EMISSIONS TEST REPORT FOR A LOW POWER TRANSMITTER

I. GENERAL INFORMATION

Requirement: Federal Communications Commissions

Test Requirements: 15.205, 15.207, 15.209, 15.247

Applicant: Utilicom
323 Love Place
Goleta, CA 93117

Product ID: **FCC ID: LFO-WR2411**

II. DESCRIPTION OF EQUIPMENT UNDER TEST (EUT)

The 2411 is a direct sequence spread spectrum transceiver, operating in the 2400 - 2483.5 MHz band with diversity.

Operation is half duplex (TDD), with a duty cycle of 50% (6 dB).
Output power is variable from 0 dBm to 23 dBm.

Channel center frequencies are in 2 MHz steps. Center frequency = 2400 + 2* Channel Number

Lowest channel: Channel 5 (2410 MHz)
Highest channel: Channel 35 (2470 MHz)

Four modulation rates are available:

1 Mbps: DBPSK
2 Mbps: DQPSK
5.5 and 11 Mbps: CCK

III. TEST LOCATION

All emissions tests were performed at:

Compliance Certification Services
571F Monterey Road
Morgan Hill, CA 95037

T.N. Cokenias
EMC Consultant/Agent for Utilicom

10 August 2001

TEST PROCEDURES

Radiated Emissions
Test Requirement: 15.205

Measurement Equipment Used:

HP 8593EM Spectrum Analyzer
HP 8449 Microwave pre-amplifier, 1-26.5 GHz
EMCO 3115 Double Ridged Horn antenna, 1 - 18 GHz

1. The EUT was placed on a wooden table resting on a turntable on the open air test site. The search antenna was placed 3m from the EUT. The EUT antenna was mounted vertically as per normal installation.

2. The turntable was slowly rotated to locate the direction of maximum emission at each emission falling in the restricted bands of 15.205.

3. Radiated emissions were investigated for a LOW channel, a MID channel, and HIGH channel. Emissions were investigated to the 10^{th} harmonic.

4. Careful measurements were made at the restricted bands 2310-2390 MHz and 2483.5 – 2500 MHz for the LOW and HIGH channel respectively. The preamplifier was not used for these measurements.

5. Once maximum direction was determined, the search antenna was raised and lowered in both vertical and horizontal polarizations. The maximum readings so obtained are recorded in the data listed below.

Test Results: Worst case results are presented. Refer to separate Excel spread sheet files.

Channel	**Frequency, MHz**
Low	2412
Mid	2450
High	2462

Radiated emissions were performed for three different transmitter antennas at maximum input power to antenna.

Antennas tested:

Antenna Type	Gain	UCW Model Number
Omnidirectional	9 dBi	OA2.4-9
Yagi	17 dBi	DA2.4-17
Dish Reflector	24 dBi	DA2.4-24

Bandedge testing

FCC Rule paragraph 15.247(a)3 states (for **point to multi point** systems) if transmitting antennas of directional gain greater than 6 dBi are used the peak output power from the intentional radiator shall be reduced below the above stated values by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

Point to Multi-Point Maximum Output Power (dBm)

Channel	Frequency	Antenna Gain		
	(MHz)	9 dBi	17 dBi	24 dBi
5 - 31		23	19	12
32	2464.0	17.0	15.5	14.3
33	2466.0	15.9	14	11.6
34	2468.0	15.3	13	10
35	2470.0	14.8	11.0	7.0

The lower power output levels for channels 32 - 35 are to limit the radiated levels of modulation product emissions that fall in the 2483.5 - 2500 MHz restricted band.

Bandedge Radiated Emissions Test

The restricted bands 2310 -2390 MHz and 2483.5 - 2500 MHz were investigated for radiated emissions coming from the EUT when used with each of the three antennas. The pre-amplifier was not used. For each EUT test configuration, the EUT was rotated and the search antenna raised and lowered to find the orientation for which maximum emissions occurred. EUT output power and operating channel were adjusted until emissions in the restricted bands were within limits for each antenna. Test results are summarized below:

Channel	**P max for meeting 2310-2390 MHz limit**			**P max for meeting 2483.5-2500 MHz limit**		
	G= 9 dBi	G = 17 dBi	G = 24 dBi	G = 9 dBi	G = 17 dBi	G = 24 dBi
35				14.8 dBm	11.0 dBm	7.0 dBm
34				15.3 dBm	13 dBm	10 dBm
33				15.9 dBm	14 dBm	11.6 dBm
32				17.0 dBm	15.5 dBm	14.3 dBm
31				23 dBm	23 dBm	20 dBm
5	23 dBm	22 dBm	20.8 dBm			
6	23 dBm	23 dBm	21.9 dBm			
7	23 dBm	23 dBm	22.2 dBm			
8	23 dBm	23 dBm	22.2 dBm			
9	23 dBm	23 dBm	22.2 dBm			
all others	23 dBm	23 dBm	23 dBm	23 dBm	23 dBm	23 dBm

The table above shows power levels into high gain antennas for point t to point operation. Paragraph 15.247(a)3(i) states

Systems operating in the 2400-2483.5 MHz band that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6 dBi provided the maximum peak output power of the intentional radiator is reduced by 1 dB for every 3 dB that the directional gain of the antenna exceeds 6 dBi.

NOTE: Radiated spurious and bandedge emissions tests were performed with radio set to operate at 11 Mbps. This was determined from preliminary tests to produce worst-case emissions levels.

AC Line Conducted Emissions
Test Requirement: 15.107, 15.207

Measurement Equipment Used:

Rohde & Schwarz EMI Receiver ESHS-20
Fischer Custom Communication LISN, FCC-LISN-50/250-25-2

Test Procedure

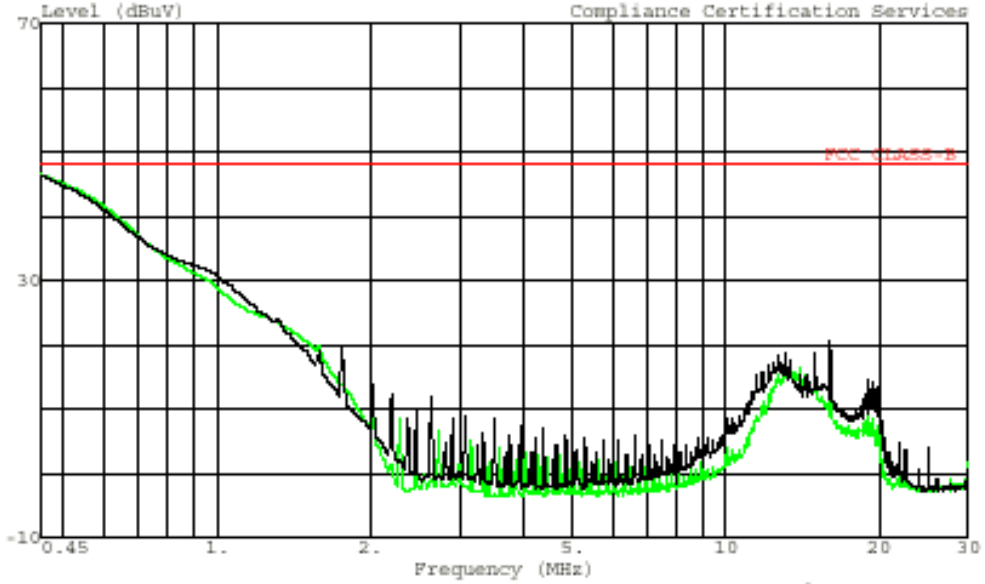
1. The EUT was placed on a wooden table 40 cm from a vertical ground plane and approximately 80 cm above the horizontal ground plane on the floor. The EUT was set to transmit normally.
2. Line conducted data was recorded for both NEUTRAL and HOT lines.

Test Results

Refer to attached graph.

561 F Monterey Road, Route 2
Morgan Hill, CA 95037-9001 USA
Tel: (408) 463-0885
Fax: (408) 463-0888

Data#: 12 File#: TOM72001.EMI Date: 07-20-2001 Time: 16:30:32



Trace: 5 Ref Trace:
Project No. :
Report No. : 010720LC
Test Engr : KERNIN CORPUZ
Company : UTILICOM
EUT Description : 2.4 GHz DSSS, S/N: UC011266
Model : 2411
EUT Config. : EUT/ANTENNA/LAPTOP
Type of Test : FCC CLASS B
Mode of Operation: TX
: QUASI-PEAK: L1(Green), L2(Black)
: 115Vac, 60Hz

Minimum 6 dB Bandwidth
Test Requirement: 15.247(a)2

Measurement Equipment Used:

HP 8593EM Spectrum Analyzer
6' length low loss coaxial cable

Test Procedures

The EUT was configured on a test bench. The EUT was set for continuous operation (TDD function turned OFF) . Frequency was set to 2.45 GHz (LOW channel). While the transmitter broadcast a steady stream of digital data, the analyzer MAX HOLD function was used to capture the envelope of the transmission occupied bandwidth.

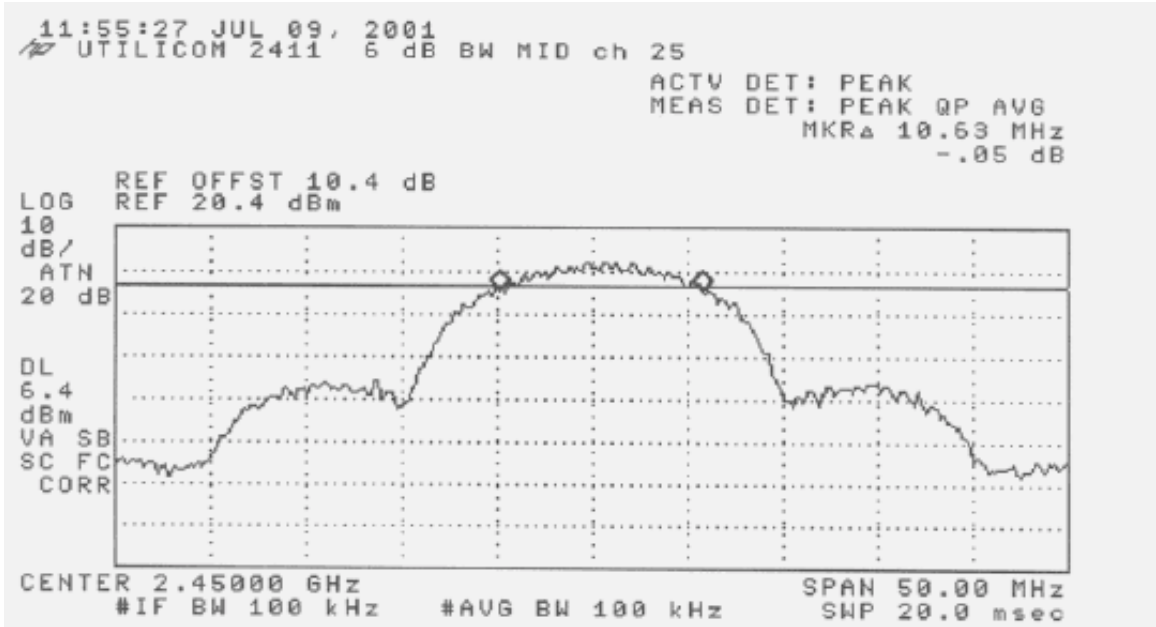
The test was repeated at 2.462 GHz (MID channel) and at 2.474 GHz (HIGH channel).

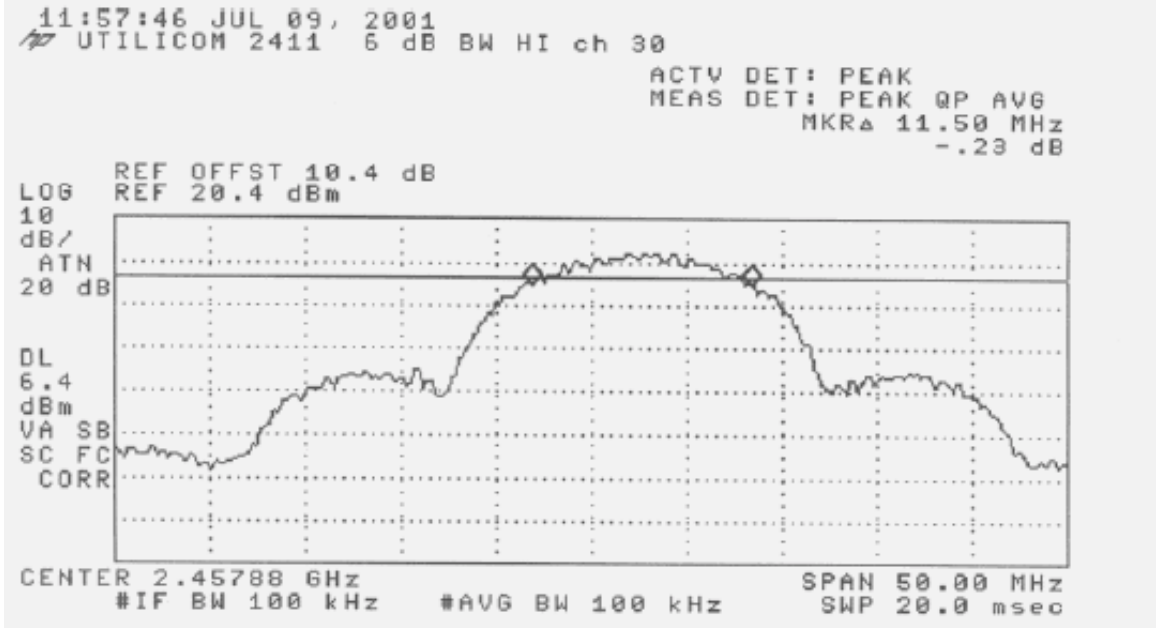
Test Results: Refer to attached spectrum analyzer charts. Data taken with RES BW of 100 kHz shows minimum 6 dB BW of 10.5 MHz. Minimum requirement: 500 kHz

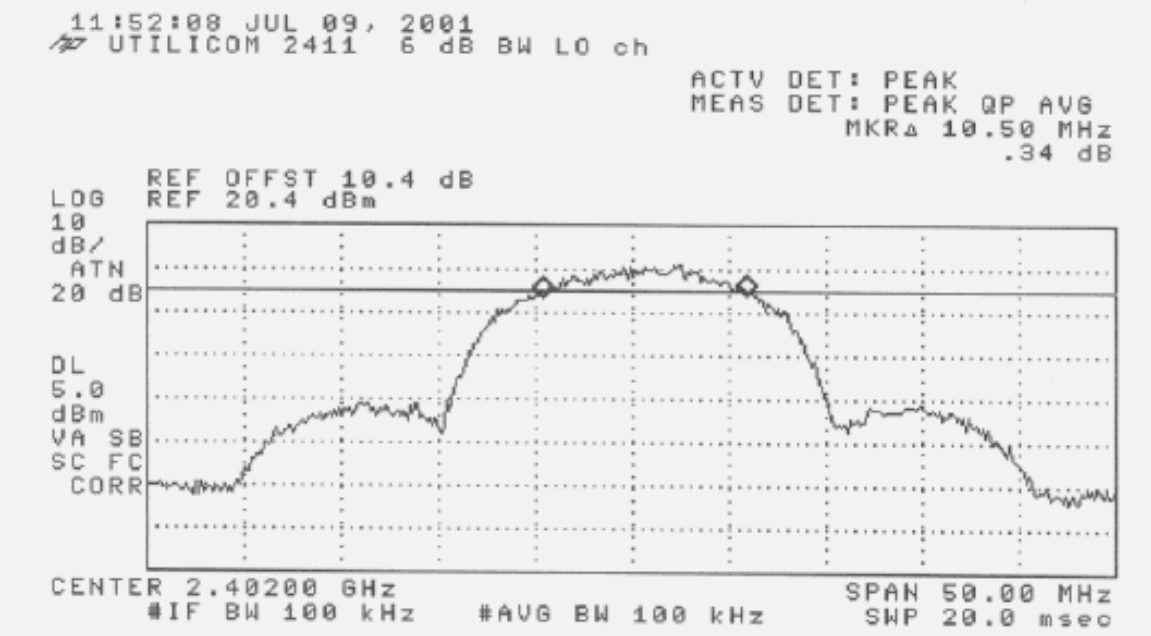
Channel	**Frequency, MHz**
Low	2402
Mid	2450
High	2460

NOTE: 6 dB bandwidth was measured at each modulation, with essentially the same bandwidth resulting. Data is presented for the 11 Mbps modulation setting.

15.247(a)2: Minimum 6 dB Bandwidth






11:52:08 JUL 09, 2001
UTILICOM 2411 6 dB BW LO ch
ACTV DET: PEAK
MEAS DET: PEAK QP AVG
MKRΔ 10.50 MHz
.34 dB
REF OFFST 10.4 dB
LOG REF 20.4 dBm
10
dB/
ATN
20 dB
DL
5.0
dBm
VA SB
SC FC
CORR
CENTER 2.40200 GHz
SPAN 50.00 MHz
#IF BW 100 kHz
#AVG BW 100 kHz
SWP 20.0 msec

RF Power Output
Test Requirement: 15.247(b)

Measurement Equipment Used:

HP 436A Power Meter
HP8482 Power Sensor

Test Procedures

1. The EUT was configured on a test bench. The power meter was zeroed and calibrated.
The control software was activated and power was set to produce highest output level.

2. The process in (1) was repeated for MID channel and HIGH channel.

Test Results

Power level readings converted to dBm are shown below. Refer also to spectrum analyzer graphs. Reference level offset corrects for external attenuation and cable loss.

Channel	Frequency, MHz	Output Power, dBm	Limit, dBm
Low	2410	22.8	30.0
Mid	2450	23.0	30.0
High	2460	22.7	30.0

Maximum output power output is variation within 0.3 dBm of design maximum 23 dBm output.

NOTE: Data is presented for the 11 Mbps modulation setting. Maximum power output is independent of modulation type

Spurious Emissions, Conducted
Test Requirement: 15.247(c)

Measurement Equipment Used:

HP 8593EM Spectrum Analyzer
2 ft length low loss A coaxial RF cable

Test Procedure

1. The EUT was configured on a test bench. The cable was connected between the EUT antenna port and the spectrum analyzer input port.

Spectrum analyzer RES BW was set to 100 kHz. The EUT's TDD function was stopped, transmission was continuous at the LOW channel. While the transmitter broadcast a steady stream of digital data, the analyzer MAX HOLD function was used to capture the envelope of the transmission.

Readings were taken out to 10fo.

2. The process in (1) was repeated for MID channel and HIGH channel.

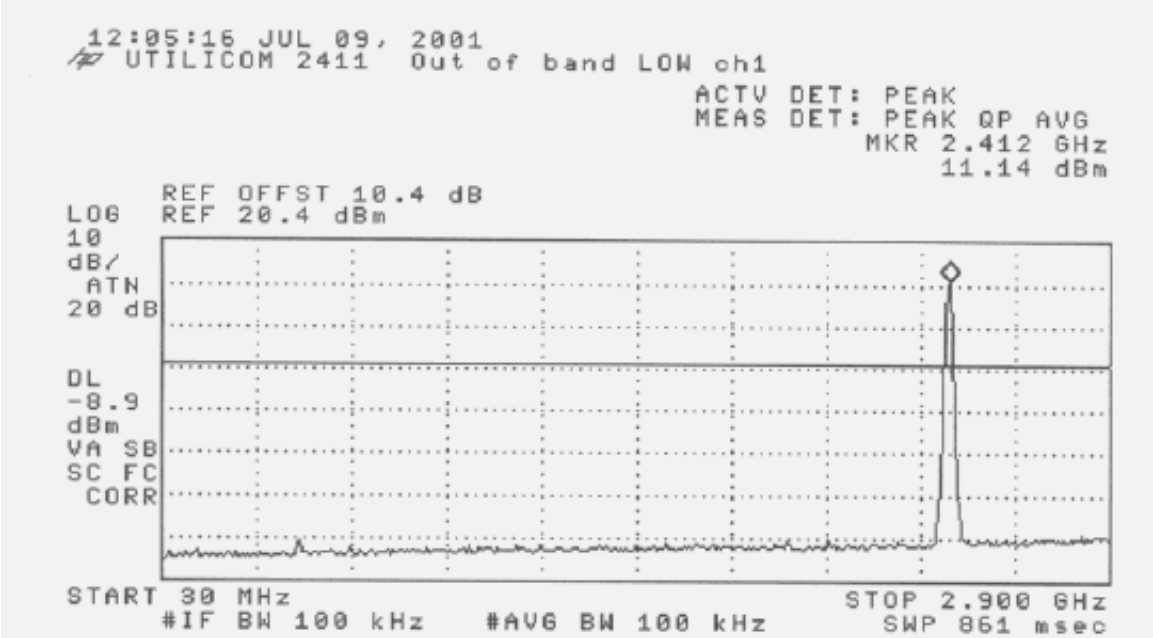
Test Results

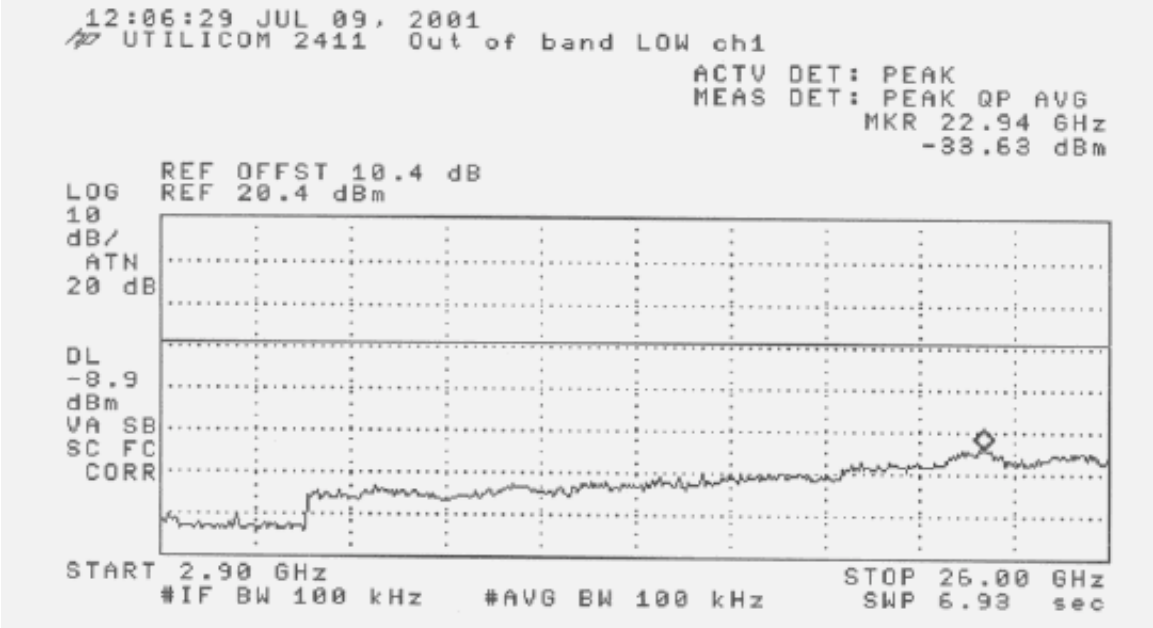
Refer to attached data sheets. Data shows out of band emissions are suppressed well below the -20 dBc minimum required by the Rules.

Channel	**Frequency, MHz**
Low	2450
Mid	2462
High	2470

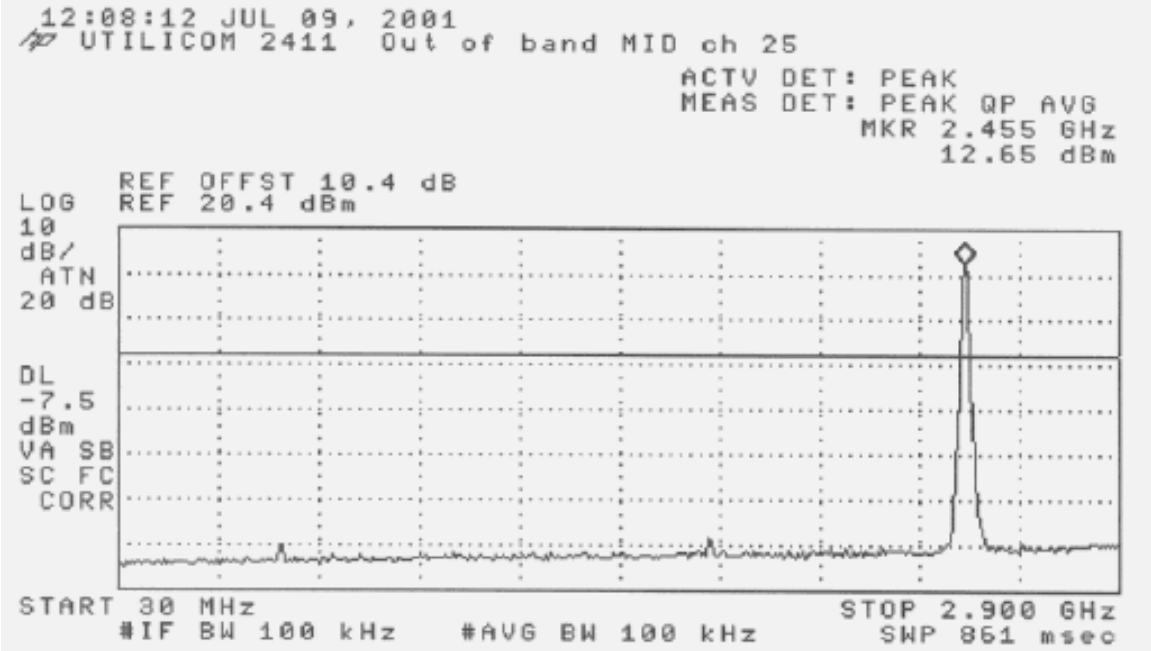
NOTE: Data is presented for the 11 Mbps modulation setting.

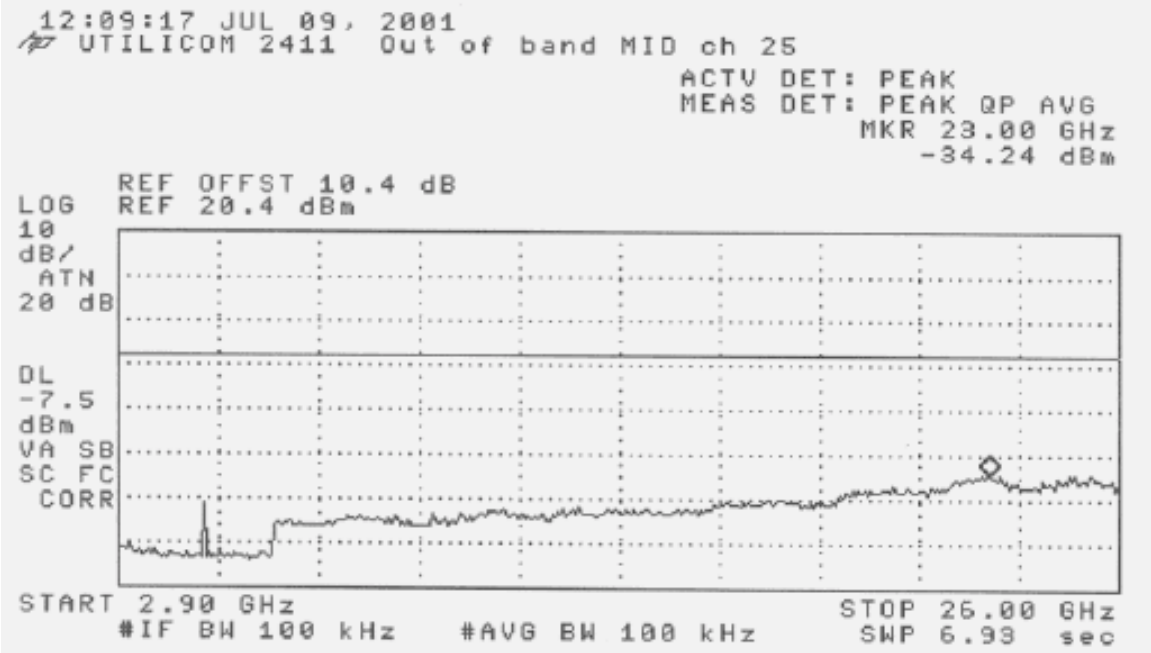
15.247(c): Spurious Emissions, Conducted, LOW Channel



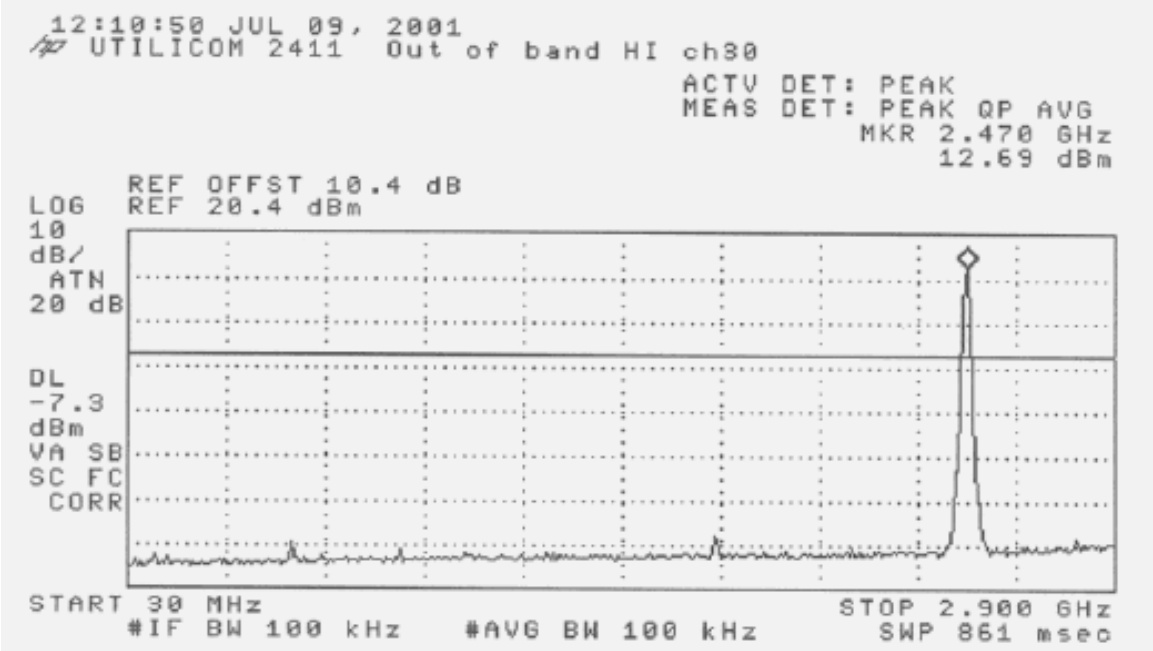


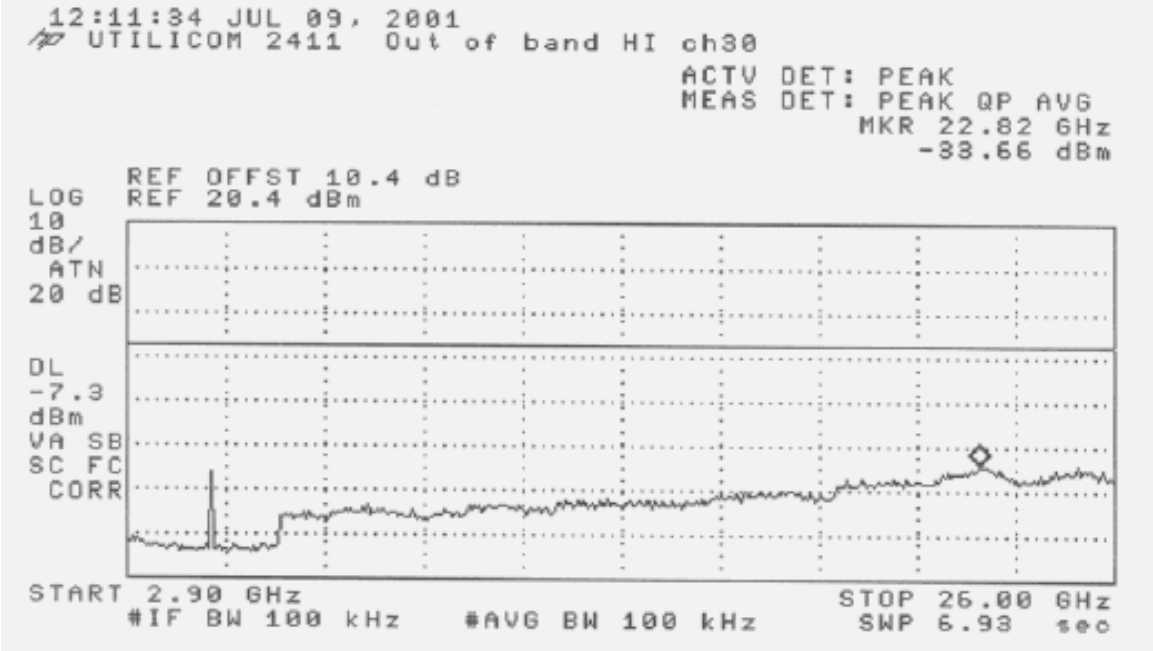
15.247(c): Spurious Emissions, Conducted, MID Channel





15.247(c): Spurious Emissions, Conducted, HIGH Channel





Power Spectral Density
Test Requirement: 15.247(d)

Measurement Equipment Used:

HP 8593EM Spectrum Analyzer
2 ft length low loss A coaxial RF cable

Test Procedure

The EUT's TDD function was stopped. For the LOW channel, the emission peak was set to the center of the display. The SPAN was set to 300 kHz, the RES BW and VID BW were set to 3 kHz, and SWEEP TIME was set to 100 seconds. The maximum trace was recorded and compared to the 8 dBm limit.

The test was repeated for MID and HIGH channel.

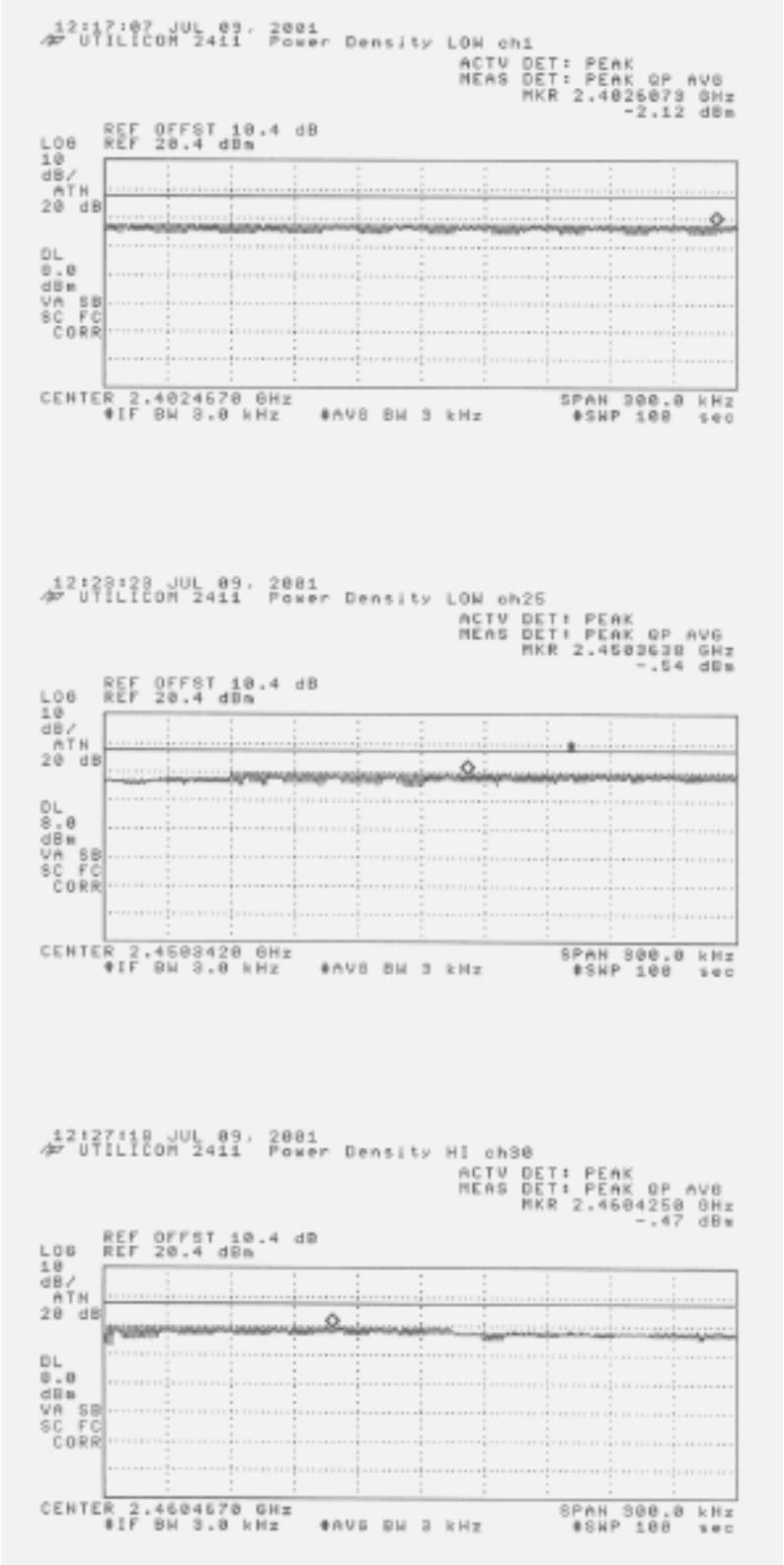
Test Results

Maximum measured PSD was approximately 0 dBm. Refer to attached spectrum analyzer charts.

Channel	**Frequency, MHz**
Low	2402
Mid	2450
High	2460

NOTE: Data is presented for the 1 Mbps modulation setting. Readings essentially identical for all four modulation types, 1 Mbps appearing to be worst case.

15.247(d): Power Spectral Density



Processing Gain
Test Requirement: 15.247(e)

Processing gain test set-up, method, and final results are attached. Actual data is submitted in a separate Excel spreadsheet document.

UC WIRELESS
WI-LAN TECHNOLOGIES INC

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PROCESSING GAIN

TEST REPORT

PRODUCT: **VIP 110-24**

July, 2001

1. General

The processing gain of a direct sequence spread spectrum (DSSS) system shall be at least 10dB according to the FCC requirements given in CFR47, para. 15.247 (e)(2). This report provides theoretical analysis and test results for a demonstration that the VIP 110-24 system meets this requirement.

2. Theoretical Background

The processing gain is measured employing the CW jamming margin method. This method is suitable for the DSSS systems where processing gain cannot be measured directly due to the inability of turning off the spreading code modulation.

The following formula describes relation between the processing gain and the jamming margin :

$$Gp = (S/N)_o + (J/S) + Lsys \qquad (1)$$

where: Gp = processing gain of the system
$(S/N)_o$ = output signal to noise ratio required for a reference bit error rate (BER)
J/S = jamming margin; jamming signal power relative to desired signal power
Lsys = system implementation loss

The maximum allowed system implementation loss is 2 dB.

The VIP 110-24 system employs Intersil HFA3861B Baseband Processor for all modulation, spreading and scrambling operations. The modulation format applied here is Complemantary Code Keying (CCK) which is a form of M-ary Orthognal Keying. According to the article, provided in the appendix , "Testing for Compliance with FCC rules 15-247e" by Carl Andren [2] required Signal to Noise Ratio $(S/N)_o$ for the reference BER of 10^{-5} is 16.4 dB. This reference BER is defined by the IEEE 802.11 standard and corresponds to the Packet Error Rate (PER) of 8% for a packet length of 1,000 bytes.

Now, we can calculate the jamming margin for a minimum processing gain of 10 dB:

$$Gp = 16.4 + (J/S) + 2 \geq 10 \text{ dB} \qquad (2)$$

Therefore, required jammer to signal ratio is:

$$(J/S) \geq -8.4 \text{ dB} \qquad (3)$$

3. Test Setup and Equipment

A block-diagram of the test setup for CW Jamming Margin Measurement is shown in Figure1.

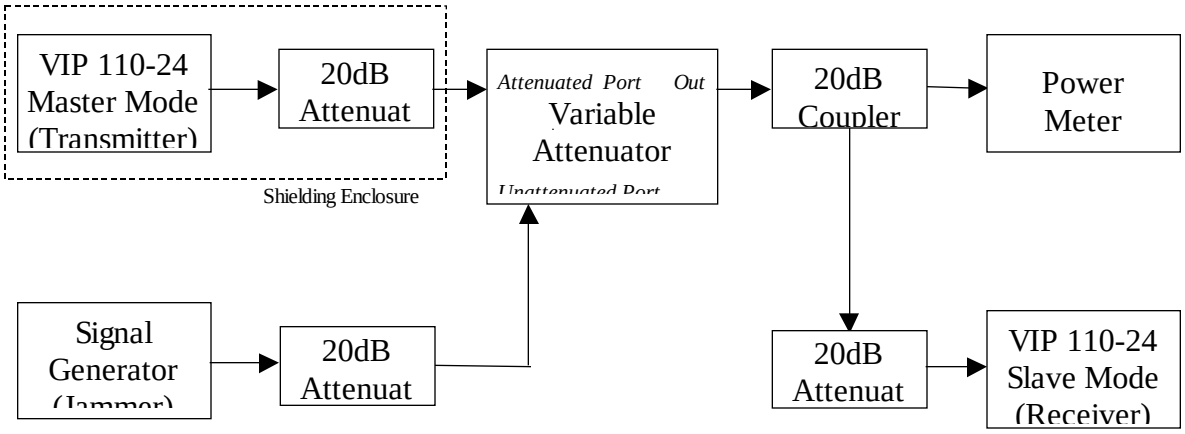

Figure 1: Test Setup for CW Jamming Margin Measurement

Test Equipment:

The following test equipment was utilized:

1. Signal Generator: Rohde&Schwarz, Model: SMIQ 03E
2. Power Meter: Hewlett Packard, Model: E4419A
3. Power Sensor, Hewlett Packard, Model: ECP-E18A
4. Variable Attenuator: Hewlett Packard, Model: HP349A
5. Coaxial Directional Coupler: Narda, Model: 22006
6. Coaxial Attenuator 20dB, 50-ohm: Weinschel Corp, Model 1.

4. Method of Measurement

The level of the CW jammer and the DSSS transmitter were initially calibrated for equal power at the receiver (-42dBm) by measuring both signals independently using a power meter. This power level corresponded to the signal level of 0 dBm on the signal generator output port. The power level on the transmitter side was adjusted using the variable attenuator. Both signals were monitored constantly for any power drift by the power meter.

When both signal were turned on, the level of the signal generator (jammer) was adjusted for a PER of 8% on the receiver side. This level was equivalent to the system jamming margin (J/S) at particular CW frequency since the transmitter level was equalized to the jammer level of 0 dBm initially. The measurement was repeated in the frequency steps of 50 kHz inside a receiver 3-dB IF channel bandwidth of 17MHz. The packet length applied on the both systems was 1,000 bytes. The test was performed on the channel 20 (Fo=2.44GHz) in the middle of the radio RF bandwidth.

Finally, 341 test points of J/S ratio were recorded and entered in an Excel spreadsheet. The worst 20% of the results were disregarded and lowest remaining J/S ratio was considered as a system jamming margin. This operation was done automatically using a command Percentile (k=0.2).

5. Test Results

The measured J/S results and resulting processing gain are given in the attached tables for every test point. The calculated processing gain results are shown also in the form of diagram for better visual presentation.

The system jamming margin, after disqualifying 20% of the lowest points, is

$$\mathbf{(J/S) = – 7.6\ dB}. \qquad (4)$$

When we enter this value in the equation (1) the resulting system processing gain is as follows:

$$\mathbf{Gp = 16.4 – 7.6 + 2 = 10.8\ dB} \qquad (5)$$

6. Relevant Documents

1. Robert C. Dixon, “Spread Spectrum Systems with Commercial Applications”, John Wiley $ Sons, New York, 1994
2. Carl Andren, “Testing for Compliance with FCC rules 15-247e”, Intersil Corporation, October, 1999
3. Richard L. Abrahams “Measurement of Processing Gain in a Direct Sequence WLAN using the CW Jammer Method”, Harris Semiconductors, Palm Bay, Florida

4. Code of Federal Regulations (CFR), Title 47 (Telecommunications), paragraph 15.247(e)(2)