Measurement of Processing Gain of the Stratum MP

May 1, 2000

I. A GENERAL DEFINITION OF THE PROCESSING GAIN

The maximum available processing gain for a direct-sequence spread-spectrum system depends on the transmitted waveform, while the actual processing gain is measured at the receiver. The implementation loss (L_{sys}) is generally the difference between these. To determine the maximum available (theoretical) processing gain, usually the number of chips N_c in the symbol waveform is considered as the nominal value, and certainly as the maximum value. But the generation of a complex waveform requires a more detailed calculation of the maximum available processing gain. The issue of independent degrees of freedom is the fundamental effect. The best method to calculate this is to assume an ideal receiver mathematically and match filter the received waveform. This maximum theoretical system processing gain represents the theoretical rejection of a center-band interfering signal, averaged over all chip-code patterns. The practical processing gain of the system must also take into account the SNR required for adequately low demodulation errors and the system implementation losses. The practical processing gain Gp is defined by[1]

$$Gp = (S/N)_{\mathbf{req}} + Mj + Lsys \qquad (1)$$

(all in dB) where

- $(S/N)_{\mathbf{req}}$ is the minimum signal-to-noise ratio after de-spreading at which the given modulation can provide adequate error performance,
- Mj is the maximum ratio of interference power to the signal power, measured at the system input, for which the system can provide the adequate error performance,
- Lsys is the system implementation losses in SNR due to practical implementation limitations.

II. CONSIDERATION OF ACTUAL PROCESSING GAIN

First, the values used for S/N and Lsys will be discussed, then the measured values of Mj will be presented.

A. REQUIRED SNR

The data modulation employed is a form of bi-orthogonal signalling in which one of 16 waveforms plus differential phase is transmitted, conveying five bits of information during each 16-chip data symbol. Each digital waveform symbol goes through a waveform pulse shaping circuit that produces a continuous phase modulation (CPM) of the carrier, that results in a nearly-square spectral shape with low spectral side-bands. The theoretical coherent S/N performance in terms of probability of symbol error (Pse) can be computed using the similar calculations as

[1] Dixon, R, Spread Spectrum Systems, Chapter 1 (New York: Wiley, 1994)

shown for simple bi-orthogonal signaling in the graph on page 259 in Wozencraft and Jacobs[1] and assuming an ideal matched filter receiver.

In fact, the manufacturer has performed simulation, numerical computation and experimentation (using unfiltered, perfectly timed received waveforms) to verify this performance. The theoretical processing gain of the chip waveform including the pulse shaping is 10.3 dB when using an ideal matched filter receiver.

Adequate system performance is achieved when the radios have degraded to 90% of their maximum throughput. This level of throughput results in a Pse of $4*10^{-5}$ (recall that each symbol is 5 data bits), resulting in an operating point output SNR = 14.8 dB.

B. ANTICIPATED SYSTEM LOSS

Lsys is the system implementation losses in SNR due to practical implementation limitations. System loss is due to a multitude of effects which include various filters, signal quantization, computation errors, timing misalignment, etc.

The very tight filtering required to conform to FCC part 15 regulations, causes mismatch between the transmitted waveform and the much-less-filtered reference waveforms in the correlator bank. (The 2400-to-2483.5-MHz band resides between two protected bands which constrain the absolute levels of signal power which may be produced, unlike the relative-power-level constraint of the part 15.247 alone). This causes a loss of approximately 1.3 dB. This was measured by removing the filters on experimental boards.

Signal quantization as well as round-off and truncation within the digital correlation subsystem result in approximately 0.45 dB departure from ideal.

Timing error in the placement of the correlation processor relative to the received signal results in an average loss of 0.25 dB. The total implementation loss is consequently 2.0 dB.

1 Wozencraft and Jacobs, "Principles of Communications".

III. MEASUREMENT PROCEDURE OF THE PROCESSING GAIN

The practical processing gain may be measured using the CW jamming margin method. *Figure 1* shows the test configuration . The actual test site is shown in Appendix-A.

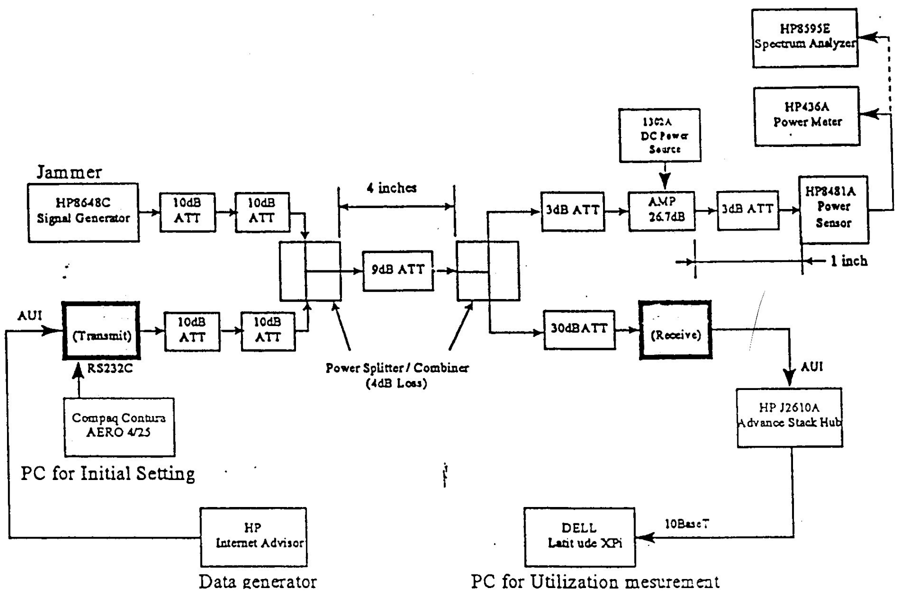

Figure 1

The “HP Internet advisor”, a data generator, is the source of continuous Ethernet frames. The rate of frame sourcing and all frame parameters can be set. The output of the “HP Internet Advisor” is fed to the Ethernet port on the Stratum MP (Transmit). A “Compaq Contura” PC is used on a local RS-232 control port on the Stratum MP for monitoring of the transmitter. An “HP8648C” signal generator is used as a jammer (causes CW interference). The desired signal and CW jamming signal are combined and then the sum is split for observation of power and for feeding to the Stratum MP (Receive).

The Jammer-to-Signal (J/S) ratio is measured using HP 436A power meter. The power meter readout of the desired signal must be compensated using the transmit stream duty factor of the desired signal frames. The detailed compensation procedure is described in Appendix-B. The spectrum analyzer is exchanged with the power meter only to verify that operation is normal and all spectra are as anticipated.

The output signal of the receiving radio is a stream of Ethernet frames that is fed through the “HPJ2610A Stack Hub” 10BaseT port to the “DELL Latitude Xpi” Ethernet card. The “DELL Latitude Xpi” is running “Lanalyzer”, a LAN monitoring software package supplied by Novell, used for measuring the rate of frames that are received without any errors (i.e. passed a 32-bit CRC check by the radio).

Although the data rate is actually 10 Mbps, the software that assigns frame buffers in the Stratum MP limits the overall throughput. It should be noted that all re-transmission protocol, acknowledgment protocol and error-correction coding are shut off for this measurement. The “HP Internet Advisor” is set to generate Ethernet frames at the maximum rate and maximum length that the radio will accept them. In this case, a utilization of 85% can be observed at the output without any interference. The Stratum MP will only download frames to the 10BaseT port if the 32-bit CRC has passed. Therefore, only the percentage utilization need be noted on the “Lanalyzer.” A measured J/S (equal to jamming margin Mj) at the input of the receiving Stratum MP which results in 76% utilization (90% of the maximum utilization of the Stratum MP), corresponds to symbol error rate of 10^{-4}.

A. DETAIL PROCEDURE OF THE MEASUREMENT

The processing gain Gp can be calculated by applying the system loss Lsys of 2 dB described above and the measured jamming margin Mj to Equation 1. The processing gain is measured across the band in 50 KHz steps across the passband of the receive SAW filter.

The output level of the signal generator (HP8648C) is adjusted in 0.1 dB steps. The CW source is shut off to measure the signal power with the "RF OFF" switch on the front panel of the signal generator. This is done after each measurement to account for any time variation of the power level. The signal source is shut off to measure the CW power. This is done after each measurement to account for any variation of the CW source power at each new frequency sample. At each frequency step, the CW source power is varied with 0.1 dB resolution in order to achieve a reading of approximately 76% on the utilization meter. After each measurement, when turning off the CW, the utilization is verified to go back up to 85%. For the band edge measurements, additional padding is inserted in the signal line in order to preserve the accuracy of the relative-power measurements on the power meter for the high J/S values. In the case of any mechanical change to the test setup, the spectra are re-verified on the spectrum analyzer.

The detail of test equipment is described below.:

- Signal generator (Jammer) : HP 8640C
- Data generator : HP Internet Advisor, J2522B
- Transmitter : Spread Spectrum Transceiver, Stratum MP (Equipment under test)
- Receiver : Spread Spectrum Transceiver, Stratum MP (Equipment under test)

- RF Amplifier : Mini-circuit ZHL1042J, Gain 26.7dB
- Power meter : HP426A
- Power Sensor : HP8481A
- Hub : HP J2610A, Advance Stack Hub
- Computers : Dell Latitude Xpi and Compaq Contura Aero4/25
- Spectrum analyzer : HP 8595E
- Power Splitter/Combiner : Mini-circuit 15542 ZFSC-2-2500

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IV. TEST RESULT

Figure 2 shows actually measured result of the processing gain of the Stratum MP against a CW jammer through entire passband of 2426 MHz to 2448 MHz. The lower 20% of the data points have been removed as per stated procedure. A table of numerical value is shown in Appendix-C.

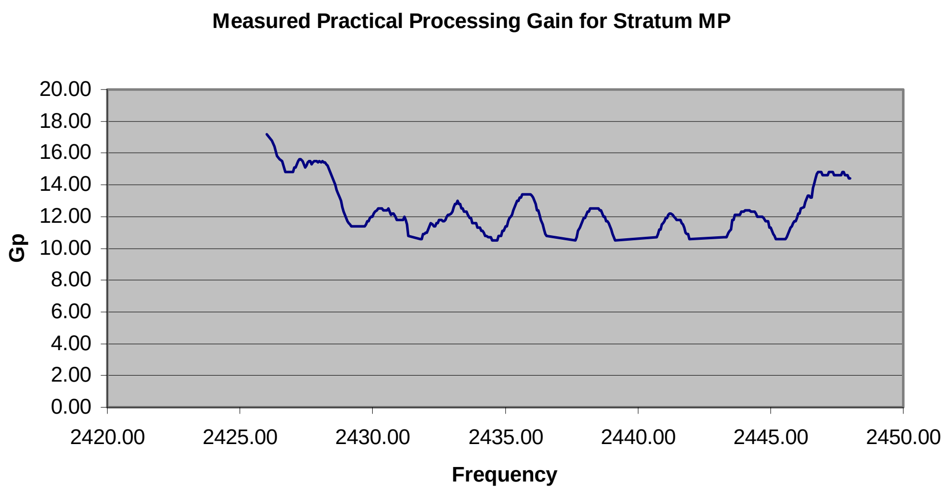


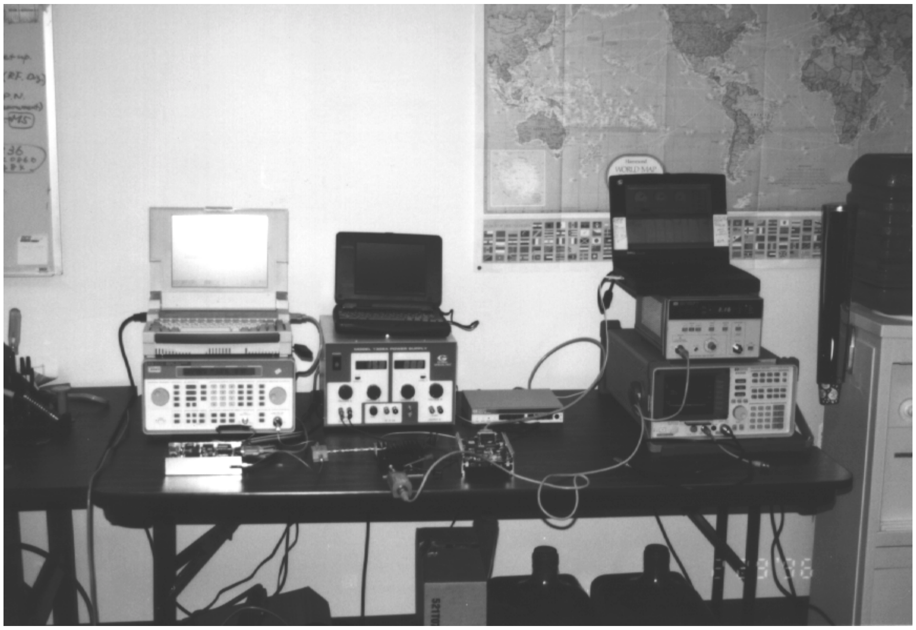
Figure 2

V. CONCLUSION

The processing gain of the Stratum MP as been measured using CW jamming margin method. The result shows that the actual processing gain of the radio, measured with the specified method of the FCC, exceeds 10 dB throughout the entire passband of the Stratum MP. This means that the Stratum MP product conforms to FCC regulation 15.247(e) prescribes that the processing gain of a direct sequence system shall be at least 10 dB.

Appendix-A

Test Site for Measurement of Processing Gain



Overall View

Appendix-B

Compensation Procedure of Power for Desired Signal

Readout of the power meter against desired signal should be compensated to continuous power because

- the power meter responds to average power,
- the Stratum MP transmits burst streams.

Compensation can be done using Equation A1.

$$P_{CONT} = P_{READ} / F_D \qquad \text{(A1)}$$

where

P_{CONT} : Continuous transmission power (W)
P_{READ} : Readout of the power meter (W)
F_D : Duty factor of the desired signal (sec/sec).

The duty factor F_D is defined as Equation A2.

$$F_D = D_T / (D_T + D_R) \quad \text{(sec/sec)} \qquad \text{(A2)}$$

where

D_T : Duration of transmission (sec)
D_R : Duration of receive (sec).

Figure A1 shows measurement result of D_T of 1.260 ms under the same condition as processing gain measurement. Figure A2 and Figure A3 show measurement result of D_R under the same condition as processing gain measurement. Two different D_R of 182 μs and 282 μs are observed. This flicker of D_R is caused by uncertainty of task duration of a microprocessor. Accordingly, averaged value of 232 μs may be used because probability of appearance of each value can be considered as equal throughout the response time of the power meter. F_D of the system can be obtained as 0.8445 (-0.73 dB) by applying these values to Equation A2. The readout of the power meter against desired signal can be compensated by applying F_D of this value to Equation A1.

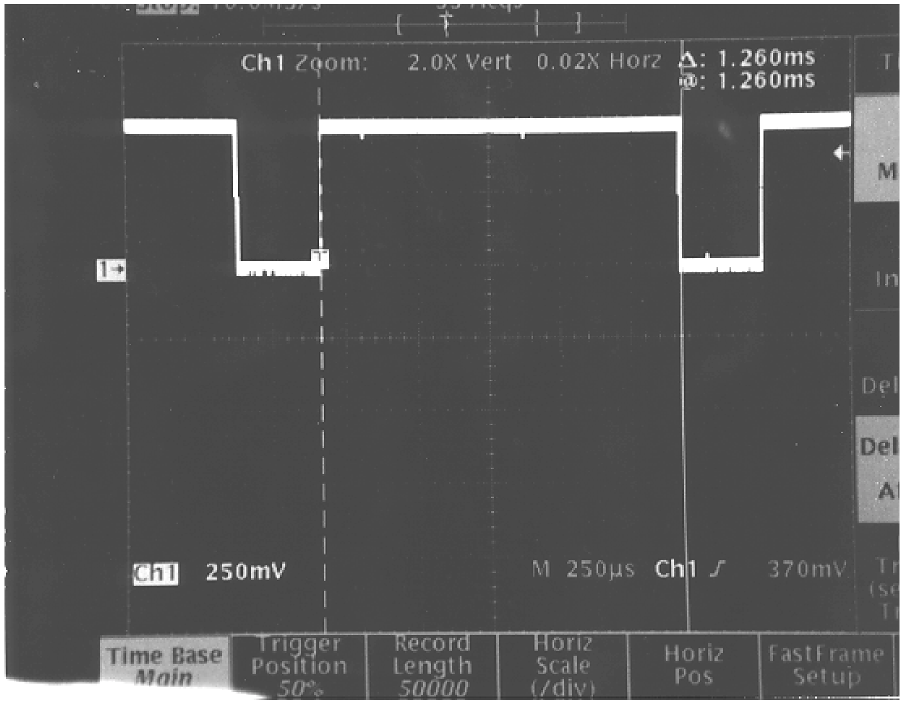

Ch1 Zoom: 2.0X Vert 0.02X Horz
Δ: 1.260ms
@: 1.260ms
Ch1 250mV
M 250µs Ch1 370mV
Time Base Main
Trigger Position 50%
Record Length 50000
Horiz Scale (/div)
Horiz Pos
FastFrame Setup

Figure A1

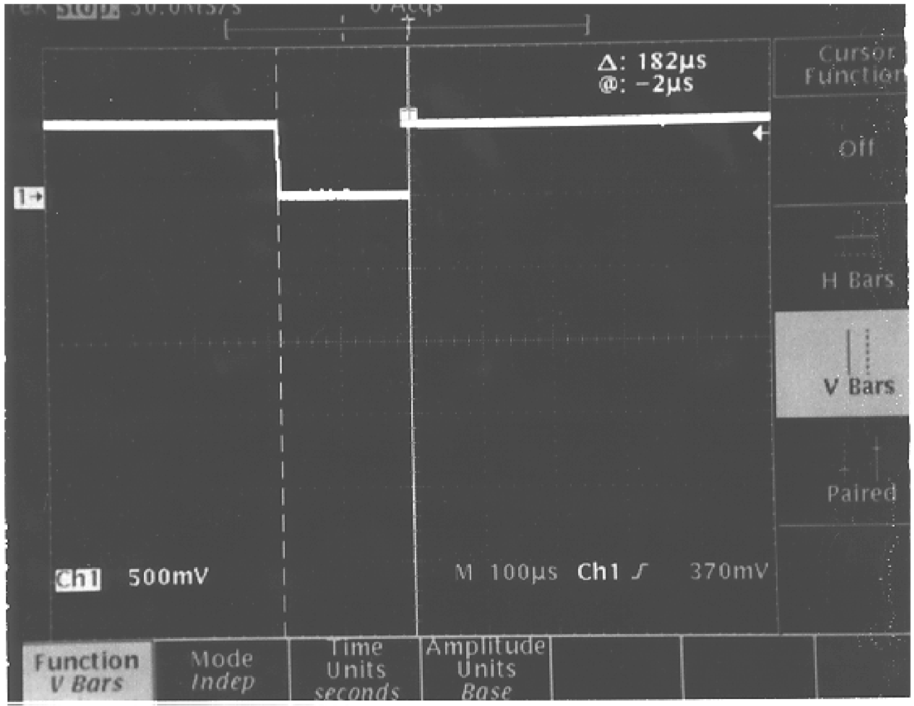


Figure A2

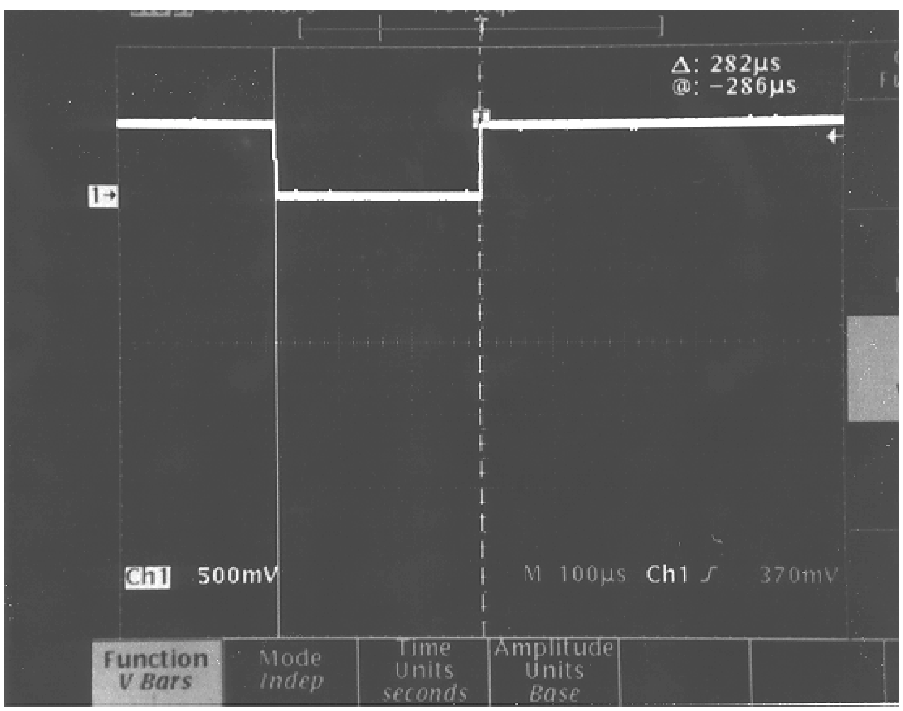


Figure A3

Appendix-C

Numerical Value of Measured Processing Gain

						Test Measurement										
						Measure Range			Signal = -42.9 dBm							
						2426-2448 Mhz			CPM requires 14.8 dB S/N for 4*10-5 Pse (=10% of max length packets in error)							
			Syntheszier			Center Frequency										
	Pwr Meter		Correction	Net		2.437 Ghz										
Freq	Amplitude	Throughput	Vs Freq	S/J (dBm)		Freq	Amplitude	Thruput	Correction	S/J (dBm)		Freq	Amplitude	Thruput	Correction	S/J (dBm)
Mhz	dBm	0.78	3.4 Ampl=			Mhz	dBm	0.78	3.4 Ampl=			Mhz	dBm	0.78	3.4 Ampl=	
2426.00	7.00	X	-46.10	-0.40		2430.10	2.10	X	-46.10	4.50		2433.70	1.40	X	-45.80	4.90
2426.10	6.80	X	-46.10	-0.20		2430.15	2.20	X	-46.10	4.40		2433.75	1.10	X	-45.80	5.20
2426.20	6.60	X	-46.10	0.00		2430.20	2.30	X	-46.10	4.30		2433.80	1.10	X	-45.80	5.20
2426.30	6.20	X	-46.10	0.40		2430.25	2.30	X	-46.10	4.30		2433.85	1.10	X	-45.80	5.20
2426.40	5.60	X	-46.10	1.00		2430.30	2.30	X	-46.10	4.30		2433.90	1.10	X	-45.80	5.20
2426.50	5.40	X	-46.10	1.20		2430.35	2.30	X	-46.10	4.30		2433.95	0.80	X	-45.80	5.50
2426.60	5.30	X	-46.10	1.30		2430.40	2.20	X	-46.10	4.40		2434.00	0.80	X	-45.80	5.50
2426.70	4.60	X	-46.10	2.00		2430.45	2.20	X	-46.10	4.40		2434.05	0.80	X	-45.80	5.50
2426.80	4.60	X	-46.10	2.00		2430.50	2.20	X	-46.10	4.40		2434.10	0.60	X	-45.80	5.70
2426.90	4.60	X	-46.10	2.00		2430.55	2.20	X	-46.10	4.40		2434.15	0.60	X	-45.80	5.70
2427.00	4.60	X	-46.10	2.00		2430.60	2.10	X	-45.90	4.30		2434.20	0.50	X	-45.80	5.80
2427.05	4.90	X	-46.10	1.70		2430.65	1.90	X	-45.90	4.50		2434.25	0.30	X	-45.80	6.00
2427.10	4.90	X	-46.10	1.70		2430.70	1.70	X	-45.90	4.70		2434.30	0.30	X	-45.80	6.00
2427.15	5.10	X	-46.10	1.50		2430.75	1.80	X	-45.90	4.60		2434.35	0.20	X	-45.80	6.10
2427.20	5.30	X	-46.10	1.30		2430.80	1.80	X	-45.90	4.60		2434.40	0.20	X	-45.80	6.10
2427.25	5.40	X	-46.10	1.20		2430.85	1.60	X	-45.90	4.80		2434.45	0.20	X	-45.80	6.10
2427.30	5.40	X	-46.10	1.20		2430.90	1.40	X	-45.90	5.00		2434.50	0.00	X	-45.80	6.30
2427.35	5.30	X	-46.10	1.30		2430.95	1.40	X	-45.90	5.00		2434.55	0.00	X	-45.80	6.30
2427.40	5.10	X	-46.10	1.50		2431.00	1.40	X	-45.90	5.00		2434.60	0.00	X	-45.80	6.30
2427.45	4.90	X	-46.10	1.70		2431.05	1.40	X	-45.90	5.00		2434.65	0.00	X	-45.80	6.30
2427.50	5.00	X	-46.10	1.60		2431.10	1.40	X	-45.90	5.00		2434.70	0.00	X	-45.80	6.30
2427.55	5.20	X	-46.10	1.40		2431.15	1.40	X	-45.90	5.00		2434.75	0.30	X	-45.80	6.00
2427.60	5.30	X	-46.10	1.30		2431.20	1.60	X	-45.90	4.80		2434.80	0.30	X	-45.80	6.00
2427.65	5.30	X	-46.10	1.30		2431.25	1.40	X	-45.90	5.00		2434.85	0.30	X	-45.80	6.00
2427.70	5.10	X	-46.10	1.50		2431.30	1.10	X	-45.90	5.30		2434.90	0.60	X	-45.80	5.70
2427.75	5.20	X	-46.10	1.40		2431.35	0.40	X	-45.90	6.00		2434.95	0.60	X	-45.80	5.70
2427.80	5.30	X	-46.10	1.30		2431.40	-0.40	X	-45.90	6.80		2435.00	0.90	X	-45.80	5.40
2427.85	5.30	X	-46.10	1.30		2431.45	-1.10	X	-45.90	7.50		2435.05	0.90	X	-45.80	5.40
2427.90	5.30	X	-46.10	1.30		2431.50	-1.10	X	-45.90	7.50		2435.10	1.10	X	-45.70	5.10
2427.95	5.20	X	-46.10	1.40		2431.55	-1.00	X	-45.90	7.40		2435.15	1.30	X	-45.70	4.90
2428.00	5.30	X	-46.10	1.30		2431.60	-0.50	X	-45.90	6.90		2435.20	1.40	X	-45.70	4.80
2428.05	5.20	X	-46.10	1.40		2431.65	-0.40	X	-45.90	6.80		2435.25	1.50	X	-45.70	4.70
2428.10	5.30	X	-46.10	1.30		2431.70	-0.40	X	-45.90	6.80		2435.30	1.80	X	-45.70	4.40
2428.15	5.20	X	-46.10	1.40		2431.75	-0.40	X	-45.90	6.80		2435.35	2.00	X	-45.70	4.20
2428.20	5.20	X	-46.10	1.40		2431.80	0.20	X	-45.90	6.20		2435.40	2.20	X	-45.70	4.00
2428.25	5.10	X	-46.10	1.50		2431.85	0.20	X	-45.90	6.20		2435.45	2.40	X	-45.70	3.80
2428.30	5.00	X	-46.10	1.60		2431.90	0.50	X	-45.90	5.90		2435.50	2.40	X	-45.70	3.80
2428.35	4.80	X	-46.10	1.80		2431.95	0.50	X	-45.90	5.90		2435.55	2.60	X	-45.70	3.60
2428.40	4.60	X	-46.10	2.00		2432.00	0.60	X	-45.90	5.80		2435.60	2.60	X	-45.70	3.60
2428.45	4.40	X	-46.10	2.20		2432.05	0.60	X	-45.90	5.80		2435.65	2.80	X	-45.70	3.40
2428.50	4.20	X	-46.10	2.40		2432.10	0.80	X	-45.90	5.60		2435.70	2.80	X	-45.70	3.40
2428.55	4.00	X	-46.10	2.60		2432.15	1.00	X	-45.90	5.40		2435.75	2.80	X	-45.70	3.40
2428.60	3.80	X	-46.10	2.80		2432.20	1.20	X	-45.90	5.20		2435.80	2.80	X	-45.70	3.40
2428.65	3.50	X	-46.10	3.10		2432.25	1.10	X	-45.90	5.30		2435.85	2.80	X	-45.70	3.40
2428.70	3.30	X	-46.10	3.30		2432.30	1.00	X	-45.90	5.40		2435.90	2.80	X	-45.70	3.40
2428.75	3.00	X	-46.10	3.60		2432.35	1.00	X	-45.90	5.40		2435.95	2.80	X	-45.70	3.40
2428.80	2.80	X	-46.10	3.80		2432.40	1.20	X	-45.90	5.20		2436.00	2.70	X	-45.70	3.50
2428.85	2.40	X	-46.10	4.20		2432.45	1.20	X	-45.90	5.20		2436.05	2.60	X	-45.70	3.60
2428.90	2.10	X	-46.10	4.50		2432.50	1.40	X	-45.90	5.00		2436.10	2.40	X	-45.70	3.80
2428.95	1.90	X	-46.10	4.70		2432.55	1.40	X	-45.90	5.00		2436.15	2.20	X	-45.70	4.00
2429.00	1.70	X	-46.10	4.90		2432.60	1.40	X	-45.90	5.00		2436.20	1.80	X	-45.70	4.40
2429.05	1.50	X	-46.10	5.10		2432.65	1.30	X	-45.90	5.10		2436.25	1.80	X	-45.70	4.40
2429.10	1.40	X	-46.10	5.20		2432.70	1.30	X	-45.90	5.10		2436.30	1.50	X	-45.70	4.70
2429.15	1.30	X	-46.10	5.30		2432.75	1.40	X	-45.90	5.00		2436.35	1.20	X	-45.70	5.00
2429.20	1.20	X	-46.10	5.40		2432.80	1.60	X	-45.90	4.80		2436.40	0.90	X	-45.70	5.30
2429.25	1.20	X	-46.10	5.40		2432.85	1.70	X	-45.90	4.70		2436.45	0.60	X	-45.70	5.60
2429.30	1.20	X	-46.10	5.40		2432.90	1.70	X	-45.90	4.70		2436.50	0.30	X	-45.70	5.90
2429.35	1.20	X	-46.10	5.40		2432.95	1.80	X	-45.90	4.60		2436.55	0.20	X	-45.70	6.00
2429.40	1.20	X	-46.10	5.40		2433.00	1.90	X	-45.90	4.50		2436.60	-0.20	X	-45.70	6.40
2429.45	1.20	X	-46.10	5.40		2433.05	2.10	X	-45.80	4.20		2436.65	-0.20	X	-45.70	6.40
2429.50	1.20	X	-46.10	5.40		2433.10	2.30	X	-45.80	4.00		2436.65	-0.40	X	-45.70	6.60
2429.55	1.20	X	-46.10	5.40		2433.15	2.30	X	-45.80	4.00		2436.70	-0.60	X	-45.70	6.80
2429.60	1.20	X	-46.10	5.40		2433.20	2.50	X	-45.80	3.80		2436.75	-0.80	X	-45.70	7.00
2429.65	1.20	X	-46.10	5.40		2433.25	2.30	X	-45.80	4.00		2436.80	-1.00	X	-45.70	7.20
2429.70	1.20	X	-46.10	5.40		2433.30	2.30	X	-45.80	4.00		2436.85	-1.20	X	-45.70	7.40
2429.75	1.30	X	-46.10	5.30		2433.35	2.00	X	-45.80	4.30		2436.90	-1.40	X	-45.70	7.60
2429.80	1.50	X	-46.10	5.10		2433.40	2.00	X	-45.80	4.30		2436.95	-1.40	X	-45.70	7.60
2429.85	1.50	X	-46.10	5.10		2433.45	1.80	X	-45.80	4.50		2437.00	-1.20	X	-45.70	7.40
2429.90	1.70	X	-46.10	4.90		2433.50	1.80	X	-45.80	4.50		2437.05	-1.80	X	-45.60	7.90
2429.95	1.80	X	-46.10	4.80		2433.55	1.80	X	-45.80	4.50		2437.10	-2.00	X	-45.60	8.10
2430.00	1.80	X	-46.10	4.80		2433.60	1.60	X	-45.80	4.70		2437.15	-2.00	X	-45.60	8.10
2430.05	2.00	X	-46.10	4.60		2433.65	1.40	X	-45.80	4.90		2437.20	-2.00	X	-45.60	8.10

						Test Measurement										
						Measure Range										
						2426-2448 Mhz										
						Center Frequency										
						2.437 Ghz										
Freq	Amplitude	Thruput	Correction	S/J (dBm)		Freq	Amplitude	Thruput	Correction	S/J (dBm)		Freq	Amplitude	Thruput	Correction	S/J (dBm)
Mhz	dBm	65%-75%	3.4 Ampl=			Mhz	dBm	65%-75%	3.4 Ampl=			Mhz	dBm	65%-75%	3.4 Ampl=	
2437.25	-2.00	X	-45.60	8.10		2440.85	0.40	X	-45.50	5.60		2444.45	1.30	X	-45.40	4.60
2437.30	-2.00	X	-45.60	8.10		2440.90	0.70	X	-45.50	5.30		2444.50	1.10	X	-45.40	4.80
2437.35	-1.70	X	-45.60	7.80		2440.95	0.80	X	-45.50	5.20		2444.55	1.10	X	-45.40	4.80
2437.40	-1.70	X	-45.60	7.80		2441.00	0.90	X	-45.50	5.10		2444.60	1.10	X	-45.40	4.80
2437.45	-1.40	X	-45.60	7.50		2441.05	1.10	X	-45.50	4.90		2444.65	1.10	X	-45.40	4.80
2437.50	-1.10	X	-45.60	7.20		2441.10	1.10	X	-45.50	4.90		2444.70	1.10	X	-45.40	4.80
2437.55	-0.70	X	-45.60	6.80		2441.15	1.30	X	-45.50	4.70		2444.75	1.00	X	-45.40	4.90
2437.60	-0.60	X	-45.60	6.70		2441.20	1.40	X	-45.50	4.60		2444.80	0.80	X	-45.40	5.10
2437.65	-0.20	X	-45.60	6.30		2441.25	1.40	X	-45.50	4.60		2444.85	0.80	X	-45.40	5.10
2437.70	0.00	X	-45.60	6.10		2441.30	1.30	X	-45.50	4.70		2444.9	0.80	X	-45.40	5.10
2437.75	0.40	X	-45.60	5.70		2441.35	1.20	X	-45.50	4.80		2444.95	0.40	X	-45.40	5.50
2437.80	0.60	X	-45.60	5.50		2441.40	1.10	X	-45.50	4.90		2445.00	0.40	X	-45.40	5.50
2437.85	0.80	X	-45.60	5.30		2441.45	1.00	X	-45.50	5.00		2445.05	0.20	X	-45.40	5.70
2437.90	1.00	X	-45.60	5.10		2441.50	1.00	X	-45.50	5.00		2445.10	0.00	X	-45.40	5.90
2437.95	1.20	X	-45.60	4.90		2441.55	1.00	X	-45.50	5.00		2445.15	-0.10	X	-45.40	6.00
2438.00	1.20	X	-45.60	4.90		2441.60	1.00	X	-45.50	5.00		2445.20	-0.30	X	-45.40	6.20
2438.05	1.40	X	-45.60	4.70		2441.65	0.80	X	-45.50	5.20		2445.25	-0.40	X	-45.40	6.30
2438.10	1.60	X	-45.60	4.50		2441.70	0.70	X	-45.50	5.30		2445.30	-0.50	X	-45.40	6.40
2438.15	1.60	X	-45.60	4.50		2441.75	0.50	X	-45.50	5.50		2445.35	-0.50	X	-45.30	6.30
2438.20	1.80	X	-45.60	4.30		2441.80	0.20	X	-45.50	5.80		2445.40	-0.40	X	-45.30	6.20
2438.25	1.80	X	-45.60	4.30		2441.85	0.10	X	-45.50	5.90		2445.45	-0.40	X	-45.30	6.20
2438.30	1.80	X	-45.60	4.30		2441.90	0.10	X	-45.50	5.90		2445.50	-0.40	X	-45.30	6.20
2438.35	1.80	X	-45.60	4.30		2441.95	-0.20	X	-45.50	6.20		2445.55	-0.40	X	-45.30	6.20
2438.40	1.80	X	-45.60	4.30		2442.00	-0.40	X	-45.50	6.40		2445.60	-0.30	X	-45.30	6.10
2438.45	1.80	X	-45.60	4.30		2442.05	-0.90	X	-45.40	6.80		2445.65	-0.10	X	-45.30	5.90
2438.50	1.80	X	-45.60	4.30		2442.10	-1.20	X	-45.40	7.10		2445.70	0.10	X	-45.30	5.70
2438.55	1.70	X	-45.60	4.40		2442.15	-1.50	X	-45.40	7.40		2445.75	0.30	X	-45.30	5.50
2438.60	1.70	X	-45.60	4.40		2442.20	-1.80	X	-45.40	7.70		2445.80	0.40	X	-45.30	5.40
2438.65	1.50	X	-45.60	4.60		2442.25	-2.30	X	-45.40	8.20		2445.85	0.60	X	-45.30	5.20
2438.70	1.30	X	-45.60	4.80		2442.30	-2.30	X	-45.40	8.20		2445.90	0.70	X	-45.30	5.10
2438.75	1.30	X	-45.60	4.80		2442.35	-2.30	X	-45.40	8.20		2445.95	0.70	X	-45.30	5.10
2438.80	1.00	X	-45.60	5.10		2442.40	-2.60	X	-45.40	8.50		2446.00	0.90	X	-45.30	4.90
2438.85	1.00	X	-45.60	5.10		2442.45	-2.60	X	-45.40	8.50		2446.05	1.20	X	-45.30	4.60
2438.90	0.90	X	-45.60	5.20		2442.50	-3.30	X	-45.40	9.20		2446.10	1.20	X	-45.30	4.60
2438.95	0.70	X	-45.60	5.40		2442.55	-3.30	X	-45.40	9.20		2446.15	1.50	X	-45.30	4.30
2439.00	0.50	X	-45.60	5.60		2442.60	-3.00	X	-45.40	8.90		2446.25	1.60	X	-45.30	4.20
2439.05	0.20	X	-45.60	5.90		2442.65	-2.50	X	-45.40	8.40		2446.30	1.90	X	-45.30	3.90
2439.10	0.00	X	-45.60	6.10		2442.70	-2.30	X	-45.40	8.20		2446.35	2.10	X	-45.30	3.70
2439.15	-0.20	X	-45.60	6.30		2442.75	-2.00	X	-45.40	7.90		2446.40	2.30	X	-45.30	3.50
2439.20	-0.20	X	-45.60	6.30		2442.80	-2.00	X	-45.40	7.90		2446.45	2.30	X	-45.30	3.50
2439.25	-0.50	X	-45.60	6.60		2442.85	-2.20	X	-45.40	8.10		2446.50	2.20	X	-45.30	3.60
2439.30	-0.70	X	-45.60	6.80		2442.90	-2.20	X	-45.40	8.10		2446.55	2.20	X	-45.30	3.60
2439.35	-0.90	X	-45.60	7.00		2442.95	-2.10	X	-45.40	8.00		2446.60	2.80	X	-45.30	3.00
2439.40	-1.00	X	-45.60	7.10		2443.00	-1.90	X	-45.40	7.80		2446.65	3.10	X	-45.30	2.70
2439.45	-1.20	X	-45.50	7.20		2443.05	-1.80	X	-45.40	7.70		2446.70	3.40	X	-45.30	2.40
2439.50	-1.40	X	-45.50	7.40		2443.10	-1.60	X	-45.40	7.50		2446.75	3.70	X	-45.30	2.10
2439.55	-1.60	X	-45.50	7.60		2443.15	-1.10	X	-45.40	7.00		2446.80	3.80	X	-45.30	2.00
2439.60	-1.80	X	-45.50	7.80		2443.20	-0.50	X	-45.40	6.40		2446.85	3.80	X	-45.30	2.00
2439.65	-1.80	X	-45.50	7.80		2443.25	-0.20	X	-45.40	6.10		2446.90	3.80	X	-45.30	2.00
2439.70	-2.00	X	-45.50	8.00		2443.30	-0.20	X	-45.40	6.10		2446.95	3.60	X	-45.30	2.20
2439.75	-2.00	X	-45.50	8.00		2443.35	-0.20	X	-45.40	6.10		2447.00	3.60	X	-45.30	2.20
2439.80	-2.30	X	-45.50	8.30		2443.40	0.10	X	-45.40	5.80		2447.05	3.60	X	-45.30	2.20
2439.85	-2.30	X	-45.50	8.30		2443.45	0.20	X	-45.40	5.70		2447.10	3.60	X	-45.30	2.20
2439.90	-2.50	X	-45.50	8.50		2443.50	0.30	X	-45.40	5.60		2447.15	3.60	X	-45.30	2.20
2439.95	-2.50	X	-45.50	8.50		2443.55	0.90	X	-45.40	5.00		2447.20	3.80	X	-45.30	2.00
2440.00	-2.50	X	-45.50	8.50		2443.60	0.90	X	-45.40	5.00		2447.25	3.80	X	-45.30	2.00
2440.05	-2.50	X	-45.50	8.50		2443.65	1.20	X	-45.40	4.70		2447.30	3.80	X	-45.30	2.00
2440.10	-2.50	X	-45.50	8.50		2443.70	1.20	X	-45.40	4.70		2447.35	3.80	X	-45.30	2.00
2440.15	-2.50	X	-45.50	8.50		2443.75	1.20	X	-45.40	4.70		2447.40	3.60	X	-45.30	2.20
2440.20	-2.50	X	-45.50	8.50		2443.80	1.20	X	-45.40	4.70		2447.45	3.60	X	-45.30	2.20
2440.25	-2.30	X	-45.50	8.30		2443.85	1.20	X	-45.40	4.70		2447.50	3.60	X	-45.30	2.20
2440.30	-2.10	X	-45.50	8.10		2443.90	1.40	X	-45.40	4.50		2447.55	3.60	X	-45.30	2.20
2440.35	-1.80	X	-45.50	7.80		2443.95	1.40	X	-45.40	4.50		2447.60	3.60	X	-45.30	2.20
2440.40	-1.60	X	-45.50	7.60		2444.00	1.40	X	-45.40	4.50		2447.65	3.60	X	-45.30	2.20
2440.45	-1.50	X	-45.50	7.50		2444.05	1.50	X	-45.40	4.40		2447.70	3.80	X	-45.30	2.00
2440.50	-1.10	X	-45.50	7.10		2444.10	1.50	X	-45.40	4.40		2447.75	3.80	X	-45.30	2.00
2440.55	-1.10	X	-45.50	7.10		2444.15	1.50	X	-45.40	4.40		2447.80	3.60	X	-45.30	2.20
2440.60	-0.60	X	-45.50	6.60		2444.20	1.50	X	-45.40	4.40		2447.85	3.60	X	-45.30	2.20
2440.65	-0.60	X	-45.50	6.60		2444.25	1.40	X	-45.40	4.50		2447.90	3.60	X	-45.30	2.20
2440.70	-0.10	X	-45.50	6.10		2444.30	1.40	X	-45.40	4.50		2447.95	3.40	X	-45.30	2.40
2440.75	0.10	X	-45.50	5.90		2444.35	1.40	X	-45.40	4.50		2448.00	3.40	X	-45.30	2.40
2440.80	0.40	X	-45.50	5.60		2444.40	1.40	X	-45.40	4.50						