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Measured Radio Frequency Emissions
From

Siemens VW Transmitter
Models 5WK48165

Report No. 415031-901
March 25, 1998

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

In testing performed February 12 and March 5, 1998, the device tested in the worst case met the allowed specifications for radiated emissions by 10.6 dB at the fundamental and by 7.1 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.

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1. Introduction

Siemens VW 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)	X	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 transmitter located in the handle on an ignition key 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-position (Manchester format) modulated code on a 315.0 MHz carrier generated by a SAW stabilized oscillator. Coding is performed by a microprocessor, timed by a 2.6 MHz dielectric resonator.

The DUT was designed and manufactured by Siemens AG, Wernerwerkstrasse 2, 93049 Regensburg, Germany. It is identified as:

Siemens VW Transmitter
Model: 5WK48165
SN: 13
FCC ID: KR55WK48165
CANADA: to be provided by Industry Canada

Two standard units were provided. We arbitrarily chose SN: 13, and performed on it the required tests. Since the transmission lasts 60 seconds when the button is pressed, no modifications were needed on the device to perform the measurements. (There are special test modes available on the DUD by depressing the buttons in certain sequence, but such were not used in these tests.)

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	Fundamental Ave. E_{lim} (3m)		Spurious** Ave. E_{lim} (3m)	
(MHz)	(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 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 assessment for compliance. 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 characterisics 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 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 315.0 MHz.

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 7.1 dB.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation

When the transmitter is activated by depressing and holding the button, it transmits Manchester encoded pulses for 325 ms, after which encoded 17 ms long words are repeated every 66 ms for total transmission of 60 seconds. For short depression of the button, the transmission lasts 325 ms. The "worst case" duty factor occurs during the 325 ms pulse. In there are pulses 0.500 ms wide, of period 1.000 ms. Since this is Manchester format coding, the pulses go low-high or high-low, thus creating wide pulse appearance, i.e., a double pulse. See Figure 6.1. For this device, duty factor is

$$K_E = 0.500 \text{ ms}/ 1.000 \text{ ms} = 0.5 \text{ or } -6.0 \text{ dB}.$$

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 53 kHz, and the center frequency is 315.070 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}	=	6.21V
	after testing	V_{oc}	=	5.98 V
Ave. current from batteries		I	=	1.7 mA (pulsed mode)

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Table 5.1 Highest Emissions Measured

Radiated Emission - RF											Siemens VW; TX
#	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	-32.6	Pk	18.9	22.3	65.0	75.6	10.6	flat
2	315.0	Dip	V	-36.0	Pk	18.9	22.3	61.6	75.6	14.0	end
3	630.0	Dip	H	-66.4	Pk	25.2	19.0	40.9	55.6	14.7	flat
4	630.0	Dip	V	-65.5	Pk	25.2	19.0	41.8	55.6	13.8	end
5	945.0	Dip	H	-79.0	Pk	28.9	16.6	34.3	55.6	21.3	flat, noise floor
6	945.0	Dip	V	-79.0	Pk	28.9	16.6	34.3	55.6	21.3	end, noise floor
7	1260.0	Horn	H	-57.9	Pk	20.4	28.1	35.4	55.6	20.2	flat
8	1575.0	Horn	H	-56.1	Pk	21.4	28.2	38.1	54.0	15.9	side
9	1890.0	Horn	H	-49.9	Pk	22.1	28.1	45.1	55.6	10.5	side
10	2205.0	Horn	H	-50.0	Pk	22.9	27.0	46.9	54.0	**7.1**	side
11	2520.0	Horn	H	-51.9	Pk	24.0	26.6	46.5	55.6	9.1	side
12	2835.0	Horn	H	-53.7	Pk	24.9	25.4	46.8	55.6	8.8	side
13	3150.0	Horn	H	-59.0	Pk	25.2	24.8	42.4	55.6	13.2	side
14											
15											
16											
17											
18			*includes -6.0 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. 2/12/98; UMich.

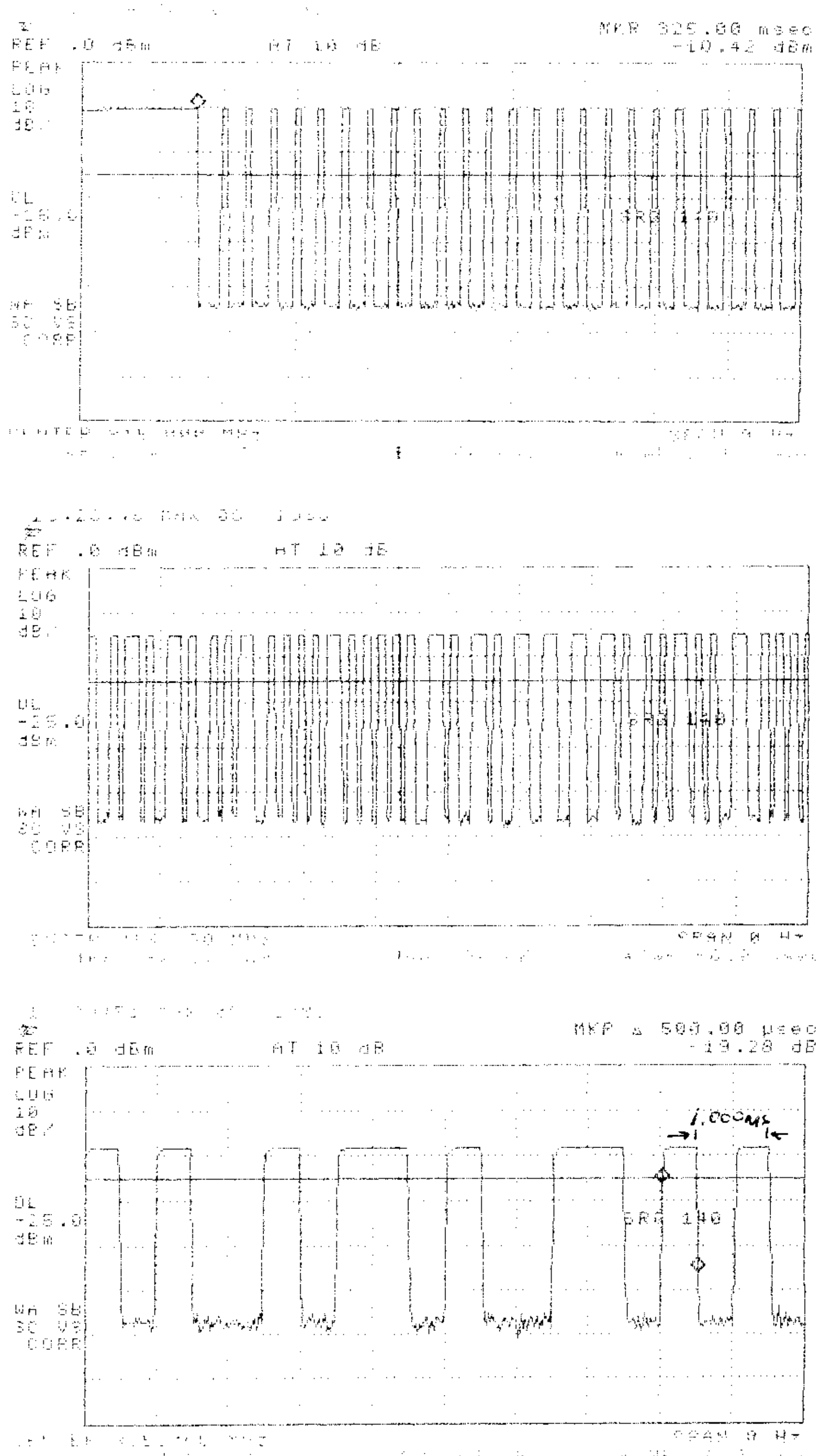

Figure 6.1. Transmissions modulation characteristics: (top) complete transmission, (center) expanded word, (bottom) expanded bits.

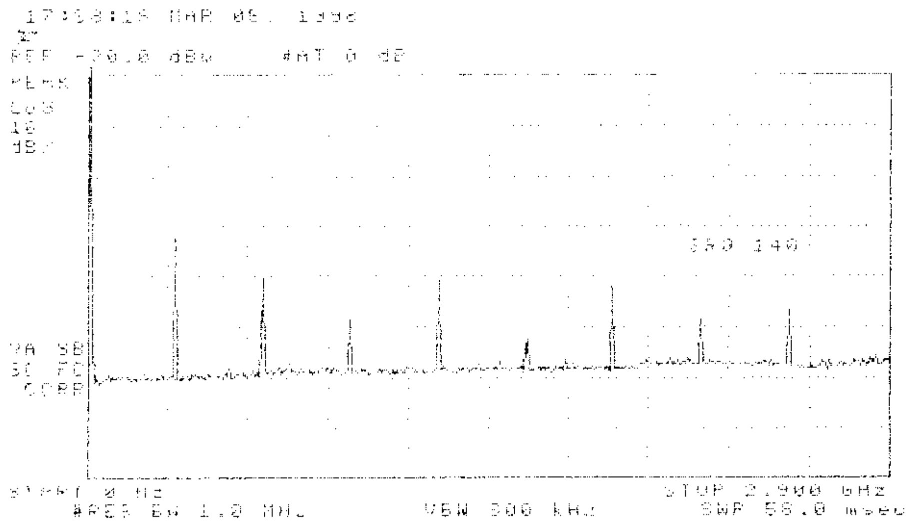

Figure 6.2. Emission spectrum of the DUT (pulsed emission).
The amplitudes are only indicative (not calibrated).

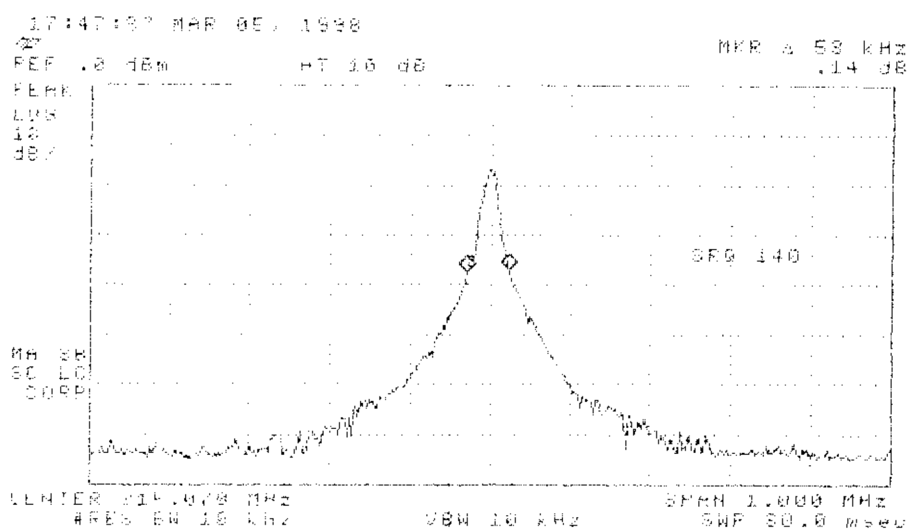

Figure 6.3. Measured bandwidth of the DUT (repeated pulsed emission).

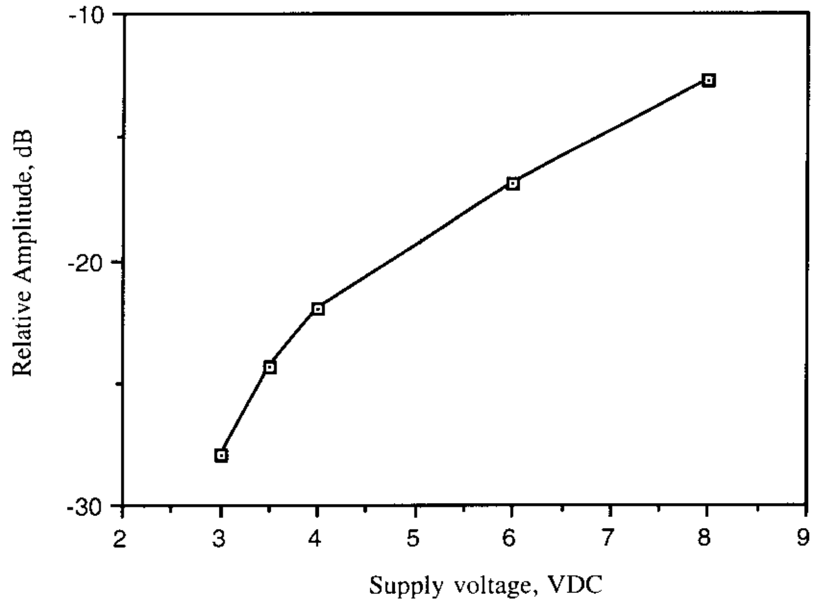

Figure 6.4. Relative emission at 315.0 MHz vs. supply voltage (pulsed emission).

1. FUNCTIONAL DESCRIPTION OF THE RF-TRANSMITTER

The transmitter is part of a RF- remote keyless entry system in an automotive application.
The rf telegram data is generated by a rolling code algorithm.This means the data of the telegram is changing by every activation of the transmitter buttons.
In general the following functions are provided:

- Lock the car
- Unlock the car
- Connect alarm
- Disconnect alarm
- Initialization

The transmitter is based on the following functional blocks:

1.1 POWER SUPPLY

The transmitter is provided with 2 Lithium batteries (CR2016), which means a total power supply voltage of + 6V.
The power of the batteries is checked with at every data telegram transmission.
In the case that the power supply drops below a defined value, no RF- telegrams will be transmitted.
The low voltage detection is determined by the components R1, U1 and the integrated A/D-converter of the microcontroller.
The electronic subassembly is protected against reverse battery by diode D1.

1.2 MICROCONTROLLER

NEC is the supplier of the microcontroller µpd 754264.
This device is a 4-bit mask-controller including E^2prom and A/D-converter on chip.
The clock of the controller is generated by a SMD-resonator settled to 2.6 MHz.

1.3 BUTTONS

The transmitter is equipped with two different buttons S1 and S2. During activating the buttons are turned to ground via an internal pull-up resistance inside of the microcontroller.
Pressing the two buttons in a special defined order, two different test-modes (modulation and carrier frequency permanent) can be activated.
These test-modes are described in line item 1.9.1 and 1.9.2.

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1.4 TRANSMISSION FORMAT

The format of the data telegram is based on Manchester code. The RF telegram changes after every new transmission.
The transmission rate is settled to 1 KBaud.

1.5 LED

The LED U1 is turned on pulsed with every transmission unless there is no low voltage status of the batteries detected.
The forward voltage across the diode is also used as a reference voltage for the A/D-conversion.

1.6 OSCILLATOR

The oscillator consists out of one colpitts oscillator stage, which is frequency stabilized by SAW resonator
The frequency is settled to 315 MHz MHz ± 100 KHz.

1.7 PARALLEL RESONANCE CIRCUIT

The printed antenna and the combination of C6 and C7 realize the parallel resonance circuit (LC-circuit).
The components C6 and C7 are designed to values, which enable SAW resonator to determine the carrier frequency.

1.8 MECHANICAL DESIGN

The mechanical design consists of two parts:

- container
- key shank

The battery compartment is integrated in the container. The polarity of the batteries is marked in the cover of the key housing.

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1.9 TRANSMITTER MODES

The testmodes are used only during testing at the production line in the Siemens plant.

1.9.1 TESTMODE 1 (CARRIER FREQUENCY)

The testmode 1 is used to determine the center frequency and the output power of the carrier signal.
The test procedure 1 is generated by the following sequence

1.) Press and keep pressed the unlock button
2.) Press and keep pressed the lock button
3.) Release the unlock button

The transmitter sends out the carrier frequency as long as the lock button is released.

1.9.2 TESTMODE 2 (MODULATION)

The testmode 2 is used to determine the modulation spectrum. During this testmode a symmetrical signal modulated with 1 KHz is transmitted.
The test procedure 2 is generated by the following sequence:

1.) Press and keep pressed the unlock button
2.) Press and keep pressed the lock button
3.) Release the unlock button
4.) Press and keep pressed the unlock button
5.) Release the lock button

The transmitter sends out the modulation as long as the unlock button is released.

1.10. SYSTEM COMPONENTS

5WK 4 8165:	transmitter 315 MHz – USA
5WK4 7971/5WK4 7972/5WK4 7973:	transmitter 315 MHz Japan (reduced emitted power) 3 variants with cosmetic deviation s(different logo for three customers

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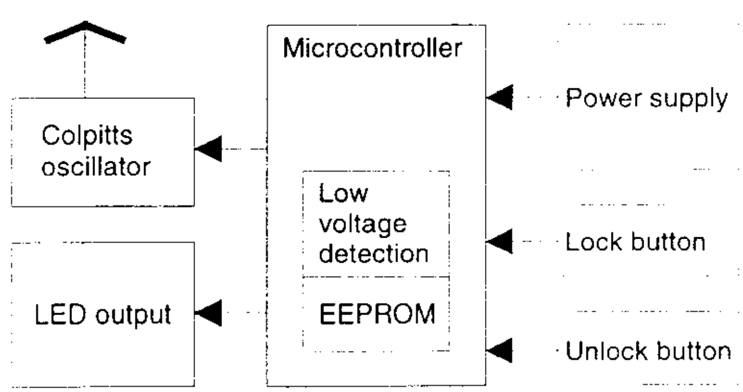
2 TECHNICAL DESCRIPTION OF THE RF TRANSMITTER

2.1 ELECTRICAL DATA

Carrier frequency:	315.05 MHz ± 100 kHz
Output power (carrier frequency):	typ. -30 dBm
Modulation:	OOK (On-Off Keying)
Duration of data telegrams (8 byte):	66ms
Transmission format	Manchester code
Transmission rate:	1 KBaud
Current consumption active:	typ. 5 mA
Current consumption stand-by:	< 1uA
Power supply	2 Li- batteries (nominal voltage 3V each)
Operation lifetime of batteries:	typ. 2 years
Operating temperature range:	-10°C...+60°C

2.2 BLOCK DIAGRAM



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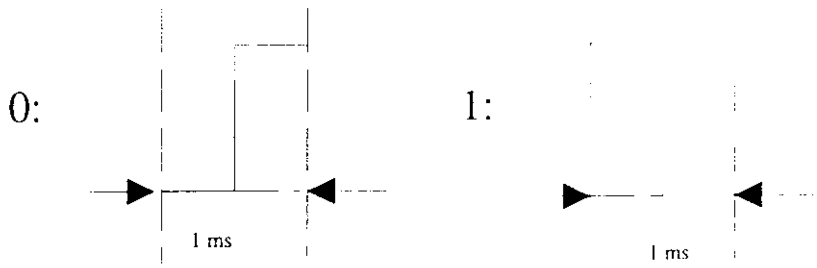
2.3 TRANSMISSION FORMAT

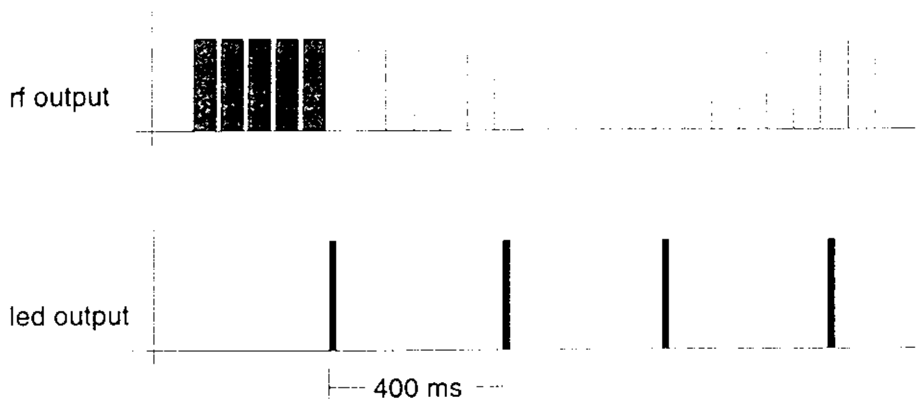
S

Transmission format is Manchester code.
Bit duration is 1 ms, transmission rate is 1 KBaud.
Time from begin telegram to begin of next telegram is 66 ms.



2.5 LED TIMING

The LED is activated every 400ms for 10ms after the transmission of 5 telegrams.



After transmission of the initialization telegram flashing up to 5 s with a frequency of approximately 1 Hz

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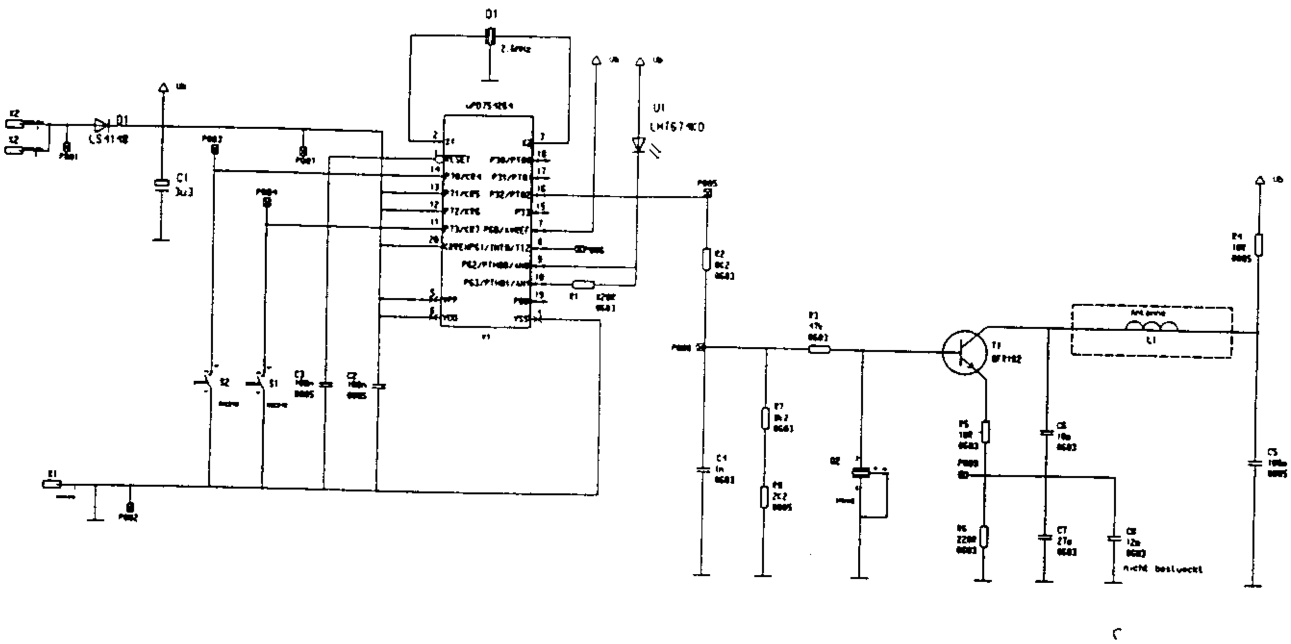
6 CIRCUIT DIAGRAM



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5 BILL OF MATERIAL FOR ELECTRONIC SUBASSMEMBLY (PCB)

Pos.	Stk.	Reference	Part	Device
1	1	R1	820 ± 5%	0603
2	1	R2	8k2 ± 5%	0603
3	1	R3	47k ± 5%	0603
4	1	R4	10R ± 5%	0805
5	1	R5	18R ± 5%	0603
6	1	R6	220R ± 5%	0603
7	1	R7	8k2 ± 5%	0603
8	1	R8	2k2 ± 5%	0805
9	1	C1	3,3uF/ 10V	Taco A
10	2	C2,C3	100nF/ 25V	0805
11	1	C4	1nF ± 10%	0603
12	1	C5	100 pF ± 5%	0805
13	1	C6	10 pF ± 0,1pF	0603
14	1	C7	27 pF ± 2%	0603
15	1	T1	BFR 182	SOT23
16	1	D1	LS4148	Quader
17	1	U1 (LED)	LHT674/KO	TOP
18	1	Q1	Resonator 2.6MHz	
19	1	V1	µD 754264 NEC	SOP20
20	1	Q2	SAW 315 MHz	QCC-8
21	2	S1, S2	Microswitch	

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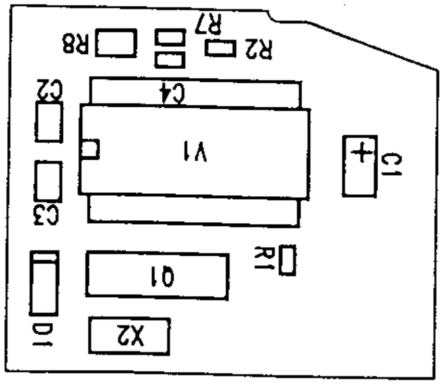
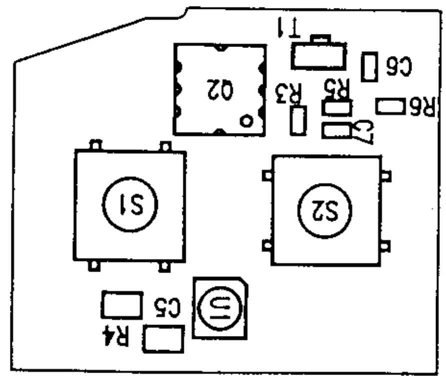
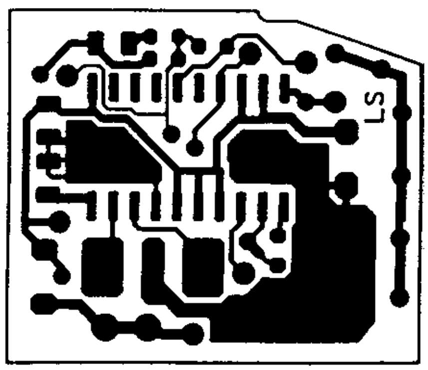
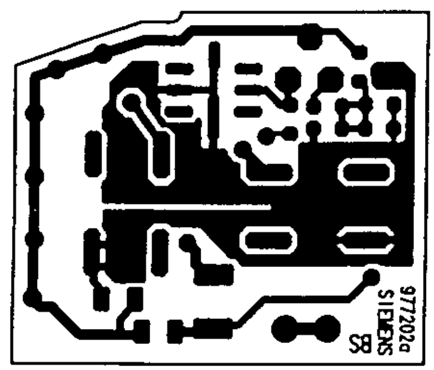
7 LAYOUT









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Re: Certifation for
Siemens VW Low Power Transmitter
Model: 5WK48165
FCC ID: KR55WK48165
CANADA: to be provided by IC

LIST OF PHOTOGRAPHS