NVLAP Testing
NVLAP Lab Code 200087-0

Class 2 Permissible Change Test Report

47 CFR Part 87

Model: TT 31 (model: 00220)

Mode S Aviation Transponder

1090 MHz

FCC ID: VZI00220

For

Trig Avionics Limited
Heriot Watt Research Park

Riccarton, Edinburgh EH14 4AP, UK

FCC Site Registration: US5305
IC Test Site Registration: 3041A-1
Report Number 180711

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
Phone / Fax (913) 837-3214

Class 2 Permissible Change Test Report

For

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

Model: TT 31 (model: 00220)

Multi-Mode S Aviation Transponder
Frequency Range: 1090 MHz

Test Date: July 18, 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 August 6, 2018

Executive Summary

The following information is submitted for consideration in processing Class 2 Permissible Change of certified equipment operating under 47 CFR Paragraph 87 Aviation Transponder transmitter equipment. The following information and associated application addresses replacement of parts to address part 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

Model: TT 31 (model: 00220) Original Grant Date 02/19/2008

FCC ID: VZI00220

Frequency of Operation: 1090 MHz

Transmit Peak Power: 282 watts peak, occupied bandwidth 8.08 MHz

Opinion / Interpretation of Results

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

Modification to Equipment Design

The modified transceiver addresses current component obsolescence and printed circuit board layout to accommodate the new replacement parts. The modulator remains unchanged as well as the performance when compared to original equipment and filing. The gain of the new devices requires one fewer driver stages than the original devices required. The transmitter has three stages, there being two stages in the output device.

Equipment Under Test

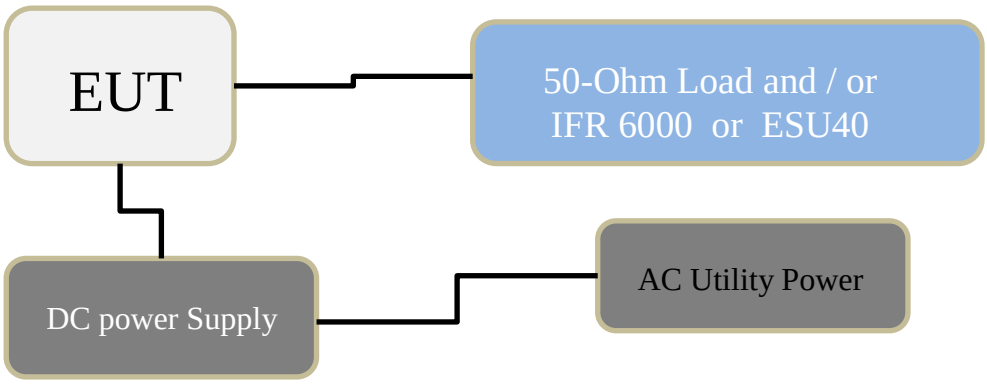
Equipment	Model / PN	Serial Number
EUT	TT 31 (model: 00220)	ENG 09371
DC Power Supply	1745	209C13

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

Equipment Function and Configuration

The TT 31 transponder is an ED-73B Class 1 compliant Mode S level 2 data link transponder. A user interface with an LCD screen and simple mode selector and code entry features control the transponder. The device interfaces with a conventional parallel altitude encoder or 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.

Equipment Configuration



Application for Certification

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

2. Identification: **Model**: TT 31 (model: 00220) **FCC ID**: VZI00220

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 8M08V1D

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. 282-Watts peak, 2.8 Watts (Average Power) delivered

7. Maximum power rating as defined in the applicable part(s) of the rules. 282 Watts (nominal peak power) and 2.8 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 50.0 volts @ 8.7 amps (433 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.

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

Applicable Standards and Test Procedures

In accordance with the Federal Communications Code of Federal Regulations, 47 CFR dated July 18, 2018, Part 2 Subpart J, Paragraphs 2.932, 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.

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	24.8° C
Relative Humidity	40%
Atmospheric Pressure	1015.8 mb

List of Test Equipment

Equipment	Manufacturer	Model (SN)	Band	Cal Date(m/d/y)	Due
☐ LISN	FCC	FCC-LISN-50-2-10(1PA) (160611)	.15-30MHz	5/2/2018	5/2/2019
☐ LISN	Compliance Design	FCC-LISN-2.Mod.cd,	.15-30MHz	10/24/2017	10/24/2018
☐ Cable	Huber & Suhner Inc.	Sucoflex102ea(L10M)(303073)	9kHz-40 GHz	10/24/2017	10/24/2018
☐ Cable	Huber & Suhner Inc.	Sucoflex102ea(1.5M)(303069)	9kHz-40 GHz	10/24/2017	10/24/2018
☒ Cable	Huber & Suhner Inc.	Sucoflex102ea(1.5M)(303071)	9kHz-40 GHz	10/24/2017	10/24/2018
☐ Cable	Belden	RG-58 (L1-CAT3-11509)	9kHz-30 MHz	10/24/2017	10/24/2018
☐ Cable	Belden	RG-58 (L2-CAT3-11509)	9kHz-30 MHz	10/24/2017	10/24/2018
☐ Antenna	ARA	BCD-235-B (169)	20-350MHz	10/24/2017	10/24/2018
☐ Antenna	EMCO	3147 (40582)	200-1000MHz	10/24/2017	10/24/2018
☐ Antenna	ETS-Lindgren	3117 (200389)	1-18 GHz	5/2/2018	5/2/2020
☐ Antenna	Com Power	AH-118 (10110)	1-18 GHz	10/24/2017	10/24/2019
☐ Antenna	Com Power	AH-840 (101046)	18-40 GHz	5/15/2017	5/15/2019
☐ Antenna	Com Power	AL-130 (121055)	.001-30 MHz	10/24/2017	10/24/2018
☐ Antenna	Sunol	JB-6 (A100709)	30-1000 MHz	10/24/2017	10/24/2018
☒ Analyzer	Rohde & Schwarz	ESU40 (100108)	20Hz-40GHz	5/2/2018	5/2/2019
☐ Analyzer	Rohde & Schwarz	ESW44 (101534)	20Hz-44GHz	12/22/2017	12/22/2018
☐ Analyzer	Rohde & Schwarz	FS-Z60, 90, 140, and 220	40GHz-220GHz	12/22/2017	12/22/2019
☐ Analyzer	HP	8591EM (3628A00871)	9kHz-1.8GHz	5/2/2018	5/2/2019
☐ Analyzer	HP	8562A (3051A05950)	9kHz-125GHz	5/2/2018	5/2/2019
☐ Analyzer	HP External Mixers	11571, 11970	25GHz-110GHz	5/2/2018	5/2/2019
☐ Amplifier	Com-Power	PA-010 (171003)	100Hz-30MHz	10/24/2017	10/24/2018
☐ Amplifier	Com-Power	CPPA-102 (01254)	1-1000 MHz	10/24/2017	10/24/2018
☐ Amplifier	Com-Power	PAM-118A (551014)	0.5-18 GHz	10/24/2017	10/24/2018
☒ Power Meter	Agilent	N1911A with N1921A	0.05-40 GHz	5/2/2018	5/2/2019
☐ Generator	Rohde & Schwarz	SMB100A6 (100150)	20Hz-6 GHz	5/2/2018	5/2/2019
☐ Generator	Rohde & Schwarz	SMBV100A6 (260771)	20Hz-6 GHz	5/2/2018	5/2/2019
☐ RF Filter	Micro-Tronics	BRC50722 (009).9G notch	30-1800 MHz	5/2/2018	5/2/2019
☐ RF Filter	Micro-Tronics	HPM50114 (017)1.5G HPF	30-18000 MHz	5/2/2018	5/2/2019
☐ RF Filter	Micro-Tronics	HPM50117 (063) 3G HPF	30-18000 MHz	5/2/2018	5/2/2019
☐ RF Filter	Micro-Tronics	HPM50105 (059) 6G HPF	30-18000 MHz	5/2/2018	5/2/2019
☐ RF Filter	Micro-Tronics	BRM50702 (172) 2G notch	30-1800 MHz	5/2/2018	5/2/2019
☐ RF Filter	Micro-Tronics	BRC50703 (G102) 5G notch	30-1800 MHz	5/2/2018	5/2/2019
☐ RF Filter	Micro-Tronics	BRC50705 (024) 5G notch	30-1800 MHz	5/2/2018	5/2/2019
☐ RF Filter	Micro-Tronics	BRC17663 (001) 9G notch	30-1800 MHz	5/2/2018	5/2/2019
☐ Attenuator	Mini-Circuits	VAT-3W2+ (14362)	30-6000 MHz	5/2/2018	5/2/2019
☐ Attenuator	Mini-Circuits	VAT-3W2+ (1445)	30-6000 MHz	5/2/2018	5/2/2019
☐ Attenuator	Mini-Circuits	VAT-3W2+ (14452)	30-6000 MHz	5/2/2018	5/2/2019
☐ Attenuator	Mini-Circuits	VAT-6W2+ (1438)	30-6000 MHz	5/2/2018	5/2/2019
☒ Coupler	Narda	VAT3002-20	950-2000 MHz	5/2/2018	5/2/2019
☒ Test Set	IFR	IFR 6000	1090 MHz	6/14/2018	6/14/2019
☒ Attenuator	JFW Industries	50FH-020-10 (1)(2)	30-18000 MHz	5/2/2018	5/2/2019
☒ Weather station	Davis	6312 (A70927D44N)		10/24/2017	10/24/2018

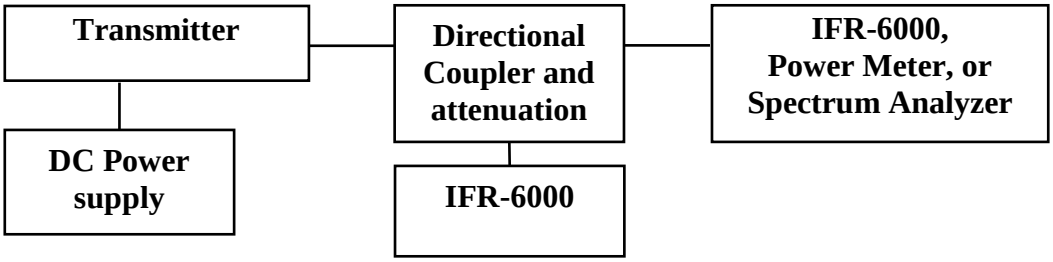
Transmitter Power Output

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 end of the antenna port cable attached to the radio mounting tray. The loss of this cable was identified by the manufacturer to have 1 dB loss and their requirement is the cable have less than 2 dB loss. Testing measurements were conducted at the end of the mounting tray RF coaxial cable. Loss from the mounting tray cable was not included or accounted for during our measurements. Connection with the antenna coaxial cable was completed by placing 50-ohm directional coupler, attenuation and/or test equipment in the antenna line. Emissions were monitored with a spectrum analyzer and measured with IFR 6000, Power Meter, and ESU40. The attenuation and test equipment provided impedance of 50-ohms to match the impedance of the standard antenna. A Rohde & Schwarz ESU40 Spectrum Analyzer was used to provide plot of the transmitter output power at the antenna port. Refer to figure one displaying plot of the output power. Data was taken in dBm and converted to watts as shown in the following Table. Data was taken per 47 CFR Paragraph 2.1046 and applicable paragraphs of Part 87.

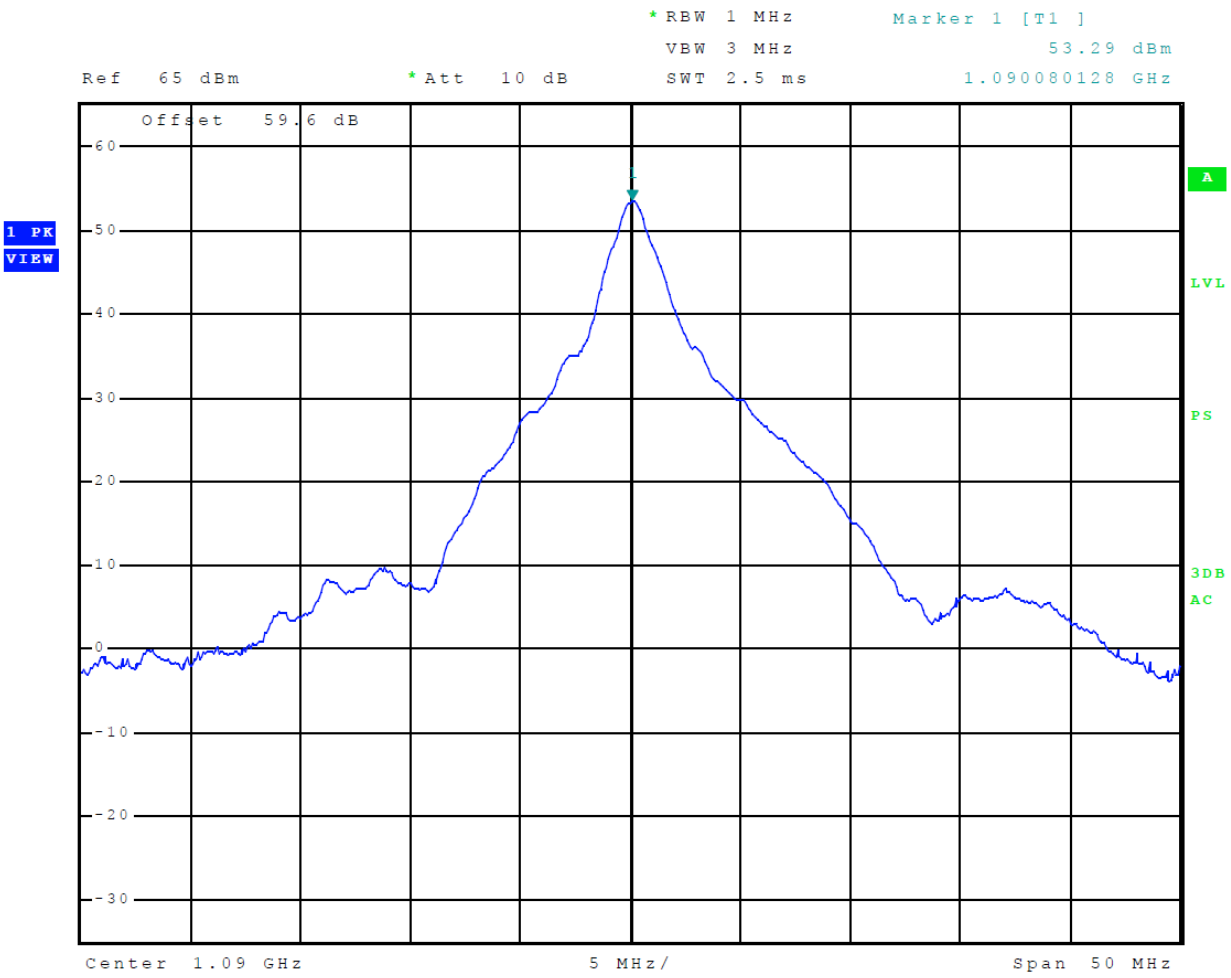


Figure 1 Output Power

P_{dBm} = power in dB above 1 milliwatt

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

Milliwatts $= 10^{(54.5)}$

= 281,838 mW = 282 Watts Peak Power

Table 1 Transmitter Power Results

Frequency (MHz)	P_{dBm}	P_{mw}	P_w
1090	54.5	281,838	282

The EUT demonstrated compliance with specifications of 47 CFR Paragraph 2.1046 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 figure two displaying plot of the 99% occupied bandwidth measurement.

Test Arrangement

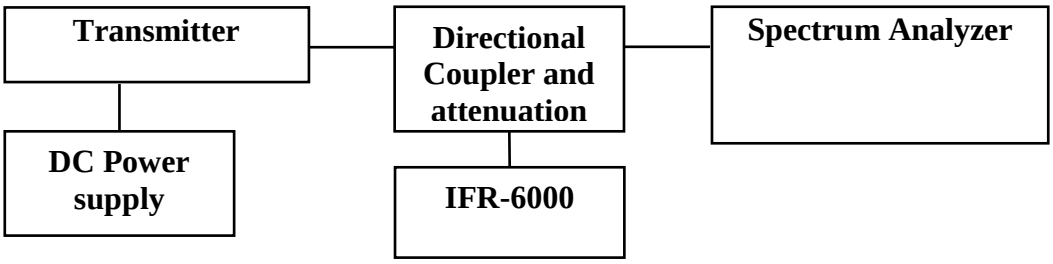


Table 2 Occupied Bandwidth Results

Operational Frequency Band (MHz)	Occupied Bandwidth (kHz)
1090 (S mode)	8,076.9

The EUT demonstrated compliance with the requirements of Paragraphs 2.1049 and 87. There are no deviations to the specifications.

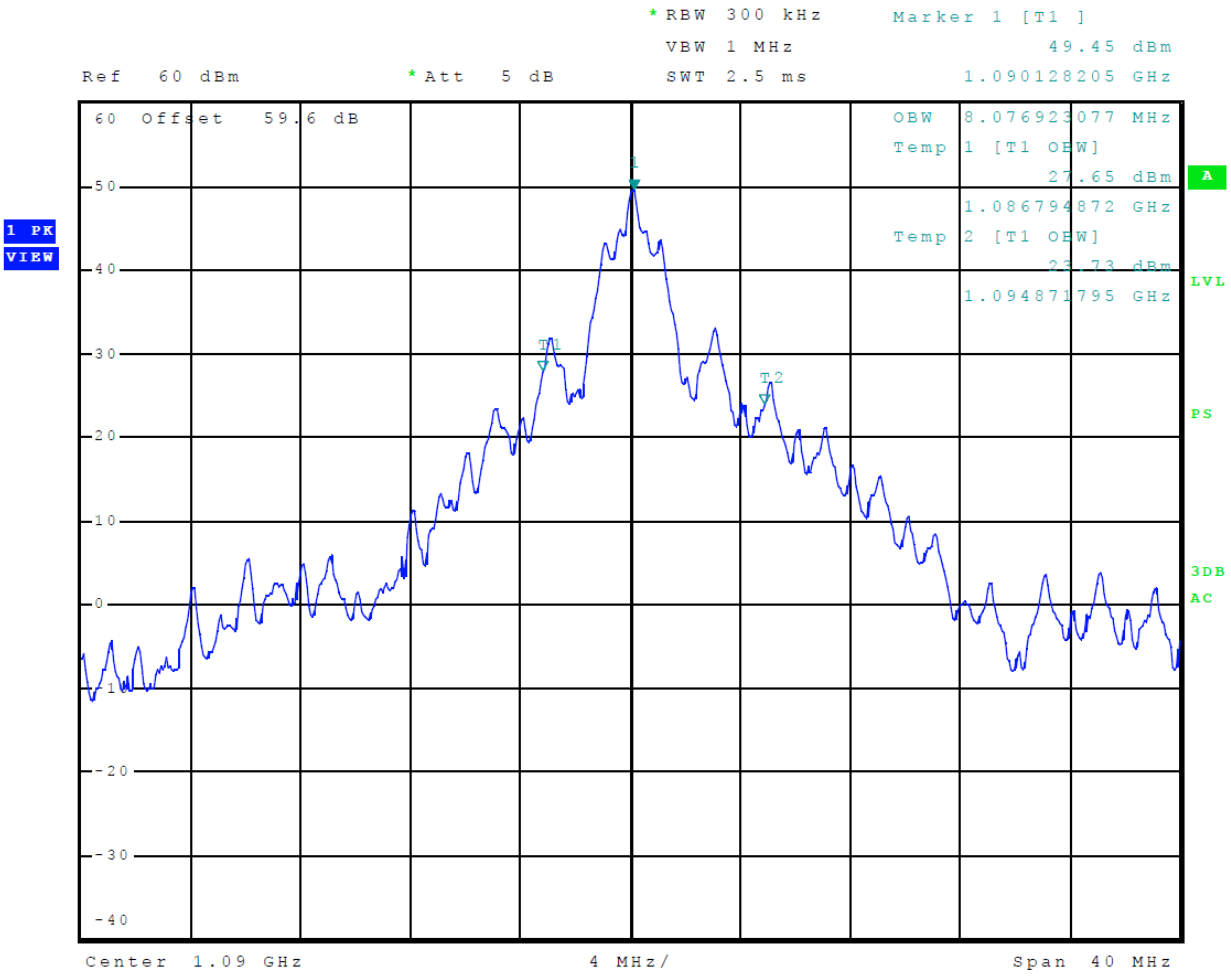


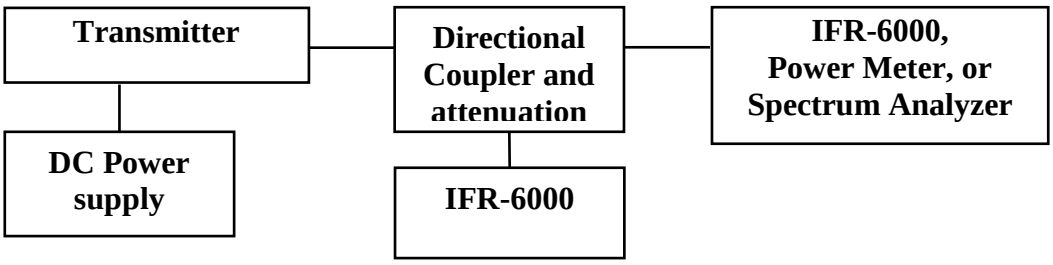
Figure 2 99% Occupied Bandwidth

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.

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 47 CFR 2.1051 and applicable paragraphs of Part 87. Refer to figures three through six displaying plots of the antenna port conducted emissions.

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

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

$= 43 + 10 \text{ Log}_{10} (2.82)$

$= 47.5$ dBc

Table 3 Spurious Emissions Results

Channel MHz	Spurious Freq. (MHz)	Measured Level (dBm)	Level Below Carrier (dBc)
1090.00	2180.0	-1.54	56.0
	3270.0	-27.41	81.9
	4360.0	-13.30	67.8
	5450.0	-22.80	77.3
	6540.0	-34.30	88.8
	7630.0	-36.40	90.9
	8720.0	-47.70	102.2
	9810.0	-46.80	101.3
	10900.0	-47.00	101.5

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

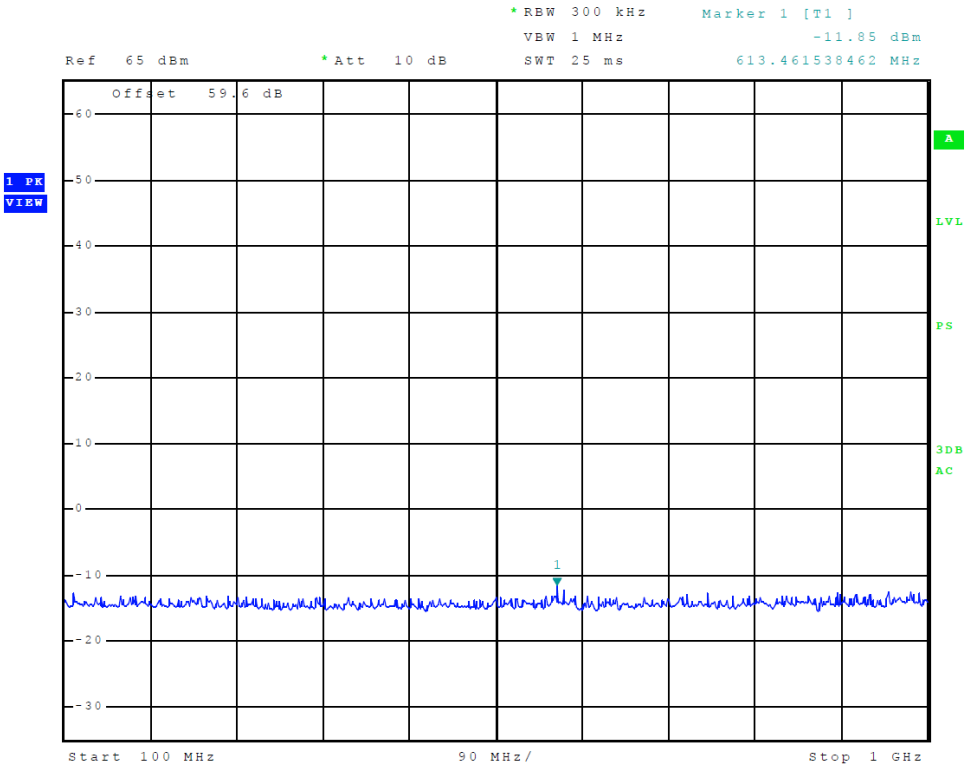


Figure 3 Spurious Emissions at Antenna Port

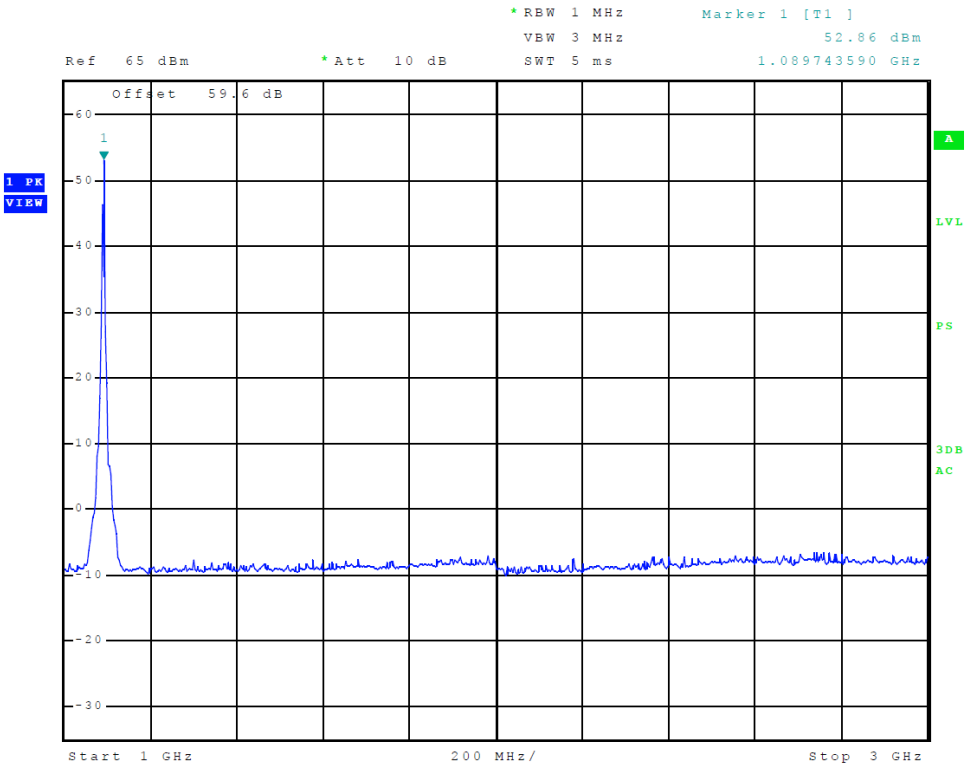


Figure 4 Spurious Emissions at Antenna Port

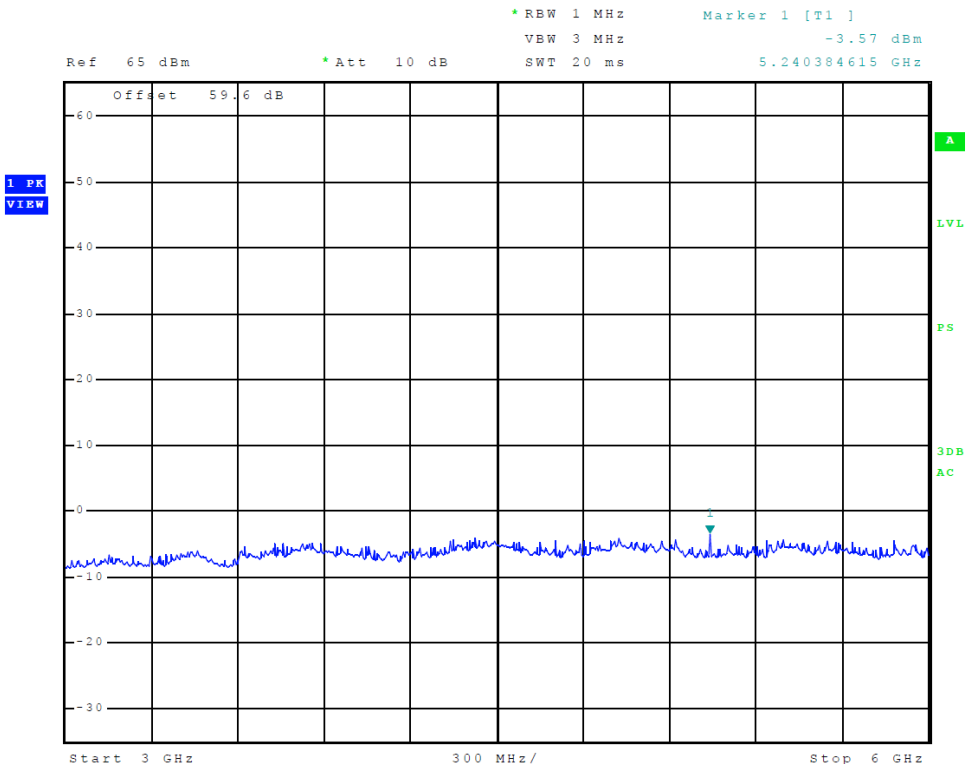


Figure 5 Spurious Emissions at Antenna Port

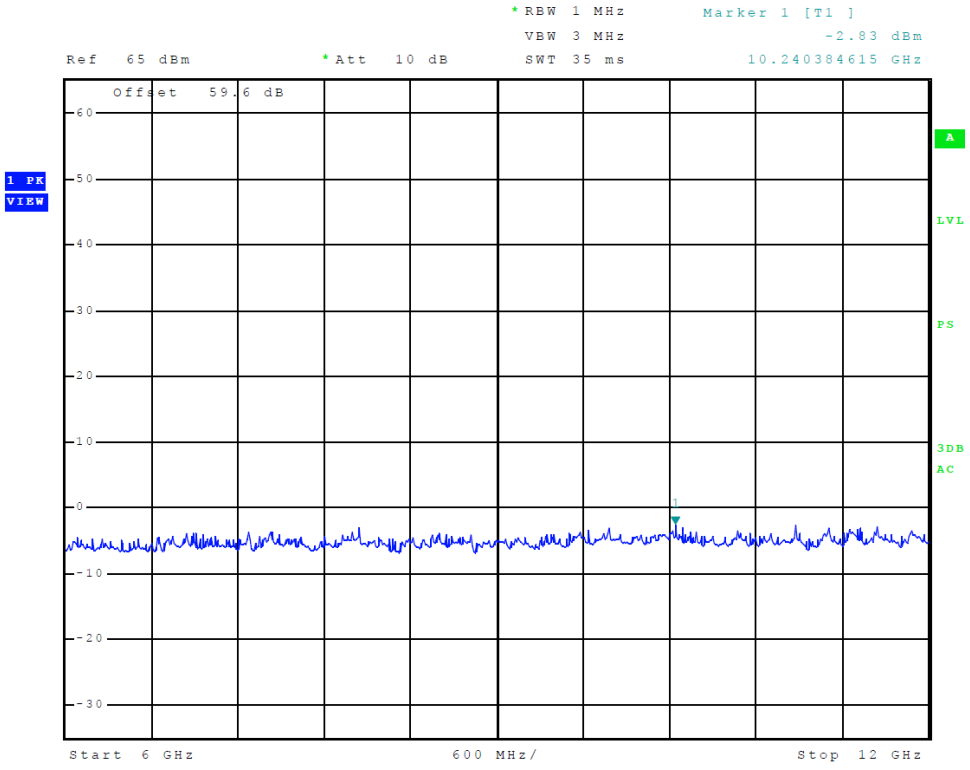


Figure 6 Spurious Emissions at Antenna Port

Annex

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

Annex A Measurement Uncertainty Calculations

The measurement uncertainty was calculated for all measurements listed in this test report according To CISPR 16–4. Result of measurement uncertainty calculations are recorded below. Component and process variability of production devices similar to those tested may result in additional deviations. The manufacturer has the sole responsibility of continued compliance.

Measurement	Expanded Measurement Uncertainty $U_{(lab)}$
3 Meter Horizontal 0.009-1000 MHz Measurements	4.16
3 Meter Vertical 0.009-1000 MHz Measurements	4.33
3 Meter Measurements 1-18 GHz	5.14
3 Meter Measurements 18-40 GHz	5.16
10 Meter Horizontal Measurements 0.009-1000 MHz	4.15
10 Meter Vertical Measurements 0.009-1000 MHz	4.32
AC Line Conducted	1.75
Antenna Port Conducted power	1.17
Frequency Stability	1.00E-11
Temperature	1.6˚C
Humidity	3%

Annex B Rogers Labs Test Equipment List

List of Test Equipment Calibration	Date (m/d/y)	Due
Antenna: Schwarzbeck Model: BBA 9106/VHBB 9124 (9124-627)	5/2/2018	5/2/2019
Antenna: Schwarzbeck Model: VULP 9118 A (VULP 9118 A-534)	5/2/2018	5/2/2019
Antenna: EMCO 6509	10/24/2016	10/24/2018
Antenna: EMCO 3143 (9607-1277) 20-1200 MHz	5/2/2018	5/2/2019
Antenna: EMCO Dipole Set 3121C	2/23/2018	2/23/2019
Antenna: C.D. B-101	2/23/2018	2/23/2019
Antenna: Solar 9229-1 & 9230-1	2/23/2018	2/23/2019
Cable: Belden 8268 (L3)	10/24/2017	10/24/2018
Cable: Time Microwave: 4M-750HF290-750	10/24/2017	10/24/2018
Frequency Counter: Leader LDC-825 (8060153	5/2/2018	5/2/2019
Oscilloscope Scope: Tektronix 2230	2/23/2018	2/23/2019
Wattmeter: Bird 43 with Load Bird 8085	2/23/2018	2/23/2019
Power Supplies: Sorensen SRL 20-25, SRL 40-25, DCR 150, DCR 140	2/23/2018	2/23/2019
R.F. Generator: SMB100A6 s/n 100623	5/2/2018	5/2/2019
R.F. Generator: SBMBV100A s/n: 260771	5/2/2018	5/2/2019
R.F. Generators: HP 606A, HP 8614A, HP 8640B	2/23/2018	2/23/2019
R.F. Power Amp 65W Model: 470-A-1010	2/23/2018	2/23/2019
R.F. Power Amp 50W M185- 10-501	2/23/2018	2/23/2019
R.F. Power Amp A.R. Model: 10W 1010M7	2/23/2018	2/23/2019
R.F. Power Amp EIN Model: A301	2/23/2018	2/23/2019
LISN: Compliance Eng. Model 240/20	5/2/2018	15/50/19
LISN: Fischer Custom Communications Model: FCC-LISN-50-16-2-08	5/2/2018	5/2/2019
Audio Oscillator: H.P. 201CD	2/23/2018	2/23/2019
ESD Test Set 2010i	2/23/2018	2/23/2019
Oscilloscope Scope: Tektronix MDO 4104	2/23/2018	2/23/2019
EMC Transient Generator HVT TR 3000	2/23/2018	2/23/2019
AC Power Source (Ametech, California Instruments)	2/23/2018	2/23/2019
Fast Transient Burst Generator Model: EFT/B-101	2/23/2018	2/23/2019
Field Intensity Meter: EFM-018	2/23/2018	2/23/2019
KEYTEK Ecat Surge Generator	2/23/2018	2/23/2019
ESD Simulator: MZ-15	2/23/2018	2/23/2019
Shielded Room not required		

Annex C Rogers Qualifications

Scot D. Rogers, Engineer

Rogers Labs, Inc.

Mr. Rogers has approximately 27 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.