Intertek ETL SEMKO

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September 29, 2004

Mr. Rich Leiterman
ThingMagic, LLC
One Broadway
Cambridge, MA 02142

Mr. Leiterman;

Enclosed you will find our Emissions report covering testing on the RFID Reader, Model: Mercury 4. Testing was performed on September 15th -17th and 22nd, 2004.

If there are any questions regarding this report, please contact the undersigned or your account representative.

Sincerely,

Nicholas Abbondante
Engineer

Jeff Goulet
Engineering Team Leader, EMC

Enclosure

Intertek Testing Services NA, Inc.
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ITS Intertek Testing Services
ETL SEMKO

Test Report
for
ThingMagic, LLC
on the
RFID Reader
Model: Mercury 4

to

FCC Part 15.247 Subpart C

Test Report #: 3065327.EMI
Date of Report: September 28, 2004

Project #s: 3065327
Dates of Test: September 15-17, 22, 2004

Total No of Pages Contained in this Report: 29

	Nicholas Abbondante, Test Engineer
	Michael F. Murphy, Staff Engineer, EMC

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ThingMagic, LLC
FCC ID: QV5MERCURY4

RFID Reader Model: Mercury 4 Serial #: Eng01 (Intertek Assigned)

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2.0 General Description

2.1 Product Description

The Mercury 4 is a modulated frequency hopping RFID reader. It contains two radios with two transmit and receive ports on each radio to allow multiple antennas to be connected to enhance the coverage area of the RFID reader. Only one antenna can be utilized at any given moment.

Two prototype versions of the EUT were received on September 15, 2004 in good operating condition. As declared by the Applicant, they are identical to production units. Both versions use the same chassis and boards, however one has a slightly larger metal baseplate for mounting purposes. A full test was performed on reader #1, and the worst case antenna and transmit port configuration was evaluated to show compliance of reader #2 to the radiated emissions limits in restricted bands with the larger baseplate. Conducted measurements were performed at the output of the EUT's transmit cables which will be supplied with the EUT.

Overview of the EUT

Description	RFID Reader
Model No. , Part No.	Mercury 4, S/N: Eng01 (Intertek Assigned, reader #1), Eng02 (reader #2)
Operating Frequency	902 - 908 MHz (Channels 0 – 49)
Number of Channels	50 Channels
Antennas	Alien Dual Antenna (RH/LH Circular) M/N:ALR9611-CR+CL 6 dBi gain Alien Dual Antenna (Circular/Linear) M/N:ALR9611-C+L 6 dBi gain Sensormatic Omnipoint Antenna M/N:IDANT10LNA25 5.75 dBi gain Matrics General Purpose Antenna M/N:ANT-GPHP 5.75 dBi gain ThingMagic Dual Antenna M/N:TM-ANT-2 6 dBi gain M/A-Com Dual-Polarization Antenna M/N:MAANAT0116 6 dBi gain

The ThingMagic RFID Reader, Model: Mercury 4, has been tested at the request of:

Company: ThingMagic, LLC
One Broadway
Cambridge, MA, 02142

Name of contact: Mr. Rich Leiterman
Telephone: 617-758-4135
Fax: 617-225-4410
Email: rich@thingmagic.com

2.2 Related Submittal(s) Grants

None.

2.3 Test Facility

Site 2C (Middle Site) is a 3m and 10m sheltered EMI measurement range located in a light commercial environment in Boxborough, Massachusetts. It meets the technical requirements of ANSI C63.4-1992 and CISPR 22:1993/EN 55022:1994 for radiated and conducted emission measurements. The shelter structure is entirely fiberglass and plastic, with outside dimensions of 33 ft x 57 ft. The structure resembles a quonset hut with a center ceiling height of 16.5 ft.

The testing floor is covered by a galvanized sheet metal groundplane that is earth-grounded via copper rods around the perimeter of the site. The joints between individual metal sheets are bridged with 2 inch wide metal strips to provide low RF impedance contact throughout. The sheets of metal are screwed in place with stainless steel, round-head screws every three inches. Site illumination and HVAC are provided from beneath the ground reference plane through flush entry ports, the port covers are electrically bonded to the ground plane.

A flush metal turntable with 12 ft. diameter and 5000 lb. load capacity is provided for floor-standing equipment. A wooden table 80 cm high is used for table-top equipment. The turntable is electrically connected to the ground plane with three copper straps. The straps are connected to the turntable at the center of it with ground braid. A copper strap is directly connected to the groundplane at the edges of the turntable. The turntable is located on the south end of the structure and the antennas are mounted 3 and 10 meters away to the north. The antenna mast is a non-conductive with remote control of antenna height and polarization. The antenna height is adjustable from 1 to 4 meters.

All final radiated emission measurements are performed with the testing personnel and measurement equipment located below the ground reference plane. The site has a full basement underneath the turntable where support equipment may be remotely located. Operation of the antenna, turntable and equipment under test is controlled by remote controls that manipulate the antenna height and polarization with a turntable control. Test personnel are located below the ellipse when measurements are performed, however the site maintains the ability of having personnel manipulate cables while monitoring test equipment. Ambient radiated emissions are 6 dB or more below the relevant FCC emission limits.

AC mains power is brought to the equipment under test through a power line filter, to remove ambient conducted noise. 50 Hz (240 VAC single phase), 60 Hz power (120 VAC single phase, 208 VAC three phase), and 60 Hz (480 VAC three phase) are available. Conducted emission measurements are performed with a Line Impedance Stabilization Network (LISN) or Artificial Mains Network (AMN) bonded to the ground reference plane. A removable vertical groundplane (2 meter X 2 meter area) is used for line-conducted measurements for table top equipment. The vertical groundplane is electrically connected to the reference groundplane.

2.4 Test Equipment and Support Equipment

Test Equipment

Description	Manufacturer	Model Number	ITS ID	Serial Number	Cal Due Date
Spectrum Analyzer	Hewlett Packard	8591E	SA0003	3346A02319	07/23/2005
Attenuator	Mini Circuits	20 dB, 50 Ohm	DS24	DS24	01/15/2005
High Frequency Cable	Megaphase	TM40 K1K1 80	CBL030	CBL030	11/11/2004
High Frequency Cable	Megaphase	TM40 K1K1 197	CBL028	CBL028	11/11/2004
Universal Power Meter	Gigatronics	8651A	GIG1	8651298	10/24/2004
Peak Power Sensor	Gigatronics	80354A	GIG2	1821196	10/24/2004
Preamplifier 1-40 GHz	Miteq	NSP4000-NF	PRE8	507145	10/22/2004
Variac	Powerstat	3PN236B	POW2	POW2	VBU*
LISN, 50 uH, 0.01-50 MHz, 24A	Solar Electronics	9252-50-R-24-BNC	LISN11	941713	06/06/2005
Attenuator	Weinschel Corporation	47-10-34	WEI8	BD8309	02/15/2004
Horn Antenna	EMCO	3115	HORN1	9512-4632	10/24/2004
Antenna	EMCO	3142	LOG4	9711-1225	02/18/2004
Spectrum Analyzer	Rohde & Schwarz	FSEK-30	ROS001	100225	05/26/2004
EMI Receiver Set	Hewlett Packard	8542E	REC2	3520A00125	12/18/2004
RF Filter	Hewlett Packard	85420E	RECFL2	3427A00126	12/18/2004
Synthesized Sweep Generator	Hewlett Packard	83620A	HEW62	3213A01244	10/20/2004
Digital Multimeter	BK Precision	391	SAF014	23100085	10/03/2004
Cable, BNC-BNC 10m	Alpha	RG-58C/U	CBL10MS3	CBL10MS3	01/15/2005
Digital 4 Line Barometer	Mannix	0ABA116	BAR2	BAR2	07/02/2005

VBU – Verified before use using calibrated test equipment

Support Equipment			
Description	**Manufacturer**	**Model Number**	**Serial Number**
The EUT does not require support equipment to function once activated.			

* - AC Power Voltage was verified using a digital multimeter, listed in the test equipment section.

Cables					
Quantity	**Type**	**Length (m)**	**Shielding**	**Ferrite**	**Connector Type**
2	Antenna Cables	6	Foil/Braid	None	Metal/360
1	Ethernet Cable	6	None	None	Plastic
1	Serial Cable	2	Foil	None	Metal/360
1	AC Mains	3	None	None	Metal/360

3.0 RF Output Power and Exposure, and 20 dB Bandwidth

15.247(a)(2), (b)(3)

3.1 Test Procedure

The EUT was connected to a peak RF power meter through a cable with suitable attenuation not to overload the meter. An offset in the meter compensated for the cable and attenuation loss. Channels were selected for testing at the low, middle, and high end of the transmit band. To measure the 20 dB bandwidth of the fundamental the EUT was then connected to a spectrum analyzer with resolution bandwidth of approximately 1% of the signal bandwidth and a marker delta function was used to find the points 20 dB down from the measured RF output power level. RF Output power was measured at varying input voltages and at the maximum and minimum settings to be used at installation. Measurements of RF output power were made at the end of the transmit cables of the EUT. Two different lengths of cable can be installed with the EUT, therefore the RF output power was measured at both output power levels.

Requirement: The RF Power Output must be below 1 W (30 dBm) and the 20 dB bandwidth must be less than 500 kHz. RF exposure must not exceed 1 mW/cm^2 at any distance greater than 20 cm from the EUT.

3.2 Test Results

Results: Passed

Performed 9/15/2004 Equipment: GIG1, GIG2, WEI8, ROS001, POW2, SAF014

Frequency GHz	Name	Max Power Reading dBm			Min Power Reading dBm			EIRP Limit dBm	Max Antenna Gain dBi	Antenna Gain Limit dBi
		120V	102V	138V	120V	102V	138V			
902.726 (CH0)	Slot 0	29.29	29.26	29.29	26.90	26.89	26.96	30.0	6.00	6.00
902.726 (CH0)	Slot 1	28.56	28.56	28.56	26.53	26.53	26.53	30.0	6.00	6.00
914.773 (CH24)	Slot 0	28.64	28.64	28.64	26.69	26.73	26.69	30.0	6.00	6.00
914.773 (CH24)	Slot 1	28.54	28.54	28.54	26.52	26.52	26.51	30.0	6.00	6.00
927.322 (CH49)	Slot 0	28.96	28.95	28.94	26.82	26.81	26.82	30.0	6.00	6.00
927.322 (CH49)	Slot 1	28.60	28.60	28.60	26.52	26.54	26.57	30.0	6.00	6.00

Frequency GHz	Name	20 dB Bandwidth kHz	Bandwidth Limit kHz
902.726 (CH0)	Slot 0	224.1	<500
902.726 (CH0)	Slot 1	225.4	<500
914.773 (CH24)	Slot 0	226.6	<500
914.773 (CH24)	Slot 1	225.4	<500
927.322 (CH49)	Slot 0	227.9	<500
927.322 (CH49)	Slot 1	249.9	<500

Using the maximum measured power of 29.29 dBm plus the 6.00 dBi antenna gain, the EIRP is 35.29 dBm (3381 mW). The radius at which the EIRP/(4*Pi*r^2) is equal to 1 mW/cm^2 is 16.4 cm, within 20cm.

4.0 Hopping Characteristics

15.247(a)(1), (b)(2)

4.1 Test Procedure

The EUT was activated and the fundamental was observed on a spectrum analyzer through sufficient attenuation to prevent overloading the analyzer. Measurements were performed at the end of the EUT's transmit cable. Channel separation was measured using max hold and a span that included several adjacent channels and bandwidth suitable for resolving individual peaks. The number of hopping channels was measured with a span that included the entire passband and bandwidth selected to show the peaks of channels using a max hold function. Channel dwell time was measured using a zero span centered on a channel, with bandwidth reduced to lower the signal level of adjacent peaks, and sweep duration varied to capture hop duration and the number of hops in ten seconds. The EUT was hopping normally during all measurements.

Requirement: The receiver must hop synchronously with the transmitter hops. Channel Separation must be greater than the 20 dB bandwidth of the fundamental, the number of hopping frequencies must be at least 50, and the average time of occupancy in any channel must be no more than 0.4 seconds in any 20 second period.

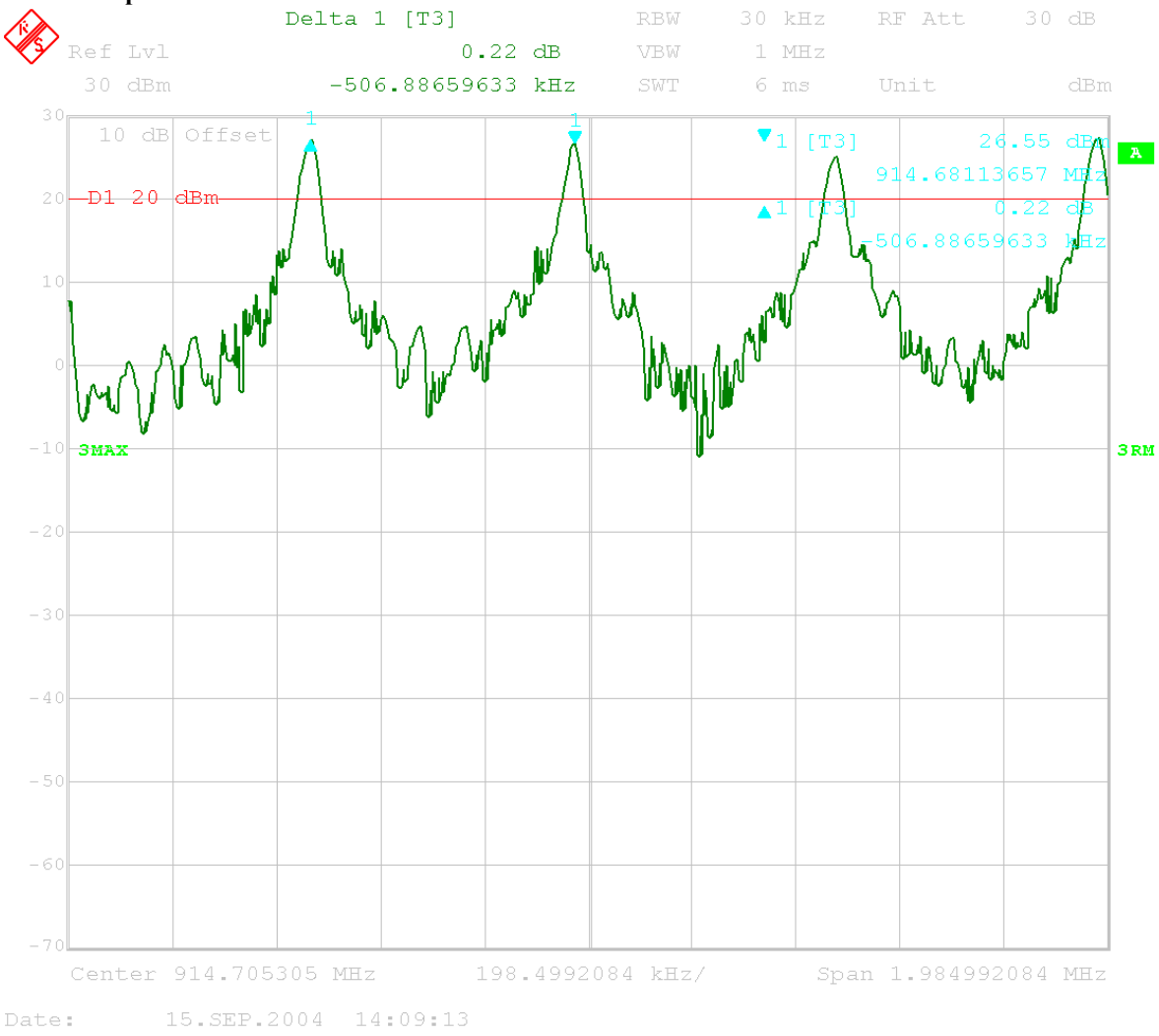
4.2 Test Results

Performed 9/15/2004 Equipment: ROS001, CBL030, WEI8

Results: Passed

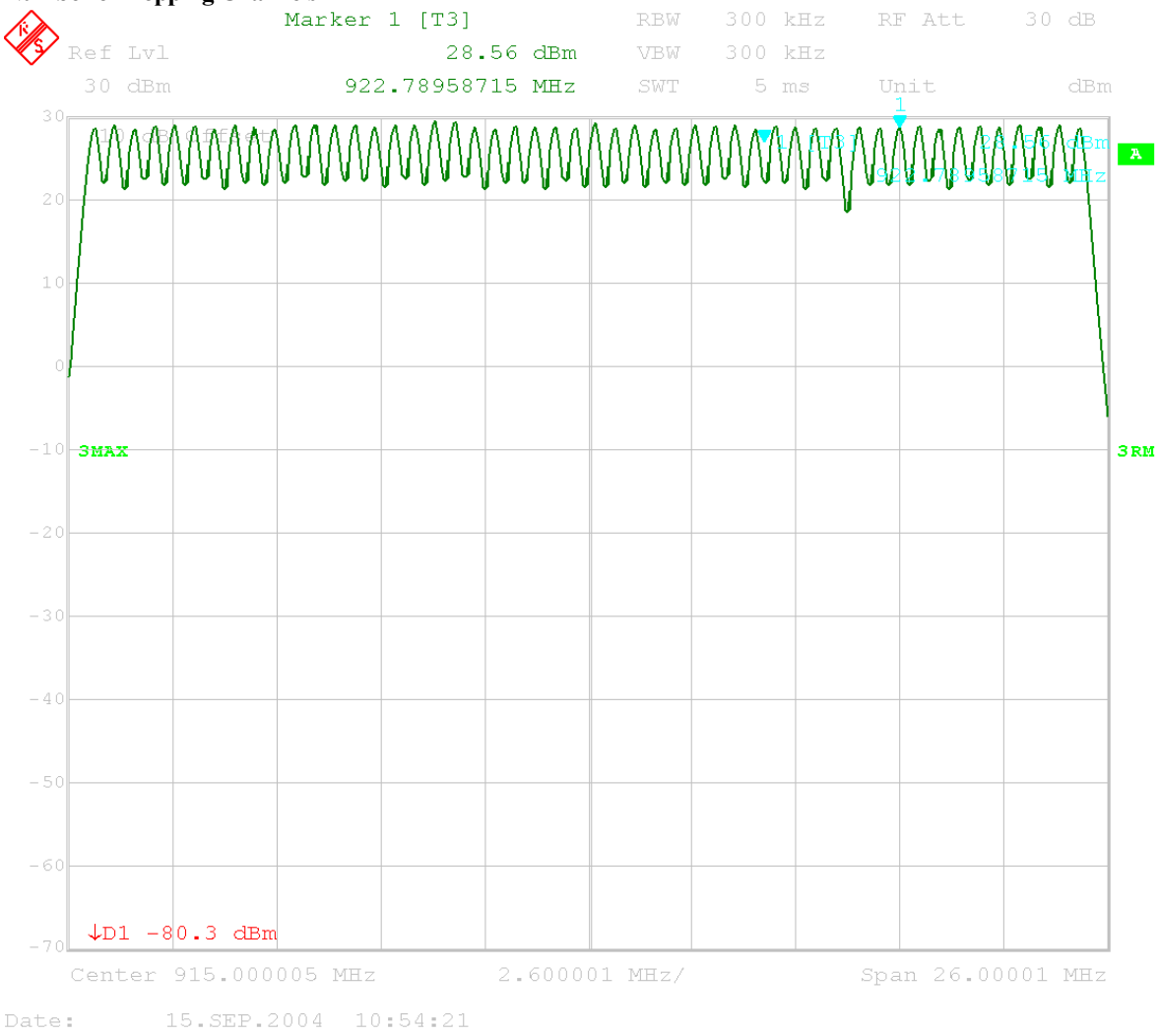
Note that the receiver and transmitter circuitry derive timing from the same LO therefore they hop synchronously.

Channel Separation



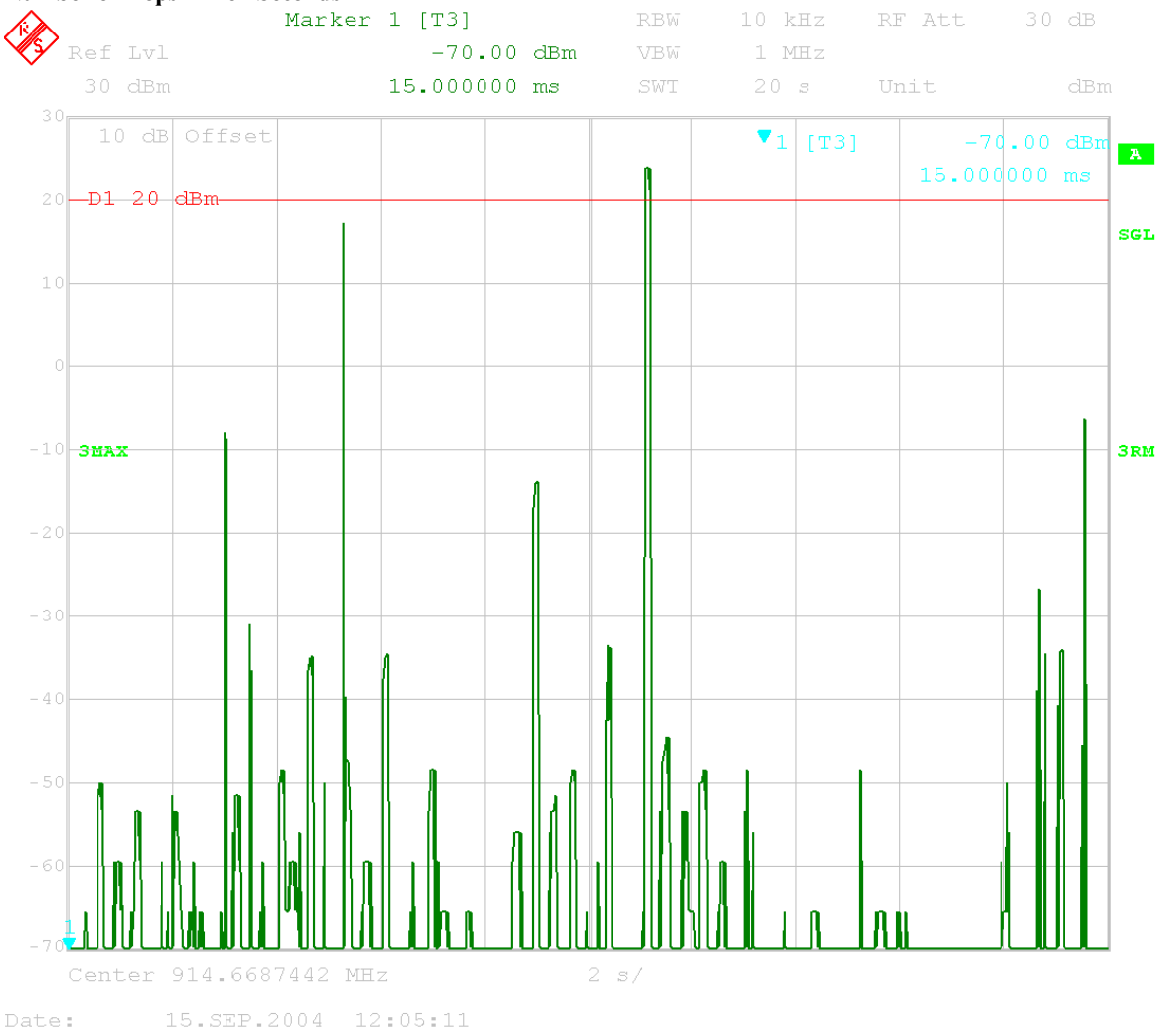
The channel separation is 507 kHz.

Number of Hopping Channels



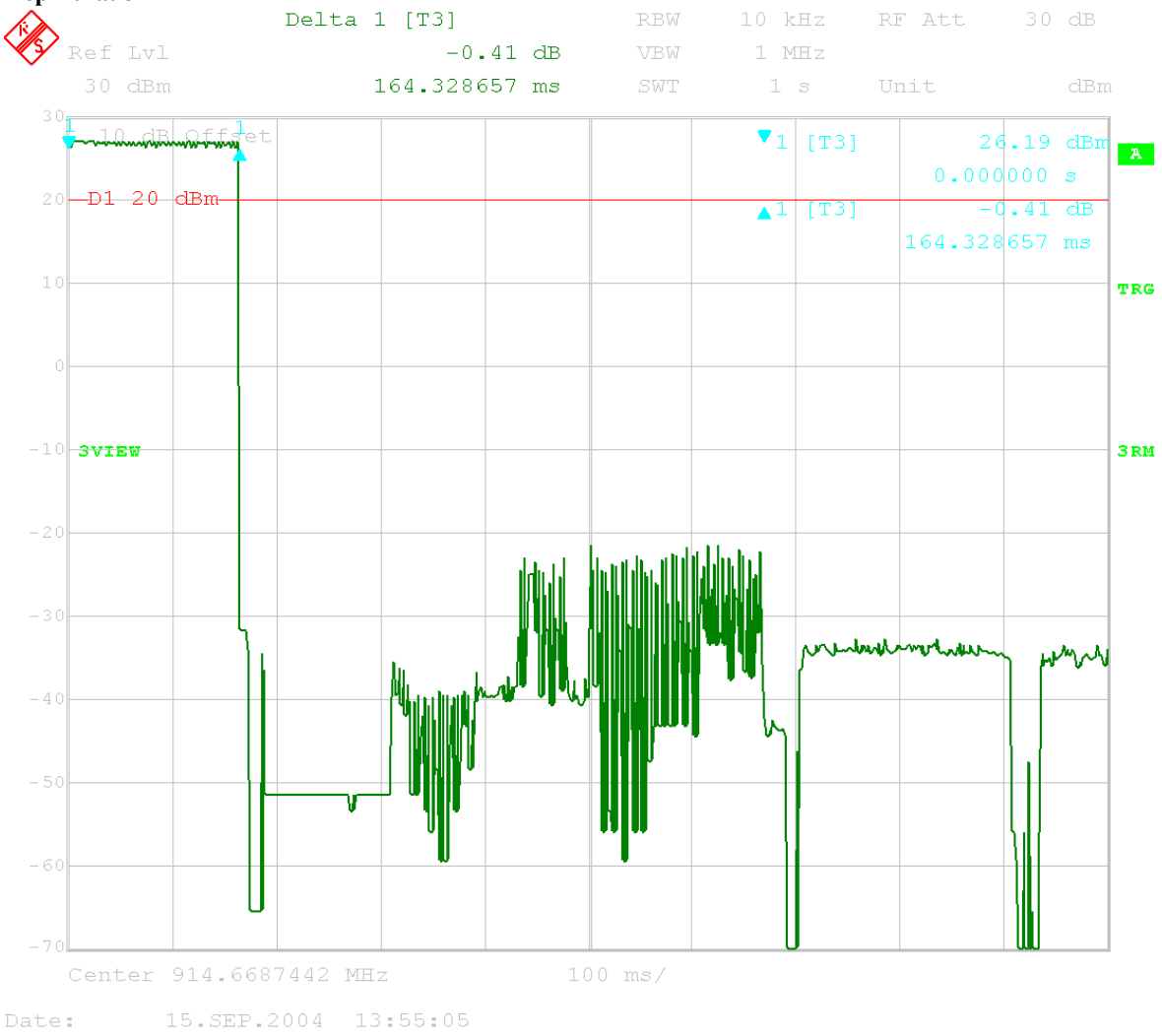
There are 50 hopping channels.

Number of Hops in Ten Seconds



There is one hop in ten seconds.

Hop Duration



One hop in ten seconds of duration 164 ms for a total on time in ten seconds of 164 ms.

5.0 Antenna Conducted Spurious Emissions and Band Edge Compliance

15.247(c)

5.1 Test Procedure

The EUT was activated at nominal power and connected to a spectrum analyzer via a cable with sufficient attenuation to prevent overloading of the analyzer. Conducted plots of emissions at the antenna port were made using a 100 kHz bandwith. A display line was used to indicate the level 20 dB lower than the level of the fundamental frequency. When a conducted emission was found in a restricted band, an antenna was used to find the field strength. All four transmit ports and a receive port were scanned and the worst case is shown as a representative sample and was used for the radiated field strength in restricted bands evaluation.

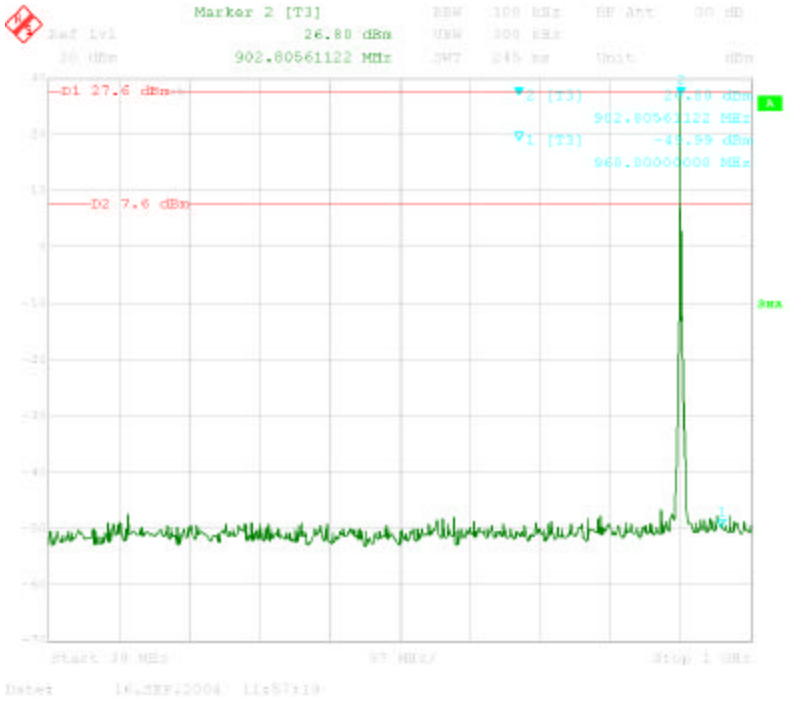
Requirement: All emissions in any 100 kHz bandwidth outside the frequency band of operation must be attenuated by at least 20 dB below the highest level of fundamental emission in any 100 kHz band inside the frequency band of operation.

5.2 Test Results

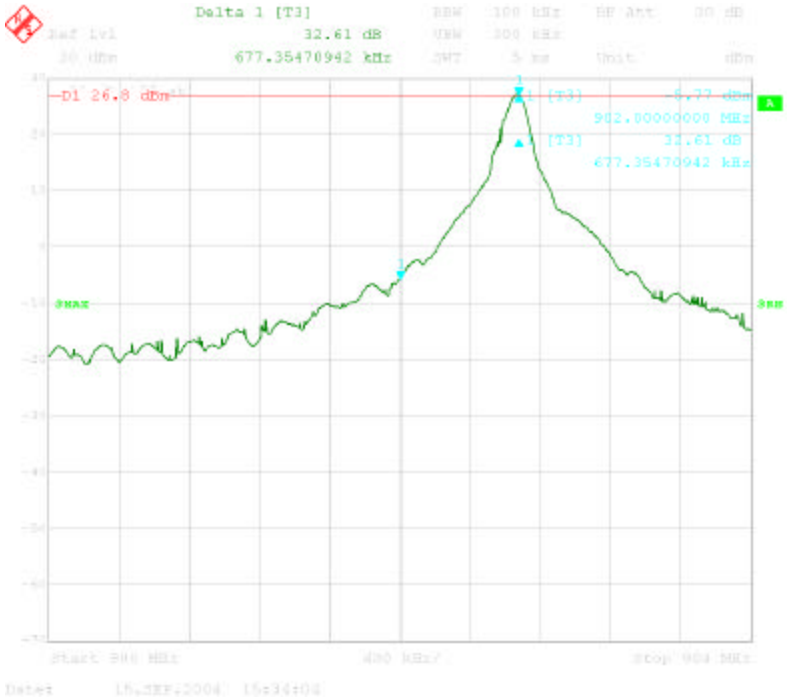
Results: Pass

Performed 9/16/2004 Equipment: PRE8, ROS001

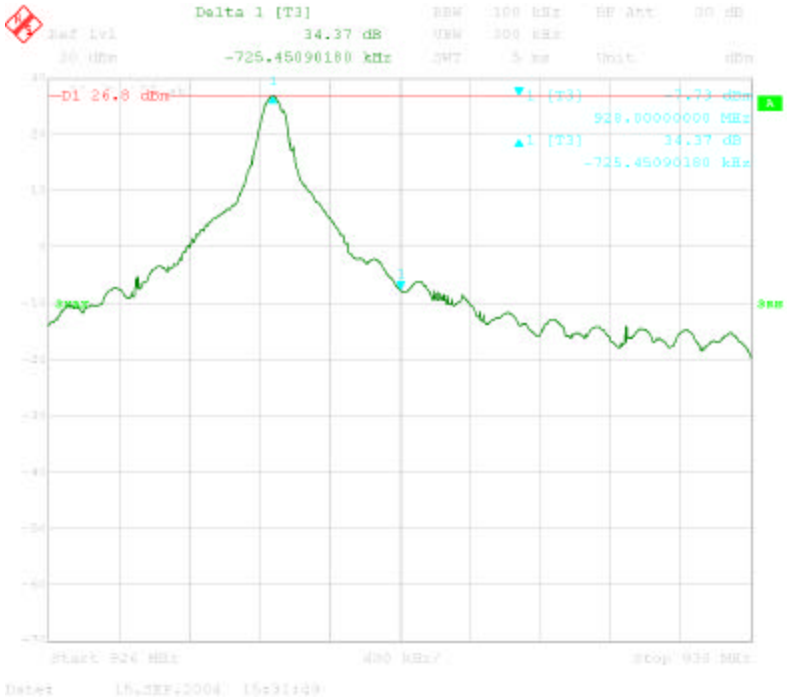
Slot 1 Radio Transmit Port #4



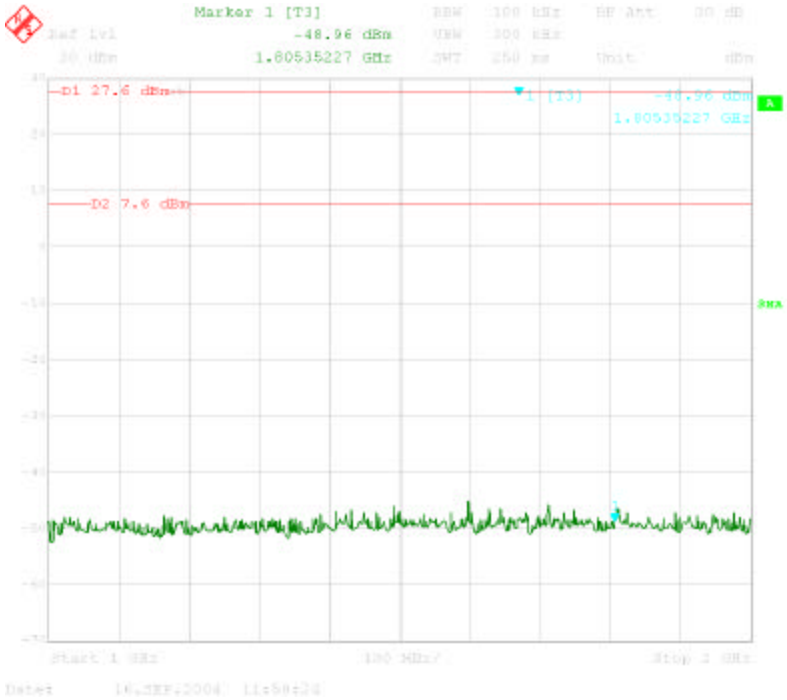
Conducted Spurious, 30 MHz – 1 GHz



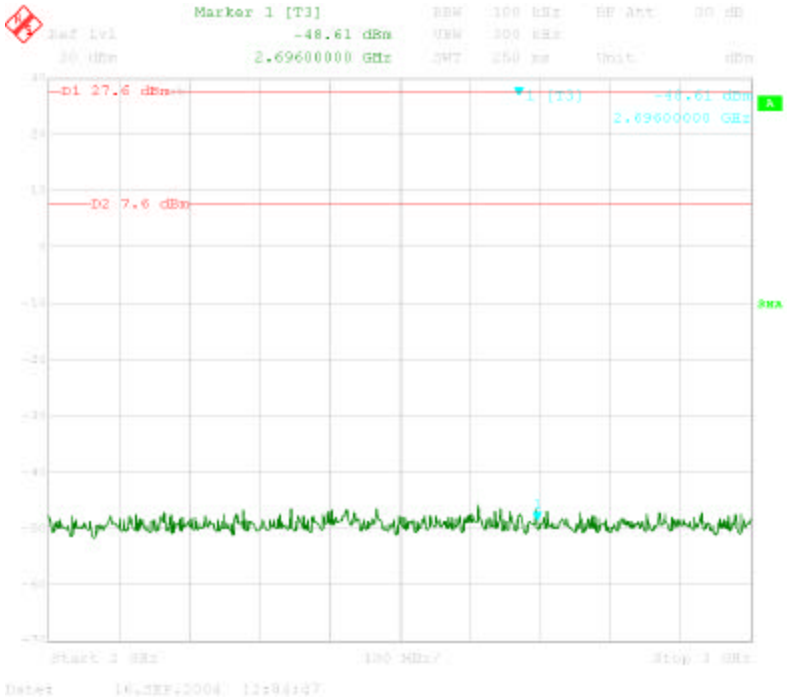
Band Edge Compliance (marker denotes lower band edge)



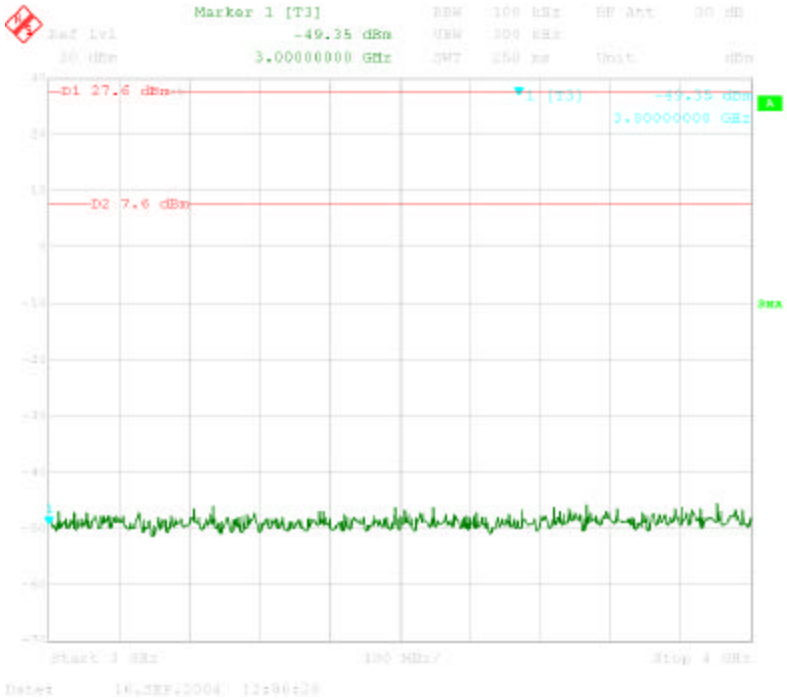
Band Edge Compliance (marker denotes upper band edge)



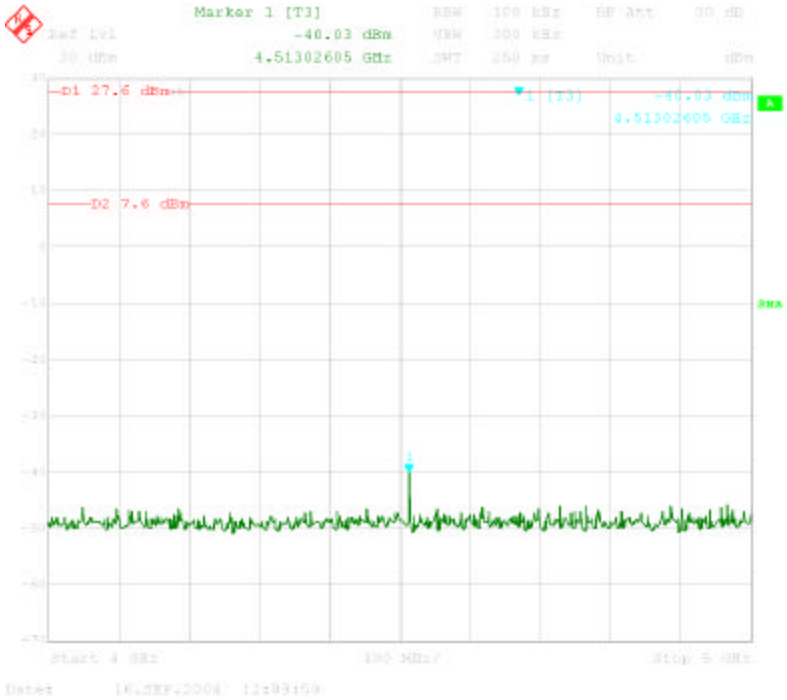
Conducted Spurious, 1 GHz – 2 GHz



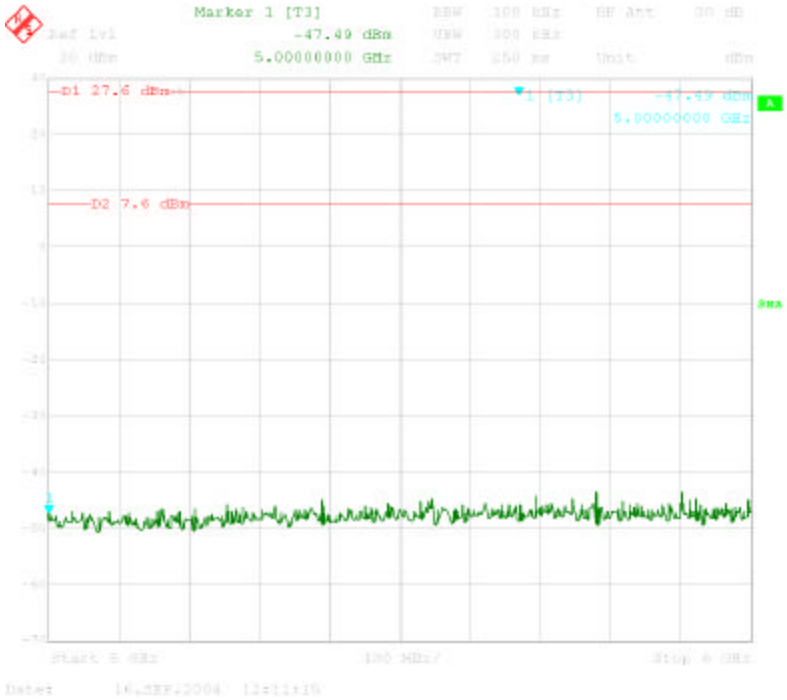
Conducted Spurious, 2 GHz – 3 GHz



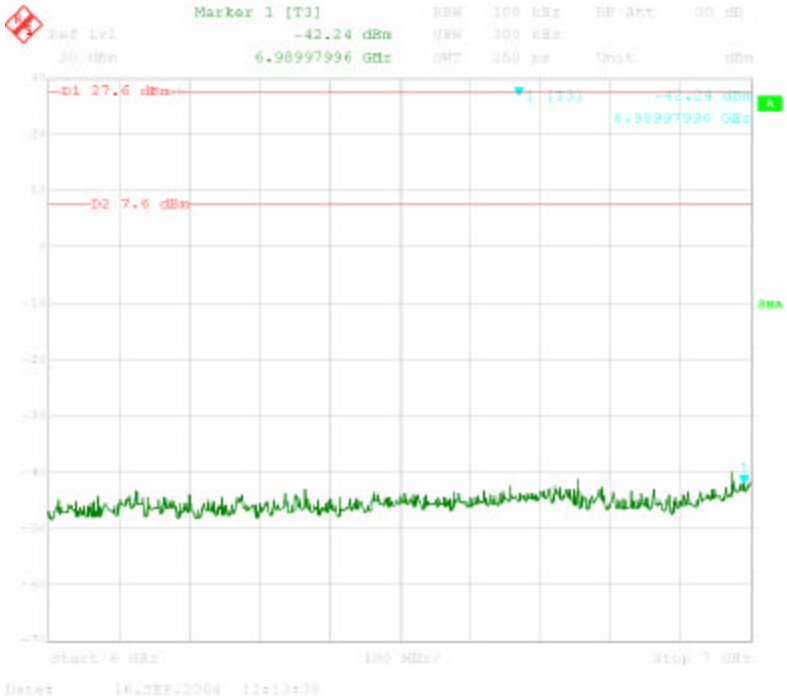
Conducted Spurious, 3 GHz – 4 GHz



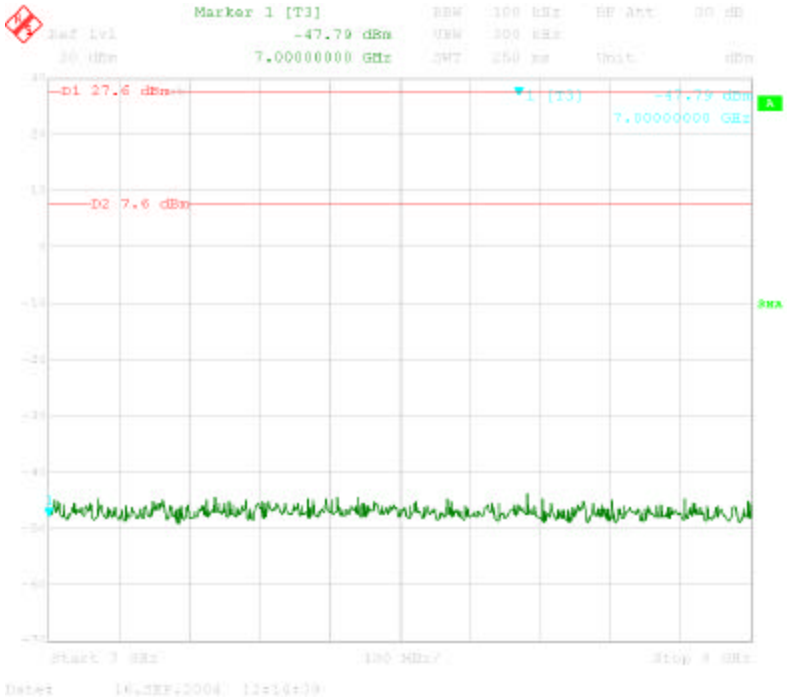
Conducted Spurious, 4 GHz – 5 GHz



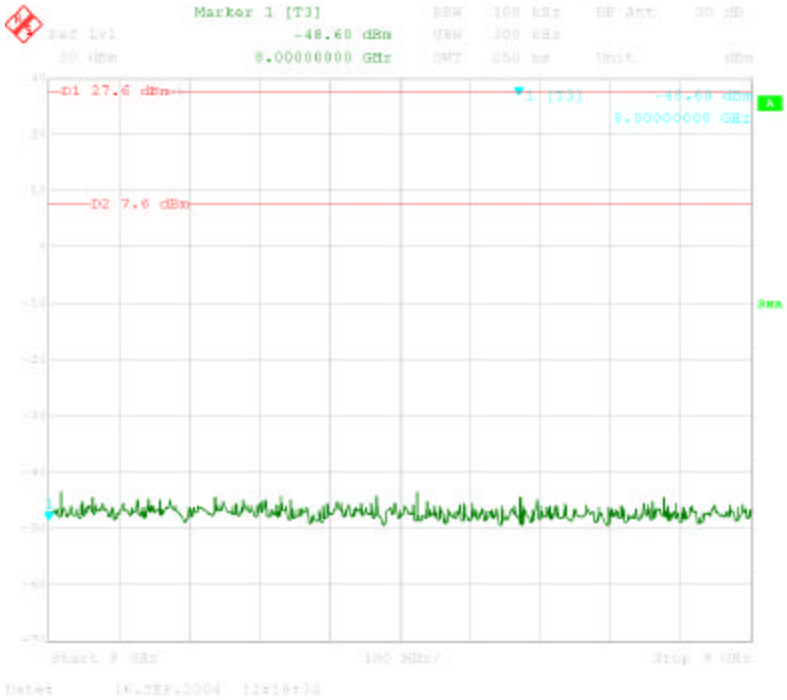
Conducted Spurious, 5 GHz – 6 GHz



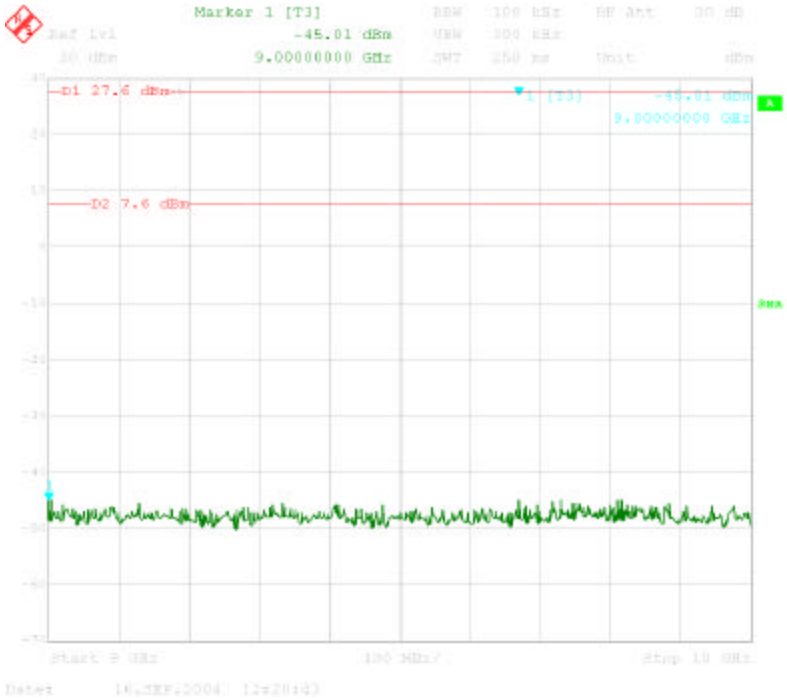
Conducted Spurious, 6 GHz – 7 GHz



Conducted Spurious, 7 GHz – 8 GHz

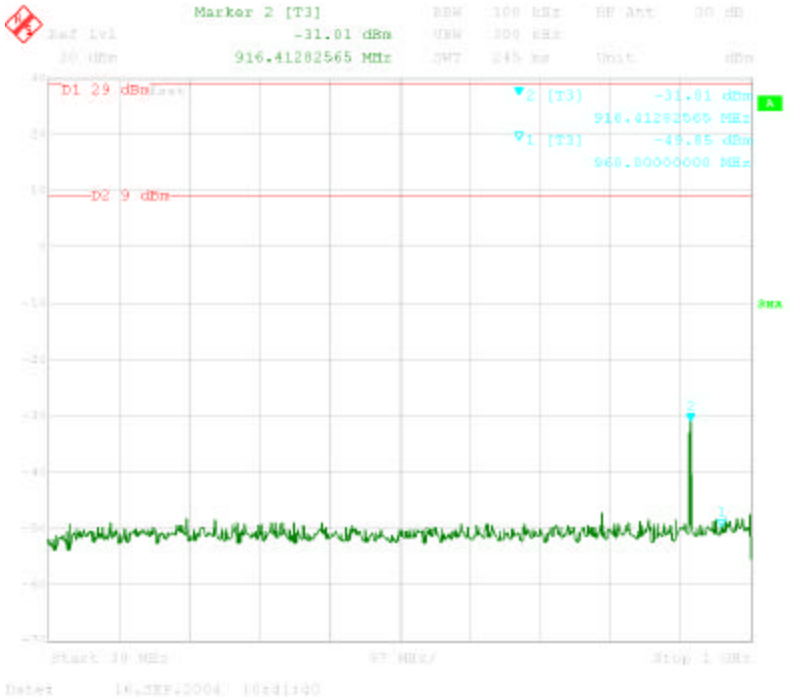


Conducted Spurious, 8 GHz – 9 GHz

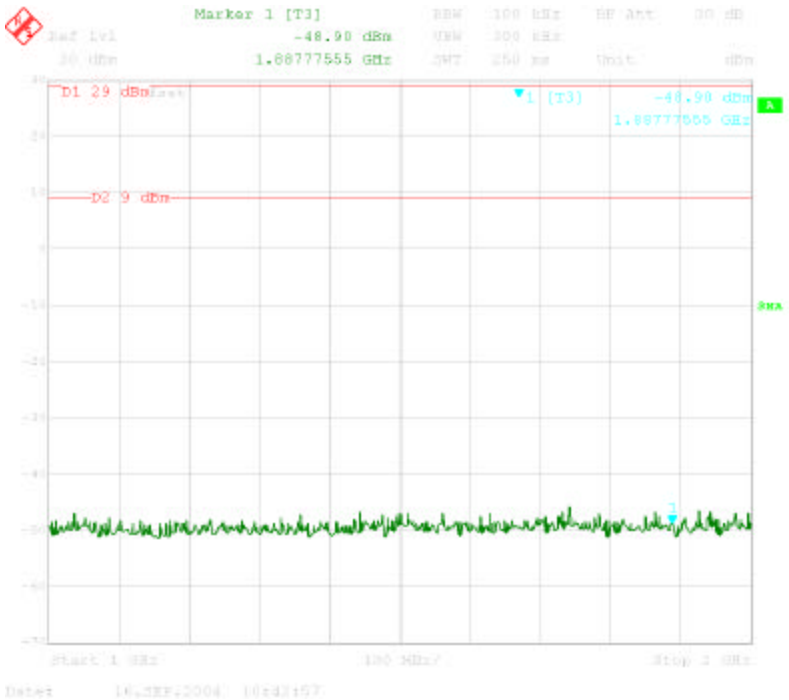


Conducted Spurious, 9 GHz – 10 GHz

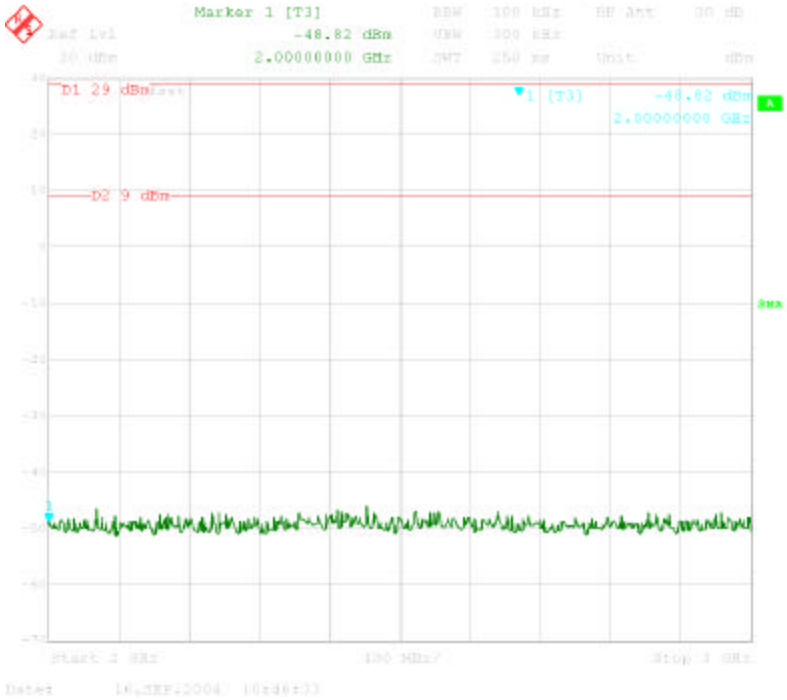
Receiver Plots



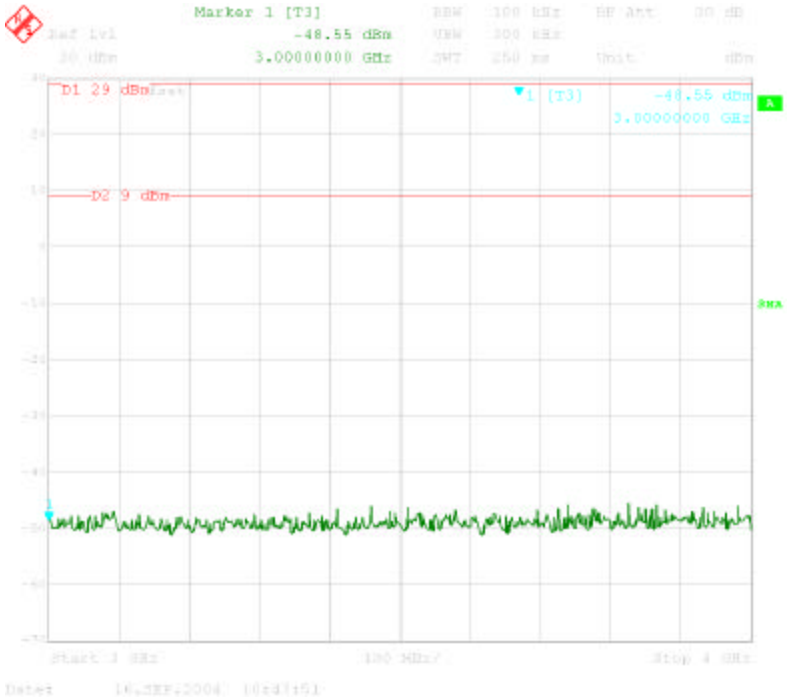
Conducted Spurious, 30 MHz – 1 GHz



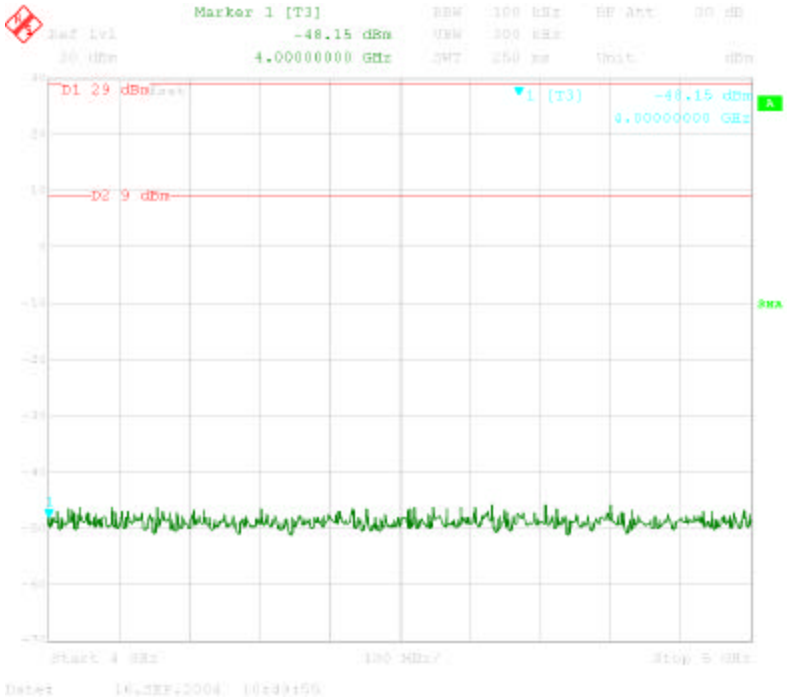
Conducted Spurious, 1 GHz – 2 GHz



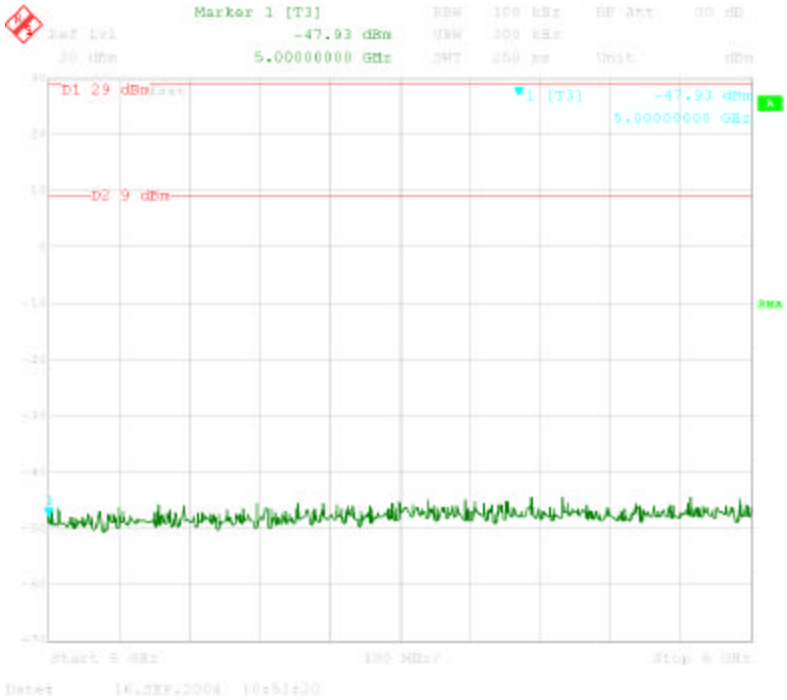
Conducted Spurious, 2 GHz – 3 GHz



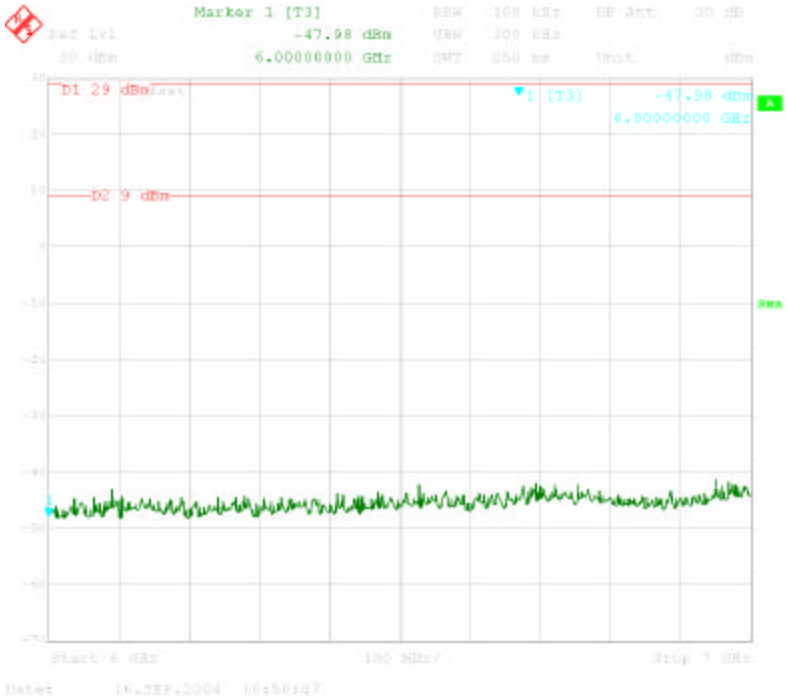
Conducted Spurious, 3 GHz – 4 GHz



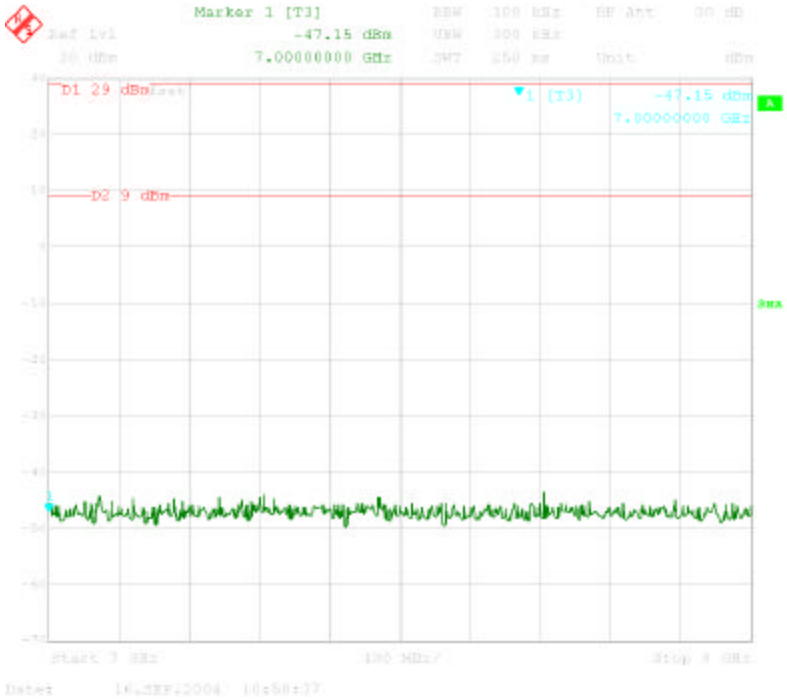
Conducted Spurious, 4 GHz – 5 GHz



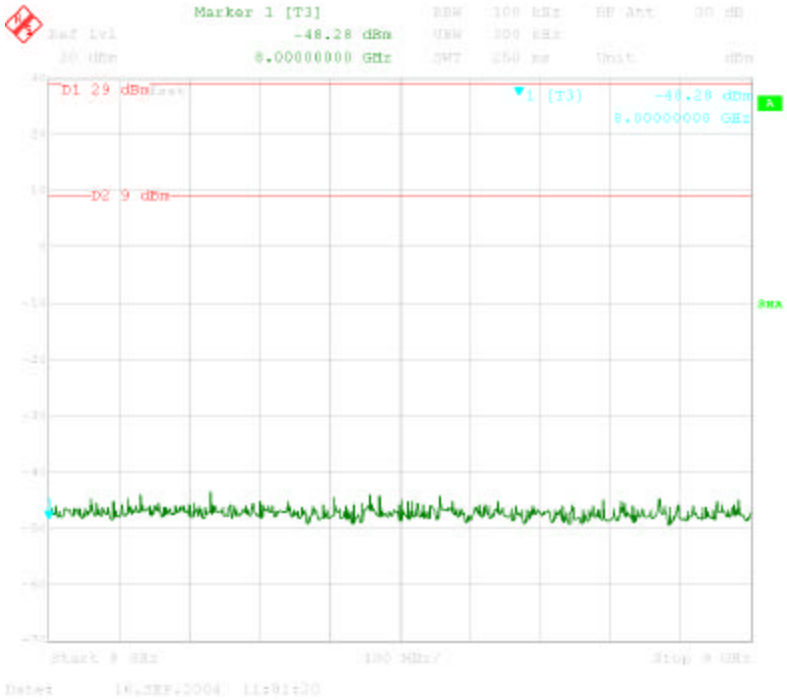
Conducted Spurious, 5 GHz – 6 GHz



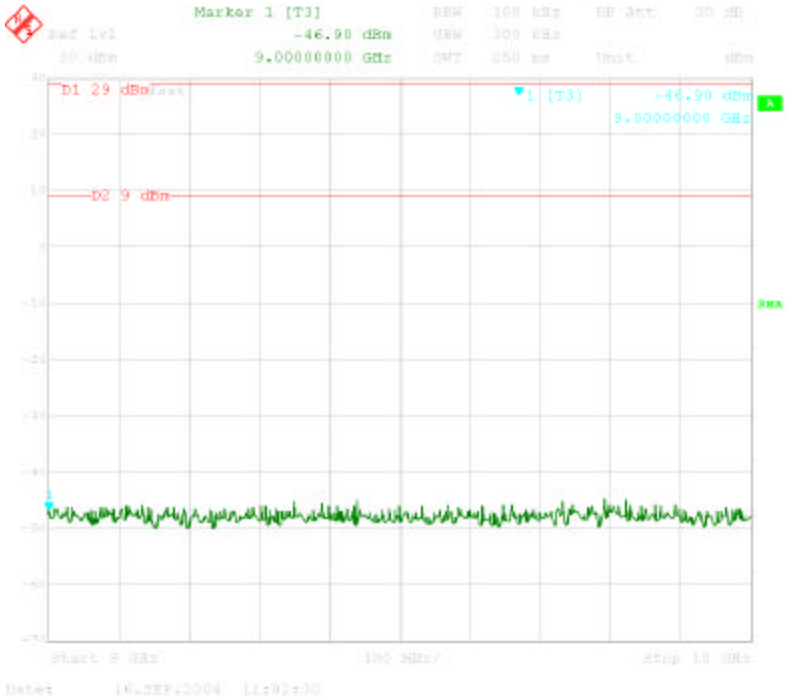
Conducted Spurious, 6 GHz – 7 GHz



Conducted Spurious, 7 GHz – 8 GHz



Conducted Spurious, 8 GHz – 9 GHz



Conducted Spurious, 9 GHz – 10 GHz

6.0 Radiated emissions in restricted bands
15.247(c)

6.1 Test Procedure

Since the EUT passed the out-of-band (spurious) antenna conducted emission test, only the radiated emission measurements in the restricted bands were performed. Spectrum Analyzer Resolution Bandwidth of 100 kHz and max hold was used at all frequencies. The EUT is placed on the wooden turntable. If the EUT attaches to peripherals, they are connected and operational (as typical as possible). During testing, all cables were manipulated to produce worst-case emissions. The signal is maximized through rotation and manipulation of the EUT in 3 orthogonal axes. The antenna height and polarization are varied during the search for maximum signal level. The antenna height is varied from 1 to 4 meters. Radiated emissions are taken at 3 m unless the signal level is too low for measurement at that distance. If necessary, a pre-amplifier is used and/or the test is conducted at a closer distance. All readings are extrapolated back to the equivalent three-meter reading using inverse scaling with distance.

Requirement: Radiated emissions in restricted bands must meet the general limits of 15.209.

6.2 Test Results

Results: Pass

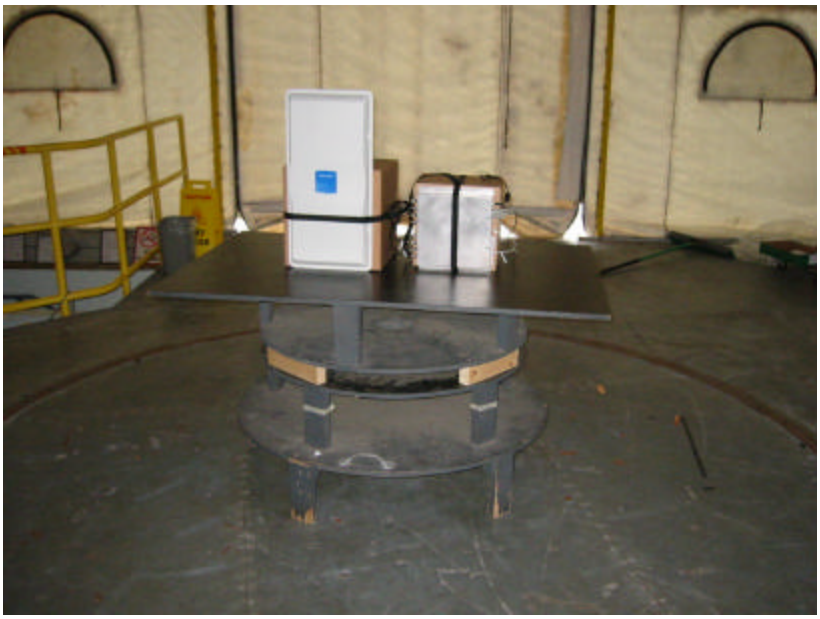
Performed 9/22/2004 Equipment: HORN1, ROS001, PRE8, CBL028, CBL030, BAR2

Radiated Emissions / Interference

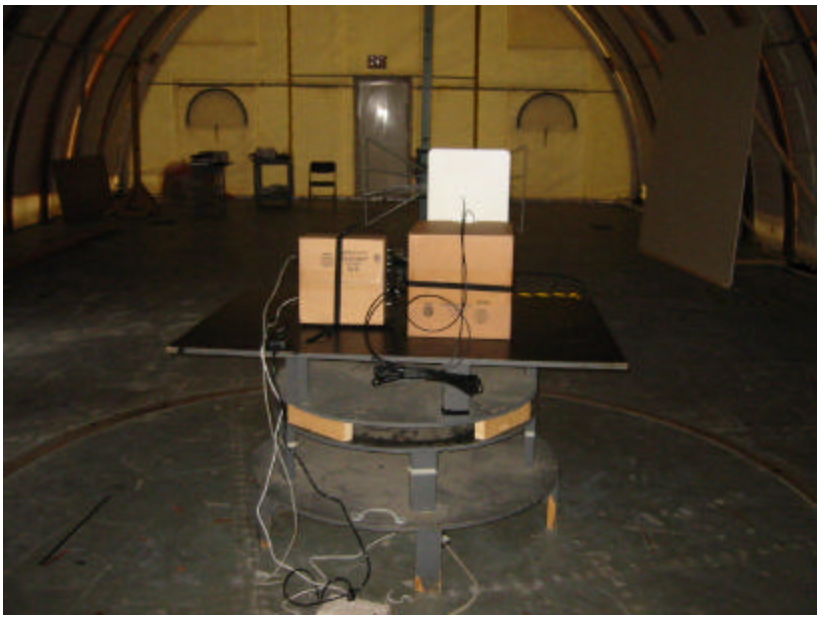
Company: ThingMagic, LLC Model #: Mercury4
Engineer: Nicholas Abbondante Location: Site 2 Serial #: Eng01
Project #: 3065327 Pressure: 1005 mB Receiver: R&S FSEK-30
Date: 09/22/04 Temp: 20c Antenna: HORN1 10-24-04 V3.ant HORN1 10-24-04 H3.ant
Standard: FCC Part 15/Cispr22 Humidity: 77% PreAmp: PRE8 10-22-04.amp
Class: B Group: None Cable(s): CBL028 11-11-2004.cbl CBL030 11-11-2004.cbl
Limit Distance: 3 meters Test Distance: 3 meters
Voltage/Frequency: 120V/60Hz Frequency Range: Restricted Bands
All antennas tested with Reader #1 unless otherwise indicated

Ant. Pol. (V/H)	Frequency MHz	Reading dB(uV)	Antenna Factor dB(1/m)	Cable Loss dB	Pre-amp Factor dB	Filter Factor dB	Net dB(uV/m)	Limit dB(uV/m)	Margin dB
Sensormatic Agile Omnipoint Antenna									
H	2707.987	24.1	30.7	4.5	19.7	-2.0	41.6	54.0	-12.4
V	3610.650	19.3	33.9	5.3	20.0	-1.5	40.0	54.0	-14.0
V	4513.312	17.1	35.1	6.9	20.6	-1.4	40.0	54.0	-14.0
Alien Dual Circular Antenna									
V	2707.987	18.4	31.3	4.5	19.7	-2.0	36.5	54.0	-17.5
V	3610.650	19.1	33.9	5.3	20.0	-1.5	39.8	54.0	-14.2
V	4513.312	20.4	35.1	6.9	20.6	-1.4	43.3	54.0	-10.7
Matrics ANT-GP-HP Antenna									
V	2707.987	20.3	31.3	4.5	19.7	-2.0	38.4	54.0	-15.6
V	3610.650	17.3	33.9	5.3	20.0	-1.5	38.0	54.0	-16.0
V	4513.312	20.7	35.1	6.9	20.6	-1.4	43.6	54.0	-10.4
ThingMagic Antenna									
V	2707.987	17.6	31.3	4.5	19.7	-2.0	35.7	54.0	-18.3
V	3610.650	17.4	33.9	5.3	20.0	-1.5	38.1	54.0	-15.9
V	4513.312	21.6	35.1	6.9	20.6	-1.4	44.5	54.0	-9.5
Alien Dual Circular/Linear Antenna									
V	2707.987	22.4	31.3	4.5	19.7	-2.0	40.5	54.0	-13.5
V	3610.650	19.5	33.9	5.3	20.0	-1.5	40.2	54.0	-13.8
V	4513.312	20.1	35.1	6.9	20.6	-1.4	43.0	54.0	-11.0
Sensormatic Agile Omnipoint Antenna with Reader #2									
H	2707.987	25.3	30.7	4.5	19.7	-2.0	42.8	54.0	-11.2
V	3610.650	19.8	33.9	5.3	20.0	-1.5	40.5	54.0	-13.5
H	4513.312	29.7	34.3	6.9	20.6	-1.4	51.8	54.0	-2.2
M/A-Com Single Element Dual CP Antenna									
V	2707.987	21.2	31.3	4.5	19.7	-2.0	39.3	54.0	-14.7
V	3610.650	16.4	33.9	5.3	20.0	-1.5	37.1	54.0	-16.9
V	4513.312	19.2	35.1	6.9	20.6	-1.4	42.1	54.0	-11.9

6.3 Configuration Photographs – Radiated Emissions



Spurious Test Setup, Front View



Spurious Test Setup, Back View

7.0 AC Line-Conducted Emissions

15.207

7.1 Test Procedure

The EUT was activated at nominal power through a Line Impedance Stabilization Network (LISN) and set to transmit normally for the duration of the test. The EUT was placed flush with the back of the turntable and a vertical coupling plane was located at a distance 40cm behind the EUT. Measurements of AC line-conducted emissions were performed via a cable and attenuator attached to the LISN.

Requirement: All AC line-conducted emissions must meet the general limits of 15.207.

7.2 Test Results

Results: Pass

Performed 9/16/2004 Equipment: CBL10MS3, DS24, SA0003, LISN11, BAR2

Conducted Emissions / Interference

Company:	ThingMagic, LLC			Model #:	Mercury4		
Engineer:	Nicholas Abbondante	Location:	Site 2	Serial #:	Eng01		
Project #:	3065327	Pressure:	1005 mB	Receiver:	HP8591E		
Date:	09/16/04	Temp:	20c	Cable:	CBL10MS3 1-15-05.cbl		
Standard:	FCC Part 15/Cispr22	Humidity:	78%	LISN 1, 2:	LISN11 [1] 6-06-05.lsn	LISN11 [2] 6-06-05.lsn	
Class:	B	Group:	None	LISN 3, N:	None	None	
Preamp:	None			Attenuator:	DS24 1-15-05.att		
Voltage/Frequency:	120V/60Hz			Frequency Range:	150 kHz - 30 MHz		

Net is the sum of worst-case lisn, cable, & attenuator losses, preamp gain, and initial reading

Frequency MHz	Reading Line 1 dB(uV)	Reading Line 2 dB(uV)	Reading Line 3 dB(uV)	Reading Neutral dB(uV)	Quasi-Peak Net dB(uV)	Quasi-Peak Limit dB(uV)	Quasi-Peak Margin dB
0.184	21.8	22.6			45.5	64.3	-18.8
0.296	9.5	11.8			34.1	60.3	-26.3
1.119	14.2	-7.3			35.3	56.0	-20.7
3.710	2.5	-5.6			23.6	56.0	-32.4
16.190	26.6	24.5			48.0	60.0	-12.0
24.630	14.9	17.2			38.9	60.0	-21.1

Frequency MHz	Reading Line 1 dB(uV)	Reading Line 2 dB(uV)	Reading Line 3 dB(uV)	Reading Neutral dB(uV)	Average Net dB(uV)	Average Limit dB(uV)	Average Margin dB
0.184	21.8	11.1			44.6	54.3	-9.7
0.296	5.7	2.0			28.2	50.3	-22.2
1.119	11.3	-25.7			32.4	46.0	-13.6
3.710	-0.6	-11.8			20.9	46.0	-25.1
16.190	18.9	16.4			40.3	50.0	-9.7
24.630	6.9	9.5			31.3	50.0	-18.7

7.3 Configuration Photographs – Line-Conducted Emissions

Line-Conducted Spurious Test Setup, Front View

Line-Conducted Spurious Test Setup, Back View