

ENGINEERING TEST REPORT



Marine Radar
Model No.: MR-1000TII
FCC ID: AFJ278000

Applicant:

Icom Incorporated
1-1-32, Kamiminami, Hirano-ku
Osaka 547-0003
Japan

Tested in Accordance With

Federal Communications Commission (FCC)
CFR 47, Parts 2 and 80 - Marine Radar @ 9300 - 9500 MHz

UltraTech's File No.: ICOM-114F80RADAR

This Test report is Issued under the Authority of
Tri M. Luu, Professional Engineer,
Vice President of Engineering
UltraTech Group of Labs



Date: August 24, 2005

Report Prepared by: Dan Huynh

Tested by: Wayne Wu & Hung Trinh

Issued Date: August 24, 2005

Test Dates: July 4 August 17, 2005

- *The results in this Test Report apply only to the sample(s) tested, and the sample tested is randomly selected.*
- *This report must not be used by the client to claim product endorsement by NVLAP or any agency of the US Government.*

UltraTech

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EXHIBIT 1. INTRODUCTION

1.1. SCOPE

Reference:	FCC Parts 2 and 80
Title:	Telecommunication - Code of Federal Regulations, CFR 47, Parts 2 & 80
Purpose of Test:	To gain FCC Certification Authorization for Radio operating in the Frequency Band 9300-9500 MHz
Test Procedures:	Both conducted and radiated emissions measurements were conducted in accordance with TIA/EIA Standard TIA/EIA- 603 - Land Mobile FM or PM Communications Equipment Measurement and Performance Standards.
Marine Categories of Station:	Shipborne Radar

1.2. RELATED SUBMITTAL(S)/GRANT(S)

None.

1.3. NORMATIVE REFERENCES

Publication	Year	Title
FCC CFR Parts 80-End	2004	Code of Federal Regulations – Telecommunication
ANSI C63.4	2004	American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz
CISPR 16-1-1	2004	Specification for Radio Disturbance and Immunity measuring apparatus and methods
TIA/EIA 603, Edition B	01-Nov-2002	Land Mobile FM or PM Communications Equipment Measurement and Performance Standards

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EXHIBIT 2. PERFORMANCE ASSESSMENT

2.1. CLIENT INFORMATION

APPLICANT	
Name:	Icom Incorporated
Address:	1-1-32, Kamiminami, Hirano-ku Oaska 547-0003, Japan,
Contact Person:	Mr. Takashi Aoki Phone #: +81-66-793-5302 Fax #: +81-66-793-0013 Email Address: export@icom.co.jp

MANUFACTURER	
Name:	Icom Incorporated
Address:	1-1-32, Kamiminami, Hirano-ku Oaska 547-0003, Japan,
Contact Person:	Mr. Takashi Aoki Phone #: +81-66-793-5302 Fax #: +81-66-793-0013 Email Address: export@icom.co.jp

2.2. EQUIPMENT UNDER TEST (EUT) INFORMATION

The following information (with the exception of the Date of Receipt) has been supplied by the applicant.

Brand Name:	Icom Incorporated
Product Name:	Marine Radar
Model Name or Number:	MR-1000TII
Serial Number:	Test Sample
Type of Equipment:	Shipborne Radar
External Power Supply:	DC 10.2 V – 42 V
Transmitting/Receiving Antenna Type:	Non-integral with wave guide RF connector
Primary User Functions of EUT:	Search, navigation and anti-collision.

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2.3. EUT'S TECHNICAL SPECIFICATIONS

TRANSMITTER						
Equipment Type:		Shipborne Radar				
Intended Operating Environment:		Marine				
Power Supply Requirement:		DC 10.2 to 42 Vdc				
RF Output Power Rating:		4 kW				
Operating Frequency Range:		9300 – 9500 MHz				
Center Frequency:		9410 MHz				
Manufacturer's Frequency Tolerance:		30 MHz				
Guard Band:		1.5/T MHz, where T is pulse-length in μ S @ FCC 80.209				
Pulse Characteristics:						
Range (nm)	Antenna Rotation (rpm)	PRF (Hz)	Short Pulse		Long Pulse	
			Pulse Width (nS)	Guard Band (MHz)	Pulse Width (nS)	Guard Band (MHz)
0.125	48	2880	80	18.75	80	18.75
0.250						
0.500						
0.750	36	2160	250	6.00	350	4.29
1.000						
1.500						
2.000						
3.000						
4.000	24	720	900	1.67	900	1.67
6.000						
8.000						
12.00						
16.00						
24.00						
32.00						
36.00						
48.00						
Intermediate Frequency:		60 MHz				
IF Bandwidth		10 MHz / 3 MHz				
Occupied Bandwidth (99%):		77.6 MHz				
Emission Designation*:		77M6P0N				
Type of Antenna:		Slotted Waveguide Array				

*Bn is the measured 99% occupied bandwidth.

Antenna Description:	Manufacturer: Icom Inc. Type: Slotted Waveguide Array Frequency Range: 9410 MHz \pm 30 MHz In/Out Impedance: 50 Ohms Gain: 27 dBi Length of Antenna: 1200 mm Horizontal Beam Width: 2° Vertical Beam Width: 25°
Temperature Rating:	-25°C to +70°C

2.4. LIST OF EUT'S PORTS

Port Number	EUT's Port Description	Number of Identical Ports	Connector Type	Cable Type (Shielded/Non-shielded)
1	DC Power	1	2-Wire Lead	Non-shielded
2	NMEA1	1	8 pin CMC	Shielded
3	NMEA1	1	7 pin CMC	Shielded
4	Scanner Unit	1	8 pin CMC	Shielded

EXHIBIT 3. EUT OPERATING CONDITIONS AND CONFIGURATIONS DURING TESTS

3.1. CLIMATE TEST CONDITIONS

The climate conditions of the test environment are as follows:

Temperature:	21°C
Humidity:	51%
Pressure:	102 kPa
Power input source:	DC 10.2 to 42 Vdc

3.2. OPERATIONAL TEST CONDITIONS & ARRANGEMENT FOR TEST SIGNALS

Operating Modes:	The transmitter was operated in a continuous transmission mode in pulse mode as specified in the Test Data.
Special Test Software:	N/A
Special Hardware Used:	N/A
Transmitter Test Antenna:	The EUT is tested with the transmitter antenna port terminated to a 50 Ohms RF Load.

Transmitter Test Signals	
Frequency Band(s):	9300 MHz – 9500 MHz
Test Frequency(ies):	9410 MHz
Transmitter Wanted Output Test Signals:	
<ul style="list-style-type: none"> ▪ Transmitter Power (measured maximum output power): ▪ Normal Test Modulation: ▪ Modulating signal source: 	65.05 dBm peak (3.20 kW) 33.53 dBm average (2.25 W) P0N Internal

EXHIBIT 4. SUMMARY OF TEST RESULTS

4.1. LOCATION OF TESTS

All of the measurements described in this report were performed at Ultratech Group of Labs located in the city of Oakville, Province of Ontario, Canada.

- AC Power line Conducted Emissions were performed in UltraTech's shielded room, 16'(L) by 12'(W) by 12'(H).
- Radiated Emissions were performed at the Ultratech's 3 Meter Open Field Test Site (OFTS) situated in the Town of Oakville, province of Ontario.
- The above sites have been calibrated in accordance with ANSI C63.4, and found to be in compliance with the requirements of Sec. 2.948 of the FCC Rules. The descriptions and site measurement data of the Oakville Open Field Test Site has been filed with FCC office (FCC File No.: 31040/SIT 1300B3) and Industry Canada office (Industry Canada File No.: IC2049). Last Date of Site Calibration: Jan. 10, 2005.

4.2. APPLICABILITY & SUMMARY OF EMC EMISSION TEST RESULTS

FCC Rules	Test Requirements	Applicability (Yes/No)
2.1046, 80.215	RF Power Output	Yes
2.1047, 80.213(g)	Modulation Characteristics	Yes
2.1049	Occupied Bandwidth	Yes
80.211(f)	Emission Limitations	Yes
2.1051, 2.1057 & 80.211(f)	Spurious Emissions at Antenna Terminals	Yes
2.1053, 2.1057 & 80.211(f)	Field Strength of Spurious Radiation	Yes
2.1055 & 80.209 (b)	Frequency Stability	Yes
1.1307, 1.1310, 2.1091	RF Exposure Limit	Yes
FCC Part 15, Subpart B, Class B	This device, Marine Radar, Model MR-1000TII, has been tested and found to comply with FCC Part 15, Subpart B Class B – unintentional radiators. The compliance test report is kept on file and it is available upon request.	Yes

4.3. MODIFICATIONS INCORPORATED IN THE EUT FOR COMPLIANCE PURPOSES

None.

4.4. DEVIATION OF STANDARD TEST PROCEDURES

None.

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EXHIBIT 5. MEASUREMENTS, EXAMINATIONS & TEST DATA FOR EMC EMISSIONS

5.1. TEST PROCEDURES

This section contains test results only. Details of test methods and procedures can be found in TIA/EIA 603 and Exhibit 7 of this report

5.2. MEASUREMENT UNCERTAINTIES

The measurement uncertainties stated were calculated in accordance with requirements of UKAS Document LAB 34 with a confidence level of 95%. Please refer to Exhibit 6 for Measurement Uncertainties.

5.3. MEASUREMENT EQUIPMENT USED

The measurement equipment used complied with the requirements of the Standards referenced in the Methods & Procedures ANSI C63.4 and CISPR 16-1-1.

5.4. ESSENTIAL/PRIMARY FUNCTIONS AS DECLARED BY THE MANUFACTURER

The essential function of the EUT is to correctly communicate data to and from radios over RF link.

5.5. RF POWER OUTPUT [§§ 2.1046 & 80.215]

5.5.1. Limits

§ 80.215

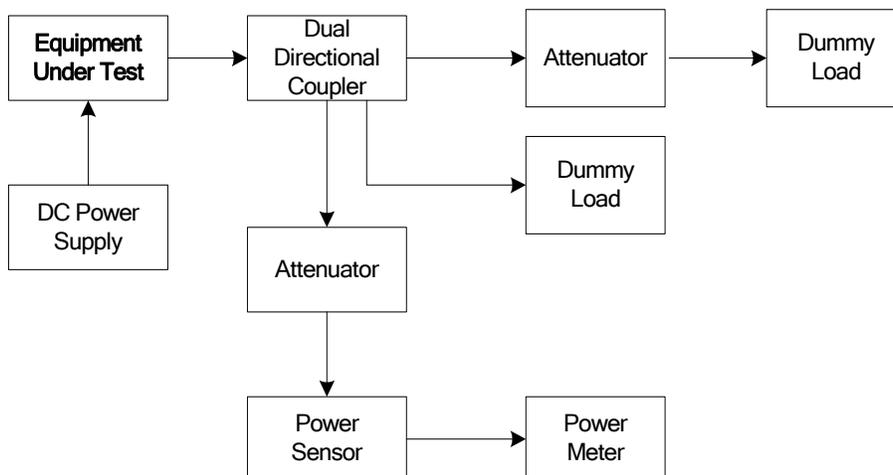
5.5.2. Method of Measurements

Refer to Section 7.1 of this test report for test procedures.

5.5.3. Test Equipment List

Test Instruments	Manufacturer	Model No.	Serial No.	Frequency Range
Dual Directional Coupler	Hewlett-Packard	11692D	1212A03620	2-18GHz
Dummy Load	Generic	BEC 91-15A	--	DC-18GHz
Dummy Load	Generic	BEC 91-15A	--	DC-18GHz
Attenuator	Weinschel	23-20-34	BH7876	DC-18GHz
Attenuator	Weinschel	48-30-34	BM5354	DC-18GHz
DC Power Supply	Tenma	72-7295		DC 0-40 V, 0-5A.
Power Meter	Hewlett Packard	436A	1725A02249	10 kHz - 50GHz, sensor dependent
Power Sensor	Hewlett Packard	8481A	2702A68983	10 MHz-18 GHz

5.5.4. Test Arrangement



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5.5.5. Test Data

Signal Frequency: 9410 MHz					
Pulse Length (ns)	Range (nm)	PRF (Hz)	Duty Cycle (%)	Measured Conducted Average Power P_a (dBm)	¹ Measured Conducted Peak Power P_p (dBm)
(PL1) 78.3	0.5	2827	0.022	28.47	65.05
(PL2) 78.2	1	2115	0.017	27.15	64.85
(PL3) 252.2	2	2116	0.053	31.98	64.74
(PL4) 356.7	4	2116	0.075	33.53	64.78
(PL5) 901.2	8	706	0.064	32.86	64.80

Note: (1) $P_p = P_a - 10 \cdot \log(\text{Duty Cycle})$
(2) Average E.I.R.P. = $P_a + G_i$

Where: P_a : Conducted average power in dBm
 P_p : Conducted peak power in dBm
 G_i : Transmitter antenna gain in dBi

5.6. MODULATION CHARACTERISTICS [§§ 2.1047 & 80.213(g)]

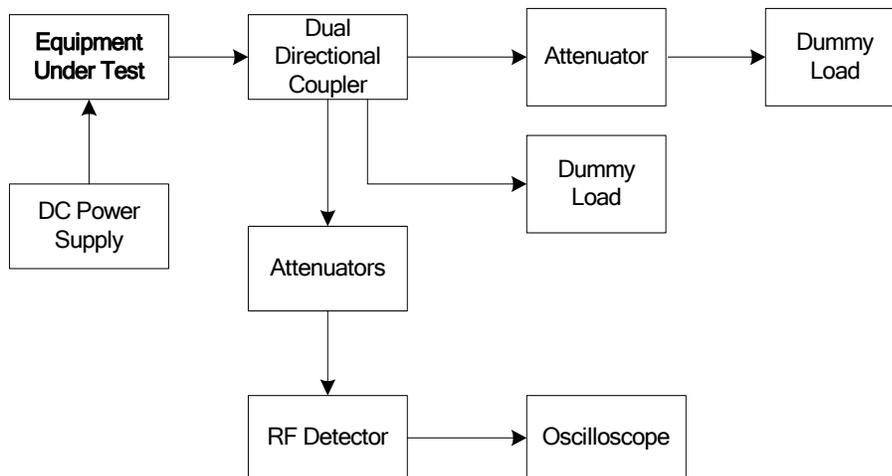
5.6.1. Limits

§ 80.213(g): Radar stations operating in the bands above 2.4 GHz may use any type of modulation consistent with the bandwidth requirements in § 80.209(b).

5.6.2. Test Equipment List

Test Instruments	Manufacturer	Model No.	Serial No.	Frequency Range
Dual Directional Coupler	Hewlett-Packard	11692D	1212A03620	2 - 18 GHz
Dummy Load	Generic	BEC 91-15A	--	DC-18GHz
Dummy Load	Generic	BEC 91-15A	--	DC-18GHz
Attenuator	Weinschel	23-20-34	BH7876	DC-18 GHz
Attenuator	Weinschel	48-30-34	BM5354	DC-18 GHz
Attenuator	Weinschel	46-20-34	BM1347	DC-18 GHz
DC Power Supply	Tenma	72-7295	--	DC 0-40 V, 0-5A.
RF Detector	Narda	503A-03	105	10 MHz - 18 GHz
Oscilloscope	Hewlett-Packard	54801A	US38380192	DC-500 MHz 1G sampling

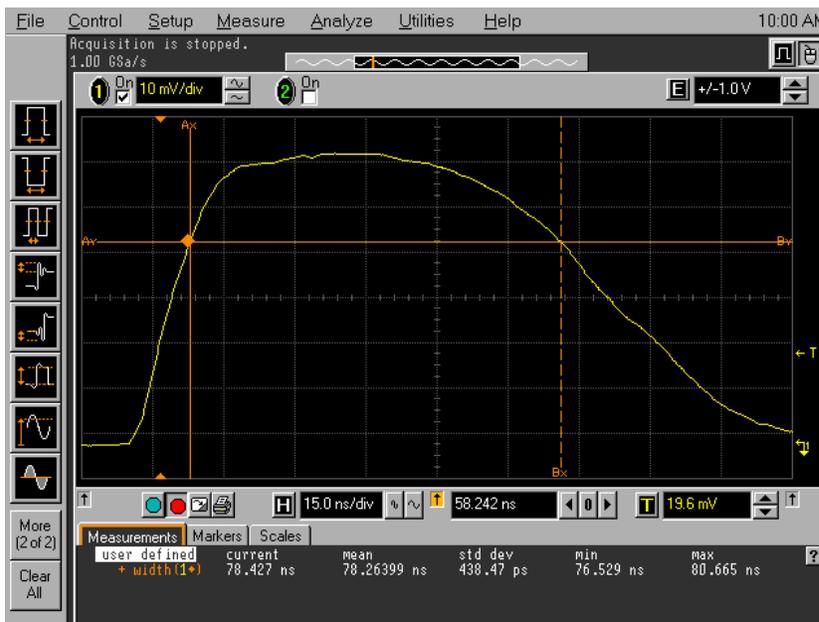
5.6.3. Test Arrangement



5.6.4. Test Data

See the following plots for pulse width and pulse rise time:

Plot 5.6.4.1: 70% Amplitude Pulse Width, PL1 (0.5 nm Range)



Plot 5.6.4.2: Pulse Rise Time, PL1 (0.5 nm Range)



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Plot 5.6.4.3: 70% Amplitude Pulse Width, PL2 (1 nm Range)



Plot 5.6.4.4: Pulse Rise Time, PL2 (1 nm Range)



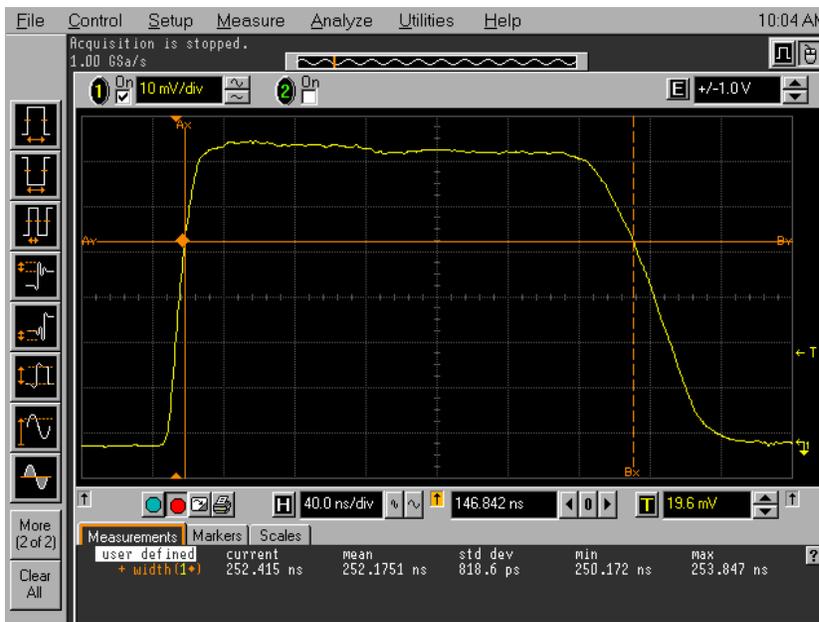
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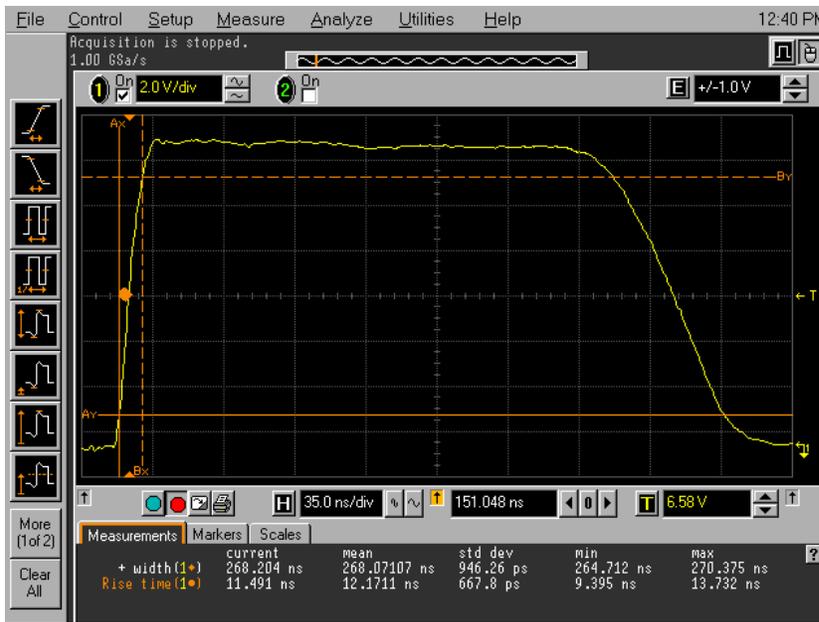
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Plot 5.6.4.5: 70% Amplitude Pulse Width, PL3 (2 nm Range)



Plot 5.6.4.6: Pulse Rise Time, PL3 (2 nm Range)



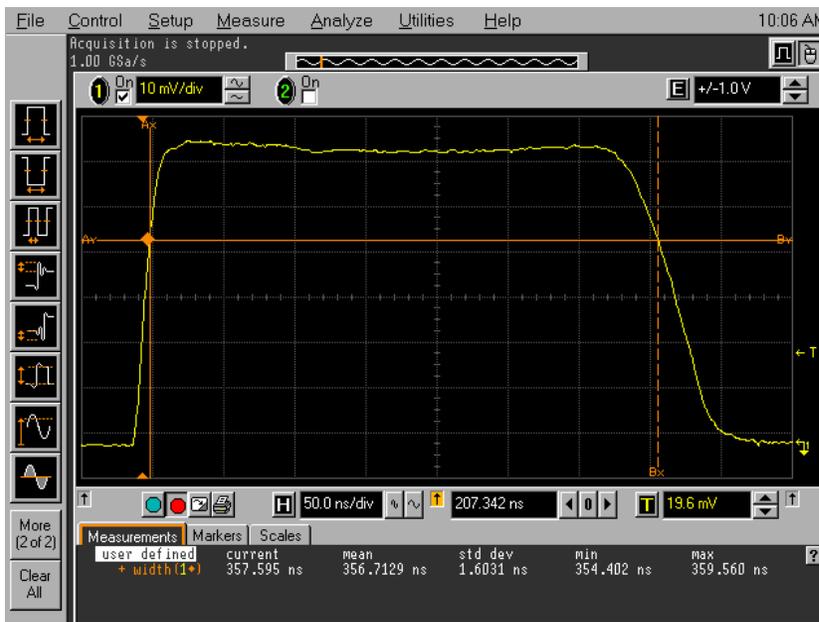
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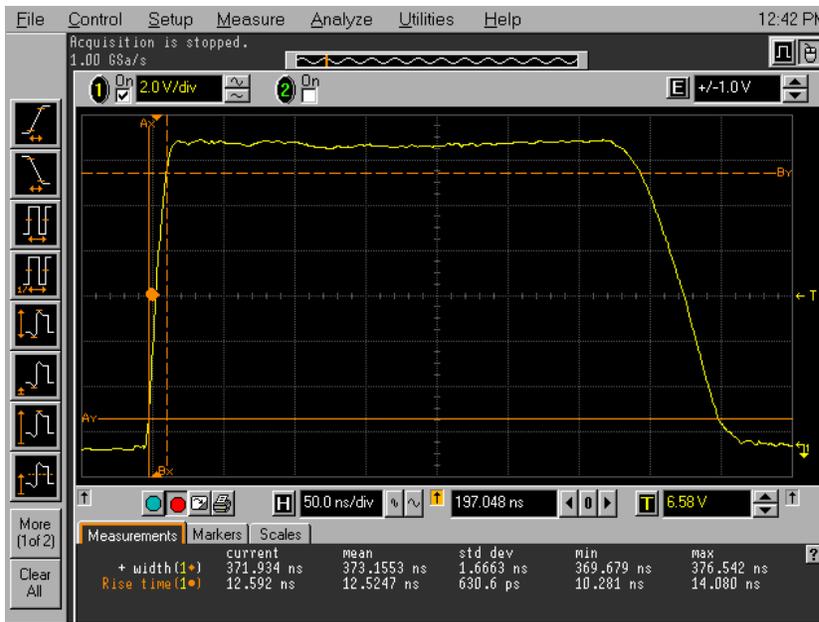
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Plot 5.6.4.7: 70% Amplitude Pulse Width, PL4 (4 nm Range)



Plot 5.6.4.8: Pulse Rise Time, PL4 (4 nm Range)



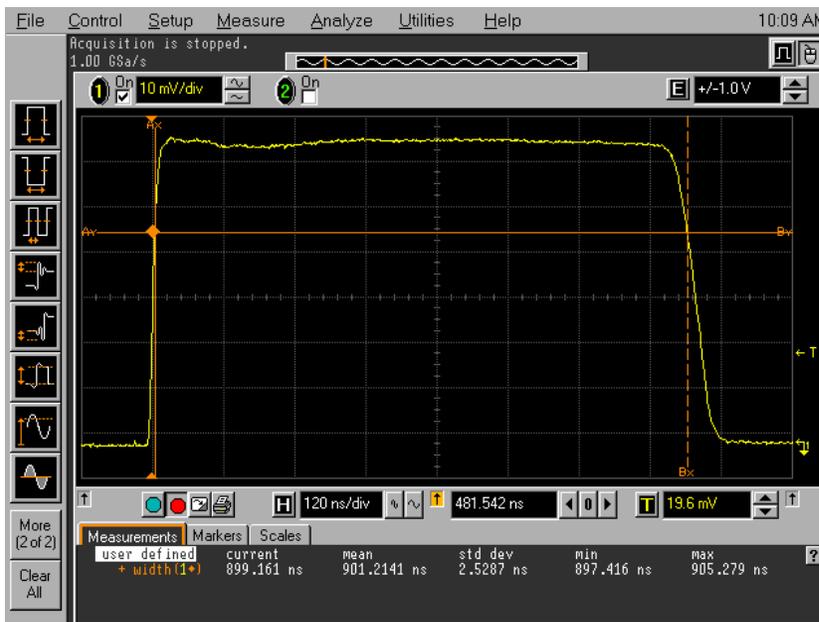
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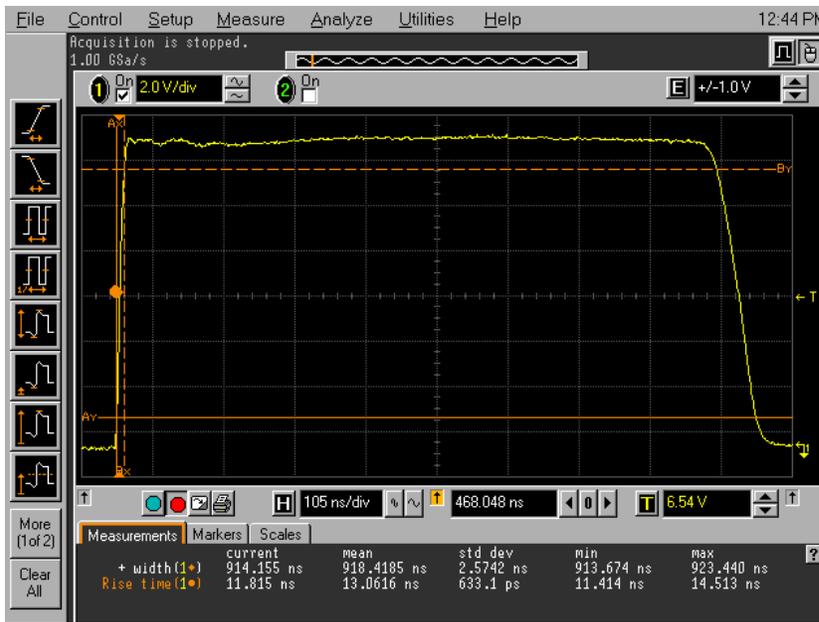
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Plot 5.6.4.9: 70% Amplitude Pulse Width, PL5 (8 nm Range)



Plot 5.6.4.10: Pulse Rise Time, PL5 (8 nm Range)



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5.7. EMISSION LIMITATIONS & OCCUPIED BANDWIDTH [§§ 2.1049, 80.211 (f) & 80.209 (b)]

5.7.1. Limits

See 47 CFR 2.1049, 80.211 & 80.209 (b)

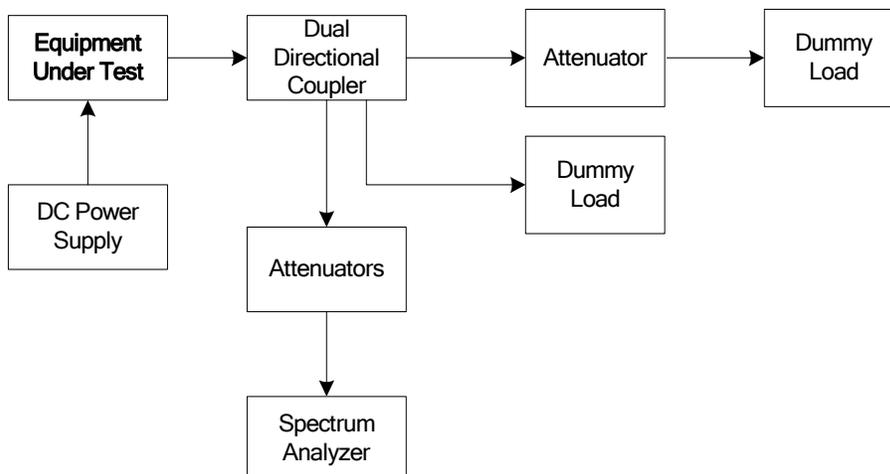
5.7.2. Method of Measurements

TIA/EIA 603, Edition B and Section 7.4 of this test report.

5.7.3. Test Equipment List

Test Instruments	Manufacturer	Model No.	Serial No.	Frequency Range
Dual Directional Coupler	Hewlett-Packard	11692D	1212A03620	2 - 18 GHz
Dummy Load	Generic	BEC 91-15A	--	DC-18GHz
Dummy Load	Generic	BEC 91-15A	--	DC-18GHz
Attenuator	Weinschel	23-20-34	BH7876	DC-18 GHz
Attenuator	Weinschel	48-30-34	BM5354	DC-18 GHz
Attenuator	Weinschel	46-20-34	BM1347	DC-18 GHz
DC Power Supply	Tenma	72-7295	--	DC 0-40 V, 0-5A.
Spectrum Analyzer	Advantest	R3271	15050203	100 Hz-26.5GHz

5.7.4. Test Arrangement

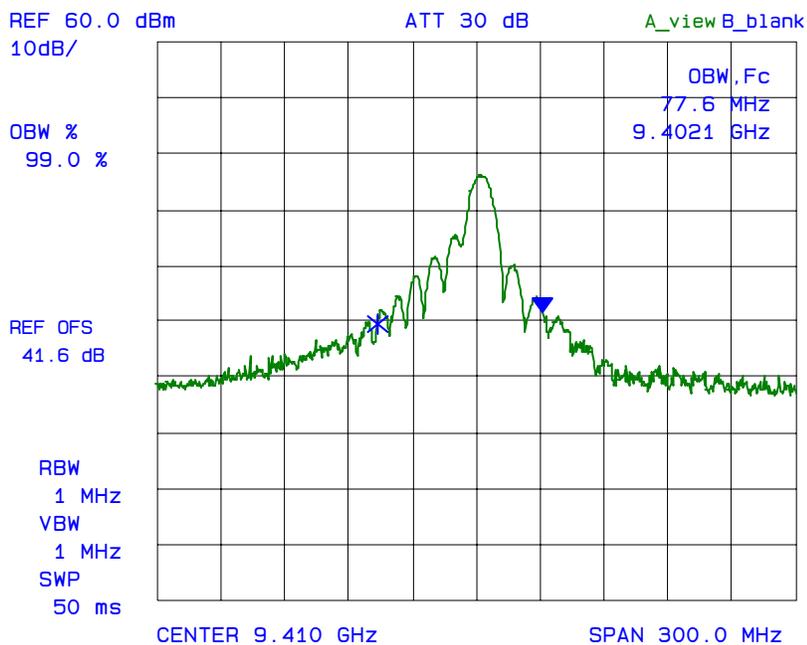


5.7.5. Test Data

Signal Frequency: 9410 MHz		
Pulse Length (nS)	Range (nm)	99% OBW (MHz)
(PL1) 78.3	0.5	77.6
(PL2) 78.2	1	76.3
(PL3) 252.2	2	43.3
(PL4) 356.7	4	36.4
(PL5) 901.2	8	12.4

See the following plots for 99% bandwidth measurements

Plot 5.7.5.1: 99% Occupied Bandwidth
PL1 (0.5 nm Range)
Test Frequency: 9410 MHz



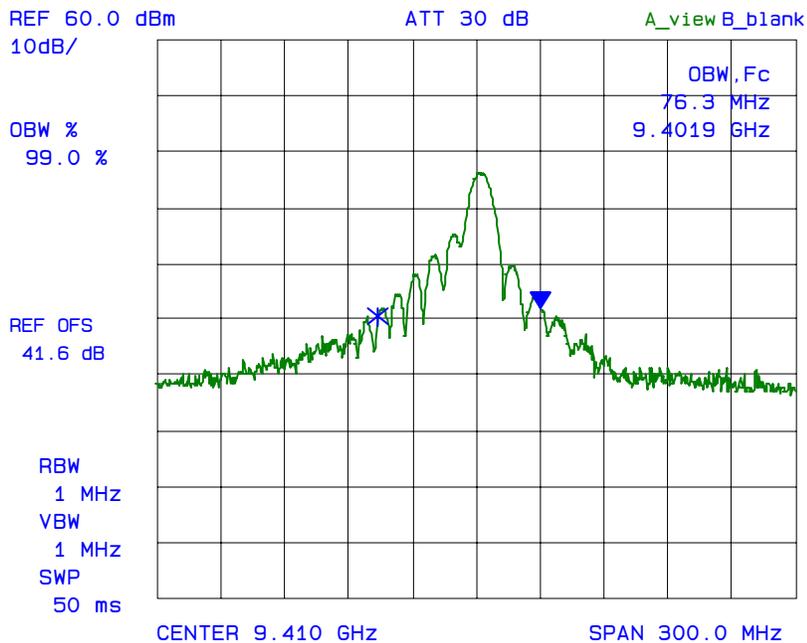
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Plot 5.7.5.2: 99% Occupied Bandwidth
PL2 (1 nm Range)
Test Frequency: 9410 MHz



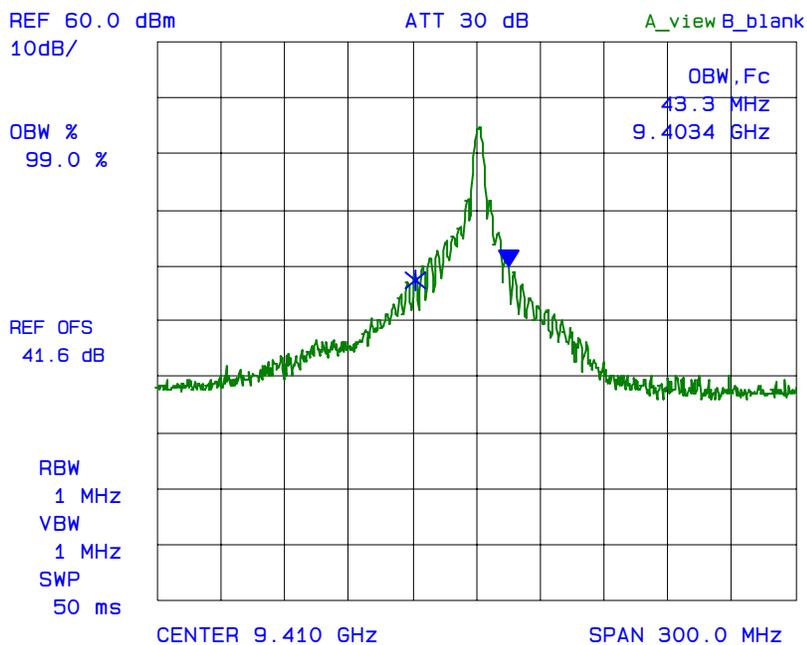
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Plot 5.7.5.3: 99% Occupied Bandwidth
PL3 (2 nm Range)
Test Frequency: 9410 MHz



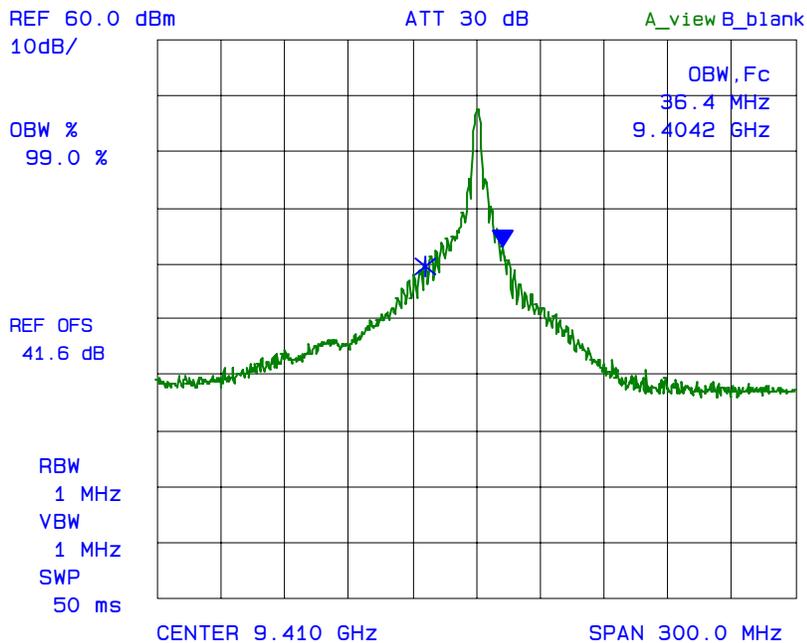
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Plot 5.7.5.4: 99% Occupied Bandwidth
PL4 (4 nm Range)
Test Frequency: 9410 MHz



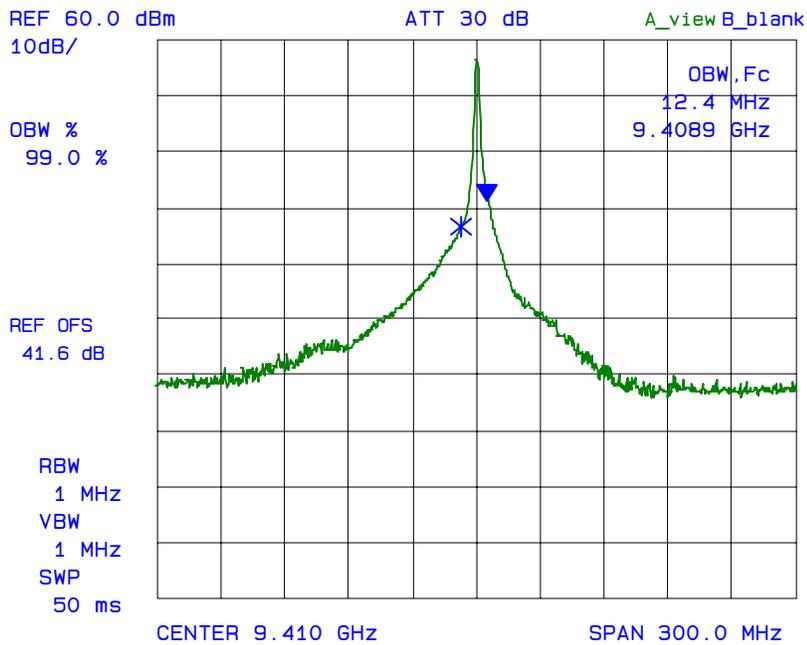
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Plot 5.7.5.5: 99% Occupied Bandwidth
PL5 (8 nm Range)
Test Frequency: 9410 MHz



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5.8. SPURIOUS EMISSIONS AT ANTENNA TERMINALS [§§ 2.1051, 2.1057 & 80.211(f)]

5.8.1. Limits

§ 80.211 (f): The emissions must be attenuated below the mean power to at least $43 + 10\log_{10}$ (mean power in watts) dB.

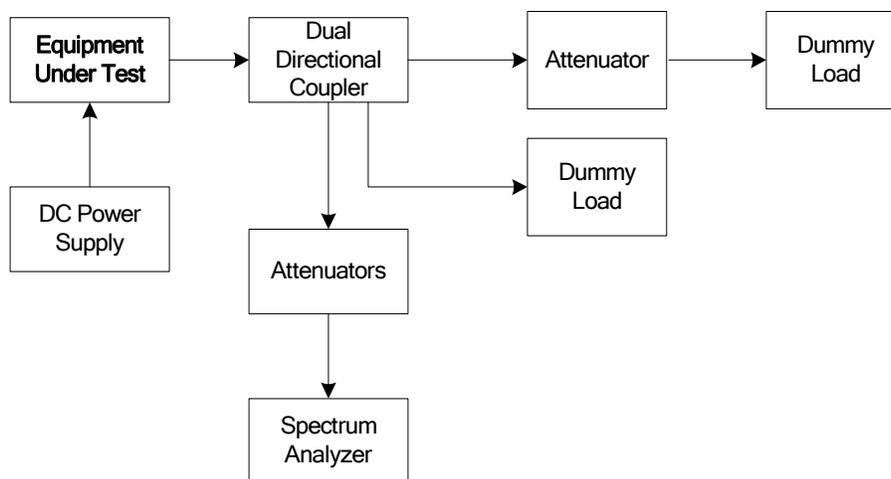
5.8.2. Method of Measurements

Refer to Section 7.5 of this report for measurement details.

5.8.3. Test Equipment List

Test Instruments	Manufacturer	Model No.	Serial No.	Frequency Range
Spectrum Analyzer/ EMI Receiver	Rohde & Schwarz	FSEK20/B4/B21	834157/005	9 kHz – 40 GHz with external mixer
Dual Directional Coupler	Hewlett-Packard	11692D	1212A03620	2 - 18 GHz
Dummy Load	Generic	BEC 91-15A	--	DC-18GHz
Dummy Load	Generic	BEC 91-15A	--	DC-18GHz
Attenuator	Weinschel	23-20-34	BH7876	DC-18 GHz
Attenuator	Weinschel	48-30-34	BM5354	DC-18 GHz
Attenuator	Weinschel	46-20-34	BM1347	DC-18 GHz
DC Power Supply	Tenma	72-7295	--	DC 0-40 V, 0-5A.

5.8.4. Test Arrangement



5.8.5. Test Data

Plot 9.5.5.1: Spurious Emissions at Antenna Terminals
PL1 (0.5 nm Range)
Test Frequency: 9410 MHz



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Plot 9.5.5.2: Spurious Emissions at Antenna Terminals
PL1 (0.5 nm Range)
Test Frequency: 9410 MHz

Marker 1 is the noise floor



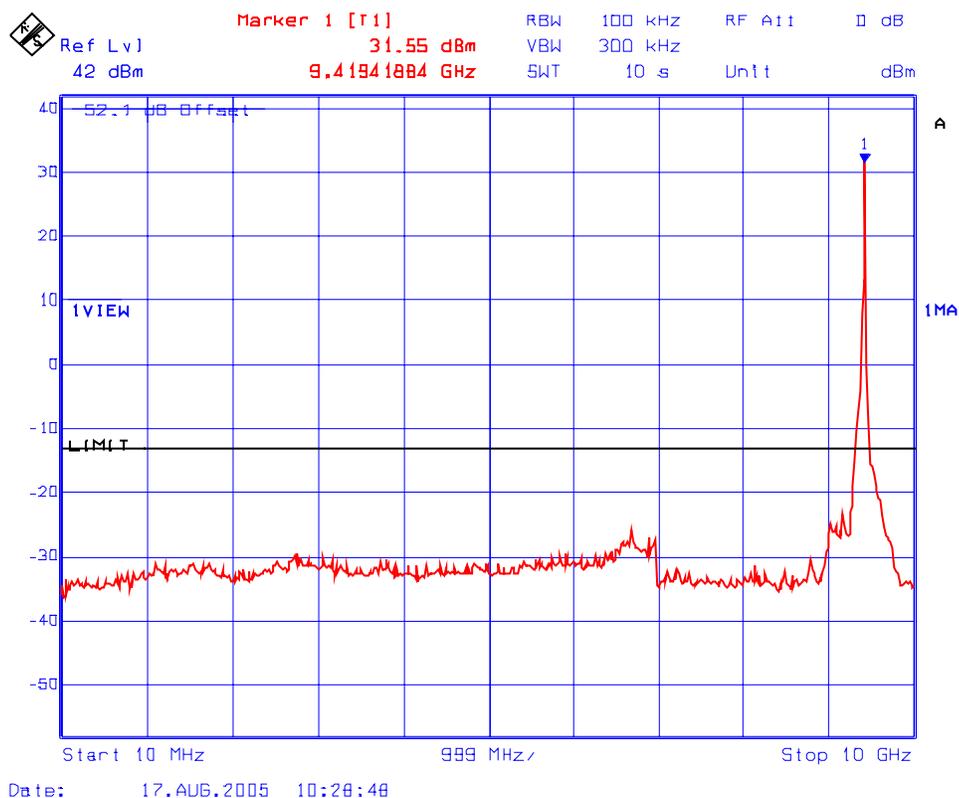
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Plot 9.5.5.3: Spurious Emissions at Antenna Terminals
PL2 (1 nm Range)
Test Frequency: 9410 MHz



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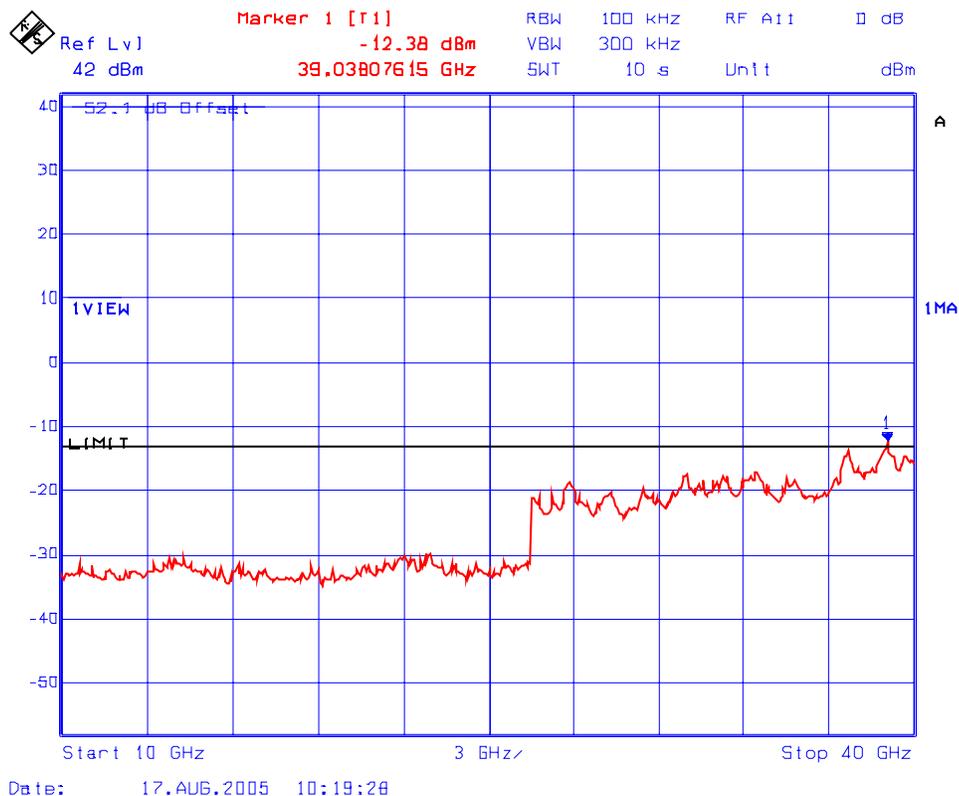
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Plot 9.5.5.4: Spurious Emissions at Antenna Terminals
PL2 (1 nm Range)
Test Frequency: 9410 MHz

Marker 1 is the noise floor



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Plot 9.5.5.5: Spurious Emissions at Antenna Terminals
PL3 (2 nm Range)
Test Frequency: 9410 MHz



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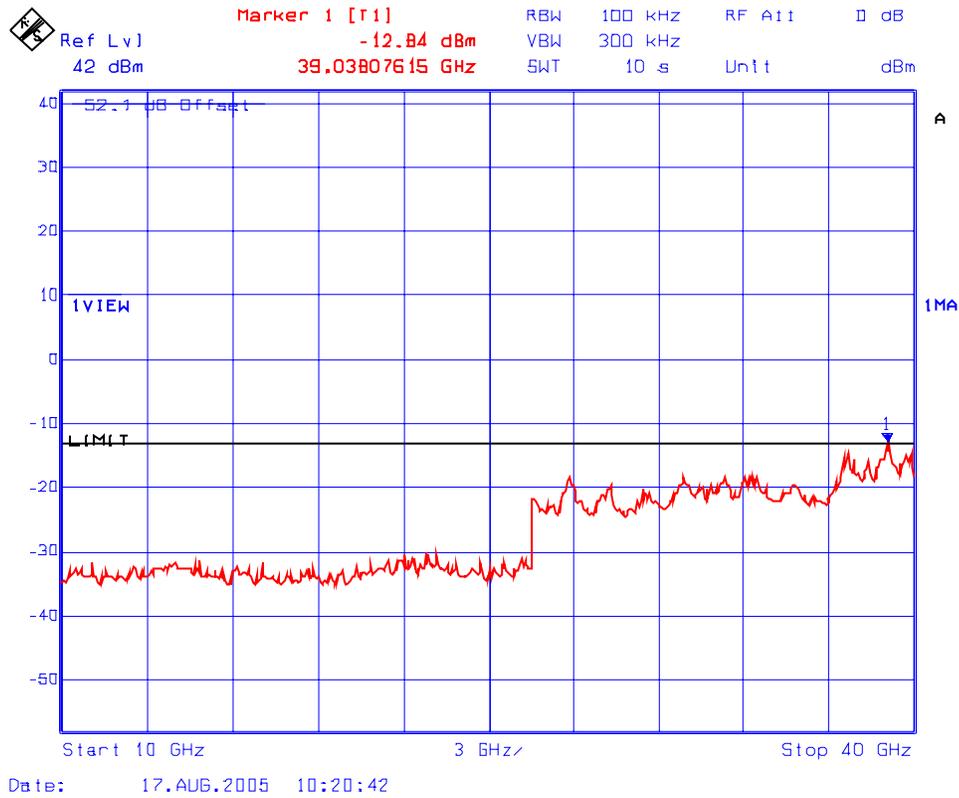
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Plot 9.5.5.6: Spurious Emissions at Antenna Terminals
PL3 (2 nm Range)
Test Frequency: 9410 MHz

Marker 1 is the noise floor



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Plot 9.5.5.7: Spurious Emissions at Antenna Terminals
PL4 (4 nm Range)
Test Frequency: 9410 MHz



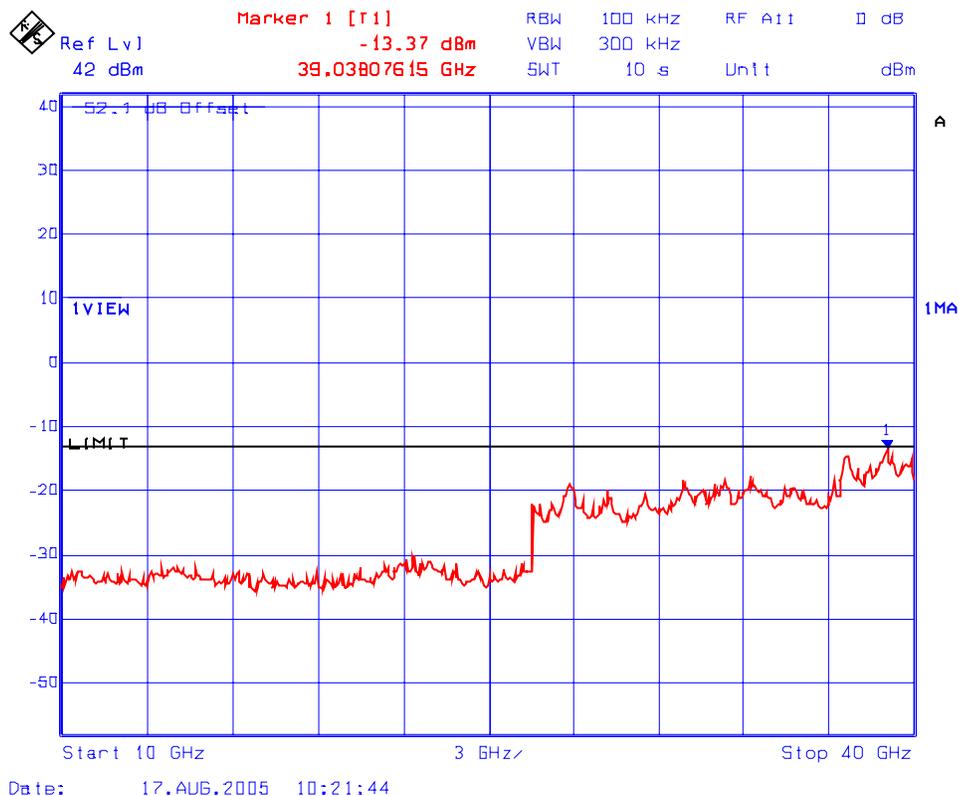
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Plot 9.5.5.8: Spurious Emissions at Antenna Terminals
PL4 (4 nm Range)
Test Frequency: 9410 MHz
Marker 1 is the noise floor



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Plot 9.5.5.9: Spurious Emissions at Antenna Terminals
PL5 (8 nm Range)
Test Frequency: 9410 MHz



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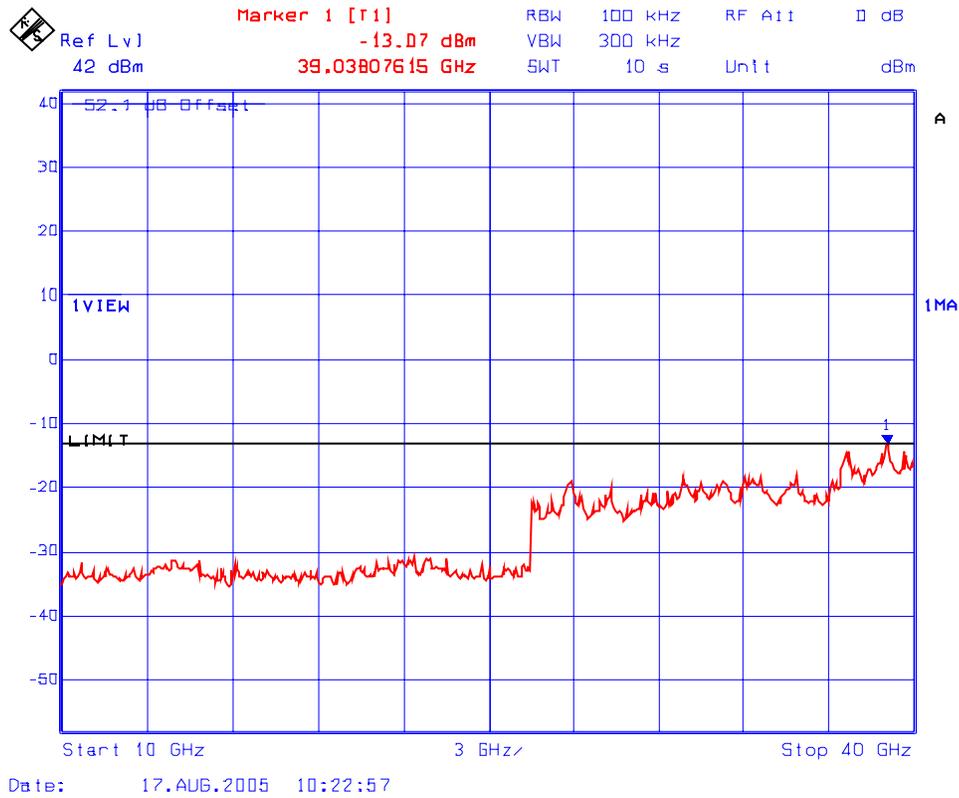
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Plot 9.5.5.10: Spurious Emissions at Antenna Terminals
PL5 (8 nm Range)
Test Frequency: 9410 MHz

Marker 1 is the noise floor



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File #: ICOM-114F80RADAR
August 24, 2005

All test results contained in this engineering test report are traceable to National Institute of Standards and Technology (NIST)

5.9. FIELD STRENGTH OF SPURIOUS RADIATION [§§ 2.1053, 2.1057 & 80.211(f)]

5.9.1. Limits

§ 80.211 (f): The emissions must be attenuated below the mean power to at least $43 + 10\log_{10}$ (mean power in watts) dB.

5.9.2. Method of Measurements

The spurious/harmonic ERP measurements are using substitution method specified in Exhibit 7, § 7.2 of this report and its value in dBc is calculated as follows:

- (1) If the transmitter's antenna is an integral part of the EUT, the ERP is measured using substitution method.
- (2) If the transmitter's antenna is non-integral and diverse, the lowest ERP of the carrier with 0 dBi antenna gain is used for calculation of the spurious/harmonic emissions in dBc:
Lowest ERP of the carrier = EIRP – 2.15 dB = $P_c + G - 2.15$ dB = xxx dBm (conducted) + 0 dBi – 2.15 dB
- (3) Spurious /harmonic emissions levels expressed in dBc (dB below carrier) are as follows:

ERP of spurious/harmonic (dBc) = ERP of carrier (dBm) – ERP of spurious/harmonic emission (dBm)

5.9.3. Test Equipment List

Test Instruments	Manufacturer	Model No.	Serial No.	Frequency Range
Spectrum Analyzer/ EMI Receiver	Rohde & Schwarz	FSEK20/B4/B21	834157/005	9 kHz – 40 GHz with external mixer
Active Loop Antenna	EMCO	6507	8906-1167	1 kHz – 30 MHz
Biconilog Antenna	EMCO	3143	1029	20 MHz to 2 GHz
Horn Antenna	EMCO	3155	9701-5061	1 GHz – 18 GHz
Horn Antenna with Mixer	EMCO	3160-09	1007	18 GHz – 26.5 GHz
Horn Antenna with Mixer	EMCO	3160-10	1001	26.5 GHz – 40 GHz

5.9.4. Test Setup

See radiated emissions test setup photos.

5.9.5. Test Data

The following data represents the worst case results:

Fundamental Frequency:	9410 MHz
RF Output Power:	33.53 dBm (2.25 W)
Test Frequency Range:	30 MHz – 40 GHz
Modulation:	PL4 (4nm Range)
Limit:	$43 + 10\log_{10}(\text{mean power in watts}) = 44 + 10\log_{10}(2.25) = 46.52 \text{ dBc}$

All emissions are greater than 20 dB below limit.

5.10. TRANSMITTER FREQUENCY TOLERANCE [§§ 2.1055 & 80.209 (b)]

5.10.1. Limits

§ 80.209(b) When pulse modulation is used in land and ship radar stations operating in the bands above 2.4 GHz the frequency at which maximum emission occurs must be within the authorized bandwidth and must not be closer than $1.5/T$ MHz to the upper and lower limits of the authorized bandwidth where “T” is the pulse duration in microseconds. In the band 14.00–14.05 GHz the center frequency must not vary more than 10 MHz from 14.025 GHz.

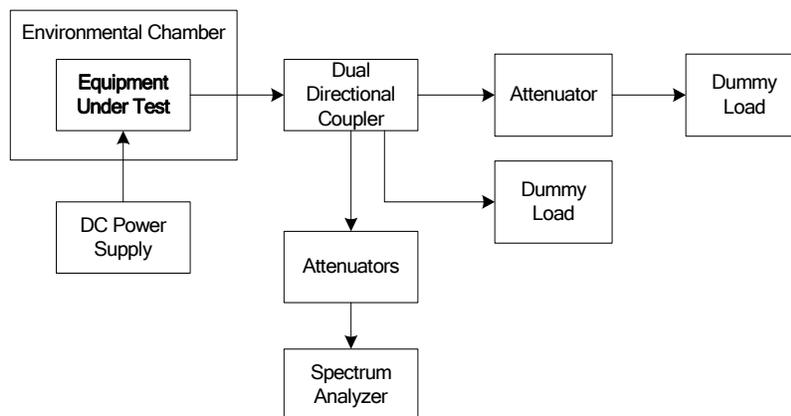
5.10.2. Method of Measurements

Refer to Section 7.3 of this report for measurement details

5.10.3. Test Equipment List

Test Instruments	Manufacturer	Model No.	Serial No.	Frequency Range
Dual Directional Coupler	Hewlett-Packard	11692D	1212A03620	2 - 18 GHz
Dummy Load	Generic	BEC 91-15A	--	DC-18GHz
Dummy Load	Generic	BEC 91-15A	--	DC-18GHz
Attenuator	Weinschel	23-20-34	BH7876	DC-18 GHz
Attenuator	Weinschel	48-30-34	BM5354	DC-18 GHz
Attenuator	Weinschel	46-20-34	BM1347	DC-18 GHz
DC Power Supply	Tenma	72-7295	--	DC 0-40 V, 0-5A.
Spectrum Analyzer	Advantest	R3271	15050203	100 Hz-26.5GHz
Temperature & Humidity Chamber	Tenney	T5	9723B	-40o to +60 o C range

5.10.4. Test Arrangement



5.10.5. Test Data

Product Name:	Marine Radar
Model No.:	MR-1000TII
Center Frequency:	9410 MHz
Full Power Level:	See Section 5.5 RF Power Output
Frequency Tolerance Limit:	30 MHz (Manufacturer specification)
Max. Frequency Tolerance Measured:	+15.4 MHz
Input Voltage Rating:	24 Vdc nominal

Variation of Ambient Temperature (°C)	Frequency Drift Due to Temperature (MHz) PL1 (0.5nm)
-30	+15.4
-20	+14.0
-10	+11.7
0	+8.6
+10	+8.0
+20	+9.4
+30	+4.6
+40	+3.1
+50	-0.6
+60	-4.3
+70	-1.1

Variation of Primary Supply Voltage at 20 °C (V)	Frequency Drift Due to Supply Voltage Variations (MHz) PL1 (0.5nm)
10.2	+11.1
24.0	+9.4
42.0	+10.0

5.11. RF EXPOSURE REQUIRMENTS [§§ 1.1310 & 2.1091]

The following criteria shall be used to evaluate the environmental impact of human exposure to RF radiation:

FCC 1.1310:- The criteria listed in the following table shall be used to evaluate the environmental impact of human exposure to radio-frequency (RF) radiation as specified in 1.1307(b).

TABLE 1—LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)

Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (mW/cm ²)	Averaging time (minutes)
(A) Limits for Occupational/Controlled Exposures				
0.3–3.0	614	1.63	*(100)	6
3.0–30	1842/f	4.89/f	*(900/f ²)	6
30–300	61.4	0.163	1.0	6
300–1500 .....	.....	.....	f/300	6
1500–100,000 .....	.....	.....	5	6
(B) Limits for General Population/Uncontrolled Exposure				
0.3–1.34	614	1.63	*(100)	30
1.34–30	824/f	2.19/f	*(180/f ²)	30
30–300	27.5	0.073	0.2	30
300–1500 .....	.....	.....	f/1500	30
1500–100,000 .....	.....	.....	1.0	30

f = frequency in MHz

* = Plane-wave equivalent power density

NOTE 1 TO TABLE 1: Occupational/controlled limits apply in situations in which persons are exposed as a consequence of their employment provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. Limits for occupational/controlled exposure also apply in situations when an individual is transient through a location where occupational/controlled limits apply provided he or she is made aware of the potential for exposure.

NOTE 2 TO TABLE 1: General population/uncontrolled exposures apply in situations in which the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or can not exercise control over their exposure.

Calculation Method of RF Safety Distance:

$$S = PG/4\pi r^2 = EIRP/4\pi r^2 \implies r = \sqrt{PG/4\pi S} = \sqrt{EIRP/4\pi S}$$

- Where:
- P: power input to the antenna in mW
 - EIRP: Equivalent (effective) isotropic radiated power.
 - S: power density mW/cm²
 - G: numeric gain of antenna relative to isotropic radiator
 - r: distance to center of radiation in cm

MPE Evaluation

EVALUATION OF RF EXPOSURE COMPLIANCE REQUIREMENTS	
RF Exposure Requirements	Compliance with FCC Rules
Minimum calculated separation distance between antenna and persons required: 3.46 m	Manufacturer' instruction for separation distance between antenna and persons required: 3.5 m.
Antenna installation and device operating instructions for installers (professional/unskilled users), and the parties responsible for ensuring compliance with the RF exposure requirement	See user manual.
Caution statements and/or warning labels that are necessary in order to comply with the exposure limits	See user manual.
Any other RF exposure related issues that may affect MPE compliance	None.

Limits for General Population/Uncontrolled Exposure:

Antenna Gain = 27 dBi = $10^{(27/10)}$ numeric
 Pp = 4 kW = 4000000 mW = 66.02 dBm (rated peak power)
 Duty Cycle = 0.075 % (Maximum measured duty cycle)
 Pa = Pp + 10*log(Duty Cycle) = 66.02 dBm + 10*log(0.075/100) dBm = 34.77 dBm = 3000 mW (average power)
 S = 1 mW/cm² (Limit for General Population/Uncontrolled Exposure)

$$r = \sqrt{PaG/4\pi S} = \sqrt{(3000 \text{ mW})(10^{(27/10)}) / 4\pi(1)} = 345.90 \text{ cm} = 3.46 \text{ m}$$

EXHIBIT 6. MEASUREMENT UNCERTAINTY

The measurement uncertainties stated were calculated in accordance with the requirements of NIST Technical Note 1297 and LAB 34

6.1. RADIATED EMISSION MEASUREMENT UNCERTAINTY

CONTRIBUTION (Radiated Emissions)	PROBABILITY DISTRIBUTION	UNCERTAINTY (\pm dB)	
		3 m	10 m
Antenna Factor Calibration	Normal (k=2)	± 1.0	± 1.0
Cable Loss Calibration	Normal (k=2)	± 0.3	± 0.5
EMI Receiver specification	Rectangular	± 1.5	± 1.5
Antenna Directivity	Rectangular	+0.5	+0.5
Antenna factor variation with height	Rectangular	± 2.0	± 0.5
Antenna phase center variation	Rectangular	0.0	± 0.2
Antenna factor frequency interpolation	Rectangular	± 0.25	± 0.25
Measurement distance variation	Rectangular	± 0.6	± 0.4
Site imperfections	Rectangular	± 2.0	± 2.0
Mismatch: Receiver VRC $\Gamma_1 = 0.2$ Antenna VRC $\Gamma_R = 0.67$ (Bi) 0.3 (Lp) Uncertainty limits $20\text{Log}(1 \pm \Gamma_1 \Gamma_R)$	U-Shaped	+1.1 -1.25	± 0.5
System repeatability	Std. Deviation	± 0.5	± 0.5
Repeatability of EUT		-	-
Combined standard uncertainty	Normal	+2.19 / -2.21	+1.74 / -1.72
Expanded uncertainty U	Normal (k=2)	+4.38 / -4.42	+3.48 / -3.44

Calculation for maximum uncertainty when 3m biconical antenna including a factor of k = 2 is used:

$$U = 2u_c(y) = 2x(+2.19) = +4.38 \text{ dB} \quad \text{And} \quad U = 2u_c(y) = 2x(-2.21) = -4.42 \text{ dB}$$

EXHIBIT 7. MEASUREMENT METHODS

7.1. CONDUCTED POWER MEASUREMENTS

- The following shall be applied to the combination(s) of the radio device and its intended antenna(e).
- If the RF level is user adjustable, all measurements shall be made with the lowest and highest power level available to the user for that combination.
- The measurement shall be performed using normal operation of the equipment with modulation.

Peak Power Measurements using a Diode Detector:

- Connect the transmitter output to a diode detector through an attenuator
- Connect the diode detector to the vertical channel of an oscilloscope.
- Observe and record the (y) parameter of the DC level on the oscilloscope.
- Replace the transmitter by a RF signal generator
- Set the signal generator frequency be the same as the transmitter frequency
- Adjust the rf output level of the RF signal generator until the DC level on the oscilloscope is same as that (y) recorded in the above step.
- Measure the RF signal generator output level using a power meter
- Calculate the total peak power (Pp) by adding the signal generator level with the attenuator value and the cable loss.

Duty Cycle Measurements:

Duty Cycle measurements if the transmitter's transmission is transient

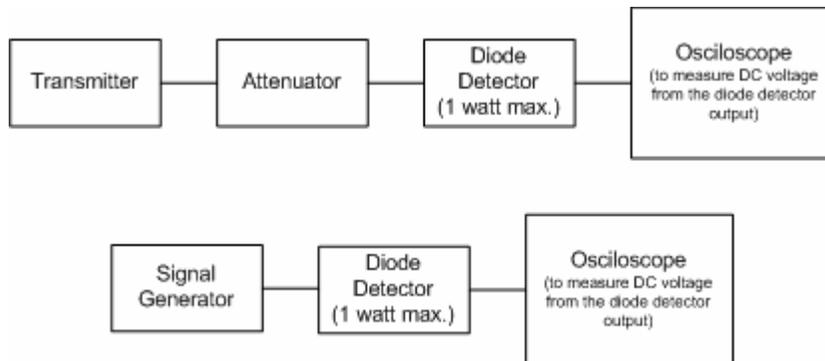
- Using a EMI Receiver with the frequency span set to 0 Hz and the sweep time set at a suitable value to capture the envelope peaks and the duty cycle of the transmitter output signal;
- The duty cycle of the transmitter, $x = \text{Tx on} / (\text{Tx on} + \text{Tx off})$ with $0 < x < 1$, is measure and recorded in the test report. For the purpose of testing, the equipment shall be operated with a duty cycle that is equal or more than 0.1.

Calculation of Average EIRP:

- The e.i.r.p. shall be calculated from the above measured power output "Pp", the observed duty cycle x, and the applicable antenna assembly gain "G" in dBi, according to the formula:

$$\text{EIRP} = P_p + G + 10\log(x)$$

Figure 1.



7.2. RADIATED POWER MEASUREMENTS (ERP & EIRP) USING SUBSTITUTION METHOD

7.2.1. Maximizing RF Emission Level (E-Field)

- (a) The measurements was performed with full rf output power and modulation.
- (b) Test was performed at listed 3m open area test site (listed with FCC, IC, ITI, NVLAP, ACA & VCCI).
- (c) The transmitter under test was placed at the specified height on a non-conducting turntable (80 cm height)
- (d) The BICONILOG antenna (20 MHz to 1 GHz) or HORN antenna (1 GHz to 18 GHz) was used for measuring.
- (e) Load an appropriate correction factors file in EMI Receiver for correcting the field strength reading level

Total Correction Factor recorded in the EMI Receiver = Cable Loss + Antenna Factor
(dBuV/m) = Reading (dBuV) + Total Correction Factor (dB/m)

- (f) Set the EMI Receiver #1 and #2 as follows:

Center Frequency:	test frequency
Resolution BW:	1 MHz
Video BW:	same
Detector Mode:	positive
Average:	off
Span:	3 x the signal bandwidth

- (g) The test antenna was lowered or raised from 1 to 4 meters until the maximum signal level was detected.
- (h) The transmitter was rotated through 360° about a vertical axis until a higher maximum signal was received.
- (i) The test antenna was lowered or raised again from 1 to 4 meters until a maximum was obtained. This level was recorded.
- (j) The recorded reading was corrected to the true field strength level by adding the antenna factor, cable loss and subtracting the pre-amplifier gain.
- (k) The above steps were repeated with both transmitters' antenna and test receiving antenna placed in vertical and horizontal polarization. Both readings with the antennas placed in vertical and horizontal polarization shall be recorded.
- (l) Repeat for all different test signal frequencies

7.2.2. Measuring the EIRP of Spurious/Harmonic Emissions using Substitution Method

(a) Set the EMI Receiver (for measuring E-Field) and Receiver #2 (for measuring EIRP) as follows:

Center Frequency:	equal to the signal source
Resolution BW:	1 MHz
Video BW:	same
Detector Mode:	positive
Average:	off
Span:	3 x the signal bandwidth

(b) Load an appropriate correction factors file in EMI Receiver for correcting the field strength reading level

Total Correction Factor recorded in the EMI Receiver = Cable Loss + Antenna Factor
 $E \text{ (dBuV/m)} = \text{Reading (dBuV)} + \text{Total Correction Factor (dB/m)}$

(c) Select the frequency and E-field levels obtained in the Section 8.2.1 for ERP/EIRP measurements.

(d) Substitute the EUT by a signal generator and one of the following transmitting antenna (substitution antenna):

- ◆ DIPOLE antenna for frequency from 30-1000 MHz or
- ◆ HORN antenna for frequency above 1 GHz }

(e) Mount the transmitting antenna at 1.5 meter high from the ground plane.

(f) Use one of the following antenna as a receiving antenna:

- ◆ DIPOLE antenna for frequency from 30-1000 MHz or
- ◆ HORN antenna for frequency above 1 GHz }

(g) If the DIPOLE antenna is used, tune it's elements to the frequency as specified in the calibration manual.

(h) Adjust both transmitting and receiving antenna in a VERTICAL polarization.

(i) Tune the EMI Receivers to the test frequency.

(j) Lower or raise the test antenna from 1 to 4 meters until the maximum signal level was detected.

(k) The transmitter was rotated through 360° about a vertical axis until a higher maximum signal was received.

(l) Lower or raise the test antenna from 1 to 4 meters until the maximum signal level was detected.

(m) Adjust input signal to the substitution antenna until an equal or a known related level to that detected from the transmitter was obtained in the test receiver.

(n) Record the power level read from the Average Power Meter and calculate the ERP/EIRP as follows:

$$P = P1 - L1 = (P2 + L2) - L1 = P3 + A + L2 - L1$$

$$\text{EIRP} = P + G1 = P3 + L2 - L1 + A + G1$$

$$\text{ERP} = \text{EIRP} - 2.15 \text{ dB}$$

$$\text{Total Correction factor in EMI Receiver \# 2} = L2 - L1 + G1$$

Where: P: Actual RF Power fed into the substitution antenna port after corrected.

P1: Power output from the signal generator

P2: Power measured at attenuator A input

P3: Power reading on the Average Power Meter

EIRP: EIRP after correction

ERP: ERP after correction

(o) Adjust both transmitting and receiving antenna in a HORIZONTAL polarization, then repeat step (k) to (o)

(p) Repeat step (d) to (o) for different test frequency

(q) Repeat steps (c) to (j) with the substitution antenna oriented in horizontal polarization.

(r) Actual gain of the EUT's antenna is the difference of the measured EIRP and measured RF power at the RF port. Correct the antenna gain if necessary.

Figure 2

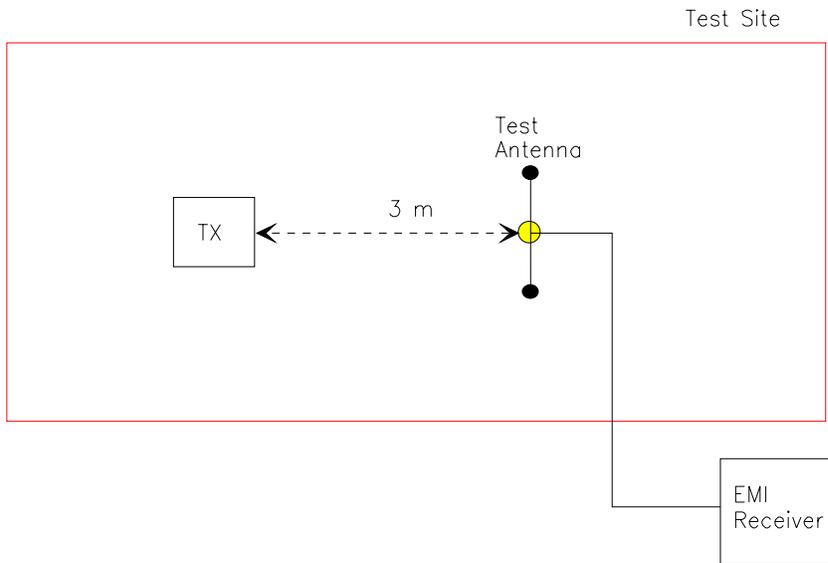
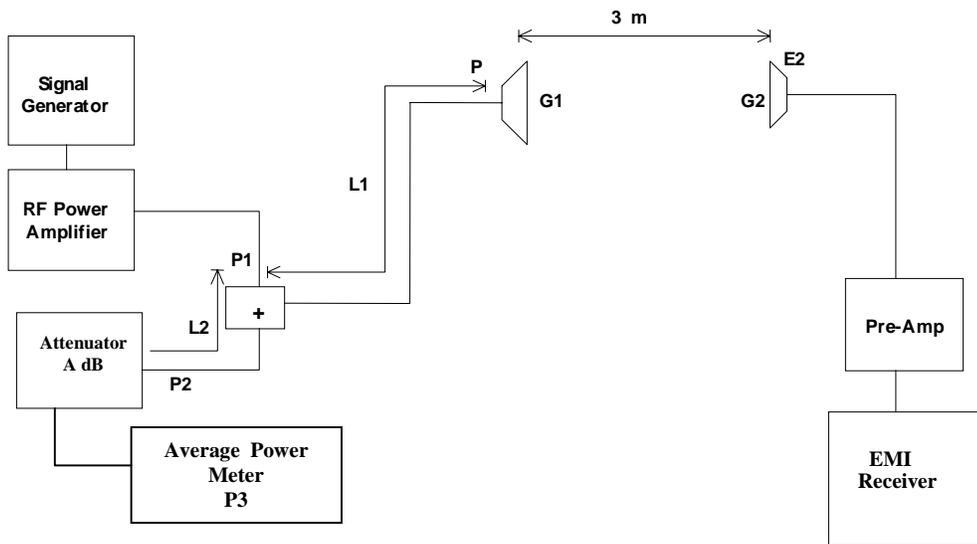


Figure 3



7.3. TRANSMITTER FREQUENCY TOLERANCE

Refer to FCC @ 2.1055.

- (a) The Transmitter Frequency Tolerance shall be measured with variation of ambient temperature as follows:
From -30 to +50 centigrade except that specified in subparagraph (2) & (3) of this paragraph.
- (b) Frequency measurements shall be made at extremes of the specified temperature range and at intervals of not more than 10 centigrade through the range. A period of time sufficient to stabilize all of the components of the oscillator circuit at each temperature level shall be allowed prior to frequency measurement. The short-term transient effects on the frequency of the transmitter due to keying (except for broadcast transmitters) and any heating element cycling normally occurring at each ambient temperature level also shall be shown. Only the portion or portions of the transmitter containing the frequency determining and stability circuitry need be subjected to the temperature variation test.
- (d) The Transmitter Frequency Tolerance supply shall be measured with variation of primary supply voltage as follows:
 - (1) Vary primary supply voltage from 85 to 115 percent of the nominal value for other than hand carried battery equipment.
 - (2) For hand carried, battery powered equipment, reduce primary supply voltage to the battery operating end point which shall be specified by the manufacturer.
 - (3) The supply voltage shall be measured at the input to the cable normally provide with the equipment, or at the power supply terminals if cables are not normally provided. Effects on frequency of transmitter keying (except for broadcast transmitters) and any heating element cycling at the nominal supply voltage and at each extreme also shall be shown.
- (e) When deemed necessary, the Commission may require tests of Transmitter Frequency Tolerance under conditions in addition to those specifically set out in paragraphs (a), (b), (c) and (d) of this section. (For example, measurements showing the effect of proximity to large metal objects, or of various types of antennas, may be required for portable equipment).

7.4. EMISSION LIMITATIONS

The following EMI Receiver bandwidth shall be used for measurement of Emission Limitations Measurements:

- (1) 1% of the authorized occupied bandwidth.
- (2) The all cases the Video Bandwidth shall be equal or greater than the measuring bandwidth.

7.5. SPURIOUS EMISSIONS (CONDUCTED)

With transmitter modulation characteristics described in Out-of-Band Emissions measurements @ 2.1049, the transmitter spurious and harmonic emissions were scanned. The spurious and harmonic emissions were measured with the EMI Receiver controls set as RBW = 1 % of Authorized Bandwidth minimum, VBW ≥ RBW and SWEEP TIME = AUTO).