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TEST REPORT

Subject: Processing Gain For WaveLAN IEEE PC CARD type 2 HS

Ref.: FCC Rules 47 CFR Part 15, Section 5.247d

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Change History:

Date	Section	Description
04/16/99, Rev. A		Initial release.
05/6/99, Rev. B	2	Changed spreading gain into processing gain.
	4.1	For data rates of 5.5 and 11 Mbit/s changed processing gain requirements of 9 dB into 10 dB.
	4.2	Changed description for demodulated data availability at the interconnection between RF and DSP into the interconnection between DSP and digital circuits. Changed spreading gain into processing gain.
	7.2, 7.3	Changed sub sections Measurement Results and Measurement Conclusion.
	Annex A	Updated flow chart.

1. Summary:

This document describes the Receiver Processing Gain verification measurements performed at the WaveLAN-II PC-Card Type 2, according to Ref.[2].

2. Conclusion:

The Lucent WaveLAN-II PC-Card Type 2 product confirms to the minimum required 10 dB processing gain, as set forth by the FCC for operation in the 2.4 GHz ISM band.

3. References:

1- Document FCC 97-114, Appendix C, Guidance on Measurements for Direct Sequence Spread Spectrum Systems.
2- Hardware Functional Specification for WaveLAN-II Embedded, High Speed, Doc. No. 011735, Rev. A, Source Organization Lucent Technologies WCND Utrecht.
3- Viterbi, A. J., Principles of Coherent Communications, New York, McGraw-Hill 1966.
4- Proakis, J.G., Digital Communications, New York, McGraw-Hill 1989, page 270.

4. Measurement description:

4.1 Test introduction - FCC requirements:

Part of FCC certification for the Lucent WaveLAN IEEE 802.11 High Speed compliant Network Interface Card (NIC) is a processing gain test. This test proves that the receiver of the tested product employs a true spread spectrum device receiver structure, taking full advantage of the direct sequence spread spectrum modulation technique.

This test verifies the receiver processing gain to be 10 dB or more for a data rate of 1, 2, 5.5 and 11 Mbit/s, by monitoring the Bit Error Rate (BER) of the product under test for each data rate, while operating under strict defined received signal conditions.

Several methods of showing compliance to the rules are possible, from a stepped CW jammer to a continuous sweeping CW interferer. For this test the discrete stepped CW jammer method was chosen, as described in Ref.[1].

Therefore a receiver input signal is applied to the product under test, in the presence of a Continuous Wave (CW) interference source, also referred to as CW jammer.

The test takes place at the product Functional Specification (Ref.[2]) specified conditions for BER rate measurements, specifying a BER equal or better than 10^-8 at a receiver input level of -55 dBm. For practical reasons these test are performed at -55 dBm or -53 dBm. This small deviation from the Functional Specification should not cause any deviation from the specified Bit Error Rate, since the received levels are well above the thermal noise.

The test criteria for meeting the minimal processing gain is such that it takes the theoretical calculated SNR for the applied modulation technique and specified BER as a reference. From this given SNR the processing gain is subtracted, yielding the CW Jammer to Signal ratio J/S. From Ref. [4], likewise as Ref.[3] consulted in Ref. [1], it is determined that for a BER of 10^-8 the SNR (S/N)o equals:

13 dB @ 1 Mbit/s,
15 dB @ 2 Mbit/s,
15 dB @ 5.5 Mbit/s,
18 dB @ 11 Mbit/s.

Thus the J/S ratio for a processing gain of 10 dB that must be met is calculated as:

-13 + 10 = -3 dB @ 1 Mbit/s (DBPSK),

-15 + 10 = -5 dB @ 2 Mbit/s (DQPSK),

-15 + 10 = -5 dB @ 5.5 Mbit/s (CCK),

-18 + 10 = -8 dB @ 11 Mbit/s (CCK).

Two types of measurement corrections are allowed for as described in Ref.[1]. The first taking into account 2 dB implementation losses, thus increasing the absolute J/S ratio by 2 dB.

The second correction allows for deleting the 20% worst-case frequencies in the processing gain test that causes the test at that CW interference to fail. This implies that for the considered 14 MHz wide measurement interval the worst case 57 CW jammer frequencies can be ignored, being those that result in received data errors/missing frames (20% of 14 MHz *(1 MHz/50 KHz) + 1 = (20% * 281) + 1 = 57).

4.2 Test sequence:

The measurements are performed at a 50 KHz CW jammer raster. For each CW jammer frequency 10^8 bits are transmitted by the reference transmitter, and received by the product under test. For practical reasons 50.000 messages are transmitted. After blanking out frame overhead 1927 bits per frame are monitored. This results in 50.000 * 1927 = 9650000 transmitted bits for a BER test, which is a mere 1.4% less than the targeted 10^8 bits. Though it would be more elegant to show BER compliance for at least say ten times 10^8 transmitted/received bits, the time involved with this grows significantly. Since the CW interferer is stepped in a 50 KHz raster, covering the receiver bandwidth of 14 MHz, it is considered that the BER requirement is sufficiently met since such a multitude of measurements are taken.

The total measurement is being performed under computer control, hereafter referred to as controller. It involves the control over the reference transmitter, CW-interference generator, receiver under test and received data error-checker/frame counter. The controller is programmed by a configuration file, that lists the CW jammer frequencies and CW jammer signal levels. The controller program flow chart is given in Annex A, WaveLAN-II FCC Processing Gain Measurements, Controller Flow Chart.

The transmitted data pattern is fixed, and known at the receiver. Therefore the error checker compares the known transmitted data sequence with received data sequence. Received data errors and missing received frames information is retrieved by the controller.

In the receiver at the inter-connection between the received data demodulator output at the DSP and the digital interface the demodulated received RF signal is made available to an error checker. This error checker is a dedicated piece of hardware that monitors real-time the received data, gating-out any other non-relevant information that is present in the received data (message header, message length field, CRC field, diagnostic information field etc.). For a chosen Tx message length of 230 bytes this yields 1927 useable bits.

The test sequence is as follows: the controller issues a request to the transmitter for 1000 frames to be transmitted. Once this number of frames has been transmitted the transmitter signals to the controller the completion of this. The controller reads the number of received frames and number of erroneous received frames. If there are no missing frames or received data errors detected, the controller increases the CW interference level by 1 dB. Consequently it re-issues a 1000 frames transmit request, and the test is re-started. This sequence is repeated until received data errors or missing frames are detected.

Now instead of a quick error scan using 1000 frames, 50000 frames (equals 10^8 bits) are transmitted to verify the BER. For this test the CW jammer level is lowered 1 dB, compared to the CW jammer level at which the first receive data errors and/or missing frames were detected. All the measurement results are recorded for later use.

After completion of the 50000 frames BER test, the spreading gain verification test continues by raising the CW jammer frequency by 50 KHz and re-setting the CW jammer level to the start value, taken from the controller configuration file. For this new CW frequency the measurements are repeated as described above (see Annex A).

All CW frequencies and power levels are listed in a command-file that is read by the controller at start up.

Before measurements are started, the receiver input level and CW jammer level need to be calibrated. See figure 1 for the test set-up.

The test takes place at an arbitrarily chosen channel, being channel two (2417 MHz).

4.3 Receiver level calibration:

The receiver input level is calibrated using the RF power meter. For this purpose, the reference transmitter output attenuator is set to 0 dB. The CW jammer is disabled during the calibration. Using the RF power meter at the receiver input of the device under test, the received level at the receiver input is measured for a continuos active reference transmitter. The attenuator value is calculated to achieve a received level of -55 dBm. Finally the attenuator is adjusted to this value.

4.4 CW level calibration:

The reference transmitter is disabled during this calibration. The CW jammer generator output level is set to 0 dBm, and the RF power meter value is read. The difference in CW output level setting and RF power meter measured at receiver input of the device under test is the attenuation of the test set-up. This is the correction factor that needs to be applied for analysis of the measurements results.

5. Equipment used:

# Item needed	Description
1	Portable PC with WaveLAN-II NIC, Zenith Z-lite, SN-3GSAZW000061, for receiver.
1	Portable PC with WaveLAN-II NIC, NCR 3150, SN 17-26106224, for transmitter.
1	Software 'Testware, V5.09', Rev. 0, <TW.EXE>, 141456 bytes, 12-13-1998. Used for the transmitter and receiver.
2	WaveLAN IEEE Turbo NIC.
1	PC + IEEE interface card, NCR PC6, SN 17-17039925 and CEC PC<>488 interface card.
1	Received error checker, wire-wrap prototype, Lucent WCND designed and built.
1	Power supply, Delta D030-1, for error checker.
1	Spectrum Analyzer, HP 9592B SN 3009U00102.
1	Power Meter, Rohde & Schwarz, Millivolt meter URV5, SN 893430/070.
1	Power Sensor, Rhode & Schwarz, type NRV-Z2 828218.02, SN 860925/005.
1	CW jammer generator, Gigatronics 7200, SN 746604.
1	Variable attenuator, 0-70 dB, Midwest Microwave, Model 1044.
2	Fixed attenuator, 10 dB, Inmet Corp., model 18AH-10.
1	RF power splitter, ARRA 3-9200-2, SN 2001.
1	Misc. IEEE cabling.
1	Misc. SMA cabling.
1	RF shielded cage.

6. Measurement set_up:

The test setup is given below in Figure 1, measurement test set-up. To avoid interference that can disrupt the measurement, the whole test is performed within a RF shielded cage.

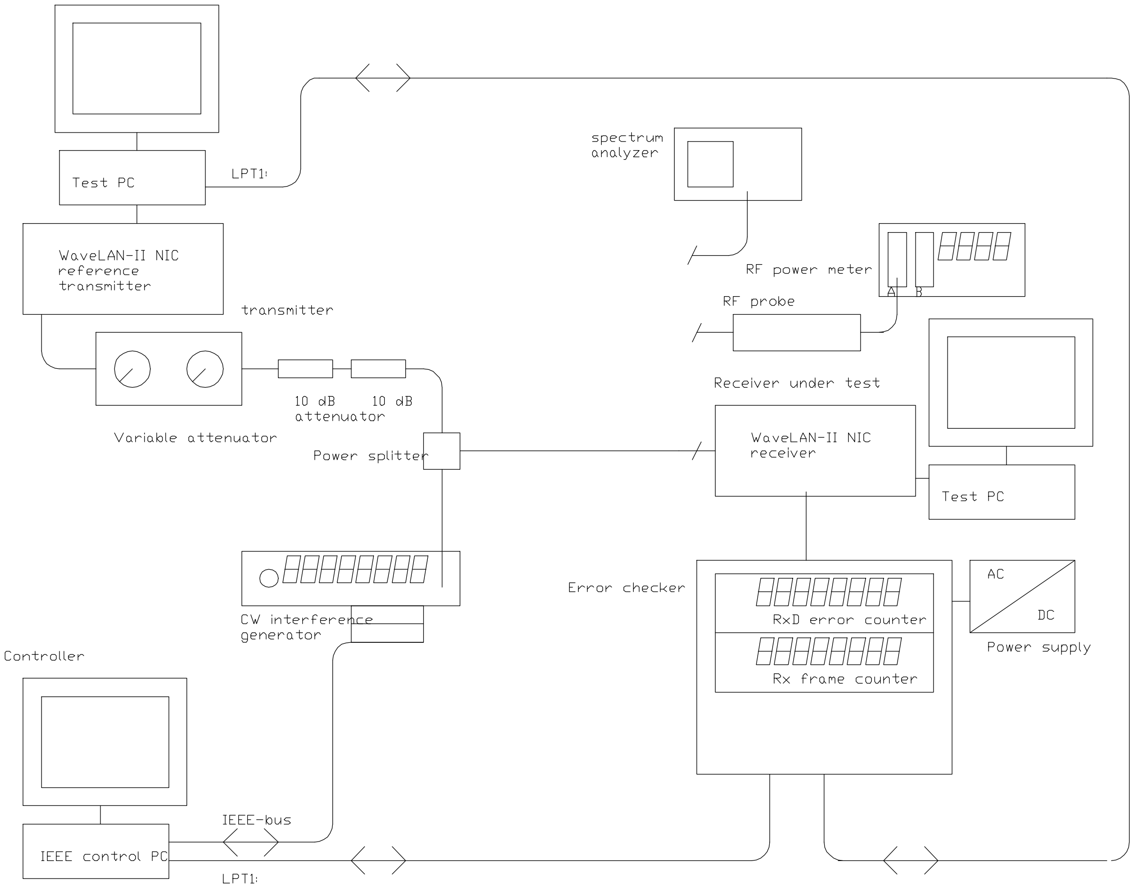

Figure 1, measurement test set-up.

7. Measurement results:

7.1 Calibrations:

Receiver calibration 1, 2, 5.5 and 11 Mbit/s: For 0 dB total attenuator setting the received level at the receiver input equals +10 dBm.
Test setting: the fixed attenuator is chosen to be 20 dB, the variable attenuator is set to 45, respectively 43 dB attenuation.

CW jammer generator calibration: For a 0 dBm output level at the generator the received level at the receiver input is -6 dBm.

7.2 Processing Gain Measurement Results:

For each CW jammer frequency between Fc +/-7 MHz, being the receiver bandwidth, a BER measurement is taken.
For each CW measurement frequency the jammer level is varied from -66 dBm to -58 dBm a the receiver input, yielding a J/S ratio of -11 to -3 dB, respectively -13 to -5 dB.
For some CW frequencies received data errors/missing frames are detected while performing the BER test.

Applying the allowed margin of 2 dB implementation losses for 1 Mbit/s, a 1 dB implementation loss for 5.5 and 11 Mbit/s, and no implementation loss for 2 Mbit/s, together with the rule of discarding the 20% worst-case jamming/signal points (Ref.[1]), results in meeting the specified BER for which less than 20% of the measured CW interference frequencies were found to cause received data errors and/or missing frames.
These percentage numbers are respectively 16% @ 1 Mbit/s, 3% @ 2 Mbit/s, 17% @ 5.5 Mbit/s and 18% @ 11 Mbit/s.
Therefore, a J/S ratio better or equal to -5 dB @ 1 Mbit/s, -5 dB @ 2 Mbit/s, -7 dB @ 5.5 Mbit/s and -9 dB @ 11 Mbit/s is measured.

7.3 Measurement Conclusion:

The tested product complies to the required Processing Gain of 10 dB for a data rate of 1, 2, 5.5 and 11 Mbit/s, as set forth in Ref.[1].

Annex A: Flow-Chart IEEE control program