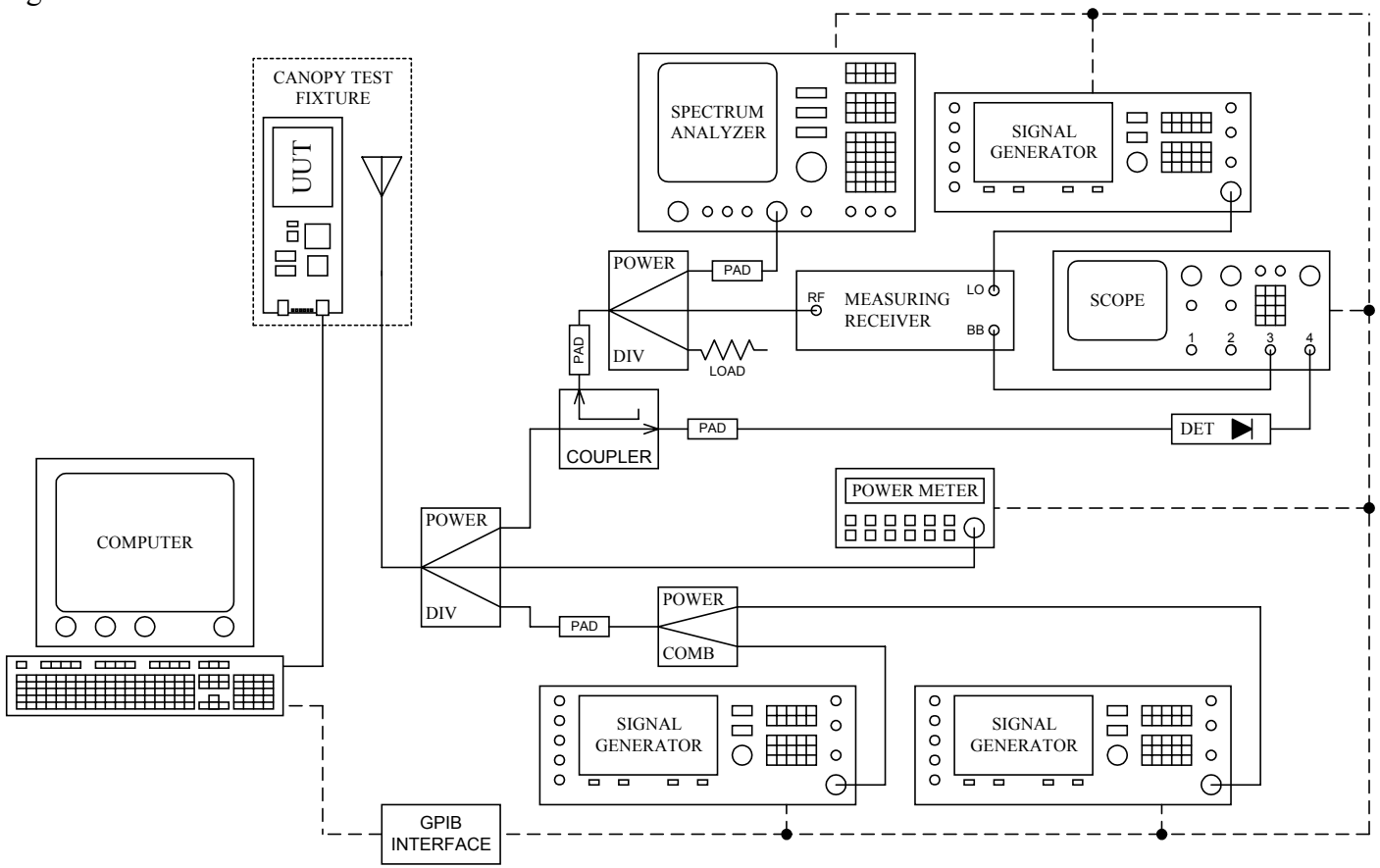
CANOPY 5700ISM Radiated Test
Testing for Compliance with FCC Part 15.247 when Operated in the ISM Band

9 April 2003

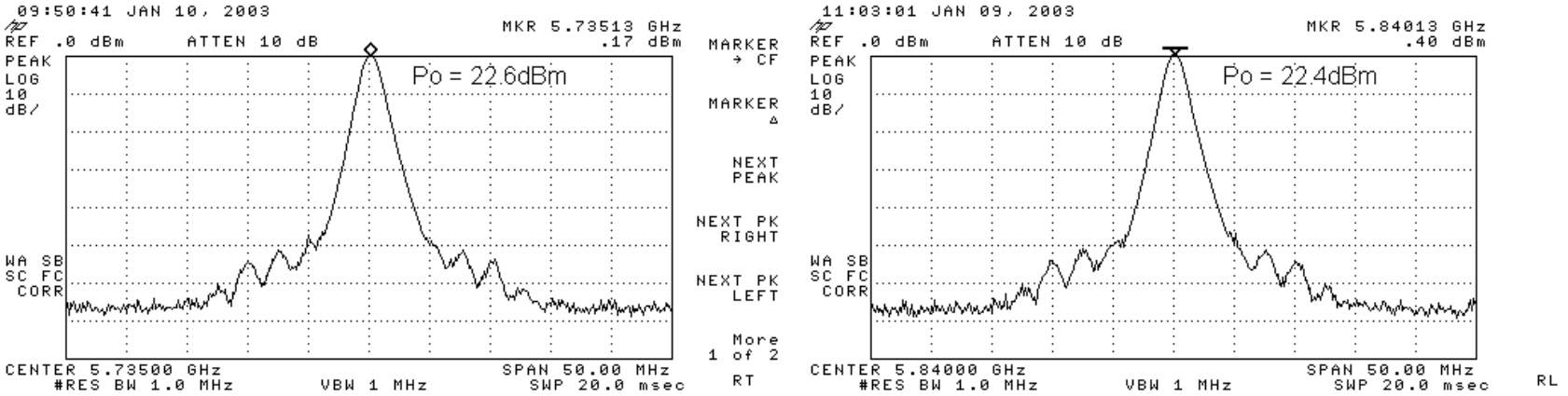
Compliance testing with FCC rules part 15.247 was performed in radiated fashion since production CANOPY units have no RF connector. A test fixture was used to make power spectral density, maximum output power, and occupied bandwidth measurements. A reference antenna replacing the UUT calibrated the coupling factor for the test fixture. Measurements were made on CANOPY unit serial #0A003EF01D36.

The test setup diagram is as follows:



Spectrum Analyzer Reference Level Calibration

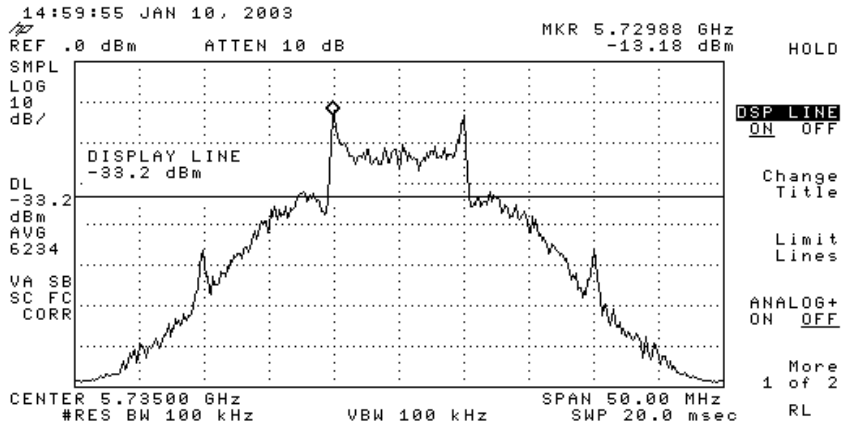
The silent carrier power at all test frequencies was normalized (via the RF attenuator pads in the test station) to 0dBm in the analyzer plots. The dBm units in the plots can be translated to dBc. TX bit error test pattern was initiated at maximum transmit duty cycle and data throughput for the radio under test. This will result in 97.7% duty cycle or an average power versus maximum power ratio of -0.10dB.

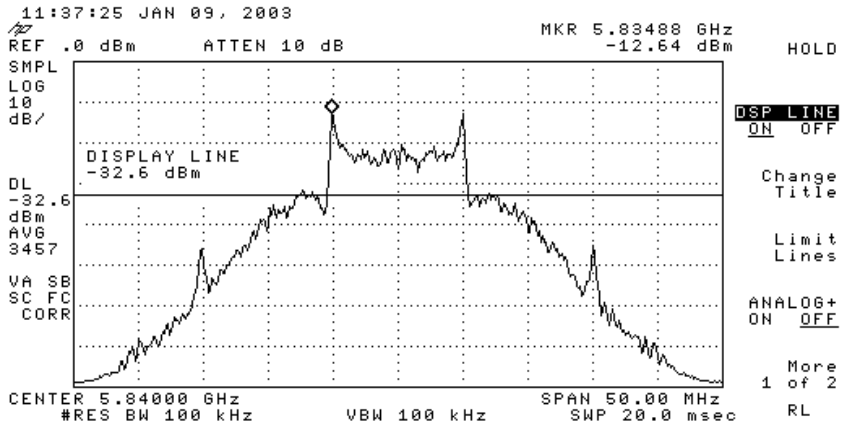


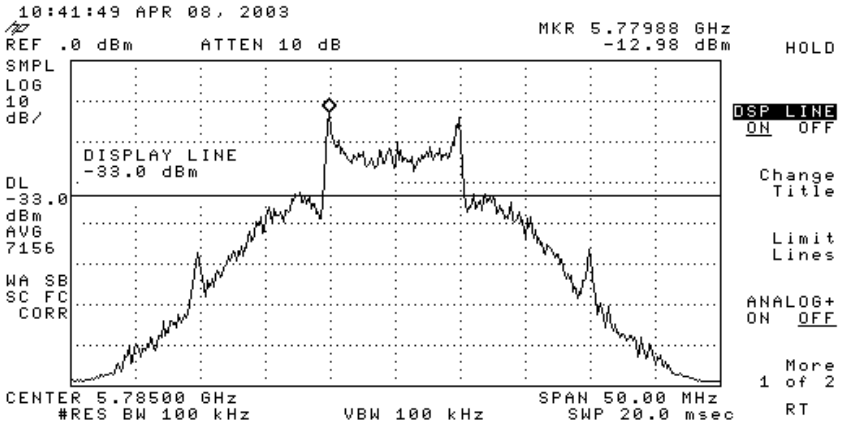
15.247c. Band Edge Requirements

The following plot shows that the CANOPY radio produces an acceptable out-of-band spectral output when operated at the channel limits of 5735MHz at the lowest frequency, and 5840MHz at the highest frequency. The display line indicated the –20dB specification limit for non-restricted out-of-band spectral emissions.

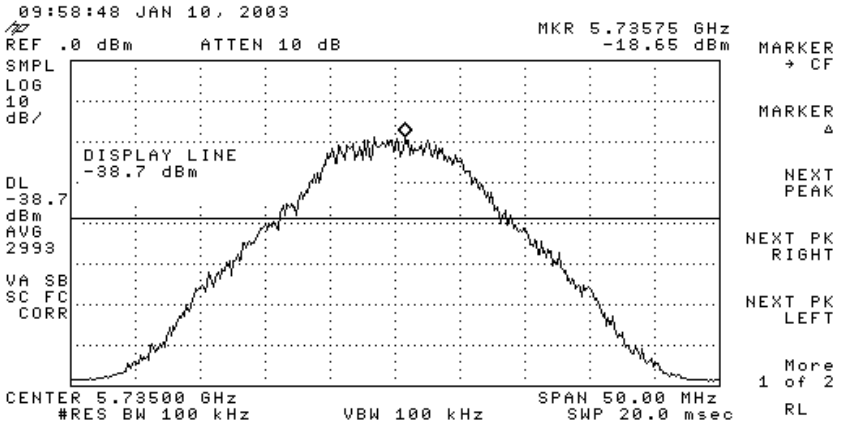
2-Level FSK – 10Mb Signaling

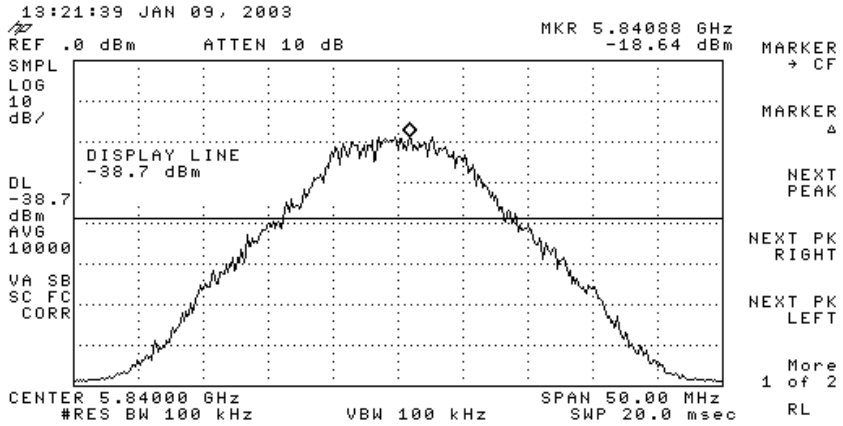


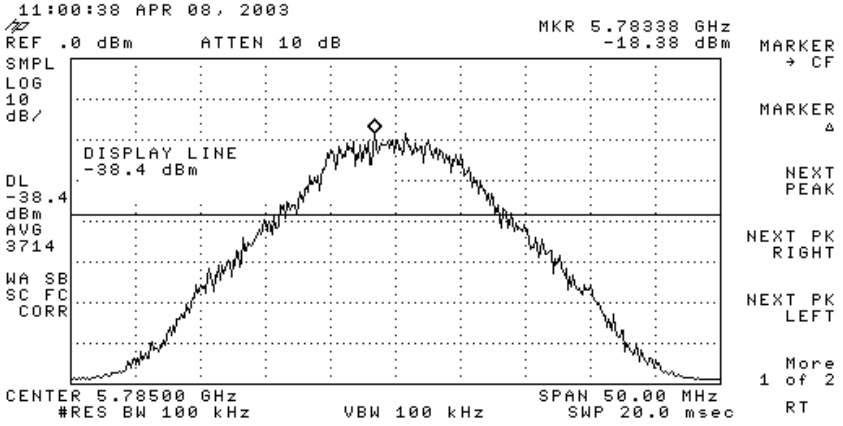




4-Level FSK – 20Mb Signaling





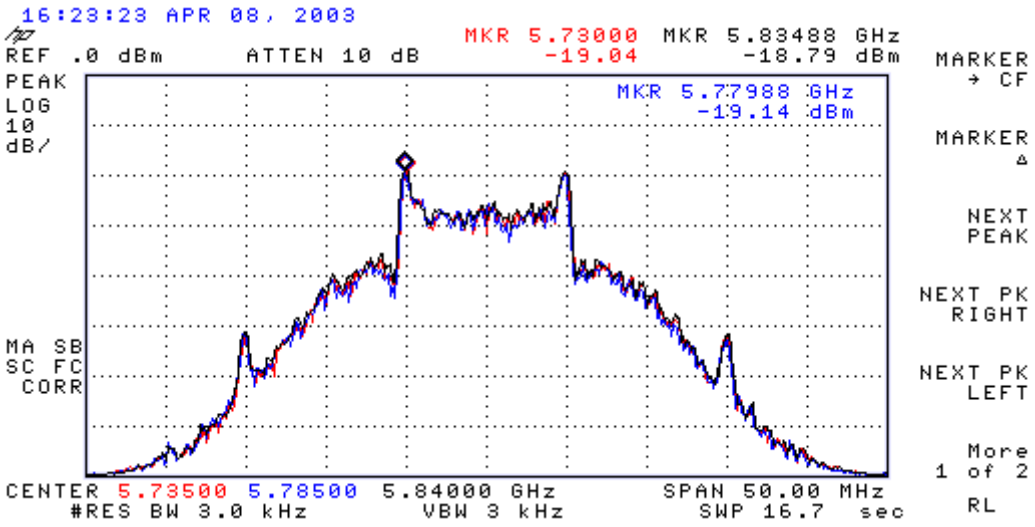


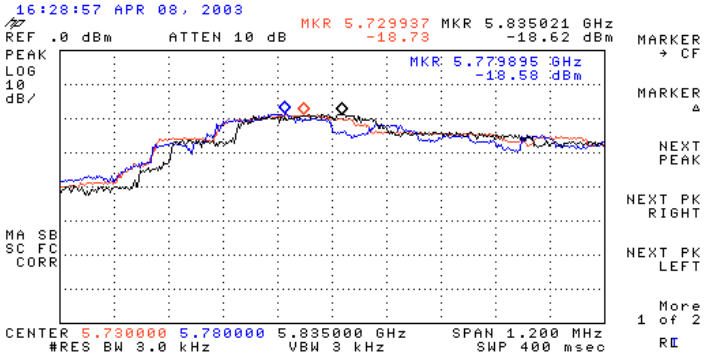
The test results indicated that the band-edge spectral emissions were more than 20dB below the in-band power for both 2FSK and 4FSK modulation modes. The carrier frequencies tested were 5735 and 5840MHz.

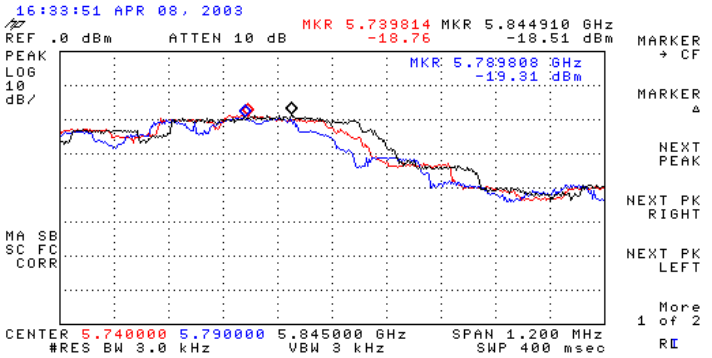
15.247d. Conducted Peak Power Spectral Density

The plots showed below display the peak power spectral density results for the radio operation in the frequency band 5725-5850MHz. The carrier power (translated to a conducted measurement) at the antenna port was 22.6dBm maximum at 5735MHz. At 5785MHz the carrier power was 22.2dBm and 5840MHz the carrier power was 22.4dBm. The specification limit for this unit under test in the plots shown below was –14.6dBc (8dBm).

2-Level FSK – 10Mb Signaling



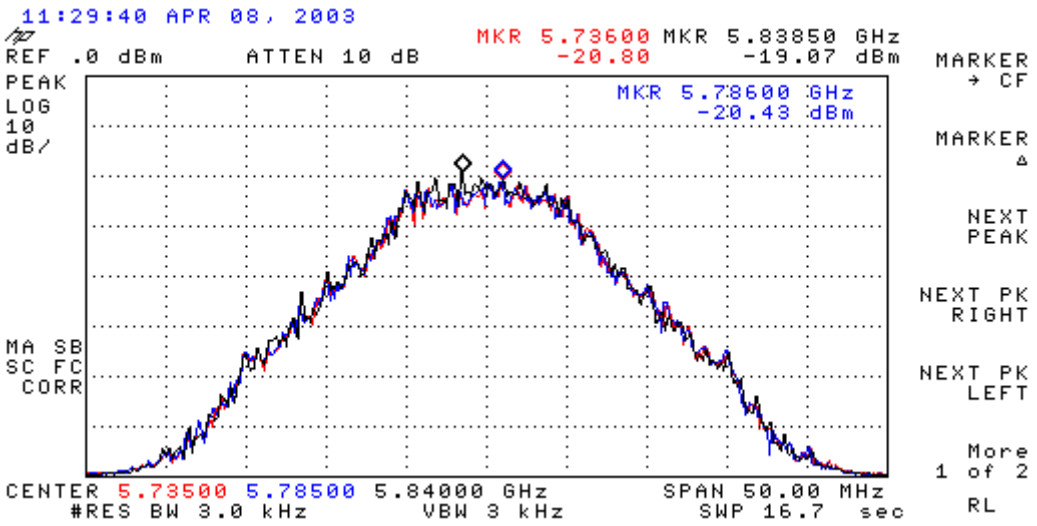


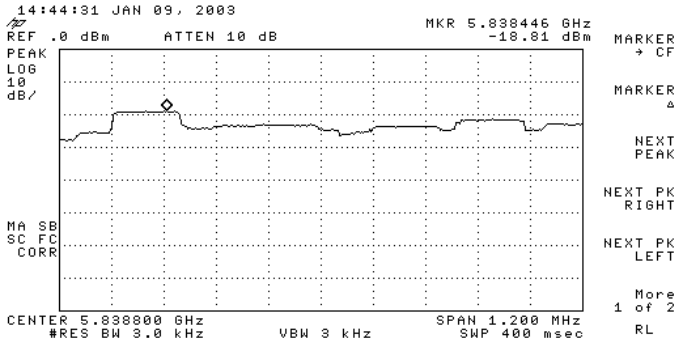


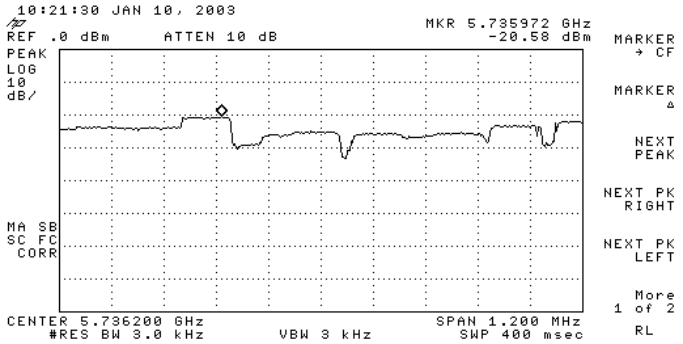
2FSK Modulation Results:

The maximum peak power spectral density when measured in a 3kHz resolution bandwidth was –18.51dBc (3.89dBm) at the uppermost operating frequency of 5840MHz. At 5785MHz the maximum peak power spectral density was measured to be –18.58dBc (3.62dBm). The maximum peak power spectral density was measured to be -18.73dBc (3.87dBm) at the lowest operating frequency of 5735MHz.

4-Level FSK – 20Mb Signaling







4FSK Modulation Results:

The maximum peak power spectral density when measured in a 3kHz resolution bandwidth was –18.81dBc (3.59dBm) at the uppermost operating frequency of 5840MHz. At 5785MHz the maximum peak power spectral density was measured to be –20.36dBc (1.84dBm). At the lowest operating frequency, 5735MHz the maximum peak power spectral density was measured to be –20.58dBc (2.02dBm).

CANOPY 5700ISM Radiated Test
Testing for Compliance with FCC Part 15.209 when Operated in the ISM Band

13 February 2003

A CANOPY 5700 ISM unit, serial #0A003EF01D36, was tested outdoors to check compliance with FCC requirement 15.209, restricted band emissions for ISM data-modulated radios. As the CANOPY radio is already type-approved for U-NII band operation, the tests performed here were limited to measurements of transmit harmonic energy and ISM transmit spectral mask.

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 1 or 3 meters during the test.

The FCC requirement for restricted band emissions is stated in terms of field strength at 500uV/m at a distance of 3 meters. Using the free space impedance of 377 ohms, the equivalent power density is –61.78dBm/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.

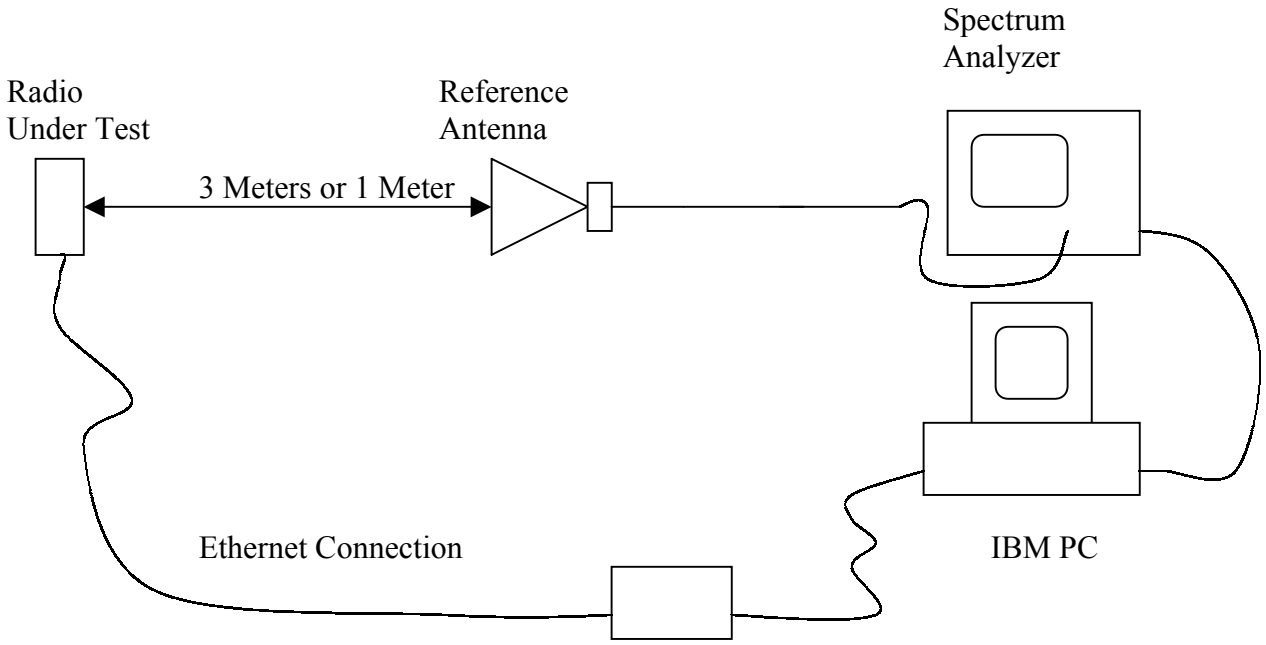
To calculate the power density at the horn antennas, the power level received by the antenna is offset by the log ratio of the effective aperture of the antenna to one square meter. The calculation of the effective aperture is done using:

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

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 test antennas and test radio were mounted on adjustable tripods and placed 1 or 3 meters apart, depending on the measurement antenna type.

The test setup diagram is as follows:

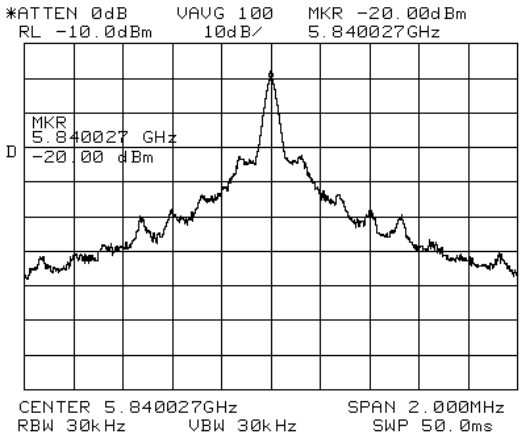


Two different antennas were used, an EMCO model 3115 ridged-waveguide horn antenna covering the 1 to 18GHz frequency range, and an EMCO model 3116 ridged-waveguide horn antenna covering the 18 to 40GHz frequency range. The model 3116 measurement antenna is calibrated for a 1-meter measurement distance, the model 3115 for a 3-meter distance.

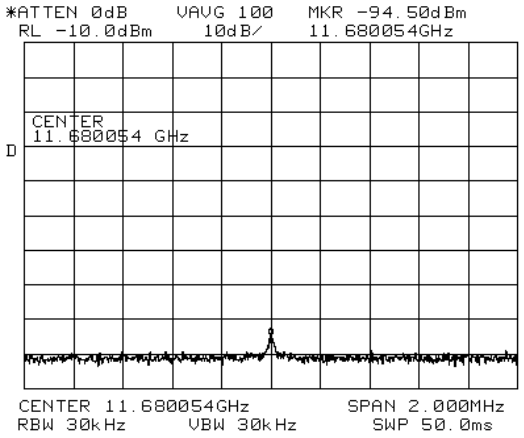
The radio has a CW mode for testing purposes and was used to measure the harmonic levels radiated from the radio. In normal mode operation, the modulated spectrum of the radio has a lower power-spectral density, making accurate measurements difficult. With no modulation, the measurement bandwidth could be reduced to 2MHz, allowing greater dynamic range for the test equipment. Measurements were made using a 30 kHz resolution bandwidth and a 2MHz bandwidth.

Harmonic level as a function of channel frequency was reviewed. After testing the radio at both the high and low channels if the ISM band, we determined that harmonic content was not strongly tied to the channel frequency. An RF frequency of 5840MHz was chosen for this test. Data from the analyzer was transferred to the laptop computer and later processed. The raw spectral plots from the HP8564E analyzer are given below:

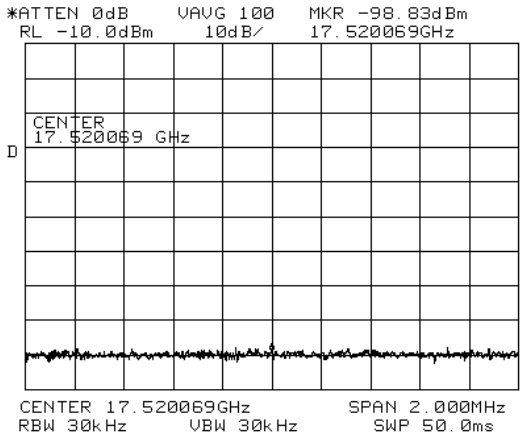
Plot 1: Fundamental frequency: 2MHz Span, 30kHz RBW:



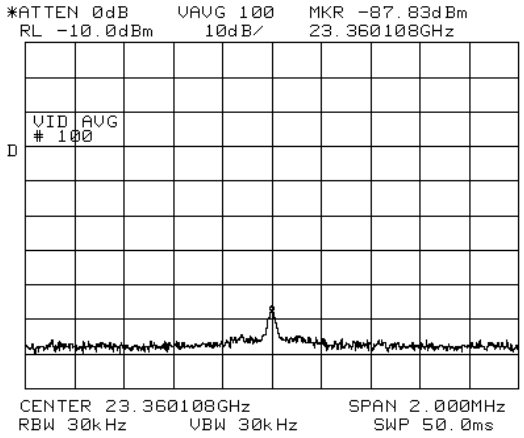
Plot 2: Second Harmonic, 2MHz Span, 30kHz RBW:



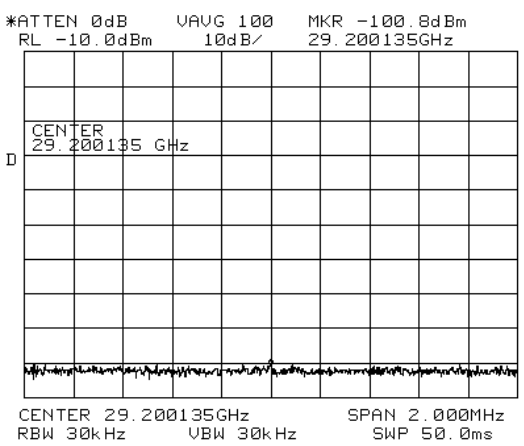
Plot 3: Third Harmonic, 2MHz Span, 30kHz RBW:



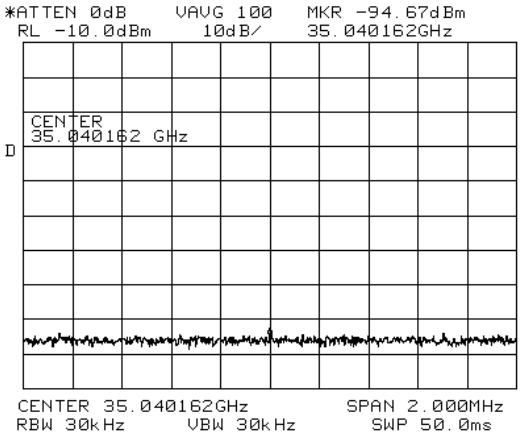
Plot 4: Fourth Harmonic, 1 meter, 2MHz Span, 30kHz RBW:



Plot 5: Fifth Harmonic, 1meter, 2MHz Span, 30kHz RBW:



Plot 6: Sixth Harmonic, 1 meter, 2MHz Span, 30kHz 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 (dB)	0.30	0.80	1.50
Reference Level			
Total Error, ±dB	***1.37***	***1.48***	***1.95***

For a confidence level of 68%, the error budget is then ±0.93dB.

The following Excel spreadsheet cells show the corrected power levels of the radio. The first sheet shows an ERP of +30.79 dBm ±0.93dB when the radio was operating at 5840MHz, well under the FCC limit of +36dBm for part 15.247 (3) devices.

CANOPY ISM Test of Unit #0A003EF01D36

CW Mode	30kHz or 1MHz RBW/VBW
Frequency (MHz):	**5840**
Harmonic:	**Fund**
Analyzer Reading	-20.00
Noise Floor	-102.83
Adjusted Analyzer Level	-20.00
Cable Loss	-3.28
dBm at Antenna Connector	-16.72
Antenna Factor (dB/m)	35.90
Antenna Gain (dBi)	9.80
Path loss	-57.31
Power Level at Antenna	-26.52
dBuV Level at Antenna	80.48
Radio ERP in dBm	30.79

Harmonic Frequency Testing 3 meter - Spreadsheet Summary for CANOPY with Integral Antenna:

CANOPY ISM Test of Unit #0A003EF01D36 * Restricted Band

CW Mode	30kHz or 1MHz RBW/VBW			Agilent 8564EC Analyzer		
	Freq:=>	11680.00	17520.00	23360.00	29200.00	35040.00
5840.00	**Fund**	**2nd**	**3rd**	**4th**	**5th**	**6th**
Analyzer Reading	-20.00	-94.50	-98.83	-87.83	-100.80	-94.67
Noise Floor	-102.83	-101.20	-100.00	-99.00	-103.30	-96.33
Adjusted Analyzer Level (including 1 meter to 3 meter conversion on 4th thru 6th)	-20.00	-95.54	-105.10	-97.72	-113.93	-109.19
Cable Loss	-3.28	-4.64	-5.70	-7.08	-8.50	-10.53
dBm at Antenna Connector	-16.72	-90.91	-99.40	-90.64	-105.43	-98.66
Antenna Factor (dB/m)	35.90	40.60	44.70	45.30	46.50	50.00
Antenna Gain (dBi)	9.80	10.90	9.00	12.20	12.90	11.00
Path loss	-57.31	-63.33	-66.85	-69.35	-71.29	-72.88
Power Level at Antenna	-26.52	-101.81	-108.40	-102.84	-118.33	-109.66
dBuV Level at Antenna	80.48	45.79	43.30	49.46	35.17	47.34
Radio ERP in dBm	30.79	-38.47	-41.54	-33.48	-47.04	-36.79
FCC Restricted Band Emissions Limit	N/A	5.00E-04		5.00E-04		
FCC Out-of-Band Emissions Limit (dBm ERP)	N/A		-27.00		-27.00	-27.00
Emissions Limit in dBuv	N/A	45.22	59.65	45.22	59.65	59.65
Radio Level to FCC Limit in dB (CW Mode)	N/A	-0.58	16.35	-4.25	24.48	12.31
CW to Modulated Mode Reduction (dB)		7	7	8	8	9
Radio Level to FCC Limit in dB (Modulated Mode)		6.42	23.35	3.75	32.48	21.31

The results show that the radio with integral antenna meets the FCC limit of 500uV/m on the harmonics that fall in the restricted band. Since the radio can be equipped with a reflector dish for increased range, testing was done to determine the harmonic energy levels for this configuration.

Harmonic Frequency Testing - Spreadsheet Summary for CANOPY with Reflector Dish:

CANOPY ISM Test of Unit #0A003EF01D36
with Reflector

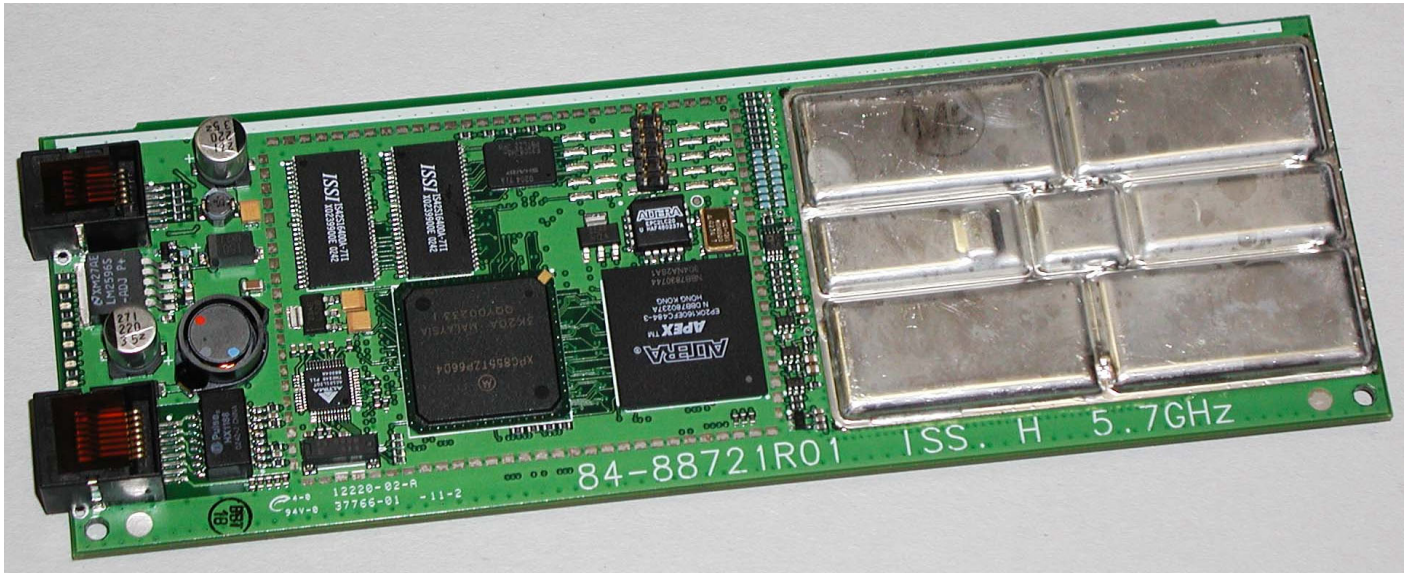
				* Restricted Band		
CW Mode	30kHz or 1MHz RBW/VBW			Agilent 8564EC Analyzer		
	Freq:=>	11680.00	17520.00	23360.00	29200.00	35040.00
5840.00	**Fund**	**2nd**	**3rd**	**4th**	**5th**	**6th**
Analyzer Reading	-20.00	-97.50	-99.17	-96.67	-101.70	-95.83
Noise Floor	-102.83	-101.20	-100.50	-98.17	-102.80	-97.33
Adjusted Analyzer Level	-20.00	-99.92	-104.96	-111.56	-117.74	-110.72
Cable Loss	-3.28	-4.64	-5.70	-7.08	-8.50	-10.53
dBm at Antenna Connector	-16.72	-95.28	-99.26	-104.48	-109.24	-100.19
Antenna Factor (dB/m)	35.90	40.60	44.70	45.30	46.50	50.00
Antenna Gain (dBi)	9.80	10.90	9.00	12.20	12.90	11.00
Path loss	-74.91	-80.93	-84.45	-86.95	-88.89	-90.47
Power Level at Antenna	-26.52	-106.18	-108.26	-116.68	-122.14	-111.19
dBuV Level at Antenna	80.48	41.42	43.44	35.62	31.36	45.81
Radio ERP in dBm	48.39	-25.25	-23.81	-29.73	-33.26	-20.72
FCC Restricted Band Emissions Limit	N/A	5.00E-04		5.00E-04		
FCC Out-of-Band Emssions Limit (dBm ERP)	N/A		-27.00		-27.00	-27.00
Emissions Limit in dBuv	N/A	45.22	59.65	45.22	59.65	59.65
Radio Level to FCC Limit in dB(CW Mode)	N/A	3.79	16.21	9.59	28.29	13.84
CW to Modulated Mode Reduction(dB)		7	7	8	8	9
Radio Level to FCC Limit in dB(Modulated Mode)		10.79	23.21	17.59	36.29	22.84

Testing distance was 22.75 meters to insure far-field operation of reflector. Unit was rotated in both azimuth and elevation planes to find peak harmonic energy. The results show that the reflector-equipped unit also meets FCC limits for harmonic content.

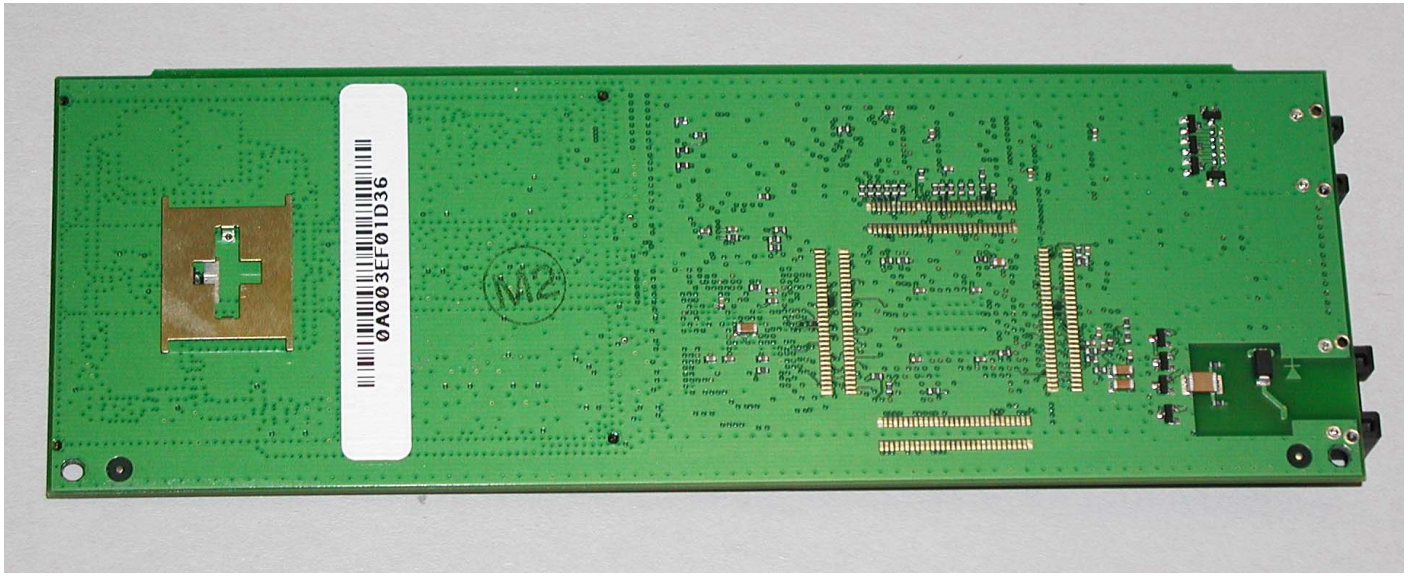
The outdoor radiated test site:

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.

CANOPY unit #0A003EF01D36, Radio Printed Wiring Board (Component Side):



CANOPY Unit #0A003EF01D36, Radio Printed Wiring Board (Solder Side):



The fully assembled CANOPY Unit #0A003EF01D36