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Measured Radio Frequency Emissions From

TRW Volvo Low Power Transmitter Model GQ43VT16T

Report No. 415031-932
June 24, 1998

For:
TRW-TED
24175 Research Drive
Farmington Hills, MI 48335

EXHIBIT E
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Tests supervised by:
Report approved by:
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Summary
Tests for compliance with FCC Regulations subject to Part 15, Subparts B and C, were performed on TRW Volvo transmitter. This device is subject to the Rules and Regulations as a transmitter and as a digital device.

In testing performed June 12, 1998, the device tested in the worst case met the allowed specifications for radiated emissions by 12.6 dB at the fundamental and by 22.7 dB at the harmonics (see p. 6). Besides harmonics, there were no other significant spurious emissions found; emissions from digital circuitry were negligible. The conductive emission tests do not apply, since the device is powered by two 3 V lithium cells.

1. Introduction

TRW Volvo transmitter 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	July 1997/HP
Spectrum Analyzer (9kHz-26GHz)	X	Hewlett-Packard 8593E SN: 3107A01131	June 1997/HP
Spectrum Analyzer (0.1-1500 MHz)	X	Hewlett-Packard 182T/8558B SN: 1529A01114/543592	August 1996/U of M Rad Lab
Preamplifier (5-1000MHz)	X	Watkins-Johnson A11 -1 plus A25-1S	May 1996/U of M Rad Lab
Preamplifier (5-4000 MHz)	X	Avantek	Nov. 1992/ U of M Rad Lab
Power Meter		Hewlett-Packard 432A	August 1989/U of M Rad Lab
w/ Thermistor		Hewlett-Packard 478A	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)		Hewlett-Packard 8656A	January 1990/U of M Rad Lab
Printer	X	Hewlett-Packard 2225A	August 1989/HP

3. Configuration and Identification of Device Under Test

The DUT is a low power match-pack size transmitter designed to send identification and control signals to a matching receiver in the car. It is activated by depressing either of the two buttons. Rolling code encrypted digital words are transmitted. The emission is a pulse-width modulated code on a 433.92MHz carrier generated by a SAW stabilized oscillator. Coding is performed by a microprocessor, timed by a 2.0 MHz resonator.

The DUT was designed and manufactured by TRW France SA, Rue du Petit Albi - Batiment D, Cergy Saint Christophe, France 95800. It is identified as:

TRW VolvoTransmitter
Model: GQ43VT16T
SN: 25
FCC ID: GQ43VT16T
CANADA: to be provided by Industry Canada

Two units were provided, one standard (SN: 25), and one modified for CW emission (SN: 24). The CW unit was used for emission measurements, and the standard unit was used for duty factor and occupied bandwidth measurements.

3.1 EMI Relevant Modifications

None.

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 genereated 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 [Ref: 15.231(b), 15.205(a)] --Transmitter.

Frequency (MHz)	Fundamental Ave. E_{lim} (3m)		Spurious** Ave. E_{lim} (3m)	
	(μV/m)	dB (μV/m)	(μV/m)	dB (μV/m)
260.0-470.0	3750-12500*		375-1250	
322-335.4 399.9-410 608-614	Restricted Bands		200	46.0
960-1240 1300-1427 1435-1626.5 1660-1710 1718.9-1722.2 2200-2300	Restricted Bands		500	54.0

* Linear interpolation, formula: E = -7083 + 41.67*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: Average readings apply above 1000 MHz (1 MHz BW)
Quasi-Peak readings apply to 1000 MHz (120 kHz BW)

4.2 Conductive Emission Limits
The conductive emission limits and tests do not apply here, since the DUT is powered by two internal 3 V lithium batteries.

5. Radiated Emission Tests and Results

5.1 Anechonic Chamber Measurements
To familiarize with the radiated emission behavior of the DUT, the DUT was first studied and measured in a 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 testing for radiated emissions, the transmitter was activated using the lock/unlock button with a special wooden clamp for repeated pulse emissions. It was placed on the test table flat , on its side, or on its end.

In the chamber we studied and recorded all the emissions using a bicone antenna up to 300 MHz and a ridged horn antenna above 200 MHz. The measurements made in the chamber below 1 GHz are used for pre-test evaluation only. The measurements made above 1 GHz are used in pre-test evaluation and in the 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). Consequently it is not essential to measure the DUT for both antenna polarizations, as long as the DUT is measured on all three of its major axis. 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 4.34 GHz using bicone and the ridge horn antennas, 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 434 and 868.0 MHz using tuned dipoles and/or the high frequency bicone.

Figure 5.1 shows the DUT placed flat on the open-site table. This is the placement and the orientation of the DUT with respect to the antenna for the worst case emission at 434 MHz.

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

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

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 12.6 dB.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation

When the transmitter is activated by depressing a button, it transmits PWM code for 658 ms, consisting of a sync word followed by a two identical identification/command words. The ones and zeros are encoded by narrow (0.3366 ms) and wide (0.6358) pulses of repetition period of 4.0625 ms. The "worst case" duty factor occurs when all the pulses are wide. See Figure 6.1. For this case, the duty factor is

$$K_E = 0.6358 \text{ ms}/4.0625 \text{ ms} = 0.157 \text{ or } -16.1 \text{ dB}.$$

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 433.93 MHz, or 1.085 MHz. From the plot we see that the -20 dB bandwidth is 60 kHz, and the center frequency is 433.92 MHz.

6.4 Effect of Supply Voltage Variation

The DUT has been designed to be powered by two 3 V batteries. For this test, the batteries were replaced by a laboratory variable power supply and relative power radiated was measured at the fundamental as the voltage was varied from 3.0to 8.0 volts. The emission variation is shown in Figure 6.4.

6.5 Input Voltage at Battery Terminals

Batteries:	before testing	V_{oc}	=	6.60 V
	after testing	V_{oc}	=	5.58 V
Ave. current from batteries		I	=	15.0 mA (CW mode)

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Table 5.1 Highest Emissions Measured

Radiated Emission - RF											TRW Volvo TX; 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	433.9	Dip	H	-23.6	Pk	21.8	20.9	68.2	80.8	**12.6**	flat
2	433.9	Dip	V	-28.2	Pk	21.8	20.9	63.6	80.8	17.2	end
3	868.0	Dip	H	-65.4	Pk	28.1	17.2	36.4	60.8	24.4	flat
4	868.0	Dip	V	-72.3	Pk	28.1	17.2	29.5	60.8	31.3	side
5	1302.0	Horn	H	-52.5	Pk	20.9	28.0	31.3	54.0	**22.7**	side
6	1736.0	Horn	H	-55.6	Pk	21.8	28.0	29.1	54.0	24.9	flat
7	2170.0	Horn	H	-66.0	Pk	20.4	28.1	17.2	60.8	43.6	side
8	2604.0	Horn	H	-67.3	Pk	21.4	28.2	16.8	60.8	44.0	flat
9	3037.0	Horn	H	-60.9	Pk	22.1	28.1	24.0	60.8	36.8	side
10	3471.0	Horn	H	-58.9	Pk	22.9	27.0	27.9	60.8	32.9	flat
11	3905.0	Horn	H	-66.7	Pk	24.0	26.6	21.6	54.0	32.4	side
12	4339.0	Horn	H	-69.1	Pk	24.9	25.4	21.3	54.0	32.7	side
13											
14											
15											
16			All transmitter orientations were measured; above are the major emissions.								
17											
18			*includes -16.1 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. 6/12/98; U of Mich.

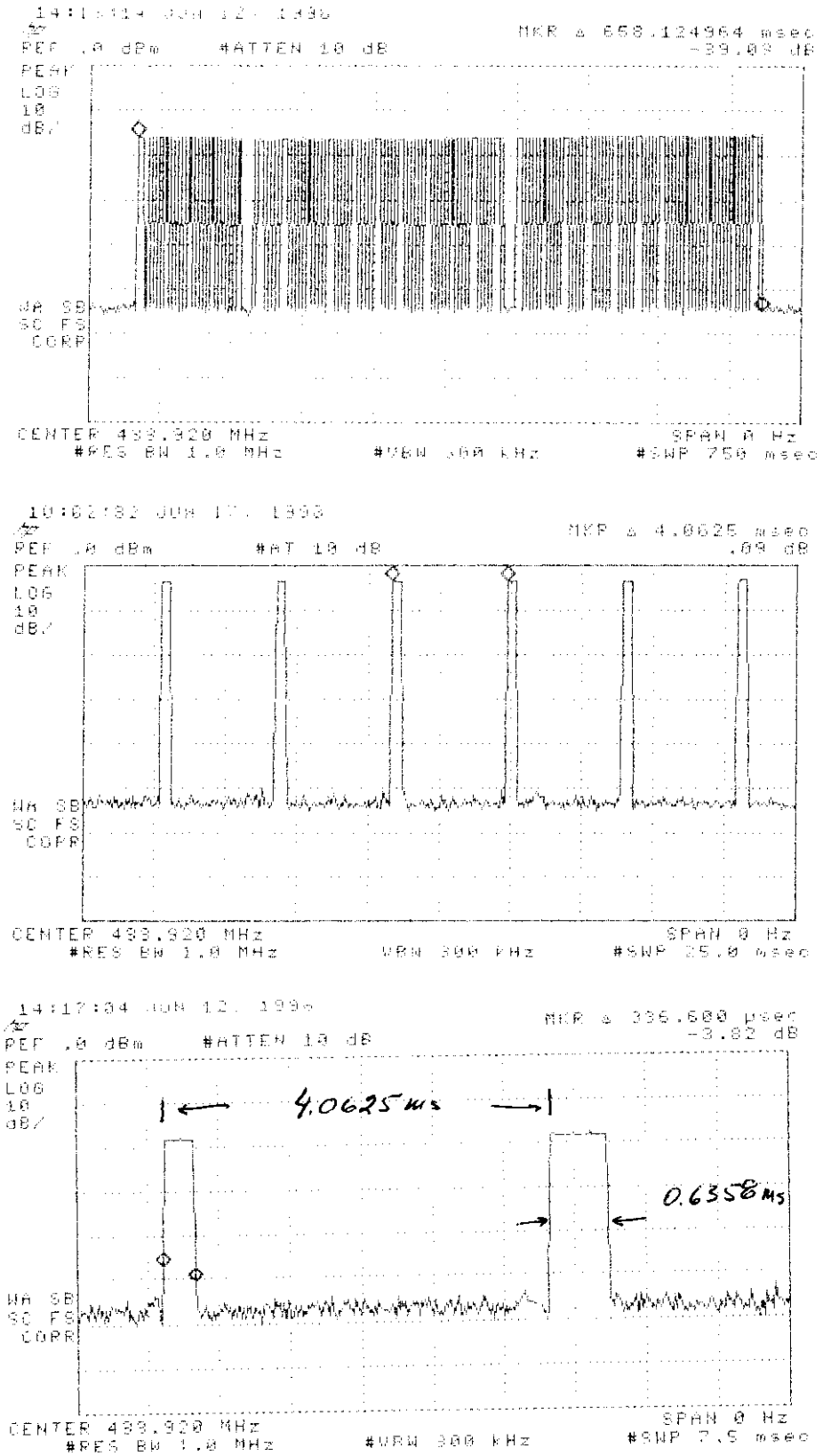

Figure 6.1. Transmissions modulation characteristics: (top) complete transmission, (center) expanded word, (bottom) expanded bits.

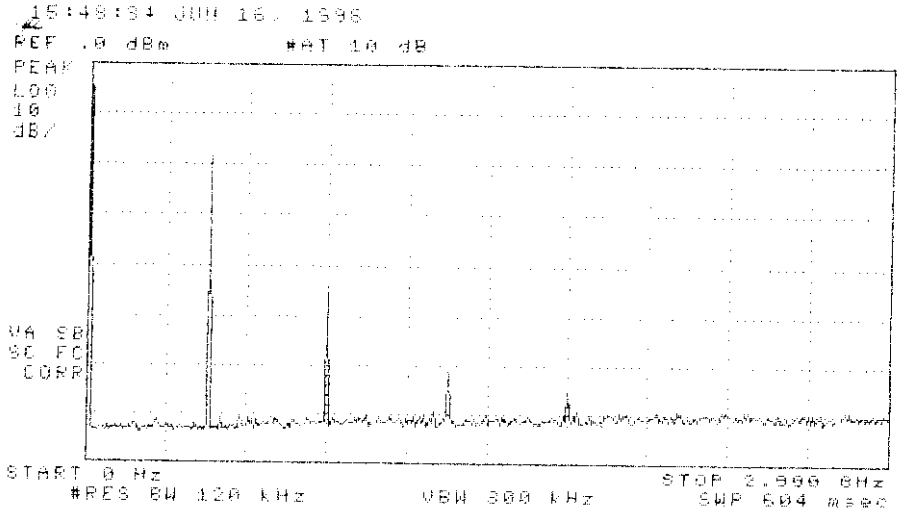

Figure 6.2. Emission spectrum of the DUT (pulsed emission).
The amplitudes are only indicative (not calibrated).

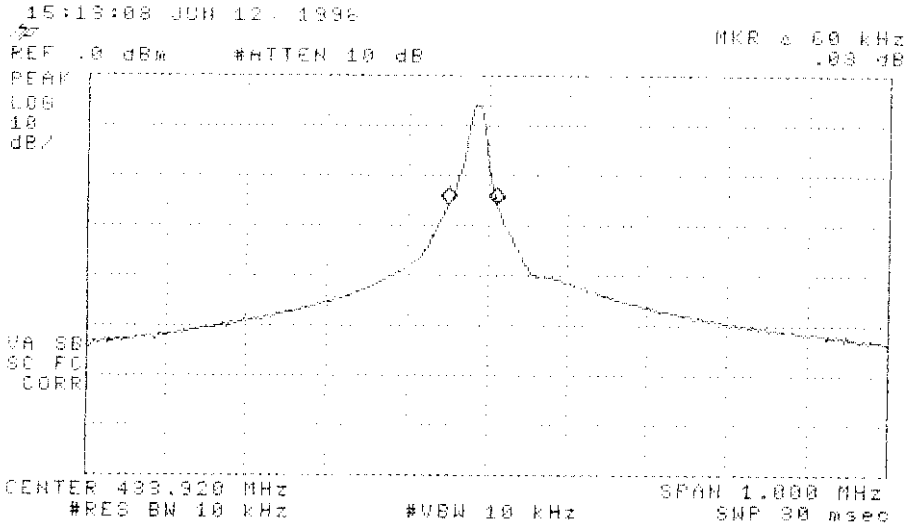

Figure 6.3. Measured bandwidth of the DUT (pulsed emission).

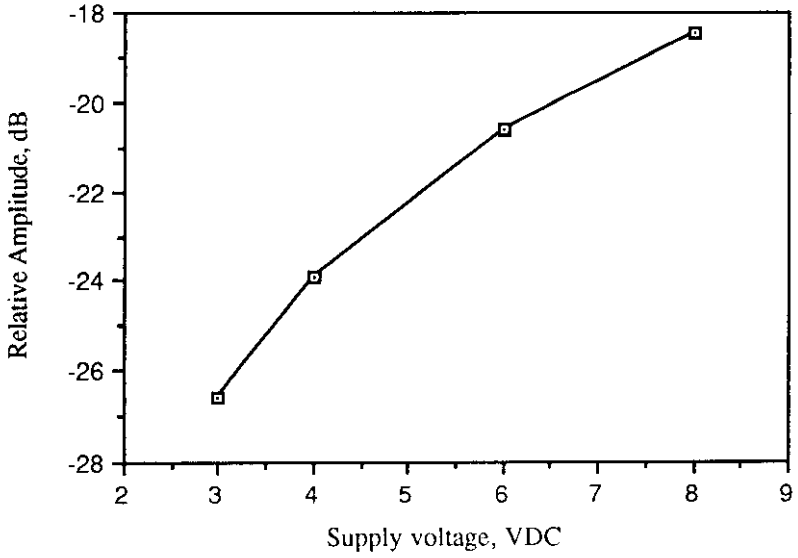

Figure 6.4. Relative emission at 315.0 MHz vs. supply voltage (pulsed emission).

TRW Module Systems SA

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Technical notice of the RKE RF Transmitter/Receiver

Transmitter type : 04686482AA

Receiver type : 04686474AA

EXHIBIT F

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1. Transmitter

Power supply	:	2 Lithium battery (2*3 Volts)
Lifetime of the batteries	:	> 2 years for a medium use
Frequency	:	433.92 MHz ± 80KHz
Modulation	:	AM
Typical power	:	< 20µW
Operating Temperature	:	-20°C à +50°c

It can be transported by hand
Internal antenna

2. Receiver

Power supply	:	Battery of the car from 9 Volts to 16 Volts
Maximal consumption	:	< 5 mA
Type of receiver	:	AM single frequency
Operating temperature	:	-40°C à +85°C

Internal antenna