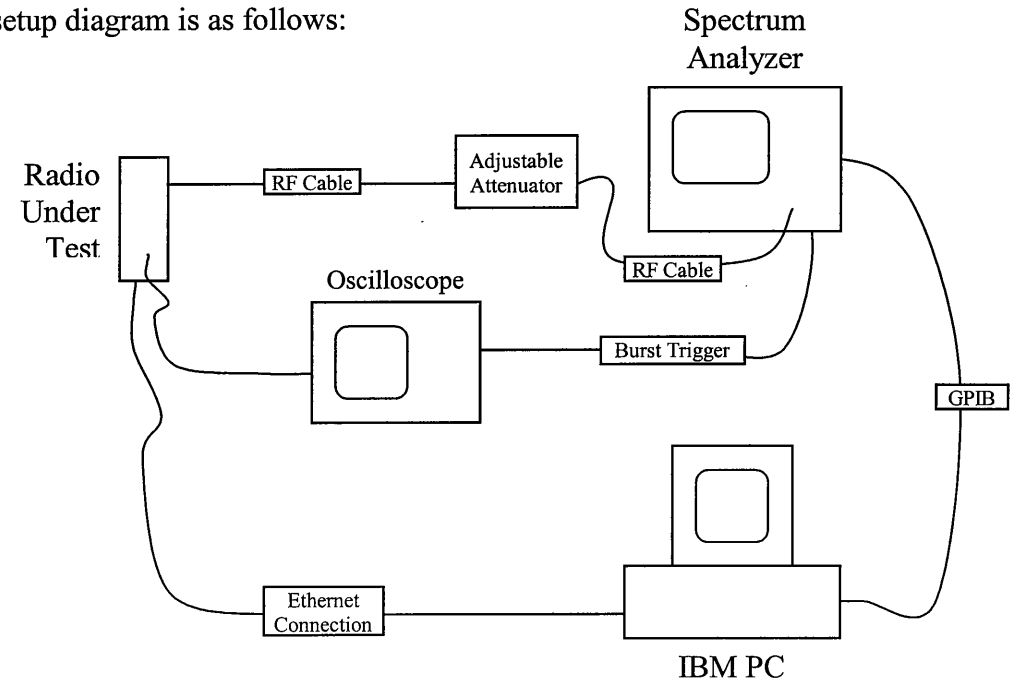
RADIO EMISSIONS TEST REPORT

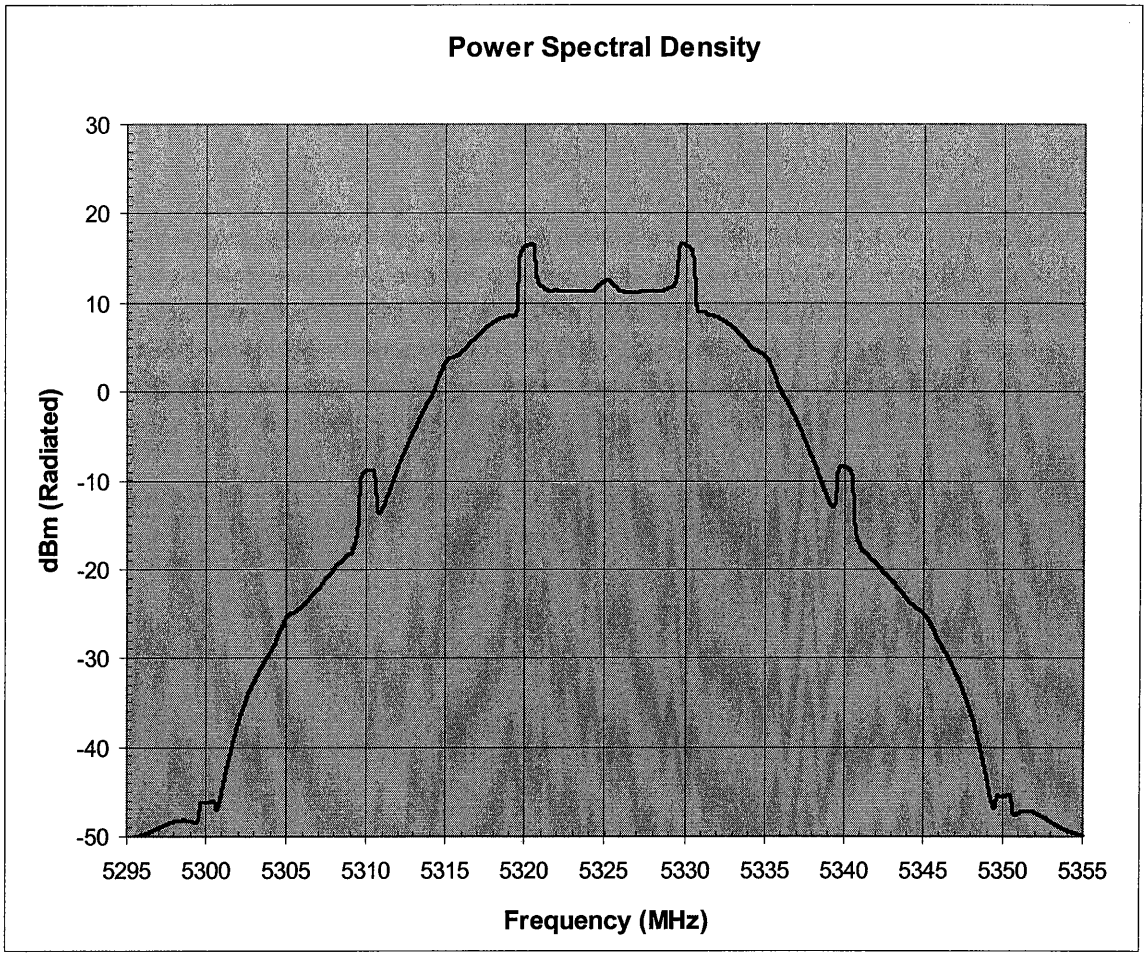
WHISP Radiated Test
19 July 2001

Compliance testing with FCC rules part 15.407 was performed in both conducted and radiated tests. The power spectral density measurement was setup on WHISP unit serial #170 before an antenna was added. The radio was connected to an HP (Agilent) 8596E Spectrum analyzer. Measurements were taken in 0Hz span with the spectrum analyzer synchronized to the transmitter's data burst. This allowed the analyzer to make time gated power measurements of the radio.

The test setup diagram is as follows:



Silent carrier signal from the radio under test was used to calibrate the spectrum analyzer through the adjustable attenuator for a carrier power of 0 dBm. TX bit error test pattern was initiated to maximize the transmit duty cycle and data throughput for the radio under test. A testing program on the PC computer collected the 0Hz span power sweeps over a 60MHz frequency band. Post processing integrated the power measurements into the 1MHz measurement bandwidths for the plotted power spectral density. The data was offset via the radiated carrier power measurement (+29.41dBm) and plotted as shown.



The plot shown above indicates the worst case results for the radio operation in the frequency band 5250-5350MHz. The results show that at +/-5MHz from the carrier frequency the maximum power in a 1MHz BW is +16.65dBm radiated. In the region +/-25 to 26MHz the maximum amplitude was –45.39dBm or 3.8dB better than the maximum restricted band power of -41.5dBm radiated. From these measurements it can be seen that the WHiSP radio #170 passses the FCC part 15 specifications.

WHISP Radiated Test

19 July 2001

WHISP unit serial #170 was tested outdoors to check compliance with FCC requirement 15.209, restricted band emissions. The testing was done using a model 3115 and a model 3116 calibrated dual-ridged waveguide-horn antennas manufactured by EMCO, Inc., an Agilent 8564EC 40GHz spectrum analyzer, and a laptop to control the DUT and take data from the spectrum analyzer. The two antennas combined allowed a frequency measurement range of 1GHz to 40GHz. The spatial separation between the EMCO horn antennas and the DUT was maintained at 3 meters during the test.

The FCC requirement for restricted band emissions is stated in terms of field strength and is 500uV/m at 3 meters. Using the free space impedance of 377 ohms, the equivalent power density is $-61.78 dBm/m^2$. This power density number was used as the pass/fail criteria for the test. Cable losses, antenna gains, and other correction factors were entered into an Excel spreadsheet along with the results of the testing.

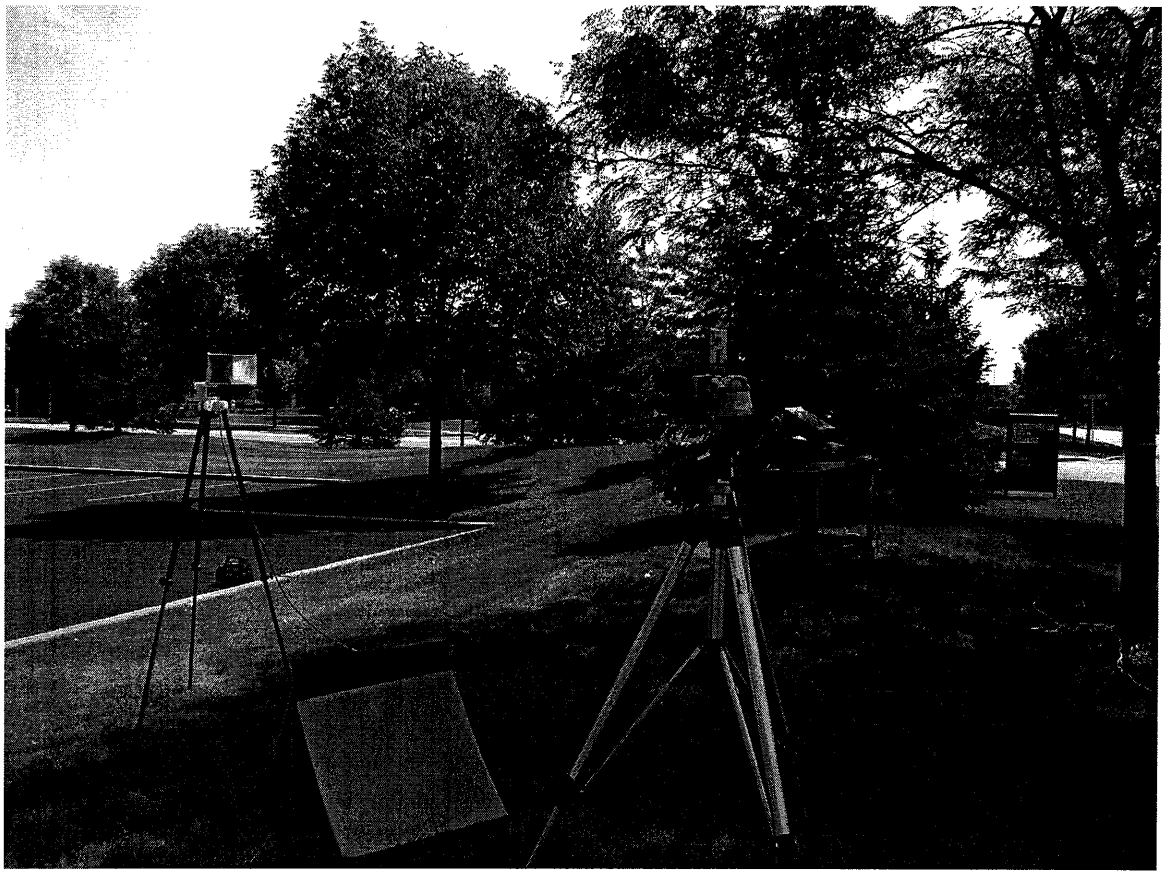
To calculate the power density at the horn antennas, the power level received by the antenna is offset by the log ratio of the effective aperture of the antenna to one square meter. The calculation of the effective aperture is done using:

$$A_{em} = e_{cd}(\lambda^2/4\pi)D_{o,}$$

D_o is the directivity of the antenna, e_{cd} is the efficiency, and λ is the wavelength of the frequency under observation. In the equation, e_{cd} and D_o may be replaced by the numeric gain of the antenna. Using the calibration data from the manufacturer, the effective area of the antenna was computed for each measurement frequency and the appropriate dB correction factor applied.

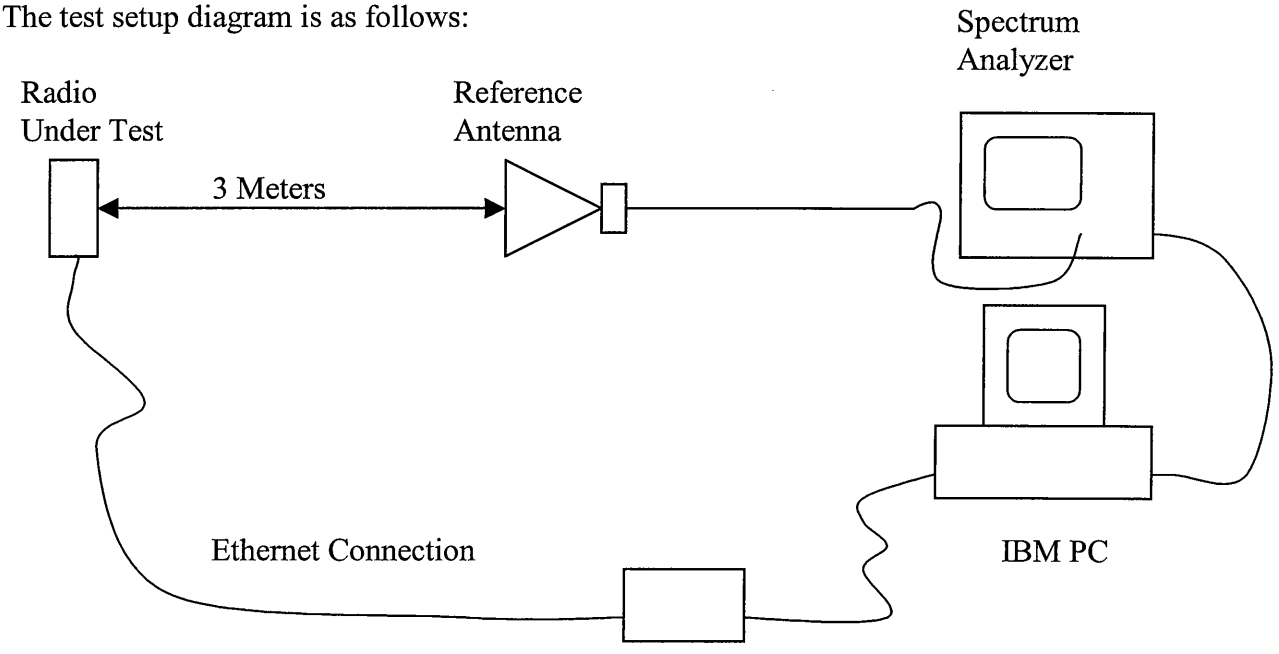
The operating frequency of the radio presented a challenge to measuring the harmonics radiated by the radio. Since the highest harmonic to be measured is 37GHz, finding test equipment that possess reasonable noise figures and obtaining coax cables with mode-free moderate loss is difficult. The resolution bandwidth of 1MHz also adds to the problem of making an effective radiated power measurement. As an aid in performing these measurements, the radio was designed with the ability to operate in continuous-wave mode, permitting the use of narrow bandwidths on the analyzer.

The picture below shows the configuration of the test set-up:



The test antenna and test radio were mounted on adjustable tripods and placed 3 meters apart. Absorbing panels were placed on the ground to reduce the effects of ground reflections.

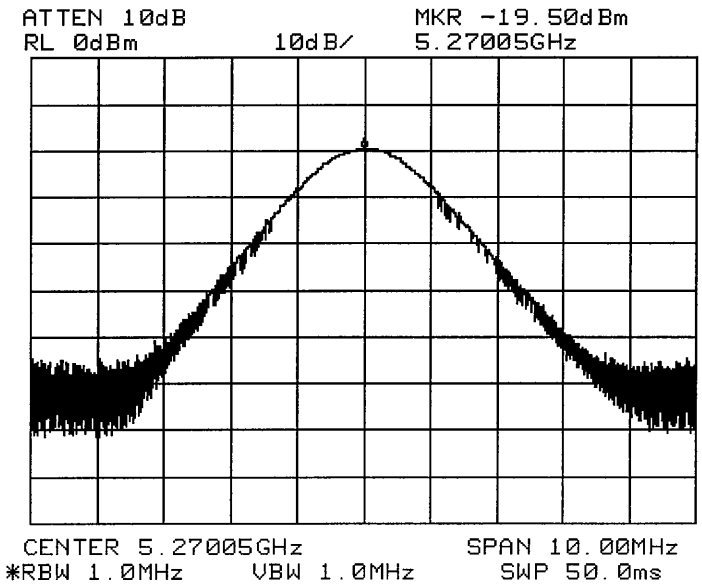
The test setup diagram is as follows:



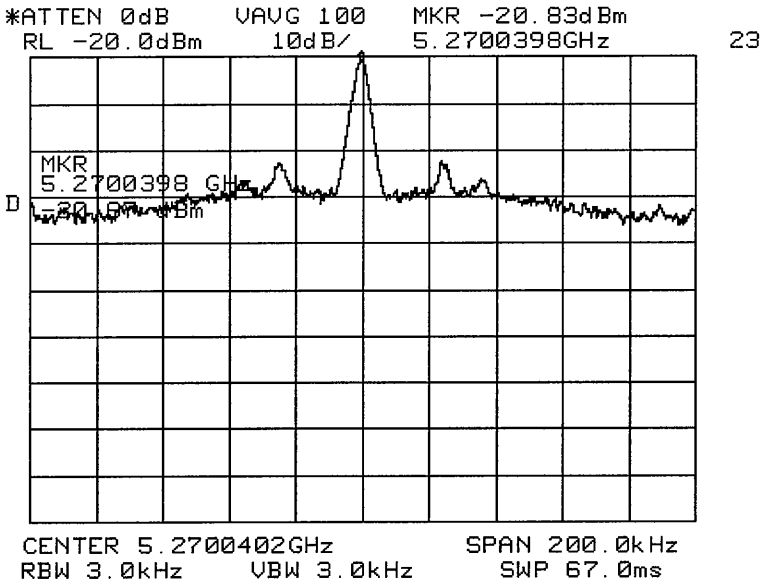
The radio has a CW mode for testing purposes and was used to measure the harmonic levels radiated from the radio. With no modulation, the measurement bandwidth could be reduced below 1MHz, allowing greater dynamic range for the test equipment. Measurements were made using 300Hz and 3 kHz resolution bandwidths and, when signal levels permitted, a 1MHz bandwidth.

An RF frequency of 5270MHz was chosen for this test since this was the frequency having the highest spurious emissions levels. Data from the analyzer was transferred to the laptop computer and later processed. The raw spectral plots from the HP8593E analyzer are given below:

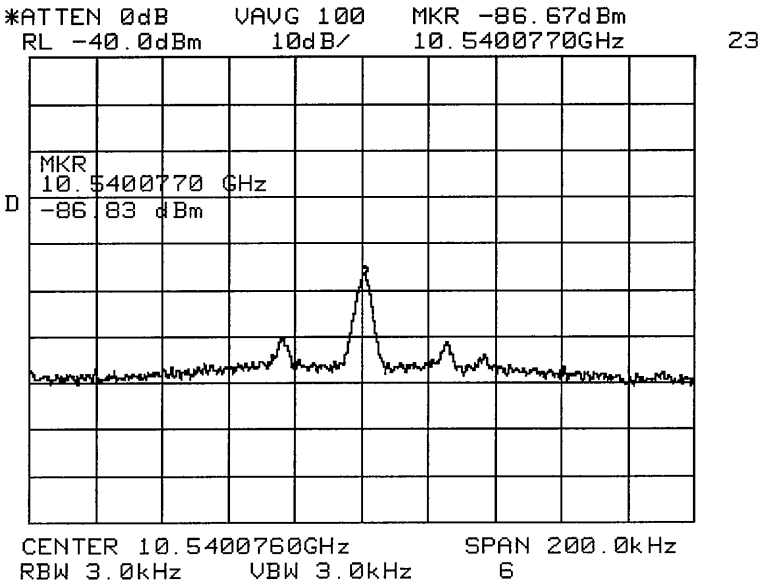
Plot 1: Fundamental frequency: 1MHz RBW:



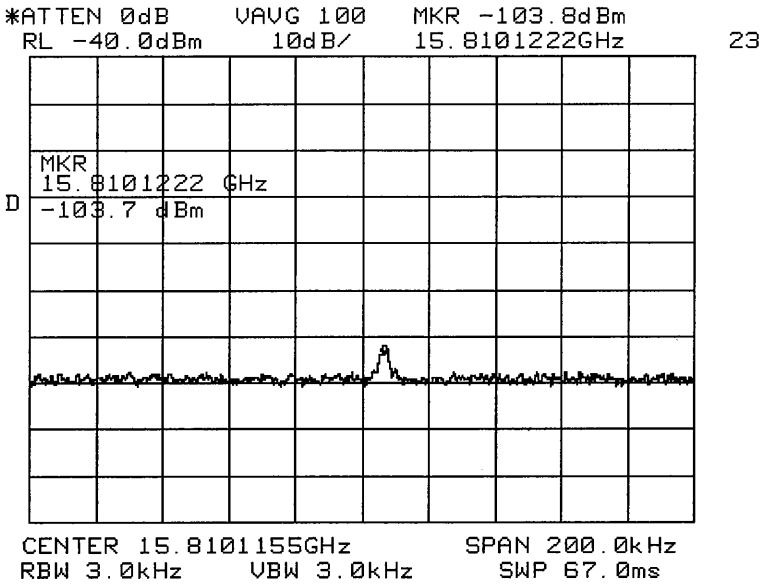
Plot 2: Fundamental frequency, 3kHz RBW:



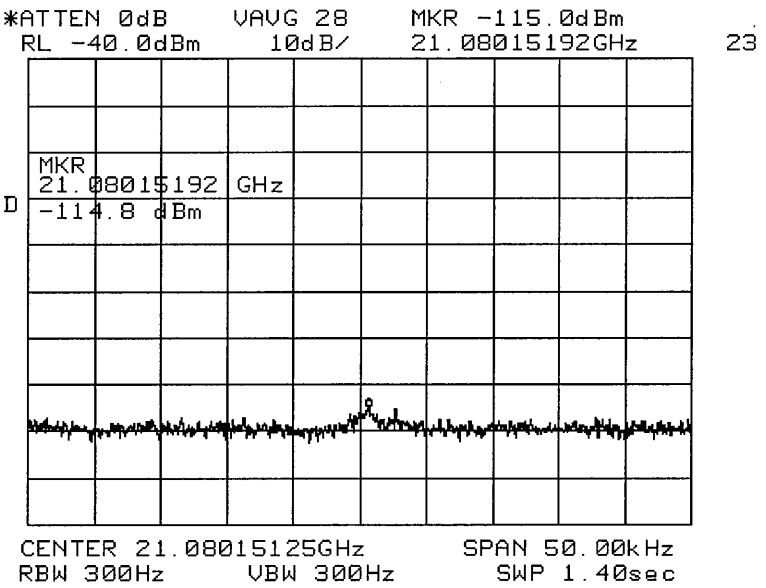
Plot 3: Second Harmonic, 3kHz RBW:



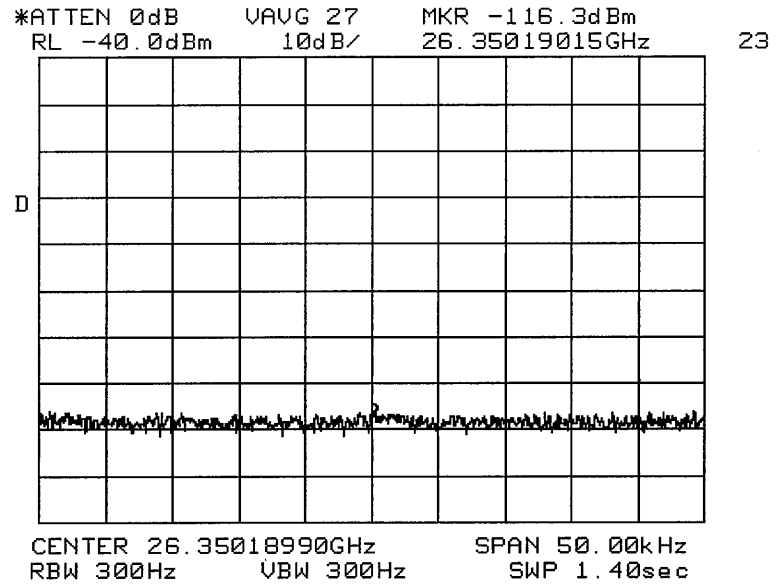
Plot 4: Third Harmonic, 3kHz RBW:



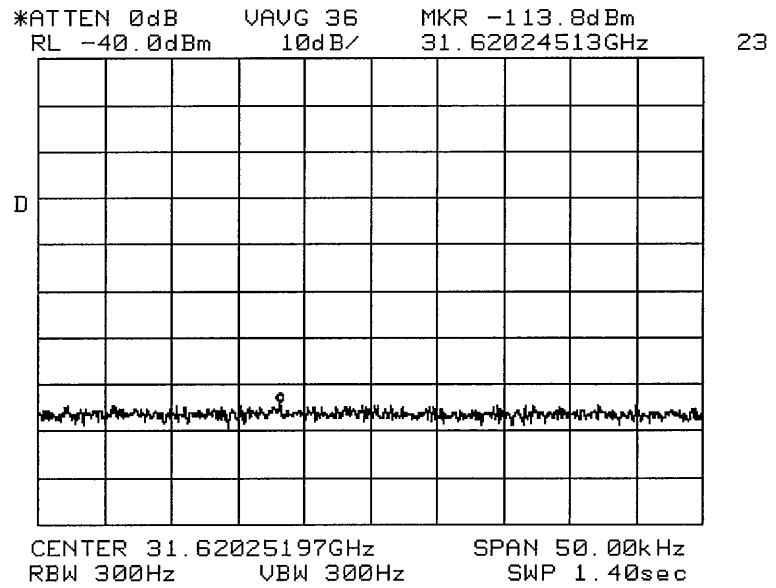
Plot 5: Fourth Harmonic, 300Hz RBW:



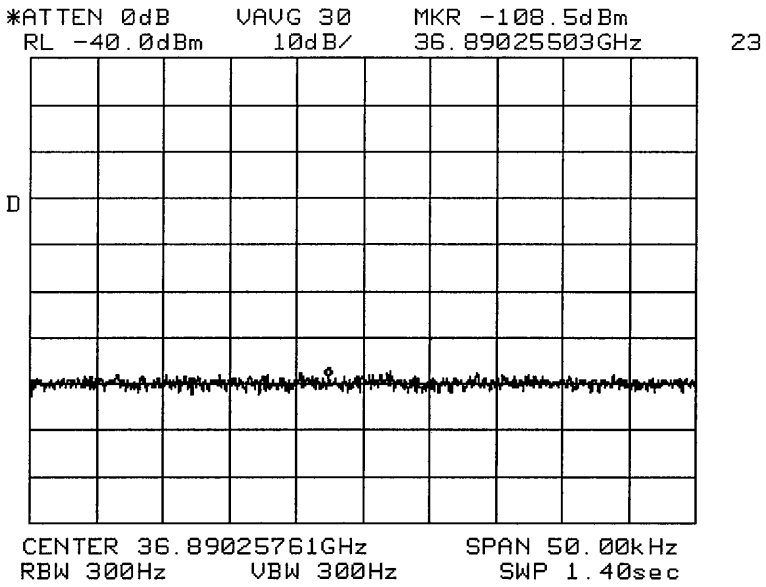
Plot 6: Fifth Harmonic, 300Hz RBW:



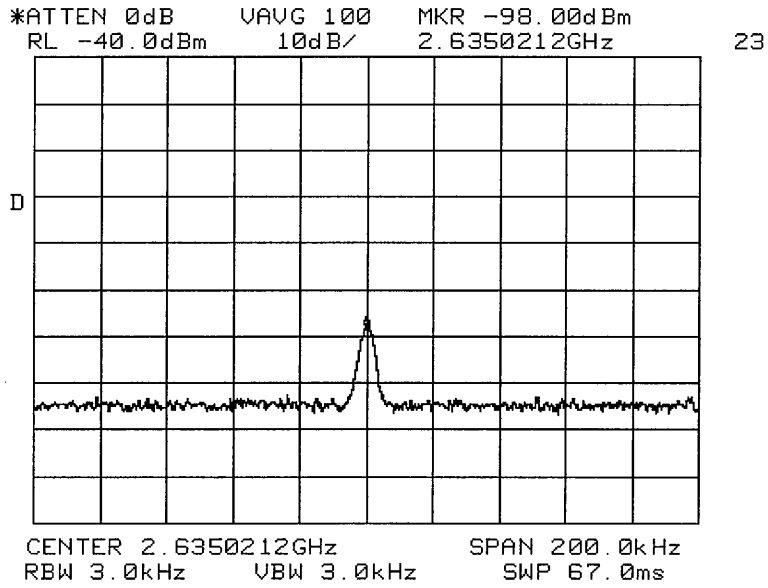
Plot 7: Sixth Harmonic, 300Hz RBW:



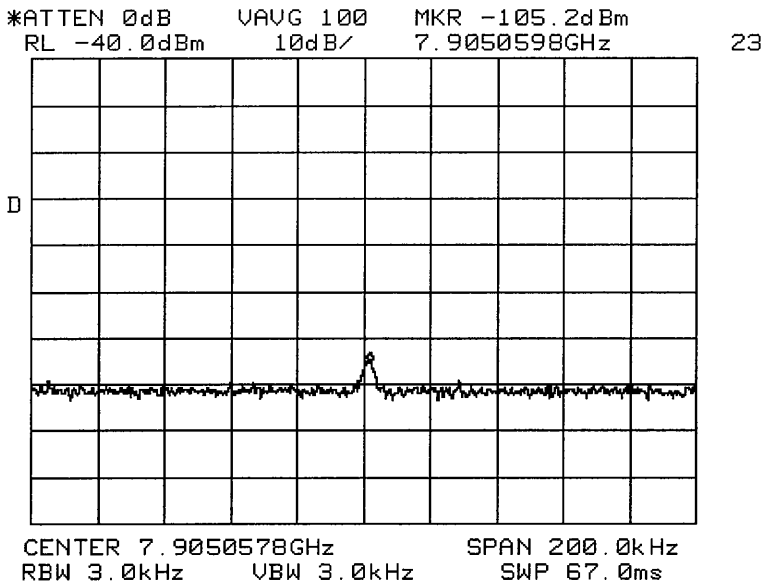
Plot 8: Seventh Harmonic, 300Hz RBW:



Plot 9: VCO Feedthrough, 3kHz RBW:



Plot 10, VCO 3rd Harmonic, 3kHz RBW:



A sample of the error budgeting is shown below. The total error is given in the last row, and shows that the error spread does not exceed +/- 2dB over the frequency range. Although not shown in the sample below, the error terms for the coax cable and the spectrum analyzer are included in the final error terms of the bottom row.

Measurement Error Budget	1-18GHz	18-30GHz	30-40GHz
Error Contribution (dB)	**EMCO 3115**	**EMCO 3116**	**EMCO 3116**
VSWR Contribution in dB	1.00	0.88	0.88
Amplitude Uncertainty	0.30	0.80	1.50
Reference Level			
Total Error, Plus/Minus dB	***1.37***	***1.48***	***1.95***

The following Excel spreadsheet cells show the corrected power levels of the radio. The first sheet shows an ERP of +29.4dBm when the radio was operating at 5270MHz.

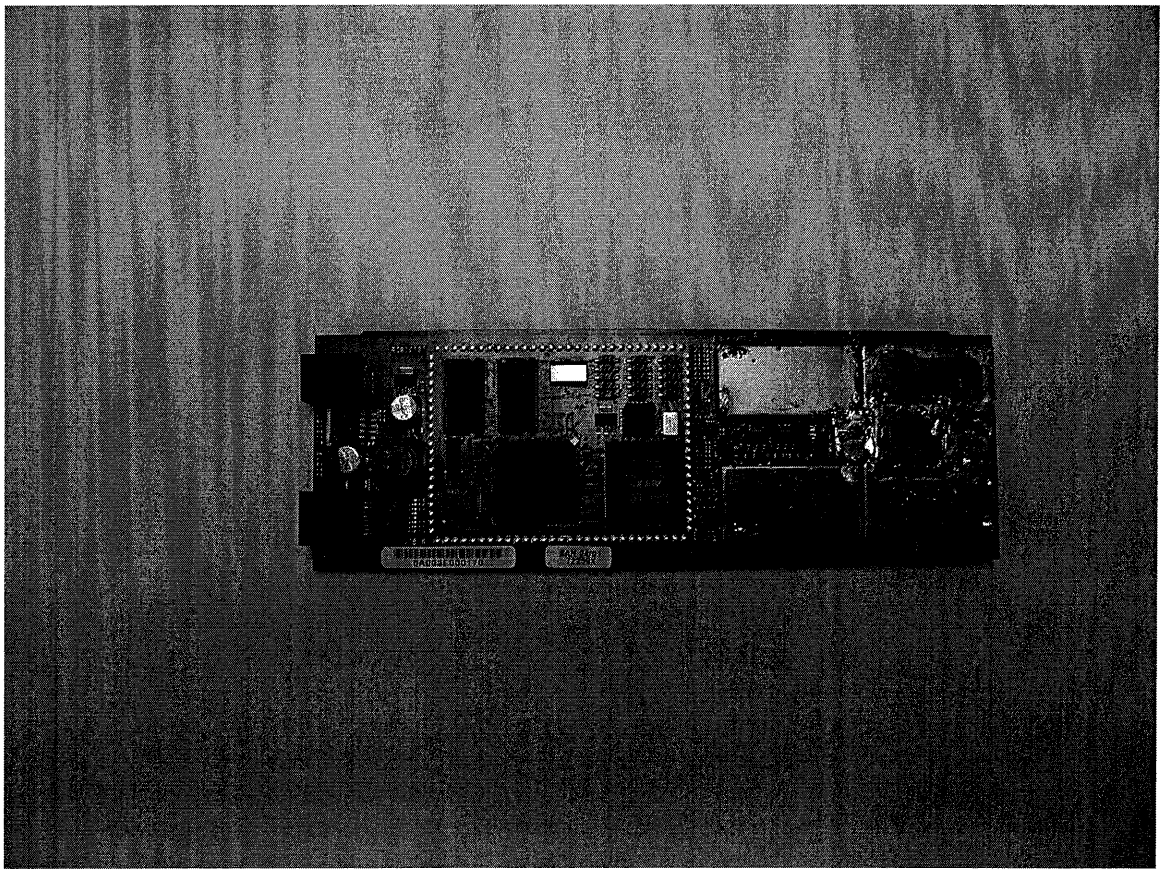
	5270.003	**Fund**
rssi		-20.83
preamp		
cable		-3.023
antenna		9.2
path		-56.42041438
dBm at ref ant.		-27.007
dBm at radio		29.41341438

Harmonic Frequency Testing Spreadsheet Summary:

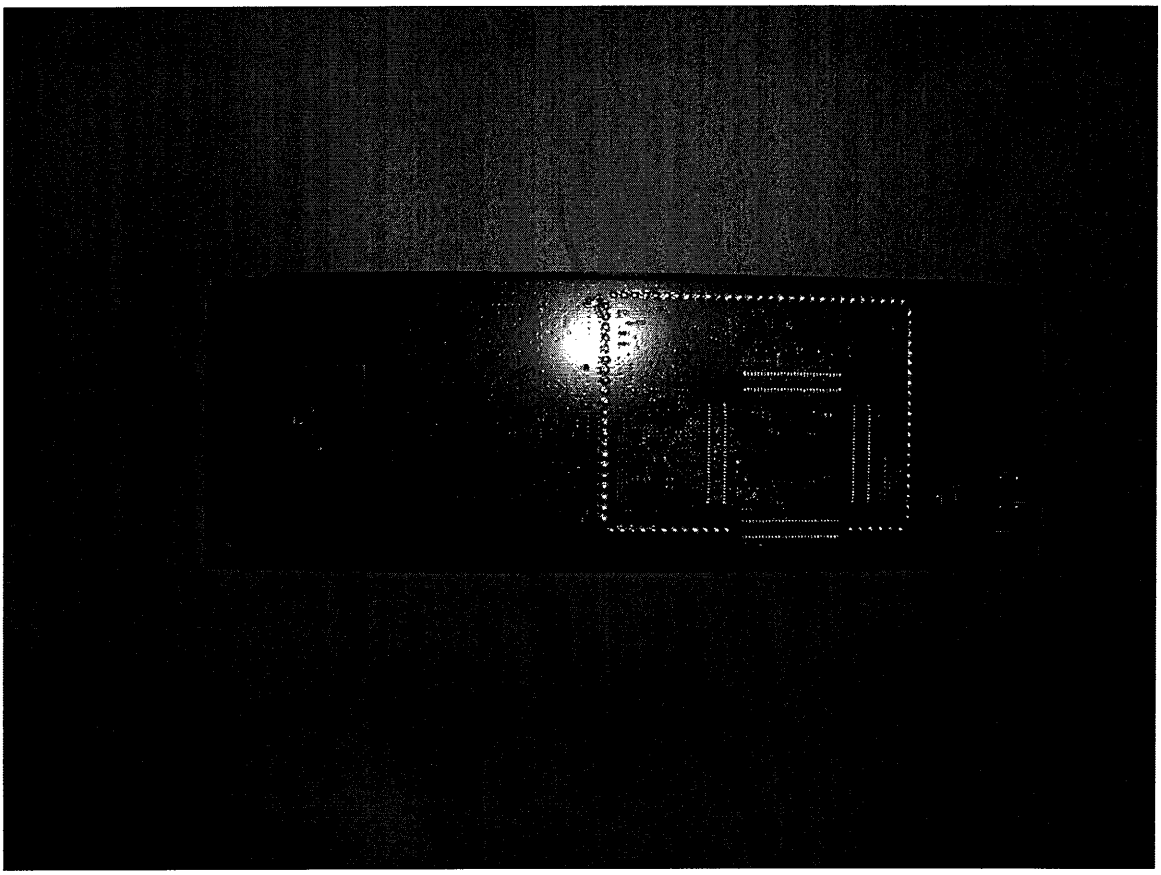
CW Mode	3kHz or 300Hz RBW/VBW				37101.00	Agilent 8564EC Analyzer			
	Freq:=>	2635.00	7905.00	10540.01	15810.01	21080.01	26350.02	31620.02	36890.02
5270.00	**Fund**	**VCO**	**3*LO**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**
Analyzer Level	-20.83	-98.00	-105.20	-86.67	-103.80	-115.00	-116.30	-113.80	-108.50
Cable Loss	-3.02	-2.00	-3.90	-4.46	-6.03	-7.00	-8.05	-9.07	-10.10
Antenna Gain	9.20	7.70	10.00	13.90	15.40	12.30	12.20	12.20	15.30
Path Loss	-56.42	-50.40	-59.94	-62.44	-65.96	-68.46	-70.40	-71.98	-73.32
Power Level at Antenna (dBm)	-27.01	-103.70	-111.30	-96.11	-113.17	-120.30	-120.45	-116.93	-113.70
Power Level at radio (dBm)	29.41	-53.30	-51.36	-33.67	-47.21	-51.84	-50.05	-44.95	-40.38
Level relative to Carrier, dB		82.71	80.77	63.08	76.62	81.25	-3.25	-6.41	6.71
calculated antenna aperture	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
antenna correction to sq. meter in dB	26.69	22.17	29.41	28.01	30.03	35.63	37.67	39.25	37.49
power density at 3 meters (dBm/m^2)	-0.32	-81.53	-81.89	-68.10	-83.14	-84.67	-82.78	-77.68	-76.21
FCC Limit of 500uV/m @ 3meter in dBm	-61.78								
dB better or worse than FCC limit		19.75	20.11	6.32	21.36	22.89	21.00	15.90	14.43

The results show that the radio meets the FCC limit of 500uV/m on the harmonics. The highest level was from the second harmonic and had the lowest margin by being only 6.3 dB better than the limit specification. Even with the measurement uncertainty of the equipment, the radio was still 4.37dB better than the limit.

WHISP unit #170 Component Side:



WHISP Unit #170, Solder Side:



Discussion with Technical Contact at Motorola to Resolve Technical Issues

09/07/2001Telecon with Motorola Inc: Gary Schulz; Rich Keniuk; John Ley
Elite Electronic Engineering Inc.: Ray Klouda

Tuning Range of Device- Device can tune from 5275 to 5325 MHz in 5 MHz steps.

Power output is 30 dBm ERP. The patch antenna is integrated in the PC board. No other antennas are used with this device.

Testing at minimum of 3 frequency required- Device was checked at all channels. Worst-case results were reported.

Band edge compliance tests:

At high end: The power spectral density plot shows the highest channel. Emissions in the restricted band 5.35 to 5.46 MHz were checked worst case was reported. The worst case was 3.8 dB below limit. See page 2 of report.

At low end: Use the power spectral density plot at the highest channel, which has the identical emission characteristics as the lowest channel to demonstrate emissions in the 5.15 to 5.25 GHz band will comply to 15.407(2) and (7). The plot shows that the emissions have maximum ERP of –45 dBm/MHz.

Technical Description of how 15.407(c) is met: The logic in the radio inhibits transmission in the event of frequency error. The data protocol and firmware prevent transmission when there is no data present.

Frequency Stability: This device is specified to operated over the temperature range of –30 deg. C to +65 deg. C with frequency tolerance of 25 ppm.

Operational Manual shows Upper Band frequency range? This device does not include the upper band. The upper band will be a separate device.