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Testing of

Electromagnetic Emissions

per

USA:	CFR Title 47, Part 15.231	(Emissions)
USA:	CFR Title 47, Part 2.1091;2.1093	(Exposure)
Canada:	ISED RSS-210/GENE	(Emissions)
Canada:	ISED RSS-102	(Exposure)

are herein reported for

TRW Automotive

335098-101, 335098-102

Test Report No.: 20161111-RPTTRW010001Ar1

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Applicant/Provider:

TRW Automotive

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Date of Issue:

November 11, 2016

Results of testing completed on (or before) October 28, 2016 are as follows.

Emissions: The transmitter intentional emissions **COMPLY** with the regulatory limit(s) by no less than 5.9 dB. Transmit chain spurious or harmonic emissions **COMPLY** by no less than 9.3 dB. Unintentional spurious emissions from digital circuitry **COMPLY** with radiated emission limit(s) by at least 20 dB.

Revision History

Rev. No.	Date	Details	Revised By
r0	November 11, 2016	Initial Release.	J. Brunett
r1	December 6, 2016	Correct Typographical Errors.	J. Brunett

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1 Test Report Scope and Limitations

1.1 Laboratory Authorization

Test Facility description and attenuation characteristics are on file with the FCC Laboratory, Columbia, Maryland (FCC Reg. No: 688478) and with ISED Canada, Ottawa, ON (File Ref. No: IC8719A-1).

1.2 Report Retention

For equipment verified to comply with the regulations herein, the manufacturer is obliged to retain this report with the product records for the life of the product, and no less than ten years. A copy of this Report will remain on file with this Laboratory until November 2026.

1.3 Subcontracted Testing

This report does not contain data produced under subcontract.

1.4 Limitation of Results

The test results contained in this report relate only to the item(s) tested. Any electrical or mechanical modification made to the test item subsequent to the test date shall invalidate the data presented in this report. Any electrical or mechanical modification made to the test item subsequent to this test date shall require reevaluation.

1.5 Copyright

This report shall not be reproduced, except in full, without the written approval of Willow Run Test Labs, LLC.

1.6 Endorsements

This report shall not be used to claim product endorsement by any accrediting, regulatory, or governmental agency.

1.7 Test Location

The EUT was fully tested by **Willow Run Test Labs, LLC**, 7117 Fieldcrest Dr., Brighton, Michigan 48116 USA. Table 1 lists all site(s) employed herein. Specific test sites utilized are also listed in the test results sections of this report.

Table 1: Test Site List.

Description	Location	Quality Num.
OATS (3 meter)	8501 Beck Rd. Bldg 2227, Belleville MI 48111	OATSA

1.8 Traceability and Equipment Used

Pertinent test equipment used for measurements at this facility is listed in Table 2. The quality system employed at Willow Run Test Labs, LLC has been established to ensure all equipment has a clearly identifiable classification, calibration expiry date, and that all calibrations are traceable to the SI through NIST, other recognized national laboratories, accepted fundamental or natural physical constants, ratio type of calibration, or by comparison to consensus standards.

Table 2: Equipment List.

Description	Manufacturer/Model	SN	Quality Num.	Last Cal By / Date Due
Spectrum Analyzer	Rhode-Schwarz / FSV30	101660	RSFSV30001	RS / May-2018
Log Periodic Antenna	EMCO / 3146	9305-3614	LOGEMCO01	Lib. Labs/ April-2017
Quad Ridge Horn	ETS Lind. / 3164-04	00066988	HRNQR316401	Lib. Labs / April-2017

2 Test Specifications and Procedures

2.1 Test Specification and General Procedures

The ultimate goal of TRW Automotive is to demonstrate that the Equipment Under Test (EUT) complies with the Rules and/or Directives below. Detailed in this report are the results of testing the TRW Automotive 335098-101, 335098-102 for compliance to:

Country/Region	Rules or Directive	Referenced Section(s)
United States	Code of Federal Regulations	CFR Title 47, Part 15.231
Canada	ISED Canada	ISED RSS-210/GENe

It has been determined that the equipment under test is subject to the rules and directives above at the date of this testing. In conjunction with these rules and directives, the following specifications and procedures are followed herein to demonstrate compliance (in whole or in part) with these regulations.

ANSI C63.4:2014	"Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz"
ANSI C63.10:2013 (USA)	"American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices"
CFR 47 2.1091/1093	"447498 D01 General RF Exposure Guidance v06: RF Exposure Procedures and Equipment Authorization Policies for Mobile and Portable Devices"
ISED Canada	"The Measurement of Occupied Bandwidth"
ICES-003; Issue 6 (2016)	"Information Technology Equipment (ITE) Limits and methods of measurement"
ISED Canada RSS-102	"Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)"

3 Configuration and Identification of the Equipment Under Test

3.1 Description and Declarations

The equipment under test is a wireless tire pressure and temperature sensor. The EUT is approximately 8 x 6 x 2 cm (approx) in dimension, and is depicted in Figure 1. It is powered by 3 VDC Lithium cell battery. In use, this device is permanently affixed inside the tire of a motor vehicle. Table 3 outlines provider declared EUT specifications.



Figure 1: Photos of EUT.

Table 3: EUT Declarations.

General Declarations			
Equipment Type:	TPMS	Country of Origin:	Not Declared
Nominal Supply:	3 VDC	Oper. Temp Range:	-40°C to 120°C
Frequency Range:	315 MHz	Antenna Dimension:	Not Declared
Antenna Type:	valve stem	Antenna Gain:	Not Declared
Number of Channels:	1	Channel Spacing:	Not Applicable
Alignment Range:	Not Declared	Type of Modulation:	FSK
United States			
FCC ID Number:	GQ4-72T	Classification:	DSC
Canada			
IC Number:	1470A-53T	Classification:	Remote Control Device, Vehicular Device

3.1.1 EUT Configuration

The EUT is configured for testing as depicted in Figure 2.

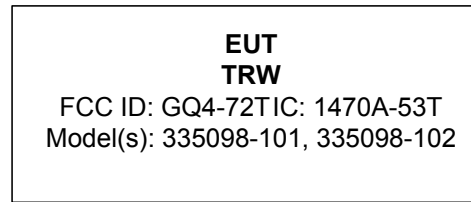


Figure 2: EUT Test Configuration Diagram.

3.1.2 Modes of Operation

This device is capable of three key modes of operation. Upon manually activated LF interrogation (through the use of special LF tool at a vehicle dealership), the EUT responds with a single transmission containing a number of frames used to configure the device with the vehicle. When the EUT is placed in the vehicle tire and the vehicle drives, it can, in the worst case, periodically transmit where the duration of each transmission is always less than 1 second and the silent period between transmissions is at least 30 times the duration of the transmission, and never less than 10 seconds. In the case of an emergency condition, the EUT will transmit tire pressure and temperature information throughout the duration of the condition. This EUT can be programmed via LF tools to emulate a wide range of tire pressure sensors at a single tool specific frequency.

3.1.3 Variants

There are two electrically identical variants of the EUT. Model 335098-101 employs a valve stem mounted at a 40 degree angle from the PCB. Model 335098-102 employs a valve stem mounted at a 20 degree angle from the PCB.

3.1.4 Test Samples

Six samples in total were provided; two samples (one of each variant) capable of demonstrating worst-case normal operation, two samples for CW mode activation, and two samples open for testing and photographs. Samples were programmed/activated in worst case on time, worst case emission bandwidth, and CW mode using a supplied LF tool.

3.1.5 Functional Exerciser

Normal operating EUT functionality was verified by observation of transmitted signal.

3.1.6 Modifications Made

There were no modifications made to the EUT by this laboratory.

3.1.7 Production Intent

The EUT appears to be a production ready sample.

3.1.8 Declared Exemptions and Additional Product Notes

The EUT is permanently installed in a transportation vehicle. As such, digital emissions are exempt from US and Canadian digital emissions regulations (per FCC 15.103(a) and IC correspondence on ICES-003).

The EUT also employs some modes of operation that alert the vehicle user of sudden changes in tire pressure. Such alert modes fall under FCC 15.231(a)(4), and may operate during the pendency of the alarm condition. A detailed list of all operating modes is included in the Description of Operation exhibit included in this application.

4 Emissions

4.1 General Test Procedures

4.1.1 Radiated Test Setup and Procedures

Radiated electromagnetic emissions from the EUT are first pre-scanned in our shielded anechoic chamber or GTEM test cell. Spectrum and modulation characteristics of all emissions are recorded. Instrumentation, including spectrum analyzers and other test equipment as detailed in Section 1.7 are employed. After pre-scan, emission measurements are made on the test site of record. If the EUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in relevant test standards are followed. Alternatively, a layout closest to normal use (as declared by the provider) is employed if the resulting emissions appear to be worst-case in such a configuration. See Figure 3. All intentionally radiating elements that are not fixed-mounted in use are placed on the test table lying flat, on their side, and on their end (3-axes) and the resulting worst case emissions are recorded. If the EUT is fixed-mounted in use, measurements are made with the device oriented in the manner consistent with installation and then emissions are recorded.

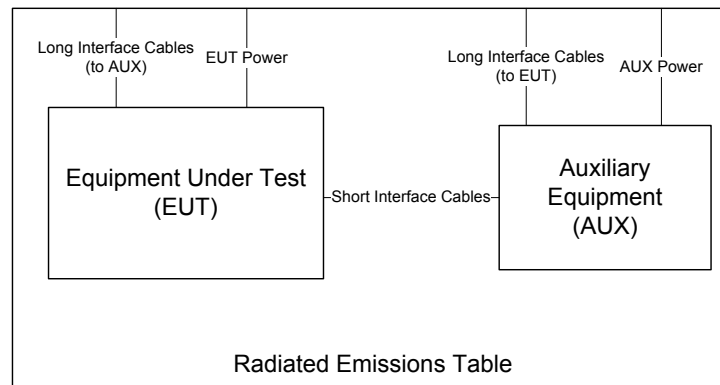


Figure 3: Radiated Emissions Diagram of the EUT.

If the EUT exhibits spurious emissions due to internal receiver circuitry, such emissions are measured with an appropriate carrier signal applied. For devices with intentional emissions below 30 MHz, a shielded loop antenna is used. It is placed at a 1 meter receive height. Emissions between 30 MHz and 1 GHz are measured using tuned dipoles and/or calibrated broadband antennas. For both horizontal and vertical polarizations, the test antenna is raised and lowered from 1 to 4 m in height until a maximum emission level is detected. The EUT is then rotated through 360° in azimuth until the highest emission is detected. The test antenna is then raised and lowered one last time from 1 to 4 m and the worst case value is recorded. Emissions above 1 GHz are characterized using standard gain horn or broadband ridge-horn antennas on our OATS with a 4 × 5 m rectangle of H-4 absorber placed over the ground screen covering the OATS ground screen. Care is taken to ensure that test receiver resolution and video bandwidths meet the regulatory requirements, and that the emission bandwidth of the EUT is not reduced. Photographs of the test setup employed are depicted in Figure 4.

Where regulations allow for direct measurement of field strength, power values (dBm) measured on the test receiver / analyzer are converted to dBμV/m at the regulatory distance, using

$$E_{dist} = 107 + P_R + K_A - K_G + K_E - C_F$$

where P_R is the power recorded on spectrum analyzer, in dBm, K_A is the test antenna factor in dB/m, K_G is the combined pre-amplifier gain and cable loss in dB, K_E is duty correction factor (when applicable) in dB, and C_F is a distance conversion (employed only if limits are specified at alternate distance) in dB. This field strength value is then compared with the regulatory limit. If effective isotropic radiated power (EIRP) is computed, it is computed as

$$EIRP(dBm) = E_{3m}(dB\mu V/m) - 95.2.$$

When presenting data at each frequency, the highest measured emission under all possible EUT orientations (3-axes) is reported.

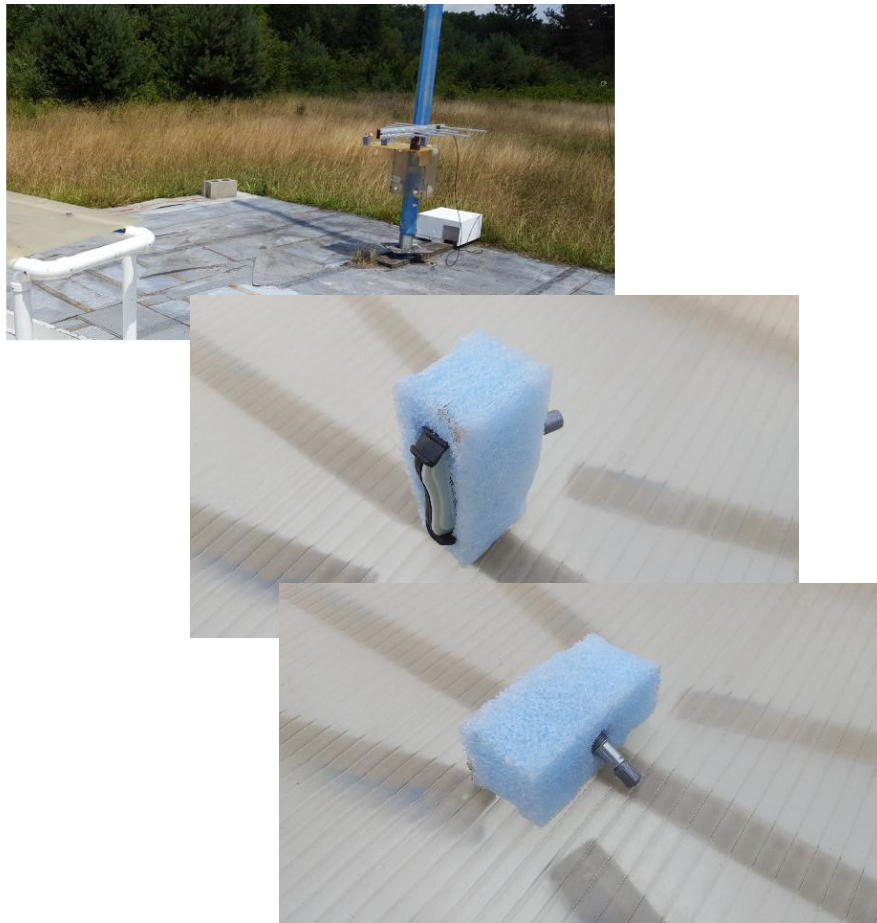


Figure 4: Radiated Emissions Test Setup Photograph(s).

4.1.2 Conducted Emissions Test Setup and Procedures

Battery Power Conducted Spurious The EUT is not subject to measurement of power line conducted emissions as it is powered solely by its internal battery.

4.1.3 Power Supply Variation

Tests at extreme supply voltages are made if required by the the procedures specified in the test standard, and results of this testing are detailed in this report.

Power supply variation testing was not performed for this device.

4.1.4 Thermal Variation

Tests at extreme temperatures were not performed for this device.

4.2 Intentional Emissions

4.2.1 Fundamental Emission Pulsed Operation

Test Setup & Procedure The test equipment and facilities were setup in accordance with the standards and procedures listed in Section 2.1. Environmental conditions were set at the appropriate temperature and thermal balance was checked with a thermocouple based probe. Duty cycle is reported for all relevant modes of operation. The test equipment employed includes RSFSV30001, LOGEMCO01.

Measurement Results The details and results of testing the EUT are summarized in Table 4. Plots showing the measurements made to obtain these values are provided in Figure 5.

Table 4: Fundamental Emission Pulsed Operation.

Detector	Span	IF Bandwidth	Video Bandwidth	Test Date:	30-Oct-16
Pk	0	1 MHz	3 MHz	Test Engineer:	Joseph Brunett
				EUT:	TRW TPMS
				EUT Mode:	Modulated
				Meas. Distance:	10 cm

FCC/IC									
#	EUT Test Mode*	Overall Transmission			Internal Frame Characteristics			Computed Duty Cycle	
		Min. Repetition Rate (sec)	Max. No. of Frames	Total Transmission Length (sec)	Max. Frame Length (ms)	Min. Frame Period (ms)	Frame Encoding	(%)	(dB)
1	Worst-case LEARN (Man Activ.) Mode. See Subfigure (a)	single	4	0.23	8.0	<100ms	Manually activated LEARN transmission consists of four 8.0 ms FSK frames. Two of which may occur within any given 100 ms window.	16.0	15.9
2	Worst-case DRIVE (Periodic) Mode. See Subfigure (b)	23.5	4	0.2165	8.0	<100ms	Worst Case periodic transmission consists of four 8.0 ms FSK frames every 23.5 seconds. Two frames may be transmitted within any given 100 ms window.	16.0	15.9

Example Calculation: Worst Case FSK Duty (%) = (2 x 8.0 ms) / 100 ms) x 100 = 16.0 %

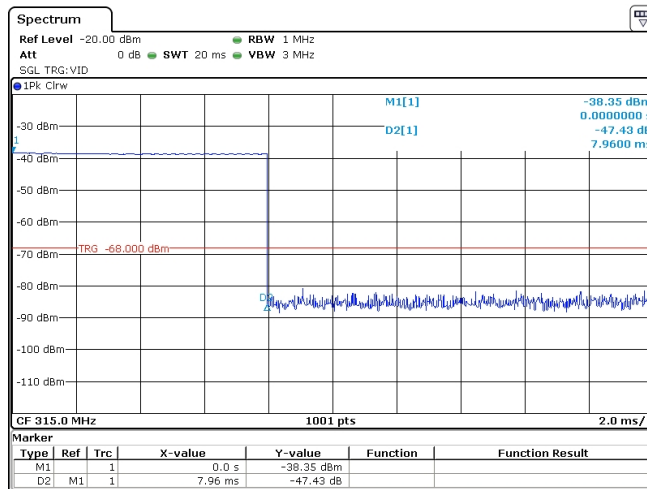
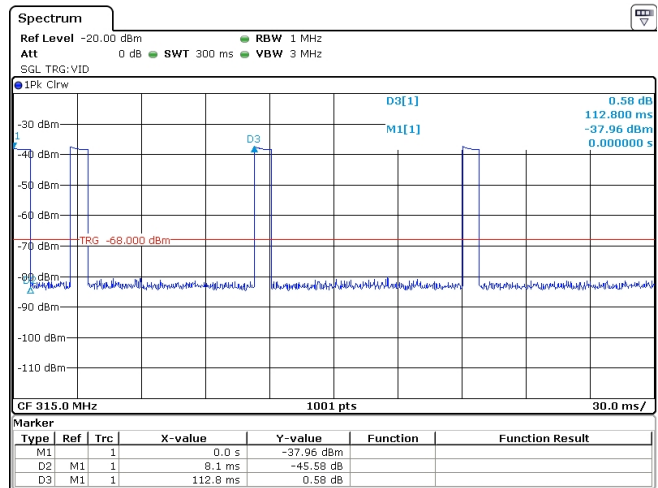
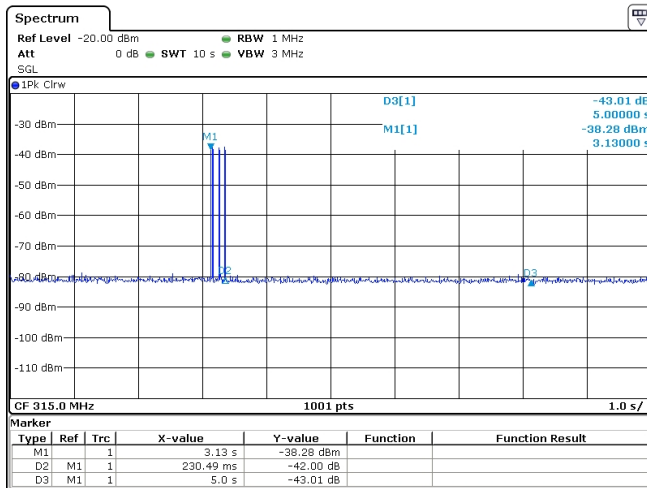


Figure 5(a): Fundamental Emission Pulsed Operation.

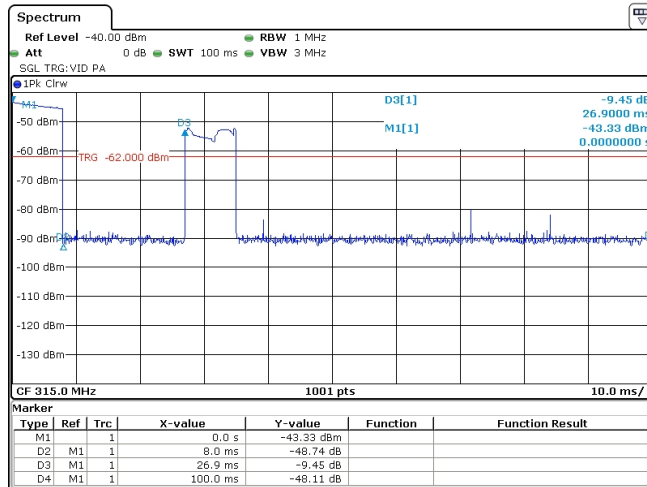
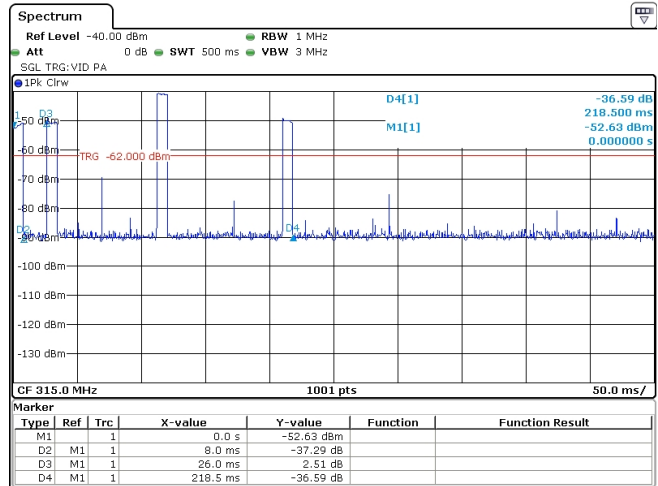
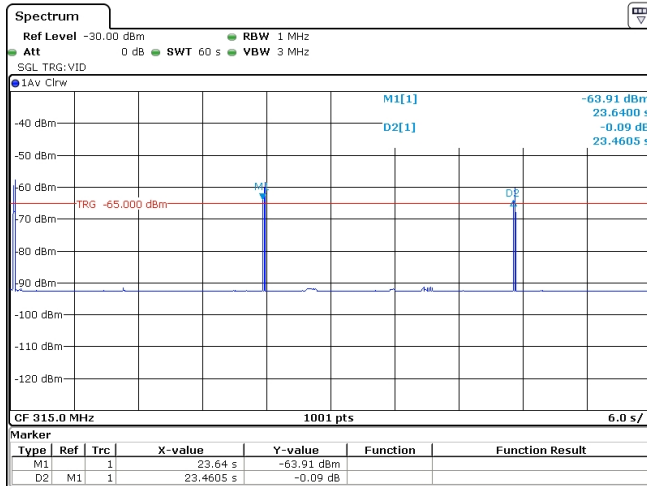


Figure 5(b): Fundamental Emission Pulsed Operation.

4.2.2 Fundamental Emission Bandwidth

Test Setup & Procedure The test equipment and facilities were setup in accordance with the standards and procedures listed in Section 2.1. Environmental conditions were set at the appropriate temperature and thermal balance was checked with a thermocouple based probe. Emission bandwidth (EBW) of the EUT is measured with the device placed in the test mode(s) with the shortest available frame length and minimum frame spacing. The 20 dB EBW is measured as the max-held peak-detected signal when the IF bandwidth is greater than or equal to 1% of the receiver span. For complex modulations other than ASK and FSK, the 99% emission bandwidth per IC test procedures has a different result, and is also reported. The test equipment employed includes RSFSV30001, LOGEMCO01.

Measurement Results The details and results of testing the EUT are summarized in Table 5. Plots showing the measurements made to obtain these values are provided in Figure 6.

Table 5: Fundamental Emission Bandwidth.

Detector	IF Bandwidth	Video Bandwidth	Test Date:	30-Oct-16
Pk	10 kHz	30 kHz	Test Engineer:	Joseph Brunett
			EUT:	TRW TPMS
			EUT Mode:	Modulated
			Meas. Distance:	10 cm

FCC/IC						
#	Modulation	Center Frequency (MHz)	20 dB EBW (MHz)	EBW Limit (MHz)	99% OBW (MHz)	
1	FSK	315	0.0999	0.7875	0.122	
2						

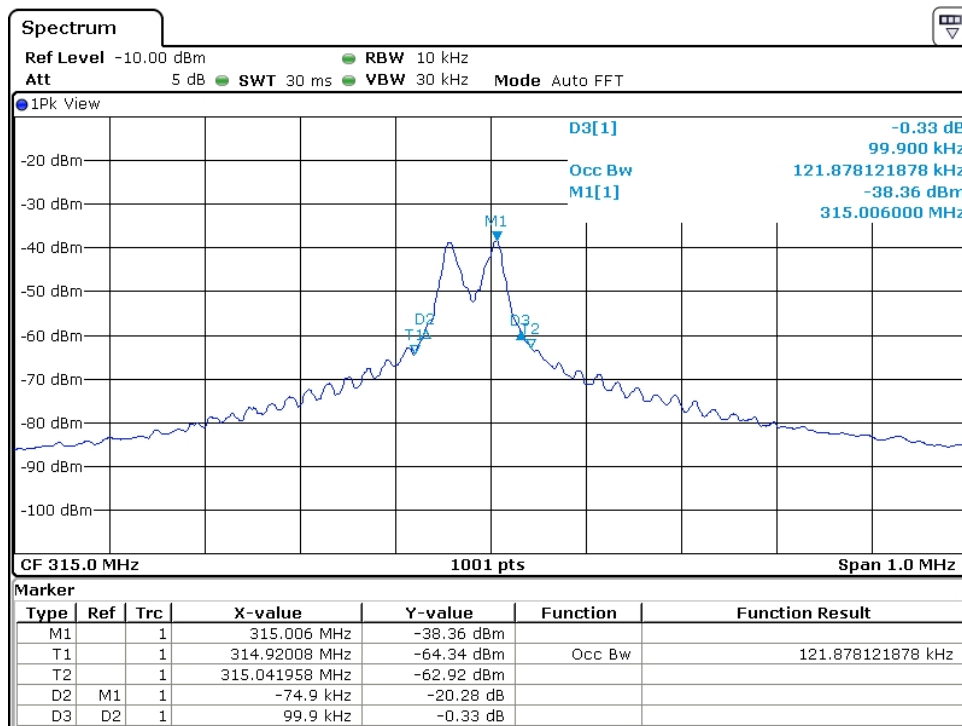


Figure 6: Fundamental Emission Bandwidth.

4.2.3 Fundamental Emission Field Strength

Test Setup & Procedure The test equipment and facilities were setup in accordance with the standards and procedures listed in Section 2.1. Environmental conditions were set at the appropriate temperature and thermal balance was checked with a thermocouple based probe. Fundamental emissions are measured at the regulatory distance on our OATS. The test equipment employed includes RSFSV30001, LOGEMCO01.

Measurement Results The details and results of testing the EUT are summarized in Table 6.

Table 6: Fundamental Emission Field Strength.

Frequency Range	Det	IF Bandwidth	Video Bandwidth	Test Date:	30-Oct-16
25 MHz f 1 000 MHz	Pk/QPk	120 kHz	300 kHz	Test Engineer:	Joseph Brunett
f > 1 000 MHz	Pk	1 MHz	3 MHz	EUT:	TRW TPMS
f > 1 000 MHz	Avg	1 MHz	10 kHz	EUT Mode:	CW
				Meas. Distance:	3 meters

FCC/IC												
#	Freq. MHz	Ant. Used	Ant. Pol.	Pr (Pk) dBm	Pr (Avg)* dBm	Ka dB/m	Kg dB	E3(Pk) dBµV/m	E3(Avg) dBµV/m	FCC/IC E3(Avg) Lim. dBµV/m	Pass dB	Comments
1	335098-101 (40 deg stem)											
2	315.0	LOGP	H	-12.9	-28.8	14.1	32.6	75.6	59.7	67.7	8.0	flat
3	315.0	LOGP	V	-11.1	-27.0	14.1	32.6	77.4	61.5	67.7	6.2	end
4	335098-102 (20 deg stem)											
5	315.0	LOGP	H	-12.6	-28.5	14.1	32.6	75.9	60.0	67.7	7.7	flat
6	315.0	LOGP	V	-10.8	-26.7	14.1	32.6	77.7	61.8	67.7	5.9	end
#	Freq. MHz	DC Supply Voltage		Relative Pr (Pk) dBm**								
7	315.0	2.60		-14.3								
8	315.0	2.80		-12.5								
9	315.0	3.00		-11.1								
10	315.0	3.15		-9.5								
11	315.0	3.30		-9.0								

*Avg data computed from Peak Measured Data and EUT Duty Cycle. EUT in CW mode.

** EUT in CW mode.

4.2.4 Exposure and Potential Health Hazard

To demonstrate compliance with with regulations that place limitations on human electromagnetic field exposure for both the general public and for workers, we compute EIRP from measured emission data. These levels are compared with limits placed by the directives and recommendations detailed in Section 2.1. Table 7 details the results of these computations.

Table 7: Electromagnetic Field Exposure.

<p>USA REF: 2.1091/1093, 447498 D01 General RF Exposure Guidance v06</p> <p>IC REF: RSS-102 Issue 5</p> <p>Min. Sep. Distance: <5mm</p>	<p>Test Date: 30-Oct-16</p> <p>Test Engineer: Joseph Brunett</p> <p>EUT: TRW TPMS</p> <p>EUT Mode: CW</p> <p>Meas. Distance: 3 meters</p>
---	--

Freq. MHz	E3(Pk)* dBµV/m	Duty Factor dB	E3(Avg)** dBuV/m	EIRP(Avg)** dBm	EIRP(Avg)** mW
315.00	77.4	.0	77.4	-17.8	.0164994
Canada			USA		
Calculated SAR Threshold (Avg) mW	1-g SAR Body Power Threshold Exclusion Limit (Avg) mW	10-g SAR Extremity Power Threshold Exclusion Limit (Avg) mW	Calculated SAR Threshold (Avg)	1-g SAR Body Power Threshold Exclusion Limit (Avg)	10-g SAR Extremity Power Threshold Exclusion Limit (Avg)
.0164994	69.1	172.8	.0018520	3.0	7.5

*As Measured / Computed from highest fundamental emission, see fundamental emission section of this report.

**Only RMS level is required, RMS/6min << Pk, Peak emission employed to demonstrate compliance.

4.3 Unintentional Emissions

4.3.1 Transmit Chain Spurious Emissions

Test Setup & Procedure The test equipment and facilities were setup in accordance with the standards and procedures listed in Section 2.1. Environmental conditions were set at the appropriate temperature and thermal balance was checked with a thermocouple based probe. Spurious radiated emissions measurements are performed to 10 times the highest fundamental operating frequency. The test equipment employed includes RSFSV30001, LOGEMCO01, HRNQR316401.

Measurement Results The details and results of testing the EUT are summarized in Table 8.

Table 8: Transmit Chain Spurious Emissions.

Frequency Range	Det	IF Bandwidth	Video Bandwidth	Test Date:	30-Oct-16
25 MHz f 1 000 MHz	Pk/QPk	120 kHz	300 kHz	Test Engineer:	Joseph Brunett
f > 1 000 MHz	Pk	1 MHz	3 MHz	EUT:	TRW TPMS
f > 1 000 MHz	Avg	1 MHz	10kHz	EUT Mode:	CW
				Meas. Distance:	3 meters

Transmitter Unintentional Spurious Emissions												FCC/IC
#	Freq. MHz	Ant. Used	Ant. Pol.	Pr (Pk) dBm	Pr (Avg)* dBm	Ka dB/m	Kg dB	E3(Pk) dBµV/m	E3(Avg) dBµV/m	FCC/IC E3lim (Avg) dBµV/m	Pass dB	Comments
1	335098-101 (40 deg stem)											
2	630.0	LOGP	H	-66.0	-81.9	19.5	29.3	31.2	15.3	47.7	32.4	flat
3	630.0	LOGP	V	-68.0	-83.9	19.5	29.3	29.2	13.3	47.7	34.4	end
4	945.0	LOGP	H	-73.7	-89.6	23.2	26.3	30.2	14.3	47.7	33.4	flat
5	945.0	LOGP	V	-70.9	-86.8	23.2	26.3	33.0	17.1	47.7	30.6	end
6	1260.0	R-Horn	H	-76.1	-92.0	25.0	-0.2	56.1	40.2	54.0	13.8	max all
7	1575.0	R-Horn	H	-75.9	-91.8	27.7	-0.2	59.0	43.0	54.0	10.9	max all
8	1890.0	R-Horn	H	-87.6	-103.5	29.4	-0.2	49.0	33.1	54.0	20.9	max all
9	2205.0	R-Horn	H	-93.0	-108.9	30.9	-0.3	45.1	29.2	54.0	24.8	max all
10	2520.0	R-Horn	H	-92.8	-108.7	33.1	-0.3	47.6	31.7	54.0	22.3	max all
11	2835.0	R-Horn	H	-92.8	-108.7	35.6	-0.3	50.1	34.2	54.0	19.8	max all
12	3150.0	R-Horn	H	-91.8	-107.7	36.7	-0.3	52.2	36.3	54.0	17.7	max all
13	335098-102 (20 deg stem)											
14	630.0	LOGP	H	-65.6	-81.5	19.5	29.3	31.6	15.7	47.7	32.0	flat
15	630.0	LOGP	V	-67.2	-83.1	19.5	29.3	30.0	14.1	47.7	33.6	flat
16	945.0	LOGP	H	-71.9	-87.8	23.2	26.3	32.0	16.1	47.7	31.6	flat
17	945.0	LOGP	V	-70.9	-86.8	23.2	26.3	33.0	17.1	47.7	30.6	flat
18	1260.0	R-Horn	H	-75.3	-91.2	25.0	-0.2	56.9	41.0	54.0	13.0	max all
19	1575.0	R-Horn	H	-74.3	-90.2	27.7	-0.2	60.6	44.6	54.0	9.3	max all
20	1890.0	R-Horn	H	-87.4	-103.3	29.4	-0.2	49.2	33.3	54.0	20.7	max all
21	2205.0	R-Horn	H	-91.5	-107.4	30.9	-0.3	46.6	30.7	54.0	23.3	max all
22	2520.0	R-Horn	H	-92.0	-107.9	33.1	-0.3	48.4	32.5	54.0	21.5	max all
23	2835.0	R-Horn	H	-91.8	-107.7	35.6	-0.3	51.1	35.2	54.0	18.8	max all
24	3150.0	R-Horn	H	-91.1	-107.0	36.7	-0.3	52.9	37.0	54.0	17.0	max all
25												

*Avg data computed from Peak Measured Data and EUT Duty Cycle. EUT in CW mode.

4.3.2 Radiated Digital Spurious

The results for the measurement of digital spurious emissions are not reported herein as all digital emissions were greater than 20 dB below the regulatory limit. Radiation from digital components was measured to 4 GHz, or to five times the maximum digital component operating frequency, whichever is greater.

5 Measurement Uncertainty

The maximum values of measurement uncertainty for the laboratory test equipment and facilities associated with each test are given in the table below. This uncertainty is computed for a 95.45% confidence level based on a coverage factor of $k = 2$.

Table 9: Measurement Uncertainty.

Measured Parameter	Measurement Uncertainty [†]
Radio Frequency	$\pm(f_{Mkr}/10^7 + RBW/10 + (SPN/(PTS - 1))/2 + 1 \text{ Hz})$
Conducted Emm. Amplitude	$\pm 1.8 \text{ dB}$
Radiated Emm. Amplitude (30 – 200 MHz)	$\pm 2.7 \text{ dB}$
Radiated Emm. Amplitude (200 – 1000 MHz)	$\pm 2.5 \text{ dB}$
Radiated Emm. Amplitude ($f > 1000 \text{ MHz}$)	$\pm 3.7 \text{ dB}$
DC and Low Frequency Voltages	$\pm 2\%$
Temperature	$\pm 0.5^\circ\text{C}$
Humidity	$\pm 5\%$

[†]Ref: CISPR 16-4-2:2011+A1:2014