The University of Michigan
Radiation Laboratory
3228 EECS Building
Ann Arbor, MI 48109-2122
Tel: (734) 647-1792

Measured Radio Frequency Emissions
From

TRW JR RKE Transmitter Model GQ43VT17T

Report No. 415031-964
September 2, 1998

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

Contact:
Daliang Shi
Tel: (248)426-3012
Fax: (248)478-7241
PO: verbal

EXHIBIT E

Page 1-10 of 10

U of Mich file 415031-964

Measurements made by: Scott Lukas

Tests supervised by:
Report approved by:

Valdis V. Liepa
Research Scientist

Summary
Tests for compliance with FCC Regulations subject to Part 15, Subparts B and C, were performed on TRW JX transmitter. This device is subject to the Rules and Regulations as a transmitter and as a digital device.

In testing performed August 25, 1998, the device tested in the worst case met the allowed specifications for radiated emissions by 2.0 dB at the fundamental and by 3.3 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 VDC lithium cells.

1. Introduction

TRW JR 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	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 1997U 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)		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 (0.1-2.06 MHz)	X	Hewlett-Packard 8657B	January 1994/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 any of the four buttons. The emission is a pulse-width modulated code on a 314.9 MHz 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-TED, 24175 Research Drive, Farmington Hills, MI 48335. It is identified as:

TRW JR Transmitter
Model: GQ43VT17T
SN:
FCC ID: GQ43VT17T
CANADA: to be provided by Industry Canada

Two units were provided, one standard, and one modified for CW emission. 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

No modifications were made 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 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 VDC 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 3.149 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 314.9, 629.8, and 944.7 MHz using tuned dipoles and/or the high frequency bicone.

Figure 5.1 shows the DUT placed flat 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 2.0 dB.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation

When the transmitter is activated, it transmits PWM code for aproximately 35 seconds, as long as the button remains depressed. The transmission consists of a sync word (50ms) followed by identification/command words (26.5ms) repeating every 73.5ms. For momentary operation, transmission consists of a sync word followed by two identification/command words, total transmission time 198 ms. A command word consists of fifty-six 195 μs wide pulses. These pulses encode data by "low-high" and "high-low" transitions. When "low-high" transition is followed by "high-low" transition, a double width pulse appears. Such then is counted as two pulses in the computation. See Figure 6.1. The "worst case" occurs when two whole words fall within a 100 ms window. For this case, the duty factor is

$$K_E = (56 * 0.195\text{ms})*2 / 100\text{ms} = 0.2184 \text{ or } -13.2 \text{ dB}.$$

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 314.95 MHz, or 787.25 KHz. From the plot we see that the -20 dB bandwidth is 188 kHz, and the center frequency is 314.95 MHz.

6.4 Effect of Supply Voltage Variation

The DUT has been designed to be powered by two 3 VDC batteries. For this test, the batteries were drained and a laboratory variable power supply was attached to their poles. Relative power radiated was measured at the fundamental as the voltage was varied from 3.0 to 9.0 volts. The emission variation is shown in Figure 6.4.

6.5 Input Voltage at Battery Terminals

Batteries:	before testing	V_{oc}	=	6.40 V
	after testing	V_{oc}	=	5.92 V
Ave. current from batteries		I	=	9.4 mA (CW mode)

The University of Michigan
Radiation Laboratory
3228 EECS Building
Ann Arbor, Michigan 48109-2122
(734) 647-1792

Table 5.1 Highest Emissions Measured

TRW JR-TX; FCC/IC

Radiated Emission - RF

#	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	314.9	Dip	H	-19.3	Pk	18.9	19.8	73.6	75.6	**2.0**	flat *worst case
2	314.9	Dip	V	-29.7	Pk	18.9	19.8	63.2	75.6	12.4	end
3	629.8	Dip	H	-50.8	Pk	25.2	16.5	51.8	55.6	3.8	flat
4	629.8	Dip	V	-53.6	Pk	25.2	16.5	49.0	55.6	6.6	end
5	944.7	Dip	H	-59.3	Pk	28.9	14.1	49.3	55.6	6.3	flat
6	944.7	Dip	V	-59.2	Pk	28.9	14.1	49.4	55.6	6.2	side
7	1259.6	Horn	H	-35.4	Pk	20.4	28.1	50.7	55.6	4.9	flat
8	1574.5	Horn	H	-42.2	Pk	21.4	28.2	44.8	54.0	9.2	flat
9	1889.4	Horn	H	-35.5	Pk	22.1	28.1	52.3	55.6	3.3	flat
10	2204.3	Horn	H	-40.9	Pk	22.9	27.0	48.8	54.0	5.2	end
11	2519.2	Horn	H	-46.3	Pk	24.0	26.6	44.9	55.6	10.7	flat
12	2834.1	Horn	H	-46.8	Pk	24.9	25.4	46.5	55.6	9.1	flat
13	3149.0	Horn	H	-59.4	Pk	25.2	24.8	34.8	55.6	20.8	flat
14											
15											
16			All transmitter orientations were measured; above are the major emissions.								
17											
18			*includes -13.2 dB duty factor								
17											

Digital Emissions

#	Freq. MHz	Ant. Used	Ant. Pol.	Pr dBm	Det. Used	Ka dB/m	Kg dB	E3* dBμV/m	E3lim dBμV/m	Pass dB	Comments
22											
23											
24			Digital emissions are more than 20 dB below FCC Class B limit								
25											

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. 8/25/98; U of Mich.

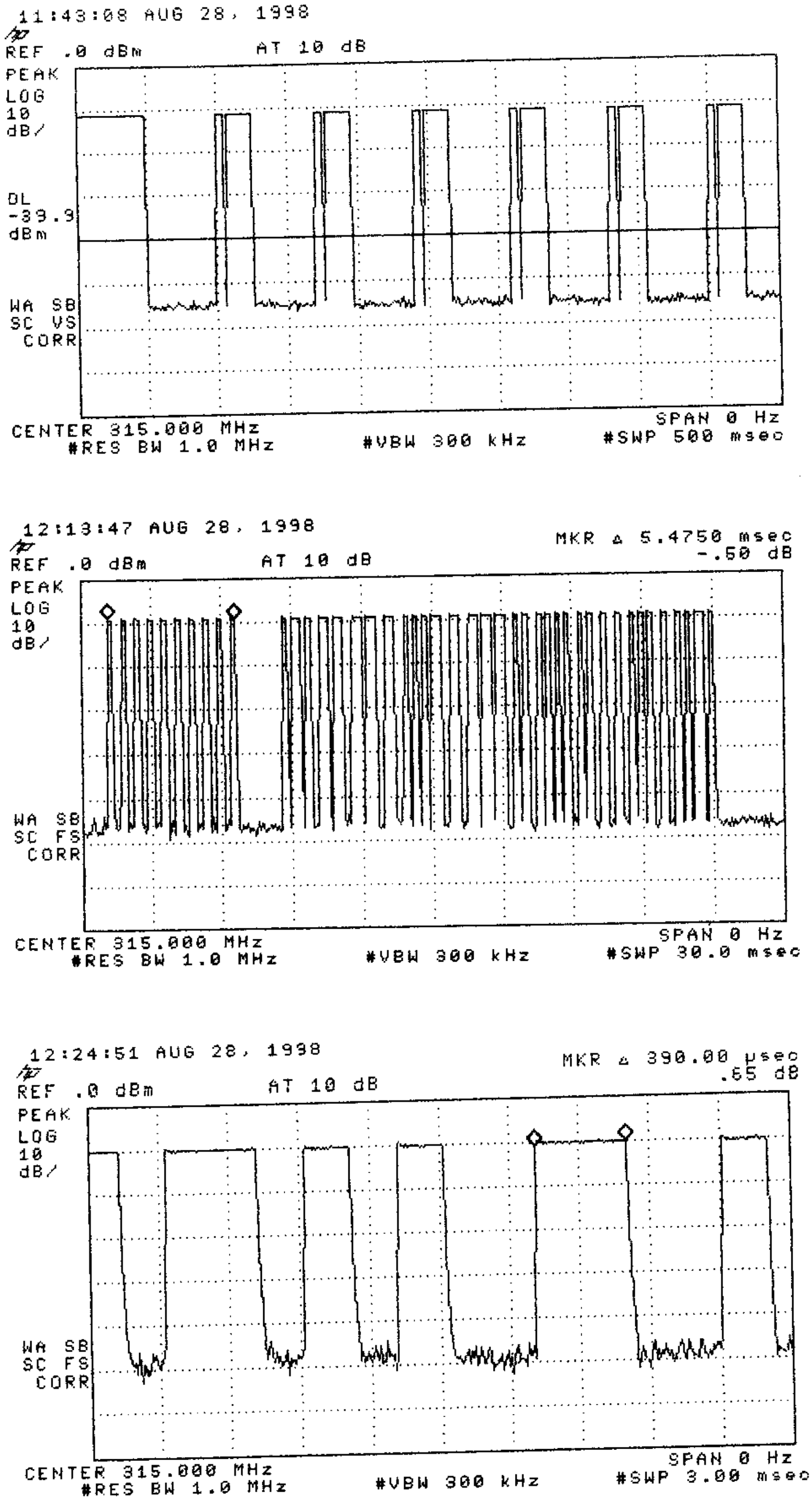

Figure 6.1. Transmissions modulation characteristics: (top) complete transmission, (center) expanded word, (bottom) expanded bits.

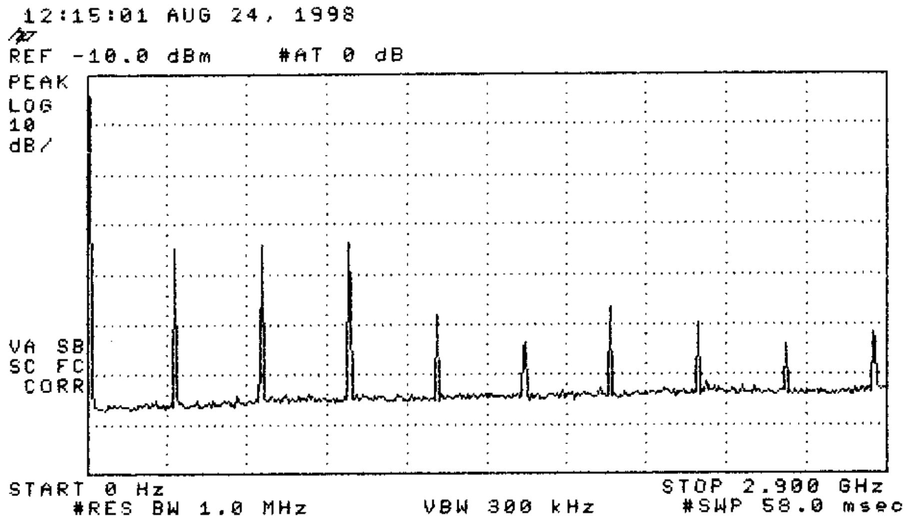

Figure 6.2. Emission spectrum of the DUT (pulsed emission).
The amplitudes are only indicative (not calibrated).

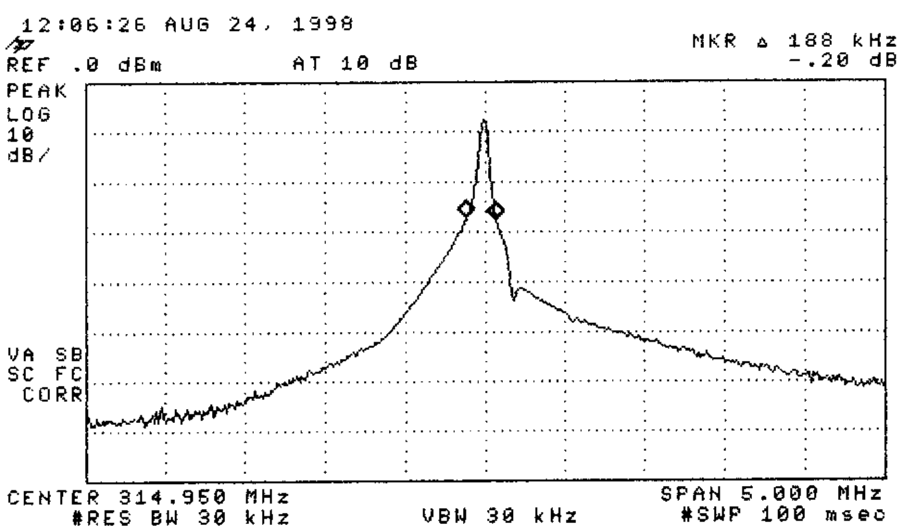

Figure 6.3. Measured bandwidth of the DUT (pulsed emission).

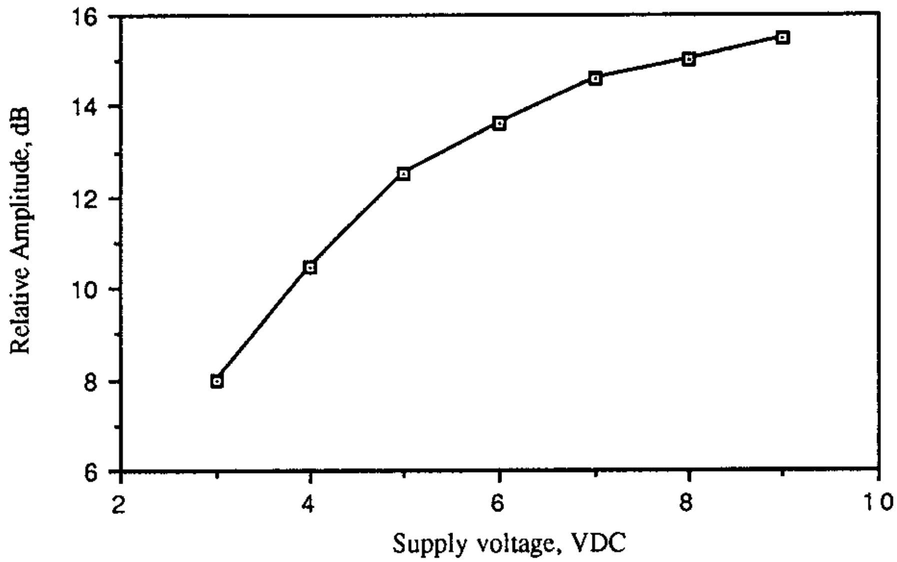

Figure 6.4. Relative emission at 315.0 MHz vs. supply voltage (pulsed emission).

2001 JR/KJ RKE Transmitter

Principles of Circuit Operation

The transmitter utilizes a SAW resonator controlled oscillator to generate a carrier of frequency of 315.0 MHz.. When a button is pressed, a Keeloq encoder will generate an associated encrypted command code; the code will be modulated onto the 315 MHz. carrier by means of ASK modulation; the modulated RF carrier then will be radiated through the onboard antenna.

The transmitter will enter sleep mode after the pressed button is released or after a button is pressed down for about 27.5 seconds, whichever comes first. The Keeloq encoder updates the content of coding for each time of transmitting with a specific encryption key.

EXHIBIT F
Page 1 of 1
U of Mich file 415031-964