NVLAP Testing
NVLAP Lab Code 200087-0

# Class 2 Permissible Change Test Report

47CFR Part 87

# Model: TT22

Multi-Mode S Aviation Transponder

1090 MHz

FCC ID: VZI00745

For

## Trig Avionics Limited
## Heriot Watt Research Park
Riccarton
Riccarton, Edinburgh EH14 4AP, UK

FCC Site Registration: US5305
IC Test Site Registration: 3041A-1
Report Number 180130B

Authorized Signatory: Scot D Rogers
Scot D. Rogers

NVLAP Testing
NVLAP Lab Code 200087-0

**ROGERS LABS, INC.**

4405 West 259th Terrace
Louisburg, KS 66053
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# Class 2 Permissible Change Test Report

For

## Trig Avionics Limited
## Heriot Watt Research Park

Riccarton
Riccarton, Edinburgh EH14 4AP, UK
Phone: 011 44 131 449 8810

# Model: TT22

## Multi-Mode S Aviation Transponder

Model: TT22
Part Number: 000675-00-01
Frequency Range: 1090 MHz

Test Date: January 30, 2018

Certifying Engineer: Scot D Rogers

Scot D. Rogers
Rogers Labs, Inc.
4405 W. 259th Terrace
Louisburg, KS 66053
Telephone / Facsimile: (913) 837-3214

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## Revision History

Revision 1 Issued February 14, 2018

## Executive Summary

The following information is submitted for consideration in processing Class 2 Permissible Change of certified equipment operating under 47CFR Paragraph 87 Aviation transmitter equipment. The following information and associated application address parts obsolescence. No additional operational features or performance are provided with the updated components.

Name of Applicant: Trig Avionics Limited
Heriot Watt Research Park
Riccarton, Edinburgh EH14 4AP, UK
Phone: +44 131 449 8810

Model: TT22 Original Grant Date 07/10/2009

FCC ID: VZI00745

Frequency of Operation: 1090 MHz

Transmit Peak Power: 133.7 watts, occupied bandwidth 8.575 MHz A mode, 8.200 MHz S mode

## Opinion / Interpretation of Results

| Tests Performed | Results |
|---|---|
| Requirements per 47CFR paragraphs 2.1031-2.1057 and Paragraph 87 | Complies |

## Equipment Under Test

| Equipment | Model / PN | Serial Number |
|---|---|---|
| EUT | TT22 | ENG 06862 |
| DC Power Supply | 1745 | 209C13 |

Test results in this report relate only to the items tested.

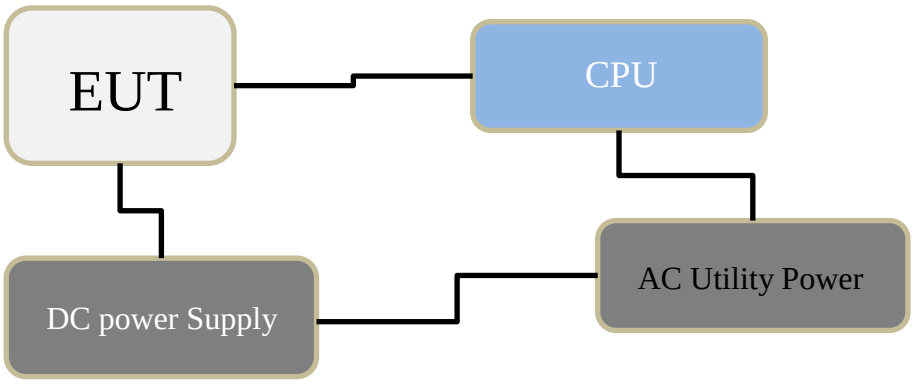
### *Equipment Function and Configuration*

The TT22 transponder is an ED-73B Class 2 compliant Mode S level 2 data link transponder. A remote user interface with an LCD screen and simple mode selector and code entry features controls the transponder. The device interfaces to a serial altitude encoder. Additional serial interfaces are provided to receive GPS position information. The GPS position information provides the data set for ADS-B transmissions. The transponder is based around low power receiver and transmitter subsystems, with the low-level transponder state machines implemented in a programmable logic device (PLD). An integrated microcontroller performs the Mode S protocol functions, manages the transponder state, and controls the user interfaces. Test results in this report relate only to the products described in this report.

### *Modification to Equipment Design*

The modified version of the transceiver addresses component obsolescence and printed circuit board layout to accommodate the replacement parts. The modulator remains unchanged as well as the performance when compared to original equipment and filing. The replacement power output device and its associated driver are now contained in a single device package. The design appears to provide two amplification stages with the replacement parts but there are three as in the original design.

### *Equipment Configuration*



## Application for Certification

1. Manufacturer: Trig Avionics Limited
   Heriot Watt Research Park
   Riccarton, Edinburgh EH14 4AP, UK

2. Identification: **Model**: TT22 **FCC ID**: VZI00745

3. A copy of the installation and operating instructions furnished to the end user. Refer to the instruction manual furnished with original application for details.

4. Emission Type: Emissions Designation 7M42V1D

5. Frequency Range: 1090 MHz

6. Range of operating power values or specific operating power levels, and description of any means provided for variation of operating power. 141-Watts peak, 1.4 Watts (Average Power) delivered

7. Maximum power rating as defined in the applicable part(s) of the rules. 141 Watts (nominal peak power) and 1.4 watts average delivered from this EUT. Maximum power output as determined by appropriate standards during certification per CFR 47 paragraph 87.131. The specifications of RTCA/DO-181C stipulate 125W peak minimum and 500W maximum RF peak output power.

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. Final amplifier operates at 50 volts @ 8.7 amps (435 watts peak power).

9. Provide the tune-up procedure over the power range, or at specific operating power levels. Refer to the tune-up procedure furnished with original application for details.

10. A schematic diagram and a description of all circuitry and devices provided for determining and stabilizing frequency, for suppression of spurious radiation, for limiting modulation, and for limiting power. Refer to the schematics and technical exhibits furnished with original filing for details.

11. A photograph or drawing of the equipment identification plate, or label showing the information to be placed thereon shall be provided. Refer to the identification label exhibit and information provided with original application for details.

12. Photographs (8" x 10") of the equipment of sufficient clarity to reveal equipment construction and layout, including meters, if any, and labels for controls and meters and sufficient views of the internal construction to define component placement and chassis assembly. Insofar as these requirements are met by photographs or drawings contained in instruction manuals supplied with the certification request, additional photographs are necessary only to complete the required showing. Refer to the exhibits of this application for details.

13. For equipment employing digital modulation techniques, a detailed description of the modulation system to be used, including the response characteristics (frequency, phase, and amplitude) of any filters provided, and a description of the modulating wave train, shall be submitted for the maximum rated conditions under which the equipment will be operated. The unit employs pulse modulation prescribed by FAA TSOC112. This

requires pulses of 0.500 ±0.050 microseconds for Mode S with rise times of 0.100-microsecond maximum and fall-times of 0.200 microseconds maximum for both. The maximum rated condition, Mode S reply, has a 120-microsecond length with four pulses in the first eight microseconds, which is called the preamble, and pulses of 0.5 or 1.0 microsecond length filling in the next 112 microseconds, which is called the data block. Binary data is coded by the pulse position in the one-microsecond frames

14. The data required by Sections 2.1046 through 2.1057, inclusive, measured in accordance with the procedures set out in Section 2.1041.

15. The application for certification of an external radio frequency power amplifier under Part 97 of this chapter need not be accompanied by the data required by Paragraph (b)(14) of this section. In lieu thereof, measurements shall be submitted to show compliance with the technical specifications in Subpart C of Part 97 of this chapter and such information as required by Section 2.1060 of this part. This paragraph does not apply to this equipment.

16. An application for certification of an AM broadcast stereophonic exciter generator intended for interfacing with existing certified, or formerly type accepted or notified transmitters must include measurements made on a complete stereophonic transmitter. The instruction book must include complete specifications and circuit requirements for interconnecting with existing transmitters. The instruction book must also provide a full description of the equipment and measurement procedures to monitor modulation and to verify that the combination of stereo exciter generator and transmitter meets the emission limitations of section 73.44. This paragraph does not apply to this equipment.

17. A single application may be filed for a composite system that incorporates devices subject to certification under multiple rule parts; however, the appropriate fee must be included for each device. Separate applications must be filed if different FCC Identifiers will be used for each device. This paragraph does not apply to this equipment.

18. The device is not a software-defined radio and requirements of 2.944 do not apply to this application.

19. Applications for certification of equipment operating under part 27 of this chapter, that a manufacturer is seeking to certify for operation in the: This paragraph does not apply to this equipment.

    (i) 1755-1780 MHz, 2155-2180 MHz, or both bands shall include a statement indicating compliance with the pairing of 1710-1780 and 2110-2180 MHz specified in §§27.5(h) and 27.75 of this chapter.
    (ii) 1695-1710 MHz, 1755-1780 MHz, or both bands shall include a statement indicating compliance with §27.77 of this chapter.
    (iii) 600 MHz band shall include a statement indicating compliance with §27.75 of this chapter.

20. Applications for certification of equipment operating under Part 87 of this chapter and capable of operating on the 700 MHz interoperability channels (See §90.531(b)(1) of this chapter) shall include a Compliance Assessment Program Supplier's Declaration of Conformity and Summary Test Report or, alternatively, shall include a document

detailing how the applicant determined that its equipment complies with §90.548 of this chapter and that the equipment is interoperable across vendors. This paragraph does not apply to this equipment.

21. Contain at least one drawing or photograph showing the test set-up for each of the required types of tests applicable to the device for which certification is requested. These drawings or photographs must show enough detail to confirm other information contained in the test report. Any photographs used must be focused originals without glare or dark spots and must clearly show the test configuration used.

## Applicable Standards and Test Procedures

In accordance with the Federal Communications Code of Federal Regulations, 47CFR dated January 30, 2018, Part 2 Subpart J, Paragraphs 2.907, 2.911, 2.913, 2.925, 2.932, 2.926, 2.1031 through 2.1057; and applicable paragraphs of Part 87 the following information is submitted for consideration in processing Class 2 Permissible Change of Certified Equipment. Test procedures used were the established Methods of Measurement of Radio-Noise Emissions as described in ANSI C63.26-2015.

## Units of Measurements

| | |
|---|---|
| Radiated EMI | Data is in dBµV/m; dB/m referenced to one microvolt per meter |
| Antenna Conducted | Data is in dBm, dB referenced to one milliwatt |

## Test Site Locations

| | |
|---|---|
| Radiated EMI | The radiated emissions testing performed at the 3 meters, Open Area Test Site (OATS) located at Rogers Labs, Inc., 4405 W. 259th Terrace, Louisburg, KS. |
| Site Registration | Refer to Annex for Site Registration Letters |

## Environmental Conditions

| | |
|---|---|
| Ambient Temperature | 20.8° C |
| Relative Humidity | 40% |
| Atmospheric Pressure | 1028.7 mb |

## List of Test Equipment

| Equipment | Manufacturer | Model (SN) | Band | Cal Date | Due |
|---|---|---|---|---|---|
| ☐ LISN | FCC | FCC-LISN-50-2-10(1PA) (160611) | .15-30MHz | 5/17 | 5/18 |
| ☒ Cable | Time Microwave | 750HF290-750 (L10M) | 9kHz-40 GHz | 10/17 | 10/18 |
| ☐ Cable | Belden | RG-58 (L1-CAT3-11509) | 9kHz-30 MHz | 10/17 | 10/18 |
| ☐ Cable | Belden | RG-58 (L2-CAT3-11509) | 9kHz-30 MHz | 10/17 | 10/18 |
| ☐ Antenna | ARA | BCD-235-B (169) | 20-350MHz | 10/17 | 10/18 |
| ☐ Antenna | EMCO | 3147 (40582) | 200-1000MHz | 10/17 | 10/18 |
| ☒ Antenna | ETS-Lindgren | 3117 (200389) | 1-18 GHz | 5/17 | 5/18 |
| ☐ Antenna | Com Power | AH-118 (10110) | 1-18 GHz | 10/17 | 10/19 |
| ☐ Antenna | Com Power | AH-840 (101046) | 18-40 GHz | 5/17 | 5/19 |
| ☒ Antenna | Com Power | AL-130 (121055) | .001-30 MHz | 10/17 | 10/18 |
| ☒ Antenna | Sunol | JB-6 (A100709) | 30-1000 MHz | 10/17 | 10/18 |
| ☐ Antenna | EMCO | 3143 (9607-1277) | 20-1200 MHz | 5/17 | 5/18 |
| ☐ Analyzer | HP | 8591EM (3628A00871) | 9kHz-1.8GHz | 5/17 | 5/18 |
| ☐ Analyzer | HP | 8562A (3051A05950) | 9kHz-125GHz | 5/17 | 5/18 |
| ☐ Analyzer | HP External Mixers | 11571, 11970 | 25GHz-110GHz | 5/17 | 5/18 |
| ☒ Analyzer | Rohde & Schwarz | ESU40 (100108) | 20Hz-40GHz | 5/17 | 5/18 |
| ☒ Amplifier | Com-Power | PA-010 (171003) | 100Hz-30MHz | 10/17 | 10/18 |
| ☒ Amplifier | Com-Power | CPPA-102 (01254) | 1-1000 MHz | 10/17 | 10/18 |
| ☒ Amplifier | Com-Power | PAM-118A (551014) | 0.5-18 GHz | 10/17 | 10/18 |
| ☐ Power Mtr | Agilent | N1911A with N1921A | 0.05-18 GHz | 5/17 | 5/18 |

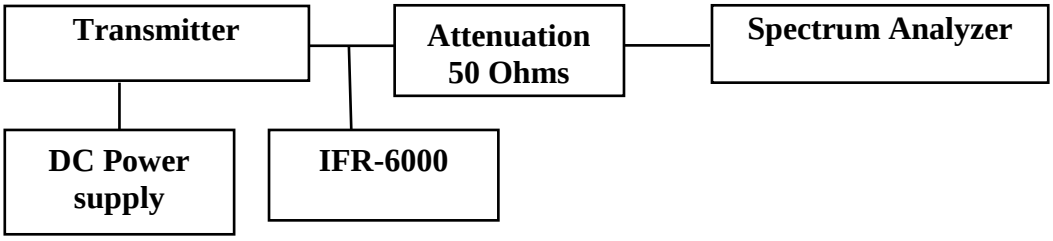
# Transmitter Power Output

### *Measurements Required*

Measurements shall be made to establish the radio frequency power delivered by the transmitter into the standard output termination. The power output shall be monitored and recorded and no adjustment shall be made to the transmitter after the test has begun, except as noted below:

If the power output is adjustable, measurements shall be made for the highest and lowest power levels.

### *Test Arrangement*




The radio frequency power output was measured at the antenna terminal by placing 50-dB attenuation in the antenna line and observing the emission with the spectrum analyzer. The spectrum analyzer offered an impedance of 50Ω to match the impedance of the standard antenna and inline attenuation. A Rohde & Schwarz ESU40 Spectrum Analyzer was used to measure the radio frequency power at the antenna port. Data was taken in dBm and converted to watts as shown in the following Table. Data was taken per 47CFR Paragraph 2.1046(a) and applicable paragraphs of Part 87.

$P_{dBm}$ = power in dB above 1 milliwatt

Milliwatts $= 10^{(PdBm/10)}$ Watts = (Milliwatts) x 0.001(W/mW)

Milliwatts $= 10^{(54.30/10)}$

= 269,153.5 mW = 270 Watts Peak Power

### *Table 1 Transmitter Power Results*

| Frequency (MHz) | $P_{dBm}$ | $P_{mw}$ | $P_w$ |
|---|---|---|---|
| 1090 | 54.30 | 269,153.5 | 270 |

The EUT demonstrated compliance with spe3cifications of 47CFR Paragraph 2.1046(a) and applicable Parts of 2 and 87. There are no deviations to the specifications.

# Modulation Characteristics

## *Measurements Required*

A curve or equivalent data that shows that the equipment will meet the modulation requirements of the rules under which the equipment is to be licensed shall be submitted.

The modulation specifications are defined by the FAA TSO-C112 standard for use in the Mode A, Mode C, and Mode S interrogations. This requires pulses of 0.500 ±0.050 microseconds for Mode S with rise times of 0.100-microsecond maximum and fall-times of 0.200 microseconds maximum for both. The maximum rated condition, Mode S reply, has a 120-microsecond length with four pulses in the first eight microseconds, which is called the preamble, and pulses of 0.5 or 1.0 microsecond length filling in the next 112 microseconds, which is called the data block. Binary data is coded by the pulse position in the one-microsecond frames.

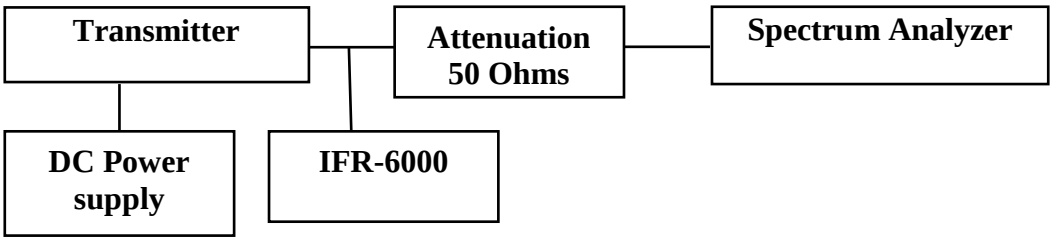
The Modulation characteristics remain as presented in the original application.

# Occupied Bandwidth

### *Measurements Required*

The occupied bandwidth, that is the frequency bandwidth such that below its lower and above its upper frequency limits, the mean powers radiated are equal to 0.5 percent of the total mean power radiated by a given emission. Refer to figures three and four displaying plots of the 99% occupied bandwidth measurement.

### *Test Arrangement*




### *Table 2 Occupied Bandwidth Results*

| Operational Frequency Band (MHz) | Occupied Bandwidth (MHz) |
|---|---|
| 1090 (A mode) | 7.650 |
| 1090 (S mode) | 7.175 |

The EUT demonstrated compliance with the requirements of Paragraphs 2.1046(a) and 87. There are no deviations to the specifications.

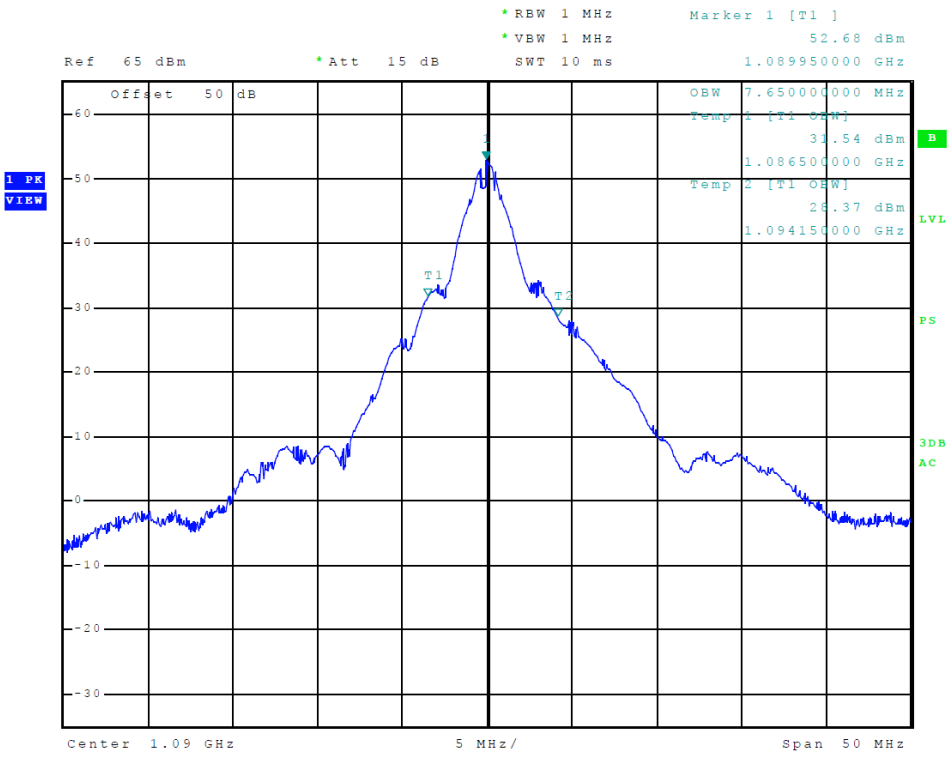



**Figure 1 Occupied Bandwidth (A mode)**

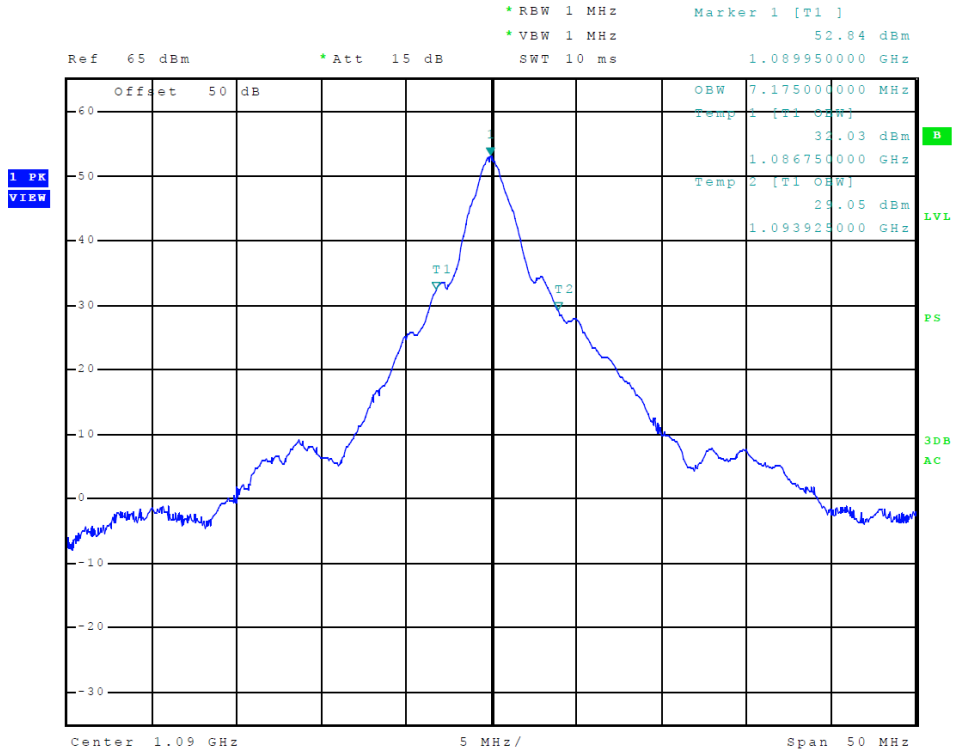


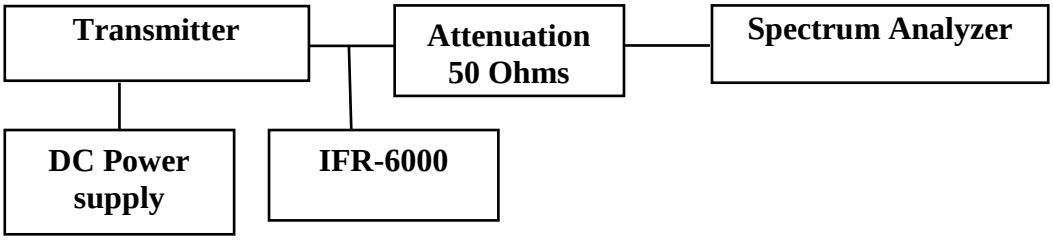

**Figure 2 Occupied Bandwidth (S mode)**

# Spurious Emissions

## *Measurements Required*

The radio frequency voltage or power 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. To gain dynamic range in the test equipment, a high pass filter attenuated the fundamental frequency of operation was used to observe the harmonic emissions.

## *Test Arrangement*




The radio frequency output was passively coupled to a Rohde &Schwarz ESU40 Spectrum Analyzer. The spectrum analyzer was used to observe the radio frequency spectrum with the transmitter operating in its normal mode. The frequency spectrum from 9 kHz to 12 GHz was observed. Data was taken per 47CFR 2.1051 and applicable paragraphs of Part 87.

Limit: Spurious emissions must be attenuated below the peak output power by the at least $43 + 10 \text{ Log}_{10}(P_w)$

Attenuation $= 43 + 10 \text{ Log}_{10}(P_w)$

$= 43 + 10 \text{ Log}_{10} (2.70)$

$= 47.3$ dBc

### *Table 3 Spurious Emissions Results (A mode)*

| Channel MHz | Spurious Freq. (MHz) | Measured Level (dBm) | Level Below Carrier (dBc) |
|---|---|---|---|
| 1090.00 | 2180.0 | -74.17 | 128.5 |
| | 3270.0 | -73.37 | 127.7 |
| | 4360.0 | -68.82 | 123.2 |
| | 5450.0 | -72.20 | 126.6 |
| | 6540.0 | -72.75 | 127.1 |
| | 7630.0 | -72.54 | 126.9 |
| | 8720.0 | -72.05 | 126.4 |
| | 9810.0 | -71.69 | 126.1 |
| | 10900.0 | -71.22 | 125.6 |

Data was taken per 2.1051 and applicable parts of 47CFR paragraph 87. There are no deviations to the specifications.

### *Table 4 Spurious Emissions Results (S mode)*

| Channel MHz | Spurious Freq. (MHz) | Measured Level (dBm) | Level Below Carrier (dBc) |
|---|---|---|---|
| 1090.00 | 2180.0 | -68.77 | 123.1 |
| | 3270.0 | -68.93 | 123.3 |
| | 4360.0 | -68.08 | 122.4 |
| | 5450.0 | -70.57 | 124.9 |
| | 6540.0 | -70.91 | 125.2 |
| | 7630.0 | -70.03 | 124.4 |
| | 8720.0 | -70.37 | 124.7 |
| | 9810.0 | -69.53 | 123.9 |
| | 10900.0 | -69.22 | 123.6 |

Data was taken per 2.1051 and applicable parts of 47CFR paragraph 87. There are no deviations to the specifications.

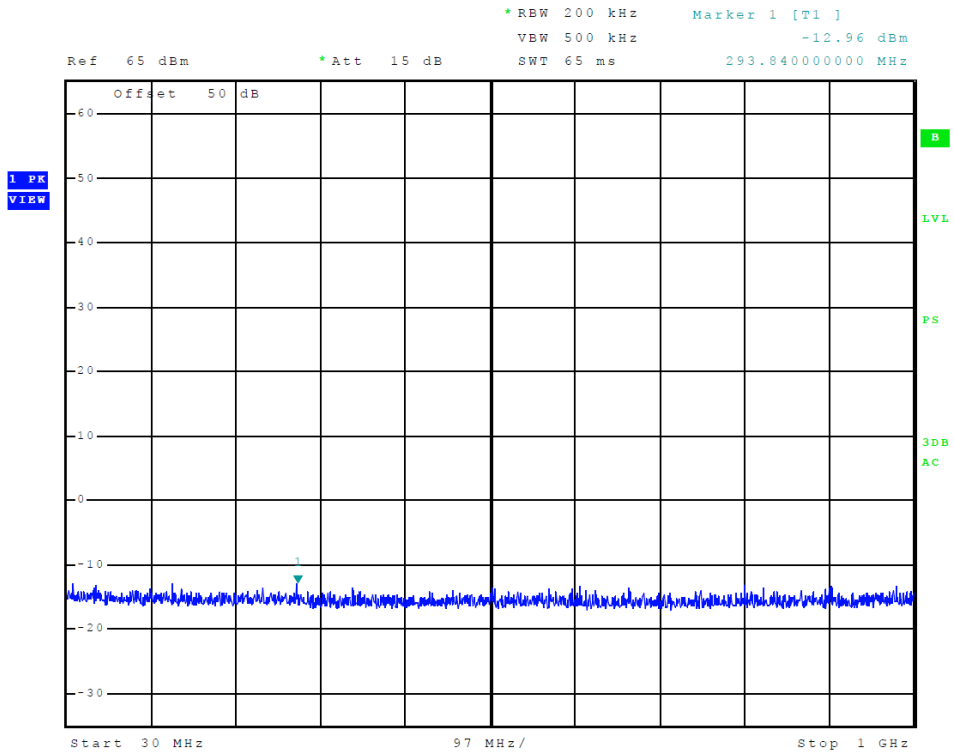



**Figure 3 Spurious Emissions at Antenna Port (A mode)**

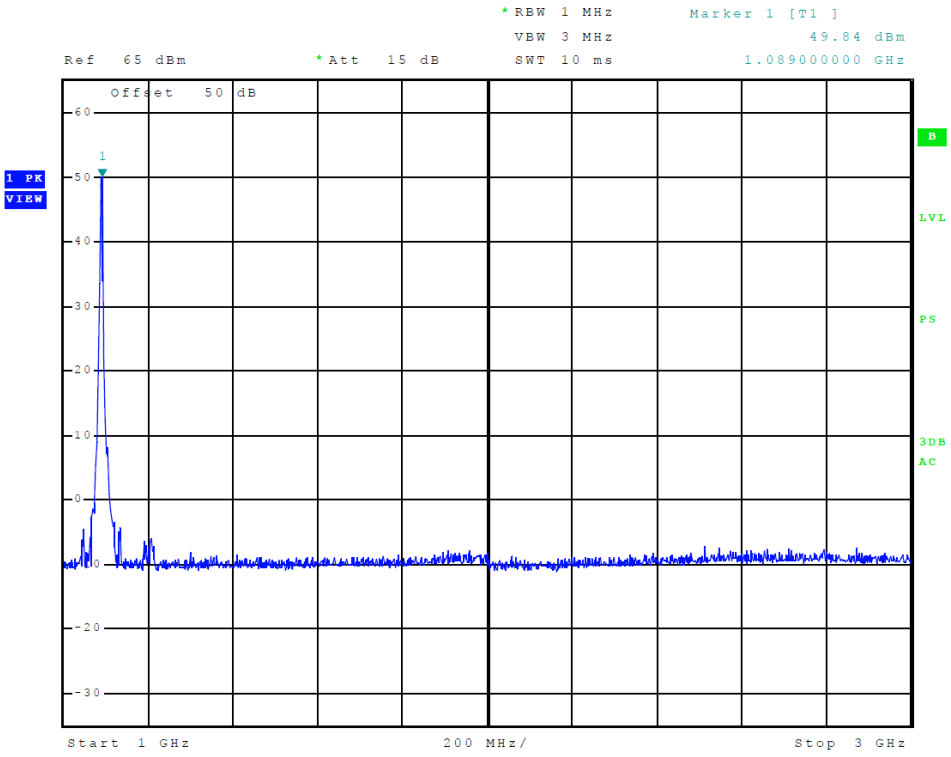



**Figure 4 Spurious Emissions at Antenna Port (A mode)**

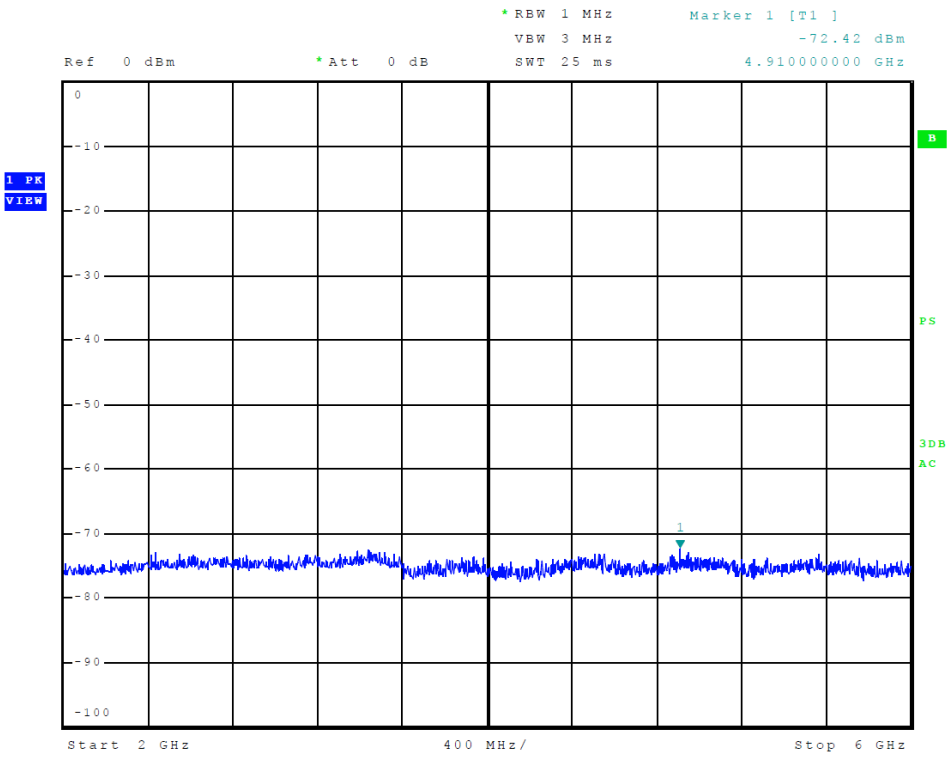



**Figure 5 Spurious Emissions at Antenna Port (A mode)**

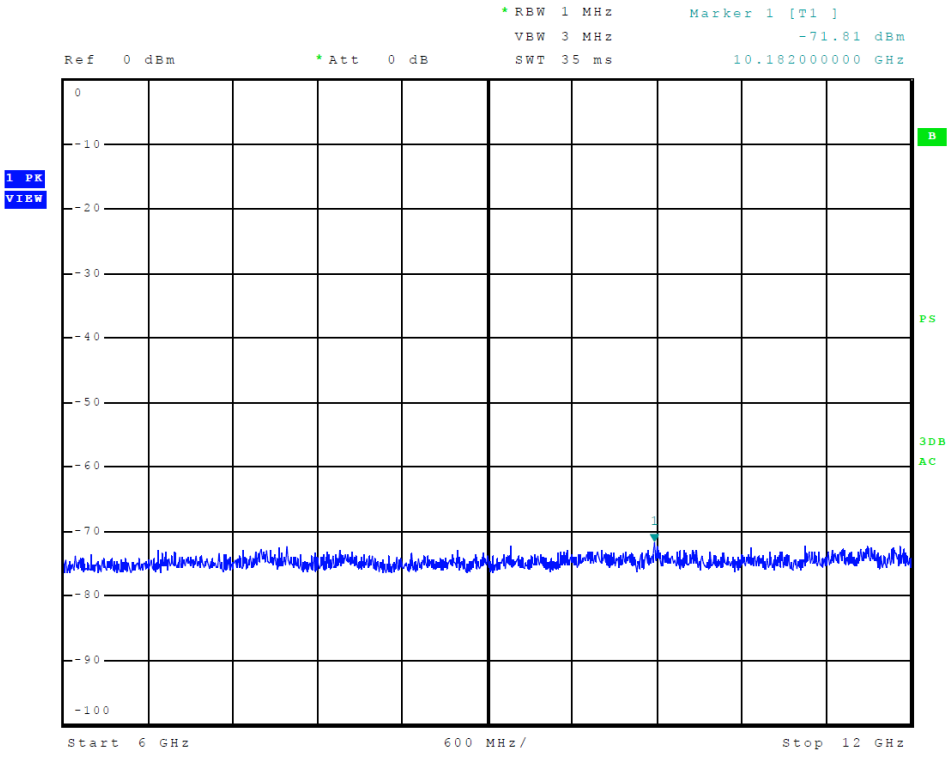



**Figure 6 Spurious Emissions at Antenna Port (A mode)**

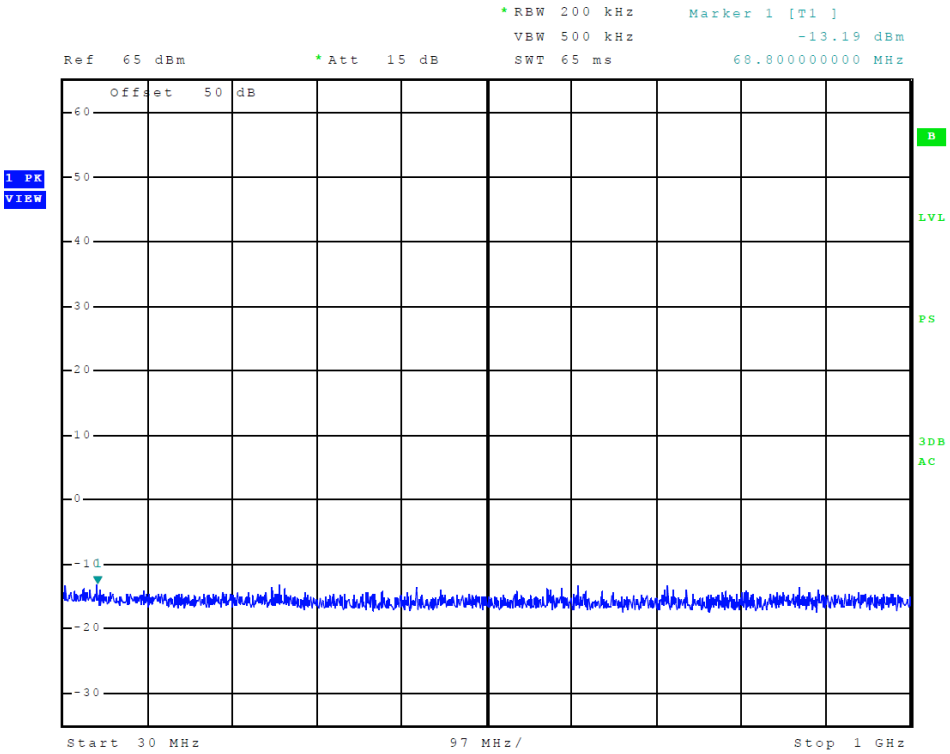



**Figure 7 Spurious Emissions at Antenna Port (S mode)**

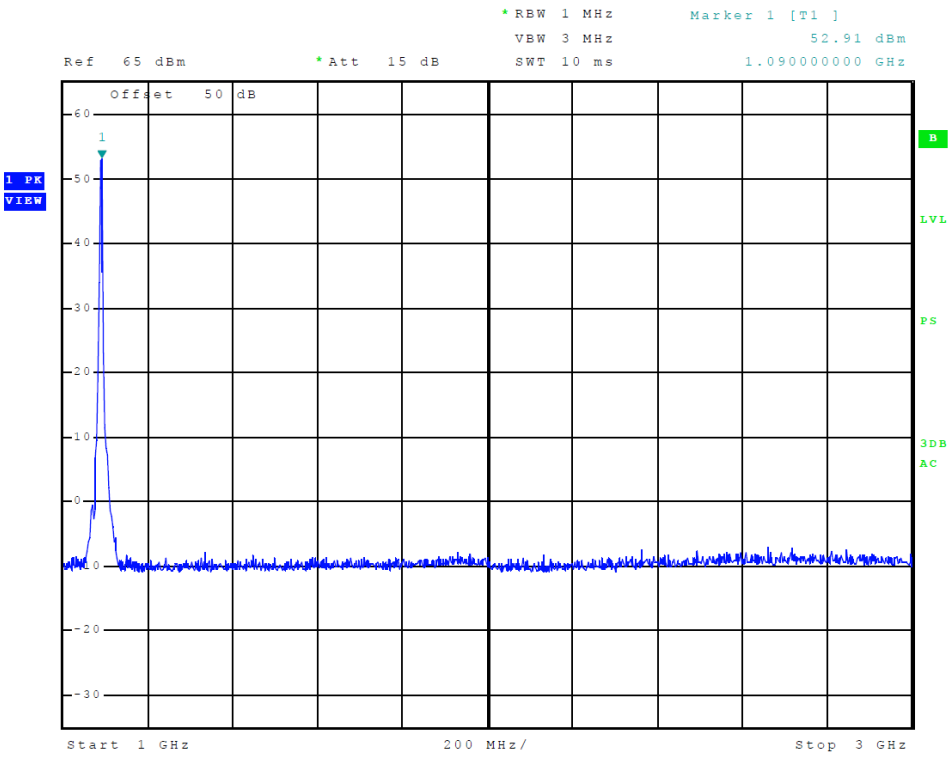



**Figure 8 Spurious Emissions at Antenna Port (S mode)**

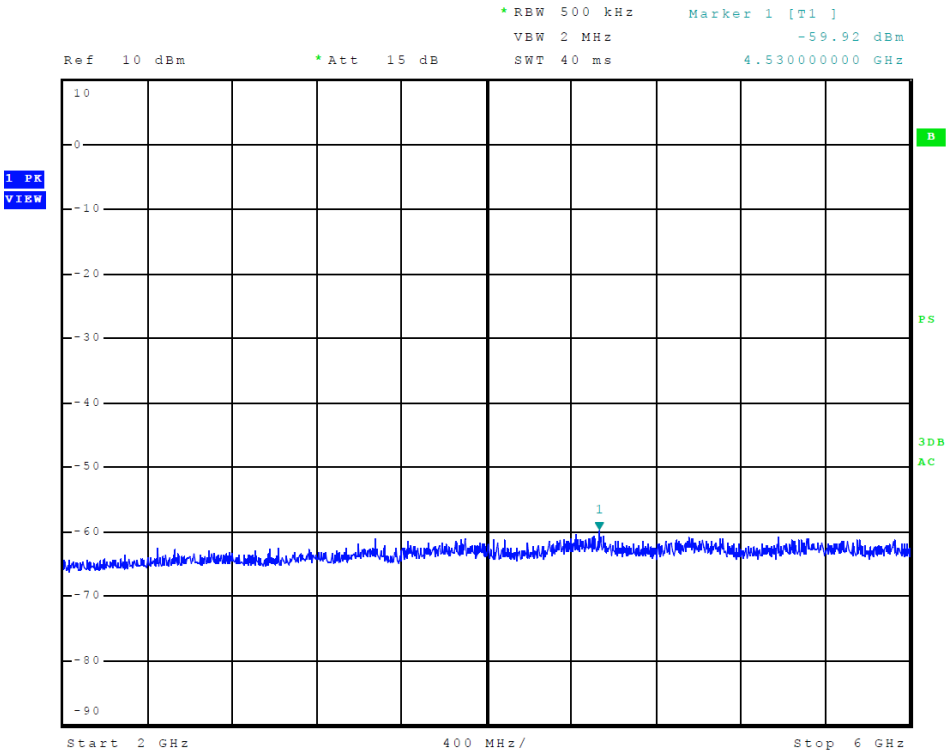



**Figure 9 Spurious Emissions at Antenna Port (S mode)**

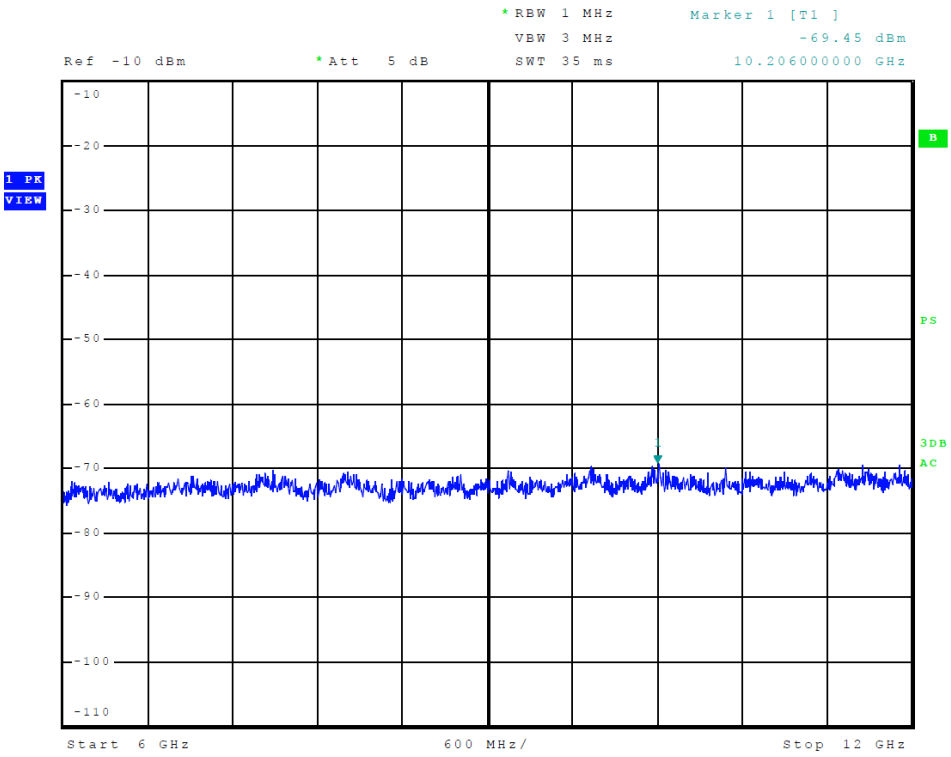



**Figure 10 Spurious Emissions at Antenna Port (S mode)**

# Annex

- Annex A Measurement Uncertainty Calculations
- Annex B Rogers Labs Test Equipment List
- Annex C Rogers Qualifications

## *Annex A Measurement Uncertainty Calculations*

Measurement uncertainty calculations were made for the laboratory. Result of measurement uncertainty calculations are recorded below for AC line conducted and radiated emission measurements.

| Measurement Uncertainty | $U_{(E)}$ | $U_{(lab)}$ |
|---|---|---|
| 3 Meter Horizontal 30-200 MHz Measurements | 2.08 | 4.16 |
| 3 Meter Vertical 30-200 MHz Measurements | 2.16 | 4.33 |
| 3 Meter Vertical Measurements 200-1000 MHz | 2.99 | 5.97 |
| 10 Meter Horizontal Measurements 30-200 MHz | 2.07 | 4.15 |
| 10 Meter Vertical Measurements 30-200 MHz | 2.06 | 4.13 |
| 10 Meter Horizontal Measurements 200-1000 MHz | 2.32 | 4.64 |
| 10 Meter Vertical Measurements 200-1000 MHz | 2.33 | 4.66 |
| 3 Meter Measurements 1-6 GHz | 2.57 | 5.14 |
| 3 Meter Measurements 6-18 GHz | 2.58 | 5.16 |
| AC Line Conducted | 1.72 | 3.43 |

## *Annex B Rogers Labs Test Equipment List*

| List of Test Equipment | Calibration Date | Due |
|---|---|---|
| Spectrum Analyzer: Rohde & Schwarz ESU40 | 5/17 | 5/18 |
| Spectrum Analyzer: HP 8562A, HP Adapters: 11518, 11519, and 11520 Mixers: 11517A, 11970A, 11970K, 11970U, 11970V, 11970W | 5/17 | 5/18 |
| Spectrum Analyzer: HP 8591EM | 5/17 | 5/18 |
| Antenna: EMCO Biconilog Model: 3143 | 5/17 | 5/18 |
| Antenna: Sunol Biconilog Model: JB6 | 10/17 | 10/18 |
| Antenna: EMCO Log Periodic Model: 3147 | 10/17 | 10/18 |
| Antenna: Com Power Model: AH-118 | 10/17 | 10/18 |
| Antenna: Com Power Model: AH-840 | 5/17 | 5/18 |
| Antenna: Antenna Research Biconical Model: BCD 235 | 10/17 | 10/18 |
| Antenna: Com Power Model: AL-130 | 10/17 | 10/18 |
| Antenna: EMCO 6509 | 10/17 | 10/18 |
| LISN: Compliance Design Model: FCC-LISN-2.Mod.cd, 50 µHy/50 ohms/0.1 µf | 10/17 | 10/18 |
| R.F. Preamp CPPA-102 | 10/17 | 10/18 |
| Attenuator: HP Model: HP11509A | 10/17 | 10/18 |
| Attenuator: Mini Circuits Model: CAT-3 | 10/17 | 10/18 |
| Attenuator: Mini Circuits Model: CAT-3 | 10/17 | 10/18 |
| Cable: Belden RG-58 (L1) | 10/17 | 10/18 |
| Cable: Belden RG-58 (L2) | 10/17 | 10/18 |
| Cable: Belden 8268 (L3) | 10/17 | 10/18 |
| Cable: Time Microwave: 4M-750HF290-750 | 10/17 | 10/18 |
| Cable: Time Microwave: 10M-750HF290-750 | 10/17 | 10/18 |
| Frequency Counter: Leader LDC825 | 2/17 | 2/18 |
| Oscilloscope Scope: Tektronix 2230 | 2/17 | 2/18 |
| Wattmeter: Bird 43 with Load Bird 8085 | 2/17 | 2/18 |
| Power Supplies: Sorensen SRL 20-25, SRL 40-25, DCR 150, DCR 140 | 2/17 | 2/18 |
| R.F. Generators: HP 606A, HP 8614A, HP 8640B | 2/17 | 2/18 |
| R.F. Power Amp 65W Model: 470-A-1010 | 2/17 | 2/18 |
| R.F. Power Amp 50W M185- 10-501 | 2/17 | 2/18 |
| R.F. Power Amp A.R. Model: 10W 1010M7 | 2/17 | 2/18 |
| R.F. Power Amp EIN Model: A301 | 2/17 | 2/18 |
| LISN: Compliance Eng. Model 240/20 | 2/17 | 2/18 |
| LISN: Fischer Custom Communications Model: FCC-LISN-50-16-2-08 | 2/17 | 2/18 |
| Antenna: EMCO Dipole Set 3121C | 2/17 | 2/18 |
| Antenna: C.D. B-101 | 2/17 | 2/18 |
| Antenna: Solar 9229-1 & 9230-1 | 2/17 | 2/18 |
| Audio Oscillator: H.P. 201CD | 2/17 | 2/18 |
| ESD Test Set 2010i | 2/17 | 2/18 |
| Fast Transient Burst Generator Model: EFT/B-101 | 2/17 | 2/18 |
| Field Intensity Meter: EFM-018 | 2/17 | 2/18 |
| KEYTEK Ecat Surge Generator | 2/17 | 2/18 |
| Shielded Room 5 M x 3 M x 3.0 M | | |

## *Annex C Rogers Qualifications*

***Scot D. Rogers, Engineer***

**Rogers Labs, Inc.**

Mr. Rogers has approximately 17 years' experience in the field of electronics. Work experience includes six years working in the automated controls industry and remaining years working with the design, development and testing of radio communications and electronic equipment.

Positions Held:

| | | |
|---|---|---|
| Systems Engineer: | A/C Controls Mfg. Co., Inc. | 6 Years |
| Electrical Engineer: | Rogers Consulting Labs, Inc. | 5 Years |
| Electrical Engineer: | Rogers Labs, Inc. | Current |

Educational Background:

1) Bachelor of Science Degree in Electrical Engineering from Kansas State University

2) Bachelor of Science Degree in Business Administration Kansas State University

3) Several Specialized Training courses and seminars pertaining to Microprocessors and Software programming.