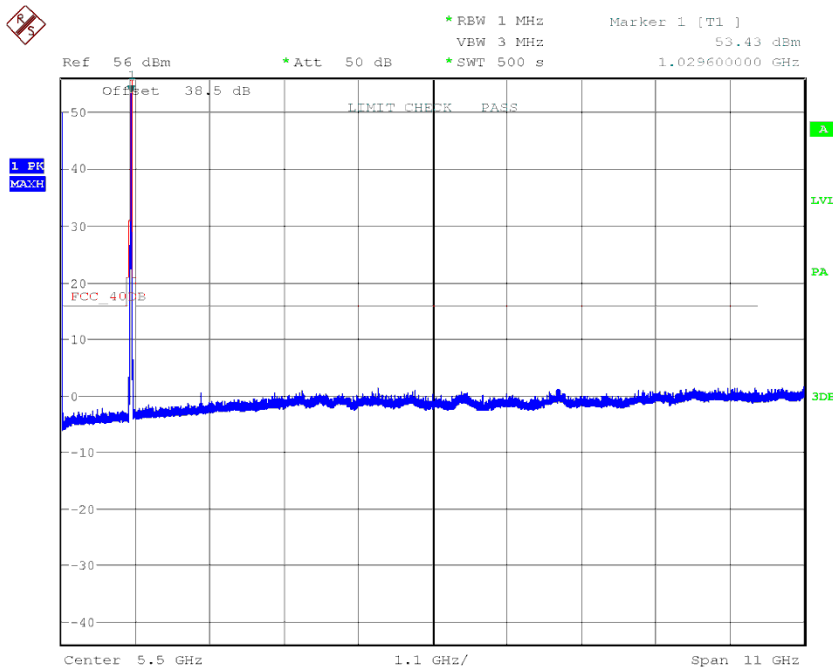
The test results are shown in Figure F-15 through Figure F-16.

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Figure F-15 – Close-In Spurious Emissions at Antenna Terminals



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Figure F-16 – Spurious Emissions at Antenna Terminals

F.8 Field Strength of Spurious Radiation (2.1053)

Requirements:

47 CFR Section 2.1053

(a) Measurements shall be made to detect spurious emissions that may be radiated directly from the cabinet, control circuits, power leads, or intermediate circuit elements under normal conditions of installation and operation. Curves or equivalent data shall be supplied showing the magnitude of each harmonic and other spurious emissions. ... Information submitted shall include the relative radiated power of each spurious emission with reference to the rated power output of the transmitter, assuming all emissions are radiated from halfwave dipole antennas.

(b) The measurements specified in paragraph (a) of this section shall be made for the following equipment:

(2) All equipment operating on frequencies higher than 25 MHz.

47 CFR Section 2.1057(a) ...the spectrum shall be investigated from the lowest radio frequency generated in the equipment without going below 9 kHz, up to at least the frequency shown below:

(1) If the equipment operates below 10 GHz: to the tenth harmonic of the highest fundamental frequency or to 40 GHz, whichever is lower.

47 CFR Section 87.139(a) "... the mean power of any emission must be attenuated below the mean power of the transmitter (pY) as follows:

(1) When the frequency is removed from the assigned frequency by more than 50 percent up to and including 100 percent of the authorized bandwidth the attenuation must be at least 25 dB.

(2) When the frequency is removed from the assigned frequency by more than 100 percent up to and including 250 percent of the authorized bandwidth the attenuation must be at least 35 dB.

(3) When the frequency is removed from the assigned frequency by more than 250 percent of the authorized bandwidth the attenuation for aircraft station transmitters must be at least 40 dB; and the attenuation for aeronautical station transmitters must be at least $43 + \log_{10}(pY)$ dB.

The TTR-2100 has a peak power of 269 Watts.

The Spurious Radiation test Requirements are shown below in Table F-15.

Table F-15 – Spurious Radiation Test Requirements (87.139(a)(3))

Frequency Band	Emission Level	Absolute FCC Limit (Peak)
Below 970 MHz	-40 dBc	+14.3 dBm
From 970 MHz to 1000 MHz	-35 dBc	+19.3 dBm
From 1000 MHz to 1010 MHz	-25 dBc	+29.3 dBm
From 1050 MHz to 1060 MHz	-25 dBc	+29.3 dBm
From 1060 MHz to 1090 MHz	-35 dBc	+19.3 dBm
Over 1090 MHz	-40 dBc	+14.3 dBm

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Assuming the worst case requirement of 40dBc, the maximum field strength is computed by the following procedure:

FCC Limit = 40 dBc

$$\text{Limit (Watts)} = \text{Ptx(average)} * 10^{\frac{-\text{FCC Limit (dBc)}}{10}}$$

This level is converted to a field strength value "E" based on a dipole radiator:

$$E^2 = (30 * G * L) / R \quad \text{Where:}$$

- G = 1.64 (dipole gain)
- L = Limit (Watts)
- R = 1 meter (Test distance)
- E = Field strength (volts/meter).

The TTR-2100 has a peak power of 269 Watts and a maximum duty cycle of 2%.

$$\text{Peak Power} = 10 * \log(269 / 0.001) = 54.30 \text{ dBm, Assumed Duty Cycle} = 0.02$$

$$\text{Ptx(average)} = 269 * 0.02 = 5.38 \text{ Watts average}$$

$$\text{FCC Limit (dBc)} = 40$$

$$\text{Limit (Watts)} = 5.38 \text{ W} * 10^{(-40 / 10)} = 5.38 \times 10^{-4} \text{ W average}$$

$$E^2 = 30 * 1.64 * 5.38 \times 10^{-4} = 0.026 \text{ V}^2/\text{m}^2$$

$$E \text{ (V/m)} = \sqrt{0.026} = 163,000 \text{ } \mu\text{V/m average}$$

$$E \text{ (dB}\mu\text{V/m)} = 20 * \log(163,000 \text{ } \mu\text{V/m)} = 104.227 \text{ dB}\mu\text{V/m}$$

Since the FCC Limit is average power, and the receiver used to detect the radiated power is a peak power reading instrument, the FCC Limit must be converted to peak power, which can be accomplished in two ways. The first method is to simply convert the average limit to peak by taking it out of dB, squaring it, divide by the duty cycle, and convert it back to dB. The second method is to take the difference (in dB) between peak power and average power at a given duty cycle (assumed maximum 2%) and add it to the average limit in dB μ V/m.

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Method 1:

Limit (average) = 104.22 dB μ V/m
Limit (average) = $10^{(104.22/20)} = 163,000 \mu\text{V/m}$
Limit (peak) = $((163,000)^2) / 0.02 = 1.323 \times 10^{12} \mu\text{V/m}$
Limit (peak) = $10 * \log(1.323 \times 10^{12} \mu\text{V/m}) = 121.22 \text{ dB}\mu\text{V/m}$

Method 2:

Limit (average) = 104.22 dB μ V/m
Peak Power (mW) = $10^{(54.3/10)} = 269,000. \text{ mW}$
Average Power (mW) = $269,000 \text{ mW} * 0.02 = 5,380 \text{ mW}$
Average Power (dBm) = $10 * \log(5,380 \text{ mW}) = 37.308 \text{ dBm}$
Difference (dB) = $54.3 \text{ dBm(peak)} - 37.308 \text{ dBm(average)} = 17 \text{ dB}$
Limit (peak) = $104.22 \text{ dB}\mu\text{V/m} + 17 \text{ dB} = 121.22 \text{ dB}\mu\text{V/m}$

Therefore, the absolute limit of **121.22 dB μ V/m** is used for these tests.

Test Equipment and Setup:

The equipment used for Field Strength of Spurious Radiation measurements is shown in Table F-16.

Table F-16 – Equipment Used for Spurious Emissions Tests

Equipment	Manufacturer/Model Number	Specific Identification
Receiver/Transmitter Module	Rockwell Collins TTR-2100 (822-2911-950R)	S/N 44MHK
Test Harness	Rockwell Collins TTR-2100 Breakout Panel	N/A
SST-2010	Rockwell Collins	N/A
RGS-2000	BF Goodrich	
8-Way Combiner	Mini-Circuits, ZB8PD-2000-S+	N/A
Spectrum Analyzer	Rohde & Schwarz, FSU	460-0155-003
AC Power Supply	Agilent 6812B	469-0077-787
Attenuator (20 dB)	Weinschel	N/A
Personal Computer	Generic PC	N/A
Ethernet Switch	D-Link DSS-16+	N/A
EMI Test Receiver (150 kHz – 18 GHz)	Rohde & Schwarz ESU	469-0074-442
Pre-Amplifier (1 GHz – 18 GHz)	Hewlett Packard 8449B, Opt. H02	469-0076-631
Active Monopole Antenna (150 kHz – 25 MHz)	Electro-Metrics RVA30	460-0113-398
Bi-conical Antenna (25 MHz – 200 MHz)	A.H. Systems SAS-200/540	469-0069-226
Antenna, Double Ridge Guide (200 MHz - 1GHz)	EMCO 3106	469-0070-774
Antenna, Double Ridge Guide (1 GHz – 18 GHz)	EMCO 3115	460-0133-793
Antenna, Double Ridge Guide (18 GHz – 40 GHz)	SAS-574	469-0075-832

The test setups for the Field Strength of Spurious Radiation measurements are shown in Figure F-17.

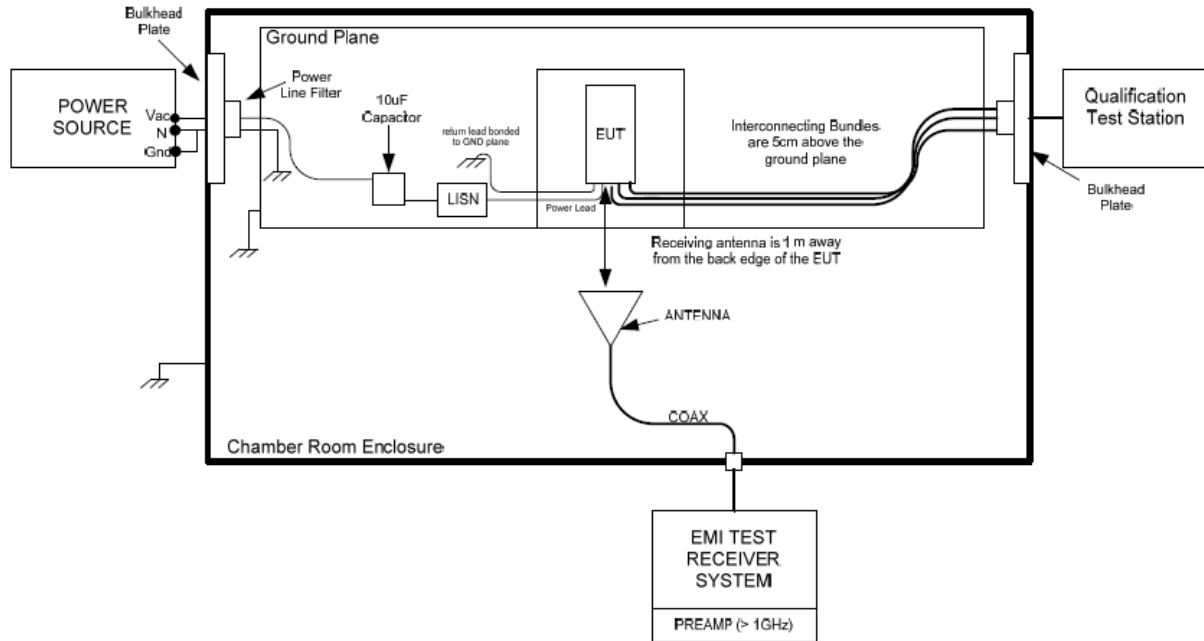


Figure F-17 – Field Strength of Spurious Radiation Test Setup Diagram

Test Procedure:

The test procedure from RTCA DO-160F, Section 21 shall be used. This procedure is used for the certification of civil aviation electronics.

The lowest critical RF frequency generated in the equipment is 20 MHz. DO-160F specifies a start frequency of 100 MHz so this range was extended down to 150 kHz for testing.

The radiated emissions shall be taken with the TTR-2100 in normal TA mode with two simulated Mode C targets and two simulated Mode S targets.

Test Results:

Results are provided in spectral plot forms for vertical and horizontal polarizations from 150 kHz to 10.3 GHz. Note the rod antenna used for emissions testing below 25 MHz only provides measurements in the vertical polarization. No emissions exceeded the FCC limit of 121.22 dBμV/m.

Spectrum plots for are shown in Figure F-18 and Figure F-19.

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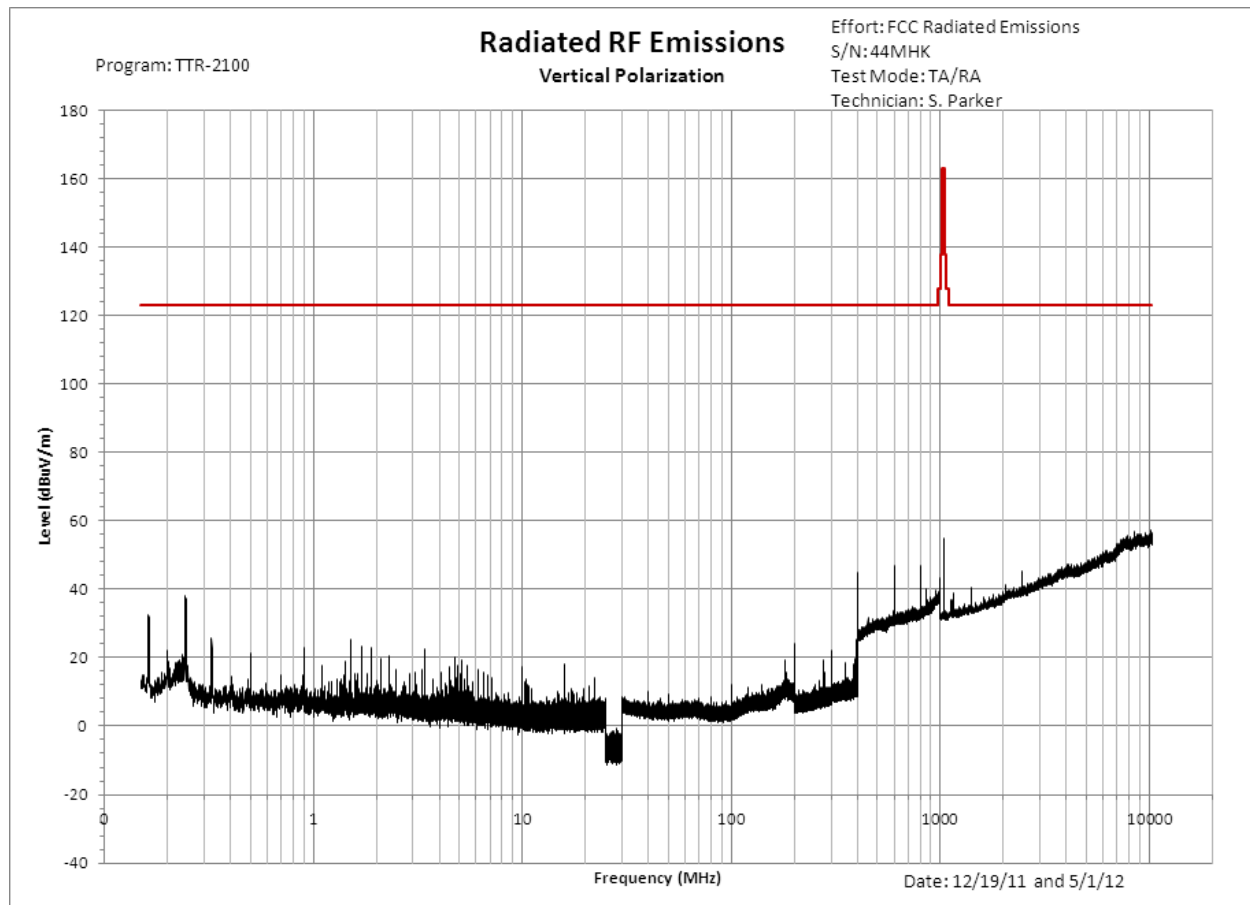


Figure F-18 – Radiated Spurious Emissions, 150 kHz – 10.3 GHz, Vertical Polarization

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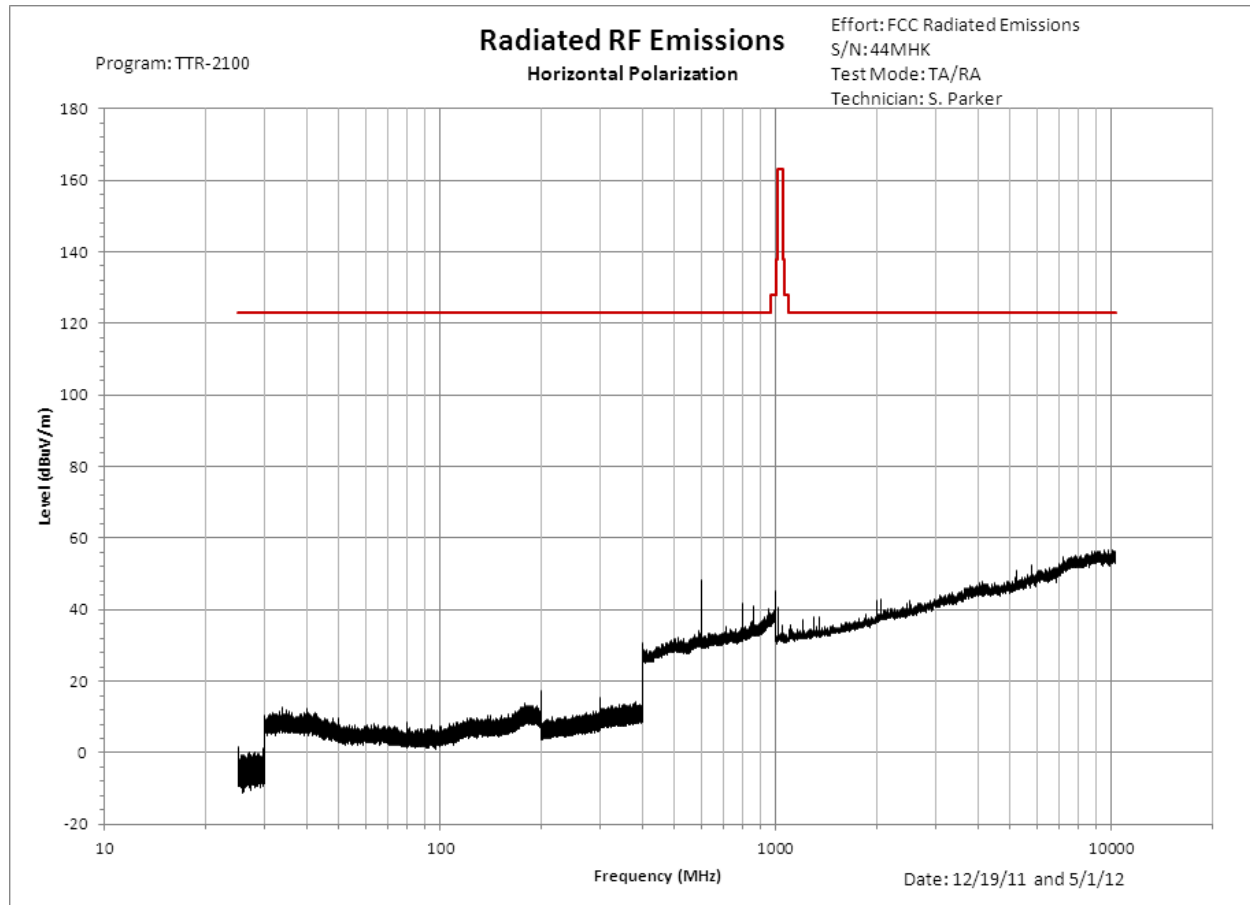


Figure F-19 – Radiated Spurious Emissions, 25 MHz – 10.3 GHz, Horizontal Polarization