PCTEST Engineering Laboratory, Inc.

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CERTIFICATE OF COMPLIANCE

SYMBOL TECHNOLOGIES INC.
1 Symbol Plaza
Holtsville, NY 11742-1300
Attn: Sandy Mazzola, Regulatory Engineer
cc: Dean La Rosa, Senior Design Engineer

Dates of Tests: Sept. 20-21, 2001
Report S/N: 15.210820493.H9P
Test Site: PCTEST Lab, Columbia MD U.S.A.

FCC ID	**H9PCRS1**
APPLICANT	**SYMBOL TECHNOLOGIES INC.**

FCC Rule Part(s):	**§ 15.247; ANSI C-63.4 (1992)**
Classification:	**Spread Spectrum Transceiver (BLUETOOTH)**
Method/System:	**HYBRID System**
Equipment Type:	**BLUETOOTH Transceiver & Wireless Ring Scanner**
Max Output Power:	**0.001 Watts**
Frequency Range:	**2412 – 2483.5 MHz**
Trade/Model No(s).:	***SYMBOL - CRS1-10000-00***

This equipment has been shown to be capable of compliance with the applicable technical standards as indicated in the measurement report and was tested in accordance with the measurement procedures specified in ANSI C-63-4.

I attest to the accuracy of data. All measurements reported herein were performed by me or were made under my supervision and are correct to the best of my knowledge and belief. I assume full responsibility for the completeness of these measurements and vouch for the qualifications of all persons taking them.

PCTEST certifies that no party to this application has been denied the FCC benefits pursuant to Section 5301 of the Anti-Drug Abuse Act of 1988, 21 U.S.C. 862.

Randy Ortanez
President

LAB CODE 100431-0

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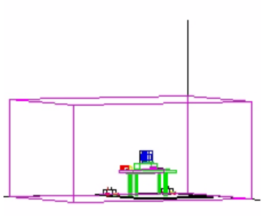
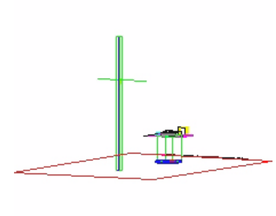


MEASUREMENT REPORT

Scope - Measurement and determination of electromagnetic emissions (EME) of radio frequency devices including intentional and/or unintentional radiators for compliance with the technical rules and regulations of the Federal Communications Commission.



§2.983(a) General Information

Applicant Name:	**SYMBOL TECHNOLOGIES INC.**
Address:	**1 Symbol Plaza** **Holtsville, NY 11742-1300**
Attention:	**Sandy Mazzola, Regulatory Engineer** **cc: Dean La Rosa, Senior Design Engineer**

- FCC ID: **H9PCRS1**
- Class: Spread Spectrum Transceiver (Hybrid)
- Type: BLUETOOTH Transceiver & Wireless Ring Scanner
- Freq. Range: 2412 – 2483.5 MHz
- Method/System: Direct Sequence System (DSS)
- Model No(s): **CRS1-10000-00**
- Max. RF Output Power: 0.001 W
- Rule Part(s): § 15.247
- Dates of Tests: Sept. 20-21, 2001
- Place of Tests: PCTEST Lab, Columbia, MD U.S.A.
- Test Report S/N: 15. 210820493.H9P

Lab Code 100431-0

INTRODUCTION

The measurement procedure described in American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9kHz to 40GHz (ANSI C63.4-1992) and FCC Public Notice dated July 12, 1995 entitled "Guidance on Measurement for Direct Sequence Spread Spectrum Systems" were used in the measurement of **SYMBOL Spread Spectrum Wireless BLUETOOTH Transceiver & wireless ring scanner.**

These measurement tests were conducted at ***PCTEST Engineering Laboratory, Inc.*** facility in New Concept Business Park, Guilford Industrial Park, Columbia, Maryland. The site address is 6660-B Dobbin Road, Columbia, MD 28145. The test site is one of the highest points in the Columbia area with an elevation of 390 feet above mean sea level. The site coordinates are 39° 11'15" N latitude and 76° 49'38" W longitude. The facility is 1.5 miles North of the FCC laboratory, and the ambient signal and ambient signal strength are approximately equal to those of the FCC laboratory. There are no FM or TV transmitters within 15 miles of the site. The detailed description of the measurement facility was found to be in compliance with the requirements of § 2.948 according to ANSI C63.4 on October 19, 1992.

PCTEST Location

The map at right shows the location of the PCTEST Lab, its proximity to the FCC Lab, the Columbia vicinity area, the Baltimore-Washington International (BWI) airport, and the city of Baltimore, and the Washington, D.C. area. (see Figure1).

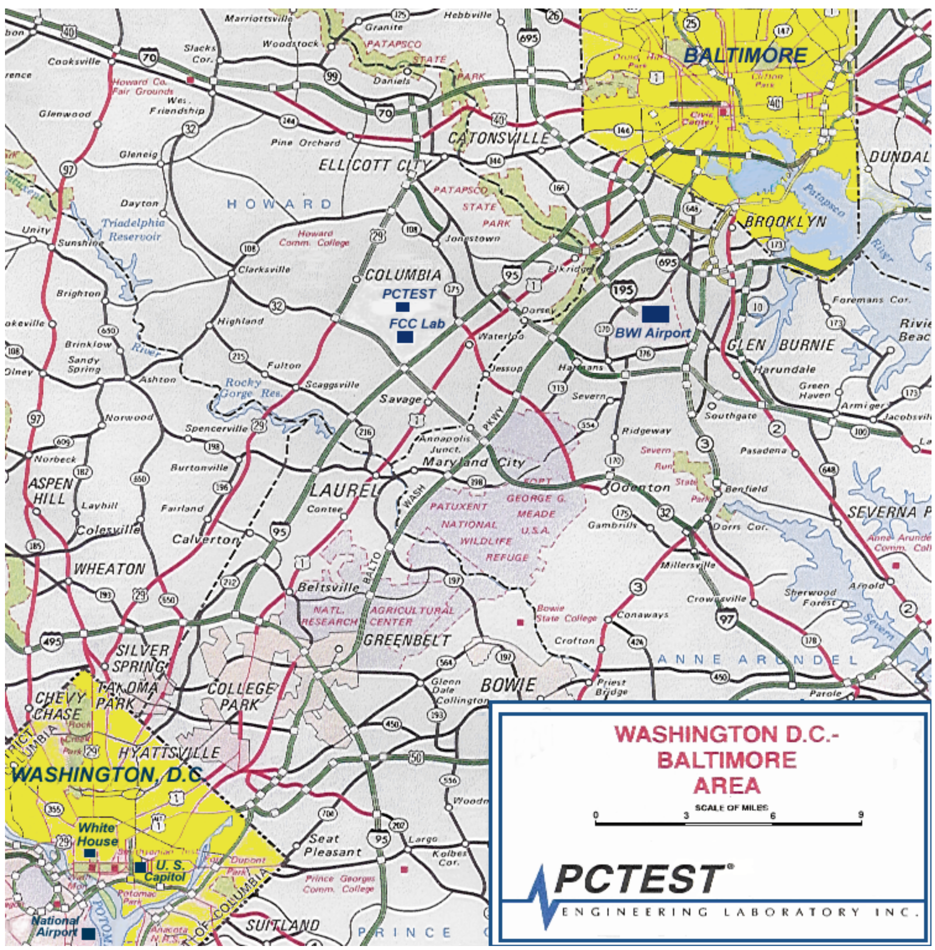


Figure 1. Map of the Greater Baltimore and Metropolitan Washington, D.C. area.

PRODUCT INFORMATION

Equipment Description:

The Equipment under test (EUT) is the **SYMBOL TECHNOLOGIES INC. CRS1-10000-00** wireless Ring Scanner using spread spectrum direct sequence and time division duplex techniques.

Frequency Range:	2412 – 2483.5 MHz
Modulation:	CCK, DBPSK, DQPSK
Max RF Output Power:	0.001 Watts
Antenna:	Polarization Linear
Power Consumption:	100mA
Power Supply:	3.6 VDC
Dimensions (W x H x D):	70 x 50 x 30 mm

Description of Tests

Conducted Emissions

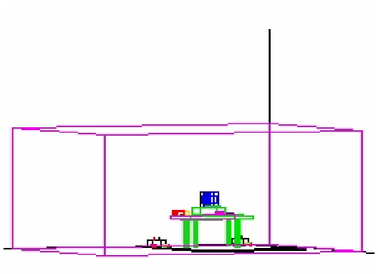


Figure 4. Shielded Enclosure Line-Conducted Test Facility

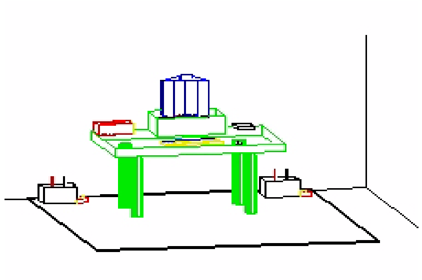


Figure 2. Line Conducted Emission Test Set-Up

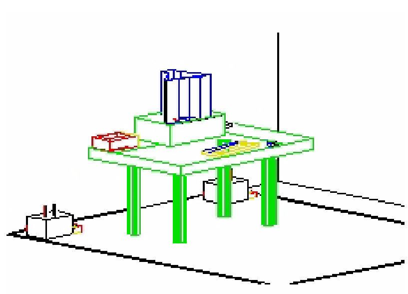


Figure 3. Wooden Table & Bonded LISNs

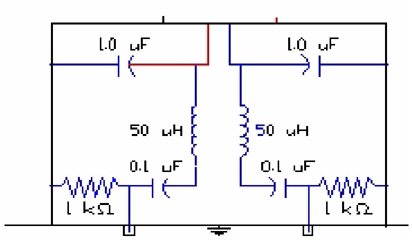


Figure 5. LISN Schematic Diagram

The line-conducted facility is located inside a 16'x20'x81' shielded enclosure. It is manufactured by Ray Proof Series 81 (see Figure 2). The shielding effectiveness of the shielded room is in accordance with MIL-Std-285 or NSA 65-6. A 1m. x 1.5m. wooden table 80cm. high is placed 40cm. away from the vertical wall and 1.5m away from the side wall of the shielded room (see Figure 3). Solar Electronics and EMCO Model 3725/2 (81kHz-30MHz) 50Ω/50µH Line-Impedance Stabilization Networks (LISNs) are bonded to the shielded room (see Figure 4). The EUT is powered from the Solar LISN and the support equipment is powered from the EMCO LISN. Power to the LISNs are filtered by a high-current high-insertion loss Ray Proof power line filters (810dB 14kHz-81GHz). The purpose of the filter is to attenuate ambient signal interference and this filter is also bonded to the shielded enclosure. All electrical cables are shielded by braided tinned copper zipper tubing with inner diameter of 1/2". If the EUT is a DC-powered device, power will be derived from the source power supply it normally will be powered from and this supply lines will be connected to the Solar LISN. LISN schematic diagram is shown in Figure 5. All interconnecting cables more than 1 meter were shortened by non-inductive bundling (serpentine fashion) to a 1-meter length. Sufficient time for the EUT, support equipment, and test equipment was allowed in order for them to warm up to their normal operating condition. The RF output of the LISN was connected to the spectrum analyzer to determine the frequency producing the maximum EME from the EUT. The spectrum was scanned from 450kHz to 30MHz with 20 msec. sweep time. The frequency producing the maximum level was reexamined using EMI/ Field Intensity Meter and Quasi-Peak adapter. The detector function was set to CISPR quasi-peak mode. The bandwidth of the receiver was set to 81 kHz. The EUT, support equipment, and interconnecting cables were arranged and manipulated to maximize each EME emission. Each emission was maximized by: switching power lines; varying the mode of operation or resolution; clock or data exchange speed; scrolling H pattern to the EUT and/or support equipment, and powering the monitor from the floor mounted outlet box and the computer aux AC outlet, if applicable; whichever determined the worst-case emission. Photographs of the worst-case emission can be seen in Appendix C. Each EME reported was calibrated using the HP8640B signal generator.

Description of tests (Continued)

Radiated Emissions

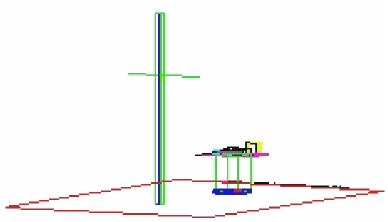


Figure 6. 3-Meter Test Site

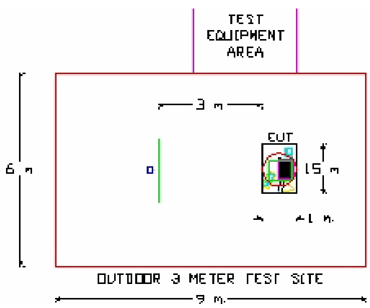


Figure 7. Dimensions of Outdoor Test Site

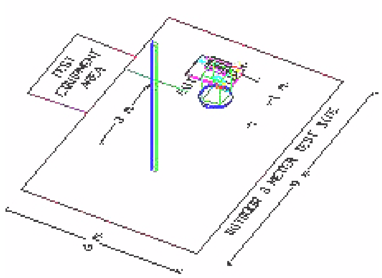


Figure 8. Turntable and System Setup

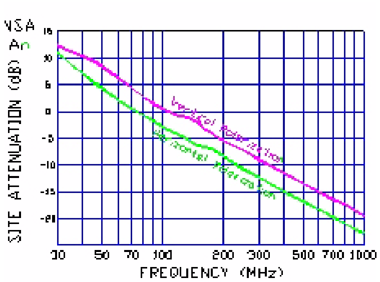


Figure 9. Normalized Site Attenuation Curves (H&V)

Preliminary measurements were made indoors at 1 meter using broadband antennas, broadband amplifier, and spectrum analyzer to determine the frequency producing the maximum EME. Appropriate precaution was taken to ensure that all EME from the EUT were maximized and investigated. The system configuration, clock speed, mode of operation or video resolution, turntable azimuth with respect to the antenna were noted for each frequency found. The spectrum was scanned from 30 to 200 MHz using biconical antenna and from 200 to 8100 MHz using log-spiral antenna. Above 1 GHz, linearly polarized double ridge horn antennas were used.

Final measurements were made outdoors at 3-meter test range using Roberts™ Dipole antennas or horn antenna (see Figure 6). The test equipment was placed on a wooden and plastic bench situated on a 1.5 x 2 meter area adjacent to the measurement area (see Figure 7). Sufficient time for the EUT, support equipment, and test equipment was allowed in order for them to warm up to their normal operating condition. Each frequency found during pre-scan measurements was re-examined and investigated using EMI/Field Intensity Meter and Quasi-Peak Adapter. The detector function was set to CISPR quasi-peak mode and the bandwidth of the receiver was set to 810kHz or 1 MHz depending on the frequency or type of signal.

The half-wave dipole antenna was tuned to the frequency found during preliminary radiated measurements. The EUT, support equipment and interconnecting cables were re-configured to the set-up producing the maximum emission for the frequency and were placed on top of a 0.8-meter high non-metallic 1 x 1.5 meter table (see Figure 8). The EUT, support equipment, and interconnecting cables were re-arranged and manipulated to maximize each EME emission. The turntable containing the system was rotated; the antenna height was varied 1 to 4 meters and stopped at the azimuth or height producing the maximum emission. Each emission was maximized by: varying the mode of operation or resolution; clock or data exchange speed; scrolling H pattern to the EUT and/or support equipment, and powering the monitor from the floor mounted outlet box and the computer aux AC outlet, if applicable; and changing the polarity of the antenna, whichever determined the worst-case emission. Photographs of the worst-case emission can be seen in Appendix C. Each EME reported was calibrated using the HP8640B signal generator. The Theoretical Normalized Site Attenuation Curves for both horizontal and vertical polarization are shown in Figure 9.

§ 15.205 Restricted Bands

Special attention is made for the EUT's harmonic and spurious radiated emission in the restricted bands of operation. The EUT was tested from 9kHz and up to the tenth harmonic of the fundamental frequency of the transmitter using CISPR quasi peak detector below 1GHz. Above 1 GHz, average measurements was used using RBW 1 MHz – VBW 81Hz and linearly polarized horn antennas. In addition, peak measurements were taken to ensure that the peak levels are not more than 20dB above the average limit. All out of band emissions, other than those created by the spreading sequency, data sequence, and the carrier modulation must not exceed the limits show in Table 2 per 15.209.

Frequency (MHz)	F/S (UV/m)	Meas. Dist. (Meters)
0.009-0.490	2400/F (kHz)	300
0.490-1.705	24000/F (kHz)	30
1.705-30.00	30	30
30.0-88.0	810	3
88.0-216.0	150	3
216.0-960.0	200	3
Above 960	500	3

Tab. 2. Radiated Emission Limits Per 15.209

Test Equipment

HP 8566B	**Spectrum Analyzer 810Hz-22GHz**
HP83017A	**Microwave Analyzer 40dB Gain (0.5 – 26.5 GHz)**
HP 3784A	**Digital Transmission Analyzer**
Gigatronics	**POWER METER MODEL 8651A**
EMCO 3115	**Horn Antenna (1 – 18GHz)**
HP 8495A	**20dB Attenuator (DC-40GHz) 0-70dB**
HP 8493B	**81dB Attenuator**
MicroCoax Cables	**Low Loss Microwave Cables (1-26.5 GHz)**
CDI Dipoles	**Dipole Antennas (30 – 8100 MHz)**

§ 15.203 Antenna Requirement

An intentional radiator antenna shall be designed to ensure that no antenna other that that furnished by the applicant can be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with this requirement.

CONCLUSION

The **SYMBOL CRS1-10000-00** complies with the requirement of §15.203. The antenna is a **permanently attached antenna.**

§ 15.247(a)(2) – Direct Sequence Bandwidth

Minimum Standard – 6dB bandwidth for direct sequence systems must be at least 500Hz (0.5 MHz).

Res. Bandwidth =	810 kHz (5dB/div)
Vid. BW =	810 kHz
Span =	30 MHz
Ref. Level	-37 dBm
Sweep	81.0ms
Attenuator	0 dB ext. pad
6dB Bandwidth – Mkr Delta	**(6dB down from peak)**
(see attached spectrum plots)	

FREQUENCY (MHz)	Channel	6dB Bandwidth (MHz)
2402	01	.510
2442	41	.522
2482	81	.526

Table 3. 6dB Bandwidth measurements

REMARKS:

PASS

§ 15.247(b) Maximum Peak Output Power

Minimum Standard – The maximum peak output power of the transmitter shall not exceed 1 watt.

Res. Bandwidth =	3 MHz (7dB/div)
Vid. BW=	3 MHz
Span=	10 MHz
Ref. Level	0 mW
Sweep	5 ms sec
Attenuator	3 dB ext. pad

Max. Power Peak + Atten = dBm ⇒ Watts

FREQUENCY (MHz)	Channel	Power Output Conducted (dBm)	Power Output Radiated (mW)
2402	01	0.0	1.0
2442	41	0.0	1.0
2482	81	0.0	1.0

Table 4. Output Power Measurements

Notes:

The Power Output measurements were taken with a Peak reading Power Meter.

REMARKS:

PASS

§ 15.247(c) Power Density

Minimum Standard – The transmitted power density averaged over any 1 second interval shall not be greater than 8dBm in any 3kHz bandwidth within these bands.

Res. Bandwidth =	3 kHz (81dB/div)
Vid. BW =	3 kHz
Span =	300 kHz
Ref. Level	-40 dBm
Sweep	1000 sec

Peak + Atten = dBm ⇒ (Limit < 8dBm)

FREQ (MHz)	Channel	Power Density (dBm)
2402	01	-12.38
2442	41	-14.13
2482	81	-13.62

Table 5. Output Power Density Data.

REMARKS:

PASS

RADIATED Measurements (Fundamental & Harmonics)

Operating Frequency: 2402 MHz

Distance of Measurements: 3 meters

Channel: 01

FREQ. (MHz)	**Level*** (dBm)	**AFCL** (dB)	**POL** (H/V)	**DET QP/AVG**	**F/S** (μV/m)	**F/S** (dBμV/m)	**Margin** (dB)
2402.0	- 43.0	31.3	H	Peak	58277.4	95.3	n/a
4804.0	- 89.0	44.4	H	Peak	1318.3	62.4	- 32.8
7206.0	- 101.4	49.7	H	Peak	582.1	55.3	- 39.9
9608.0	- 121.2	53.7	H	Peak	94.4	39.5	- 55.7
12010.0	- 129.5	57.2	H	Peak	54.3	34.7	- 60.5
14412.0	< - 132						

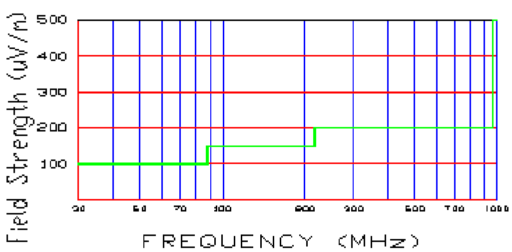


Figure 10. Restricted band harmonics and spurious limits.

Above 1 GHz limit is 500 uV/m (54dBu/m)

NOTES:

1. All harmonics in the restricted bands specified in §15.205 are below the limit shown in table 2. (note: * Restricted Band)

2. All harmonics/spurs are at least 20 dB below the highest emission in the authorized band using RBW = 810kHz

3. Average Measurements > 1GHz using RBW = 1 MHz VBW = 81 Hz

4. The peak emissions above 1 GHz are not more than 20 dB above the average limit.

5. The antenna is manipulated through typical positions, polarity and length during the tests.

6. The EUT is supplied with nominal AC voltage or/and a new/fully recharged battery.

7. The spectrum is measured from 9kHz to the 81th harmonic and the worst-case emissions are reported.

8. < - 132 are below the analyzer floor level.

RADIATED Measurements (Fundamental & Harmonics) (Cont.)

Operating Frequency: 2442 MHz

Distance of Measurements: 3 meters

Channel: 41

FREQ. (MHz)	Level* (dBm)	AFCL (dB)	POL (H/V)	DET QP/AVG	F/S (µV/m)	F/S (dBµV/m)	Margin (dB)
2442.0	- 43.3	31.5	H	Peak	57411.7	95.2	n/a
4884.0	- 89.2	44.7	H	Peak	1333.5	62.5	- 32.7
7326.0	- 102.0	49.9	H	Peak	555.9	54.9	- 40.3
9768.0	- 120.7	54.0	H	Peak	103.5	40.3	- 54.9
12210.0	- 128.5	57.4	H	Peak	62.4	35.9	- 59.3
14652.0	< - 132						

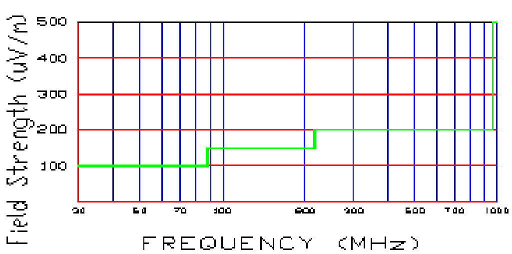


Figure 11. Restricted band harmonics and spurious limits.

Above 1 GHz limit is 500 uV/m (54dBu/m)

NOTES:

1. All harmonics in the restricted bands specified in §15.205 are below the limit shown in table 2. (note: * Restricted Band)

2. All harmonics/spurs are at least 20 dB below the highest emission in the authorized band using RBW = 810kHz

3. Average Measurements > 1GHz using RBW = 1 MHz VBW = 81 Hz

4. The peak emissions above 1 GHz are not more than 20 dB above the average limit.

5. The antenna is manipulated through typical positions, polarity and length during the tests.

6. The EUT is supplied with nominal AC voltage or/and a new/fully recharged battery.

7. The spectrum is measured from 9kHz to the 81th harmonic and the worst-case emissions are reported.

8. < - 132 are below the analyzer floor level.

RADIATED Measurements (Fundamental & Harmonics) (Cont.)

Operating Frequency: 2482 MHz

Distance of Measurements: 3 meters

Channel: 81

FREQ. (MHz)	Level* (dBm)	AFCL (dB)	POL (H/V)	DET QP/AVG	F/S (µV/m)	F/S (dBµV/m)	Margin (dB)
2482.0	- 43.0	31.7	H	Peak	60603.8	95.7	N/a
4964.0	- 87.9	45.0	H	Peak	1603.3	64.1	- 31.1
7446.0	- 100.6	50.1	H	Peak	668.3	56.5	- 38.7
9928.0	- 119.0	54.2	H	Peak	128.8	42.2	- 53.0
12410.0	- 126.8	57.7	H	Peak	78.5	37.9	- 57.3
14892.0	< - 132						

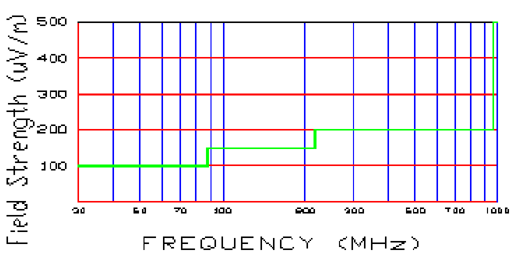


Figure 12. Restricted band harmonics and spurious limits.

Above 1 GHz limit is 500 uV/m (54dBu/m)

NOTES:

1. All harmonics in the restricted bands specified in §15.205 are below the limit shown in table 2. (note: * Restricted Band)

2. All harmonics/spurs are at least 20 dB below the highest emission in the authorized band using RBW = 810kHz

3. Average Measurements > 1GHz using RBW = 1 MHz VBW = 81 Hz

4. The peak emissions above 1 GHz are not more than 20 dB above the average limit.

5. The antenna is manipulated through typical positions, polarity and length during the tests.

6. The EUT is supplied with nominal AC voltage or/and a new/fully recharged battery.

7. The spectrum is measured from 9kHz to the 81th harmonic and the worst-case emissions are reported.

8. < - 132 are below the analyzer floor level.

RADIATED Measurements (Spurious)

Operating Frequency: 2412 – 2483.5 MHz

Distance of Measurements: 3 meters

FREQ. (MHz)	**Level*** (dBm)	**AFCL**** (dB)	**POL** (H/V)	**Height** (m)	**Azimuth** (° angle)	**F/S** (µV/m)	**Margin***** (dB)
66.6	- 83.0	5.8	H	2.8	0	31.0	- 10.2
83.0	- 91.0	7.8	H	2.6	190	15.5	- 16.2
200.0	- 91.5	16.5	H	1.4	190	39.9	-11.5
230.0	- 88.2	17.9	H	1.4	90	68.2	- 9.3
420.0	- 104.0	24.2	V	1.3	80	22.9	- 18.8
618.0	- 104.0	28.5	H	1.2	30	37.4	- 14.6

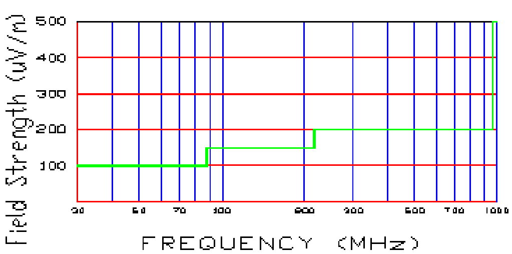


Figure 13. Restricted band harmonics and spurious limits.

NOTES:

1.All emissions were investigated and the worst case emissions are reported

2. For hand-held devices, the EUT is rotated through three orthogonal axis to determine which configuration produces the maximum emissions.

3. The EUT is supplied with the minimal AC voltage or/and a new/fully recharged battery.

4. The EUT was tested up to the 81th harmonic (24 GHz) and no significant emission was found.

Above 1 GHz limit is 500 uV/m (54dBu/m)

§ 15.247(e) PROCESSING GAIN (from SYMBOL)

See attached Processing Gain data and test report from SYMBOL

Results:

PASS

The test results of Section 15.247(e) were confirmed by PCTEST Engineering Lab.

§ 15.247(e) PROCESSING GAIN (from SYMBOL) Continued

BLUETOOTH APPROVALS

The following exhibit indicates the FCC Spread Spectrum requirements in Section 15.247 for devices meeting the Bluetooth Specifications in the 2.4 GHz band as of February 2001 operating in the USA. The purpose of this exhibit is to help expedite the approval process for Bluetooth devices. This exhibit provides items that vary for each device and also provides a list of items that are common to Bluetooth devices that explains the remaining requirements. The list of common items can be submitted for each application for equipment authorization. This exhibit only specifies requirements in Section 15.247, requirements in other rule Sections for intentional radiators such as in Section 15.203 or 15.207 must be also be addressed.

For each individual device, the following items, 1-7 will vary from one device to another and must be submitted.

1) The occupied bandwidth in Section 15.247(a)(1)(ii).
2) Conducted output power specified in Section 15.247(b)(1).
3) EIRP limit in Section 15.247(b)(3).
4) RF safety requirement in Section 15.247(b)(4)
5) Spurious emission limits in Section 15.247(c).
6) Power spectral density requirement in Section 15.247(f) in the acquisition mode.

For all devices, the following items, 1-12, are common to all Bluetooth devices and will not vary from one device to another. This list can be copied into the filing.

1 Output power and channel separation of a Bluetooth device in the different operating modes:
The different operating modes (data-mode, acquisition-mode) of a Bluetooth device don't influence the output power and the channel spacing. There is only one transmitter which is driven by identical input parameters concerning these two parameters.
Only a different hopping sequence will be used. For this reason, the RF parameters in one op-mode is sufficient.
2 Frequency range of a Bluetooth device:
The maximum frequency of the device is: 2402 – 2480 MHz.
This is according the Bluetooth Core Specification V 1.0B (+ critical errata) for devices which will be operated in the USA. Other frequency ranges (e.g. for Spain, France, Japan) which are allowed according the Core Specification must not be supported by the device.
3 Co-ordination of the hopping sequence in data mode to avoid simultaneous occupancy by multiple transmitters:
Bluetooth units which want to communicate with other units must be organized in a structure called piconet. This piconet consist of max. 8 Bluetooth units. One unit is the master the other seven are the slaves. The master co-ordinates frequency occupation in this piconet for all units. As the master hop sequence is derived from it's BD address which is unique for every Bluetooth device, additional masters intending to establish new

§ 15.247(e) PROCESSING GAIN (from SYMBOL) Continued

piconets will always use different hop sequences.

4 Example of a hopping sequence in data mode:

Example of a 79 hopping sequence in data mode:
40, 21, 44, 23, 42, 53, 46, 55, 48, 33, 52, 35, 50, 65, 54, 67,
56, 37, 60, 39, 58, 69, 62, 71, 64, 25, 68, 27, 66, 57, 70, 59,
72, 29, 76, 31, 74, 61, 78, 63, 01, 41, 05, 43, 03, 73, 07, 75,
09, 45, 13, 47, 11, 77, 15, 00, 64, 49, 66, 53, 68, 02, 70, 06,
01, 51, 03, 55, 05, 04

5 Equally average use of frequencies in data mode and short transmissions:

The generation of the hopping sequence in connection mode depends essentially on tw input values:

1. LAP/UAP of the master of the connection
2. Internal master clock

The LAP (lower address part) are the 24 LSB's of the 48 BD_ADDRESS. The BD_ADDRESS is an unambiguous number of every Bluetooth unit. The UAP (upper address part) are the 24 MSB's of the 48 BD_ADDRESS. The internal clock of a Bluetooth unit is derived from a free running clock which is never adjusted and is never turned off. For synchronization with other units, only the offsets are used. It has no relation to the time of the day. Its resolution is at least half the RX/TX slot length of 312. µs. The clock has a cycle of about one day (23h30). In most case it is implemented as 28 bit counter. For the deriving of the hopping sequence the entire LAP (24 bits), 4 LSB's (4 bits) (Input 1) and the 27 MSB's of the clock (Input 2) are used. With this input values different mathematical procedures (permutations, additions, XOR-operations) ar performed to generate the sequence. This will be done at the beginning of every new transmission.

Regarding short transmissions, the Bluetooth system has the following behavior: The first connection between the two devices is established, a hopping sequence is generated. For transmitting the wanted data, the complete hopping sequence is not used and the connection ends. The second connection will be established. A new hopping sequence is generated. Due to the fact that the Bluetooth clock has a different value, because the period between the two transmission is longer (and it cannot be shorter) than the minimum resolution of the clock (312.5 µs). The hopping sequence wil always differ from the first one.

6 Receiver input bandwidth, synchronization and repeated single or multiple packets:

The input bandwidth of the receiver is 1 MHz.

In every connection, one Bluetooth device is the master and the other one is the slave. The master determines the hopping sequence (see chapter 5). The slave follows this sequence. Both devices shift between RX and TX time slot according to the clock of the master. Additionally the type of connection (e.g. single or multi-slot packet) is set up at the beginning of the connection. The master adapts its hopping frequency and its TX/R: timing is according to the packet type of the connection. Also, the slave of the connection uses these settings. Repeating of a packet has no influence on the hopping sequence. The hopping sequence generated by the master of the connection will be followed in any case. That means, a repeated packet will not be send on the same frequency, it is send on the next frequency of the hopping sequence

7 Dwell time in data mode

The dwell time of 0.3797s within a 30 second period in data mode is independent from the packet type (packet length). The calculation for a 30 second period is a follows:
Dwell time = time slot length * hop rate / number of hopping channels *30s

§ 15.247(e) PROCESSING GAIN (from SYMBOL) Continued

Example for a DH1 packet (with a maximum length of one time slot)
Dwell time = 625 µs * 1600 1/s / 79 * 30s = 0.3797s (in a 30s period)
For multi-slot packet the hopping is reduced according to the length of the packet.
Example for a DH5 packet (with a maximum length of five time slots)
Dwell time = 5 * 625 µs * 1600 * 1/5 *1/s / 79 * 30s = 0.3797s (in a 30s period)
This is according the Bluetooth Core Specification V 1.0B (+ critical errata) for all Bluetooth devices. Therefore, all Bluetooth devices comply with the FCC dwell time requirement in the data mode.
This was checked during the Bluetooth Qualification tests.
The Dwell time in hybrid mode is approximately 2.6 mS (in a 12.8s period)

8 Channel Separation in hybrid mode

The nominal channel spacing of the Bluetooth system is 1Mhz independent of the operating mode.
The maximum "initial carrier frequency tolerance" which is allowed for Bluetooth is fcenter = 75 kHz.
This was checked during the Bluetooth Qualification tests (Test Case: TRM/CA/07-E) for three frequencies (2402, 2441, 2480 MHz).

9 Derivation and examples for a hopping sequence in hybrid mode

For the generation of the inquiry and page hop sequences the same procedures as described for the data mode are used (see item 5), but this time with different input vectors:
**For the inquiry hop sequence, a predefined fixed address is always used. This results in the same 32 frequencies used by all devices doing an inquiry but every time with a different start frequency and phase in this sequence.
**For the page hop sequence, the device address of the paged unit is used as the input vector. This results in the use of a subset of 32 frequencies which is specific for that initial state of the connection establishment between the two units. A page to different devices would result in a different subset of 32 frequencies.
So it is ensured that also in hybrid mode, the frequency is used equally on average.
Example of a hopping sequence in inquiry mode:
48, 50, 09, 13, 52, 54,41, 45, 56, 58, 11, 15, 60, 62, 43, 47, 00, 02, 64, 68, 04, 06, 17, 21, 08, 10, 66, 70, 12, 14, 19, 23
Example of a hopping sequence in paging mode:
08, 57, 68, 70, 51, 02, 42, 40, 04, 61, 44, 46, 63, 14, 50, 48, 16, 65, 52, 54, 67, 18, 58, 56, 20, 53, 60, 62, 55, 06, 66, 64

10 Receiver input bandwidth and synchronization in hybrid mode:

The receiver input bandwidth is the same as in the data mode (1 MHz). When two Bluetooth devices establish contact for the first time, one device sends an inquiry access code and the other device is scanning for this inquiry access code. If two devices have been connected previously and want to start a new transmission, a similar procedure takes place. The only difference is, instead of the inquiry access code, a special access code, derived from the BD_ADDRESS of the paged device will be, will be sent by the master of this connection. Due to the fact that both units have been connected before (in the inquiry procedure) the paging unit has timing and frequency information about the page scan of the paged unit. For this reason the time to establish the connection is reduced.

11 Spread rate / data rate of the direct sequence signal

The Spread rate / Data rate in inquiry and paging mode can be defined via the access code. The access code is the only criterion for the system to check if there is a valid transmission or not. If you regard the presence of a valid access code as one bit of information, and compare it with the length of the access code of 68 bits, the Spread rate

§ 15.247(e) PROCESSING GAIN (from SYMBOL) Continued

/ Data rate will be 68/1.

12 Spurious emission in hybrid mode

The Dwell in hybrid mode is shorter than in data mode. For this reason the spurious emissions average level in data mode is worst case. The spurious emissions peak level is the same for both modes.

§ 15.247(e) PROCESSING GAIN (from SYMBOL) Continued

A Minimal Bluetooth-Based Computing and Communication Platform

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Abstract

In this technical note we present an autonomous wireless communication and computing platform and its applications. The system is based on a Bluetooth communication module and a microcontroller. It is designed for a minimum use of resources while still being flexible. This platform is being used to set up large ad hoc networks, e.g. for collaborative remote sensing. In general, it can be used as a small but generic wireless networking node.

1. Introduction

Recently, networking multiple small devices in an uncoordinated and uncentralized fashion by wireless means has generated much interest. The Bluetooth technology [1] is an emerging communication standard that provides ad hoc configuration of master/slave piconets up to eight units. It allows data rates up to several hundred kilobytes per second. We have designed and implemented an autonomous programmable computing unit with Bluetooth communications. The system is being used to implement a collaborative sensor network [2] and serves as a testbed for ad hoc networking protocols in networks comprising large numbers of mobile autonomous nodes.

A brief overview of the design considerations and the hardware implementation of such a network node is given in sections 2 and 3. Details of the power consumption of the system components are discussed in section 3. The final section 4 deals with the systems operating software, protocols, and applications.

2. Design Considerations

Commercial Bluetooth solutions are available as fully self-contained transceiver modules. They are designed to be used as add-on peripherals. They feature an embedded CPU, different types of memory, as well as baseband and radio circuits. The modules offer a generic Host Controller Interface (HCI) to the lower layers of the Bluetooth protocol stack while the higher layers of the protocol and applications must be implemented on the host system. Since the in-system CPU and memory are not available for user specific implementations, even a minimal standalone Bluetooth node needs an additional host CPU to execute applications and the corresponding higher layers of the Bluetooth protocol.

Having networks of hundreds of autonomous mobile nodes in mind, devices need to be carefully designed. Some of the features we considered in the design are:

- In-circuit programmable platform
- Component count
- Overall system size
- Sensor and user interface
- Single voltage with power management

3. System Overview

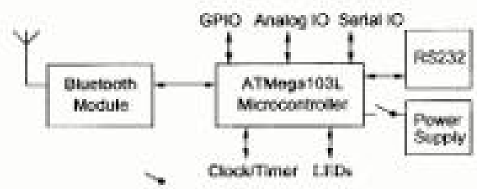

Figure 1. Schematic system overview

To run applications and the higher Bluetooth protocol layers, the Atmel ATMega103L SOC microcontroller with embedded memory was chosen. It features an 8-bit RISC core with up to 4 MIPS at 4 MHz, 128 Kbytes Flash memory and

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§ 15.247(e) PROCESSING GAIN (from SYMBOL) Continued

BLUETOOTH SPECIFICATION Version 1.1
Baseband Specification

11 HOP SELECTION

In total, 10 types of hopping sequences are defined –five for the 79-hop and five for the 23-hop system, respectively. Using the notation of parentheses () for figures related to the 23-hop system, these sequences are:

- A **page hopping sequence** with 32 (16) unique wake-up frequencies dis-tributed equally over the 79 (23) MHz, with a period length of 32 (16);
- A **page response sequence** covering 32 (16) unique response frequencies that all are in an one-to-one correspondence to the current page hopping sequence. The master and slave use different rules to obtain the same sequence;
- An **inquiry sequence** with 32 (16) unique wake-up frequencies distributed equally over the 79 (23) MHz, with a period length of 32 (16);
- A **inquiry response sequence** covering 32 (16) unique response frequencies that all are in an one-to-one correspondence to the current inquiry hop-ping sequence.
- A **channel hopping sequence** which has a very long period length, which does not show repetitive patterns over a short time interval, but which distributes the hop frequencies equally over the 79 (23) MHz during a short time interval;

For the page hopping sequence, it is important that we can easily shift the phase forward or backward, so we need a 1-1 mapping from a counter to the hop frequencies. For each case, both a hop sequence from master to slave and from slave to master are required.

The inquiry and inquiry response sequences always utilizes the GIAC LAP as lower address part and the DCI as upper address part in deriving the hopping sequence, even if it concerns a DIAC inquiry.

11.1 GENERAL SELECTION SCHEME

The selection scheme consists of two parts:

- selecting a sequence;
- mapping this sequence on the hop frequencies;

The mapping from the input to a particular hop frequency is performed in the selection box. Basically, the input is the native clock and the current address. In **CONNECTION** state, the native clock (CLKN) is modified by an offset to equal the master clock (CLK). Only the 27 MSBs of the clock are used. In the **page** and **inquiry** substates, all 28 bits of the clock are used. However, in **page** substate the native clock will be modified to the master's estimate of the paged unit. The address input consists of 28 bits, i.e., the entire LAP and the 4 LSBs of the
UAP. In **CONNECTION** state, the address of the master is used. In **page** sub-state the address of the paged unit is used. When in **inquiry** substate, the

UAP/LAP corresponding to the GIAC is used. The output constitutes a pseudo-random sequence, either covering 79 hop or 23 hops, depending on the state.

For the 79-hop system, the selection scheme chooses a segment of 32 hop frequencies spanning about 64 MHz and visits these hops once in a random order. Next, a different 32-hop segment is chosen, etc. In case of the **page**, **page scan**, or **page response** substates, the same 32-hop segment is used all the time (the segment is selected by the address; different units will have dif-ferent paging segments). In connection state, the output constitutes a pseudo-random sequence that slides through the 79 hops or 23 hops, depending on the selected hop system. For the 23-hop systems, the segment size is 16.

§ 15.247(e) PROCESSING GAIN (from SYMBOL) Continued

4 Kbytes SRAM, a serial interface as well as several power modes. The Bluetooth module [3] is a fully shielded subsystem that is attached to a serial port of the microcontroller. External serial ports are used for data transfer and in-circuit programming. An external antenna is mounted with the required ground plane onto the 4x6 cm PCB substrate.

A voltage regulator is used to supply the necessary operating voltage from a small battery pack to the main components individually. This allows exact monitoring of power consumption and duty cycles.

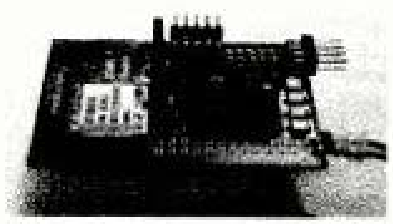

Figure 2. System mounted on battery pack

The system power consumption for different operating modes is given in table 1. It shows that the dominant component in such a wireless network node today is the Bluetooth module. The values presented clearly show that Bluetooth is not yet ready for deployment in real world scenarios. However, improved Bluetooth products [4] and advanced power management will eventually reduce power consumption considerably. Our system design allows for easy replacement of the Bluetooth transceiver module, once improved modules are available on the market.

Table 1. System power consumption at 3.3 V

CPU Power Down, Bluetooth detached	9.9 mW
Running, Bluetooth detached	26.4 mW
Running, Bluetooth Transmit/Receive mode	108.9 mW
Running, Bluetooth Inquiry mode	148.8 mW

4. System Software and Applications

The system software provides low-level drivers, a scheduler and the host portion of the Bluetooth protocol stack. There are drivers for serial ports, analog to digital converter, general purpose IO, random number generator, system clock, and sensors. The scheduler provides event-driven scheduling of system and application tasks.

We ported the host portion of the Bluetooth protocol stack from an open source Linux implementation [5] to our microcontroller environment. The Linux version of the Bluetooth stack required multithreading capabilities and access to the serial port. On our system these functions are taken care of by the scheduler and the low-level drivers. The main obstacle in porting was the limited memory provisions of the microcontroller, since the original protocol stack was not optimized for memory consumption.

Devices can autonomously communicate using Bluetooth wireless technology. Supported layers are HCI and the Logical Link Control and Adaption Protocol (L2CAP). Inquiry, connection establishment to other devices, and disconnection procedures have been implemented and tested.

We are developing an application that deduces the topology of mobile Bluetooth devices based on the ability to inquire other Bluetooth devices within range. Whenever an unknown device enters inquiry range, its presence is detected. This information is then disseminated throughout the known part of the network. Approaches and first results are described in [6]. Furthermore, the system can also be used as a wireless interface peripheral.

Future work on the system software will concentrate on minimizing memory usage of the Bluetooth stack and adding the Service Discovery Protocol (SDP). In the application domain, the Smart-Its project [2] will make use of the system to form mobile ad hoc networks of collaborative sensors.

5. Conclusions

The implementation of a small, standalone communication platform using the Bluetooth protocol has been described. The feasibility of scaling the Bluetooth protocol stack to an embedded device with limited resources has been demonstrated. Even though the current implementation can hardly be deployed in real world scenarios due to its high power consumption, it serves well as a demonstration platform for research in mobile and ad hoc connected networks (MANETs) and distributed sensor networks.

References

[1] Bluetooth Special Interest Group, *Specification of the Bluetooth System v1.1*, December 2000.

[2] The Smart Its Project, http://www.smart-its.org.

[3] Ericsson Microelectronics, *ROK 101 008 Bluetooth Module Datasheet*, 2001.

[4] Frank Op't Eynde et. al., "A Fully-Integrated Single-Chip SOC for Bluetooth," in *Proceedings of IEEE International Solid-State Circuits Conference - ISSCC 2001*, February 2001, pp. 196–197.

[5] Axis Communications, "Axis Bluetooth Driver Software," http://sourceforge.net/projects/openbt/.

[6] Thomas Moser and Lukas Karrer, "The EventCollector Concept," M.S. thesis, ETH Zürich, Distributed Systems Group, 2001.

§ 15.247(e) PROCESSING GAIN (from SYMBOL) Continued

7.1.3.2 B in security mode 3

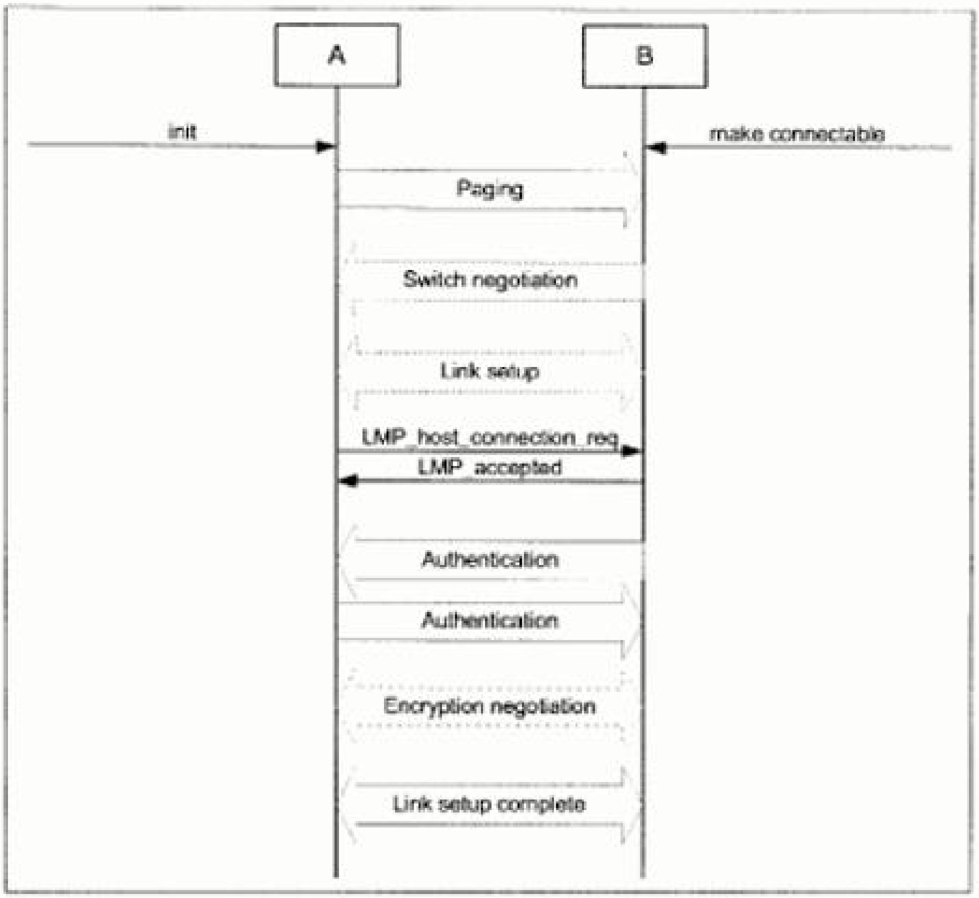

Figure 7.2: Link establishment procedure when both the paging device (A) and the paged device (B) are in security mode 3.

7.1.4 Conditions

The paging procedure shall be according to and the paging device should use the Device access code and page mode received through a previous inquiry. When paging is completed, a physical link between the two Bluetooth devices is established.

If role switching is needed (normally it is the paged device that has an interest in changing the master/slave roles) it should be done as early as possible after the physical link is established. If the paging device does not accept the switch, the paged device has to consider whether to keep the physical link or not.

Both devices may perform link setup (using LMP procedures that require no interaction with the host on the remote side). Optional LMP features can be used after having confirmed (using LMP_feature_req) that the other device supports the feature.

§ 15.247(e) PROCESSING GAIN (from SYMBOL) Continued

7.3 CONNECTION ESTABLISHMENT

7.3.1 Purpose

The purpose of the connection establishment procedure is to establish a connection between applications on two Bluetooth devices.

7.3.2 Term on UI level

'Bluetooth connection establishment'

7.3.3 Description

In this sub-section, the initiator (A) is in security mode 3. During connection establishment, the initiator cannot distinguish if the acceptor (B) is in security mode 1 or 3.

7.3.3.1 B in security mode 2

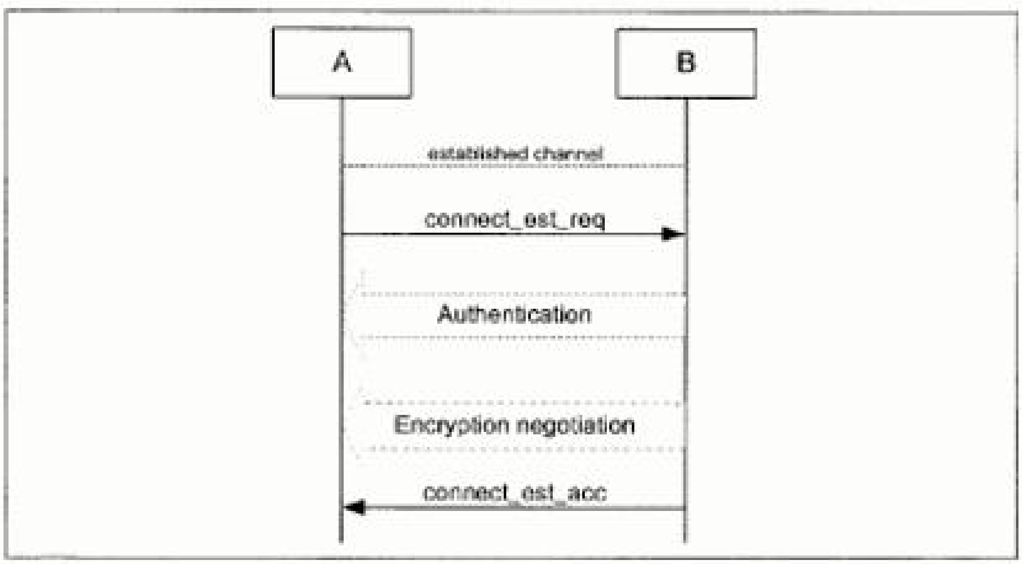

Figure 7.5: Connection establishment procedure when the initiator (A) is in security mode 3 and the acceptor (B) is in security mode 2.

§ 15.247(e) PROCESSING GAIN (from SYMBOL) Continued

FCC ID H9PCRS1

MEMORANDUM – PROCESSING GAIN REPORT FOR INTEL(R) PERSONAL WIRELESS
MODULE

Subject: Results of Processing Gain Tests for FCC Qualification

1 INTRODUCTION

This memo presents the results of the Processing Gain (PG) tests carried out for FCC qualification of the Intel(R) Personal Wireless Module chip. The FCC states that the PG from a hybrid
Bluetooth receiver must be greater than 17 dB when measured in accordance with the Continuous Wave (CW) jamming margin method. Testing of the Intel(R) Personal Wireless Module “B”
Bluetooth chip has found the PG due to the DS section to be approximately 5 dB and the PG due to the FH part to be approximately 15 dB. It is therefore concluded that the Intel(R) Personal
Wireless Module Bluetooth Chip complies with the FCC PG requirements for radio communication
systems.
The rest of this paper outlines the PG measurement technique and discusses the test results. Appendix A contains a list of test equipment and Appendix B contains a printout of the measurement results.

2 METHOD

2.1 PG Definition

The Processing Gain from a frequency hopping communication system is derived from two parts, the FH section and the DS section. The PG due to FH is given by a simple equation and is constant. However measurement of the PG due to DS is a little more complex. One technique is to use the CW jamming margin method. This method measures PG due to DS using the following algorithm:

A CW signal generator is stepped in 50kHz increments across the passband of the system, recording at each point the generator level required to produce the 0.1% Packet Error Rate (PER). This is the jammer level. This level is then referenced to the output power of the intended Bluetooth signal and the Jammer to Signal Ratio JSR is thus calculated. The worst 4 JSR measurements are discarded and the worst remaining JSR is used to calculate the PG due to DS as follows:

sys p L JSR SNR G □□□□□□min

where Gp = the processing gain of the system, SNR = the signal to noise ratio required for 0.1% BER, JSRmin = minimum J/S ratio and Lsys = system losses.

§ 15.247(e) PROCESSING GAIN (from SYMBOL) Continued

2.2 PG Measurement Technique

Figure 1 provides an overview of the PG measurement technique. The measurement is performed in two parts, measurement of the system SNR and measurement of JSRmin.

Figure 1: PG Measurement Technique

The system SNR is calculated using the following algorithm. Generate Bluetooth PRBS-9 packets using a Bluetooth chip emulator (1) and a Vector Signal Generator (2). Combine this signal with white noise of a constant level, which is generated using a noise source (4) and a CW Signal Generator (3). Then vary the level of the Bluetooth signal until the BER measured by the Bluetooth chip (7) is 0.1%. The resulting SNR is the signal level divided by the Noise level.

The JSR for a given jamming frequency is calculated using the following algorithm. Generate Bluetooth PRBS-9 packets using the Bluetooth chip emulator (1) and the Vector Signal Generator (2). Combine this signal with a constant CW tone at the jamming frequency using a CW Signal Generator (5) and a combiner (6). Then vary the level of the Bluetooth signal until the PER measured by the Casira Bluetooth Module (7) is 0.1%. The resulting JSR is the signal level divided by the jamming level.

3 RESULTS

3.1 Overview

The measurements found that the PG due to DS caused by the access code in page and inquiry mode is found to be approximately 5dB when the access code is a relatively random mixture of 1's and 0's. A random access code causes the most Inter Symbol Interference (ISI) and hence the worst PG for a hybr id system. Therefore only the results for this access code are used in the PG calculation.

The PG due to FH is given as

PGFH = 10 log10 (number of frequency hops)

The number of hops in a Bluetooth system is 32, therefore the PG due to FH is approximately 15 dB. When this is added to the PG due to DS, the total PG for the Bluetooth chip is approximately 20 dB, above the minimum PG requirement for FCC qualification.

3.2 Detailed Results

Test Date: 17/11/00
Sample Time: 30 seconds
Access Code: c6967e
Signal Frequency: 2.432GHz

Receiver Sensitivity: -88.7 dBm
Jammer Signal Level: -85.7 dBm
Measured SNR: 18.8dB
System Losses: 2dB

§ 15.247(e) PROCESSING GAIN (from SYMBOL) Continued

To calculate processing gain, ignore the worst 20% of data points and then apply the following formula:

sys p L JSR SNR G □□□□□□□min
Where Gp = Processing Gain of the module
SNR = signal to noise ratio of the module
JSmin = minimum J/S ratio after the worst 20% of J/S samples have been discarded
Lsys = System losses
A total of 20 samples were taken by stepping the jamming signal frequency offsets in 50kHz increments over the bandwidth of the receiver. The worst 4 samples were found at –500kHz, -450kHz, -400kHz and 500kHz and were discarded. The remaining minimum J/S ratio was found to be -15.4dB at an offset of +350kHz
Thus, the processing gain due to direct sequence spreading in page and inquiry mode is
dB Gp 4 . 5 2 4 . 15 8 . 18 □□□□□□□□
-500 -400 -300 -200 -100 0 100 200 300 400 500
-30
-25
-20
-15
-10
-5
0
5
J a m m i n g F r e q u e n c y O f f s e t (k H z)
J/S (dBs)
J / S r a t i o p e r f o r m a n c e f o r P r o c e s s i n g G a i n F CC T e s t i n g

APPENDIX A - TEST EQUIPMENT LIST
Reference: Instrument Type Name
1 Bluetooth IC Emulator
Board
N/A
2 Vector Signal Generator IFR2052
3 CW Signal Generator IFR2025
4 White Noise Generator HP33120A
5 RF Mixer M8HC-7
6 RF Combiner 6 dB loss combiner
7 Bluetooth Motherboard and
Bluetooth chip Module
Bluetooth Development Kit
8 5V, 4A DC Power Supply N/A
9 Spectrum Analyser HP E4405B

§ 15.247(e) PROCESSING GAIN (from SYMBOL) Continued

Timestamp: 14:42.43, 16/11/2000
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = -500 kHz
Level = -68.7 dBm BER = 0.03% PER = 0.01% SER1 = 0.01% SER2 = 0.01%
Level = -70.7 dBm BER = 0.32% PER = 0.79% SER1 = 0.79% SER2 = 0.79%
Level = -69.7 dBm BER = 0.11% PER = 0.18% SER1 = 0.18% SER2 = 0.18%
Level = -68.7 dBm BER = 0.04% PER = 0.03% SER1 = 0.02% SER2 = 0.02%
Level = -69.2 dBm BER = 0.06% PER = 0.05% SER1 = 0.05% SER2 = 0.05%
Level = -69.7 dBm BER = 0.11% PER = 0.16% SER1 = 0.16% SER2 = 0.16%
Level = -69.5 dBm BER = 0.09% PER = 0.11% SER1 = 0.11% SER2 = 0.11%
Level = -69.3 dBm BER = 0.07% PER = 0.05% SER1 = 0.05% SER2 = 0.05%
J/S = -16.50 dB (SER = 0.05%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = -450 kHz
Level = -69.2 dBm BER = 0.06% PER = 0.05% SER1 = 0.05% SER2 = 0.05%
Level = -71.2 dBm BER = 0.84% PER = 1.72% SER1 = 1.69% SER2 = 1.69%
Level = -70.2 dBm BER = 0.26% PER = 0.40% SER1 = 0.40% SER2 = 0.40%
Level = -69.2 dBm BER = 0.07% PER = 0.06% SER1 = 0.06% SER2 = 0.06%
Level = -69.7 dBm BER = 0.12% PER = 0.18% SER1 = 0.18% SER2 = 0.18%
Level = -69.5 dBm BER = 0.09% PER = 0.14% SER1 = 0.14% SER2 = 0.14%
Level = -69.3 dBm BER = 0.07% PER = 0.08% SER1 = 0.08% SER2 = 0.08%
J/S = -16.40 dB (SER = 0.08%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = -400 kHz
Level = -69.3 dBm BER = 0.04% PER = 0.02% SER1 = 0.02% SER2 = 0.02%
Level = -71.3 dBm BER = 0.44% PER = 0.72% SER1 = 0.71% SER2 = 0.71%
Level = -70.3 dBm BER = 0.13% PER = 0.11% SER1 = 0.11% SER2 = 0.11%
Level = -69.3 dBm BER = 0.04% PER = 0.01% SER1 = 0.01% SER2 = 0.01%
Level = -69.8 dBm BER = 0.08% PER = 0.03% SER1 = 0.02% SER2 = 0.02%
Level = -70.3 dBm BER = 0.13% PER = 0.10% SER1 = 0.10% SER2 = 0.10%
J/S = -15.40 dB (SER = 0.10%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = -350 kHz
Level = -70.3 dBm BER = 0.05% PER = 0.01% SER1 = 0.01% SER2 = 0.01%
Level = -72.3 dBm BER = 0.88% PER = 1.67% SER1 = 1.64% SER2 = 1.64%
Level = -71.3 dBm BER = 0.19% PER = 0.10% SER1 = 0.10% SER2 = 0.10%
Level = -70.3 dBm BER = 0.06% PER = 0.01% SER1 = 0.01% SER2 = 0.01%
Level = -70.8 dBm BER = 0.09% PER = 0.04% SER1 = 0.04% SER2 = 0.04%
Level = -71.3 dBm BER = 0.17% PER = 0.12% SER1 = 0.12% SER2 = 0.12%
Level = -71.1 dBm BER = 0.13% PER = 0.05% SER1 = 0.05% SER2 = 0.05%
J/S = -14.60 dB (SER = 0.05%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = -300 kHz
Level = -71.1 dBm BER = 0.03% PER = 0.15% SER1 = 0.15% SER2 = 0.15%
Level = -69.1 dBm BER = 0.00% PER = 0.00% SER1 = 0.00% SER2 = 0.00%
Level = -70.1 dBm BER = 0.01% PER = 0.00% SER1 = 0.00% SER2 = 0.00%

Level = -71.1 dBm BER = 0.03% PER = 0.19% SER1 = 0.19% SER2 = 0.19%
Level = -70.6 dBm BER = 0.02% PER = 0.04% SER1 = 0.04% SER2 = 0.04%
Level = -70.8 dBm BER = 0.02% PER = 0.09% SER1 = 0.09% SER2 = 0.09%
J/S = -14.90 dB (SER = 0.09%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = -250 kHz

§ 15.247(e) PROCESSING GAIN (from SYMBOL) Continued

Level = -70.8 dBm BER = 0.00% PER = 0.03% SER1 = 0.02% SER2 = 0.02%
Level = -72.8 dBm BER = 0.05% PER = 2.34% SER1 = 2.29% SER2 = 2.29%
Level = -71.8 dBm BER = 0.01% PER = 0.33% SER1 = 0.33% SER2 = 0.33%
Level = -70.8 dBm BER = 0.00% PER = 0.03% SER1 = 0.03% SER2 = 0.03%
Level = -71.3 dBm BER = 0.01% PER = 0.11% SER1 = 0.11% SER2 = 0.11%
Level = -71.1 dBm BER = 0.00% PER = 0.11% SER1 = 0.11% SER2 = 0.11%
Level = -70.9 dBm BER = 0.00% PER = 0.03% SER1 = 0.03% SER2 = 0.03%
J/S = -14.80 dB (SER = 0.03%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = -200 kHz
Level = -70.9 dBm BER = 0.00% PER = 0.00% SER1 = 0.00% SER2 = 0.00%
Level = -72.9 dBm BER = 0.00% PER = 0.34% SER1 = 0.34% SER2 = 0.34%
Level = -71.9 dBm BER = 0.00% PER = 0.07% SER1 = 0.07% SER2 = 0.07%
Level = -72.4 dBm BER = 0.00% PER = 0.15% SER1 = 0.15% SER2 = 0.15%
Level = -72.2 dBm BER = 0.00% PER = 0.12% SER1 = 0.12% SER2 = 0.12%
Level = -72.0 dBm BER = 0.00% PER = 0.05% SER1 = 0.05% SER2 = 0.05%
J/S = -13.80 dB (SER = 0.07%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = -150 kHz
Level = -71.9 dBm BER = 0.00% PER = 0.00% SER1 = 0.00% SER2 = 0.00%
Level = -73.9 dBm BER = 0.00% PER = 0.03% SER1 = 0.02% SER2 = 0.02%
Level = -75.9 dBm BER = 0.01% PER = 0.83% SER1 = 0.82% SER2 = 0.82%
Level = -74.9 dBm BER = 0.00% PER = 0.16% SER1 = 0.16% SER2 = 0.16%
Level = -73.9 dBm BER = 0.00% PER = 0.03% SER1 = 0.02% SER2 = 0.02%
Level = -74.4 dBm BER = 0.00% PER = 0.08% SER1 = 0.07% SER2 = 0.07%
Level = -74.9 dBm BER = 0.00% PER = 0.18% SER1 = 0.18% SER2 = 0.18%
Level = -74.7 dBm BER = 0.00% PER = 0.10% SER1 = 0.10% SER2 = 0.10%
J/S = -11.00 dB (SER = 0.10%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = -100 kHz
Level = -74.7 dBm BER = 0.00% PER = 0.00% SER1 = 0.00% SER2 = 0.00%
Level = -76.7 dBm BER = 0.00% PER = 0.05% SER1 = 0.05% SER2 = 0.05%
Level = -78.7 dBm BER = 0.01% PER = 2.05% SER1 = 2.01% SER2 = 2.01%
Level = -77.7 dBm BER = 0.00% PER = 0.30% SER1 = 0.30% SER2 = 0.30%
Level = -76.7 dBm BER = 0.00% PER = 0.06% SER1 = 0.06% SER2 = 0.06%
Level = -77.2 dBm BER = 0.00% PER = 0.13% SER1 = 0.12% SER2 = 0.12%
Level = -77.0 dBm BER = 0.00% PER = 0.08% SER1 = 0.07% SER2 = 0.07%
J/S = -8.70 dB (SER = 0.07%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = -50 kHz
Level = -77.0 dBm BER = 0.00% PER = 0.00% SER1 = 0.00% SER2 = 0.00%
Level = -79.0 dBm BER = 0.00% PER = 0.00% SER1 = 0.00% SER2 = 0.00%
Level = -81.0 dBm BER = 0.01% PER = 0.05% SER1 = 0.05% SER2 = 0.05%
Level = -83.0 dBm BER = 0.16% PER = 0.73% SER1 = 0.72% SER2 = 0.72%
Level = -82.0 dBm BER = 0.03% PER = 0.26% SER1 = 0.26% SER2 = 0.26%
Level = -81.0 dBm BER = 0.01% PER = 0.06% SER1 = 0.06% SER2 = 0.06%
Level = -81.5 dBm BER = 0.02% PER = 0.13% SER1 = 0.13% SER2 = 0.13%
Level = -81.3 dBm BER = 0.02% PER = 0.11% SER1 = 0.11% SER2 = 0.11%
Level = -81.1 dBm BER = 0.04% PER = 0.06% SER1 = 0.06% SER2 = 0.06%
J/S = -4.60 dB (SER = 0.06%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = +0 kHz
Level = -68.7 dBm BER = 0.00% PER = 0.00% SER1 = 0.00% SER2 = 0.00%
Level = -70.7 dBm BER = 0.00% PER = 0.00% SER1 = 0.00% SER2 = 0.00%

§ 15.247(e) PROCESSING GAIN (from SYMBOL) Continued

Level = -72.7 dBm BER = 0.00% PER = 0.00% SER1 = 0.00% SER2 = 0.00%
Level = -74.7 dBm BER = 0.00% PER = 0.00% SER1 = 0.00% SER2 = 0.00%
Level = -76.7 dBm BER = 0.00% PER = 0.00% SER1 = 0.00% SER2 = 0.00%
Level = -78.7 dBm BER = 0.00% PER = 0.00% SER1 = 0.00% SER2 = 0.00%
Level = -80.7 dBm BER = 0.01% PER = 0.00% SER1 = 0.00% SER2 = 0.00%
Level = -82.7 dBm BER = 0.04% PER = 0.04% SER1 = 0.03% SER2 = 0.03%
Level = -84.7 dBm BER = 7.51% PER = 48.26% SER1 = 27.11% SER2 = 28.05%
Level = -83.7 dBm BER = 0.31% PER = 1.01% SER1 = 0.86% SER2 = 0.86%
Level = -82.7 dBm BER = 0.05% PER = 0.24% SER1 = 0.18% SER2 = 0.18%
Level = -81.7 dBm BER = 0.01% PER = 0.00% SER1 = 0.00% SER2 = 0.00%
Level = -82.2 dBm BER = 0.02% PER = 0.13% SER1 = 0.10% SER2 = 0.10%
Level = -82.0 dBm BER = 0.02% PER = 2.31% SER1 = 2.24% SER2 = 2.24%
Level = -81.8 dBm BER = 0.02% PER = 0.06% SER1 = 0.05% SER2 = 0.05%
J/S = -3.90 dB (SER = 0.05%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = +50 kHz
Level = -81.8 dBm BER = 0.11% PER = 0.02% SER1 = 0.02% SER2 = 0.02%
Level = -83.8 dBm BER = 0.68% PER = 2.16% SER1 = 1.82% SER2 = 1.82%
Level = -82.8 dBm BER = 0.28% PER = 0.35% SER1 = 0.29% SER2 = 0.29%
Level = -81.8 dBm BER = 0.09% PER = 0.02% SER1 = 0.02% SER2 = 0.02%
Level = -82.3 dBm BER = 0.15% PER = 0.25% SER1 = 0.22% SER2 = 0.22%
Level = -82.1 dBm BER = 0.12% PER = 0.09% SER1 = 0.07% SER2 = 0.07%
J/S = -3.60 dB (SER = 0.07%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = +100 kHz
Level = -82.1 dBm BER = 1.55% PER = 15.88% SER1 = 13.44% SER2 = 13.51%
Level = -80.1 dBm BER = 0.28% PER = 5.78% SER1 = 5.47% SER2 = 5.47%
Level = -78.1 dBm BER = 0.03% PER = 0.09% SER1 = 0.09% SER2 = 0.09%
J/S = -7.60 dB (SER = 0.09%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = +150 kHz
Level = -78.1 dBm BER = 0.41% PER = 13.58% SER1 = 11.96% SER2 = 12.16%
Level = -76.1 dBm BER = 0.09% PER = 0.42% SER1 = 0.42% SER2 = 0.42%
Level = -74.1 dBm BER = 0.00% PER = 0.00% SER1 = 0.00% SER2 = 0.00%
Level = -75.1 dBm BER = 0.01% PER = 0.02% SER1 = 0.02% SER2 = 0.02%
Level = -76.1 dBm BER = 0.04% PER = 0.41% SER1 = 0.41% SER2 = 0.41%
Level = -75.6 dBm BER = 0.03% PER = 0.10% SER1 = 0.10% SER2 = 0.10%
J/S = -10.10 dB (SER = 0.10%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = +200 kHz
Level = -75.6 dBm BER = 0.26% PER = 7.53% SER1 = 7.00% SER2 = 7.00%
Level = -73.6 dBm BER = 0.02% PER = 0.17% SER1 = 0.17% SER2 = 0.17%
Level = -71.6 dBm BER = 0.00% PER = 0.00% SER1 = 0.00% SER2 = 0.00%
Level = -72.6 dBm BER = 0.00% PER = 0.03% SER1 = 0.03% SER2 = 0.03%
Level = -73.6 dBm BER = 0.02% PER = 0.14% SER1 = 0.14% SER2 = 0.14%
Level = -73.1 dBm BER = 0.01% PER = 0.04% SER1 = 0.04% SER2 = 0.04%
Level = -73.3 dBm BER = 0.01% PER = 0.05% SER1 = 0.05% SER2 = 0.05%
Level = -73.5 dBm BER = 0.03% PER = 0.09% SER1 = 0.09% SER2 = 0.09%
J/S = -12.20 dB (SER = 0.09%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = +250 kHz
Level = -73.5 dBm BER = 0.25% PER = 3.58% SER1 = 3.46% SER2 = 3.46%
Level = -71.5 dBm BER = 0.01% PER = 0.03% SER1 = 0.03% SER2 = 0.03%
Level = -72.5 dBm BER = 0.06% PER = 0.57% SER1 = 0.57% SER2 = 0.57%

§ 15.247(e) PROCESSING GAIN (from SYMBOL) Continued

Level = -72.0 dBm BER = 0.02% PER = 0.12% SER1 = 0.12% SER2 = 0.12%
Level = -71.5 dBm BER = 0.01% PER = 0.04% SER1 = 0.04% SER2 = 0.04%
Level = -71.7 dBm BER = 0.01% PER = 0.05% SER1 = 0.05% SER2 = 0.05%
Level = -71.9 dBm BER = 0.02% PER = 0.10% SER1 = 0.10% SER2 = 0.10%
J/S = -14.00 dB (SER = 0.05%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = +300 kHz
Level = -71.7 dBm BER = 0.08% PER = 0.10% SER1 = 0.10% SER2 = 0.10%
J/S = -14.00 dB (SER = 0.10%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = +350 kHz
Level = -71.7 dBm BER = 0.25% PER = 1.43% SER1 = 1.41% SER2 = 1.41%
Level = -69.7 dBm BER = 0.02% PER = 0.03% SER1 = 0.02% SER2 = 0.02%
Level = -70.7 dBm BER = 0.08% PER = 0.14% SER1 = 0.14% SER2 = 0.14%
Level = -70.2 dBm BER = 0.03% PER = 0.74% SER1 = 0.74% SER2 = 0.74%
Level = -69.7 dBm BER = 0.02% PER = 0.02% SER1 = 0.02% SER2 = 0.02%
Level = -69.9 dBm BER = 0.02% PER = 0.03% SER1 = 0.02% SER2 = 0.02%
Level = -70.1 dBm BER = 0.03% PER = 0.03% SER1 = 0.03% SER2 = 0.03%
Level = -70.3 dBm BER = 0.03% PER = 0.06% SER1 = 0.06% SER2 = 0.06%
Level = -70.5 dBm BER = 0.06% PER = 0.13% SER1 = 0.13% SER2 = 0.13%
J/S = -15.40 dB (SER = 0.06%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = +400 kHz
Level = -70.3 dBm BER = 0.07% PER = 0.05% SER1 = 0.05% SER2 = 0.05%
Level = -72.3 dBm BER = 1.28% PER = 4.62% SER1 = 4.42% SER2 = 4.42%
Level = -71.3 dBm BER = 0.24% PER = 0.48% SER1 = 0.47% SER2 = 0.47%
Level = -70.3 dBm BER = 0.06% PER = 0.06% SER1 = 0.06% SER2 = 0 .06%
Level = -70.8 dBm BER = 0.12% PER = 0.15% SER1 = 0.15% SER2 = 0.15%
Level = -70.6 dBm BER = 0.11% PER = 0.08% SER1 = 0.08% SER2 = 0.08%
J/S = -15.10 dB (SER = 0.08%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = +450 kHz
Level = -70.6 dBm BER = 0.17% PER = 0.11% SER1 = 0.11% SER2 = 0.11%
Level = -68.6 dBm BER = 0.01% PER = 0.00% SER1 = 0.00% SER2 = 0.00%
Level = -69.6 dBm BER = 0.04% PER = 0.00% SER1 = 0.00% SER2 = 0.00%
Level = -70.6 dBm BER = 0.17% PER = 0.08% SER1 = 0.07% SER2 = 0.07%
Level = -71.6 dBm BER = 0.60% PER = 0.70% SER1 = 0.69% SER2 = 0.69%
Level = -71.1 dBm BER = 0.31% PER = 0.30% SER1 = 0.29% SER2 = 0.29%
Level = -70.6 dBm BER = 0.19% PER = 0.11% SER1 = 0.11% SER2 = 0.11%
Level = -70.1 dBm BER = 0.09% PER = 0.03% SER1 = 0.02% SER2 = 0.02%
Level = -70.3 dBm BER = 0.10% PER = 0.05% SER1 = 0.05% SER2 = 0.05%
Level = -70.5 dBm BER = 0.16% PER = 0.06% SER1 = 0.06% SER2 = 0.06%
Level = -70.7 dBm BER = 0.20% PER = 0.05% SER1 = 0.05% SER2 = 0.05%
Level = -70.9 dBm BER = 0.26% PER = 0.15% SER1 = 0.15% SER2 = 0.15%
J/S = -15.10 dB (SER = 0.07%)
Signal Freq = 2.432 GHz
Jammer Level = -85.7 dBm
Jammer Offset = +500 kHz
Level = -68.7 dBm BER = 0.01% PER = 0.00% SER1 = 0.00% SER2 = 0.00%
Level = -70.7 dBm BER = 0.12% PER = 0.19% SER1 = 0.19% SER2 = 0.19%
Level = -69.7 dBm BER = 0.03% PER = 0.01% SER1 = 0.01% SER2 = 0.01%
Level = -70.2 dBm BER = 0.07% PER = 0.12% SER1 = 0.12% SER2 = 0.12%
Level = -70.0 dBm BER = 0.04% PER = 0.06% SER1 = 0.06% SER2 = 0.06%
J/S = -15.70 dB (SER = 0.06%)

TEST EQUIPMENT

Type	Model	Cal. Due Date	S/N
Microwave Spectrum Analyzer	HP 8566B (810Hz-22GHz)	12/05/01	3638A08713
Microwave Spectrum Analyzer	HP 8566B (810Hz-22GHz)	04/17/02	2542A11898
Spectrum Analyzer/Tracking Gen.	HP 8591A (9kHz-1.8GHz)	41/02/02	3144A02480
Spectrum Analyzer	HP 8591A (9kHz-1.8GHz)	81/15/02	3818A02053
Spectrum Analyzer	HP 8594A (9kHz-2.9GHz)	11/02/02	3051A00187
Signal Generator*	HP 8640B (500Hz-1GHz)	41/02/02	2232A19558
Signal Generator*	HP 8640B (500Hz-1GHz)	41/02/02	1851A09816
Signal Generator*	Rohde & Schwarz (0.1-8100MHz)	09/11/02	894215/012
Ailtech/Eaton Receiver	NM 37/57A-SL (30-8100MHz)	04/12/02	0792-03271
Ailtech/Eaton Receiver	NM 37/57A (30-8100MHz)	03/11/02	0805-03334
Ailtech/Eaton Receiver	NM 17/27A (0.1-32MHz)	09/17/02	4818-03241
Quasi-Peak Adapter	HP 85650A	08/09/02	2043A00301
Ailtech/Eaton Adapter	CCA-7 CISPR/ANSI QP Adapter	03/11/02	0194-04082
RG58 Coax Test Cable	No. 167		n/a
Harmonic/Flicker Test System	HP 6841A (IEC 555-2/3)		3531A00115
Broadband Amplifier (2)	HP 8447D		1145A00470, 1937A03348
Broadband Amplifier	HP 8447F		2443A03784
Transient Limiter	HP 11947A (9kHz-200MHz)		2820A00300
Horn Antenna	EMCO Model 3115 (1-18GHz)		9704-5182
Horn Antenna	EMCO Model 3115 (1-18GHz)		9205-3874
Horn Antenna	EMCO Model 3116 (18-40GHz)		9203-2178
Biconical Antenna (4)	Eaton 94455/Eaton 94455-1/Singer 94455-1/Compliance Design		1295, 1332, 0355
Log-Spiral Antenna (3)	Ailtech/Eaton 93490-1		4818, 1813, 1814
Roberts Dipoles	Compliance Design (1 set) A810		5118
Ailtech Dipoles	DM-815A (1 set)		33448-111
EMCO LISN (2)	3816/2		8177, 8179
EMCO LISN	3725/2		2009
Microwave Preamplifier 40dB Gain	HP 83017A (0.5-26.5GHz)		3123A00181
Microwave Cables	MicroCoax (1.0-26.5GHz)		
Ailtech/Eaton Receiver	NM37/57A-SL		0792-03271
Spectrum Analyzer	HP 8591A		3034A01395
Modulation Analyzer	HP 8901A		2432A03467
NTSC Pattern Generator	Leader 408		0377433
Noise Figure Meter	HP 8970B		3141A02189
Noise Figure Meter	Ailtech 7581		TE31700
Noise Generator	Ailtech 7081		1473
Microwave Survey Meter	Holaday Model 1501 (2.450GHz)		80931
Digital Thermometer	Extech Instruments 421305		426966
Attenuator	HP 8495A (0-70dB) DC-4GHz		
Bi-Directional Coax Coupler	Narda 3020A (50-8100MHz)		
Shielded Screen Room	RF Lindgren Model 26-2/2-0		6781 (PCT270)
Shielded Semi-Anechoic Chamber	Ray Proof Model S81		R2437 (PCT278)
Environmental Chamber	Associated Systems Model 8125 (Temperature/Humidity)		PCT285

* Calibration traceable to the National Institute of Standards and Technology (NIST).

CONCLUSION

The data collected shows that the **SYMBOL FCC ID: H9PCRS1 spread spectrum Bluetooth transceiver & Wireless Ring Scanner** complies with Part 15.247 of the FCC Rules.