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Radiation Laboratory
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Measured Radio Frequency Emissions From

Schrader Remote Tire Pressure Monitoring Transmitter PN: 70503025

Report No. 415031-964
December 28, 1998

For:
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1609 Airport Road
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PO: verbal

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Summary

Tests for compliance with FCC Regulations, subject to Part 15, Subpart C, were performed on Schrader Remote Tire Pressure Monitoring Transmitter. This device is subject to Rules and Regulations as a low power (data) transmitter. As a Digital Device it is exempt, but such measurements we make as a matter of routine to assess the transmitters's overall emissions.

The Sensor was tested " in free space", i.e., without a tire and off a rim. In testing performed on December 18, 21, and 23, 1998, the device tested in the worst case met the 15.231(e) limits for radiated emissions by 3.2 dB (see p. 6). Besides harmonics there were no other significant spurious emissions found.

No conductive emission tests were made, since the transmitter is powered by a 3 V internal lithium battery.

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1. Introduction

Schrader Remote Tire Pressure Monitoring Transmitter, PN: 70503025, was tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989. The tests were performed at the University of Michigan Radiation Laboratory Willow Run Test Range following the procedures described in ANSI C63.4-1992 "Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz". The attenuation characteristics of the Open Site facility are on file with FCC Laboratory, Columbia, Maryland. (FCC file 31040/SIT)

2. Test Procedure and Equipment Used

The test equipment commonly used in our facility is listed in Table 2.1 below. The second column identifies the specific equipment used in these tests. The HP 8593E spectrum analyzer is used for primary amplitude and frequency reference.

Table 2.1. Test Equipment.

Test Instrument	Equipment Used	Manufacturer/Model	Cal. Date/By
Spectrum Analyzer (9kHz-22GHz)		Hewlett-Packard 8593A SN: 3107A01358	June 1998/HP
Spectrum Analyzer (9kHz-26GHz)	X	Hewlett-Packard 8593E SN: 3107A01131	July 1998/HP
Spectrum Analyzer (0.1-1500 MHz)	X	Hewlett-Packard 182T/8558B SN: 1529A01114/543592	August 1998/U of M Rad Lab
Preamplifier (5-1000MHz)	X	Watkins-Johnson A11 -1 plus A25-1S	May 1997/U of M Rad Lab
Preamplifier (5-4000 MHz)	X	Avantek	Nov. 1992/ U of M Rad Lab
Power Meter w/ Thermistor		Hewlett-Packard 432A Hewlett-Packard 478A	August 1989/U of M Rad Lab August 1989/U of M Rad Lab
Broadband Bicone (20-200 MHz)	X	University of Michigan	July 1988/U of M Rad Lab
Broadband Bicone (200-1000 MHz)	X	University of Michigan	June 1996/U of M Rad Lab
Dipole Antenna Set (25-1000 MHz)	X	University of Michigan	June 1996/U of M Rad Lab
Dipole Antenna Set (30-1000 MHz)		EMCO 3121C SN: 992	June 1996/U of M Rad Lab
Active Loop Antenna (0.090-30MHz)		EMCO 6502 SN: 2855	December 1993/ EMCO
Active Rod (30Hz-50 MHz)		EMCO 3301B SN: 3223	December 1993/EMCO
Ridge-horn Antenna (0.5-5 GHz)	X	University of Michigan	February 1991/U of M Rad Lab
LISN Box		University of Michigan	May 1994/U of M Rad Lab
Signal Cables	X	Assorted	January 1993/U of M Rad Lab
X-Y Plotter		Hewlett-Packard 7046A	During Use/U of M Rad Lab
Signal Generator (0.1-990 MHz)	X	Hewlett-Packard 8656A	January 1990/U of M Rad Lab

3. Configuration and Identification of Device Under Test

The DUT is a 5.2 x 5.5 x 1.5 cm size potted tire pressure sensor/transmitter that mounts on a rim inside the tire and uses a pemanently attached wire antenna. When the vehicle is in motion it transmits the tire pressure information to the receiver in the vehicle. The transmission consists of eight PWM words repeated typically every 60 seconds. The 315 MHz carrier is generated by a SAW stabilized oscillator. The coding is performed by an ASIC timed by a 32.768 kHz crystal oscillator.

The DUT was designed and manufactured by Schrader Electronics Limited, 11 Technology Park, Belfast Road, Antrim BT41 1QS, Northern Ireland. It is identified as:

Schrader Remote Tire Pressure Monitoring Transmitter
PN: 70503025
SN: FCC21
FCC ID: MRXTSR300
CANADA:

Three devices were provided. These were: (1) modified for CW emission that was used for radiated emission measurements, (2) modified for pulsed emissions for signal (pulse) and bandwidth characteristic measurements, and (3) unpotted board for photographs.

3.1 EMI Relevant Modifications

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

4. Emission Limits

4.1 Radiated Emission Limits

The DUT tested falls under the category of an Intentional Radiators and the Digital Devices, subject to Subpart C, Section 15.231; and Subpart B, Section 15.109 (transmitter generated signals excluded); and Subpart A, Section 15.33. The applicable testing frequencies with corresponding emission limits are given in Tables 4.1 and 4.2 below. As a digital device, the DUT is considered as a Class B device.

Table 4.1 Radiated Emission Limits (15.231(e)) — Transmitter (Data).

Frequency	Fundamental Ave. E_{lim} (3m)		Spurious** Ave. E_{lim} (3m)	
(MHz)	(μV/m)	dB (μV/m)	(μV/m)	dB (μV/m)
260-470	1500-5000*		150-500	
315	2418	67.7	241.8	47.7

* Linear interpolation, formula: E = -2833.2 + 16.67*f (MHz)
** Measure up to tenth harmonic; 120 kHz BW up to 1 GHz, 1 MHz BW above 1 GHz

Table 4.2. Radiated Emission Limits (Ref: 15.33, 15.35, 15.109) -- Digital (Class B).

Freq. (MHz)	E_{lim} (3m) μV/m	E_{lim} dB(μV/m)
30-88	100	40.0
88-216	150	43.5
216-960	200	46.0
960-2000	500	54.0

Note: Quasi-Peak readings apply to 1000 MHz (120 kHz BW)
Average readings apply above 1000 MHz (1 MHz BW)

4.2 Conductive Emission Limits

The conductive emission limits and tests do not apply here, since the DUT is powered by a 3 V internal lithium battery.

5. Radiated Emission Tests and Results

5.1 Anechoic Chamber Measurements

To familiarize with the radiated emission behavior of the DUT, the DUT was first studied and measured in a semi-shielded anechoic chamber. In the chamber there is a set-up similar to that of an outdoor 3-meter site, with a turntable, an antenna mast, and a ground plane. Instrumentation includes spectrum analyzers and other equipment as needed.

In the chamber we studied and recorded all the emissions using a ridged horn antenna up to 3.15 GHz. The measurements made in the chamber below 1 GHz are used for pre-test evaluation only. The measurements made above 1 GHz are also used in pre-test evaluation and in final compliance assessment. We note that for the horn antenna, the antenna pattern is more directive and hence the measurement is essentially that of free space (no ground reflection). In the chamber we also recorded the spectrum and modulation characteristics of the carrier. These data are presented in subsequent sections. We also note that in scanning from 30 MHz to 3.15 GHz, there were no other significant spurious emissions observed.

5.2 Outdoor Measurements

After the chamber measurements, the emissions were re-measured on the outdoor 3-meter site at 315.0, 630.0, and 945.0 MHz using tuned dipoles and/or the high frequency bicone.

Figure 5.1 shows the DUT placed on the open-site table.

5.3 Computations and Results

To convert the dBm measured on the spectrum analyzer to dB(μV/m), we use expression

$$E_3(\text{dB}\mu\text{V/m}) = 107 + P_R + K_A - K_G + K_E$$

where P_R = power recorded on spectrum analyzer, dB, measured at 3m
K_A = antenna factor, dB/m
K_G = pre-amplifier gain, including cable loss, dB
K_E = pulse operation correction factor, dB (see 6.1)

When presenting the data, at each frequency the highest measured emission under all of the possible orientations is given. Computations and results are given in Table 5.1. There we see that the DUT meets the limit by 3.2 dB at fundamental and by 6.7 dB at harmonics.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation

The transmitter is activated by rotation of the wheel and transmits once every minute. The transmission consists of 8 words of 99.5 ms period. In a word there is a 2.213 ms lead-in pulse, followed by five 0.375 ms wide sync pulses, and then followed by 31narrow and wide data pulses (assume all wide for the worst case). See Figure 6.1. For such case, the averaging factor is

$$K_E = (1 \times 2.213 + (5 + 31) \times 0.375) \text{ ms} / 99.5 \text{ ms} = 0.158 \text{ or } -16.0 \text{ dB}$$

6.2 Emission Spectrum

Using the ridge-horn antenna and DUT placed in its aperture, emission spectrum was recorded and is shown in Figure 6.2.

6.3 Bandwidth of the Emission Spectrum

The measured spectrum of the signal is shown in Figure 6.3. The allowed (-20 dB) bandwidth is 0.25% of 315.0 MHz, or 786 kHz, and from the plot we see that the -20 dB bandwidth is 60.0 kHz, and the center frequency is 314.974 MHz.

6.4 Effect of Supply Voltage Variation

The DUT has been designed to be powered by a 3 V battery. For this device, the electronics and the battery are potted, hence no easy access available to perform these mesurements.

6.5 Input Voltage and Current at Battery Terminals

Batteries:	before testing	V_{oc} =	not accessable
	after testing	V_{oc} =	not accessable
		I =	not accessable

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Table 5.1 Highest Emissions Measured

Radiated Emission - RF Schrader TX, Model: TSR300; FCC/IC

#	Freq. MHz	Ant. Used	Ant. Pol.	Pr dBm	Det. Used	Ka dB/m	Kg dB	E3* dBμV/m	E3lim dBμV/m	Pass dB	Comments
1	315.0	Dip	H	-24.0	Pk	18.9	21.4	64.5	67.7	**3.2**	flat
2	315.0	Dip	V	-24.0	Pk	18.9	21.4	64.5	67.7	3.2	side
3	630.0	Dip	H	-64.5	Pk	25.2	18.1	33.7	47.7	14.0	flat
4	630.0	Dip	V	-62.9	Pk	25.2	18.1	35.3	47.7	12.4	flat
5	945.0	Dip	H	-64.4	Pk	28.9	15.7	39.8	47.7	7.9	flat
6	945.0	Dip	V	-63.2	Pk	28.9	15.7	41.0	47.7	**6.7**	side
7	1260.0	Horn	H	-46.0	Pk	20.4	28.1	37.3	47.7	10.4	flat
8	1575.0	Horn	H	-46.1	Pk	21.4	28.2	38.1	47.7	9.6	flat
9	1890.0	Horn	H	-45.2	Pk	22.1	28.1	39.8	47.7	7.9	flat
10	2205.0	Horn	H	-58.2	Pk	22.9	27.0	28.7	47.7	19.0	side
11	2520.0	Horn	H	-60.0	Pk	24.0	26.6	28.4	47.7	19.3	side
12	2835.0	Horn	H	-62.8	Pk	24.9	25.4	27.7	47.7	20.0	flat
13	3150.0	Horn	H	-66.0	Pk	25.2	24.8	25.4	47.7	22.3	side
14											
15											
16											
17											
18			*includes -16.0 dB duty factor								
19											
20			Digital emissions are more than 20 dB below FCC Class B limit								
21											
22											
23											
24											
25											
26											
27											

Conducted Emissions

#	Freq. MHz	Line Side	Det. Used	Vtest dBμV	Vlim dBμV	Pass dB	Comments
1							
2	Not applicable						
3							
4							
5							
6							
7							

Meas. 12/21/1998; UMich.

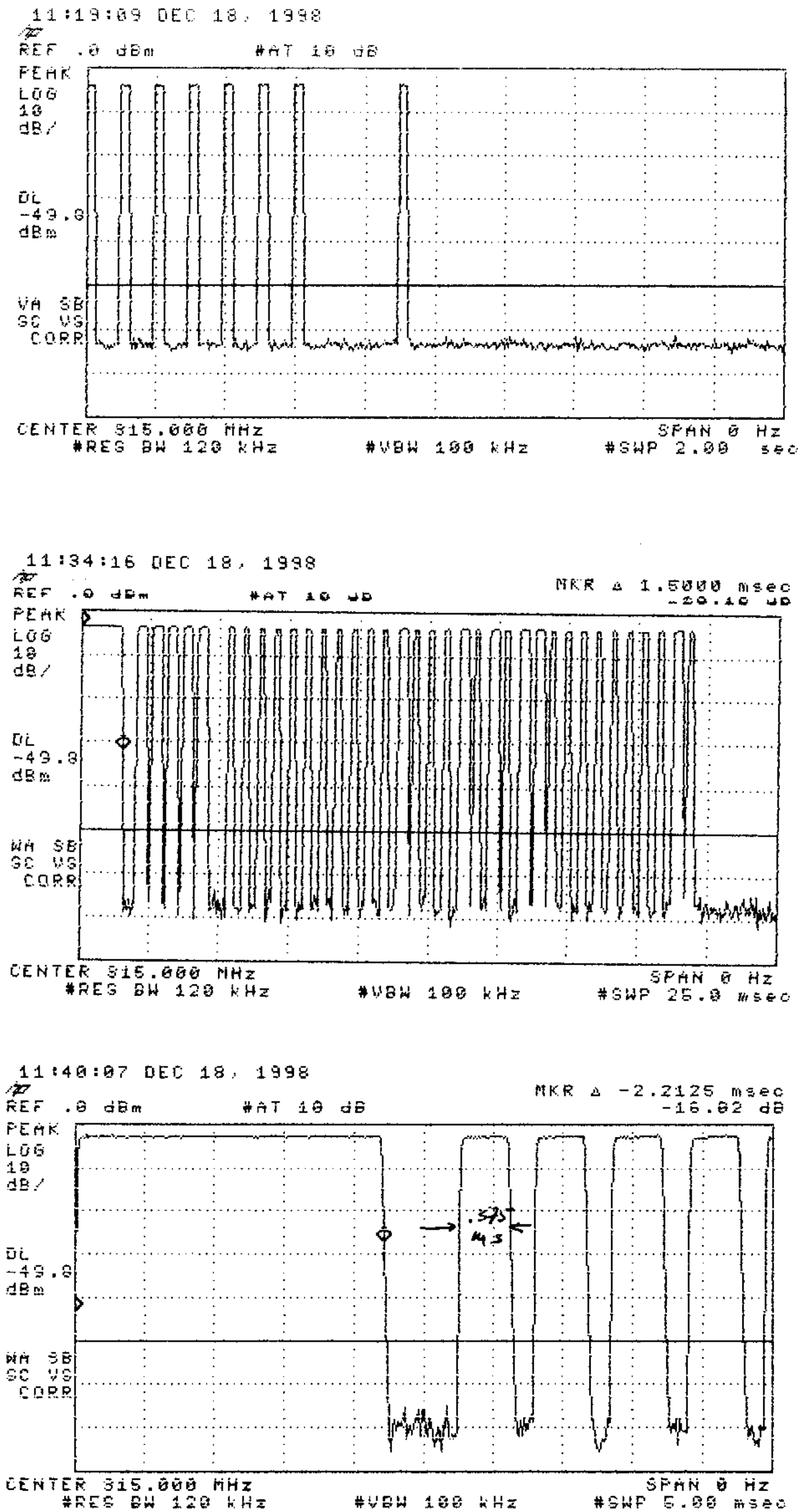

Figure 6.1. Transmissions modulation characteristics: (top) complete transmission, (center) expanded word, (bottom) expanded bits.

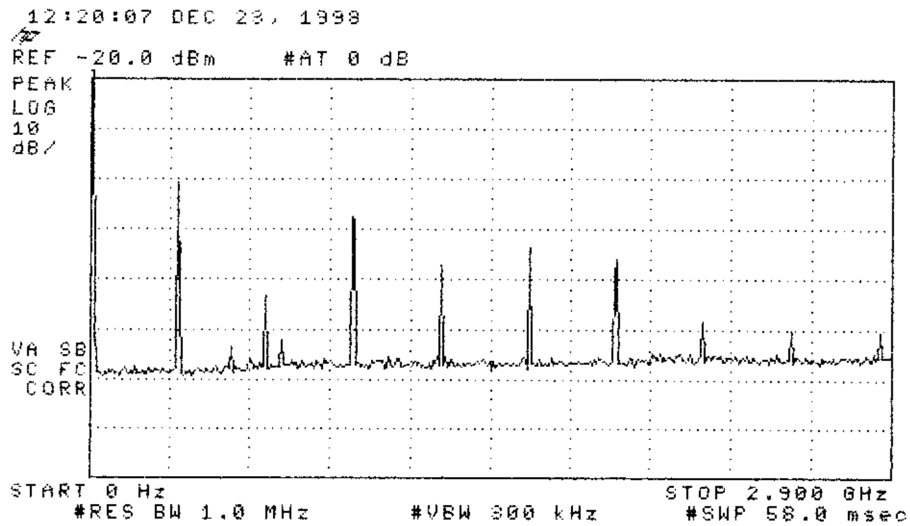

Figure 6.2. Emission spectrum of the DUT in free space (repeated pulsed emission). The amplitudes are only indicative (not calibrated).

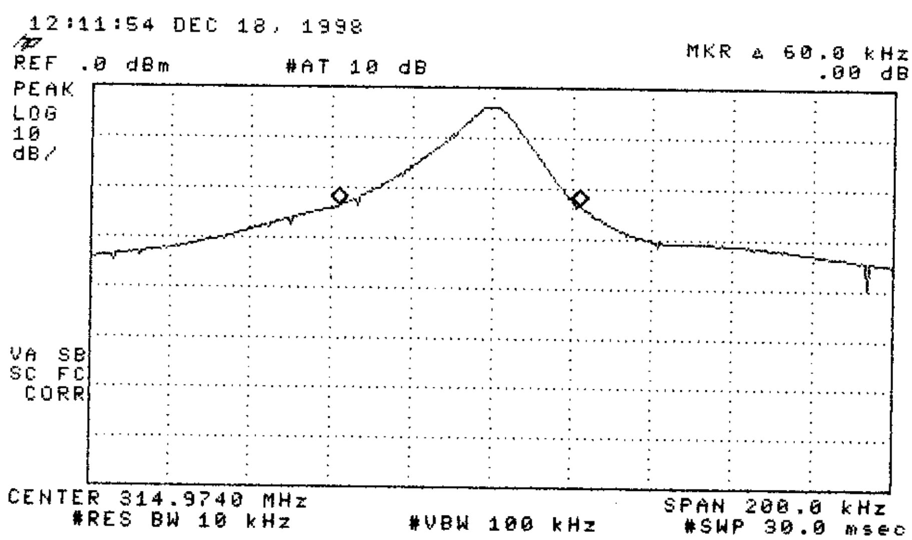

Figure 6.3. Measured bandwidth of the DUT (repated pulsed emission).

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Description of RTPM Transmitter (SRF) Features

The Aftermarket RTPM system has been developed to monitor a vehicle's tire pressures and display real-time pressure values or warning messages/indications to the driver of the vehicle. An electronic unit inside each tyre, mounted to the valve stem, periodically measures the tyre pressure and by means of radio waves transmits the pressure value to a passenger compartment mounted receiver. This receiver controls a display which can be configured to indicate the real time pressure in each wheel or display an alarm condition when the tyre pressure falls below a certain pre-defined threshold.

In this system, each wheel unit consists of a low profile enclosure mounted on the back of a conventional clamp-in tyre valve on the inside of the wheel and tyre. The enclosure houses an electronic unit consisting mainly of a battery, pressure sensor, roll switch, control electronics and a radio transmitter. The entire assembly is fully potted to protect the electronics from the environment. The overall size and weight are kept to a minimum and the entire enclosure locates down inside the drop well centre. This ensures that tyre fitting and tyre removal problems do not arise.

The wheel units measure tyre pressure and report the information to the dashboard receiver via radio wave communication. To conserve battery power, the pressure is sampled periodically, typically once every 30 seconds. Also, the RF transmissions are made on a periodic basis of typically every minute, provided the tyre pressure is not changing rapidly. Rapid changes of tyre pressure, of greater than 1 psi in a 30 second period are detected by the pressure measurements and immediately reported to the dashboard receiver. This ensures the driver is warned of a hazardous pressure level immediately if it occurs.

A roll switch which detects vehicle movement is used to further save battery power. While the vehicle is in motion at a speed greater than typically 20 mph the device behaves on the above described manner regarding pressure sampling and RF transmissions.

Each wheel unit has a unique identity code which is programmed into the transmitter at assembly. Up to 2 million identity codes are available to prevent crosstalk between vehicles. Each RF transmission contains pressure information and the identity code of the particular wheel, to allow the receiver to both know which of the four wheels has reported and to reject all reports from other vehicles with a similar system fitted in close proximity. This completely avoids false pressure reports from adjacent vehicles.

The RTPM transmitter has the following modes of operation:

1. OFF Mode
   This is the state the devices leave the Schrader factory. In this state the devices do not sample pressure or transmit any information.

2. LEARN Mode
   This mode is when a magnet is placed close to the transmitter for more than 5 seconds. When this occurs, the device transmits a 5 second burst of 8 words every second with the function code set to LEARN (Ref. Data Protocol Diagram). This mode is used for both testing and to allow the system receiver to memorise the transmitter identity codes.

3. SLEEP Mode
   This mode of operation is when the device is operating normally on a vehicle and is neither sampling pressure or transmitting. The device is simply waiting for a time period to end, such as the 30 seconds between each pressure sample while driving.

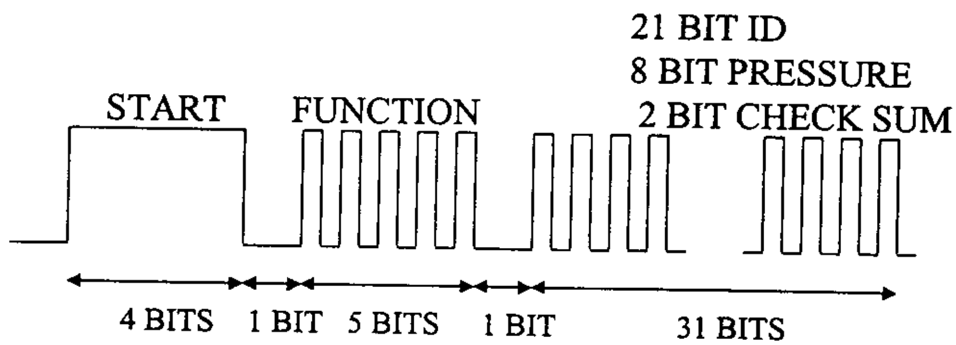
4. Pressure Sample Mode
   This mode is when the device is actually powering up the pressure sensor and measuring the tyre pressure. This occurs once every 30 seconds, only while driving.

5. RF Transmit Mode
   In this mode the device is transmitting the measured pressure and wheel identity code to the vehicle receiver. This occurs over a 1 second period with 8 bursts of data (Ref. Data Protocol Diagram). Normally the device transmits once every minute while driving. However, when a pressure change of more than 1 psi since the last transmitted pressure is measured, an extra transmission is made.

SCHRADER RTPMS DATA PROTOCOL
AFTERMARKET GENERATION 3 (AM)

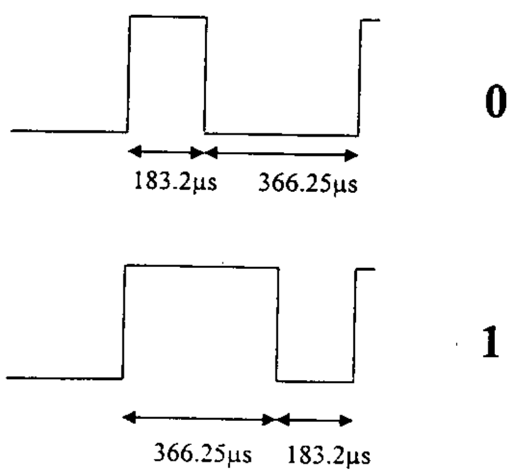
BIT WIDTH = 549.45 μS
DATA RATE = 1.820 kHz

1 WORD



42 BITS = 23.08ms

BIT FORMAT



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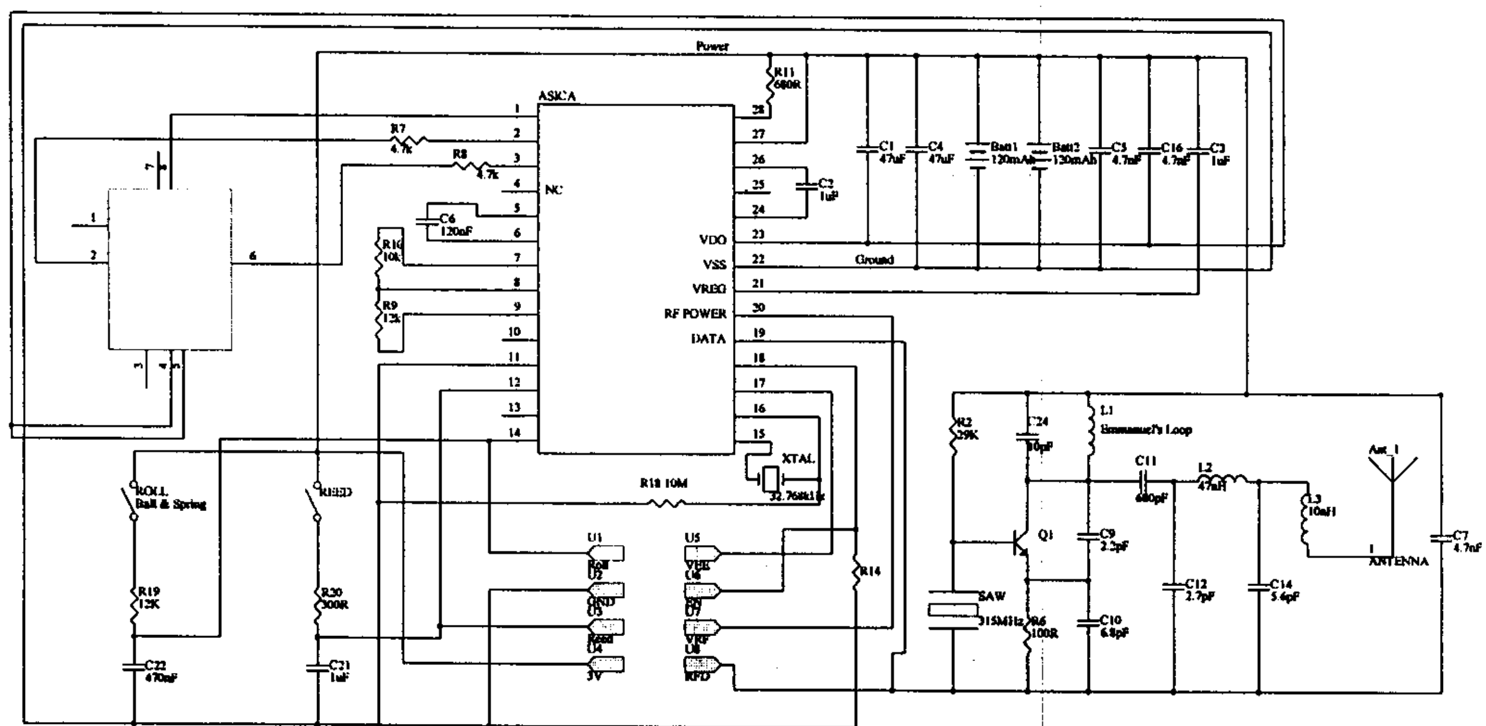
PART OF __________

SHEET __ OF __



ISSUE	DESCRIPTION	ECN	DATE

TITLE Schematic of Goodyear Tx

DRAWN	CHECKED	APPROVED	DATE
DRAWING No. ________			

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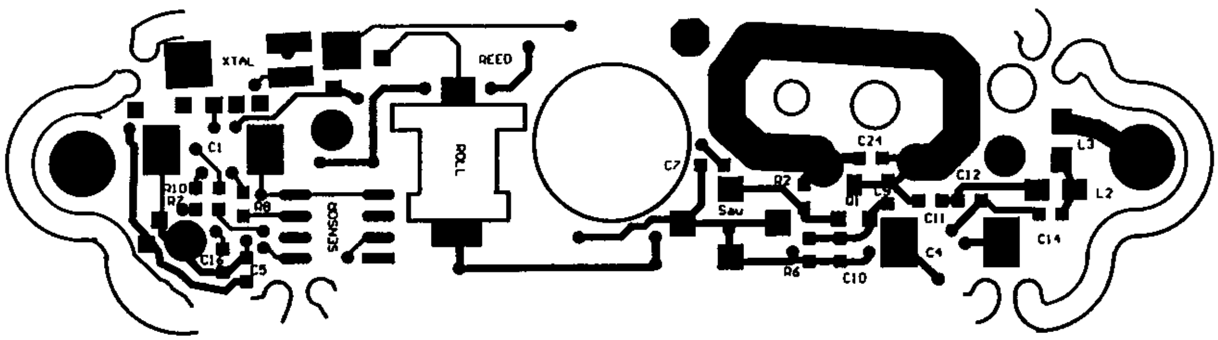

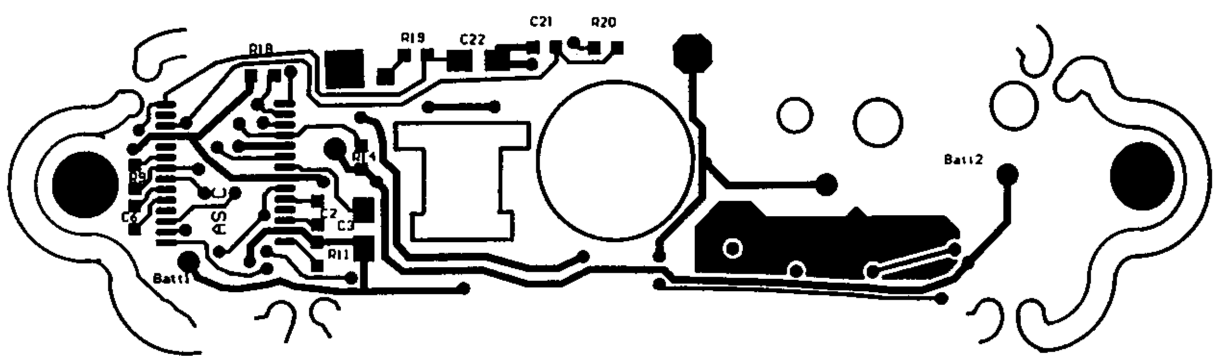

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Designator	Part Type
Ant_1	ANTENNA
ASIC	ASIC28 SSOP
Batt1	120mAh
Batt2	120mAh
C1	47uF
C10	6.8pF
C11	680pF
C12	2.7pF
C14	5.6pF
C16	4.7nF
C2	1uF
C21	1uF
C22	470nF
C24	10pF
C3	1uF
C4	47uF
C5	4.7nF
C6	120nF
C7	4.7nF
C9	2.2pF
L1	PCB trace inductor
L2	47nH
L3	10nH
Q1	BFR35
R10	10K
R11	680R
R14	10K
R18	10M
R19	12K
R2	29K
R20	300R
R6	100R
R7	4.7K
R8	4.7K
R9	12K
REED	Reed Switch
ROLL	Ball & Spring
SAW	315MHz
SENSOR	PRESS.SEN.SO8
XTAL	32.768KHz

Re: Certification for Schrader-Bridgeport
Remote Tire Pressure Transmitter
PN: 70503025
FCC ID: MRXTSR300
CANADA:

LIST OF PHOTOGRAPHS