TSS-4100

Exhibit F – Test Report

Exhibit F – Required Measurements

The data required by 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 Scope

This section documents the methods and results of FCC Compliance Testing of the Rockwell Collins TSS-4100 Integrated Surveillance System, Collins part number 822-2132-910. Tests performed in this document pertain to the Traffic Module, which implements a complete TCAS and Transponder system in compliance with RTCA documents DO-185A and DO-181C, respectively. The Traffic Module is comprised of two modules, a receiver, part number 653-4570-204 and transmitter 653-4575-004.

Note: The TSS-4100 is the hardware component of the TSS LRU; the TSSA (CPN 810-0052-910) is the software component of the TSS LRU. For the purpose of this document, the combination of the TSS-4100 and the TSSA-4100 will be referred to as the TSS-4100.

F.1.1 Test Procedure and Requirements Matrix

This section documents the test procedures used, and records the results of tests to demonstrate compliance with the applicable requirements of parts 2 and 87 of the FCC Rules and Regulations.

The Table F-1 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

FCC Part 2 Section	FCC 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

Measurement Convention

Pulse Amplitude is defined in relation to another pulse and is measured between pulse peaks.

Pulse Duration is measured between the half voltage points of the leading and trailing edges.

Pulse Rise Time is measured as the time interval between 10 percent and 90 percent of peak amplitude on the leading edge of the pulse.

Pulse Decay Time is measured as the time interval between 90 percent and 10 percent of peak amplitude on the trailing edge of the pulse.

Pulse-to-Pulse Intervals are measured between the half voltage points of their leading edges.

Phase Reversal Location is measured from the 90-degree point of the phase transition.

Phase Reversal Duration is measured between the 10 and 170-degree points of the transition.

Phase Reversal Intervals are measured between 90-degree points of the transitions.

F.1.2 Test Equipment Required

The following test equipment, or equivalent, is required for the performance of these tests. All equipment shall be in valid calibration. Equipment with equivalent or better performance may always be substituted.

Spectrum analyzer	Agilent PSA E4440A
Signal analyzer	Tektronix RSA6114A
Signal analyzer	Agilent MXA9020A with VSA software
Oscilloscope	Tektronix 7105B DPO
30dB 50W Attenuator	Aeroflex/Weinchel/24-30-34
20dB Directional Coupler	Narda/30428-20
1dB 20W Attenuator	Weinschel/9214-1
Universal Power Meter	Gigatronics 8542C
Peak Power Sensor	Gigatronics 80350A
20dB Directional Coupler	Narda/3002-20
Attenuators, as required,	
for example: 6dB Atten.	Weinschel/3M-6
Variable AC Power Supply	Agilent 6812B
Rubidium Frequency Standard	Collins test equipment.
(secondary standard)	

F.2 TSS-4100 Modulation Characteristics (2.1047)

Requirement:

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."

Section 2.1049 goes on to describe conditions of this test for various widely used modulation formats. The relevant section to the TSS-4100 is paragraph 2.1049(d), which states: "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."

That description follows.

F.2.1 ATCRBS Modulation

The Transponder section of the TSS-4100 broadcasts its replies to Air Traffic Control, ATC, at 1090MHz with various pulse widths utilizing Pulse Amplitude Modulation, PAM, and Pulse Position Modulation, PPM, at maximum output power. All of these waveforms are defined in RTCA's DO-181C and DO-185A documents.

The Transponder section of the TSS-4100 utilizes the following waveforms.

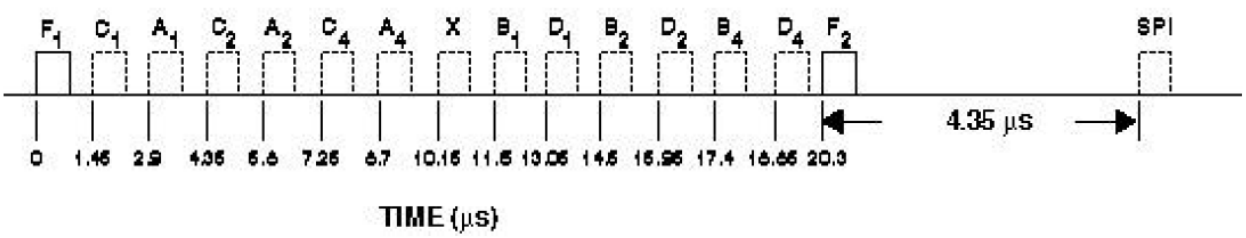
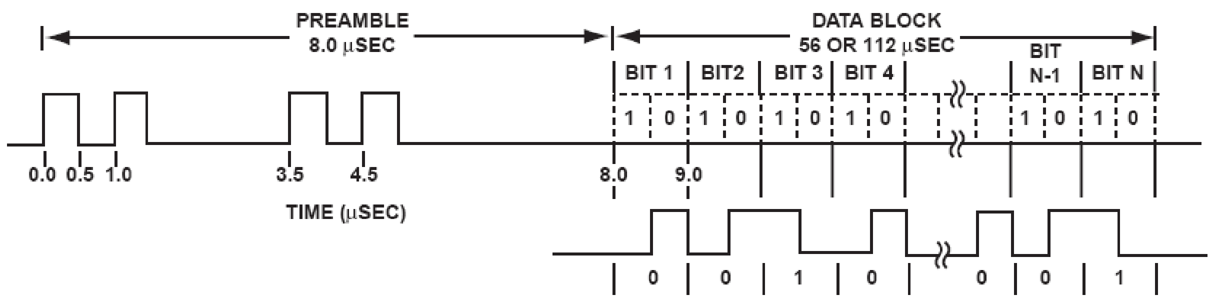


Figure 1 - ATCRBS Reply Pulse Waveform

F.2.2 Mode S Reply

All reply pulses and SPI pulses shall be 450 ±100 nanosecond duration and have rise times of from 50 to 100 nanosecond and decay times of from 50 to 200 nanoseconds. The rise and decay time may be less than 50 nanoseconds, providing the sideband radiation is no greater than that which would be produced theoretically by a trapezoidal wave having the stated rise and decay time.



Example: Reply Data Block Waveform Corresponding to bit sequence 0010...001

Figure 2 - Mode S Reply Waveform

The preamble shall consist of four 500 ± 50 nanosecond pulses. The second, third and fourth pulses shall be spaced 1.0, 3.5 and 4.5 microseconds, respectively, from the first transmitted pulse.

The block of reply data pulses shall begin 8.0 microseconds after the first transmitted pulse. Either 56 or 112 microsecond intervals shall be assigned to each transmission. A pulse with a width of 500 ± 50 nanosecond shall be transmitted either in the first or the second half of each interval. If a pulse transmitted in the second half of one interval is followed by another pulse transmitted in the first half of the next interval, the two pulses shall merge and a 1.0 microsecond ± 50 nanosecond pulse shall be transmitted.

The pulse amplitude variation between one pulse and any other pulse in a reply shall not exceed 2 dB. The pulse rise time shall not exceed 100 nanoseconds. The pulse decay time shall not exceed 200 nanoseconds.

Mode S reply pulses shall start at a defined multiple of 500 nanoseconds from the first transmitted pulse. The pulse position tolerance shall be ± 50 nanosecond, measured from the first pulse of the reply.

F.2.3 Spectral Mask for Transponder Transmissions

Frequency Difference (MHz from Carrier)			Maximum Relative Response (dB Down From Peak)
> 1.3	and	< 7	3
> 7	and	< 23	20
> 23	and	< 78	40
> 78			60

The Traffic Alert and Collision Avoidance System, TCAS, section of the TSS-4100 transmits on 1030MHz utilizing PAM, PPM, and Differential Bi-Phase Shift Keying (DPSK) modes of operation. All of these waveforms are defined in RTCA's DO-181 and DO-185 documents.

F.2.4 Mode C-Only All-Call Interrogation

The TCAS section of the TSS-4100 utilizes the following waveforms.

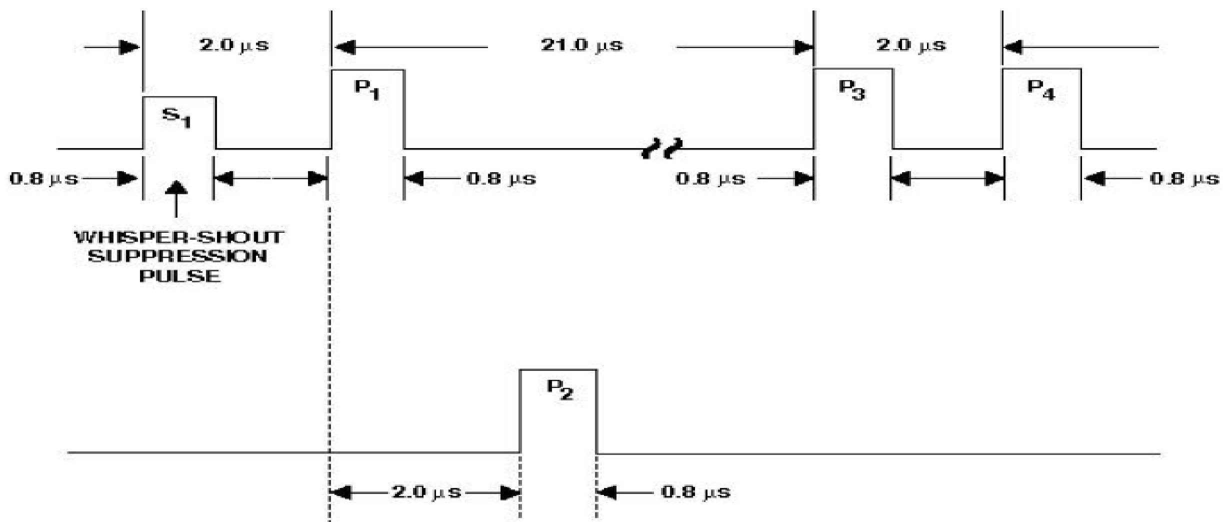


Figure 3 - Mode C-Only All-Call Interrogation Pulse Sequence.

Mode C interrogations from TCAS II equipment employs 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.

(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.2.5 Mode-S Interrogation

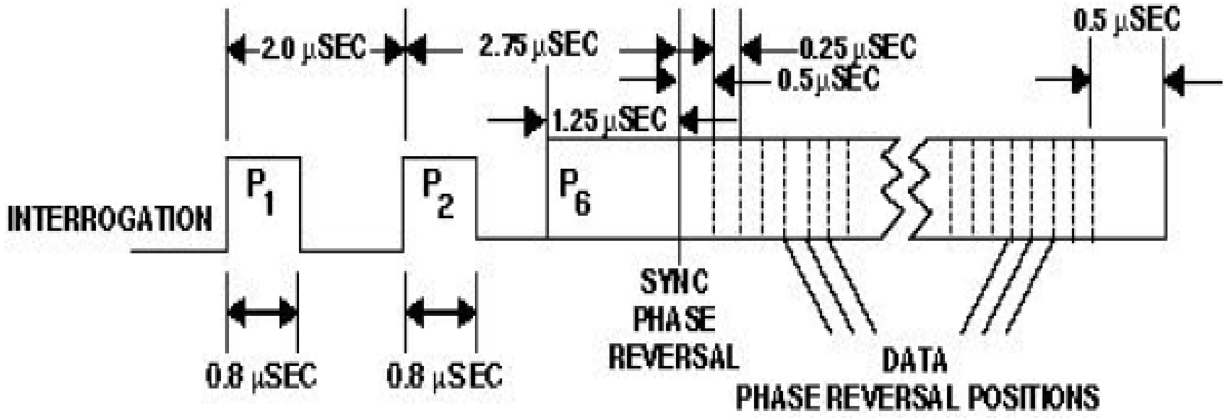


Figure 4 - Mode-S Interrogation Pulse Sequence for TCAS

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.

(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 ± 40 nanoseconds 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 microseconds ± 40 nanoseconds. The sync phase reversal of P6 occurs 1.25 microseconds ± 40 nanoseconds 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.2.6 Spectral Mask for Interrogation

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

F.2.7 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.2.8 Minimum Basic Whisper-Shout Sequence

```
                  MINIMUM EFFECTIVE RADIATED INTERFERENCE LIMITING

 STEP                     INTERROGATION POWER LEVEL    PRIORITY              MTL
NUMBER                              (dBm)                                   (-dBm)
        _______________________________
   1  |                  S.........I|    52     Note: Each 1 dB              74
      | Top Antenna                 |           reduction in the
   2  |              S.........I    |    48     sequence follows             74
      |                    Forward  |           the priority for
   3  |          S.........I        |    44     the forward beam             72
      |                  Direction  |           in Figure 2-9
   4  |      S.........I            |    40     (e.g. 1,5,9,··etc)           68
      |                             |
   5  |  S.........I                |    36                                  64
      |
   6     .........I                      32                                  60


 7,8  |              S.........I    |    48     Note: Each 1 dB              74
      | Top Antenna                 |           reduction in the
 9,10 |          S.........I        |    44     sequence follows             72
      |               Left & Right  |           the priority for
11,12 |      S.........I            |    40     the right/left               68
      |                  Direction  |           beam in Figure 2-9
13,14 |  S.........I                |    36     (e.g. 2/3,6/7···etc)         64
      |                             |
15,16    .........I                      32                                  60


  17  |         S.........I         |    43     Note: Each 1 dB              71
      | Top Antenna                 |           reduction follows
  18  |     S.........I             |    39     the priority for the         67
      |              Aft Direction  |           aft beam in Fig. 2-9
  19  |  S.........I                |    35     (e.g. 4,8,12····etc)         63
      |                             |
  20     .........I                      31                                  59


  21  |      S..I                   |    34     Note: Each 1 dB              62
      | Bottom Omni                 |           reduction in the
  22  |    S..I                     |    32     sequence follows             60
      |                             |           the priority for
  23  |  S..I                       |    30     the bottom ant in            58
      |                             |           Figure 2-9
  24      ...I                           28     (e.g. 80,81,82··etc)         56
       ___________________________________
       |         |         |         |
      22        32        42        52
       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.

"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.

Top Antenna Forward Beam Timing for Six Power Steps in the Minimum Basic Whisper-Shout Sequence. First Pulse Of Interrogation Serves As Second Pulse Of Suppression.

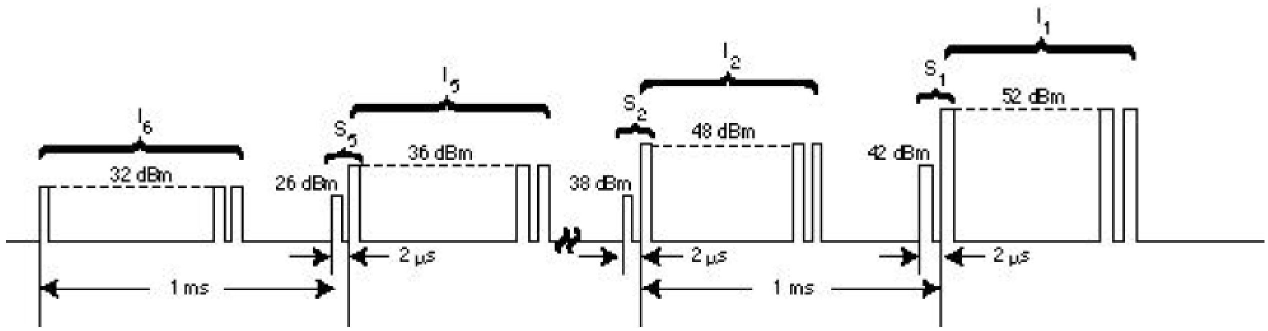


Figure 5 - Basic Whisper-Shout Sequence

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.

F.2.9 Higher Capability Whisper-Shout Sequences

For Improved De-Garbling Performance

The extent to which a whisper-shout interrogation sequence reduces synchronous garble depends on the resolution of its interrogation steps. The resolution of a whisper-shout sequence is best described in terms of "bin-width," which is the difference in dB between an interrogation and the associated suppression. For example, the bin-width of the minimum basic 6-level sequence illustrated on the previous page is 10 dB. The following table provides improvement factors for higher resolution whisper-shout sequences relative to the minimum basic 6-level sequence.

Improvement Factors for Higher Resolution Whisper-Shout Sequences

Bin-Width (dB)	Relative Degarbling Improvement Factor
10	1.0
9	1.1
8	1.2
7	1.4
6	1.5
5	1.8
4	2.0
3	2.5
2	3.3
1	4.4

High Resolution Whisper-Shout Sequence

STEP NUMBER			MINIMUM EFFECTIVE RADIATED INTERROGATION POWER LEVEL (dBm)	INTERFERENCE LIMITING PRIORITY	MTL (-dBm)
1		S..I	52	1	74
2	TOP	S.I	51	5	74
3	ANTENNA	S..I	50	9	74
4		S.I	49	13	74
5	FORWARD	S..I	48	17	74
6	DIRECTION	S.I	47	21	74
7		S..I	46	25	74
8		S.I	45	29	73
9		S..I	44	33	72
10		S.I	43	37	71
11		S..I	42	41	70
12		S.I	41	45	69
13		S..I	40	49	68
14		S.I	39	53	67
15		S..I	38	57	66
16		S.I	37	61	65
17		S..I	36	64	64
18		S.I	35	67	63
19		S..I	34	70	62
20		S.I	33	73	61
21		S..I	32	76	60
22		S.I	31	77	59
23		S..I	30	78	58
24		I	29	79	57

27 37 47 57

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.

The figure above and on the following two pages defines the high resolution whisper-shout sequence that's used in conjunction with a four-beam top-mounted directional antenna for high density ATCRBS 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.

```
                                          MINIMUM EFFECTIVE RADIATED   INTERFERENCE
STEP                                      INTERROGATION POWER LEVEL    LIMITING         MTL
NUMBER                                             (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      TOP      |            39                  20              67
    70 |          S..I     ANTENNA    |            38                  24              66
    71 |          S.I                 |            37                  28              65
    72 |        S..I         AFT      |            36                  32              64
    73 |        S.I        DIRECTION  |            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
       |______________________________|____
           |         |         |         |
           27        37        47        57
        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.

```
                                                              INTERFERENCE
                                      MINIMUM EFFECTIVE RADIATED   LIMITING
 STEP                                 INTERROGATION POWER LEVEL    PRIORITY      MTL
NUMBER                                          (dBm)                          (-dBm)

      _______________________________________
 80  |             S..I                |               34            80          62
 81  |           S..I      BOTTOM      |               32            81          60
 82  |         S..I        OMNI        |               30            82          58
 83  |        ..I                      |               28            83          56
     |_________________________________|_____
          |         |         |         |
         27        37        47        57
     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.

All whisper-shout sequence designs must satisfy the following requirements:

a. The total extent of the sequence in the forward direction must span a dynamic range of at least 24 dB where dynamic range is defined as the product of the number of whisper-shout steps and step increment. For example, a dynamic range of 24 dB, the 6-level whisper-shout sequence has a step increment of 4 dB.

b. The nominal power level of each of the interrogation pulses, if arranged in a monotonic sequence, shall increment linearly throughout the entire power range. The transmission of the interrogation steps can actually occur in any order without affecting the de-garbling performance of the whisper-shout sequence.

c. The tolerance associated with each of the interrogation pulses is the smaller of ±2 dB or 1/2 of the nominal step increment size of a monotonically arranged sequence. The tolerance associated with the nominal bin-width is the smaller of ±2 dB or 1/4 of the nominal bin-width.

d. The power level of the highest powered interrogation shall be such as to provide adequate coverage at the cross-over points of adjacent beams of a directional antenna. For a four-beam antenna the Effective Radiated Power of the highest powered interrogation shall be at least +52 dBm.

e. The level of the suppression pulse relative to the preceding interrogation pulses is within ±0.5 dB of the difference between the step increment value and the bin-width value where step increment is determined from paragraph a. above and bin-width is related to the number of steps as follows;

$$\text{Bin-width} = -0.325\ (\text{number of steps}) + 10.3.$$

f. The Minimum Trigger Level, MTL, used in the reply listening period following each interrogation shall be related to the interrogation power in such a fashion as to maintain a balance between the uplink and downlink surveillance performance.

g. The MTL values are based on the assumption that replies to all interrogations are received omni-directionally. If a directional-receive antenna is used, the MTL values must be adjusted to account for the antenna gain. For example, for a net antenna gain of +3 dB, all MTL values would be raised by 3 dB relative to the values associated with an omni-directional antenna.

h. Although the steps in the sequence may be transmitted in any order, the steps shall be dropped in order of decreasing power level when the sequence is truncated as a result of interference limiting.

F.2.10 Special Test Modes

Interrogation Test Modes
The equipment provides the following interrogation test modes for use with the bench test procedures. These modes are not flight crew selectable.

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.2.4) 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.

F.4 TSS-4100 RF Power Output (2.1046)

Requirement:

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.”

Section 2.1033(c) (8) lists required information for the submission of this report: “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.”

The pulse amplifiers used in the TSS-4100 are not aligned by adjusting the current and voltage to a set of required operating conditions. The power is set by adjusting the LO drive along with several other adjustments, and the current is whatever is required to achieve that power. The operating currents are sourced by large storage capacitors on the power amplifier/modulator, and the voltage on the final amplifying devices is the result of that current being provided through the Effective Series Resistance of those capacitors. The power supply merely serves to re-charge the capacitors. It is not capable of supplying the current for the final transistors.

The Power Amplifier is powered by a nominal +31.5 VDC regulator contained on the DSP Card (828-1843-XXX) in the TSS-4100. The voltage and current on the power devices are not measured during this alignment and are not adjustable.

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

Measurements are made on test equipment calibrated on a scheduled basis with standards traceable to the NIST.

Test Procedure:

The peak power output of the TSS-4100 was measured using test equipment connected to one of the eight antenna terminals. The equipment used for the RF Power Output Test is listed in section 0 of this document.

Prior to measuring RF output power the RF path loss from the transmitter output to the power meter sensor is calibrated with appropriate equipment. The Gigatronics 8542C power meter is zeroed out, calibrated to its internal calibration source and this path loss factor applied to the reading. The power meter is set up to measure peak power 400ns after the pulse reaches 50% of full power. The power output was measured during the four specified operating modes with the transmitter locked to the appropriate frequency.

Test Setup:

A functional block diagram of the equipment setup for the RF Power Output Test is shown in Figure 6.

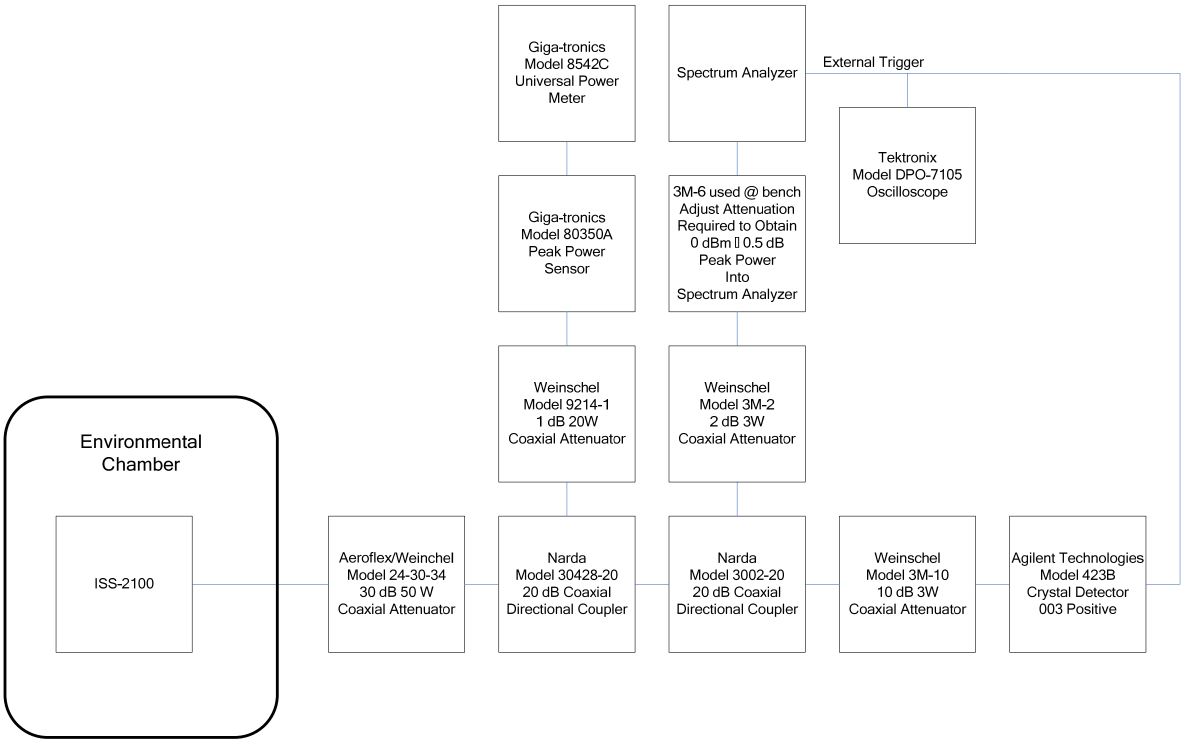


Figure 6 - RF Test Setup

Measurements:

The measured transmitter power output for each of the operating conditions is contained below:

Table F- 2 - RF Power Output

UUT Serial Number	
ATCRBS	400 W
Mode S reply	438 W
Mode C Interrogate	438 W
Mode S Interrogate	438 W

F.5 Frequency Stability (2.1055)

Requirement:

2.1055(a) (1) The frequency shall be measured with variation of ambient temperature from -30° to +50° centigrade for equipment licensed for use aboard aircraft in the Aviation Services under 47CFR2.1055.

(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. The short term transient effects on the frequency of the transmitter due to keying (except for broadcast transmitters) and any heating element cycling normally occurring at each ambient temperature level also shall be shown. Only the portion or portions of the transmitter containing the frequency determining and stabilizing circuitry need be subjected to the temperature variation test.

(c) Not applicable; the reference source is not an ovenized oscillator.

(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.

Definition from 47CFR2.1 *Frequency Tolerance.* The maximum permissible departure by the center frequency of the frequency band occupied by an emission from the assigned frequency or, by the characteristic frequency of an emission from the reference frequency.

The circuitry used for frequency determination in the TSS-4100 is a phase locked loop (PLL) referencing a 60.000 MHz Temperature Compensated Crystal Oscillator (TCXO) with a total accuracy over 10 years of 8.5 ppm. The chief property of such a design is that the frequency accuracy and stability of all channels is determined by the reference oscillator. Services that use a PLL to generate hundreds or thousands of channels do not repeat this measurement on every channel, just a representative one. Accordingly, we take this to mean that we may use one frequency to characterize the performance of our system.

87.133 (a) Frequency tolerance for frequency band (7) 950 to 1215 MHz is 20 PPM; this equates to ±20,600 Hz @1030 MHz and ±21,800 Hz @1090 MHz.

RTCA limits for the different services were used in design to set the performance limits. The most stringent of the service requirements is 1030 MHz TCAS, with a required accuracy of ± 10 kHz (DO-185A, Para 2.2.3.5). This requirement is ½ of the Part 87.133 requirement. Since the same reference is used for both frequencies in the TSS-4100, the performance in PPM will be the same at both frequencies.

Test Procedure:

The TSS-4100 was placed in a temperature chamber with all other equipment outside at room ambient. The test unit was operated at the minimum, nominal and maximum applied AC voltages. Sufficient time was allowed to stabilize the unit after the chamber reached the desired temperature. Data was taken in 10 degree steps. The unit was tested at three AC voltages for each temperature step.

The procedure to configure the spectrum analyzer to make measurement is listed below. Table F- 3 is a listing of these measurements. The Mode S Test Mode 3 waveform is selected here since the longest pulses will always give the most accurate center frequency measurement.

Table F- 3 - Transmitted Frequency vs. Input Voltage and Temperature
Mode S Interrogation P6L Pulse (1.03GHz)

DC Supply Voltage	**23.8**	**28.0**	**32.2**
% of Full Supply	**100**	**85**	**115**
Temperature	**Frequency (GHz)**	**Frequency (GHz)**	**Frequency (GHz)**
-30□C	1.029999000	1.029999000	1.029998000
-20□C	1.029998300	1.029998800	1.029999000
-10□C	1.029998800	1.029999700	1.029999000
0□C	1.029999200	1.029998500	1.029998800
10□C	1.029999200	1.029999200	1.029998800
20□C	1.029998800	1.029999500	1.029998800
30□C	1.029998700	1.029998800	1.029998700
40□C	1.029999300	1.029998800	1.029999200
50□C	1.029998700	1.029999300	1.029999500

Frequency measurement with PSA spectrum analyzer.

Center Frequency: 1030.000 MHz
Resolution Bandwidth: 1 kHz
Scan Width: 100 kHz span or 10 kHz/div
Reference Level: 0 dBm
Display Mode: 10 dB/div
Input Attenuation: 10 dB

Prior to measuring the center frequency of the transmitter, the PSA frequency accuracy shall be checked with a signal generator of known accuracy. For best accuracy in the measurement, the PSA and generator should both be locked to an external Rubidium secondary frequency standard. Since many of the test instruments now utilize auto-correcting OCXO's, or other high quality references, use of the Rubidium standard for measurement is not required, but any errors detected with the use of the signal generator shall be accounted for.

Connect the attenuators to the selected antenna port. Program TCAS for Mode S test Mode 3, 50 Hz rate.

Adjust reference level until peak of spectrum is within one division of top of display. Switch display mode to 2.0 dB/div and set Trace display to Max hold. Observe frequency of the spectrum peak and place a marker on the center frequency. Record the peak frequency. While at the same temperature, repeat for the minimum and maximum AC voltages. If there is residual frequency error in the PSA, correct for it before entering frequency data in these tables.

Measurement of Transmitter Frequency.

Alternative Procedure:

Frequency measurement setup for RSA6114A spectrum analyzer.

1) Set Transmitter into Mode S Test Mode 3, un-modulated long P6 waveform
2) Depress Preset button
3) Set CF to 1.03GHz
4) Depress Display button
5) ADD Time Overview
6) Close window by clicking on the OK button
7) Depress Trigger button
8) Select Event tab
9) Select Triggered Operation
10) Set Source to Trig In (front)
11) Set Slope to Rise
12) Set Level to 0.10V
13) Select Time tab
14) Set Position to 1%
15) Depress Amplitude button
16) Deselect Auto button next to Internal Attenuator
17) Set Attenuator to 20dB
18) Depress Analysis button
19) Select Spectrum Time tab
20) Set to Use Analysis Time
21) Select Analysis Time tab
22) Set Analysis Length 24us
23) Set Analysis Offset 11.2us
24) Select Spectrum Screen
25) Set Span 500kHz
26) Depress Settings button
27) Select Traces tab
28) Set Function to Average
29) Select Scale tab
30) Set Scale to 50dB
31) Select Prefs tab
32) Set Trace Points to 10401
33) Close Spectrum Settings Screen by clicking on the X
34) Expand Spectrum Window
35) Peak Search Marker
36) Ensure marker readout indicates a signal strength of 0 ±0.5dBm
37) If the signal level is not as specified above adjust pads between coupler and spectrum analyzer.

38) Set top of screen to 0dBm
39) Press the peak marker button to read the output frequency.
40) Read Frequency in output window at bottom of screen.

Note: This setup may now be saved for future reuse as a setup file.

After the spectrum analyzer has defined the characteristics of the output spectrum specified in the above setup push the save button. Save the screen as a JPG file in the FCC folder with the name “Frequency Measurement” followed by the serial number of the unit under test.

Equipment Setup:

The test setup for the Frequency Stability test is shown in Figure 6.

Temperature Test Measurements:

Raw temperature test results are shown in Table F- 3 and Figure 7 shows a plot of frequency vs. temperature for three power supply settings. Note the worst case error is approximately 1/5 of the limit. Also, note that there are no obvious trends versus temperature, and the frequency differences are essentially randomly distributed.

Transient Measurement:

Figure 8 shows a plot of transient frequency error at the start of a pulse. The startup transient is approximately 20 kHz and has ended in one microsecond.

Transient Measurement Procedure:

1) Set Transmitter into Mode S Test Mode 3, un-modulated long P6 waveform
2) Depress Preset button
3) Set CF to 1.03GHz
4) Set Span 110MHz
5) Depress Display button
6) ADD Amplitude vs. Time
7) ADD Frequency vs. Time
8) Select Spectrum Icon in selected displays box and depress Remove button
9) Click OK button
10) Depress Trigger button
11) Select Event tab
12) Select Triggered Operation
13) Set Source to Trig In (front)
14) Set Level to 0.10V
15) Select Time tab
16) Set Position to 2%
17) Depress Amplitude button
18) Deselect Auto button next to Internal Attenuator
19) Set Attenuator to 20dB
20) Depress Analysis button
21) Select Spectrum Time tab
22) Set to Use Analysis Time

23) Select Analysis Time tab
24) Set Analysis Length 5us
25) Set Analysis Offset 4.325us
26) Depress Settings button
27) Select Traces tab
28) Set Function to Average
29) Set number next to Function to 32
30) Select Scale tab
31) Set Vertical Scale to 20dB
32) Set Vertical Position to 2dBm
33) Set Horizontal Scale to 420ns
34) Set Horizontal Position to 4.33us
35) Select Prefs tab
36) Set Max trace points to Never decimate
37) Select Frequency vs. Time window
38) Select Trace tab
39) Set Function to Average
40) Set number next to Function to 32
41) Select Scale tab
42) Set Vertical Scale to 4MHz
43) Set Horizontal Scale to 420ns
44) Set Horizontal Position to 4.33us
45) Close Settings Screen by clicking on the X
46) Ensure maximum indication of signal is 0 ±0.5dBm on Amplitude vs. Time display
47) If the signal level is not as specified above adjust pads between coupler and RSA6114A

Note: This setup may now be saved for future reuse as a setup file.

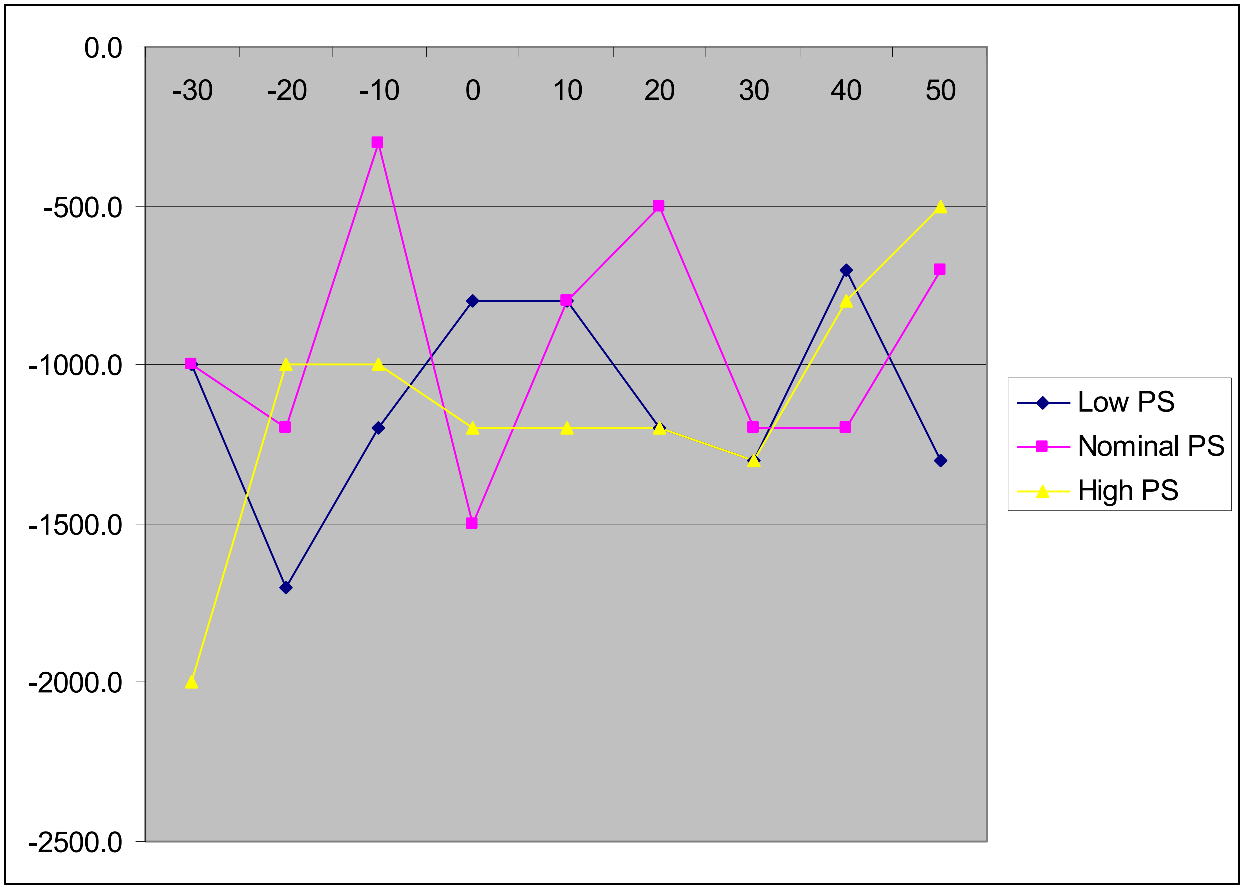


Figure 7 - Transmitter Frequency Error vs. Temperature and Power Supply (Limit is 20,600 Hz, off-scale)

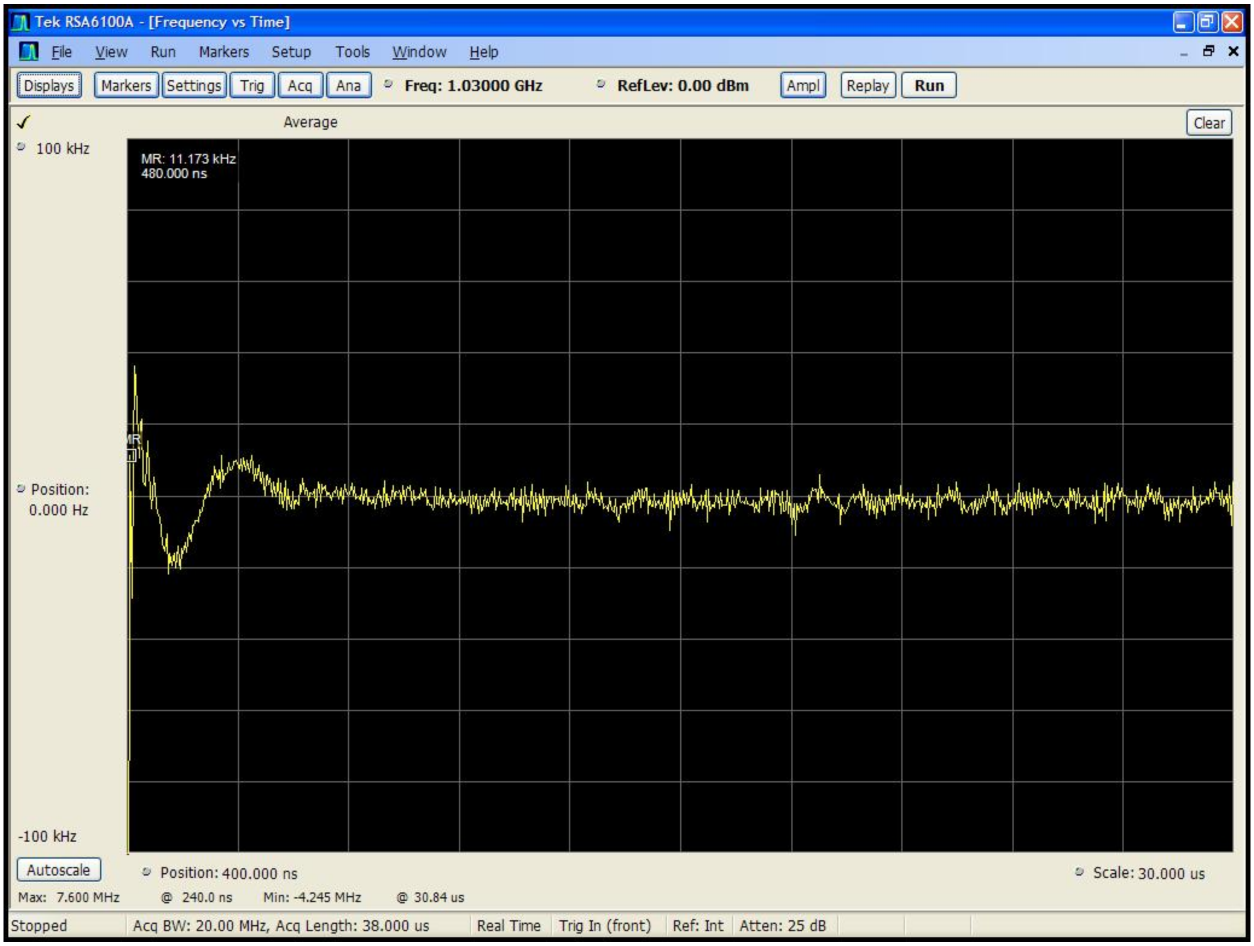


Figure 8 - First 30 Microseconds of P6 Long Pulse

F.6 TSS-4100 Occupied Bandwidth (2.1049)

Requirement:

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.”

Section 2.1049(h) “Transmitters employing digital modulation techniques—when modulated by an input signal such that its amplitude and symbol rate represent the maximum rated conditions under which the equipment will be operated. The signal shall be applied through any filter networks, pseudo-random generators or other devices required in normal service. Additionally, the occupied bandwidth shall be shown for operation with any devices used for modifying the spectrum when such devices are optional at the discretion of the user.”

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.

Section 87.137 Authorized Bandwidth for Emission Type V1D – Note 9 “To be specified on license.”

In accordance with our previous products in these services, we have a necessary bandwidth (when allowing for drift of alignment parameters over a 10 year service life, and manufacturing process drift) of

1. Transponder (DO-181C) emissions per 13M5M1D
2. TCAS (DO-185A) emissions per 27M7V1D

Test Procedure:

The Occupied Bandwidth of the TSS-4100 was measured using test equipment connected to one of the eight antenna terminals.

Measurement Objectives:

The TSS-4100 Transponder/TCAS system is designed to operate on two separate frequencies in the band at 1.030 and 1.090 GHz. During normal operation, the transmitter responds on the

1.090 GHz frequency as required by ground or aircraft based interrogations. In addition to responding to interrogations the TCAS system transmits interrogations on the 1.030 GHz frequency to track potential traffic issues. By characterizing the two interrogation waveforms we get a good idea of how the system behaves.

One of the four waveforms used by the TSS-4100 demonstrates the extreme case for occupied bandwidth. Mode S-Interrogation has the broadest spectrum because of its use of BPSK at 4 Mb by transmitting 250 ns data chips. This waveform, one of the Special Test Modes described in section F.3, is Mode S Test Mode 2. It provides a maximum number of transitions and the widest occupied bandwidth of all the waveforms used.

The opposite extreme is when the TSS-4100 uses a waveform that occupies about half of the Mode S occupied bandwidth, Mode C-Only All-Call Interrogation Pulse Sequence. This waveform, one of the Special Test Modes described in section F.2.11, is Mode C Test Mode 1. For measurement of Transponder mode occupied BW, Isolation Mode Software, not flight software, is required to command the TSS-4100 to produce the desired pulse pattern. This is characteristic of DO-181 compliant transponders.

In operation, the bandwidth used by the TSS-4100 will change with duty cycle of the various transmissions required, and the exact data being transmitted in individual messages.

Measurements:

The spectrum analyzer was set up to measure 99% occupied bandwidth, by testing for 1/2 % of the power above and below the center frequency. This corresponds to a level -26 dB to the maximum power of the transmission. Table F- 4 contains the test result for the Mode-S Interrogation Pulse and the Mode C-Only All-Call Interrogation Pulse operating modes.

Table F- 4 - TSS-4100 Occupied Bandwidth Measurement Results

Mode of Operation	99% Power Occupied Bandwidth	Reference Figure
Mode C-Only All-Call Interrogation Pulse	7.33 MHz	9
Mode-S Constant “1” Pattern	19.9 MHz	10
Mode-A ATCRBS	7.40 MHz	11

Occupied BW Measurement for a Spectrum Analyzer

Set the unit to produce only the desired pulses.
Center Frequency: As appropriate for the mode transmitted
Resolution Bandwidth: 50 kHz
Scan Width: 20 MHz span or 200 kHz/div
Reference Level: 0 dBm
Display Mode: 10 dB/div
Input Attenuation: 10 dB

Connect the attenuators to the selected antenna port.

Set the Trace function to Max hold. Sweep until a solid representation of the transmitted signal is present.

Place a marker on the peak of the spectrum and establish a delta reference. Tune the marker down in frequency until the amplitude is -26 dBc. Note the frequency. Tune the marker up in frequency until the same amplitude, -26 dBc, is obtained again and note this frequency. The difference between these two frequencies is the occupied bandwidth.

Save a screen capture of the result screen for the measurement.

Some spectrum analyzers are configurable to allow making the occupied BW measurement automatically. As long as the occupied BW can be defined as the 99% power BW, this is an acceptable method of measuring.

Repeat for all modes.

Alternative Procedure:

Occupied Bandwidth measurement setup for RSA6114A Spectrum Analyzer.

1) Set Transmitter into Mode S Test Mode 2, modulated long P6 waveform
2) Depress Preset button
3) Set CF to 1.03GHz
4) Depress Display button
5) ADD Time Overview
6) Click OK button
7) Depress Trigger button
8) Select Event tab
9) Select Triggered Operation
10) Set Source to Trig In (front)
11) Set Level to 0.10V
12) Select Time tab
13) Set Position to 1%
14) Depress Analysis button
15) Select Spectrum Time tab
16) Set to Use Analysis Time
17) Select Analysis Time tab
18) Set Analysis Length 40us
19) Select Spectrum Window
20) Depress Settings button
21) Select Freq & Span tab
22) Depress Max Real time Span
23) Select BW tab
24) Set RBW to 60kHz
25) Select Traces tab
26) Set Function to Average
27) Select Scale tab
28) Set Scale to 80dB
29) Select Prefs tab
30) Set Trace points to 10401

31) Depress Display button
32) ADD Occupied Bandwidth from RF Measurement Folder
33) Click OK button
34) Depress Settings button
35) Set RBW to 60K
36) Select Parameters tab
37) Set Measurement BW to 109MHz
38) Depress Amplitude button
39) Set Internal Attenuator to 15 dB
40) Close Settings Screen by clicking on the X
41) Select Occupied BW & xdB BW Window
42) Read Output waveform OBW

Note: This setup may now be saved for future reuse as a setup file.

After the spectrum analyzer has defined the characteristics of the output spectrum specified in the above setup push the save button. Save the screen as a JPG file in the FCC folder.

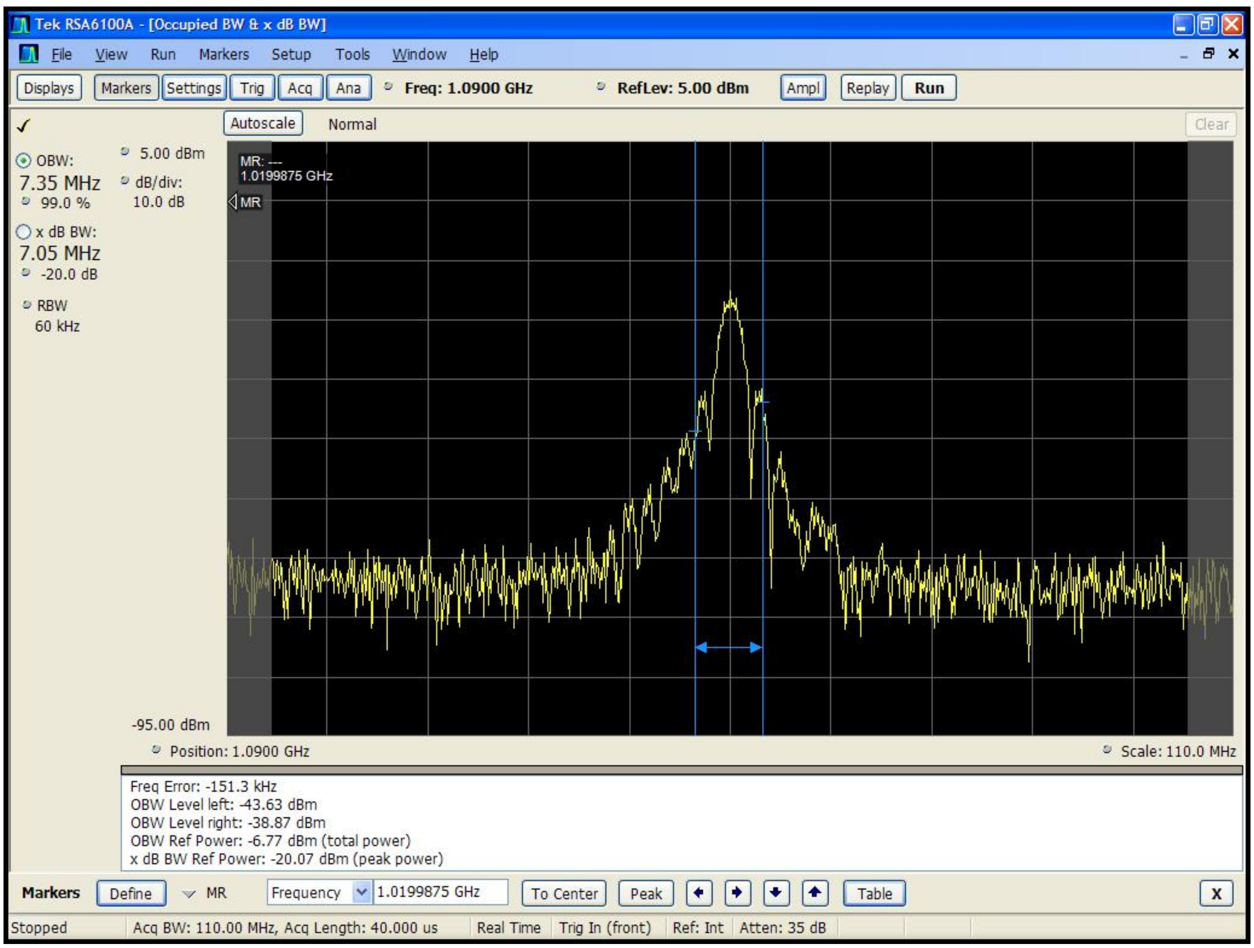


Figure 9 – Occupied bandwidth – Mode C-Only All Call Interrogation 1.03 GHz

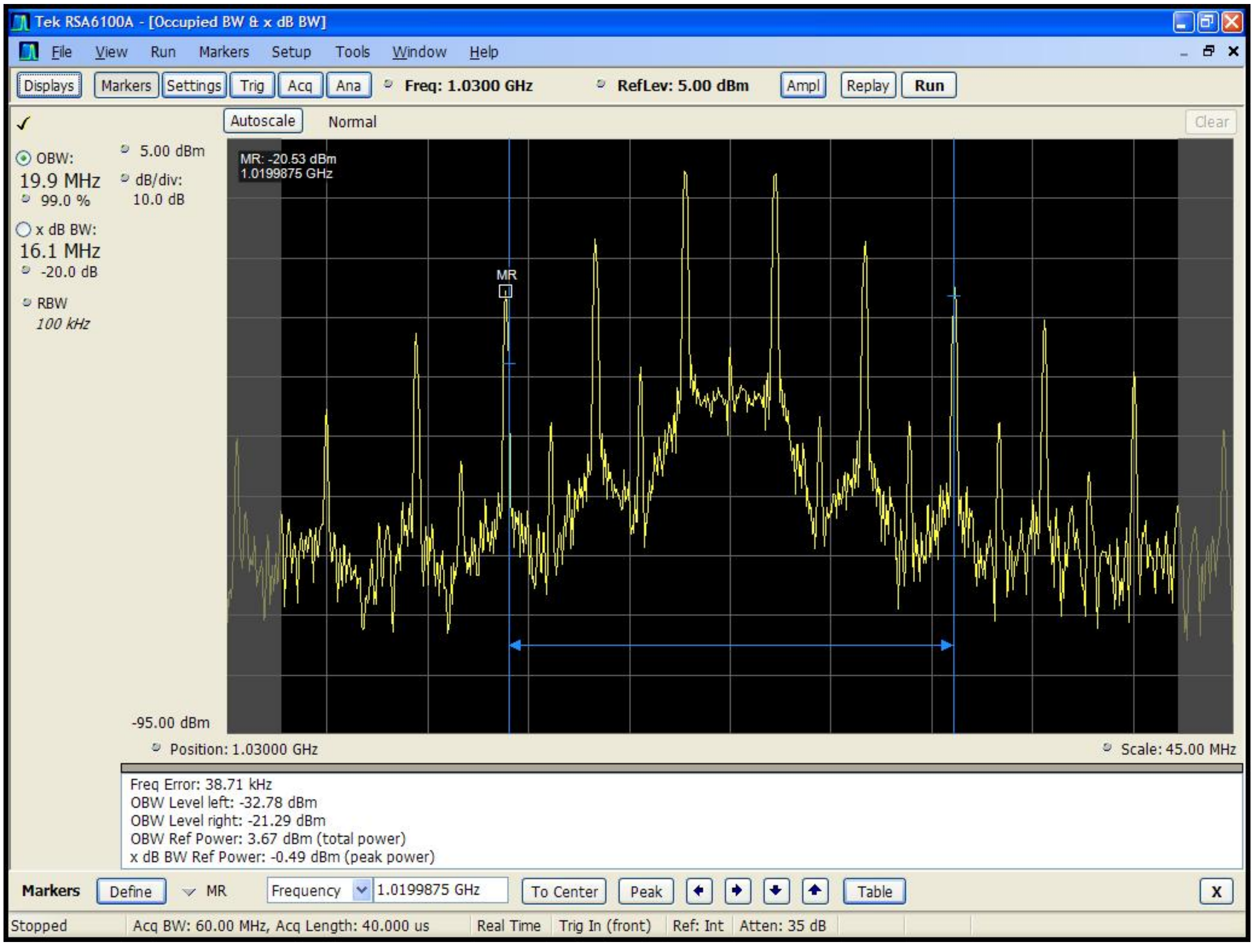


Figure 10 – Occupied bandwidth – Mode-S Interrogation 1.03 GHz

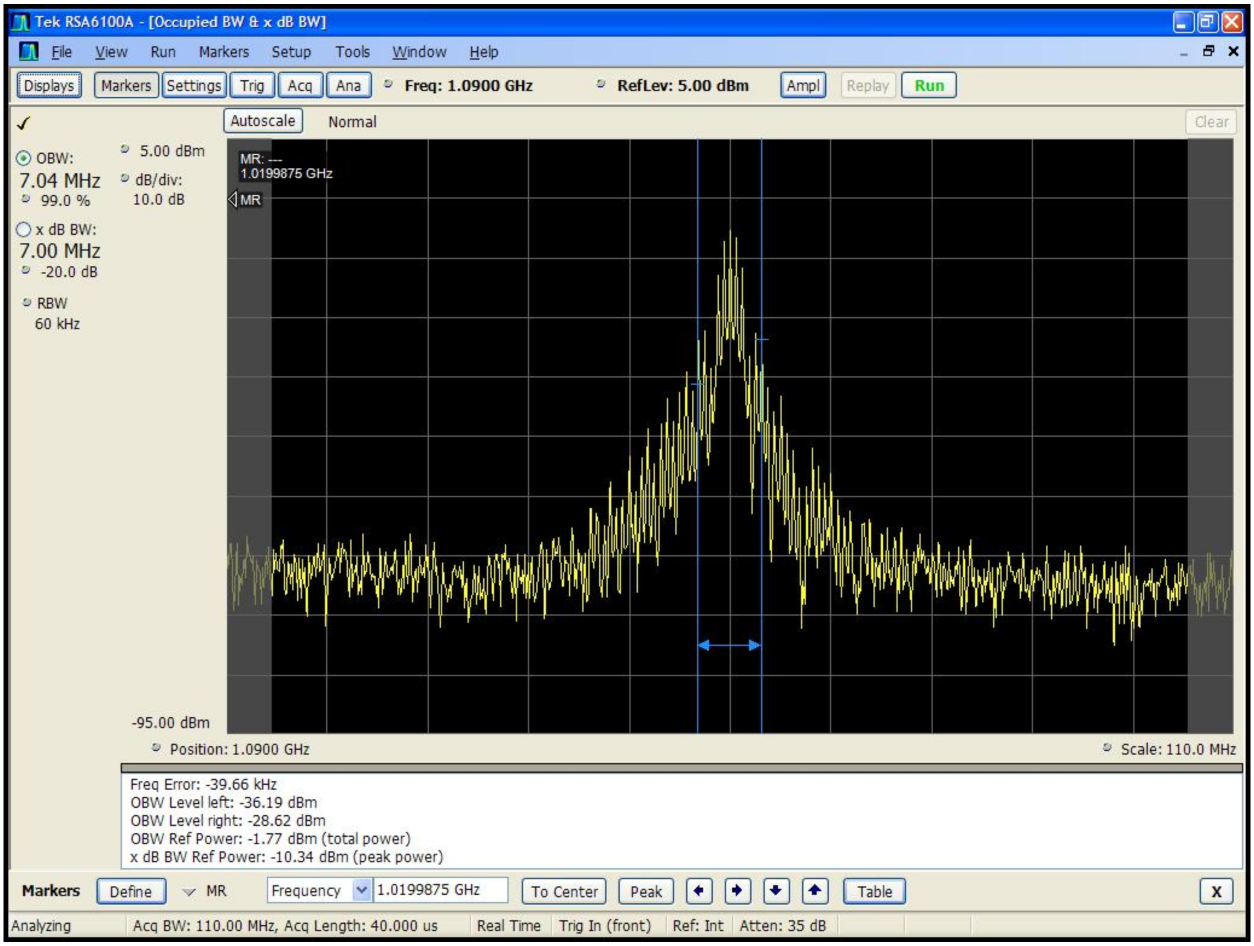


Figure 11 – Occupied BW – Mode A ATCRBS Reply at 1090 MHz

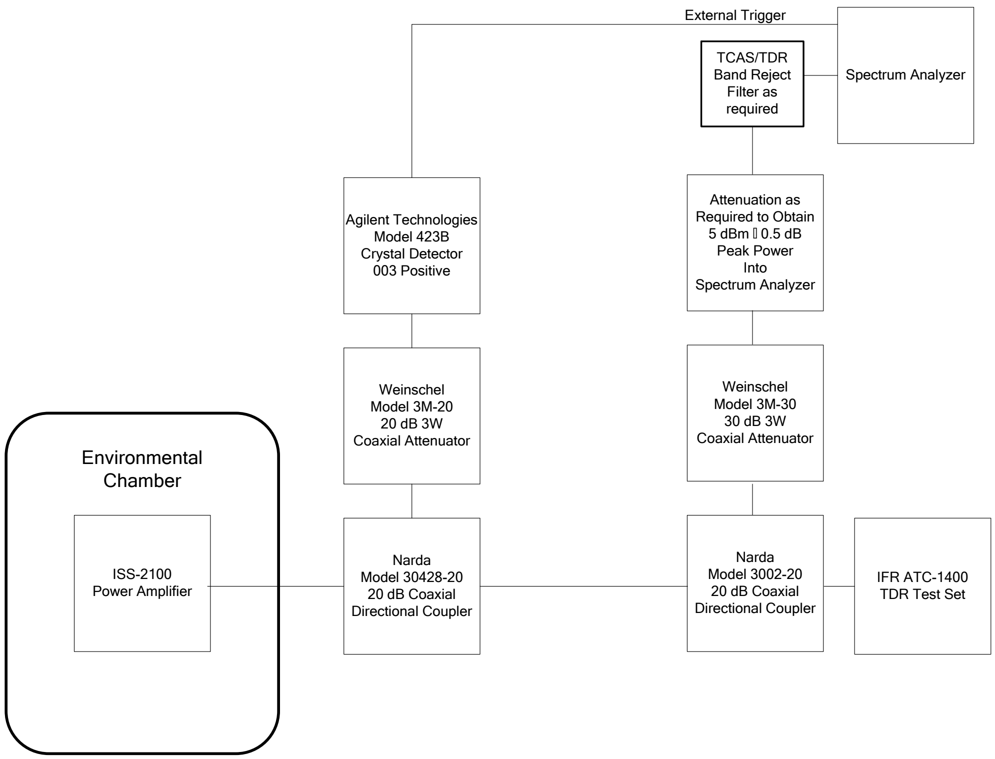


Figure 12 - Equipment Setup for Spurious Emissions Test

F.7 Spurious Emissions at Antenna Terminal (2.1051)

Requirements:

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.

The referenced section in 2.1049 is (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.

Section 87.139(d) "…when the frequency is removed from the assigned frequency by more than 250 percent of the authorized bandwidth for aircraft stations above 30 MHz and all ground stations the attenuation must be at least 43+10 log10 pY dB", where Y is the average power in Watts.

Since the TSS-4100 does not have an FCC authorized section 2.1049 bandwidth for any of the four waveforms that it needs to transmit, we will use 250% of the stated occupied bandwidth in this measurement.

The TSS-4100 Test Article has a rated peak power output of 500 watts at the rear connectors of the radio.

Ptx-peak = 500 Watts or 27.0 dBW = 57.0 dBm in all ranges. The maximum duty cycle of transmissions is 2.2%, so the average power is (500 * .022) = 11.0 W, 10.4 dBW = 40.4 dBm

The FCC limit for attenuation is 43 + 10 log10 (11W) = 53.4 dB. Stated alternatively, spurious must be < -53.4 dBc.

RTCA DO-185A, para. 2.2.3.3 Limit > 90 MHz from center frequency shall be < - 60 dBc

RTCA DO-181C, para. 2.2.4.2.3 Limit > 78 MHz from center frequency shall be < - 60 dBc

The 250% of occupied bandwidth results in:

1030 MHz, TCAS: 27.7 MHz * 2.5 = 34.625 MHz.
Low limit 1013 MHz.
High limit 1047 MHz

1090 MHz TDR: 13.5 MHz * 2.5 = 33.75 MHz
Low limit 1073 MHz.
High limit 1107 MHz

The combination of the RTCA limits and the 87.139 limits where RTCA limits don't apply produces stepped limits:

For DO-185A signals at 1030 MHz:
From 1013 to 940 MHz and from 1047 to 1120 MHz: -53.4 dBc
Below 940 MHz and above 1120 MHz: -60 dBc

For DO-181C signals at 1090 MHz:
From 1073 to 1012 MHz and 1107 to 1168 MHz: -53.4 dBc
Below 1012 and above 1168 MHz: -60 dBc.

Test Procedure:

The TSS-4100 will be connected as shown in Figure 12 to provide approximately +5 dBm to a spectrum analyzer. This level is not critical. A reference will be obtained with the spectrum analyzer tuned to the output frequency, and the spectrum examined beyond from 250% of the occupied bandwidth, or from 1013 MHz down and from 1107 MHz up for spurious outputs above -80 dBm. Spectrum searches shall use a TCAS/TDR Band Reject Filter to allow extending the dynamic range of the analyzer. This prevents the transmit signal from overloading the spectrum analyzer, especially on the high side of the transmit frequency, where the spectrum analyzer can generate harmonics larger in amplitude than the transmitter will produce.

The TSS-4100 may be run in conventional operating mode, if proper test equipment is available, and a single set of swept measurements made. Alternatively, the UUT may be configured to operate in a test mode that produces full power output at one frequency, due to the proximity of the two transmit frequency and the architecture of the transmitter.

The operator shall examine the output spectrum directly in any convenient combination of center frequency, span and resolution bandwidths desired as long as the noise floor displayed remains below -86 dBm. Ensure the entire spectrum is observed. Automated spur searches are acceptable alternatives.

In order to ensure EMI may be found during the pulse transmissions, multiple measurement sweeps shall be taken with the analyzer in “peak hold” mode.

The E4445 PSA from Agilent in the equipment list will work well with the following settings:

Start Freq	**Stop Freq**	**Res BW**	**Video BW**	**Sweep Time**
9 kHz	50 MHz	30 kHz	3 kHz	436 msec
50 MHz	1.013 GHz	100k	10k	745 msec
1.047 GHz	1.073 GHz	10k	10k	200 msec (approx)
1.107 GHz	3.00 GHz	100k	10k	2.22 sec
3.00 GHz	6.00 GHz	100k	10k	3.00 sec
6.00 GHz	9.00 GHz	100k	10k	3.00 sec
9.00 GHz	11.0 GHz	100k	10k	2.50 sec

Other settings may be used as the test conductor may determine, as long as the entire required spectrum is measured.

Record all spurious frequencies greater than -80 dBc in the space provided in Table F- 5. In this configuration the pass fail limit is -60 dBc, 20 dB greater than this.

Real Time Spectrum Analyzer Procedure:

Wideband Spurious Emissions measurement setup for RSA6114A Spectrum Analyzer

1) Set Transmitter into Mode S Test Mode 3, un-modulated long P6 waveform
2) Depress Preset button
3) Set CF to 1.03GHz
4) Depress Display button
5) ADD Time Overview
6) Click OK button
7) Depress Trigger button
8) Select Triggered Operation
9) Set Source to Trig In (front)
10) Set Level to 0.10V
11) Select Time tab
12) Set Position to 1%
13) Select Advanced tab
14) Check mark Trigger each segment in Swept acquisition mode
15) Depress Amplitude button
16) Deselect Auto button next to Internal Attenuator
17) Set Attenuator to 20dB
18) Depress Analysis button
19) Select Spectrum Time tab
20) Set to Use Analysis Time
21) Select Analysis Time tab
22) Set Analysis Length 40us
23) Select Spectrum Window
24) Depress Settings button
25) Set Start to 9kHz
26) Set Stop to 11GHz
27) Select BW tab
28) Set RBW to 60kHz
29) Select Traces tab
30) Set Function to Average
31) Select Prefs tab
32) Set Trace points to 10401
33) Close Settings Screen by clicking on the X
34) Select Spectrum Window
35) Place marker on peak or RF signal
36) Ensure marker readout indicates a signal strength of 0 □1dBm
37) If the signal level is not as specified above adjust pads between coupler and RSA6114A Spectrum Analyzer
38) Select Spectrum and expand to full screen Window

Note: This setup may now be saved for future reuse as a setup file.

After the spectrum analyzer has defined the characteristics of the output spectrum specified in the above setup push the save button. Save the screens as a JPG file in the FCC folder with the name “Section 7” followed by the frequency ranges of the test.

Results:

The Spurious Frequencies and amplitudes are shown in Table F- 5**.** This is a measurement into a broadband 50 ohm system, and does not include any frequency-dependent attenuation due to antenna mismatch. Spectrum analyzer screen captures are shown in Error! Reference source not found. through Figure 21**.**

Three emissions were detected within 20 dB of the 87.139 limit of -53.4 dBc, the second harmonic of the transmitter output and two PLL reference spurs. **Reference power for these measurements was +4.48 dBm.**

Table F- 5 - Conducted Spurious Emissions

Frequency	Level	Compliant?
2060 MHz	-66.4 dBm or -71.2 dBc	Yes
1010 MHz	-58.0 dBm or -62.8 dBc	Yes
1050 MHz	-58.3 dBm or -63.1 dBc	Yes

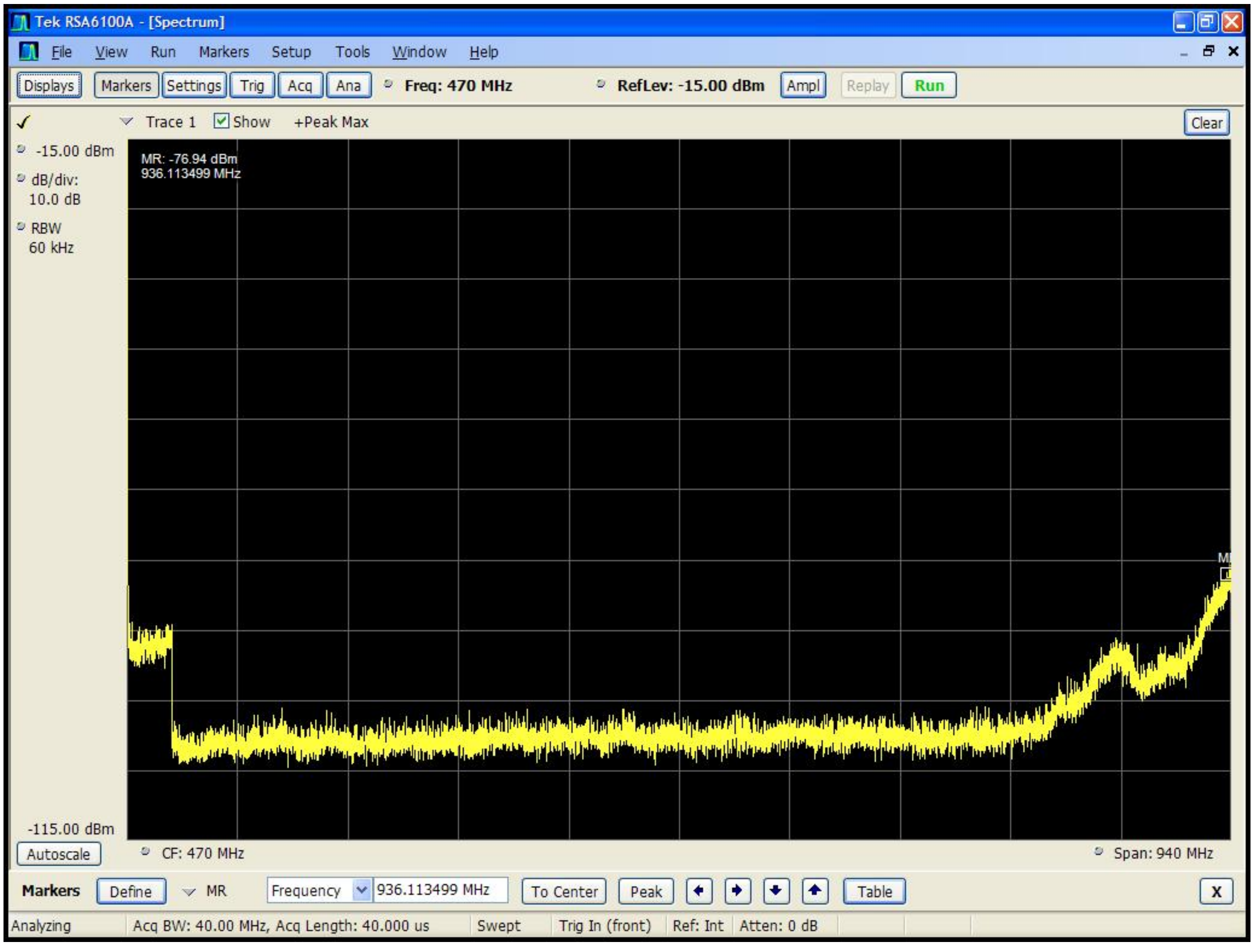


Figure 13 - 9 kHz to 940 MHz Spectrum. The noise platform at left is due to the analyzer switching settings. The noise is -90 dBc.

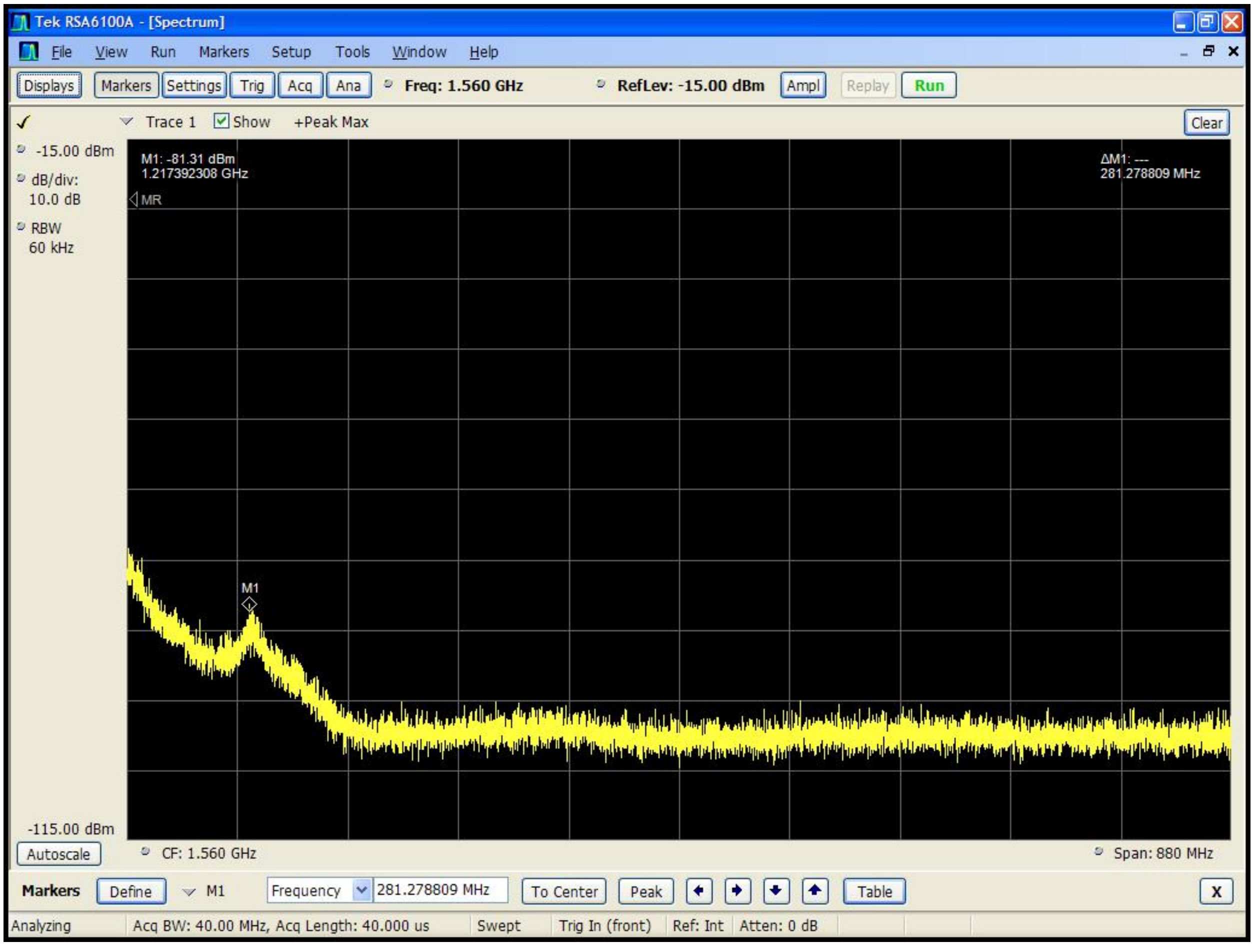


Figure 14 - 1120 MHz to 2.0 GHz. Transmitter broadband noise visible on the left

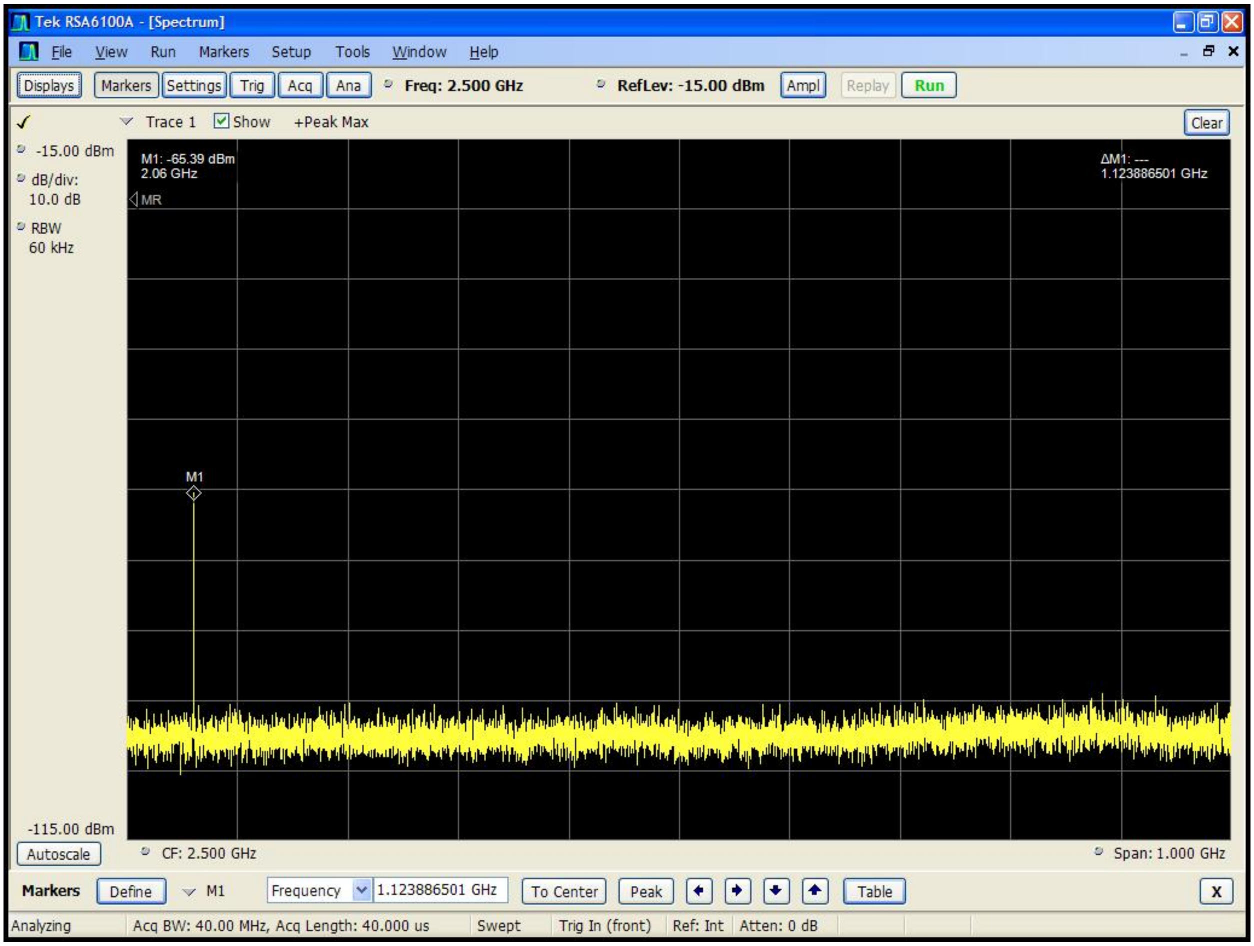


Figure 15 - 2.0 GHz to 3.0 GHz. Second harmonic noted at -66.4 dBm.

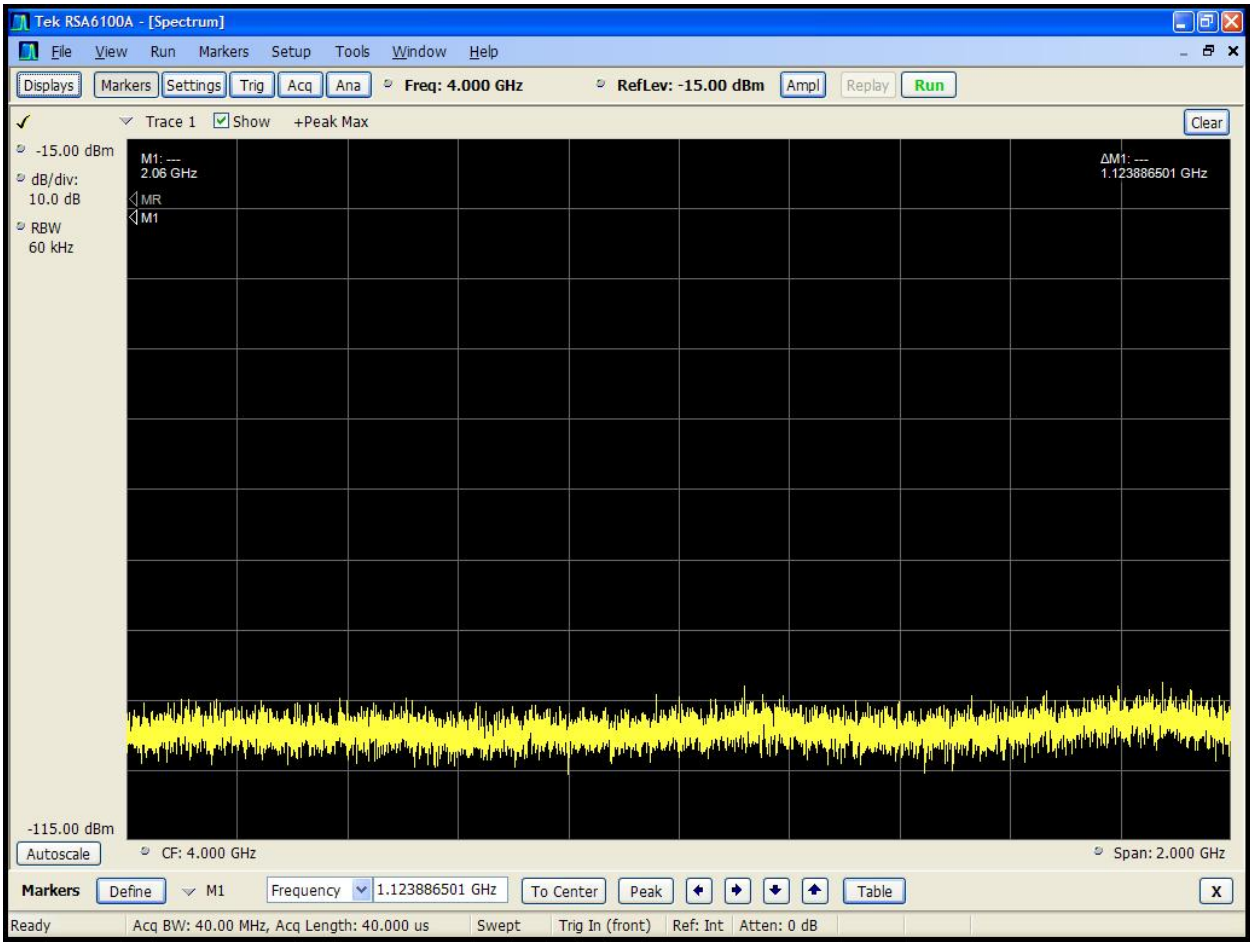


Figure 16 - 3.0 to 5.0 GHz spectrum

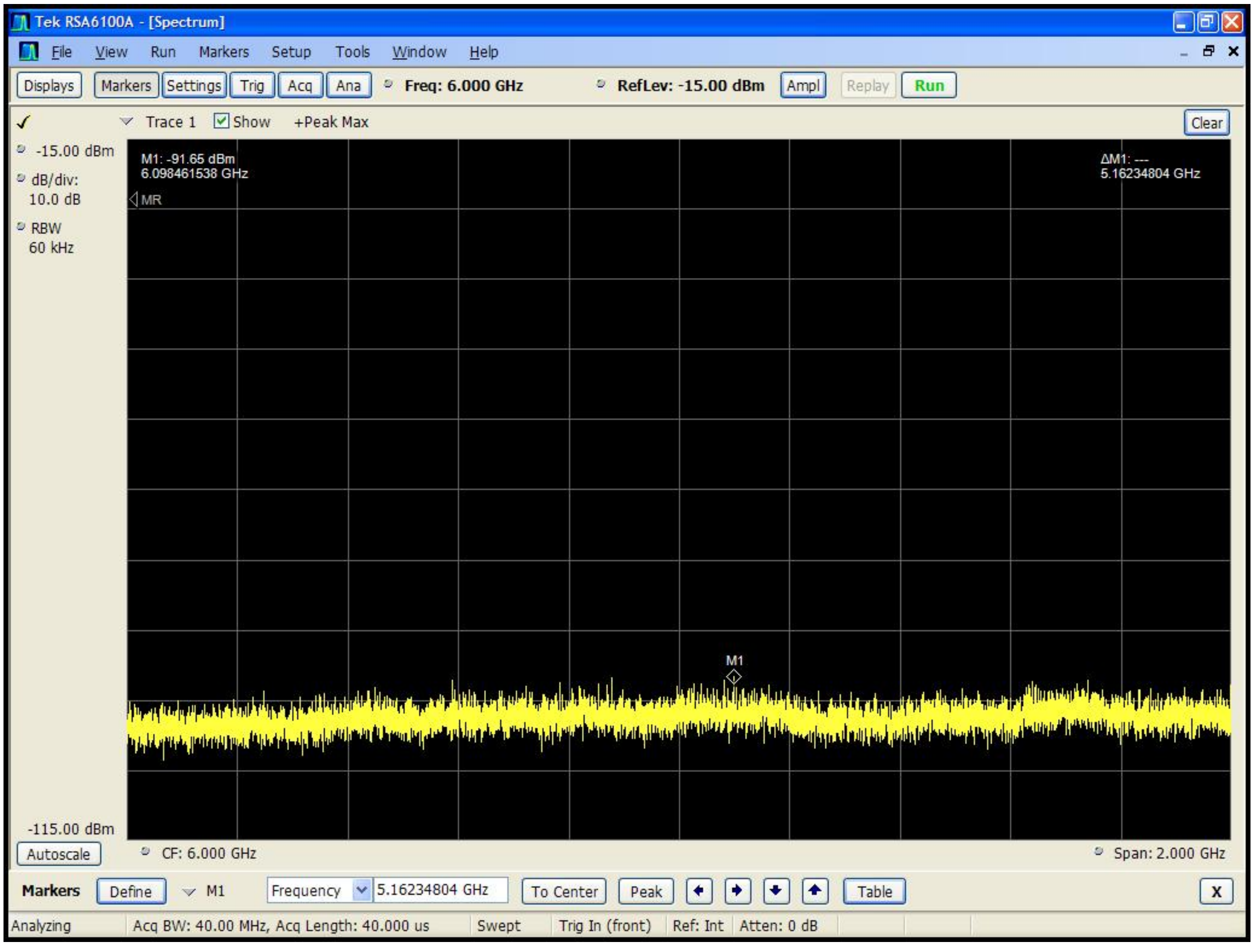


Figure 17 - 5.0 to 7.0 GHz spectrum.

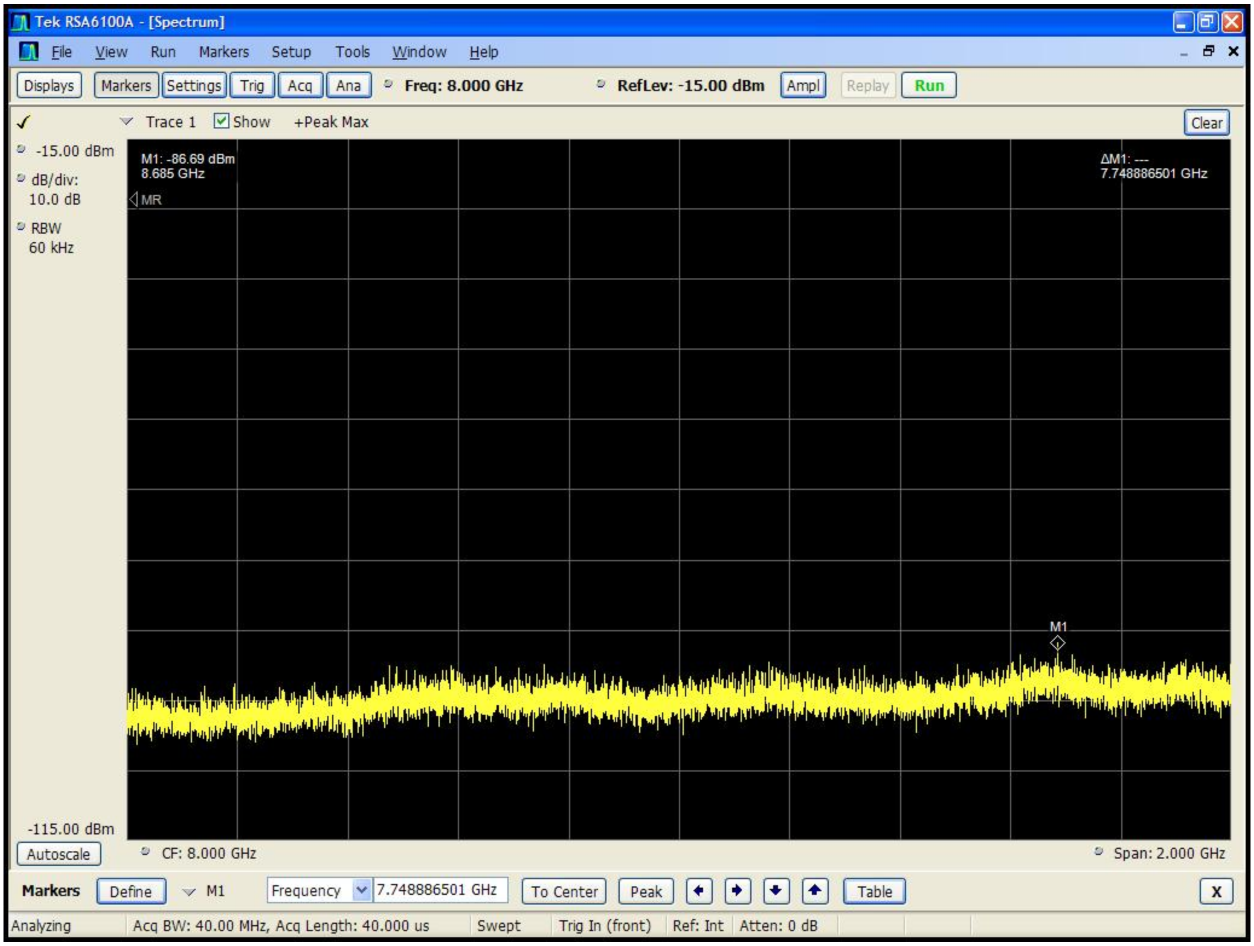


Figure 18 - 7.0 TO 9.0 GHz Spectrum

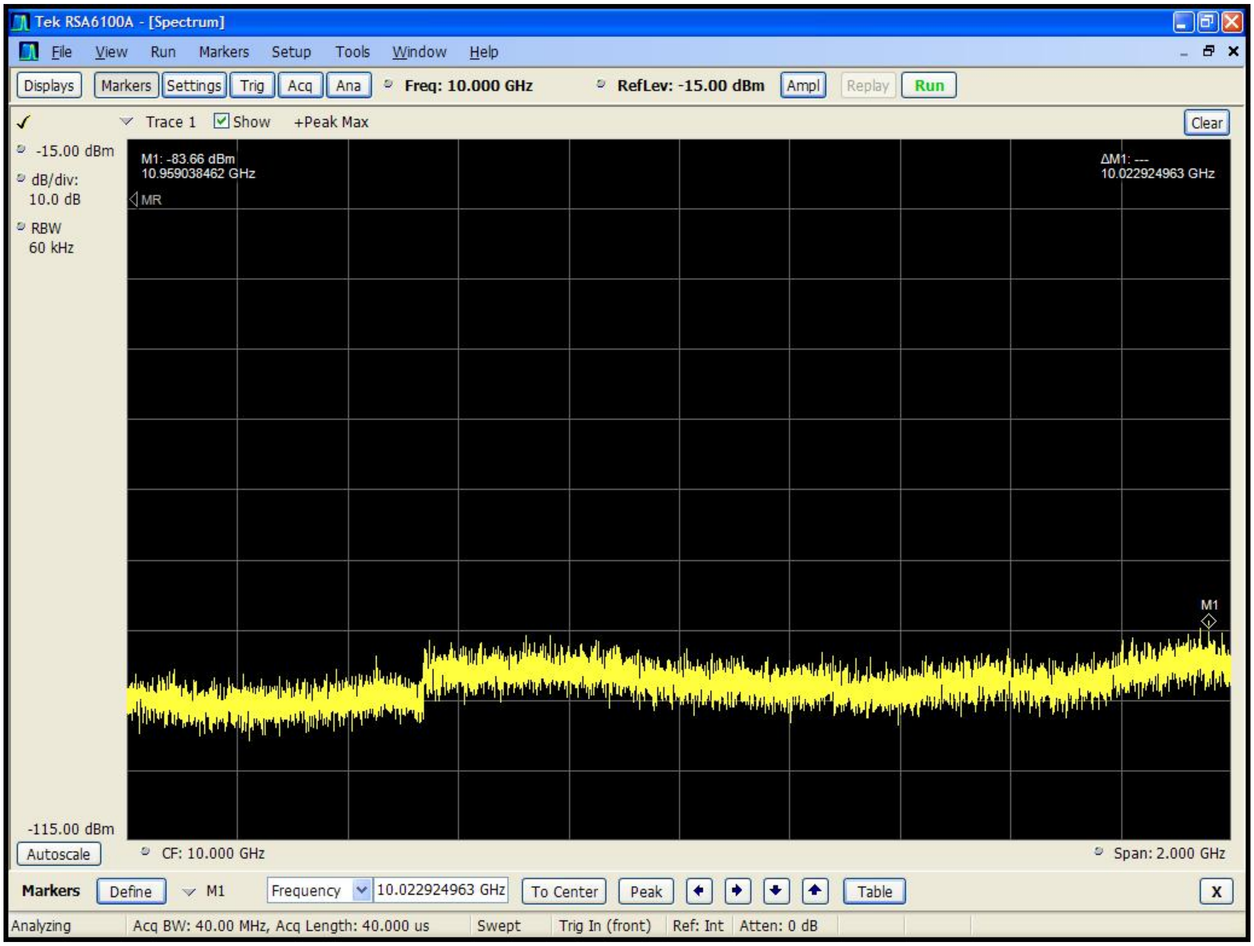


Figure 19 - 9.0 to 11.0 GHz spectrum. Discontinuity in the noise floor is from the analyzer switching settings internally. This noise is below -90 dBc.

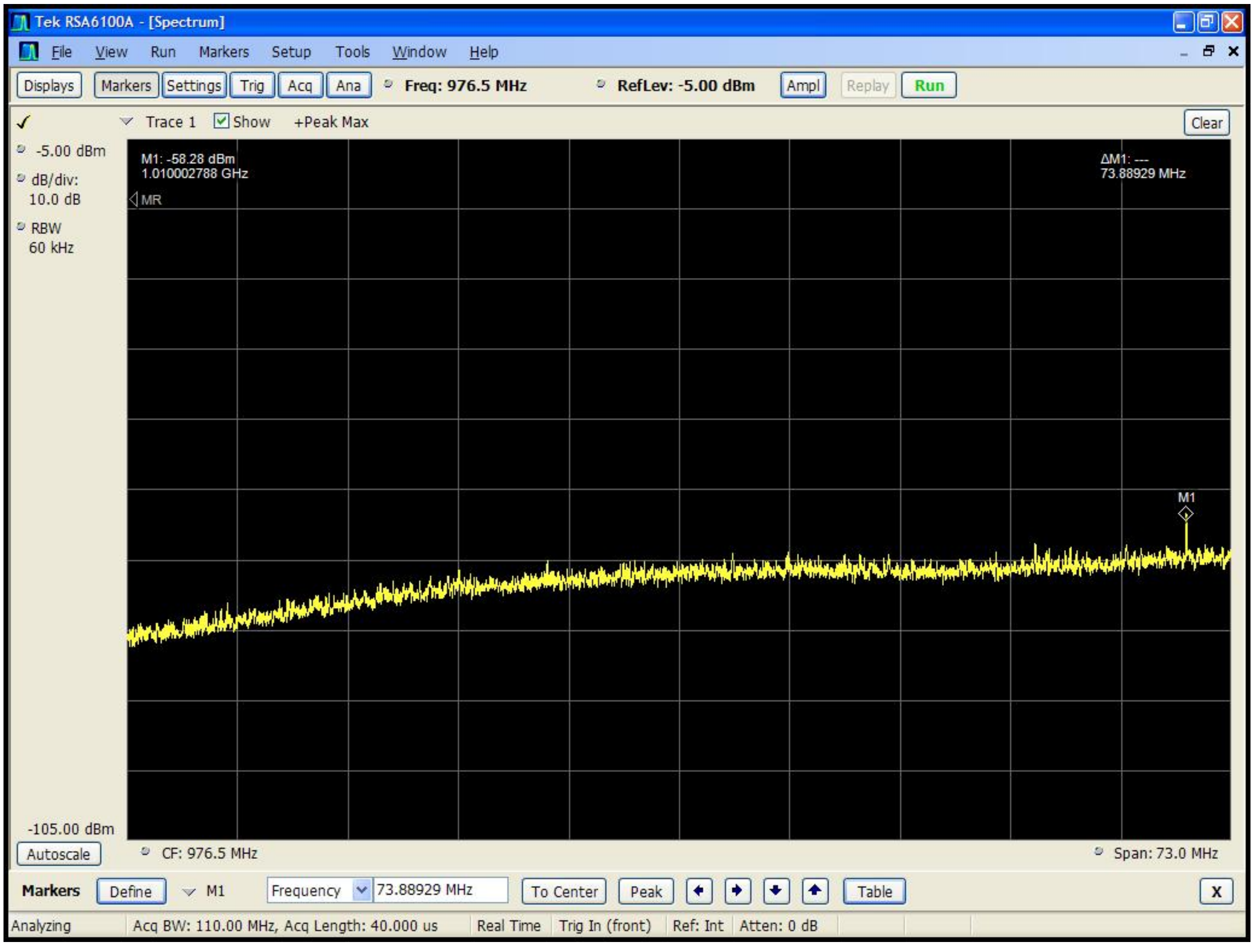


Figure 20 - Low side of transmitter spectrum within step from -53.4 dBc requirement to -60 dBc requirement. Spurious is at -58.28 dBc.

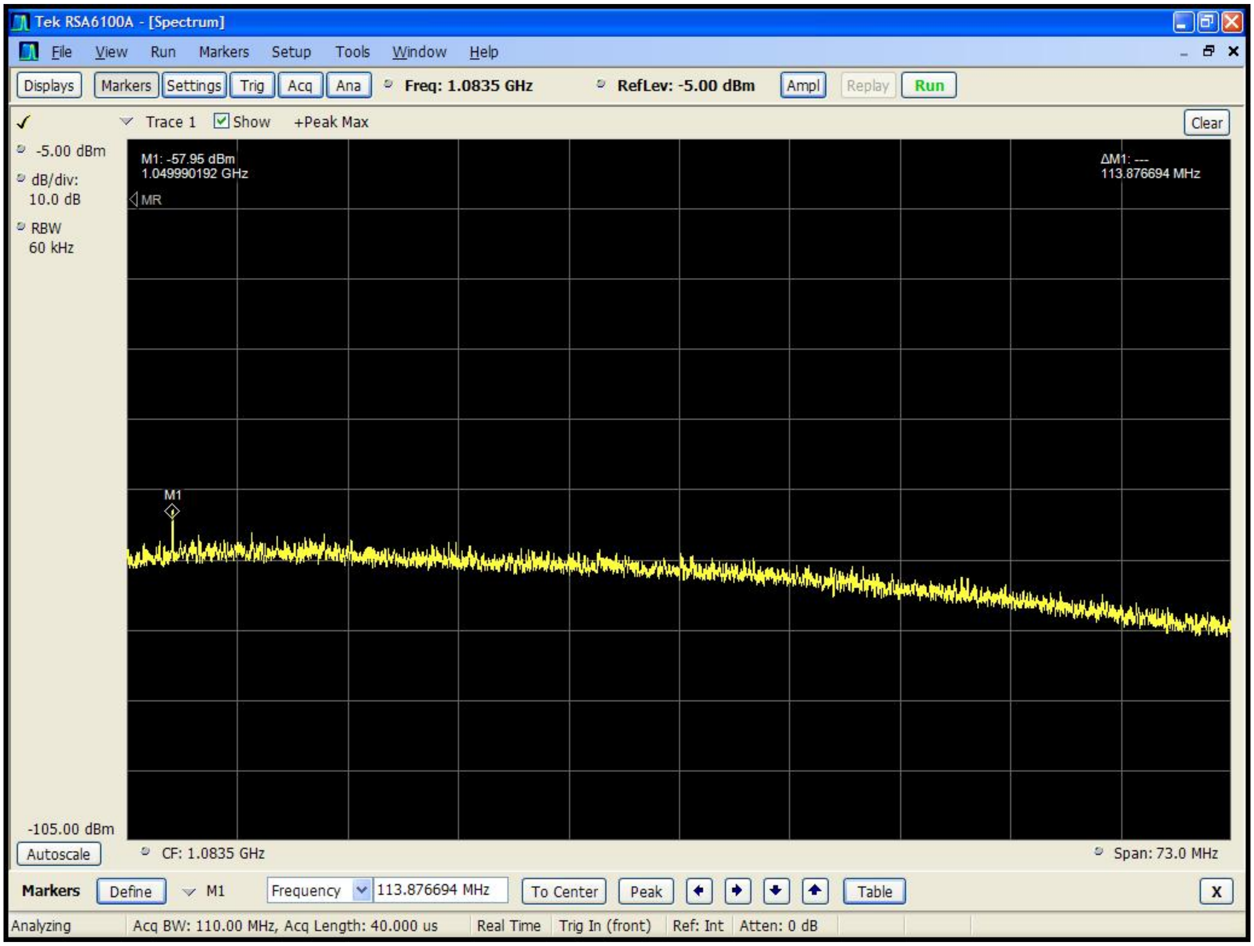


Figure 21 - Low side of transmitter spectrum within step from -53.4 dBc requirement to -60 dBc requirement. Spurious is at -58.0 dBm.

F.8 Field Strength of Spurious Radiation (2.1053)

Requirements:

Section 2.1053 (a), (b) (2), 2.1049 (h),

It can be determined from these sections that the TSS-4100 is subject to measurement; however, the performance requirements are not stated. In lieu of this, we adopt as an upper limit either the DO-160E limit or the following, whichever is the lower limit.

Section 87.139(d) "…when the frequency is removed from the assigned frequency by more than 250 percent of the authorized bandwidth for aircraft stations above 30 MHz and all ground stations the attenuation must be at least 43+10 log10 pY dB".

The maximum field strength is computed in the following MathCAD worksheet:

$Po := 500$	$yP := Po \cdot .022$	Power output in Watts - Po is peak, yP is average
$A := (43 + 10 \cdot \log(yP))$	$A = 53.414$	FCC 87.139 (d) limit in dBc - Po*.022 is to get average power from the 2.2% duty cycle.
$PL := yP \cdot 10^{\frac{-A}{10}}$	$PL = 5.012 \times 10^{-5}$	Spurious Power limit in Watts
$G := 1.64$		Antenna gain (dipole = 1.64)
$R := 1$		Radius in meters to antenna
$E := \sqrt{\frac{30 \cdot PL \cdot G}{R}}$	$E = 0.0497$	E field in V/m
$EdB\mu V := 20 \cdot \log\left(\frac{E}{10^{-6}}\right)$	$EdB\mu V = 93.92$	E field in dBμV/m

Since the previously derived limit is an average power, and the receiver used to detect the radiated power is a peak power reading instrument, the limit must be converted to peak power. This can be accomplished by removing the reference to the average power in the above analysis and replacing it with the peak power output. We choose as our limit 110 dBμV/m, for the number of significant digits.

$PL := Po \cdot 10^{\frac{-A}{10}}$	$PL = 2.278 \times 10^{-3}$	Spurious Power limit in Watts
$G := 1.64$		Antenna gain (dipole = 1.64)
$R := 1$		Radius in meters to antenna
$E := \sqrt{\frac{30 \cdot PL \cdot G}{R}}$	$E = 0.3348$	E field in V/m
$Ed B\mu V := 20 \cdot \log\left(\frac{E}{10^{-6}}\right)$	$Ed B\mu V = 110.495$	E field in dBμV/m

Test Procedure:

FCC Part 2.1057(a) states “the spectrum shall be investigated from the lowest radio frequency signal generated in the equipment, without going below 9 kHz, up to at least the frequency shown below: (a)(1) If the equipment operates below 10 GHz: to the tenth harmonic of the highest fundamental frequency or to 40 GHz, whichever is lower.” The tenth harmonic of our highest frequency is 10.900 GHz.

This test procedure follows the methodology of DO-160E Section 21. DO-160E Section 21 only specifies testing to 6 GHz. However, the same test setup, limits and methodology were used to measure radiated emissions up to the tenth harmonic of our highest frequency of operation.

The lowest RF oscillator frequency generated in the equipment is 8.33 MHz. A complete list of internally generated clocks is found in Table F- 10.

The frequency range investigated for radiated emissions was: 150 kHz to 11 GHz

The TSS-4100 was operated in ATCRBS Reply Pulse, Mode S Reply Waveform, Mode C-Only All-Call Interrogation Pulse Sequence and Mode-S Interrogation modes. Mode-S Interrogation mode represents the maximum operating condition for the unit.

The TSS-4100 Radiated Emissions Data was taken with the unit operating on each of the operating conditions specified in Table F- 6. The TSS-4100 was running operational software interfaced with test equipment used to condition the UUT to perform at nominal rates and emission types.

Table F- 6 - TSS-4100 Radiated Emissions Test Operating Conditions

Test Condition	TX Freq (MHz)
ATCRBS	1090
Mode C	1030
Mode S	1030

Equipment Setup:

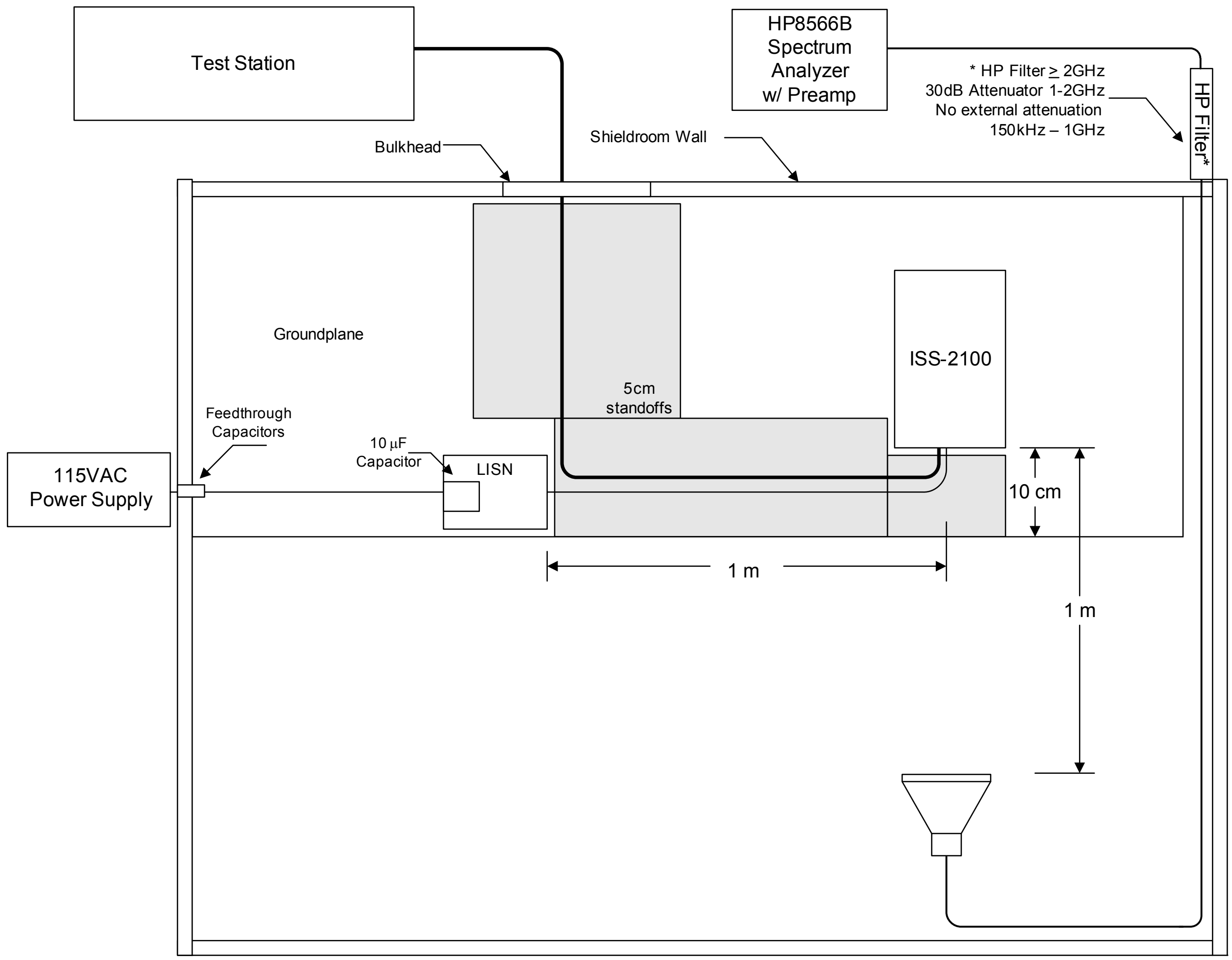


Figure 22. Field Strength of Spurious Radiation Test Setup – Top View

A. Requirements

The EUT and its interconnecting cables shall not radiate RF emission levels in excess of the limits given in Figure 23 and **Error! Reference source not found.**. The narrowband limits are based on DO-160E Category M with the limit extended down in frequency from 2MHz to 150 kHz along the semi-logarithmic slope.

Narrowband emissions shall be measured using the following HP8566B spectrum analyzer system bandwidths and dwell times. The narrowband bandwidths are specified in DO-160E, Section 21, paragraph 21.5.

Table F- 7 - Spectrum Analyzer Settings

Frequency Range	NB Band-width	Min Sweep Time per step
150kHz – 30 MHz	1 kHz	1.5s/MHz
30 MHz – 400MHz	10 kHz	0.15s/MHz
400 MHz – 1 GHz	100 kHz	0.15s/MHz
1 GHz – 11 GHz	1MHz	15s/GHz

Test Equipment

The following equipment or equivalent will be required to perform this test.

Table F- 8 - Test Equipment Used

MANUFACTURER	MODEL	DESCRIPTION	FREQ RANGE	COLLINS P/N	CAL DUE
ROHDE & SCHWARZ	ESU26	EMI RECEIVER	20Hz - 26.5GHz	469-0074-442	08/31/08
HEWLETT PACKARD	8449B OPT H02	PREAMPLIFIER	1 - 26.5GHz	460-0118-550	NONE
ELECTRO METRICS	EM-6892	ANTENNA, ACTIVE	1kHz - 50MHz	469-0069-993	06/30/08
A.H. SYSTEMS	SAS-200/540	ANTENNA, BICONICAL, RCV	20 - 330MHz	469-0073-416	05/31/08
EMC TEST SYSTEMS	3106	ANTENNA, DOUBLE RIDGE GUIDE	200M - 2GHZ	469-0070-774	08/31/09
EMCO	3105	ANTENNA, DOUBLE RIDGE GUIDE	1 - 12.5 GHZ	460-0047-850	08/31/08
K&L Microwave	11SH10-2000/ U18000-O	FILTER, HIGH PASS	Insertion Loss: <1.0 dB @ 2.0 to 18 GHz	469-0074-306	7/31/2008
K&L Microwave	11SH10-2000/ U18000-O	FILTER, HIGH PASS	Insertion Loss: <1.0 dB @ 2.0 to 18 GHz	469-0074-307	7/31/2008
FISCHER CUSTOM COMMUNICATION	FCC-LISN-5-50-1-01-DEF-STAN-59-41	LINE IMPEDANCE STABILIZATION NETWORK	1kHz - 400MHz	460-0131-814	03/31/09
NARDA	370 BNM	TERMINATOR, 50 OHM, 5W	DC - 18 GHZ	469-0072-406	07/31/10

B. Documentation

1. Data plots indicating the measured test levels in relation to the test limits. In addition, a separate data plot will be provided for the narrowband frequency range of 108MHz to 152MHz.

2. Photographs of the test setup to include current probe placements for each bundle tested.

3. The test equipment list of the actual equipment used for testing.

C. EUT Operating Conditions and Orientations Tested

During emissions tests, performance monitoring of the EUT is not required. The EUT shall be monitored to ensure full performance for each of the conditions in the operating modes noted below.

The EUT shall be setup on the ground plane with the ARINC connector facing the antenna. The EUT shall be located 10cm back from the edge of the ground plane and the interconnecting cable bundle shall be routed parallel and 10cm back from the edge of the ground plane to allow at least one meter to be exposed to the receiving antenna.

For each applicable frequency range as listed in Table F- 9, the receiving antenna will be setup as shown in Figure 24.

Table F- 9 - Antennas Used vs. Frequency

Frequency Range	Antenna Type
150kHz – 25MHz	Vertical Rod (Active)
25MHz – 200MHz	Biconical
200MHz – 1GHz	Double Ridge Guide
1GHz – 11GHz	Double Ridge Guide

D. Testing

1. Set up the EUT, wiring, associated interface circuitry and test equipment per Figure 22. Connect the power input leads to a LISN with an internal 10 microfarad capacitor.

Note: Due to the high transmitted power for the Transponder and ACAS functions, an attenuator will be inserted in series with the measurement system from 1-2GHz (transmit frequencies 1030MHz and 1090MHz). Above 2GHz, the attenuator will be replaced with high pass filters to prevent overloading of the spectrum analyzer system. These filters will be characterized for their loss which will be included in the measurement calculations.

2. With the EUT un-powered, but all equipment in the test station operating, measure and record the ambient interference level.

3. Apply +115VAC power to the EUT and place it in the applicable operating mode. A nominal duty cycle of transmissions in all services is required.

4. Measure and record emissions using the automated emissions measurement system.

5. Change the antenna and polarization as required per DO-160E. Except for the frequency range from 150 kHz to 25MHz, both horizontal and vertical polarizations are required.

6. Record any emissions within 20 dB below the limit.

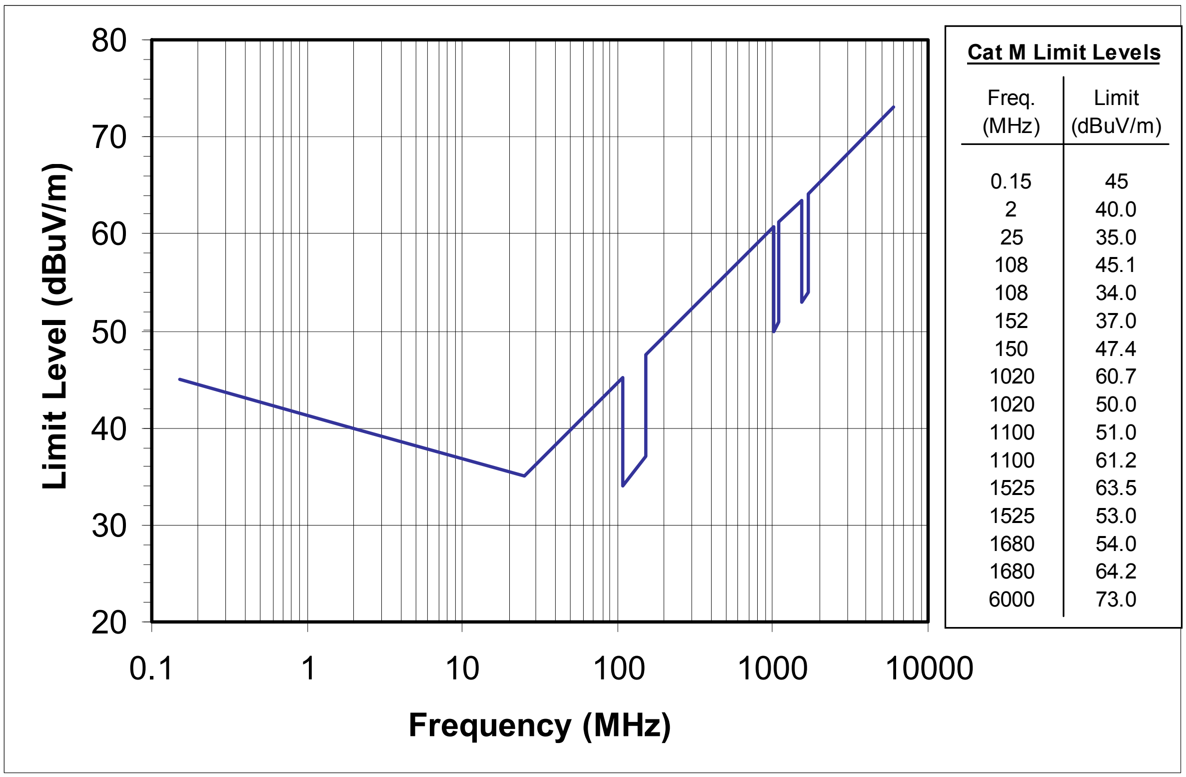


Figure 23 – DO-160 RF Radiated Emissions Limits (Narrowband)

Table F- 10 - Potential internally-generated emitters

#	**Frequency** (MHz)	**Description**
1	50.000	Traffic PPC/SysIO/DSP
2	60.000	Traffic RF/DSP Clock
3	100.000	Traffic RAM/SysIO clock
4	955.000	Traffic RX LO
5		
6		

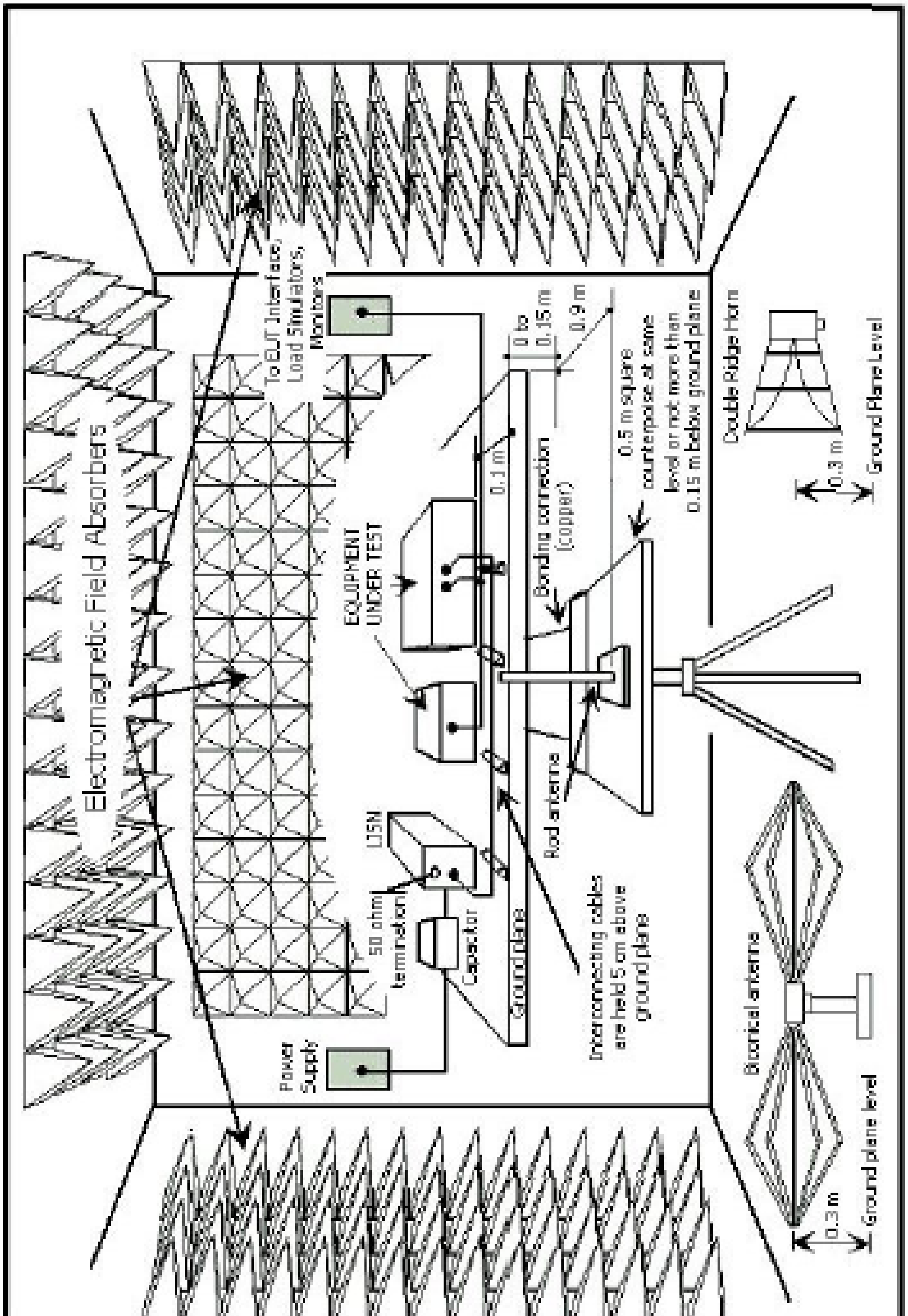


Figure 24 - RF Radiated Emissions Test Chamber Setup

Results:

Results are provided in table and spectral plot forms and are provided for ***vertical*** and ***horizontal*** polarizations from ***150 KHz to 12 GHz*** while the UUT was running in normal, operational mode. No emissions exceeded the FCC limit of 110 dBμV/m. No emission, except fundamentals, exceeded 50 dB below the limit.

Emissions Measurements (Normal Mode):

Spectrum measurements for the normal mode of operation are presented in Table F- 11.

Spectrum plots for the normal mode of operation are provided in Figure 25 through Figure 28.

Table F- 11 - Field Strength of Spurious Radiation – Normal Mode

Field Strength of Spurious Radiation					
Transmitter Frequency	**Measurement Band**	**Polarization**	**Peak Emission**		**Reference**
			Frequency (MHz)	**Level (dBμV/m)**	
Normal Operation. Xmit on 1030 and 1090 MHz, mix of all modes.	150 KHz to 200 MHz	Vertical	N/A	All emissions < 45	Figure 25
	25 MHz to 1 GHz	Horizontal	N/A	All emissions < 40	Figure 27
	1 GHz to 11 GHz	Vertical	N/A	All emissions < 60 (except fundamental)	Figure 26
		Horizontal	N/A	All emissions < 58 except for fundamentals	Figure 28

Spectrum Plots (Normal Mode):

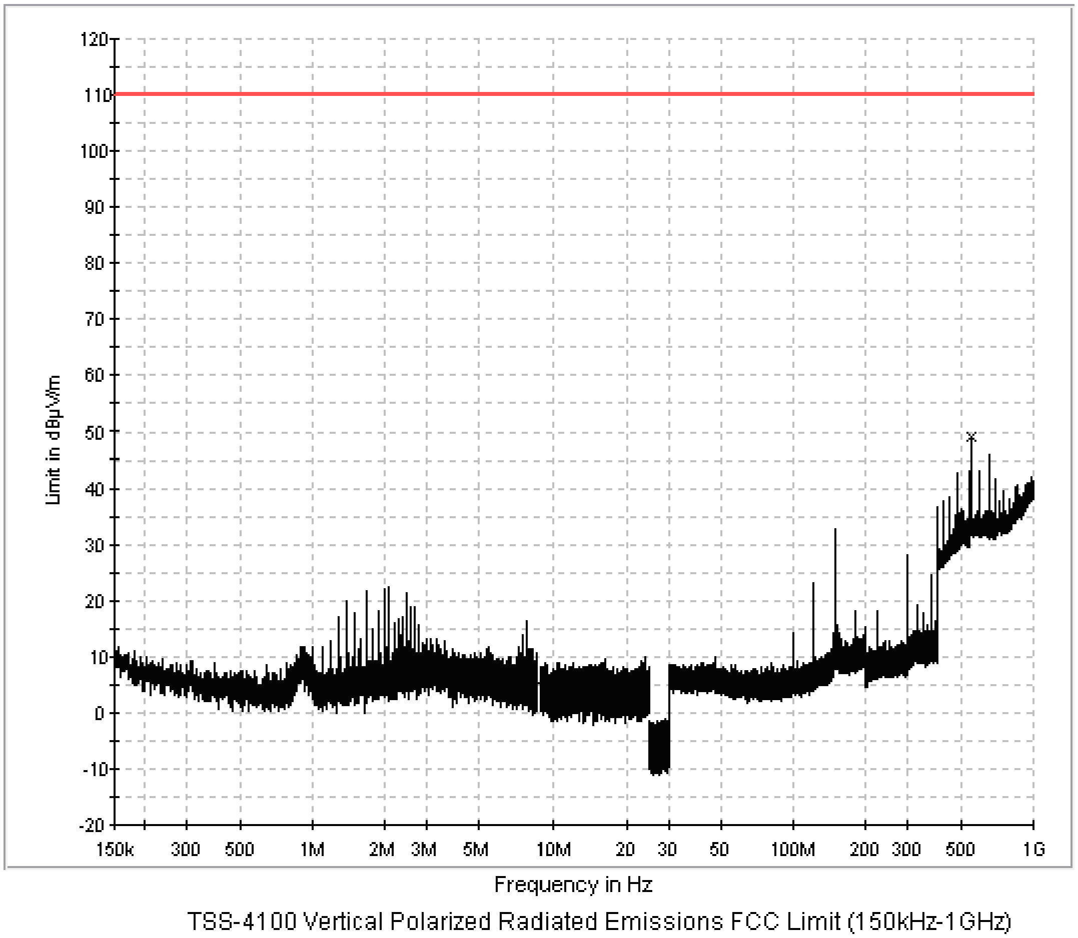


Figure 25. Radiated Spurious Emissions, 150 kHz – 1000 MHz, Vertical Polarization

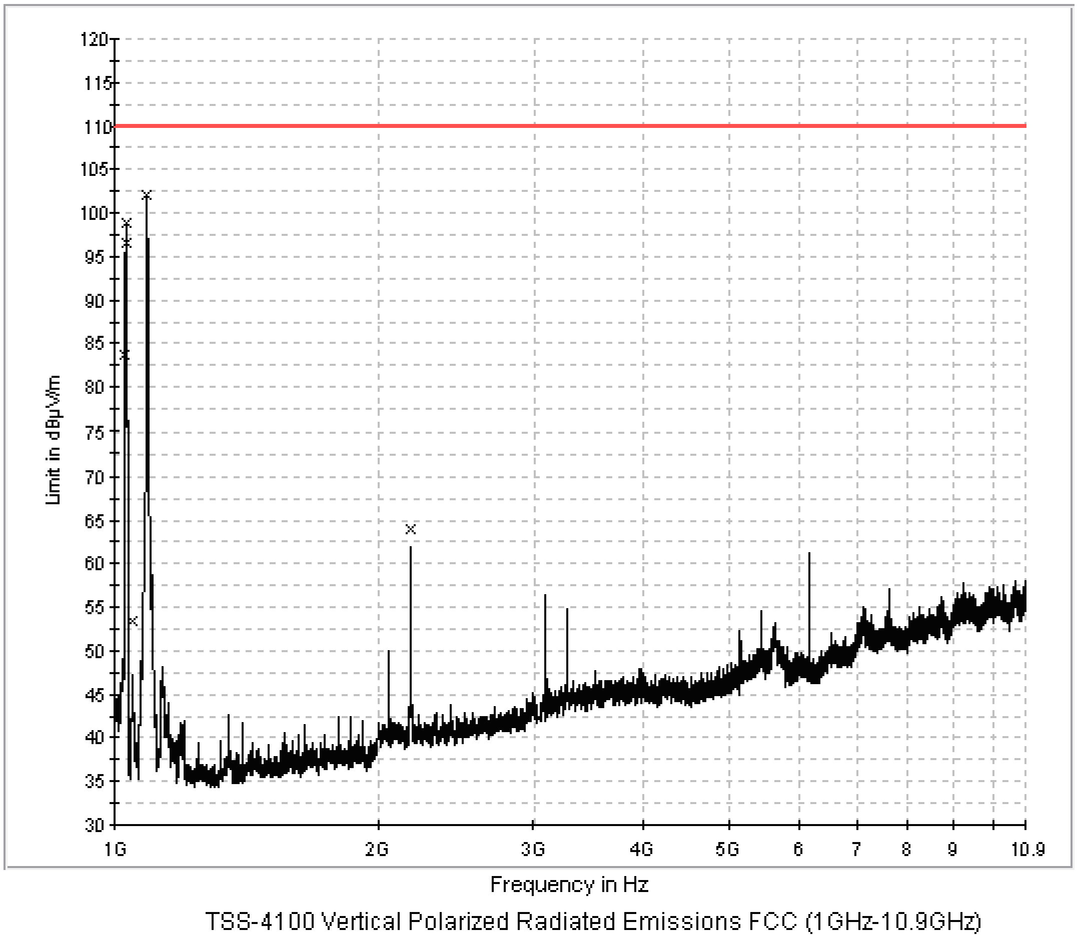
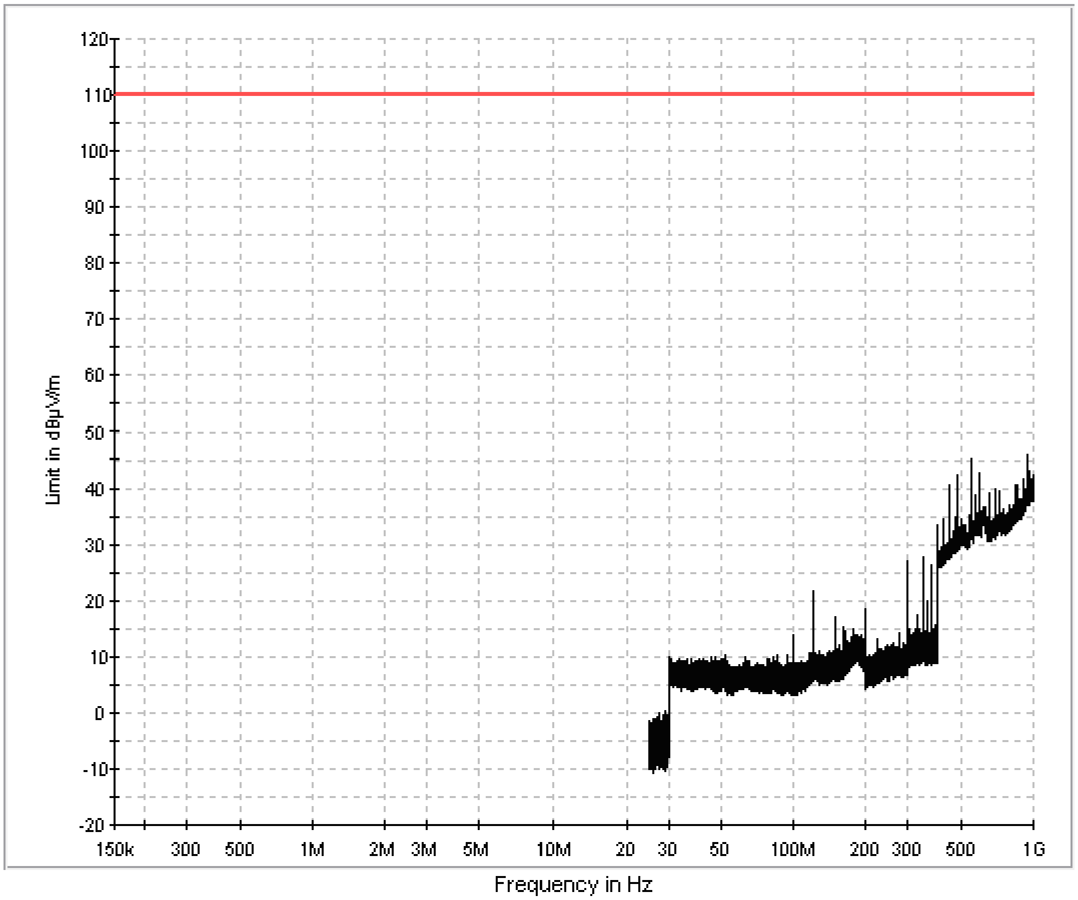


Figure 26. Radiated Spurious Emissions, 1 – 11 GHz, Vertical Polarization



TSS-4100 Horizontal Polarized Radiated Emissions FCC Limit (150kHz-1GHz)

Figure 27. Radiated Spurious Emissions, 25 MHz- 1GHz, Horizontal Polarization

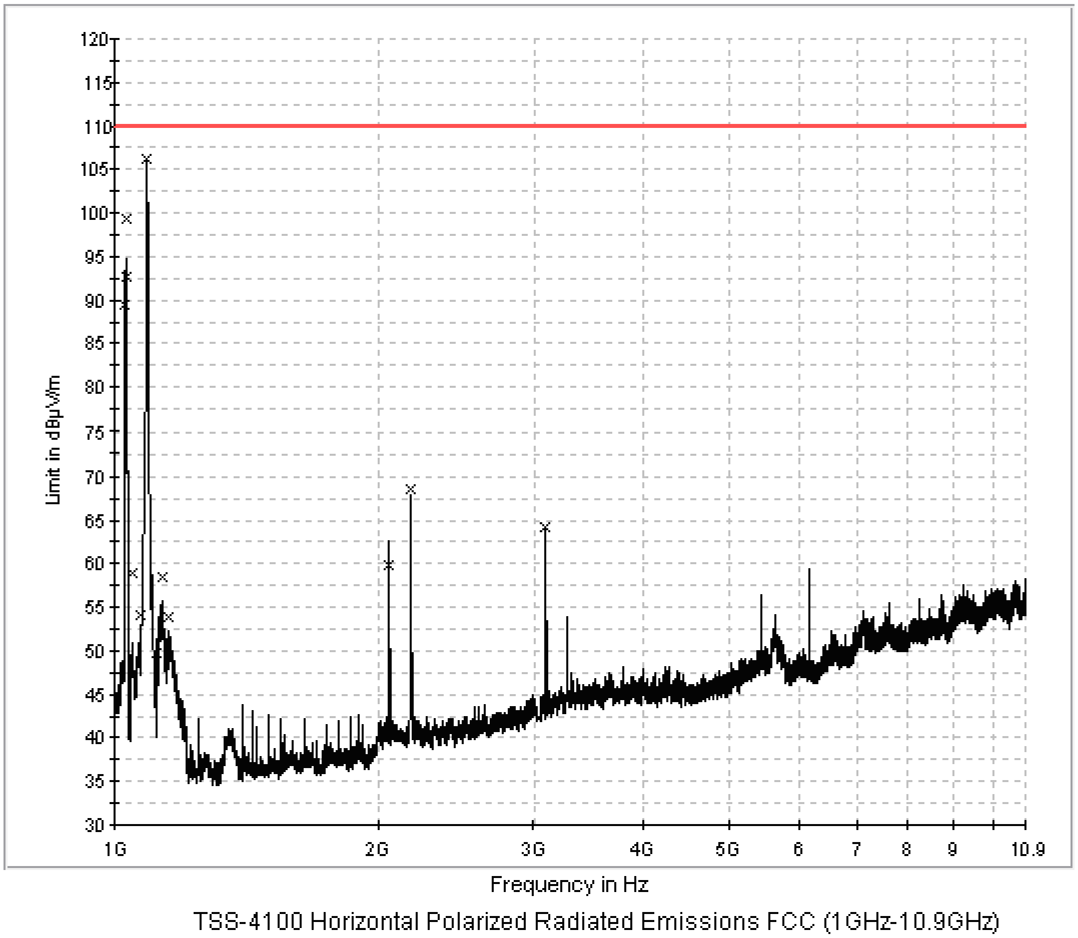


Figure 28. Radiated Spurious Emissions, 1 – 11 GHz, Horizontal Polarization