# FCC Part 15 Certification
# Test Report

## 2.4 GHz Frequency Hopping Spread Spectrum (Modular Approval)

**FCC ID: HSW-BT2022M**
**FCC Rule Part: 15.247**

**ACS Report Number: 03-0193-15BC**

Manufacturer: Cirronet, Inc.
Model: BT2022

Test Begin Date: October 6, 2003
Test End Date: October 24, 2003

Report Issue Date: January 5, 2004


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**This report contains 16 pages**

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## 1.0 GENERAL

### 1.1 Introduction
The purpose of this report is to demonstrate compliance with Part 15, Subpart C of the FCC's Code of Federal Regulations.

### 1.2 Product Description

Cirronet, Inc. supplied the following specification table for their product, the BT2022 module.

| | Item | Specification |
|---|---|---|
| 1 | Supply voltage | VDD: 3.3 V +/- 0.1 V regulated voltage. |
| 2 | Carrier frequency | 2400 MHz to 2483.5 MHz |
| 3 | Modulation method | GFSK, 1 Mbps, 0.5 BT Gaussian. |
| 4 | Maximum data rate | Asynchronous: 723.2 kbps / 57.6 kbps. |
| 5 | Transmission power | (Max +18) +16 to -12 dBm (Power control 6 stage). |
| 6 | Hopping | 1600 hops/s, 1 MHz channel space. |
| 7 | Receiving signal range | -82 to -20 dBm. |
| 8 | Receiver IF frequency | 1.5 MHz center frequency. |
| 9 | RF input impedance | 50 Ohms. |
| 10 | Baseband crystal OSC | 16 MHz. |
| 11 | Output interface | USB, PCM, SPI, UART. |
| 12 | Operation temperature | -20 to +70 °C. |
| 13 | Compliance | Bluetooth Specification Ver1.1. |
| 15 | Storage temperature | -40 to +80 °C. |
| 16 | USB specification | Ver 1.1. |

#### 1.2.1 General
The EUT, is the Cirronet Inc. radio module model BT2022, is a frequency hopping spread spectrum radio module operating in the unlicensed band of 2402 – 2480 MHz designed for data transmissions.

Detailed photographs of the EUT are included separately with this filing.

#### 1.2.2 Intended Use
The EUT is intended to be offered to OEM manufacturers for integration into their final products. These products will be limited to mobile or fixed devices as defined by the FCC.

#### 1.2.3 Antennas
The Cirronet Inc. model BT2022 uses a Cirronet 2 dB gain patch antenna using a MMCX connector.

## 2.0 LOCATION OF TEST FACILTY

All testing was performed by qualified ACS personnel located at the following address:

ACS, Inc.
5015 B.U. Bowman Drive
Buford, GA 30518

## 2.1 DESCRIPTION OF TEST FACILITY

Both the Open Area Test Site (OATS) and Conducted Emissions site have been fully described, submitted to, and accepted by the FCC, Industry Canada and the Japanese Voluntary Control Council for Interference by information technology equipment.

The following certification numbers have been issued in recognition of these accreditations and certifications:

FCC Registration Number: 89450
Industry Canada Lab Code: IC 4175
VCCI Member Number: 1831

- VCCI OATS Registration Number R-1526
- VCCI Conducted Emissions Site Registration Number: C-1608

### 2.1.1 Open Area Test Site

The open area test site consists of a 40' x 66' concrete pad covered with a perforated electro-plated galvanized sheet metal. The perforations in the sheet metal are 1/8" holes that are staggered every 3/16". The individual sheets are placed to overlap each other by 1/4" and are riveted together to provide a continuous seam. Rivets are spaced every 3" in a 3 x 20 meter perimeter around the antenna mast and EUT area. Rivets in the remaining area are spaced as necessary to properly secure the ground plane and maintain the electrical continuity.

The entire ground plane extends 12' beyond the turntable edge and 16' beyond the antenna mast when set to a 10 meter measurement distance. The ground plane is grounded via 4 - 8' copper ground rods, each installed at a corner of the ground plane and bound to the ground plane using 3/4" stainless steel braided cable.

The turntable is an all aluminum 10' flush mounted table installed in an all aluminum frame. The table is remotely operated from inside the control room located 40' from the range. The turntable is electrically bonded to the surrounding ground plane via steel fingers installed on the edge of the turn table. The steel fingers make constant contact with the ground plane during operation.

Adjacent to the turntable is a 7' x 7' square and 4' deep concrete pit used for support equipment if necessary. The pit is equipped with 5 - 4" PVC chases from the pit to the control room that allow for cabling to the EUT if necessary. The underside of the turntable can be accessed from the pit so cables can be supplied to the EUT from the pit. The pit is covered with 2 sheets of 1/4" diamond style re-enforced steel sheets. The sheets are painted to match the perforated steel ground plane, however the underside edges have been masked off to maintain the electrical continuity of the ground plane. All reflecting objects are located outside of the ellipse defined in ANSI C63.4.

A diagram of the Open Area Test Site is shown in Figure 3.2-1 below:

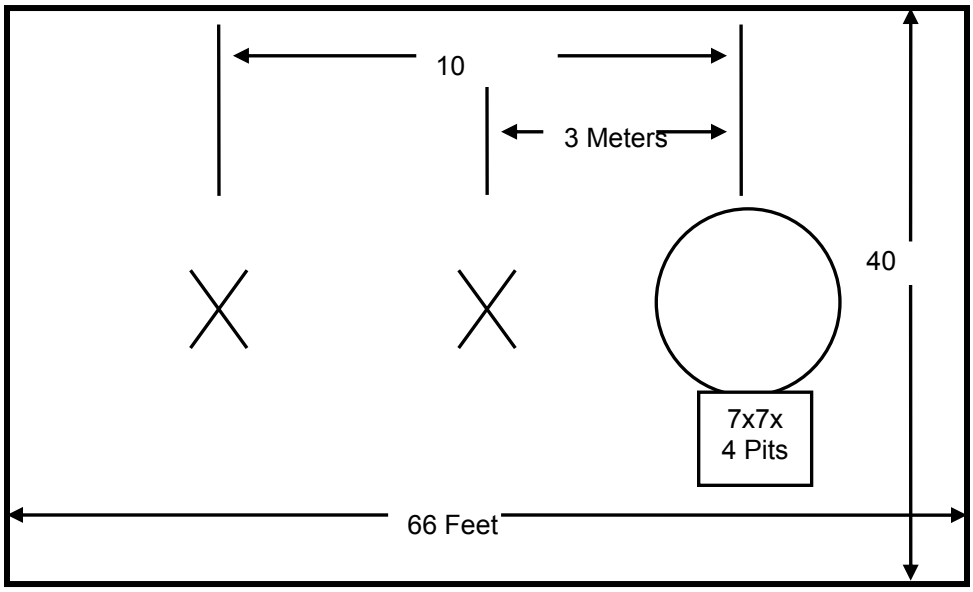


**Figure 3.2-1: Open Area Test Site**

**2.1.2 Conducted Emissions Test Site Description**
The AC mains conducted EMI site is a shielded room with the following dimensions:

- Height: 3.0 Meters
- Width: 3.6 Meters
- Length: 4.9 Meters

The room is manufactured by Rayproof Corporation and installed by Panashield, Inc. Earth ground is provided to the room via an 8' copper ground rod. Each panel of the room is connected electrically at intervals of 4".

Power to the room is filtered to prevent ambient noise from coupling to the EUT and measurement equipment. Filters are models 1B42-60P manufactured by Rayproof Corporation.

The room is of sufficient size to test table top and floor standing equipment in accordance with section 6.1.4 of ANSI C63.4.

A diagram of the room is shown below in figure 2.1.2-1:

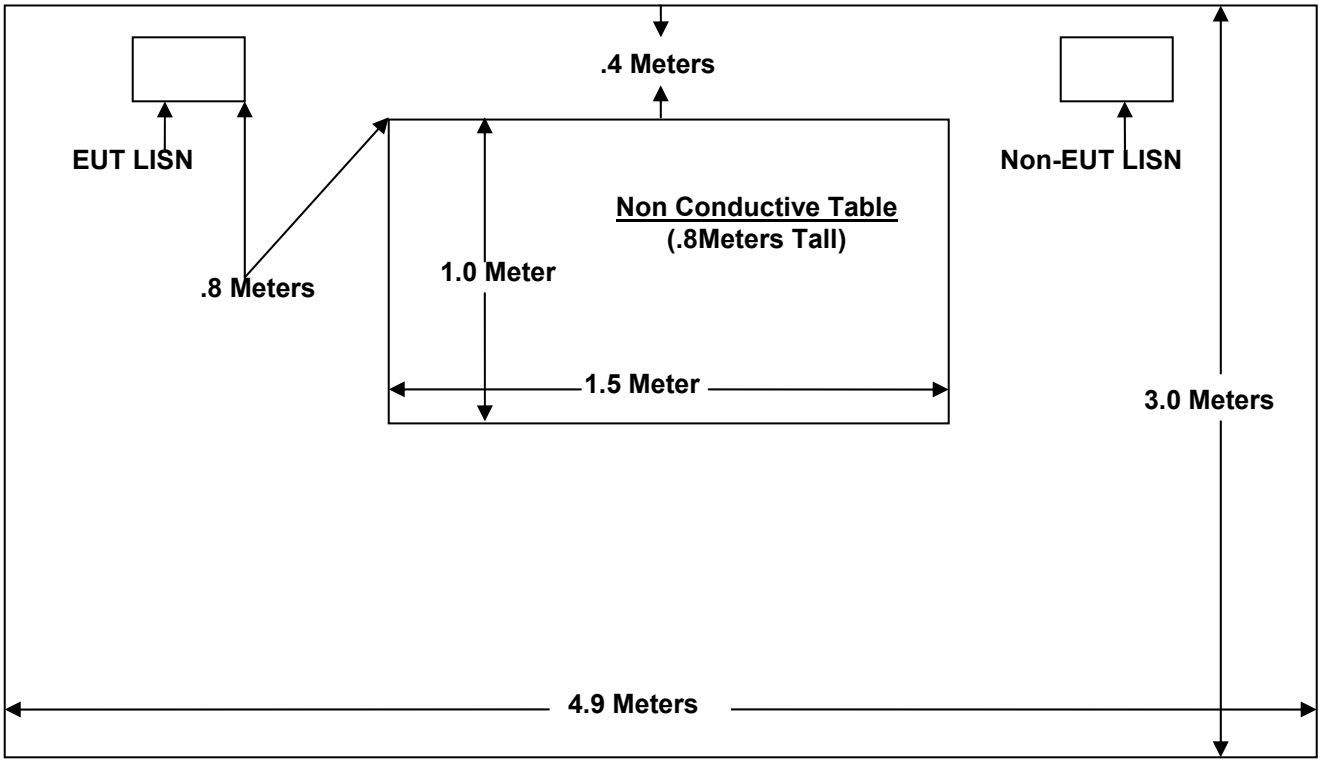


**Figure 3.3-1: AC Mains Conducted EMI Site**

**3.0 APPLICABLE STANDARD REFERENCES**

The following standards were used:

1 - ANSI C63.4-1992: Method of Measurements of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the 9KHz to 40GHz

2 - US Code of Federal Regulations (CFR): Title 47, Part 15, Subpart C: Radio Frequency Devices, Intentional Radiators (October 2000)

3 - FCC OET Bulletin 65 Appendix C - Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields

**4.0 LIST OF TEST EQUIPMENT**

All test equipment used for regulatory testing is calibrated yearly or according to manufacturer's specifications.

**Table 4-1: Test Equipment**

| Equipment Calibration Information | | | | | |
|---|---|---|---|---|---|
| **ACS #** | **Mfg.** | **Eq. type** | **Model** | **S/N** | **Cal. Due** |
| 2 | Rohde & Schwarz | Spectrum Analyzer | ESMI | 839587/003 | 12/23/03 |
| 1 | Rohde & Schwarz | Display Unit | ESDI | 839379/011 | 12/26/03 |
| 26 | Chase | Bi-Log Antenna | CBL6111 | 1044 | 10/14/04 |
| 152 | EMCO | LISN | 3825/2 | 9111-1905 | 12/11/03 |
| 153 | EMCO | LISN | 3825/2 | 9411-2268 | 12/11/03 |
| 16 | ACS | Cable | RG8 | 16 | 4/14/04 |
| 23 | ACS | Cable | RG8 | 23 | 1/3/04 |
| 24 | ACS | Cable | Heliax | 24 | 04/07/04 |
| 5 | ACS | Cable | LL-335 | None | 8/20/04 |
| 6 | ACS | Cable | LL-335 | None | 8/6/04 |
| 22 | Agilent | Pre-Amplifier | 8449B | 3008A00526 | 9/18/04 |
| 73 | Agilent | Pre-Amplifier | 8447D | 272A05624 | 04/15/04 |
| 30 | Spectrum Technologies | Horn Antenna | DRH-0118 | 970102 | 5/8/04 |
| 105 | Microwave Circuits | High Pass Filter | H1G810G1 | 2123-01 DC0225 | 6/17/04 |
| 40 | EMCO | Biconical Antenna | 3104 | 3211 | 9/19/04 |

## 5.0 EQUIPMENT UNDER TEST SETUP BLOCK DIAGRAM

**Table 5-1: Equipment List**

| Diagram Number | Manufacturer | Equipment Type | Model Number | Serial Number | FCC ID |
|---|---|---|---|---|---|
| 1 | Cirronet | Radio Module | BT2022 | 627-400 | HSW-BT2022 |
| 2 | Cirronet | Ethernet Adapter | n/a | n/a | n/a |
| 3 | Volgen | Power Adapter | SPU10R-2 | n/a | n/a |
| 4 | IBM | Laptop | 760ELD | 78-TFN16 | ANOGCF2704AT |
| 5 | IBM | Power Adapter | 12J1445 | n/a | n/a |

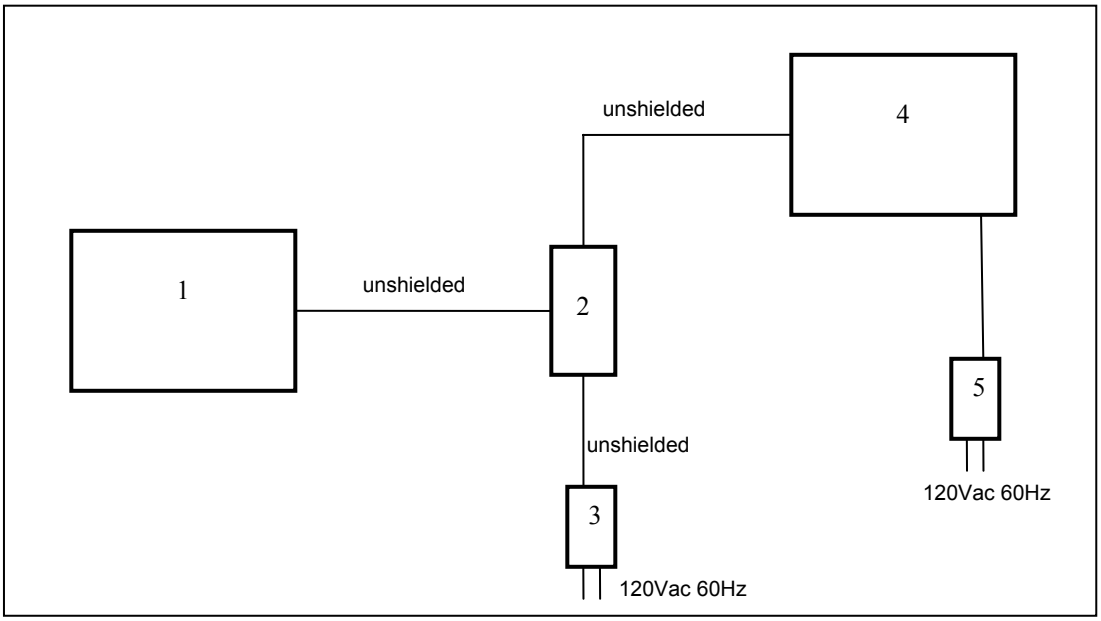


**Figure 5-2: EUT Test Setup**

## 6.0 SUMMARY OF TESTS

Along with the tabular data shown below, plots were taken of all signals deemed important enough to document.

### 6.1 Antenna Requirement - FCC Section 15.203

The EUT employs an MMCX connector. According to FCC Public Notice, DA 00-2225, the MMCX qualifies as a unique antenna coupler.

### 6.2 Power Line Conducted Emissions - FCC Section 15.207

#### 6.2.1 Test Methodology

ANSI C63.4 sections 6 and 7 were the guiding documents for this evaluation. Conducted emissions were performed from 150 kHz to 30MHz with the spectrum analyzer's resolution bandwidth set to 9 kHz and the video bandwidth set to 30 kHz.

#### 6.2.2 Test Results

The EUT will be provided DC power by the host device in which it is installed. With no connection to the AC mains this requirement is not applicable to the EUT.

### 6.3 Radiated Emissions - FCC Section 15.209(Unintentional Radiation)

Radiated emissions tests were performed over the frequency range of 30MHz to 25GHz, 10 times the highest fundamental frequency. Measurements of the radiated field strength were made at a distance of 3m from the boundary of the equipment under test (EUT) and the receiving antenna. The antenna height was varied from 1m to 4m so that the maximum radiated emissions level would be detected. Radiated measurements were made with the Spectrum Analyzer's resolution bandwidth set to 120 kHz for measurements above 30MHz.

The EUT was caused to go into a "Receive Only" mode of operation for this test. Results of the test are given in Table 6.3-1 below:

**Table 6.3-1: Radiated Emissions Tabulated Data**

| Frequency (MHz) | Uncorrected Reading (dBµV) | Antenna Polarity (H/V) | Antenna Height (cm) | Turntable Position (°) | Total Correction Factor (dB) | Corrected Reading (dBµV) | Limit (dBµV) | Margin (dB) | Results |
|---|---|---|---|---|---|---|---|---|---|
| 36.56 | 13.8 | V | 100 | 1 | 16.58 | 30.38 | 40 | 9.6 | **Pass** |
| 45.12 | 14.5 | V | 100 | 0 | 12.54 | 27.04 | 40 | 13.0 | **Pass** |
| 121.6 | 14 | H | 100 | 0 | 12.86 | 26.86 | 43.5 | 16.6 | **Pass** |
| 127.68 | 14 | H | 100 | 1 | 13.00 | 27.00 | 43.5 | 16.5 | **Pass** |
| 192.31 | 22 | H | 100 | 270 | 10.80 | 32.80 | 43.5 | 10.7 | **Pass** |
| 199.92 | 17.7 | H | 100 | 0 | 10.90 | 28.60 | 43.5 | 14.9 | **Pass** |
| 701.619 | 38.2 | H | 100 | 315 | -1.44 | 36.76 | 46 | 9.2 | **Pass** |
| 701.619 | 37.6 | V | 125 | 131 | -1.44 | 36.16 | 46 | 9.8 | **Pass** |

### 6.4 Peak Output Power Requirement - FCC Section 15.247(b)

The peak output power of the EUT was made at the antenna connector using a Rhode & Schwarz ESMI Spectrum Analyzer. For the measurement, the EUT was caused to generate a constant carrier. Results are shown below in Table 6.4-1 and a plot of the worst case is shown in Figure 6.4-1.

**Table 6.4-1: Peak Output Power**

| Channel | Frequency (MHz) | Output Power (dBm) |
|---|---|---|
| **Low** | 2402 | 15.43 |
| **Center** | 2441 | 15.59 |
| **High** | 2480 | 15.31 |

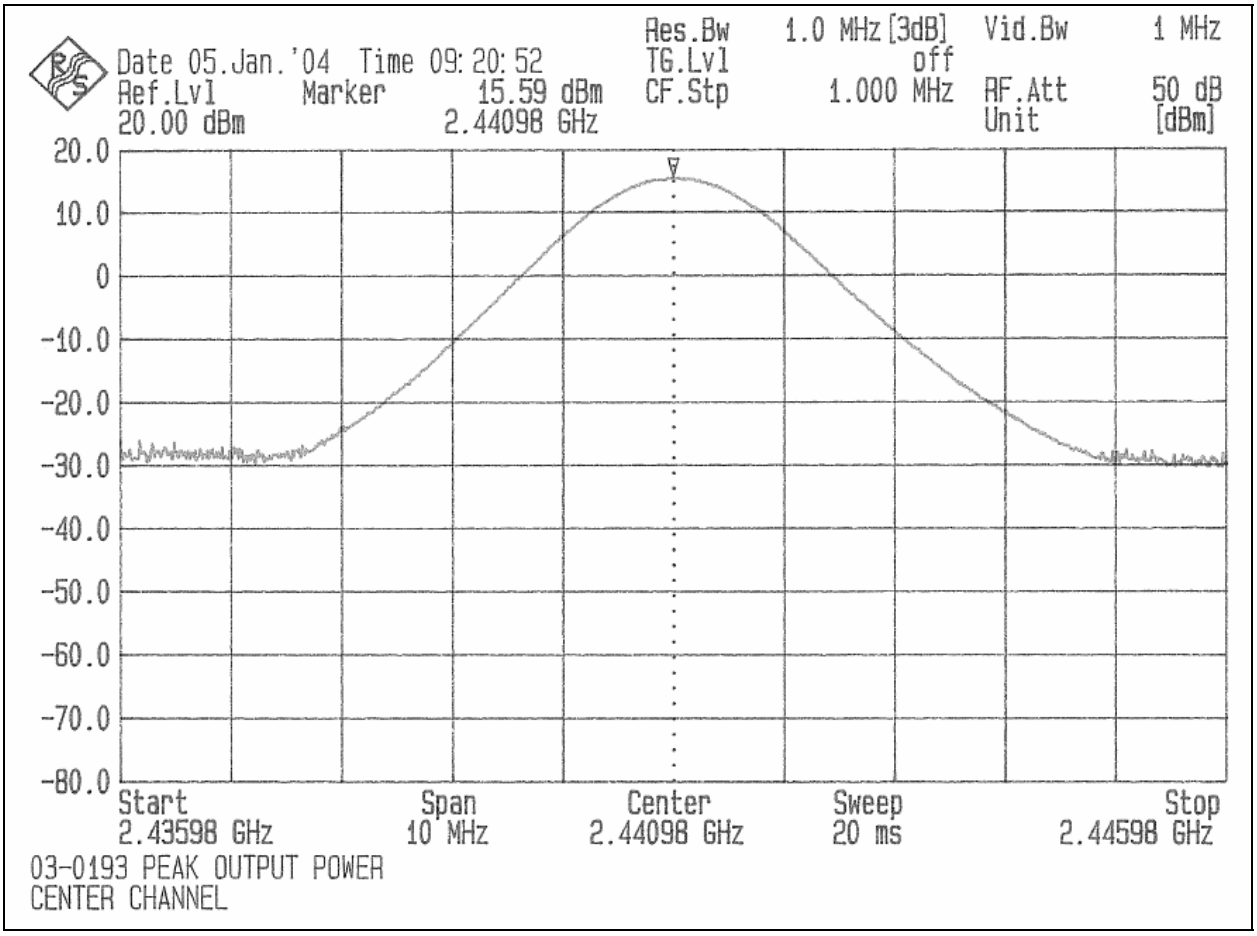


**Figure 6.4-1: Output power**

### 6.5 Channel Usage Requirements - FCC Section 15.247(a)

**15.247(a) (1):** Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. The system shall hop to channel frequencies that are selected at the system hopping rate from a pseudo randomly ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter. The system receivers shall have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shall shift frequencies in synchronization with the wanted signal.

**15.247(a) (1) (ii)**: Frequency hopping systems operating in the 2400–2483.5 MHz and 5725–5850 MHz bands shall use at least 75 hopping frequencies. The maximum 20dB bandwidth of the hopping channel is 1 MHz. The average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 30 second period.

#### 6.5.1 Adjacent Channel Separation

**Results:** The adjacent channel separation was measured to be 1.00 MHz for all channels. A plot of the High channel is shown below in figure 6.5.1-1

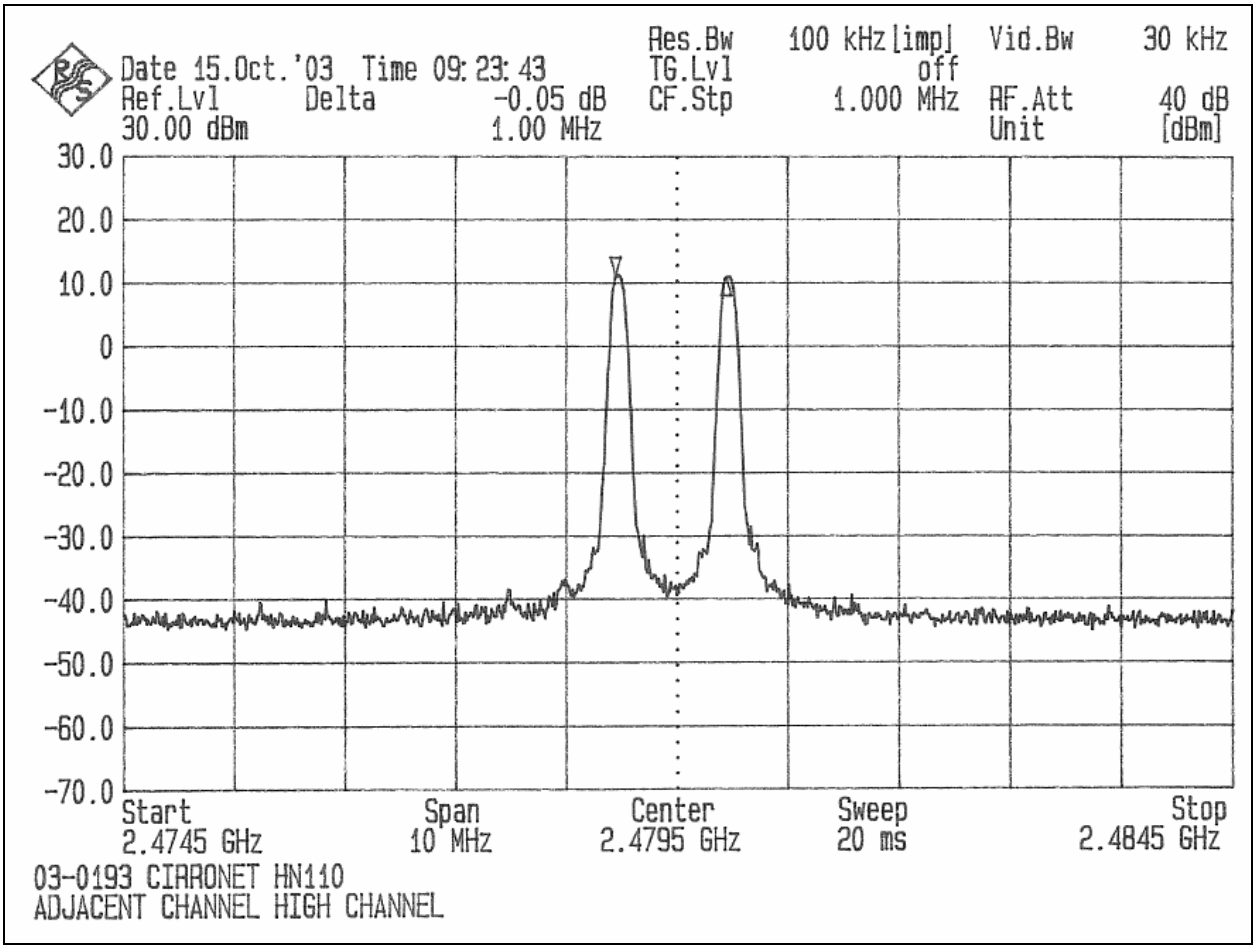


**Figure 6.5.1-1: Adjacent Channel Separation**

### 6.5.2 Number of Hopping Channels

**Result:** The 20dB bandwidth of the device is less than 250 kHz. The device employs more than 50 hopping channels as required. Results are shown in figure 6.5.2-1 below.

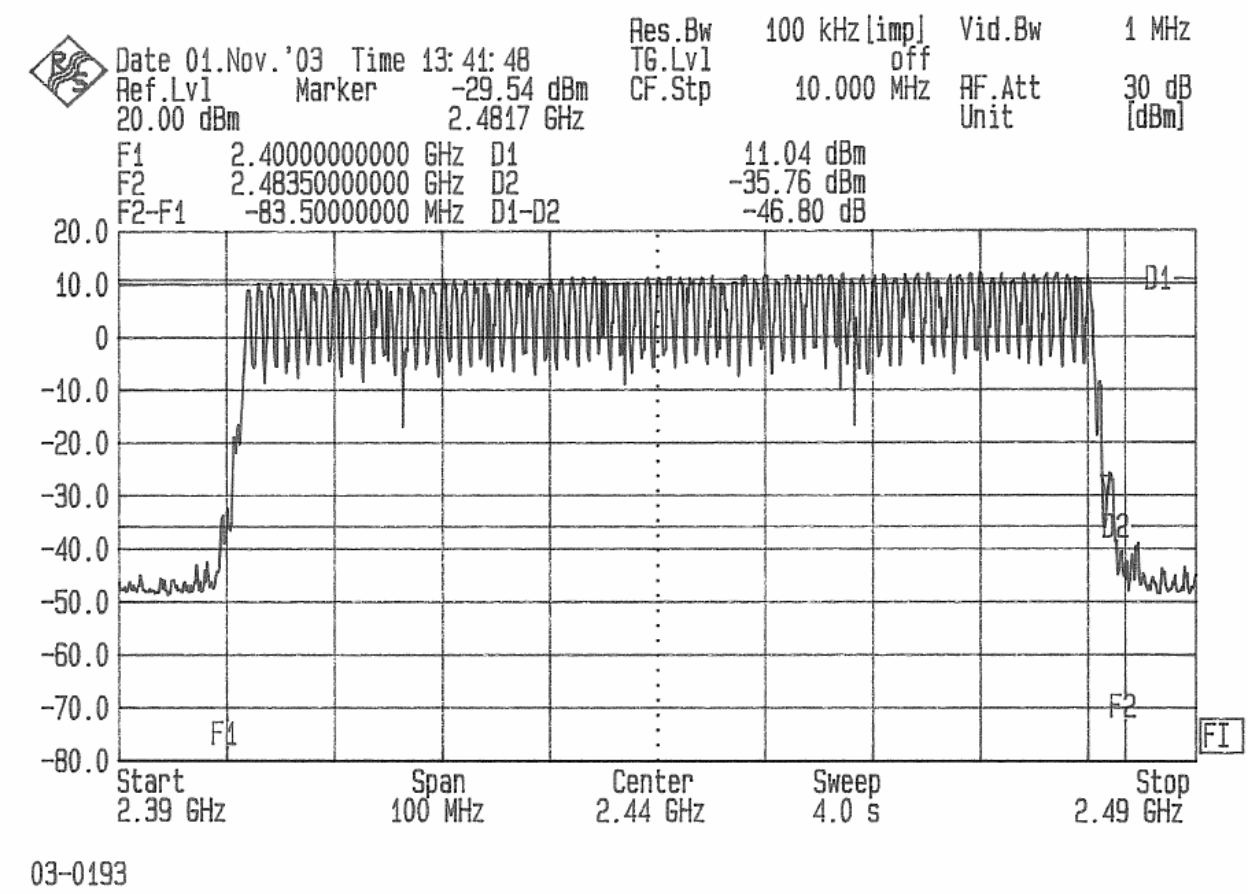


**Figure 6.5.2-1: Number of Hopping Channels**

### 6.5.3 Channel Dwell Time

**Result:** For average measurements, the measured level was reduced by a factor 27dB to account for the duty cycle of the EUT. The EUT transmits three 625uS every 100mS. The period of a single burst is 46.9mS. Therefore the duty cycle is calculated by (3x.625ms)/46.9ms = 3.99%. The duty cycle correction factor is determined using the formula: 20•log(.0399) = -27dB. See figure 6.5.3-1 and appendix I for further details.

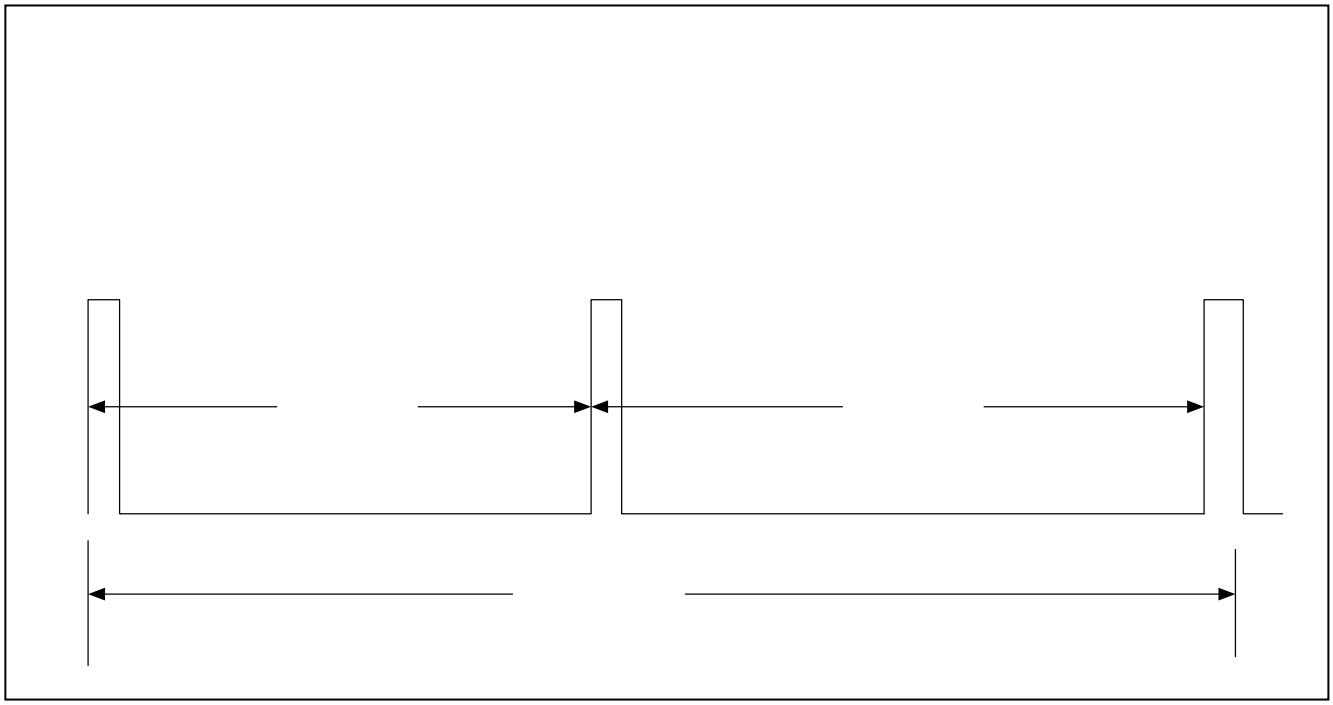

**Figure 6.5.3-1: Channel Dwell Time**

### 6.5.4 20dB Bandwidth

**Result:** The 20dB bandwidth was found to be less than 1 MHz across all channels as required. Results are shown below in Table 6.5.4-1 and a plot of the channel with the greatest bandwidth is shown in Figure 6.5.4-1.

**Table 6.5.4-1: 20dB Bandwidth**

| Channel | Frequency (MHz) | 20dB Bandwidth (kHz) |
|---|---|---|
| **Low** | 2402 | 187.50 |
| **Center** | 2441 | 192.36 |
| **High** | 2480 | 188.19 |

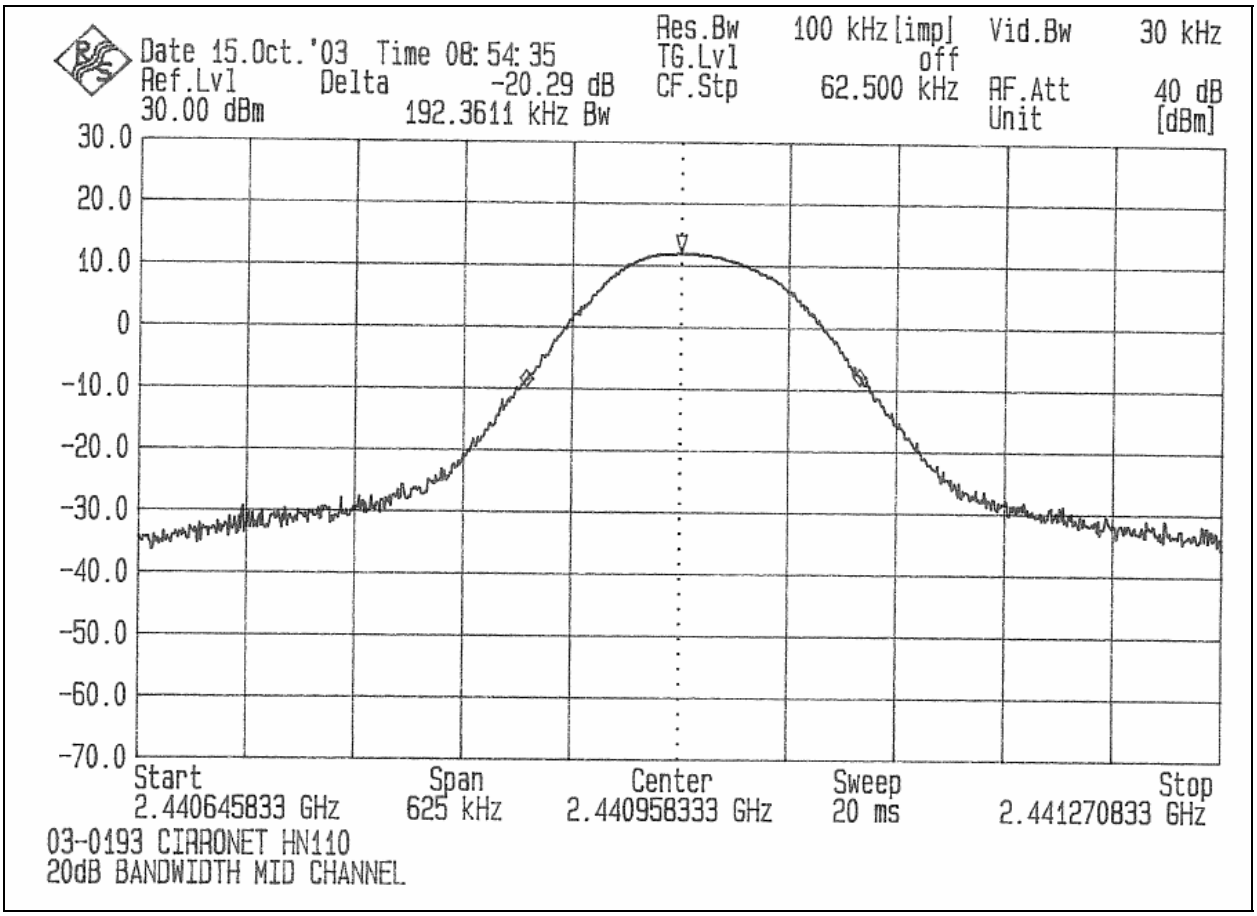


**Figure 6.5.4-1: 20dB Bandwidth**

## 6.6 Spurious Emissions - FCC Section 15.247(c)

### 6.6.1 RF Conducted Spurious Emissions

The EUT was investigated for conducted spurious emissions from 30MHz to 25GHz, 10 times the highest fundamental frequency. For each measurement, the spectrum analyzer's VBW was set to 100kHz and the RBW was set to 1MHz.

### 6.6.1.2 Test Results

**Result:** All emission found were greater than 20dB down from the fundamental carrier. The RF conducted spurious emissions found in the band of 30MHz to 25GHz are reported in Table 6.6.1.2 below. Plots were taken also and are filed separately with this filing in a file titled "03-0193 Data Plots A.doc". Each emission was compared to the fundamental reference level to determine if they were at least 20dB below the reference level.

**Table 6.6.1.2: RF Conducted Spurious Emissions**

| Frequency (MHz) | Level (dBm) | Peak Power (dBm) | Limit (dBm) | Margin (dB) | Final Result (Pass/Fail) |
|---|---|---|---|---|---|
| **High Channel:** | | | | | |
| **1012.8** | -53.85 | 15.31 | -4.69 | -49.16 | **Pass** |
| **4960.3** | -32.34 | | | -27.65 | **Pass** |
| **9922.2** | -43.39 | | | -38.7 | **Pass** |
| **12400** | -57.63 | | | -52.94 | **Pass** |
| **15000** | -76.27 | | | -71.58 | **Pass** |
| **20000** | -79.17 | | | -74.48 | **Pass** |
| **Mid Channel:** | | | | | |
| **952.1** | -60.68 | 15.59 | -4.41 | -56.27 | **Pass** |
| **4882.2** | -31.02 | | | -26.61 | **Pass** |
| **9766.6** | -49.13 | | | -44.72 | **Pass** |
| **12205.5** | -59.36 | | | -54.95 | **Pass** |
| **15000** | -76.12 | | | -71.71 | **Pass** |
| **20000** | -80.67 | | | -76.26 | **Pass** |
| **Low Channel:** | | | | | |
| **895.8** | -55.02 | 15.43 | -4.57 | -50.45 | **Pass** |
| **4805.6** | -32.04 | | | -27.47 | **Pass** |
| **9611.1** | -56.54 | | | -51.97 | **Pass** |
| **12011.1** | -64.82 | | | -60.25 | **Pass** |
| **15000** | -76.81 | | | -72.24 | **Pass** |
| **20000** | -78.53 | | | -73.96 | **Pass** |

### 6.6.2 Radiated Spurious Emissions (Restricted Bands) - FCC Section 15.205

Radiated emissions tests were made over the frequency range of 30MHz to 25GHz, 10 times the highest fundamental frequency on each antenna given in section 1.2.3.

The EUT was rotated through 360° and the receive antenna height was varied from 1m to 4m so that the maximum radiated emissions level would be detected. For frequencies below 1000MHz, quasi-peak measurements were made using a resolution bandwidth (RBW) of 120 kHz and a video bandwidth (VBW) of 300 kHz. For frequencies above 1000MHz, average measurements were made using an RBW of 1MHz and a VBW of 10Hz and peak measurements were made with RBW of 1MHz and a VBW of 1MHz.

The EUT was caused to generate a carrier signal on the hopping channel.

#### 6.6.2.1 Duty Cycle Correction

For average measurements, the measured level was reduced by a factor 27dB to account for the duty cycle of the EUT. The EUT transmits three 625uS every 100mS. The period of a single burst is 46.9mS. Therefore the duty cycle is calculated by (3x.625ms)/46.9ms = 3.99%. The duty cycle correction factor is determined using the formula: 20•log(.0399) = -27dB. See figure 6.5.3-1 and appendix I for further details.

#### 6.6.2.2 Test Results

Radiated spurious emissions found in the band of 30MHz to 25GHz are reported in Table 6.6.2.2-1. Plots of these emissions are also presented separately in file "03-0193 Data Plots B.pdf" of this filing. Each emission found to be in a restricted band as defined by section 15.205, was compared to the radiated emission limits for a class B device defined in section 15.209.

**Table 6.6.2.2-1: Radiated Spurious Emissions**

| Frequency (MHz) | Level (dBuV/m) | Detector (P/A) | Correction Factors (dB) | Corrected Level (dBuV/m) | Limit (dBuV/) | Margin (dB) | Final Result (Pass/Fail) |
|---|---|---|---|---|---|---|---|
| **High Channel** | | | | | | | |
| 4559 | 65.83 | P | 6.50 | 72.33 | 74.00 | 1.67 | **PASS** |
| 4559 | 65.88 | A | -20.50 | 45.38 | 54.00 | 8.62 | **PASS** |
| 7437 | 56.69 | P | 12.89 | 69.58 | 74.00 | 4.42 | **PASS** |
| 7437 | 56.18 | A | -14.11 | 42.07 | 54.00 | 11.93 | **PASS** |
| 9917 | 47.07 | P | 15.15 | 62.22 | 74.00 | 11.78 | **PASS** |
| 9917 | 45.75 | A | -11.85 | 33.90 | 54.00 | 20.10 | **PASS** |
| 12400 | 36.71 | P | 23.00 | 59.71 | 74.00 | 14.29 | **PASS** |
| 12400 | 36.71 | A | -4.00 | 32.71 | 54.00 | 21.29 | **PASS** |
| **Mid Channel** | | | | | | | |
| 4881 | 62.34 | p | 8.03 | 70.37 | 74.00 | 3.63 | **PASS** |
| 4881 | 62.04 | a | -18.97 | 43.07 | 54.00 | 10.93 | **PASS** |
| 7322 | 56.96 | p | 13.19 | 70.15 | 74.00 | 3.85 | **PASS** |
| 7322 | 56.31 | a | -13.81 | 42.50 | 54.00 | 11.50 | **PASS** |
| 9763 | 50.55 | p | 14.71 | 65.26 | 74.00 | 8.74 | **PASS** |
| 9763 | 48.55 | a | -12.29 | 36.26 | 54.00 | 17.74 | **PASS** |
| **Low Channel** | | | | | | | |
| 4804 | 64.19 | p | 7.66 | 71.85 | 74.00 | 2.15 | **PASS** |
| 4804 | 63.88 | a | -19.34 | 44.54 | 54.00 | 9.46 | **PASS** |
| 7205 | 52.46 | p | 13.50 | 65.96 | 74.00 | 8.04 | **PASS** |
| 7205 | 52.05 | a | -13.50 | 38.55 | 54.00 | 15.45 | **PASS** |
| 9607 | 54.08 | p | 14.27 | 68.35 | 74.00 | 5.65 | **PASS** |
| 4804 | 64.19 | p | 7.66 | 71.85 | 74.00 | 2.15 | **PASS** |

**6.6.2.3 Sample Calculation:**

$R_C = R_U + CF_T$

Where:

| | | |
|---|---|---|
| $CF_T$ | = | Total Correction Factor (AF+CA+AG)-DC(Average Measurements Only) |
| $R_U$ | = | Uncorrected Reading |
| $R_C$ | = | Corrected Level |
| AF | = | Antenna Factor |
| CA | = | Cable Attenuation |
| AG | = | Amplifier Gain |
| DC | = | Duty Cycle Correction Factor |

**Example Calculation:**

Corrected Level: 61.97 dBuV/m + 8.40 dB = 70.37 dBuV

Margin: 74 dBuV – 70.37dBuV = 3.63 dB

**7.0 Conclusion**

In the opinion of ACS, Inc. the BT2022 spread spectrum radio module, manufactured by Cirronet, Inc., meets the requirements of FCC Part 15 subpart C.