Graco Corporation

GNet
Transceiver Module

CONDUCTED EMISSION TESTING

TITLE: GNet MODULE CONDUCTED TESTS		L.S. RESEARCH, Inc. WIRELESS PRODUCT DEVELOPMENT	W66 N220 COMMERCE COURT CEDARBURG, WI 53012, USA (262)-375-4400 FAX: (262)-375-6731 email: eng@lsr.com, http://www.lsr.com
PROJECT: Gnet RADIO MODULE DEVELOPMENT			
DRAWN BY: MARC DENIS, SR RF ENG	DATE: May 4, 2005	SIZE: A	DRAWING NUMBER: GRC01ETP — REVISION: 0.2
CHECKED BY: BRIAN PETTED, VP ENG	DATE: May 4, 2005		
APPROVED BY: BRIAN PETTED, VP ENG	DATE: May 4, 2005		
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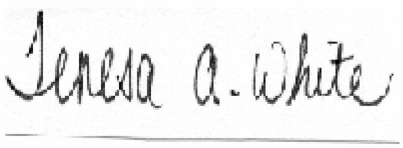
1.0 SIGNATURES

Manufacturer:	**Graco**
Date(s) of Test:	**November 24, 2003, and May 4, 2005**
Test Engineer:	**Marc Denis**
Model #:	
Serial #:	**101**
Operating Mode:	**Hopping / CW, as required per individual test**



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Kenneth L. Boston, EMC Lab Manager Date

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2.0 SCOPE

This report presents the results associated with the conducted emission tests of the Graco Gnet RF Transceiver Module. This particular module is configured for 902-928 MHz operation. This report presents conducted test results required for pre-compliance for authorization under FCC Part 15.247 as a potential frequency hopping device.

3.0 REVISION CONTROL

DATE	CHANGES	REVISION
4/8/2004	ORIGINAL RELEASE	0.0
5/4/2005	EDIT SECTION 5.1.11 TO CHANGE DISTANCE TO 20 CM	0.1
5/4/2005	ADD SECTION 5.1.14 TO ADDRESS 15.31 (E)	0.1
5/4/2005	ADD SECTION 5.2 TO ADDRESS 15.247 (G)	0.1
5/4/2005	ADD SECTION 5.3 TO ADDRESS 15.247 (H)	0.1
5/4/2005	TEST EQUIPMENT LISTING ADDED	0.1
10/03/5	TCB REVISIONS	0.2

4.0 APPLICABLE DOCUMENTS

[1] "Code of Federal Regulations Title 47, Volume 1, Sec. 1.1310 Radiofrequency radiation exposure limits" ***47CFR1.1310,*** Revised as of October 1, 2001, Page 297-298.

[2] "Code of Federal Regulations Title 47, Volume 1, Sec. 2.1091 Radiofrequency radiation exposure evaluation: mobile devices." ***47CFR2.1091,*** Revised as of October 1, 2001, Page 588-589.

[3] "Code of Federal Regulations Title 47, Volume 1, Sec. 15.31 "Measurement standards." ***47CFR15.31,*** Revised as of October 1, 2001, Page 677-681.

[4] "Code of Federal Regulations Title 47, Volume 1, Sec. 15.33 "Frequency range of radiated measurements." ***47CFR15.33,*** Revised as of October 1, 2001, Page 682-683.

[5] "Code of Federal Regulations Title 47, Volume 1, Sec. 15.35 "Measurement detector functions and bandwidths." ***47CFR15.35,*** Revised as of October 1, 2001, Page 683-684.

[6] "Code of Federal Regulations Title 47, Volume 1, Sec. 15.203 "Antenna requirement." ***47CFR15.203,*** Revised as of October 1, 2001, Page 720-721.

[7] "Code of Federal Regulations Title 47, Volume 1, Sec. 15.205 "Restricted Bands of Operation." ***47CFR15.205,*** Revised as of October 1, 2001, Page 721-722.

[8] "Code of Federal Regulations Title 47, Volume 1, Sec. 15.209 "Radiated emission limits; general requirements." ***47CFR15.209,*** Revised as of October 1, 2001, Page 723.

[9] "Code of Federal Regulations Title 47, Volume 1, Sec. 15.247 "Operation within the bands 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz." ***47CFR15.247,*** Revised as of October 1, 2001, Page 733-735.

[10] American National Standards Institute (ANSI) C63.4-1992, ``Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz," ***Electrical and Electronic Engineers, Inc***. July 17, 1992 , Document Number: SH15180.

[11] Federal Communications Commission Public Notice, ``PART 15 UNLICENSED MODULAR TRANSMITTER APPROVAL", June 26, 2000 , Document Number: DA 00-1407.

5.0 EQUIPMENT UNDER TEST CONDITIONS (CONDUCTED EMISSIONS)

The Equipment Under Test (EUT) is the configured using the L.S. Research test tool and RS-232 interface cable. Unless otherwise indicated the settings for radiated measurements are as follows:

1. Nominal Transmit and Receive Frequencies: 902 MHz to 928 MHz
2. Nominal Bit Rate: 76.8 kbps
3. Transmitter Peak Frequency Deviation: 114 kHz
4. Receiver Bandwidth: 600 kHz
5. Output Power Setting: +22.9 dBm
6. Antenna: SMA cable for conducted emissions
7. Power Supply: +9.6 VDC Nominal, +10.6 VDC Maximum, +8.6 VDC Minimum.

The following table is the list of test equipment used.

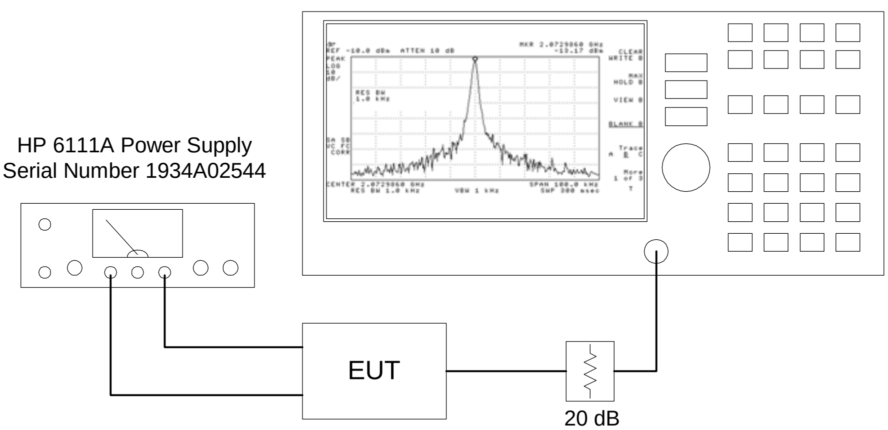
MANUFACTURER	MODEL	EQUIPMENT TYPE	LSR ASSET NUMBER	CALIBRATION DATE
Hewlett Packard	8648A	RF Generator	EE960067	10/4/2004
Agilent	E4411B	Spectrum Analyzer	CC000293C	na
Agilent	E4407B	Spectrum Analyzer	CC000221C	12/7/2004
Hewlett Packard	6111A	Power Supply	CC000220C	na
Fluke	8025B	Multimeter	CC000264C	na

5.1 Output Power and Occupied Bandwidths15.247(a) (b) (c) :

Presented below is the measurement configuration for conducted output power and occupied bandwidths. The test configuration for this device is simply direct spectrum analysis using an Agilent E4407B spectrum analyzer, LSR Asset number CC000283, calibrated October 28,2002 .

The EUT was fitted with a short 2 inch length of RG-174 cable with a female SMA connector. To this was attached a short length of RG-316/U coaxial cable and a 5 and a 15 dB attenuator. The cable and attenuators were measured to have a total insertion loss of 21 dB. An input gain offset of 21 dB was entered to produce correct readings direct from the instrument with no further correction.

The channel power measurement feature of the E4407B is utilized where appropriate.



5.1.1 Minimum Channel Separation (Part 15.247(a)(1))

Part 15.247(a)(1) requires a frequency spacing of at least 25 kHz or the 20dB emission bandwidth, which ever is greater.

The radio uses a channel plan with spacing of 525 kHz between 902 MHz and 907.5 MHz. It switches to a spacing of 430 kHz between 907.5 MHz and 922.5 MHz, then back to 525 kHz between 922.5 MHz and 928 MHz. This is necessary to accommodate some performance characteristics of the receiver circuit.

The widest 20 dB bandwidth of transmission (Section 4.1.8) is 390 kHz.

Minimum Channel Spacing of 430 kHz > 390 kHz. **PASS**

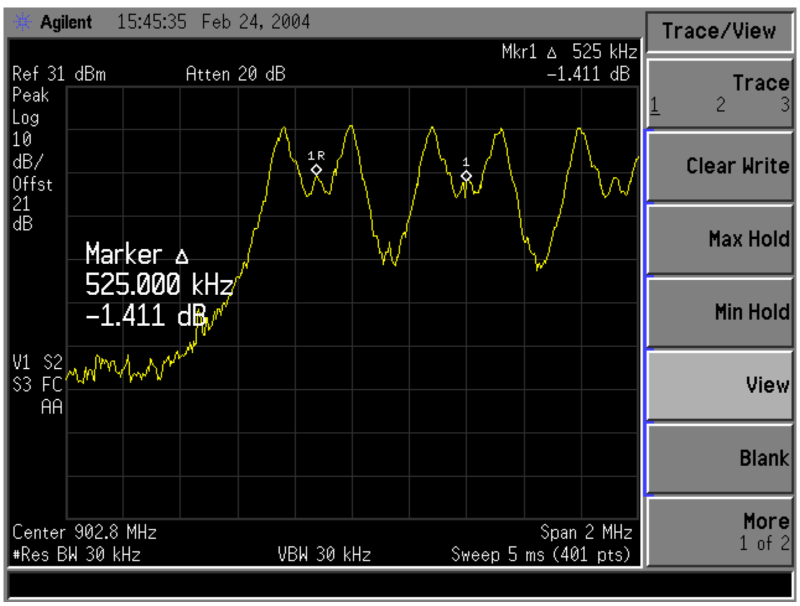


Figure 1. Channel separation at low band is 525 kHz

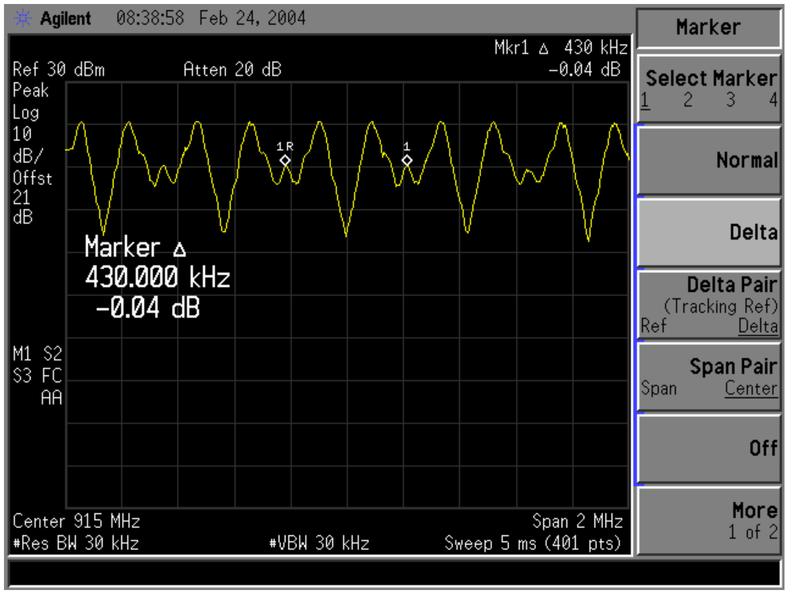


Figure 2. Channel separation at mid band is 430 kHz

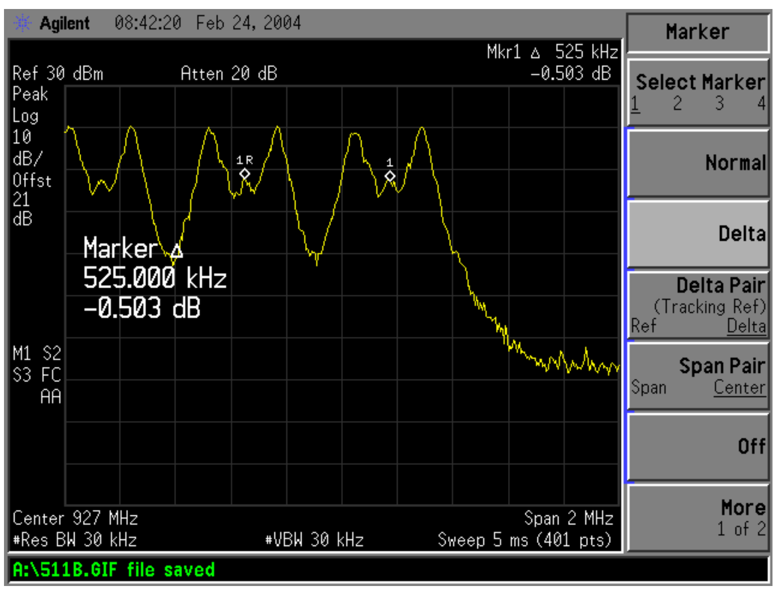


Figure 3. Channel separation at high band is 525 kHz

5.1.2 Equal Channel Usage (Part 15.247(a)(1))

50 channels are chosen from a pool of 53 available frequencies. These channels are arrayed in a table which the system uses to determine the next hopping channel. Each time a transmission is made the system uses the next frequency in the table. The table is started over once the end has been reached. Thus, any given frequency will not be reused until all other frequencies have been accessed.

5.1.3 Pseudorandom Hopping Pattern (Part 15.247(a)(1))

The hopping table is built using an 8 bit seed into an $X^{15}+1$ pseudorandom number generator giving the possibility of 256 unique pseudorandom hopping tables.. Output from the generator is used to pick frequencies from a pool of 53 available channels.

5.1.4 Receiver Synchronization (Part 15.247(a)(1))

Each receiver requires the same seed for the pseudorandom sequence generator as the transmitter it is operating with. The same seed will produce the same hop sequence in each device. Once the receiver scans and finds the transmitter on any given channel it will automatically be synchronized to go to the next correct channel by virtue of using the same hopping table.

5.1.5 Receiver Input Bandwidth (Part 15.247(a)(1))

The radio receiver is a direct conversion type with a baseband filter whose cutoff frequency is matched to the transmission spectrum. The bandwidth is 600 kHz for use at the 76.8 kbps rate. Two level frequency shift keying is used for modulation. The simple Carson bandwidth for this type of signal is given as the bit rate plus 2 times the deviation. This system uses 114 kHz deviation for the 76.8 kbps rate, giving a bandwidth of 304.8 kHz. The excess filter bandwidth allows for frequency tolerance errors between the transmitter and receiver.

5.1.6 Number of Hopping Frequencies (Part 15.247(a)(1)(i))

Transmitted 20dB bandwidth is a maximum of 390 kHz. This gives a requirement of at least 25 hopping channels. The unit is designed to operate over 50 channels, which exceeds the requirements.

Figures 4 through 14 show band usage captured in 3 MHz parts to make all channels visible. Channels have been counted and are presented below:

5+5+3.5+4.5+4+4+5+4.5+4.5+5+5=**50** **PASS**

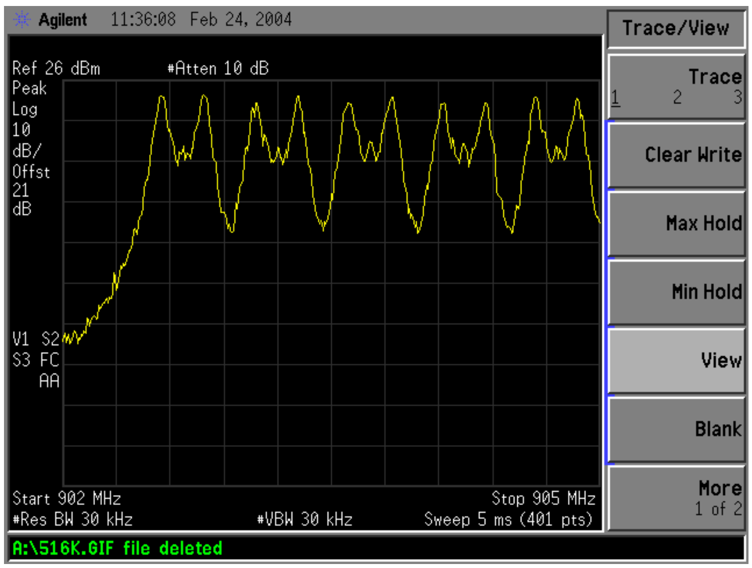


Figure 4. 5 channels from 902 MHz to 905 MHz

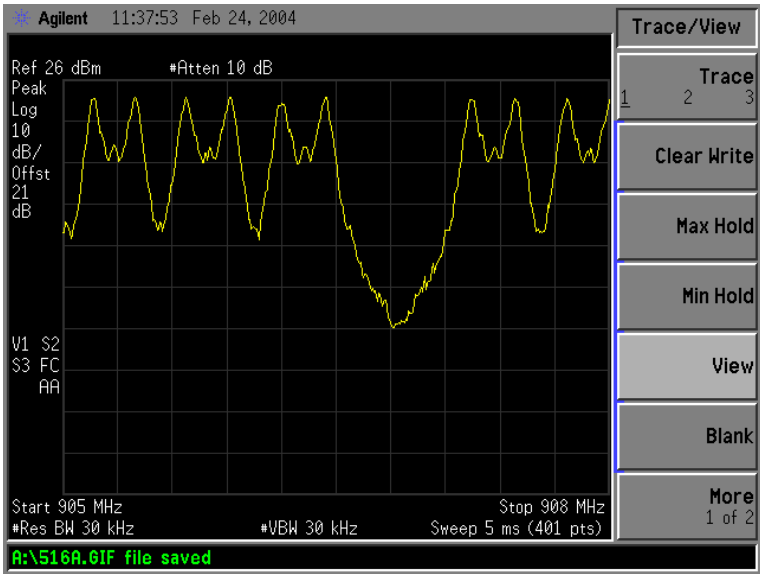


Figure 5. 5 channels from 905 MHz to 908 MHz

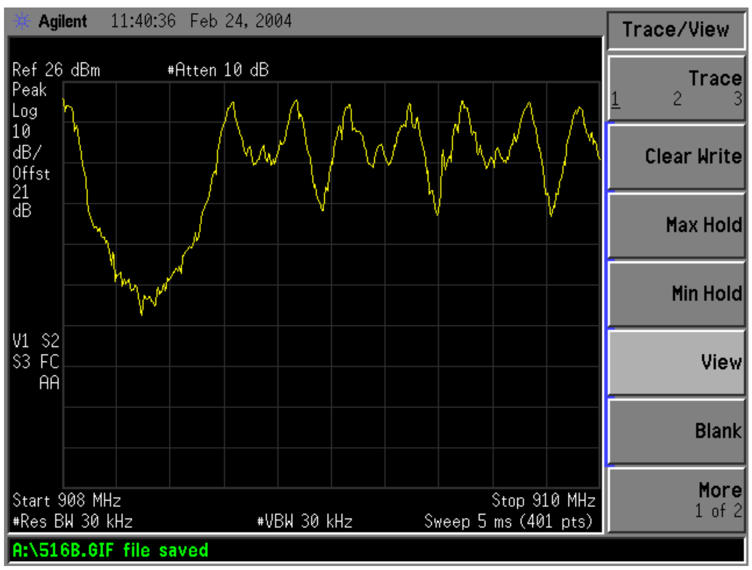


Figure 6. 3.5 channels from 908 MHz to 910 MHz

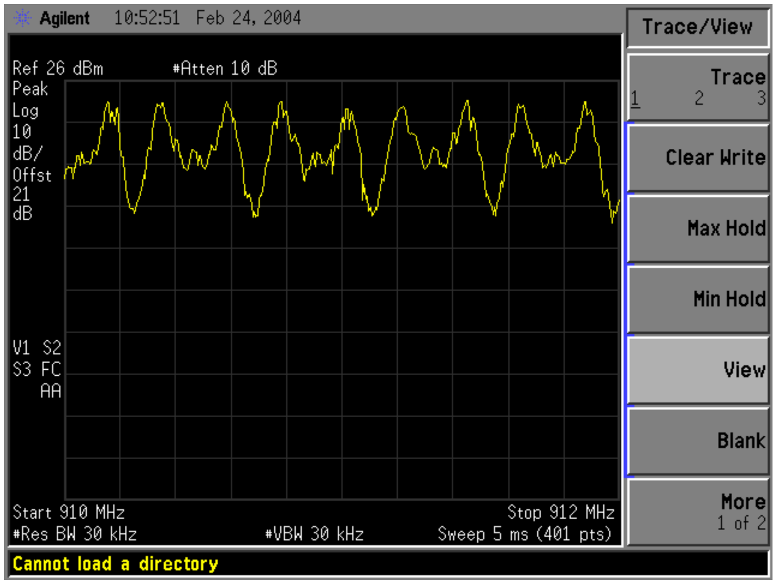


Figure 7. 4.5 channels from 910 MHz to 912 MHz

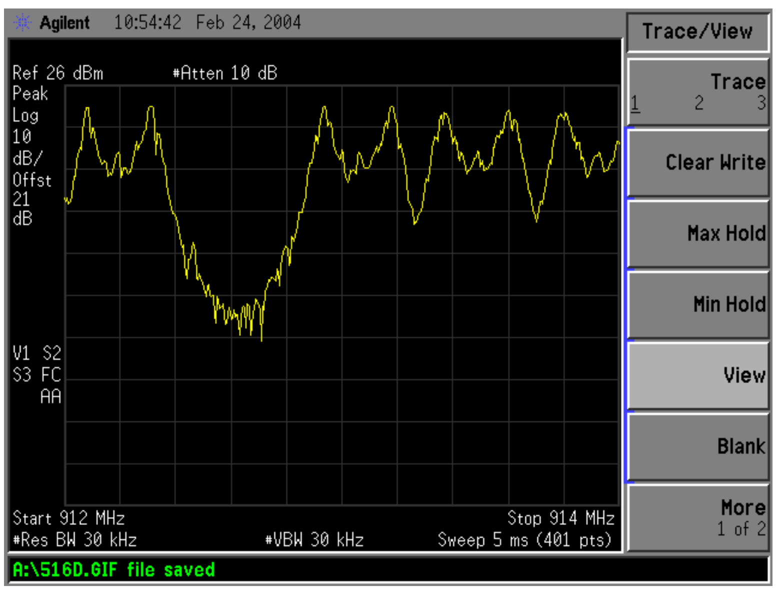


Figure 8. 4 channels from 912 MHz to 914 MHz

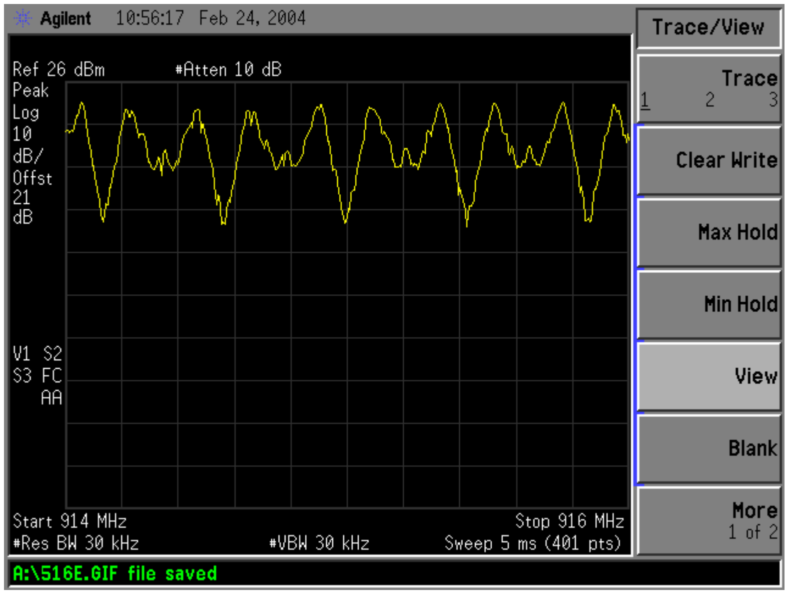


Figure 9. 4 channels from 914 MHz to 916 MHz

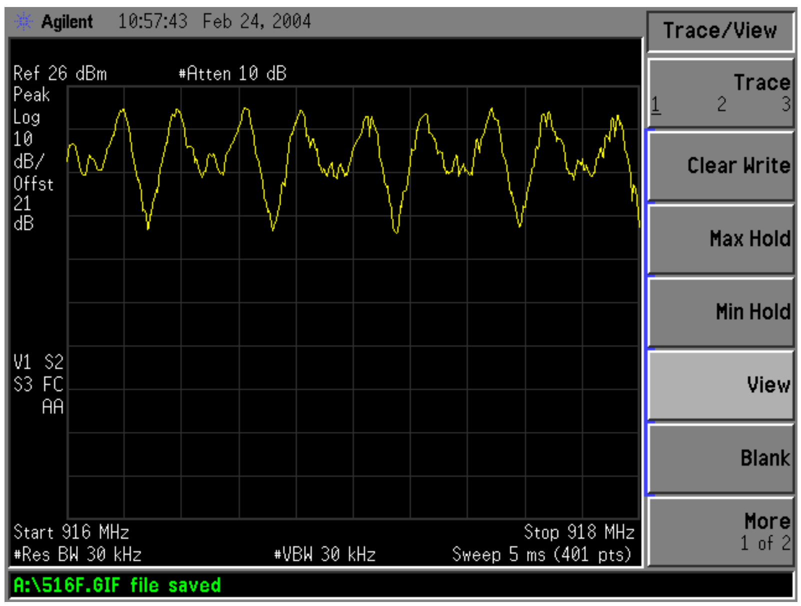


Figure 10. 5 channels from 916 MHz to 918 MHz

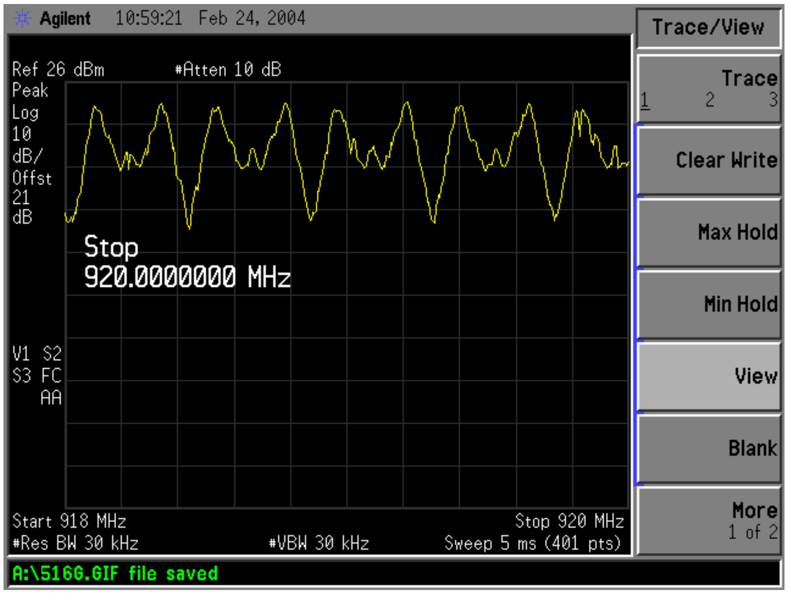


Figure 11. 4.5 channels from 918 MHz to 920 MHz

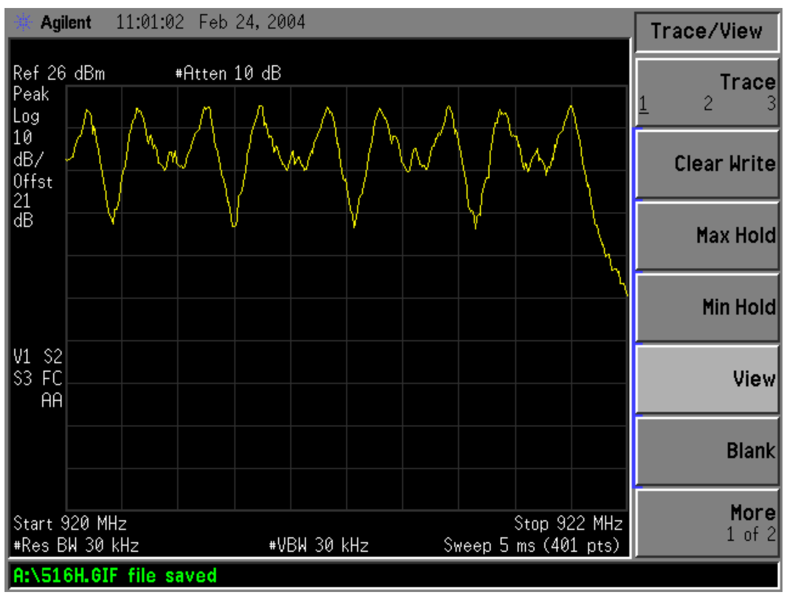


Figure 12. 4.5 channels from 920 MHz to 922 MHz

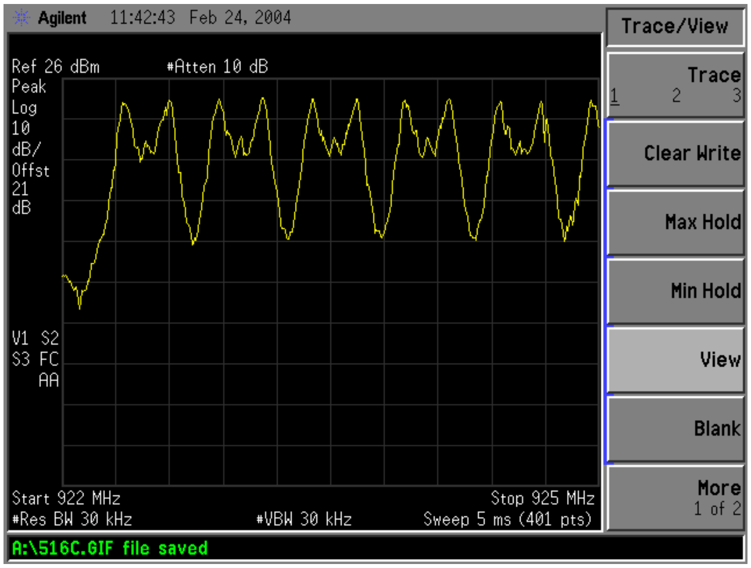


Figure 13. 5 channels from 922 MHz to 925 MHz

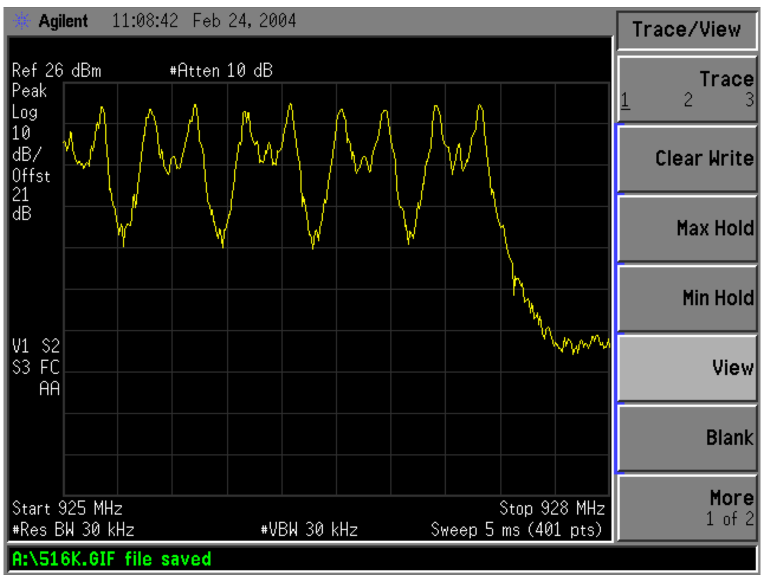


Figure 14. 5 channels from 925 MHz to 928 MHz

5.1.7 Dwell Time (Part 15.247(a)(1)(i))

A system with a 20dB bandwidth greater than 250 kHz must not occupy a given channel for more than 400 mS in a 10 second window.

The longest time any transmission will occur on a single channel is 50.5 mS (Figure 15)

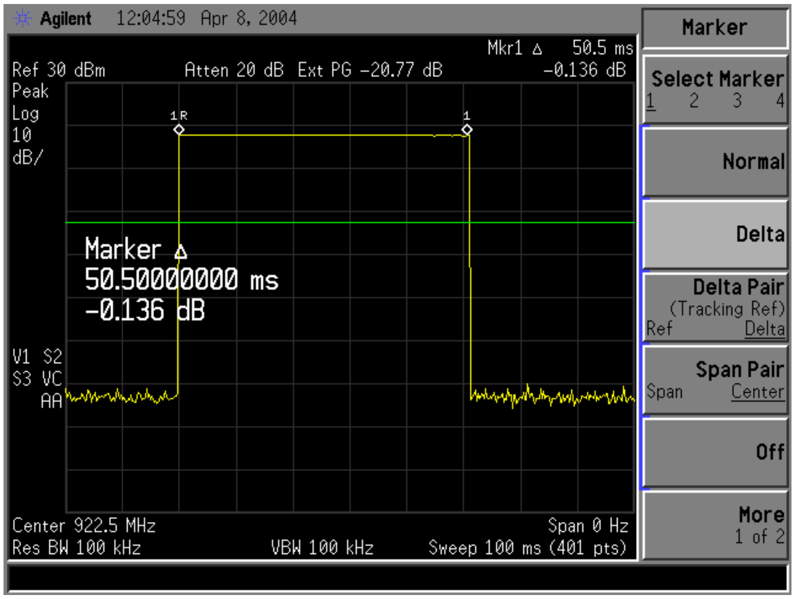


Figure 15. Longest channel dwell time is 54.5 mS.

A total of 50 channels are used. With each channel occupying 50.5 mS it will take 2.525 seconds for the sequence to repeat. 3.96 repetitions will fit into a 10 second window giving a maximum channel occupancy of 199.98 mS in a 10 second window.

199.98 mS < 400 mS **PASS**

5.1.8 20dB Bandwidth (Part 15.247(a)(1)(i))

Test Conditions	
EUT Mode	Hopping
Data Rate	76.8 kbps
EUT Power Setting	22.9 dBm
Span	1 MHz
RBW	30 kHz
VBW	30 kHz
Detector	Peak
Display Mode	Max Hold

Test Results			
Frequency (MHz)	**Measured Bandwidth (kHz)**	**Bandwidth Limit (kHz)**	**Test Indication**
902.77	388	500	**PASS**
914.85	390	500	**PASS**
927.21	385	500	**PASS**

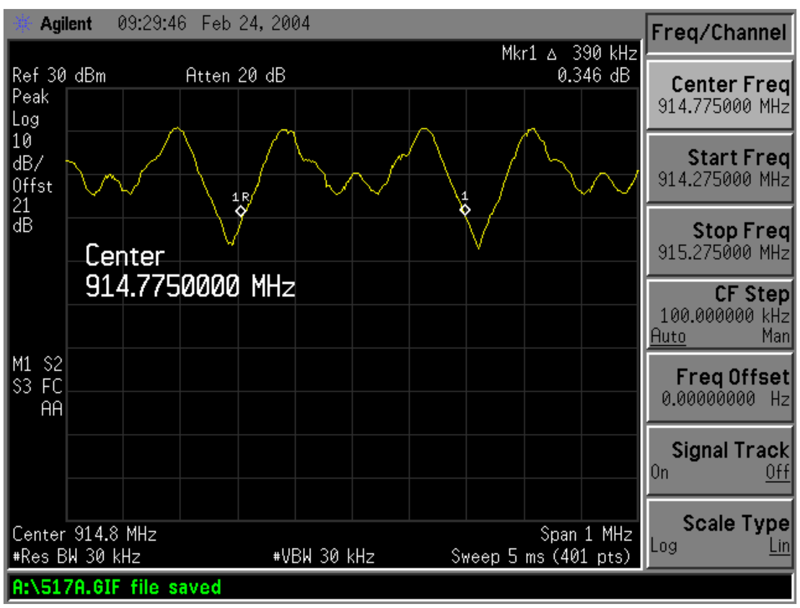


Figure 16. Widest 20 dB channel bandwidth is 390 kHz

5.1.9 Peak Output Power (Part 15.247(b)(2)

A peak output power of 1 Watt is allowed by virtue of having 50 hopping channels.

Test Conditions	
EUT Mode	Single channel transmit
Data Rate	76.8 kbps
EUT Power Setting	+22.9
EUT Supply Voltage	8.16, 906, 11.0 VDC
Span	2.25 MHz
RBW	10 kHz
VBW	100 kHz
Detector	Sampling with Power Avg.
Display Mode	Channel Power

Output Power Test Results

Set Frequency (MHz)	Supply Voltage (Volts)	Measured Power (dBm)	Power Limit (dBm)	Test Indication
902.700	8.16	22.8	30	**PASS**
	9.6	22.7	30	**PASS**
	11.0	22.1	30	**PASS**
914.775	8.16	22.0	30	**PASS**
	9.6	22.0	30	**PASS**
	11.0	21.8	30	**PASS**
927.175	8.16	21.5	30	**PASS**
	9.6	21.4	30	**PASS**
	11.0	21.3	30	**PASS**

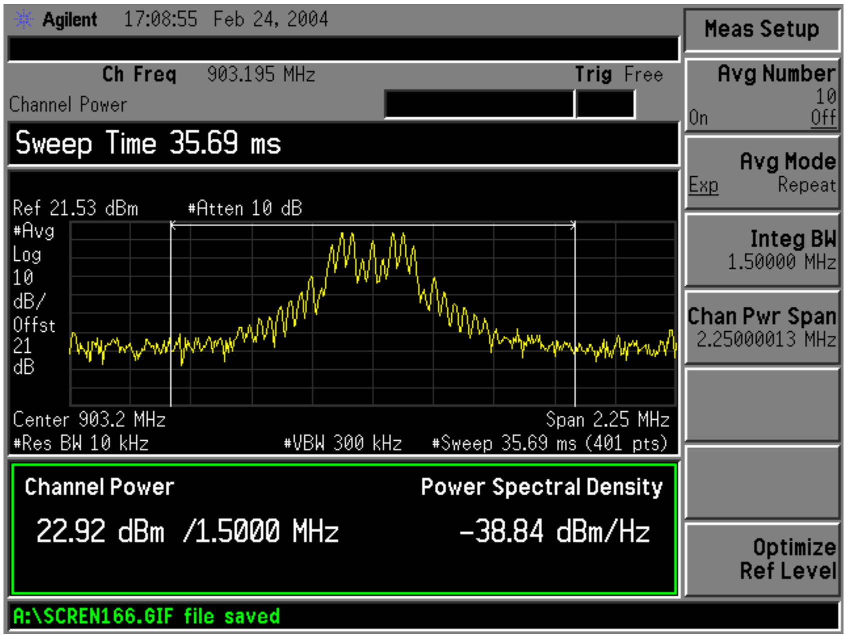


Figure 17. Highest channel power is +22.92 dBm on lowest channel at 8.6 to 10.6 volt supply input.

The Agilent E4407B has resident measurement software which measures the amount of power in a given channel. We have used this measurement capability to measure the total transmitter power. In general, power measurements should be taken with a measurement bandwidth greater than the 20 dB bandwidth of the modulated signal. In the Agilent E4407B, this is taken into account when using the "Channel Power" measurement function. The analyzer performs an integrated power measurement within the specified bandwidth. In our case, the measurement bandwidth was set to 1.50 MHz, with the RBW at 10 kHz. Then the analyzer summed up the power spectral density in 10 kHz steps over a bandwidth of 1.50 MHz giving the total integrated power over 1.50 MHz. Since the 20 dB emission bandwidth of our signal is less than 500 kHz, the 1.50 MHz bandwidth is more than sufficient to get the true output power.

5.1.10 EIRP Limit (Part15.247(b)(3))

Parts 15.247(b)(2) and 15.247(b)(3) set maximum power limit of 1 watt (+30 dBm) conducted into an antenna with 6.0 dBi of gain, or less. This gives a maximum ERP of +36.0 dBm.

The Graco GNet module has a maximum conducted output power of +22.9 dBm. The specified wire antenna has a gain of 0 dBi yielding an ERP of +22.9 dBm which is less than the limit of +36.0 dBm.

5.1.11 Maximum Permissible Exposure (Part 15.247(b)(4)))

Prediction of MPE limit at a given distance

Equation from page 18 of OET Bulletin 65, Edition 97-01

$$S = \frac{PG}{4\pi R^2}$$

where: S = power density
P = power input to the antenna
G = power gain of the antenna in the direction of interest relative to an isotropic radiator
R = distance to the center of radiation of the antenna

Maximum peak output power at antenna input terminal:	23.00	(dBm)
Maximum peak output power at antenna input terminal:	199.5262315	(mW)
Antenna gain(typical):	0	(dBi)
Maximum antenna gain:	1	(numeric)
Prediction distance:	20	(cm)
Prediction frequency:	915	(MHz)
MPE limit for uncontrolled exposure at prediction frequency:	0.61	(mW/cm^2)
Power density at prediction frequency:	0.039694	(mW/cm^2)
Maximum allowable antenna gain:	11.8659969	(dBi)
Margin of Compliance at 20cm:	11.8659969	(dB)

5.1.12 Spurious Emission at Band Edges (Part 15.247(c))

Test Conditions	
EUT Mode	Hopping
Data Rate	76.8 kbps
EUT Power Setting	22.9 dBm
EUT Supply Voltage	+9.6 VDC
Span	10 MHz
RBW	100 kHz
VBW	100 kHz
Detector	Peak
Display Mode	Max Hold

Test Results			
Band Edge	**Spur Level (dBc)**	**Spur Limit (dBc)**	**Test Indication**
Lower	-46.00	-20	**PASS**
Upper	-52.18	-20	**PASS**

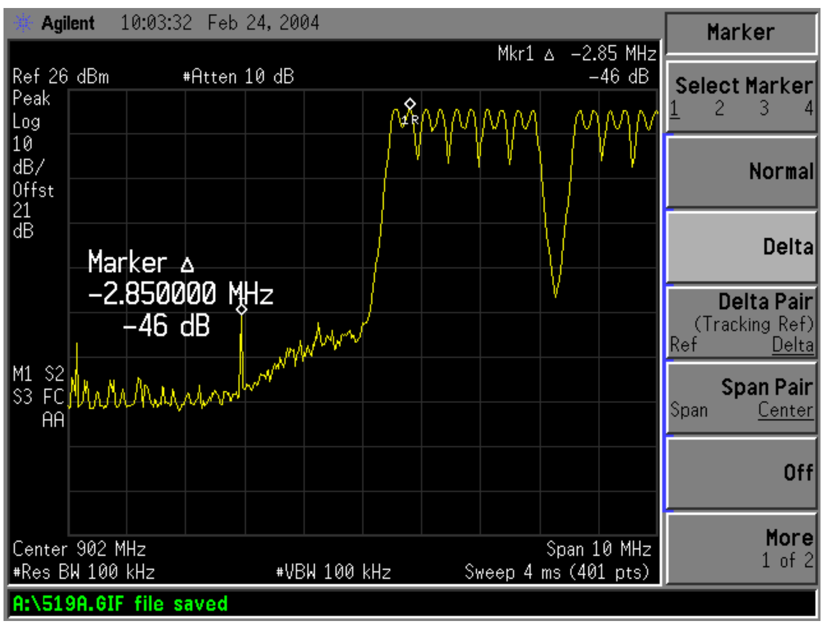


Figure 18. Spurious emission at lower band edge is -48.29 dBc.

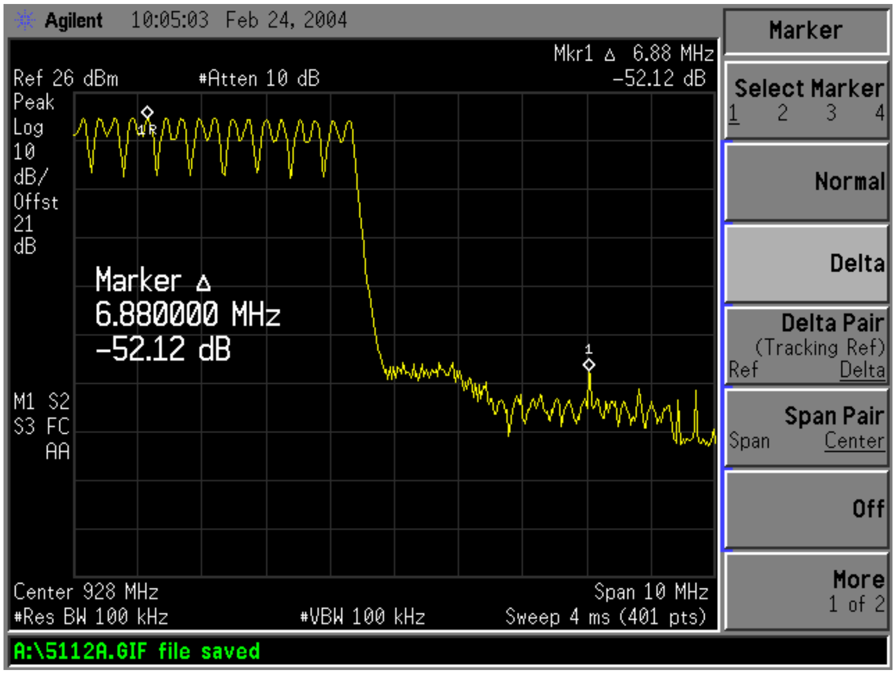


Figure 19. Spurious emission at upper band edge is -49.06 dBc.

5.1.13 Spurious Emission, Wideband (Part 15.247(c))

Test Conditions	
EUT Mode	Hopping
Data Rate	76.8 kbps
EUT Power Setting	22.9 dBm
EUT Supply Voltage	+9.6 VDC
Span	As Required
RBW	100 kHz
VBW	100 kHz
Detector	Peak
Display Mode	Max Hold

Test Results			
Frequency Span	**Spur Level (dBc)**	**Spur Limit (dBc)**	**Test Indication**
9 kHz to 902 MHz	-63.75	-20	**PASS**
928 MHz to 10 GHz	-59.60	-20	**PASS**

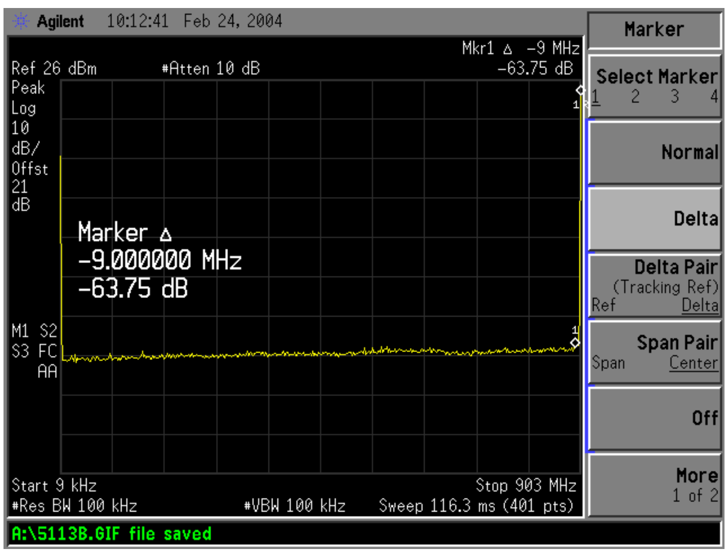


Figure 20. Spurious emission between 9 kHz and 902 MHz is -63.75 dBc.

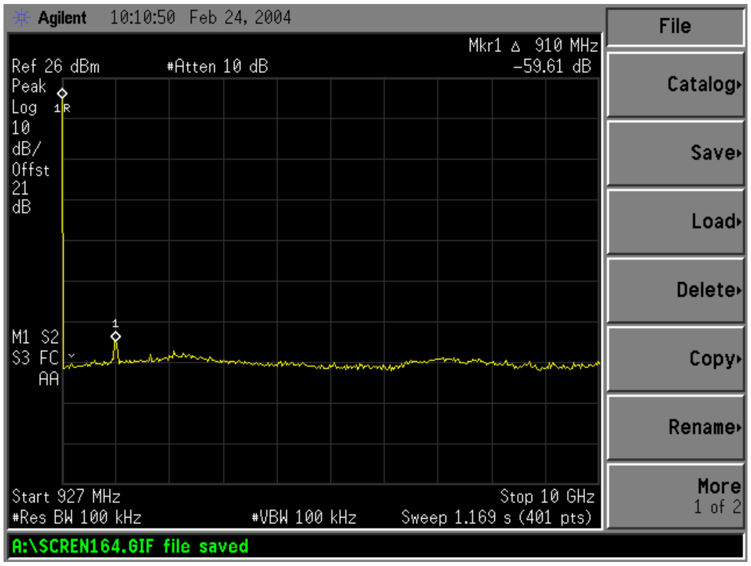
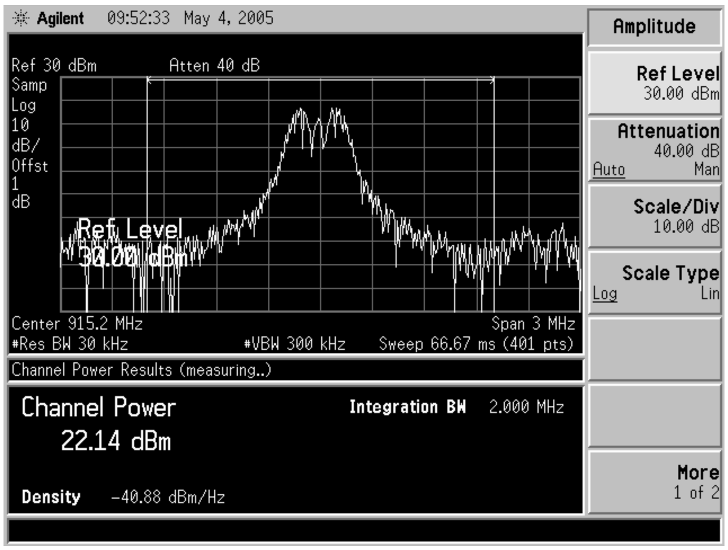


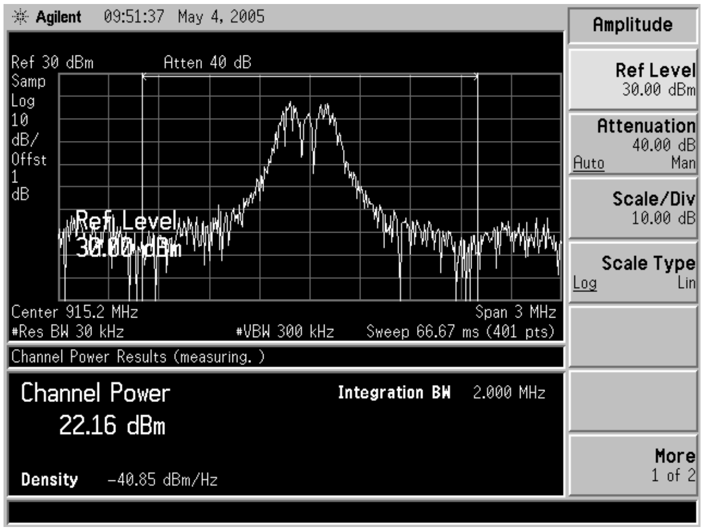
Figure 21. Spurious emission between 902 MHz and 10 GHz is -46.80 dB

5.1.14 Output Power versus Voltage Supply (Part 15.31 (e))

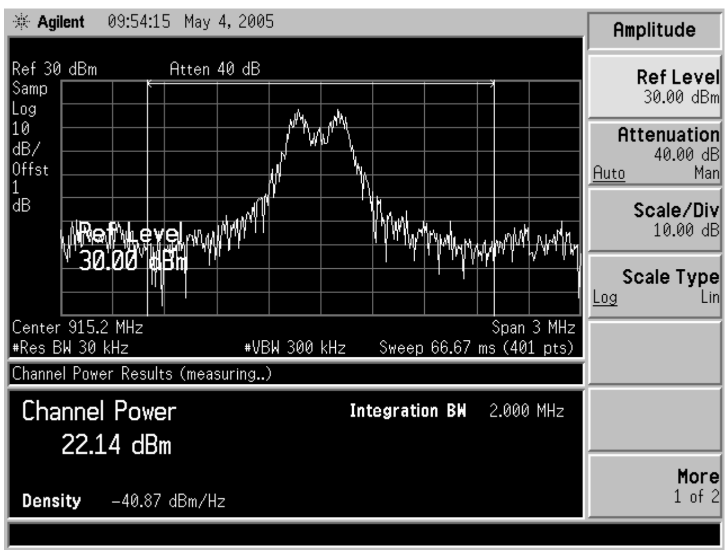
Part 15.31 (e) requires that RF output power be measured as the device supply voltage is varied from 85% to 115% of the nominal value. A sample transceiver was conditioned for operation at the center channel with full power set. A bench top power supply was varied such that the measured voltage at the transceiver board edge connector was varied plus and minus 15% from the 9.60 VDC nominal value. With cable losses calibrated out, the channel power was measured using the internal channel power measurement system on the spectrum analyzer.



Channel power measurement for Vsupply = 8.16 VDC



Channel power measurement for Vsupply = 9.60 VDC

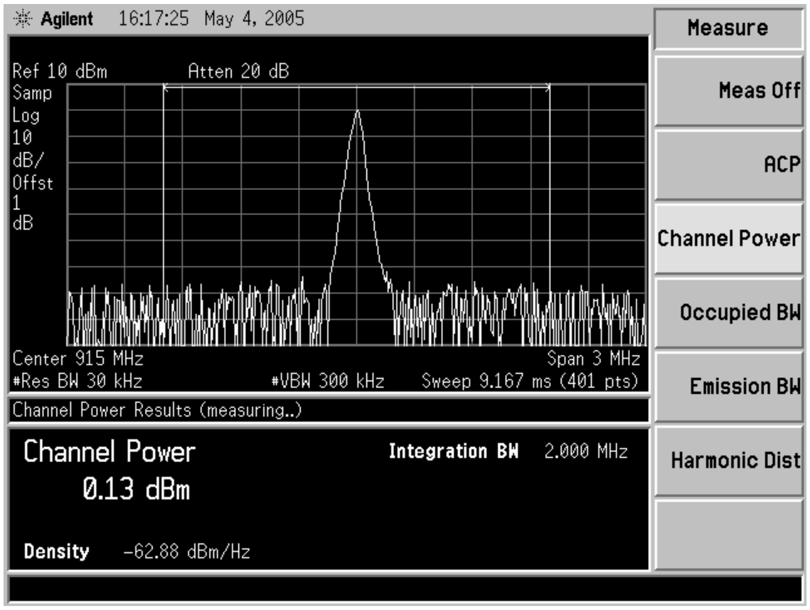


Channel power measurement for Vsupply = 11.04 VDC

Vsupply VDC	Channel Power dBm
8.16	22.14
9.60	22.16
11.04	22.14

Tabulated Results

The spectrum analyzer chosen for the measurement was verified for measurement accuracy by connecting it to the output of a calibrated RF signal generator. The generator was set to a frequency of 915.000 MHz with no modulation and with an output of 0 dBm. Using the same channel measurement procedure, the channel power of this setup was measured.



The indicated measurement of 0.13 dBm is within accepted tolerances to the set 0.0 dBm of the generator. Thus, the measurements made with the E4411B spectrum analyzer are reliable.

5.2 UTILIZATION OF ALL CHANNELS (Part 15.247 (g))

Part 15.247 (g) states: “Frequency hopping spread spectrum systems are not required to employ all available hopping channels during each transmission. However, the system, consisting of both the transmitter and the receiver, must be designed to comply with all of the regulations in this section should the transmitter be presented with a continuous data (or information) stream. In addition, a system employing short transmission bursts must comply with the definition of a frequency hopping system and must distribute its transmissions over the minimum number of hopping channels specified in this section.”

By design, 50 channels are chosen from a pool of 53 available frequencies. These channels are arrayed in a table which the system uses to determine the next hopping channel. Each time a transmission is made the system uses the next frequency in the table. The table is started over once the end has been reached. Thus, any given frequency will not be reused until all other frequencies have been accessed. In the event of a continuous data stream, the data is arranged into packets. When each packet is sent, the system hops to the next channel in the table. In the case of a short data burst (1 packet) the data is transmitted on a random channel as chosen in the table.

5.3 NON-INCORPORATION OF INTELLIGENCE TO SET CHANNELS (Part 15.247 (h))

Part 15.247 (h) states: “The incorporation of intelligence within a frequency hopping spread spectrum system that permits the system to recognize other users within the spectrum band so that it individually and independently chooses and adapts its hopsets to avoid hopping on occupied channels is permitted. The coordination of frequency hopping systems in any other manner for the express purpose of avoiding the simultaneous occupancy of individual hopping frequencies by multiple transmitters is not permitted.”

By design, the operating software uses channel hopsets which are set prior to operation. On system powerup, the operating software calculates the hop code set from information set into programmable memory during factory calibration. Thus, once network parameters are programmed, the transceiver will always use the predetermined hopset. The operating software does not employ any adaptive code which can alter the hopset while operating.

TITLE: GNet MODULE CONDUCTED TESTS		L.S. RESEARCH, Inc. WIRELESS PRODUCT DEVELOPMENT	W66 N220 COMMERCE COURT CEDARBURG, WI 53012, USA (262)-375-4400 FAX: (262)-375-6731 email: eng@lsr.com, http://www.lsr.com	
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