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May 10, 2001

Tim Johnson
U. S. Technologies
3505 Francis Circle
Alpharetta, GA 30004
(770) 740-0717

RE: System Processing Gain

Dear Tim,
I am sending you the Processing Gain Report for FCC ID L2V0536ASR2, which is one of the spread spectrum receivers that can be used to receive the AX630 Transmitter. Additional receivers are under development that will receive the AX630; however, these receivers will have identical spread spectrum parameters as the L2V0536ASR2.

The System Processing Gain testing was performed using a transmitter whose key parameters (spreading code rate, spreading code modulation type, spreading code length, spreading code sequence, data rate, data modulation type, pseudo-random code, signal filtering, and oscillator phase noise) are equivalent to this transmitter currently under application for certification. Consequently, we feel that that the System Processing Gain data submitted with this application is representative of the test results that would have been yielded if the process gain test were conducted using the AX630 Transmitter currently under test.

The theoretical process gain of the system defined by the spread occupied bandwidth (2*chipping frequency) divided by the narrowest filter in the receiver is:

$$10 \log (2.44\text{MHz} / 110\text{kHz}) = 13.46 \text{ dB}$$

Implementation losses are appended to the receiver report and show theoretical process gain plus implementation losses exceed the FCC's 10 dB process gain requirement.

Best regards,

David Alley
Axonn L.L.C.

PROCESS GAIN TESTING

RULE SECTION: 15.247(e)

The processing gain of a direct sequence system shall be at least 10 dB. The processing gain shall be determined from the ratio in dB of the signal to noise ratio with the system spreading code turned off to the signal to noise ratio with the system spreading code turned on, as measured at the demodulated output of the receiver.

TEST RESULTS:

Complies. The processing gain of the system is 12 dB inclusive of system implementation losses.

TEST EQUIPMENT:

IFR A-8000 spectrum analyzer, Boonton 4220 power meter, HP8640B signal generator, LeCroy 9400 oscilloscope, parameter extraction test fixture (see below), Mini Circuits SBL-1X mixer, Mini Circuits ZFSC-2-4 splitter, Mini Circuits ZFSWA-2-46 RF switch, HP 8495B 0-70 dB attenuator, HP 8494B 0-11 dB attenuator.

METHOD OF MEASUREMENT:

General Notes

The spread spectrum system is designed to run open loop. In open loop operation the receiver acquires the pseudo-random sequence by a correlation search on the preamble sent by the transmitter. This search aligns the incoming PRC from the transmitter to within 1/8 chip of synchronization. The receiver notes a local timing offset that achieves this correlation and sets the receiver to that offset for the remainder of the message time. The crystal controlled references at the receiver and the transmitter are specified to drift an amount that insures the receiver maintains local code timing within 1/8 chip without re-searching for the duration of the message time.

To measure the processing gain with the method requested in 15.247(e) with the pulsed nature of the system design requires us to keep the code timing of the receiver and transmitter locked for more than the prescribed transmitter on-time of 7.63 mSec. To accomplish this, the receiver spreading code will not be generated by the slave processor for the testing. The imported PRC to the receiver will be generated by a PRC generator that produces an exact replica of the PRC sequence the system uses. The PRC waveshape and timing are exactly the same as the system utilizes.

EXPLANATION OF TEST FIXTURE:

Exhibit V, Illustration V-A is the block diagram of the test fixture built to extract the information to prove compliance with 15.247(e). A HP 8640B signal generator set to the 900 MHz receive frequency feeds a Mini Circuits splitter. The splitter outputs are fed to a HP attenuator and a Mini Circuits mixer. The mixer and attenuator are then fed to a Mini Circuits RF switch. A spread spectrum biphase modulated RF signal is produced by the Mini Circuits mixer that duplicates the RF signal produced by the system transmitter. The spread spectrum signal is generated by applying a 63 chip pseudo-random code to the mixer which is generated by a shift register pseudo-random code generator. The code output by the generator is identical to the sequence used by the system transmitter. The chipping code is fed through a shift register delay line to provide the "transmitted" signal with time shifts to facilitate testing. The time shifts may be either 1/4 chip increments or infinitely variable increments less than 1/4 chip. A second output from the PRC generator feeds the receiver code filter (as opposed to the code being generated by the slave microprocessor) for several tests. The chip rate oscillator utilizes a 14.66 MHz crystal identical to the system transmitter to clock the PRC generator and delay line. The Mini Circuits RF switch allows either a spread spectrum or CW output to be selected through the switch control circuit.

The attenuator allows the CW signal to match the spread spectrum signal in power level offsetting the mixer loss.

The output of the RF switch may be routed to either the Boonton 4220 power meter for calibration or to another Mini Circuits splitter via a two-foot length of RG58 coaxial cable. The two outputs of the Mini Circuits splitter feed the two antenna inputs of the receiver through two four-inch pieces of RG188 coaxial cable connected to the Mini circuits splitter on one end and soldered to the receiver antenna inputs on the other.

The MC1496 despreader output from the receiver is routed via three different paths for testing:

a. The despreader output is fed to a Murata Erie SFE10.7MHY 110 kHz ceramic filter and then to the IFR analyzer. This will be noted as Configuration #1.

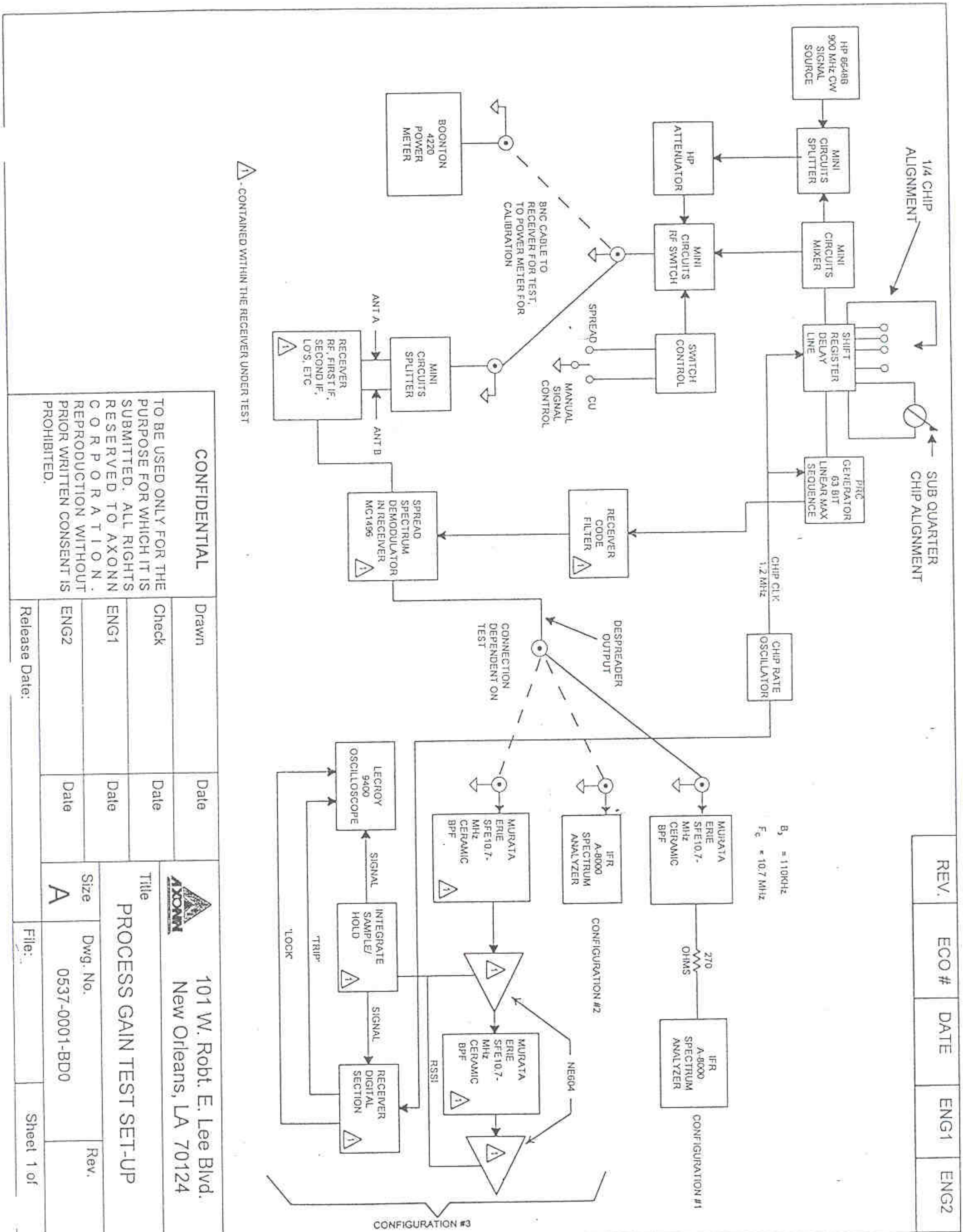
b. The despreader output is fed directly to the IFR analyzer. This will be noted as Configuration #2.

c. The despreader output is connected as usual to the remainder of the receiver. In this test, the integrated RSSI output is monitored by the LeCroy 9400 oscilloscope. This will be noted as Configuration #3.

TESTING:

Methodology

The receiver utilizes a Signetics NE604A Received Signal Strength Indication (RSSI) integrated circuit for demodulation. The NE604 RSSI output, when connected to the integrator circuit on the digital board, produces a 500 mV per 10 dB change in signal strength output. Since this signal is the one actually used for demodulation by the receiver, the last test will show that a voltage differential of at least 12 dB is experienced when the system spreading code is turned on and off. The spreading code will be manipulated at the transmission end of the system to facilitate the testing as the 1496 demodulator does not support CW operation as configured in the circuit. The NE604 detector transfer function is not linear over the dynamic range of the device, however. Because of this, we thought that a more representative view of the processing gain of the system should be measured at the correlator's output: first wide band, and then with the 110 kHz filter applied (ie. as the detector "sees" it). Another test is included at this point to show the jamming margin of the system for completeness.



HP 8648B 900 MHz CW SIGNAL SOURCE
MINI CIRCUITS SPLITTER
MINI CIRCUITS MIXER
1/4 CHIP ALIGNMENT
HP ATTENUATOR
MINI CIRCUITS RF SWITCH
SHIFT REGISTER DELAY LINE
SUB QUARTER CHIP ALIGNMENT
BOONTON 4220 POWER METER
BNC CABLE TO RECEIVER FOR TEST, TO POWER METER FOR CALIBRATION
SWITCH CONTROL
SPREAD
CU
MANUAL SIGNAL CONTROL
PRC GENERATOR 63 BIT LINEAR MAX SEQUENCE
ANT A
ANT B
MINI CIRCUITS SPLITTER
RECEIVER RF, FIRST IF, SECOND IF, LO'S, ETC
RECEIVER CODE FILTER
CHIP CLK 1.2 MHz
SPREAD SPECTRUM DEMODULATOR IN RECEIVER MC1496
CHIP RATE OSCILLATOR
DESPREADER OUTPUT
CONNECTION DEPENDENT ON TEST
- CONTAINED WITHIN THE RECEIVER UNDER TEST
B_s = 110KHz
F_c = 10.7 MHz
MURATA ERIE SFE10.7-MHz CERAMIC BPF
270 OHMS
IFR A-8000 SPECTRUM ANALYZER
CONFIGURATION #1
IFR A-8000 SPECTRUM ANALYZER
CONFIGURATION #2
MURATA ERIE SFE10.7-MHz CERAMIC BPF
MURATA ERIE SFE10.7-MHz CERAMIC BPF
NE604
RSSI
LECROY 9400 OSCILLOSCOPE
SIGNAL
INTEGRATE SAMPLE/HOLD
'TRIP'
'LOCK'
SIGNAL
RECEIVER DIGITAL SECTION
CONFIGURATION #3
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Sheet 1 of

TEST #1

This test shows the output of the 1496 decorrelator with a RF spread spectrum input signal that is decorrleated versus a CW input signal of the same power.

NOTE: These signals are not band limited by the 110 kHz bandwidth filter. These photographs show just the difference in demodulator output with the two types of signals. Test Configuration #2.

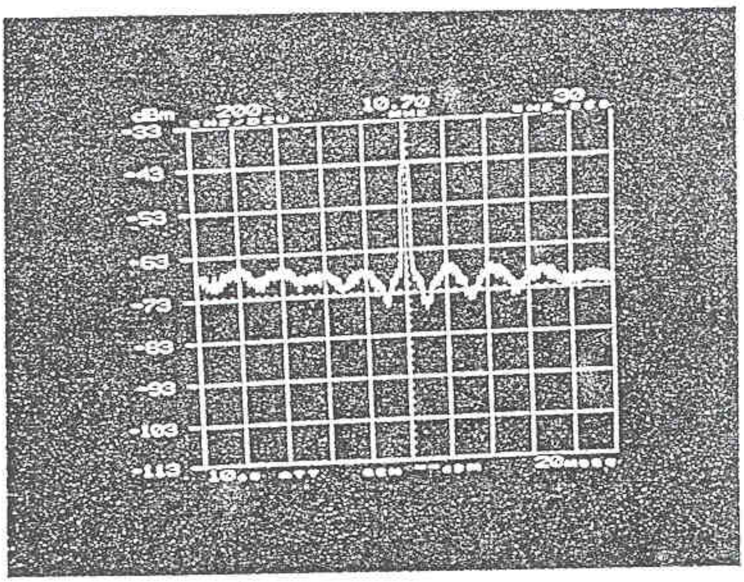

Exhibit V, Illustration V-B
Spread spectrum signal input at 900 MHz, 10.7 MHz IF output after decorrelation.