Application Revisions

Letter	Description of Change	Date	by
—	Initial Release	3/17/07	J. Rivera
a	Revised noise figure and gain test	4/7/07	G. Samsonoff
b	Switching Power Supply Noise Test	4/20/07	J. Rivera
c	Updated Can-do Section	4/28/07	D. Ferguson

Acceptance Test Procedure

		Project OSCAR Build Team
Originator: J. Rivera – WA6HTP	Date 1/17/07	**AMSAT - Project Eagle 70 cm Telecommand Receiver**
Checked by: R. Hambly	Date 2/6/07	
Approval: J. Sanford	Date 3/17/07	Rev c
Program Manager: J. Sanford	Date 3/17/07	

CONTENTS

TABLES and FIGURES

1.0 INTRODUCTION

This document details the RF testing to be performed on the AMSAT- Project Eagle 70 cm Satellite Telecommand Receiver covering the 435 - 438 MHz frequency range. This procedure does not cover environmental testing (thermal, vacuum, shock and vibration, etc.)

The USAF PAVE PAWS Space Surveillance and Missile Warning radar network poses a serious EMI threat. There are three active systems located in Massachusetts, California, and Alaska. The radar is used primarily to detect and track sea-launched (SLBM) and intercontinental ballistic missiles (ICBMs). The system also has a secondary mission of Earth-orbiting satellite detection and tracking. The radar shares the 420 – 450 MHz band with the Amateur Radio Service. It operates continuously with a peak effective radiated power of 3.6 megawatts or 95.57 dBW[1]. The radar emissions are centered on 24 frequencies[2], 4 of which directly impact the receiver since they fall within the 435 to 438 MHz satellite segment of the international band plan. Due to the serious nature of the PAVE PAWS interference threat, this acceptance test procedure will attempt to address the threat in section 25.0 with a PAVE PAWS blocking dynamic range test.

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[1] Upgraded Early Warning Radar (UEWR) Supplement to the National Missile Defense (NMD) Deployment Draft Environmental Impact Statement (EIS) Comments and Responses, page 9-488 – Space and Missile Defense Command web site: http://www.smdcen.us/pubdocs/files/nmd_deploy_feis_ch9_2.pdf

[2] All of the PAVE PAWS information in this document was derived from open source material available on the Internet (See PAVE PAWS Addendum for additional references).

2.0 APPLICABLE DOCUMENTS

2.1 J.B Stephensen, AMSAT-NA, AMSAT Eagle, 70 cm Receiver Requirements, (4-22-06, Rev 4)

2.2 J. Rivera, Project OSCAR, Acceptance Test Report – IM3 Test Equipment Validation, (Dec 27, 2006)

2.3 Ulrich L. Rohde, Theory of Intermodulation and Reciprocal Mixing: Practice, Definitions and Measurements in Devices and Systems, (QEX, Nov/Dec 2002, Jan/Feb 2003)

2.4 Robert E. Watson, *Receiver Dynamic Range*, (Watkins-Johnson Company, Tech Notes, Vol. 14, No. 1, Jan/Feb 1987)

2.5 Richard Ranson, G3ZTB, *Radio System Design – Theory and Practice*, (Besser Associates 3-day Short Course)

2.6 Hewlett Packard, HP8566B Spectrum Analyzer Operating and Programming Manual, (Part Number 08566-90040)[1]

2.7 MIL-STD-188-141B, *Conformance Test Procedures*, (Nov, 2003)

2.8 Hewlett Packard, Fundamentals of RF and Microwave Noise Figure Measurements, Application Note 57-1, Jul 1983

2.9 CAN-DO! User's Guide for Firmware v0.8 – v1.0, (Oct 11, 2004)

2.10 CAN-DO! Installation Text

2.11 CAN232 manual, Version 2.0A, (Nov 2003)

[1] All HP 8566B manuals are available on line at http://www.home.agilent.com

3.0 SOFTWARE REQUIRED

- UHU_Full.exe, Version 009 20040323 containing:
  - Python for Windows, Version 2.2.3
  - Python Win32 Extension, Build 152
  - Python Serial Port Extension for Win32, Version 1.19
  - wxPython 2.4.1.2 for Python 2.2
- Microsoft Hyper Terminal
- Bandwidth_Screen_capture.exe (WA6HTP LabView application)

4.0 TEST EQUIPMENT REQUIRED

Unless otherwise specified equivalent equipment may be substituted.

ITEM	DESCRIPTION	MFR	MODEL	QTY
1	Power Supply, 0-15 VDC, 0-2A	HP	E3610A	1
2	Dual Power Supply, 0-25 VDC, 0-1A	Agilent	E3620A	1
3	Network Analyzer 30 KHz – 20 GHz	HP	8753D	1
4	Spectrum analyzer 100 Hz – 22 GHz	HP	8566B	1
5	Signal generator 10 kHz – 1280 MHz	HP	8662A	1
6	Signal generator 100 kHz - 990 MHz	HP	8656B	1
7	Noise Figure Meter	HP	8970A	1
8	Noise Diode	HP	346B	1
9	Frequency Counter 10 MHz – 18 GHz	HP	5342A	1
10	GPS Disciplined 10 MHz reference	HP	Z3801A	1
11	6 ½ Digit Multimeter	Agilent	34401A	1
12	10-500 MHz Amplifier	Penstock	PSC-F871M	2
13	Power Combiner 0.01 – 1.5 GHz	Mini-Circuits	ZFSC-2-1W	1
14	450 MHz Lowpass filter	Mini-Circuits	ZLFX-450	2
15	Attenuator, 3 dB	JFW	50HF-003	2
16	Attenuator, 20 dB	JFW	50HF-020	1
17	30 dB Step Attenuator (1 dB steps)	JFW Ind.	50DR-055	1
18	10 dB Sped Attenuator (0.1 dB steps)	Texscan	RA-534	1
19	Termination, 50 Ohm	Pasternack	PE 6009	1
20	Personal Computer	Any	—	1
21	PCI/GPIB Adapter	National Inst.	PCI-1200	1
22	Printer	Any	—	1
23	Lawicel CAN232 Module	Dontronics	CAN232-E99	1
24	CAN-Do Widget	AMSAT	—	1

Table 4.0. Test Equipment Required

5.0 HANDLING PRECAUTIONS

The receiver printed wiring board (PWB) contains parts that are extremely sensitive to damage by electrostatic discharge (ESD). For this reason, standard ESD precautionary procedures must be used when handling this assembly. Grounding wrist bands and anti-static bags are considered standard equipment in protecting against ESD damage.

6.0 DIRECTORY OF TESTS

Table 6-1 Directory of Tests

NOTE: Do not connect power to the receiver until directed to do so.

NOTE: Turn on all test equipment and allow at least one hour warm-up time before proceeding.

NOTE: An arrow (►) to the left of an item indicates that an entry is required on the data sheet.

7.0 RECEIVER POWER SUPPLY CHECK

This test verifies that the Receiver internal power supplies will function correctly over an input range of 12.0 to 14.0 volts, and will determine the maximum current consumption. Any out of spec issues must be corrected before proceeding. *Regulator output tolerances are not specified.*

7.1 On the HP E3610A power supply press the RANGE button in to select the 15V voltage range and adjust the voltage to +12.00 VDC ±0.05 V.

7.2 Depress and hold CC SET (the constant current button), and adjust the maximum current to 0.30 A ± 0.05 A. This will limit the maximum current in case of a problem.

7.3 Connect the power supply to the DC input of the receiver.

7.4 NOTE: Allow a minimum of 45 minutes warm up time for the receiver and all of the test equipment before proceeding.

7.5 ► Note the current consumption. Record the reading in the data sheet.

7.6 ► Record the voltage at the output of the 3 VDC regulator, U19, Pin 5 and record the reading in the data sheet.

7.7 ► Record the voltage at the output of the 5 VDC regulator, U18, Pin 1 and record the reading in the data sheet.

7.8 ► Record the voltage at the output of the 5.6 VDC regulator, U20, Pin 5 and record the reading in the data sheet.

7.9 ► Record the voltage at the output of the 10 VDC regulator, U16, Pin 1 and record the reading in the data sheet.

7.10 Adjust voltage to +14.00 VDC ±0.05 V.

7.11 ► Note the current consumption. Record the reading in the data sheet.

7.12 ► Repeat steps 7.5 through 7.9.

7.13 Adjust voltage to +13.00 VDC ±0.05 V.

7.14 Depress CC SET and adjust the maximum current to 0.50 A ± 0.05 A[1].

NOTE: Correct any out of tolerance conditions before proceeding.

[1] All remaining testing will be conducted at a DC input voltage of 13.0 VDC. The load will also include the CAN232 Module and the CAN-Do Widget.

8.0 CAN-DO NETWORK INSTALLATION AND TEST

This test verifies that the Receiver module can correctly interface with the CAN-DO Widget and the desired functions can be communicated via the bus to the module. Any out of spec issues must be corrected before proceeding.

The CAN232 dongle must be powered via the CAN side (DB9 male) with 8 to 15VDC. The CAN232 dongle is ESD protected so reversing the power will not damage it, instead the power supply will be short circuited to protect the CAN232 dongle. The CAN232 dongle needs about 40-100mA depending on network loading. See Figure 8-1 for interconnection details.

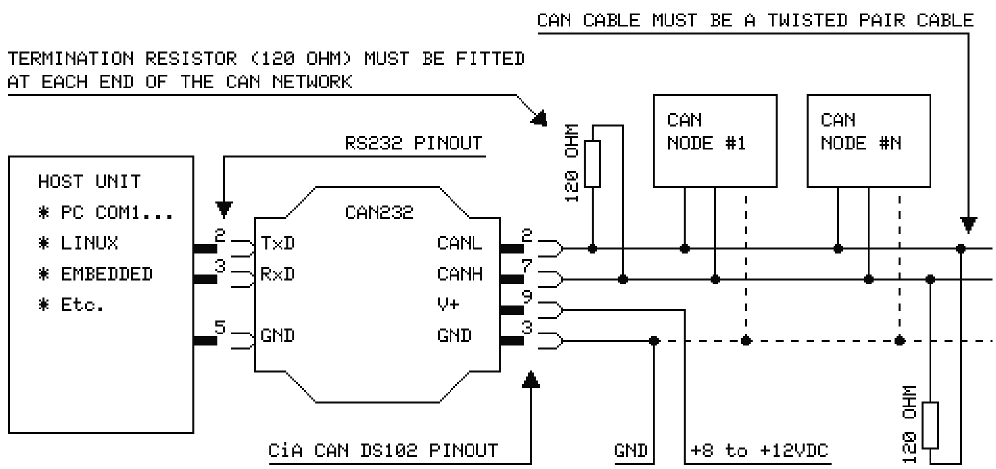

Figure 8-1. CAN-Do Interconnections

NOTE: DO NOT CONNECT THE RECEIVER UNTIL DIRECTED TO DO SO.

Refer to the CDNC documentation at http://cdnc.moraco.us/ for software installation instructions, and the latest version of the CDNC program.

8.1 Attach a Lawicel CAN232 module to the Com1 port of the computer.

8.2 Attach the CAN side of the Lawicel CAN232 to the Eagle Widget Cable

(The widget cable must be connected to power to provide power to the Lawicel CAN232 module.)

The Lawicel CAN232 module is a very small blue dongle that plugs into any PC COM Port, or any other RS232 port in an embedded system and gives an instant CAN connectivity. This means it can be treated by software as a standard COM Port (serial RS232 port) which eliminates the need for any extra drivers. Sending and receiving can be done in standard ASCII format.

The RS232 side of the dongle (DB9 female) is inserted directly into a PC's COM serial port or via a cable to the Host system (such as an embedded system etc.).

The CAN side of the dongle (DB9 male) has the same pinout as the standard CAN in Automation (CiA) DS102 profile and the CAN232 dongle must be powered via the CAN side with 8 to 15VDC.

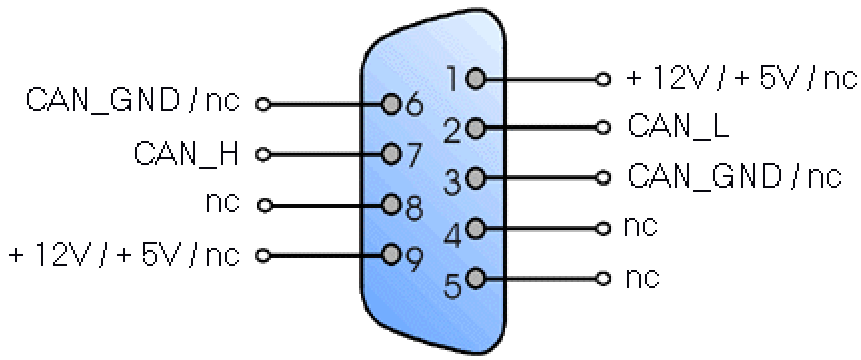

Figure 8-2. CAN-Do Pin Assignments

Consult figure 8.2 for pin assignment according to CiA recommendations DS102-1. The CAN232 is powered with +Vin (9-15VDC) at pin 9 and GND at pin 3.

The dongle is ESD protected so reversing the power will not damage the CAN232, instead the power supply will be short circuited to protect the CAN232 dongle. The CAN232 dongle needs about 40-100mA depending on how much the CAN network is loaded (i.e. numbers of nodes etc.). Below is a simple schematic showing how to connect the CAN232.

8.3 If the CAN232 in new and unused then using Hyperterm, connect to the CAN232 at 57600 baud – 8bits No parity 1 stop bit (the factory default).

8.4 If you have problems, the likely cause is Hyperterm sending CR/LF instead of just CR for the Enter Key. This can be fixed in File/Properties/Settings/ASCII_Setup. The 'Send line ends with line feeds' should not be checked. The 'Echo typed characters locally' and 'Append line feeds to incoming line ends' can be checked to make the output more readable.

8.5 Press enter several times and then press 'V' and Enter. The module should respond with something like V0108 - the version of the module. If you get a bell on enter recheck 1.2 above to insure only CR is sent on the Enter key.

8.6 Enter 'U1' and ENTER to set the CAN232 to 115200 baud.

8.7 Remove the power to the CAN232 and re-apply power. The LED's on the module should blink twice indicating the baud rate is 115200. Newer modules have the LED's inside and can be seen through the blue case on the back side opposite the label side.

8.8 Reset Hyperterm to 115200 and again send several Enter key presses and the 'V' command. If the CAN232 responds correctly, CDNC software should work. Turn off Hyperterm to free up the selected COM port.

8.9 Disconnect the power to the Widget cable and install the CAN-DO Widget of the DB15 connector. Insure the exposed pins of the widget are insulated from each other if the module is not yet installed on a satellite module.

8.10 Reconnect the power to the CAN interface cable.

8.11 When you have a CAN-DO widget and Lawicell CAN232 hooked up to the computer, Click on the CDNC icon on the desktop to start the CDNC program.

8.12 On startup the program should do a Query and detect the CAN-DO Widget. If it does not then Click on the Query button at the top of the screen. If all is working the Widget should respond and the indicators at the bottom of the screen should indicate 1 widget detected and address 63.

8.13 Edit the options and select "Query on startup" check box to make this happen automatically in the future.

8.14 Select the "display log" button to view the log of data that is passed to and from the module.

8.15 To initialize the receiver to 436.000 MHz, Select "File" "Playback Log" and find the "Receiver Init String.can" from the "My CAN Logs" directory.

8.16 On the CDNC main screen select the pull down list next to the Heartbeat button and select 50ms speed or slower.

8.17 Select the Heartbeat button to send the initialization string which will turn on the power and send the receiver initialization string to the receiver.

8.18 It is normal to have a constant heartbeat from the IHU to all of the modules on the satellite.

8.19 At this point the receiver should be functioning and receiver testing can be performed.

NOTE: CORRECT ANY OUT-OF-TOLLERANCE CONDITIONS BEFORE PROCEEDING.

8.20 ► Reconnect power to the CAN32 widget and note the total current consumption of the receiver and the widget. Enter the value in the data sheet.

NOTE: This portion of the procedure will be added once the hardware is available for integration.

8.21 Configure CAN-Do jumper settings (TBD)

8.22 CAN-Do Mode (TBD)

8.23 CAN-Do Interconnections (TBD)

9.0 SPECTRUM ANALYZER CALIBRATION

9.1 Connect the Spectrum Analyzer CAL OUTPUT to RF INPUT.

9.2 Press 2-22 GHz. This initializes the analyzer to a preset condition.

9.3 Press RECALL, 8 and adjust AMPTD CAL for a marker amplitude of -10.0 dBm ± 0.05 dBm.

9.4 Press RECALL, 9 and maximize amplitude response by adjusting FREQ ZERO for maximum on the display.

9.5 Press SHIFT, FREQUENCY SPAN to initiate a 30 second error correction routine. Upon completion of this routine "CORR'D" will be displayed at the left edge of the CRT.

9.6 Press SHIFT, START FREQ to store the correction factors.

9.7 Disconnect CAL OUTPUT from RF INPUT.

9.8 Press 2-22 GHz to return the analyzer to a preset condition.

10.0 10 MHz EXTERNAL REFERENCE

This test will insure that the receiver can be commanded to select either the external or the internal reference, and that it will lock to the external reference signal within the specified input power limits of 0 dBm ± 2 dBm. *Stability and accuracy requirements for the internal reference are not specified*.

Refer to Figure 10-1 for test configuration.

10.1 Select the external reference

10.2 Tune the receiver to 436.500000 MHz.

10.3 Set signal generator #1 to 436.500000 MHz, -50 dBm

10.4 Set signal generator #2 to 10.000000 MHz, 0 dBm

10.5 ► Record the I.F. output frequency displayed on the Frequency Counter.

10.6 ► Increase the output level of signal generator #2 to +2 dBm. The I.F. output frequency must not vary. Record the results in the data sheet.

10.7 ► Decrease the output level of signal generator #2 to -2 dBm. The I.F. output frequency must not vary. Record the results in the data sheet.

10.8 Select the internal reference.

10.9 ► Note the new I.F. output frequency in the data sheet.

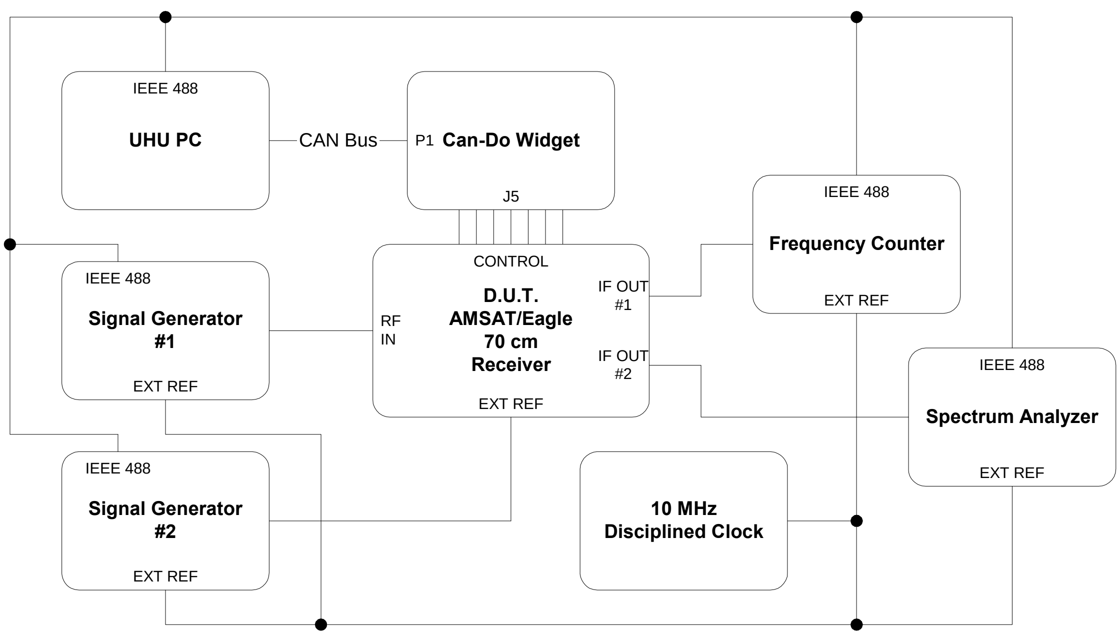

Figure 10-1. 10 MHz External Reference Test Configuration

11.0 TUNING RANGE, I.F. CENTER FREQUENCY, and SYMMETRY

This test verifies that the receiver covers the frequency range of 435 to 438 MHz, and that the I.F. is centered at 10.700 MHz, and that both IF outputs are identical. *Frequency accuracy and output symmetry are not specified.*

Refer to Figure 11-1 for test configuration.

11.1 Set the signal generator and the receiver to 435.000 MHz.

11.2 Set the signal generator output to -50 dBm

11.3 Connect the spectrum analyzer to receiver I.F. output #1, configure it, and center the signal on the display by pressing [2-22 GHz], [CENTER FREQUENCY] 10.7 [MHz], [FREQUENCY SPAN] 10 [kHz], [PEAK SEARCH], [MKR→CF], and MARKER MODE [NORMAL].

11.4 ► Verify the I.F. output is at 10.700 MHz. Record the marker frequency and level in the data sheet.

11.5 Press MARKER [Δ] and then connect the spectrum analyzer to I.F. output #2.

11.6 ► Note the marker delta level and record it in the data sheet.

11.7 Set the signal generator and the receiver to 438.000 MHz.

11.8 On the spectrum analyzer, press MARKER MODE OFF, PEAK SEARCH, MKR→CF, and MARKER MODE NORMAL to center the signal on the display.

11.9 ► Verify the I.F. output is at 10.700 MHz. Record the marker frequency and level in the data sheet.

11.10 On the spectrum analyzer press 2-22 GHz to return to a preset configuration.

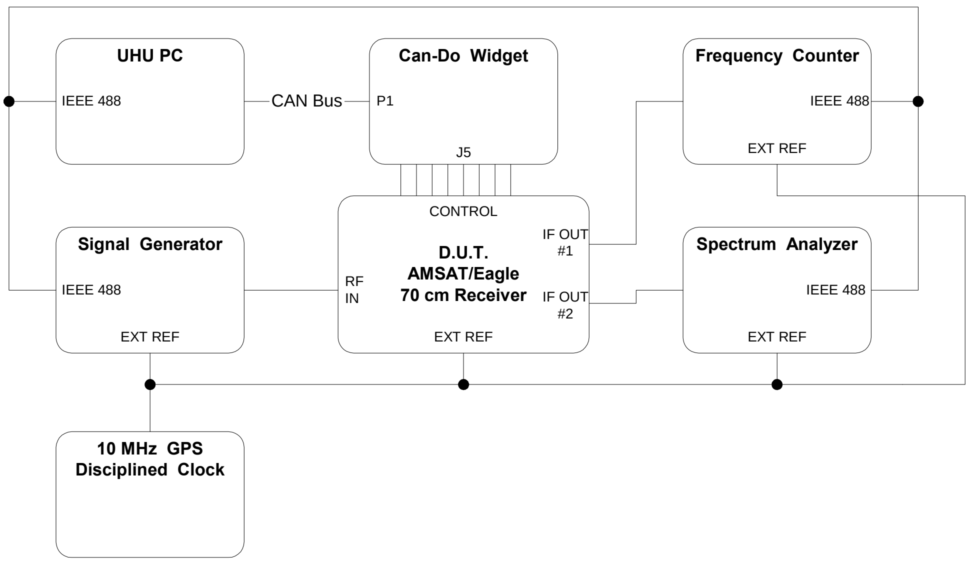

Figure 11-1. Default Test Configuration

12.0 TUNING RESOLUTION AND SPECTRUM INVERSION

This test verifies that the receiver will tune in 100 kHz steps across its full tuning range of 435.000 to 438.000 MHz and that the I.F. spectrum is not inverted.

Refer to Figure 11-1 for test configuration.

12.1 Set the receiver and signal generator to 435.000 MHz.

12.2 Set the signal generator output to -50 dBm.

12.3 Connect the spectrum analyzer to I.F. output #1 and press 2-22 GHz, CENTER FREQUENCY 10.7 MHz, FREQUENCY SPAN 10 kHz, PEAK SEARCH, MKR→REF LVL, and MARKER MODE NORMAL to center the signal in the display.

12.4 Verify an I.F. output at 10.700 MHz.

12.5 ► Record the I.F. frequency and level in the data sheet.

12.6 Increase the Frequency of the receiver and signal generator by 100 KHz.

12.7 Repeat steps 12.4 through 12.6 until reaching 438.000 MHz.

12.8 ► Increase the signal generator frequency slightly while observing the I.F. output signal frequency. Note whether the I.F. output signal varies in the same direction as the input, indicating that the spectrum in not inverted. Note the results in the data sheet.

13.0 1 dB COMPRESSION POINT (P_{-1db})

This test characterizes the receiver's 1 dB compression point. This test will determine when the receiver begins to deviate radically from linear amplitude response[1]. It is performed at the center frequency of 436.5 MHz. Although P_{-1db} is not specified, the maximum R.F. input level is specified at +12 dBm. **DO NOT EXCEED +12 dBm**. Refer to Figure 11-1. Default Test Configuration for test configuration.

13.1 Set the receiver and signal generator to 436.500 MHz.

13.2 Set the signal generator output to -70 dBm.

13.3 Connect the spectrum analyzer to I.F. output #1 and configure it by pressing [2-22 GHz], [CENTER FREQUENCY] 10.7 [MHz], [FREQUENCY SPAN] 10 [kHz], [PEAK SEARCH], [MKR→CF], [MKR→REF LVL], [ENTER dB/DIV] 1 [+dBm], [RES BW] 1 [kHz], and MARKER MODE [NORMAL].

13.4 Press [REFERENCE LEVEL] and use the [⇑] button to set the signal near the bottom of the screen. Then press MARKER MODE [Δ].

13.5 On the signal generator, press [AMPLITUDE], RESOLUTION [X10] to enable 1 dB amplitude steps.

13.6 Increase the signal generator output in 2 dB steps while observing the delta signal level on the screen[2].

---

[1] Within the linear portion of the receiver operating curve, a 1 dB increase in input will result in a 1 dB increase in IF output. (The slope of the curve is 1:1). This test finds the point in the curve where compression is starting to take place and the slope has reached 2:1. Eventually as the signal continues to increase, the receiver will saturate and the IF output level will no longer increase with increases in input, and may actually start to decrease. Operating in this non-linear portion of the curve will result in greatly reduced performance.

[2] As the receiver begins to saturate, the 2 dB increases in signal level will result in less than a 2 dB increase in IF output level

13.7 Reset the marker delta after each 2 dB increase by pressing the marker Δ key. If the signal reaches the top of the display increase the reference level on the spectrum analyzer by 10 dB and continue.

13.8 Repeat steps 13.6 and 13.7 until a 2 dB step is found that produces a 1 dB increase in IF signal level ± 0.25 dB.

13.9 Vary the input level up and down in 1 dB steps to locate the 2 dB RF input increase that most closely results in a 1.0 dB increase in IF output level. Reset the spectrum analyzer Δ key as necessary during this step.

13.10 ► Record the sig. gen. output level and the delta level on the data sheet.

14.0 I.F. BANDWIDTH

This test verifies that the I.F. bandwidth of the receiver is at least 100 kHz at the -1 dB point.

Refer to Figure 11-1 and Figure 14-1 for test configuration and bandwidth definition.

14.1 Set the receiver and signal generator to 436.500 MHz.

14.2 Set the signal generator output to -50 dBm.

14.3 Connect the spectrum analyzer to I.F. output #1 and press 2-22 GHz, CENTER FREQUENCY 10.7 MHz, FREQUENCY SPAN 200 kHz, PEAK SEARCH, MKR→CF, MKR→REF LVL, MARKER MODE OFF, ENTER dB/DIV, 1 +dBm, and RES BW 200 kHz.

14.4 Press REFERENCE LEVEL and ⇑ to set the signal level one line below the top of the display.

14.5 Set the signal generator for a 200 kHz sweep by pressing START FREQ 436.400 MHz, STOP FREQ 436.600 MHz, 1000 LIN STEPS and the 100 ms TIME/STEP button.

14.6 Initiate an automatic sweep by pressing MODE AUTO on the signal generator and capture the trace by pressing TRACE A MAX HOLD on the spectrum analyzer.

14.7 Once the passband has been “painted” on the display, stop the sweep by pressing MODE OFF on the generator and TRACE A VIEW on the analyzer.

14.8 Use Figure 14-1 as a guide and find the highest peak by pressing MARKER PEAK SEARCH on the analyzer. Then press Δ and position the cursor to the minimum amplitude point within the passband and note the marker delta value. Press Δ again and move the cursor up along the passband curve to an amplitude half the value just noted. The cursor should now be positioned at the average signal level as defined in Figure 14-1.

14.9 Press [Δ] and move the marker down the low frequency skirt until the marker delta level reads 1.00 dB, ± 0.02 dB. This point defines the -1 dB point from the average.

14.10 Press [Δ] and position the marker on the high frequency skirt. Now move the marker down the skirt until the marker delta reads 0.00 dB ± 0.02 dB.

14.11 ► The 1dB bandwidth of the receiver's passband is now displayed as the delta marker frequency. Record this value in the data sheet.

14.12 ► Capture the screen image and attach it to the data sheet using Bandwidth_Screen_Capture.exe.

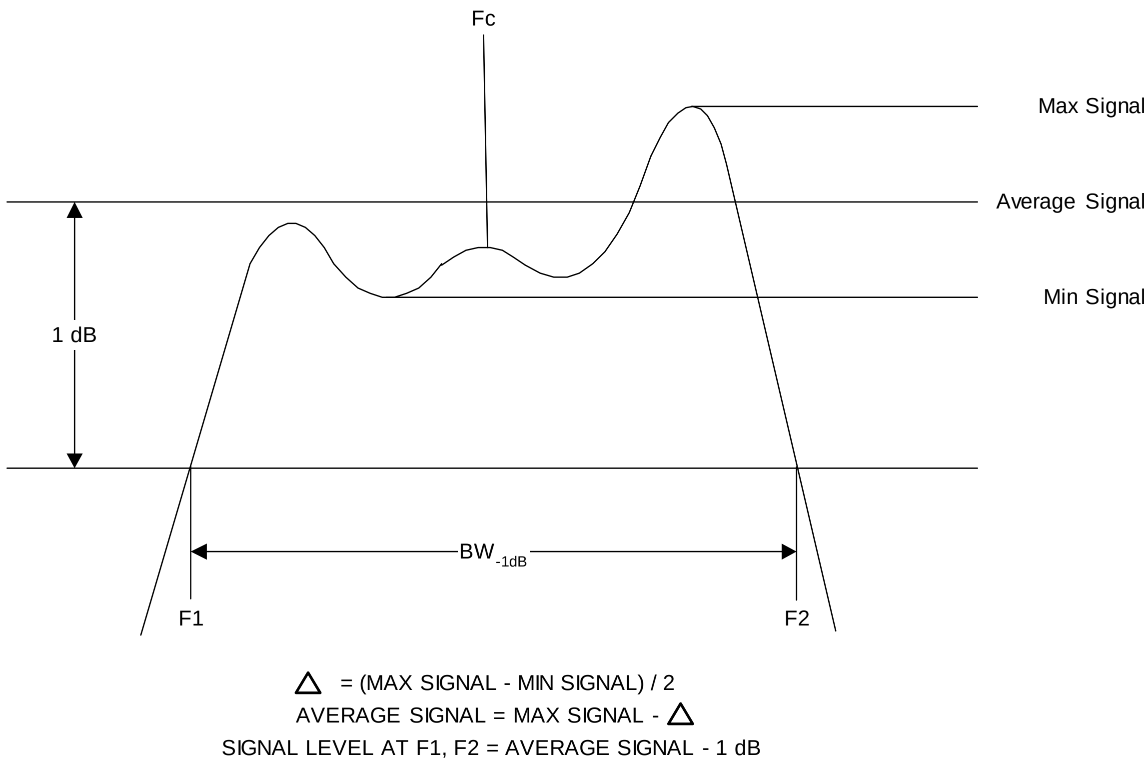

Figure 14-1. I.F. Bandwidth Definition (Ripple Exaggerated)

15.0 IMAGE REJECTION

This test will characterize the receiver's image rejection. The test will be conducted at the receiver's center frequency of 436.500 MHz. *Image rejection is not specified.*

The image frequency is calculated as follows:

RF input + (2 X IF) = 436.5 + (2 X 199) = 834.5 MHz

Refer to Figure 11-1 for the test configuration.

15.1 Set the signal generator to the receiver image frequency of 834.500 MHz, at an output level of 0 dBm.

15.2 Set the receiver to 436.500 MHz.

15.3 Connect the spectrum analyzer to I.F. output #1 and press 2-22 GHz, CENTER FREQUENCY 10.7 MHz, FREQUENCY SPAN 10 kHz, REFERENCE LEVEL 50 -dBm.

15.4 If a signal is detected skip to step 15.6.

15.5 ► Record the lack of a signal on the data sheet. The test is now completed.

15.6 If a signal is detected, press PEAK SEARCH, MKR→CF, MARKER MODE NORMAL, TRACE A VIEW, and A⇄B, TRACE B VIEW to store and display the signal in the B Register.

15.7 ► Record the signal level on the data sheet.

15.8 Press TRACE A CLEAR WRITE to return to normal operation.

15.9 Set the signal generator to 435.500 MHz, -100 dBm.

15.10 ► Adjust the signal generator output level to match the signal displayed dimly in Trace B, and enter the signal generator output level on the data sheet.

15.11 ► Enter the difference between the 0 dBm level of step 15.1 and the level of step 15.10. Record the difference on the data sheet as the image rejection.

16.0 FIRST IF REJECTION

This test will characterize the receiver's first IF rejection. The test will be conducted at the receiver's center frequency of 436.500 MHz. *First IF rejection is not specified.*

The first IF frequency is 199.000 MHz

16.1 Set the signal generator to the receiver first IF frequency of 199.000 MHz, at an output level of 0 dBm.

16.2 Repeat the previous test, starting at step 15.2.

17.0 INTERNALLY GENERATED SPURIOUS RESPONSE

This test will characterize the level of the internally generated spurious responses, referenced to the R.F. input. Spurii are searched within twice the I.F. bandwidth, from DC to 21.4 MHz, over the full frequency range of the receiver. *Internally generated spurious response is not specified.*

Refer to Figure 11-1 for test configuration.

17.1 Remove the signal generator and connect a 50 ohm termination to the R.F. input of the receiver.

17.2 Connect the spectrum analyzer to I.F. output #1 and press 2-22 GHz, CENTER FREQUENCY 10.7 MHz, FREQUENCY SPAN 200 kHz, RES BW 300 Hz, REFERENCE LEVEL 30 –dBm, DISPLAY LINE ENTER 100 –dBm.

17.3 Set the receiver to 435.00 MHz.

17.4 Observe any spurious responses that appear above the display line.

17.5 If a response appears to extend above the display line press SAVE 1, PEAK SEARCH, SIGNAL TRACK, FREQUENCY SPAN 1 kHz, RES BW, 10 Hz, MARKER MODE OFF. [1] [2]

17.6 If no spikes extend past the display line then skip to step 17.12.

17.7 If a spur is located, press PEAK SEARCH, MARKER MODE NORMAL, TRACE-A VIEW, and A⇄B to move the display to the B Register. Press TRACE-B VIEW to display the trace, and Trace-A CLEAR-WRITE to return to the A-Register.

17.8 Disconnect the 50 ohm termination and connect the Signal generator to the R.F. input. Adjust the signal generator frequency until the test signal is close to the spur. Adjust the output level to match that of the spur.

---

[1] Six different instrument states can be saved and recalled using the SAVE and RECALL buttons. This is a handy feature when you want to return to a previous configuration.

[2] SIGNAL TRACK allows the spectrum analyzer to “zoom in” on a signal from a very wide bandwidth to a very small bandwidth without loosing the signal.

17.9 Disconnect the R.F. cable from the receiver R.F. input and connect it directly to the input of the spectrum analyzer.

17.10 Press 2-22 GHz, FREQUENCY SPAN 100 Hz, REFERENCE LEVEL 60 -dBm, CENTER FREQUENCY (match the signal generator frequency), RES BW 10 Hz.

17.11 ►Press PEAK SEARCH, MARKER MODE NORMAL. In the data sheet record the output frequency and level of the Generator at the end of the cable. This is the equivalent level of the spurious response, referenced to the receiver's input.

17.12 Press RECALL 1 to return to search mode.

17.13 Increment the receive frequency 100 kHz and repeat steps 17.1 through 17.12 until reaching 438.00 MHz.

18.0 PHASE NOISE

This test measures the phase noise of the receiver by injecting a low-phase-noise signal at the R.F. input and measuring the phase noise at the I.F. output. The phase noise of the signal at the R.F. input will add to the phase noise of the receiver, therefore caution should be used when selecting a signal source for this test. The test will confirm that phase noise does not exceed the following required limits:

-77 dBc/Hz at ±5 kHz

-124 dBc/kHz at ±100 kHz

-144 dBc/kHz at ±1 MHz

Refer to Figure 11-1 for test configuration.

18.1 Set the receiver and the signal generator to 436.500 MHz.

18.2 ► Adjust the signal generator output level to a level 10 dB below P_{-1db} as determined in step 13.10. Note the level on the data sheet.

18.3 Configure the spectrum analyzer by pressing 2-22 GHz, CENTER FREQUENCY 10.700 MHz, FREQUENCY SPAN 10 kHz, PEAK SEARCH, MKR→REF LVL, RES BW 10 Hz, and MARKER MODE NORMAL.

18.4 ► Note the IF output signal level on the data sheet

18.5 Set the signal generator frequency to 436.505000 MHz (offset by 5 kHz)

18.6 On the spectrum analyzer press FREQUENCY SPAN 100 Hz,

18.7 Press SHIFT, VIDEO BW, and allow video averaging to reach 100.

18.8 ► Select noise level mode by pressing SHIFT, MARKER MODE NORMAL, NORMAL and read the noise level normalized to a 1 Hz power bandwidth. Enter the value in the data sheet.

18.9 ► Calculate the difference between the level measured in step 18.4, and the level measured in step 18.8, and then enter the absolute noise level (in dBm) and the difference value (in dBc) in the data sheet.

18.10 On the spectrum analyzer press SHIFT, SWEEP TIME to terminate video averaging and then set the signal generator frequency to 436.600000 MHz. (offset by 100 kHz) Set the reference level as necessary to keep the noise floor at least two cm above the bottom of the display.

18.11 On the spectrum analyzer repeat steps 18.7 and 18.8.

18.12 On the spectrum analyzer press SHIFT, SWEEP TIME to terminate video averaging and then set the signal generator frequency to 437.500000 MHz. (offset by 1 MHz) Set the reference level as necessary to keep the noise floor at least two cm above the bottom of the display.

18.13 Repeat steps 18.7 and 18.9.

19.0 NOISE FIGURE AND R.F.-TO-I.F. GAIN

This test verifies that the noise figure does not exceed 7 dB and will characterize the R.F.-to-I.F. gain. The noise figure meter will be used to perform and plot both measurements simultaneously. The R.F.-to-I.F. gain is not specified.

Refer to Figure 19-1 for test configuration.

Noise Figure Meter ENR Data Entry

19.1 Enter the test noise source ENR data into the noise figure meter Table 1 as follows:

a) Press RECALL, ENR, 1 on the front panel of the noise figure meter. This displays ENR table 1 data in the working table (Table 0).

b) Press ENR and the first frequency and ENR pair is shown. If the frequency is incorrect, enter the correct value and press ENTER.

c) If the frequency is OK, press ENTER and verify the ENR is correct. If the ENR is incorrect, enter the correct value and press ENTER to display the next frequency and ENR pair.

d) If the ENR is OK, press ENTER to display the next frequency and ENR pair.

e) When the last data entry is confirmed, press STORE ENR 1. This step stores the test noise source's ENR data into Table 1 of the noise figure meter.

Noise Figure Meter Calibration

19.2 Press 5.7, SPECIAL FUNCTION, 1, ENTER on the noise figure meter front panel to select Table 1. This step instructs the noise figure meter to use Table 1 (for the test noise source) to calibrate. This calibration is for the noise figure meter and will be done at the IF frequency under test (10.7 MHz).

19.3 Press 5.8, SPECIAL FUNCTION, 1, ENTER to select Table 1. This step instructs the noise figure meter to use Table 1 (the test noise source) for the noise figure and gain measurements.

19.4 Press 1.3, SPECIAL FUNCTION. This step notifies the noise figure meter that the device under test has a variable RF and Local Oscillator and a fixed IF.

19.5 Press 46.1, SPECIAL FUNCTION. This step instructs the noise figure meter not to try and control the Local Oscillator of the device under test.

19.6 Patch the test noise source output directly to the noise figure meter RF input.

19.7 Patch the test noise source 28 VDC input to the noise figure meter noise source.

19.8 Press 3.0, SPECIAL FUNCTION, 10.7, ENTER. This step instructs the noise figure meter to use 10.7 MHz as its calibration frequency.

19.9 On the noise figure meter, under the smoothing label, press INCREASE or DECREASE to see the smoothing value. A smoothing value of 16 is recommended.

19.10 Press START FREQ, 10.7, ENTER, STOP FREQ, 10.7, ENTER, CALIBRATE, CALIBRATE (press twice).

19.11 After the calibration is completed, press CORRECTED NOISE FIGURE and GAIN and the meter should read 0 dB gain and noise figure.

19.12 NOTE: The noise figure meter does not need to be re-calibrated again unless it is turned off or a different input frequency IF is used.

Data Collection

19.13 Connect the noise source to the device under test RF input, and the output of the device under test to the Noise Figure meter input.

19.14 Enter the first test frequency into the noise figure meter by pressing FREQUENCY, #, ENTER. where # is the frequency listed in Table 1 of the data sheet.

19.15 ► Tune the device under test to the test frequency and record the noise figure and gain reading in table 1 of the data sheet.

19.16 Repeat steps 20.14 and 20.15 for the test frequencies as shown in Table 1 of the data sheet.

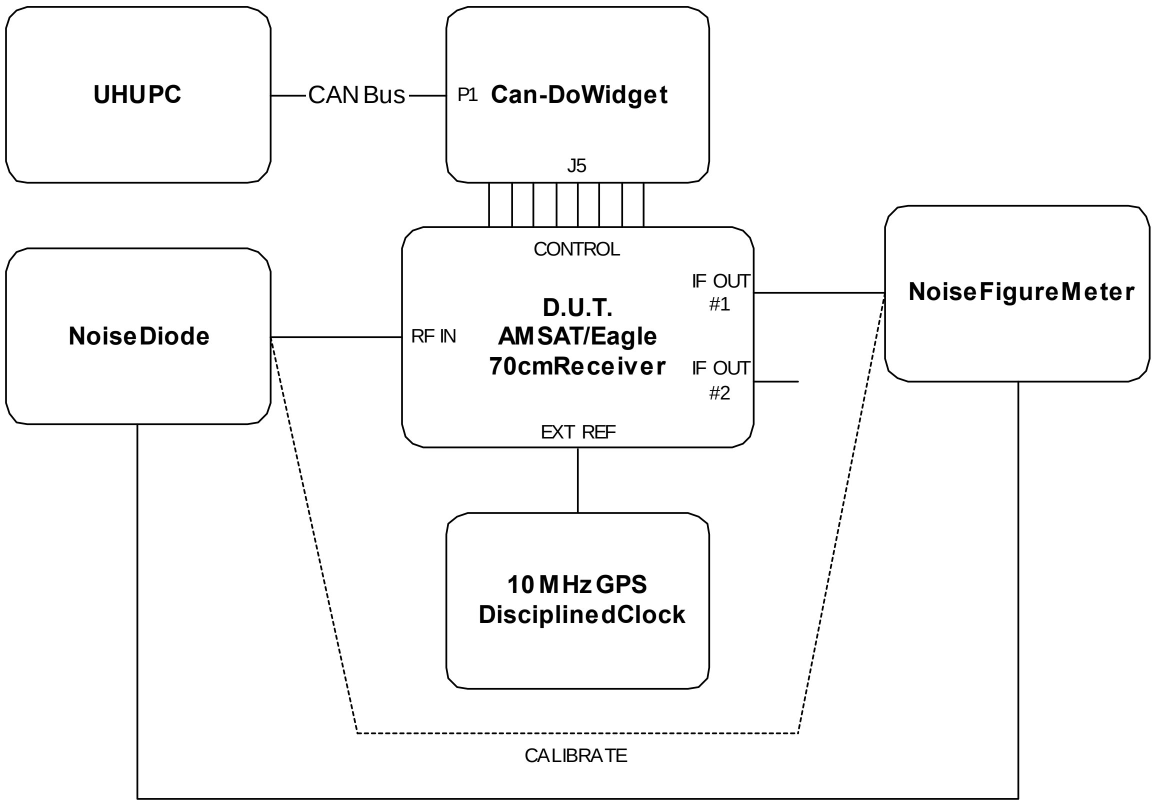

Figure 19-1. Noise Figure and R.F.-to-I.F. Gain Test Configuration

20.0 R.F. INPUT VSWR

This test will characterize the R.F. input VSWR of the receiver. *The R.F. Input VSWR is not specified.*

Refer to Figure 20-1 for test configuration.

20.1 Calibrate the network analyzer for an S11 measurement over the 435 to 438 MHz range.

20.2 Command the receiver to 436.500 MHz and connect Port-1 of the network analyzer to the R.F. input of the receiver.

20.3 ► Plot the VSWR over the 435 to 438 MHz range and attach the plot to the data sheet. Record the highest VSWR on the data sheet.

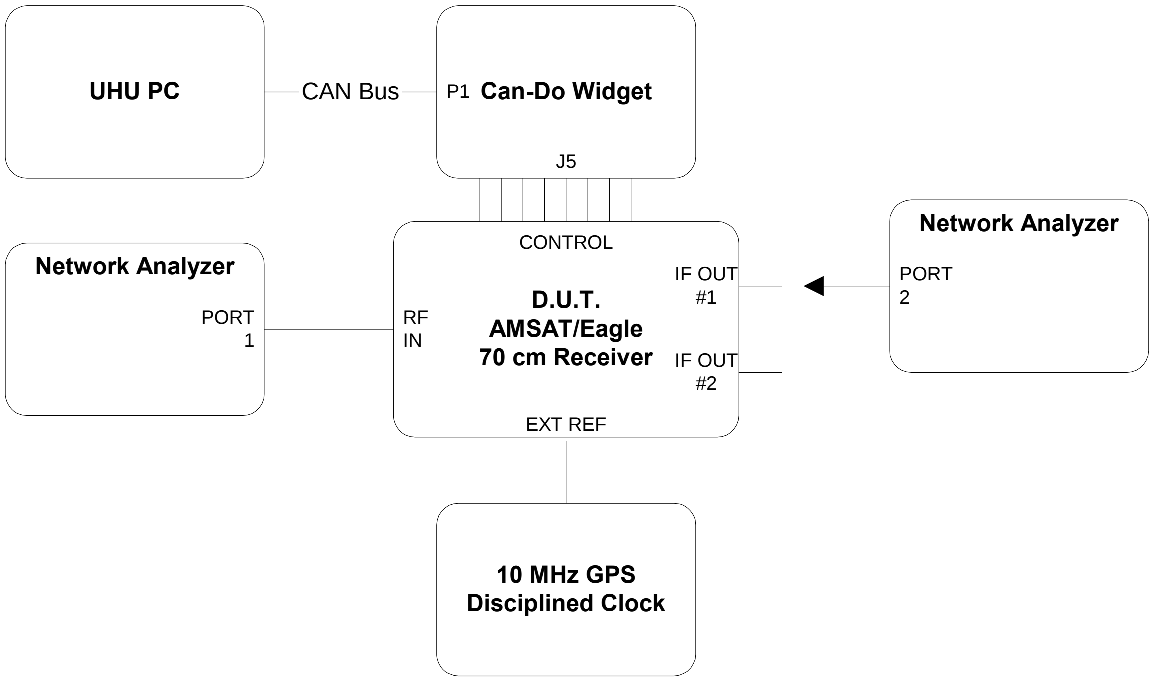

Figure 20-1. R.F. Input and Output VSWR Test Configuration

21.0 I.F. OUTPUT VSWR

This test will characterize the I.F. output VSWR of the receiver. The I.F. Output VSWR is not specified.

Refer to Figure 20-1 for test configuration.

21.1 Calibrate the network analyzer for an S11 measurement from 10.600 to 10.800 MHz.

21.2 Set the analyzer to display VSWR.

21.3 ► Measure the return loss from 10.600 to 10.800 MHz and record the maximum value obtained in the data sheet.

22.0 FIRST LOCAL OSCILLATOR LEAKAGE

This test will characterize the leakage of the first local oscillator at the receiver's R.F. input (J1). First local oscillator leakage is not specified.

Refer to Figure 22-1 for test configuration.

22.1 Command the receiver to 436.500 MHz.

22.2 On the spectrum analyzer press 2-22 GHz, CENTER FREQUENCY, 635.500 MHz, FREQUENCY SPAN, 10 kHz, PEAK SEARCH, MKR→REF LVL, MARKER MODE NORMAL.

22.3 ► Measure and record the 635.500 MHz signal level, if any, on the data sheet.

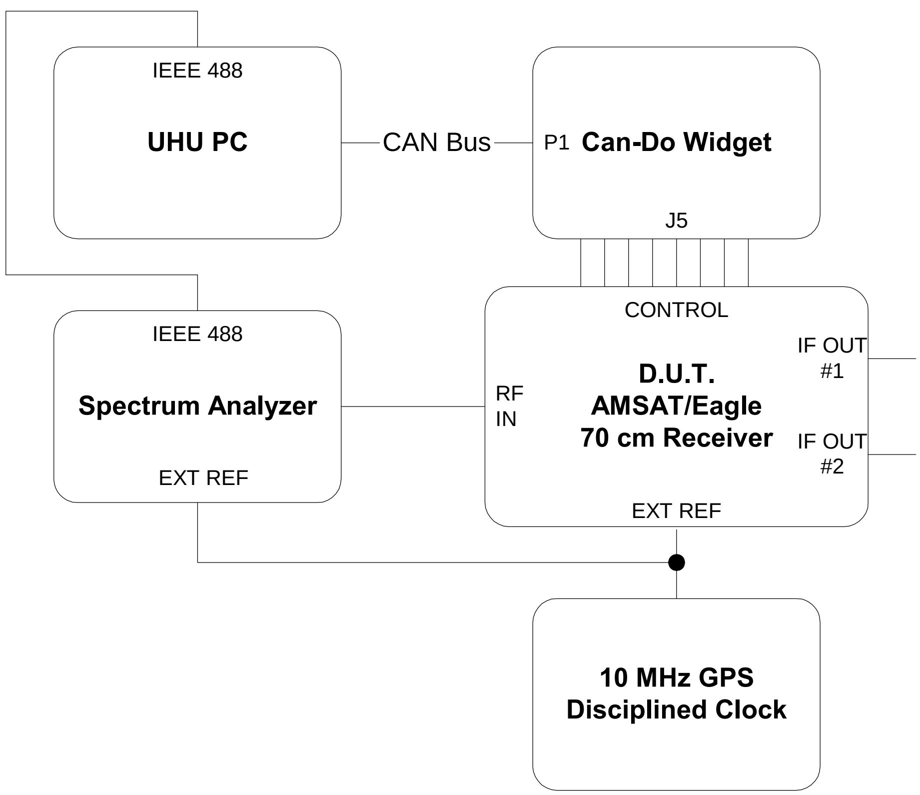

Figure 22-1. First Local Oscillator Leakage Test Configuration

23.0 OUTPUT 3rd ORDER INTERMODULATION and INTERCEPT POINT

These tests will determine output third order intermodulation (OIM_3). They will be conducted at an input level of -10 dB below P_{-1db}, and then again at -44 dBm to simulate PAVE PAWS interference.[1]

Tests will be conducted at tone separations of 1 MHz and 100 kHz using the frequencies in Table 23-1. Output intercept points will be derived from these test results.

	FREQUENCIES			
Tone Spread	$2f_1 - f_2$	f_1	f_2	$2f_2 - f_1$
1 MHz	435.000	436.000	437.000	438.000
100 kHz	435.900	436.000	436.100	436.200

Table 23-1. Test Frequencies

23.1 Set up the equipment as shown in Figure 23-1. Output Third Order Intermodulation Test Configuration, and connect the power combiner output directly to the spectrum analyzer using low-loss test cable W1 as indicated by the dashed “cal” line.

23.2 On the Agilent E3620A power supply, adjust both outputs to 15.00 VDC ± 0.05 VDC and then connect the isolation amplifiers.

23.3 Insure that current consumption is less than 100 mA for each amplifier.

23.4 Set signal generator #1 to 436.000 MHz (f_1) at -40 dBm.

23.5 Set signal generator #2 to 437.000 MHz (f_2) at -40 dBm.

23.6 Set the step attenuator to 0 dB.

23.7 On the spectrum analyzer press [2-22 GHz], [CENTER FREQUENCY], 436.500 [MHz], [FREQUENCY SPAN], 5 [MHz].

[1] There appear to be guard bands between PAVE PAW channels (see Figure 23-1) but PAVE PAWS IM_3 products could easily appear there. Testing at -44 dBm will characterize the impact of PAVE PAWS IM_3 on the receiver.

23.8 ► Calculate the -10 dB back-off point by subtracting 10 dB from the P_{-1db} value determined in step 13.10. On the spectrum analyzer press DISPLAY LINE, ENTER, and enter the calculated level using the data entry keypad. Note the back-off value in the data sheet.

23.9 ► Set both signal generator levels to the display line, then press PEAK SEARCH, MKR→REF LVL, ENTER dB/DIV, 1 +dBm, MARKER MODE OFF.

23.10 Press REFERENCE LEVEL and ⇑ to set the signal level two lines below the top of the display.

23.11 ► Once again, press DISPLAY LINE, ENTER, and enter the calculated level from step 23.8 using the data entry keypad. Fine tune both signal generator signal levels to the display line then press DISPLAY LINE OFF.

23.12 ► Use PEAK SEARCH and MARKER MODE Δ to insure that they are both within ± 0.1 dB of the back-off level calculated in step 23.8. Enter the signal generator and combiner output levels in the data sheet.

23.13 Press MARKER MODE OFF, ENTER dB/DIV, 10 +dBm. The two test tone signals are now calibrated.

23.14 Reconfigure the test setup to match Figure 23-1.

23.15 Tune the receiver to 436.000 MHz (f_1).

23.16 On the spectrum analyzer press 2-22 GHz, CENTER FREQUENCY 10.700 MHz, PEAK SEARCH, FREQUENCY SPAN 10 kHz, and MARKER MODE NORMAL.

23.17 ►Observe the spectrum analyzer while adjusting the step attenuator. Match the IF signal level to the calculated level from step 23.8 ± 0.1 dB[1]. Enter the attenuator setting in the data sheet as the receiver gain.

23.18 Tune the receiver to 435.000 MHz (the $2f_1$-f_2 IM frequency)[2]. Adjust the reference level as necessary to place the signal near the top of the display.

23.19 ►Record the marker value in the data sheet as the IM_3 value in dBm.

23.20 Tune the receiver to 438.000 MHz (the $2f_2$-f_1 IM frequency)

23.21 ►Record the marker value in the data sheet as the IM_3 value in dBm.

---

[1] This insures that the spectrum analyzer "sees" the same levels as before. This will help minimize errors.

[2] See Figure 23-1

23.22 Press ATTEN and increase the attenuation in 10 dB steps to 40 dB by pressing the ⇑ button. This reduces the level reaching the analyzer's mixer. The analyzer will automatically increase the gain to compensate. If the displayed IM_3 level decreases, then IM_3 errors are being introduced by the analyzer itself. If so, the test will need to be run again using lower levels. If the IM_3 signal level remains the same (noise will increase) then no errors are being introduced by the analyzer and the attenuator can be returned to its original state by pressing ATTEN AUTO.

23.23 Calculate OIP_3 using the formula:

$$OIP_3 = \frac{3*(P_A) - P_{IM3}}{2}$$

Where: IP_3 = Third order intercept point in dBm

P_A = Average test tones power in dBm (from step 23.8)

P_{IM3} = Average IM_3 power dBm (from step 23.19 and 23.21)

23.24 ► Enter the data into the data sheet.

23.25 Repeat the test using the 100 kHz frequency spread from Table 23-1.

23.26 Repeat both tests using receiver RF input levels of -44 dBm to characterize the effects of PAVE PAWS intermodulation.

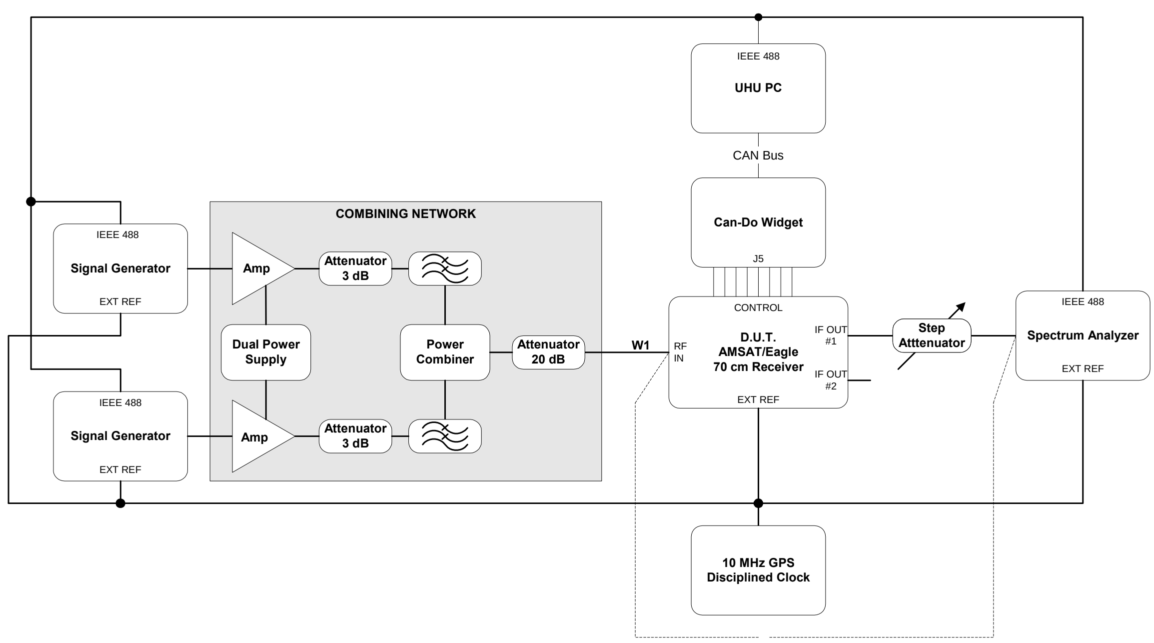

Figure 23-1. Output Third Order Intermodulation Test Configuration

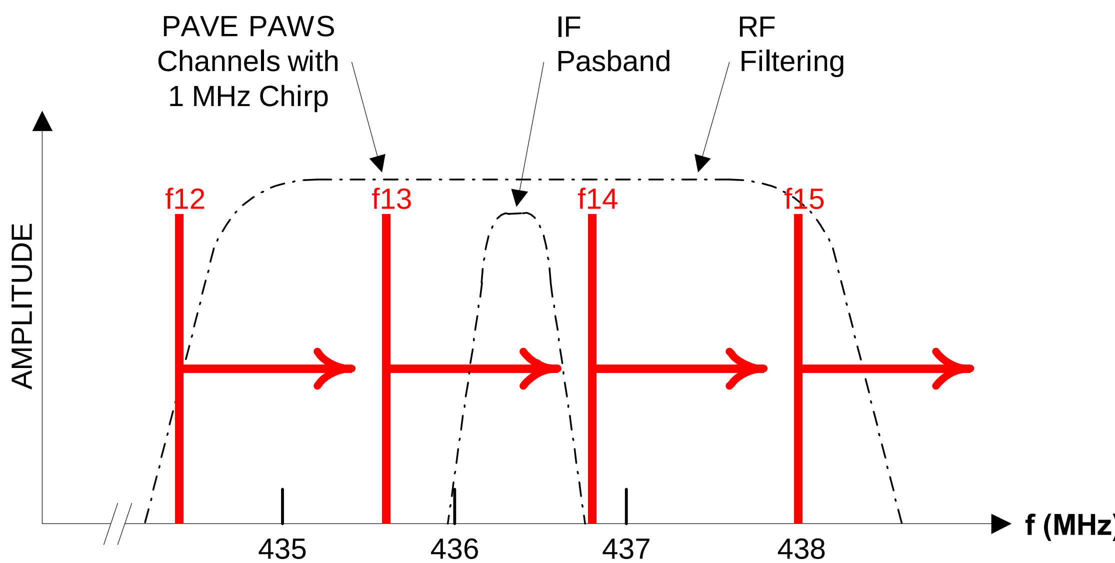

Figure 23-2. Third Order Distortion Products

24.0 INPUT 3rd ORDER INTERMODULATION and INTERCEPT POINT

Input third order intermodulation and intercept points are derived from the previous test.

24.1 ► Subtract receiver gain in step 23.17 from OIP_3 in previous test and enter the values in the data sheet.

25.0 PAVE PAWS BLOCKING DYNAMIC RANGE

PAVE PAWS interference appears to be the greatest EMI threat to successful operation of the 70 cm Telecommand Receiver.

PAVE PAWS operates in the 420 to 450 MHz band using a 24-channel band plan. In-band channels exist at 434.4, 435.6, 436.8, and 438.0 MHz. These four channels are of special concern (see Figure 23-2 and Figure 27-6)

PAVE PAWS radar is a pulsed echo-ranging system that uses frequency chirping in two distinct modes; surveillance and tracking. Their waveforms and frequency plan are detailed in the PAVE PAWS addendum at the end of this document.

The tremendous EIRP of PAVE PAWS will cause it to bury any Amateur Radio signal as it sweeps across. This much is obvious. What this test will attempt to characterize is the signal impairment that will take place as the PAVE PAWS signal nears a weak Amateur Radio signal. In other words, how close must the PAVE PAWS signal be to cause harmful interference? For the purposes of this test, harmful interference will be defined as a -10 dB reduction in S+N/N ratio.

Per the requirements document, the weak Amateur Radio signal will be set to a level of -112.4 dBm; the weakest uplink signal expected. The interfering signal will be fixed at a level of -43.0 dBm; the maximum expected level of PAVE PAWS interference. The interfering signal frequency will then be altered while observing the affect on the signal of interest.

Knowing the characteristics of the PAVE PAWS chirp rates, and characterizing the point at which signal impairment begins and ends as PAVE PAWS sweeps across, we can determine the worst case duration of expected signal dropouts. This data could then be used to insure that the command uplink forward error correction is robust enough to recover data while in the presence of PAVE PAWS EMI.

There are several sources of potential error in this test; there is no reason to assume that the phase noise of the particular signal generator used in this test will resemble PAVE PAWS. This could be a factor. And since PAVE PAWS is a classified system it is also possible that the open source information this test is based on is in error. Only a field trial will truly resolve these issues.

Refer to Figure 23-1 for test configuration. The first step is to accurately set the two signal levels. Use the high-performance HP 8662A to simulate PAVE PAWS (Signal generator 1), and the HP 8656B to simulate the Amateur Radio uplink (Signal generator 2).

25.1 As shown by the dotted line, connect the output of the power combiner to the spectrum analyzer for calibration, using the same cable that will connect it to the R.F. input of the receiver (W1 in the block diagram).

25.2 Set the signal generator 1 frequency to 435.600 MHz at -45 dBm.[1]

25.3 Set the signal generator 2 frequency to 435.800 MHz at -110 dBm.

25.4 On the spectrum analyzer press 2-22 GHz, CENTER FREQUENCY, 435.600 MHz, FREQUENCY SPAN, 200 Hz, PEAK SEARCH, MKR→CF, and MARKER MODE NORMAL. The spectrum analyzer is now set to display the PAVE PAWS signal, and the marker is showing its level.

25.5 Adjust the level of signal generator 1 for a reading of -43.0 dBm ±0.5 dBm on the spectrum analyzer. Press SAVE 1 to store the analyzer state.

25.6 On the spectrum analyzer press CENTER FREQUENCY, 435.800 MHz, REFERENCE LEVEL, 50 -dBm, PEAK SEARCH, MKR→CF, and MARKER MODE NORMAL. The spectrum analyzer is now set to display the Amateur Radio uplink signal, and the marker is showing its level.

25.7 Adjust the level of signal generator 2 for a reading of -112.4 dBm ±0.5 dBm on the spectrum analyzer. Press SAVE 2 to store the analyzer state. The setup portion of the test is now complete.

25.8 Reconnect the output of the power combiner to the R.F. input of the receiver, using the same cable used during calibration.

25.9 Command the receiver to 435.800 MHz.

25.10 To aid in locating the weak uplink signal, increase the level of signal generator 2 by +20 dB temporarily.

25.11 On the spectrum analyzer, press CENTER FREQUENCY 10.700 MHz, FREQUENCY SPAN 10 kHz, PEAK SEARCH, MKR→CF, and MARKER MODE NORMAL. The analyzer should now be centered on the uplink signal.

---

[1] PAVE PAWS Channel 13, Frequency Set A chirp start frequency (the signal chips up 1 MHz in frequency).

25.12 On the spectrum analyzer press SIGNAL TRACK, FREQUENCY SPAN 100 Hz, and once the signal is centered on the display, press SIGNAL TRACK again to turn that function off.

25.13 Reduce the level of signal generator 2 by -20 dB to its original level.

25.14 Press ENTER dB/Div 5 +dBm then press REFERENCE LEVEL and use the ⇓ button to center the signal on the display.

25.15 Press SHIFT, VIDEO BW, and allow video averaging to reach 50. Then press TRACE A VIEW, SHIFT, TRACE B BLANK to display the averaged signal.

25.16 ► Press MARKER MODE NORMAL. Move the cursor down to the noise floor and record the marker value in the data sheet as the noise level in dBm.

25.17 ► Press MARKER MODE Δ and PEAK SEARCH. Record the marker delta value in the data sheet as the signal to noise ratio in dB.

25.18 ► Press MARKER MODE NORMAL. Enter the marker value in the data sheet as the signal level in dBm.

25.19 Press TRACE A⇄B and TRACE B VIEW to store and display the signal in the B Register. Then press TRACE A CLEAR WRITE, MARKER MODE OFF, and SHIFT SWEEP TIME to return to a normal non-averaged sweep.[1]

25.20 On signal generator 1, (the PAVE PAWS simulator) press FREQUENCY, INCR SET 1 MHz, then press the RESOLUTION x10 button twice to select the 1 kHz digit. The frequency can now be changed in 1 kHz steps with the knob and 1 MHz steps with the up and down arrow buttons.

25.21 Increase the frequency of PAVE PAWS (signal generator 1) in 1 kHz steps using the tuning knob. Look for a reduction in signal to noise ratio – either a reduction in the signal level or an increase in the noise floor (use the baseline trace in Register-B for comparison). If signal impairment is suspected, temporarily shift the PAVE PAWS signal down 1 MHz with the down button to confirm.

[1] The baseline signal is now stored in Register-B and displayed as the dimmer of the two traces. This trace will be used for comparison during the test.

25.22 ► Once the uplink signal begins to degrade, back the PAVE PAWS signal off 25 kHz and begin recording data by repeating the previous step. Continue increasing the PAVE PAWS frequency until it has passed completely through the uplink frequency and is no longer having any impact on the uplink signal. During this process use signal averaging to increase accuracy as necessary by repeating steps 25.15 through 25.18. Press SHIFT and SWEEP TIME to end signal averaging and move on to the next frequency step. Enter the data in the data sheets and note any unexpected behavior such as a sloping noise floor or spurious signals. Capture screen images as necessary to document the test using Bandwidth_Screen_capture.exe.

25.23 ► Plot the data using Excel and attach it to the data sheet.

26.0 POWER SUPPLY NOISE TEST

This test will examine the IF output for power supply switching noise over a DC input range of 10.8 to 16.8 VDC.

26.1 Set the receiver and signal generator to 436.500 MHz.

26.2 Set the signal generator output to -70 dBm.

26.3 Connect the spectrum analyzer to I.F. output #1 and configure it by pressing 2-22 GHz, CENTER FREQUENCY 10.7 MHz, FREQUENCY SPAN 200 kHz, PEAK SEARCH, MKR→CF, MKR→REF LVL, ENTER dB/DIV 1 +dBm, RES BW 1 kHz, and MARKER MODE NORMAL.

26.4 While observing the spectrum analyzer for any extraneous noise, slowly adjust the DC input from 10.6 to 16.8 VDC. Note any noise observed in the data sheet.

26.5 Return the power supply voltage to 13.0 VDC.

ACCEPTANCE TEST DATA

Equipment Description	Mfr	Model	S/N	Cal Date Due
Noise Figure Meter	HP	8970A		
Noise Diode	HP	346B		
GPS 10 MHz reference	HP	Z3801A		
Spectrum analyzer	HP	8566B		
Signal generator	HP	8662A		
Signal generator	HP	8656B		
Network Analyzer	HP	8753D		
Frequency Counter	HP	5342A		
Digital Multimeter	Agilent	34401A		
30 dB Step Attenuator	JFW Ind.	50DR-055		

Table 26-1. Test Equipment Used

7.0 RECEIVER POWER SUPPLY

Reference Number	Requirement	Results		Findings	
		Required Value	Measured Value	Met	Not Met
12.00 VOLT INPUT					
7.5	Maximum receiver DC input current at 12 VDC.	≤ 0.25 A			
7.6	+3.00 VDC	± .05 V			
7.7	+5.00 VDC	± .05 V			
7.8	+5.60 VDC	± .05 V			
7.9	+10.00 VDC	± .05 V			
14.00 VOLT INPUT					
7.11	Maximum receiver DC input current at 14 VDC.	≤ 0.25 A			
7.6	+3.00 VDC	± .05 V			
7.7	+5.00 VDC	± .05 V			
7.8	+5.60 VDC	± .05 V			
7.9	+10.00 VDC	± .05 V			

8.0 CAN-DO NETWORK INSTALLATION AND TEST

Reference Number	Requirement	Results		Findings	
		Required Value	Measured Value	Met	Not Met
8.20	Maximum total DC input current at 13 VDC.	≤ 0.40 A			

10.0 10 MHz EXTERNAL REFERENCE

Reference Number	Requirement	Results		Findings	
		Required Value	Measured Value	Met	Not Met
10.5	(Establish baseline)	10.700 MHz			
10.6	Internal master oscillator must remain locked to external reference at +2 dBm input level.	Baseline ± 5 Hz			
Error! Reference source not found.	Internal master oscillator must remain locked to external reference at -2 dBm input level.	< -2 dBm			
10.9	Free-running master oscillator frequency.	Baseline ± 200 Hz			

11.0 TUNING RANGE, I.F. CENTER FREQUENCY, AND SYMMETRY

Reference Number	Requirement	Results		Findings	
		Required Value	Measured Value	Met	Not Met
11.4	IF 1 Frequency at 435 MHz	10.700 MHz ± 2 kHz			
11.4	IF 1 Level at 435 MHz	> -50 dBm			
11.6	Level difference between IF 1 and IF 2	< 0.5 dB			
11.9	IF 1 Frequency at 438 MHz	10.700 MHz ± 2 kHz			
11.9	IF 1 Level at 438 MHz	> -50 dBm			

12.0 TUNING RESOLUTION AND SPECTRUM INVERSION

Reference Number	Requirement	Results		Findings	
		Required Values	Measured Values	Met	Not Met
12.5	Tune 435.000	10.7 MHz ± 20 Hz			
12.5	Tune 435.100	10.7 MHz ± 20 Hz			
12.5	Tune 435.200	10.7 MHz ± 20 Hz			
12.5	Tune 435.300	10.7 MHz ± 20 Hz			
12.5	Tune 435.400	10.7 MHz ± 20 Hz			
12.5	Tune 435.500	10.7 MHz ± 20 Hz			
12.5	Tune 435.600	10.7 MHz ± 20 Hz			
12.5	Tune 435.700	10.7 MHz ± 20 Hz			
12.5	Tune 435.800	10.7 MHz ± 20 Hz			
12.5	Tune 435.900	10.7 MHz ± 20 Hz			
12.5	Tune 436.000	10.7 MHz ± 20 Hz			
12.5	Tune 436.100	10.7 MHz ± 20 Hz			
12.5	Tune 436.200	10.7 MHz ± 20 Hz			
12.5	Tune 436.300	10.7 MHz ± 20 Hz			
12.5	Tune 436.400	10.7 MHz ± 20 Hz			
12.5	Tune 436.500	10.7 MHz ± 20 Hz			
12.5	Tune 436.600	10.7 MHz ± 20 Hz			
12.5	Tune 436.700	10.7 MHz ± 20 Hz			
12.5	Tune 436.800	10.7 MHz ± 20 Hz			
12.5	Tune 436.900	10.7 MHz ± 20 Hz			
12.5	Tune 437.000	10.7 MHz ± 20 Hz			
12.5	Tune 437.100	10.7 MHz ± 20 Hz			
12.5	Tune 437.200	10.7 MHz ± 20 Hz			
12.5	Tune 437.300	10.7 MHz ± 20 Hz			
12.5	Tune 437.400	10.7 MHz ± 20 Hz			
12.5	Tune 437.500	10.7 MHz ± 20 Hz			
12.5	Tune 437.600	10.7 MHz ± 20 Hz			
12.5	Tune 437.700	10.7 MHz ± 20 Hz			
12.5	Tune 437.800	10.7 MHz ± 20 Hz			
12.5	Tune 437.900	10.7 MHz ± 20 Hz			
12.5	Tune 438.000	10.7 MHz ± 20 Hz			
12.8	Frequency Inversion	I.F. Not Inverted			

13.0 1 dB COMPRESSION POINT P_{-1db}

Reference Number	Requirement	Results		Findings	
		Required Value	Measured Value	Met	Not Met
13.10	1 dB RF Input Level	TBD			
13.10	Compression level	1.0 dB ±0.2 dB			

14.0 I.F. BANDWIDTH

Reference Number	Requirement	Results		Findings	
		Required Value	Measured Value	Met	Not Met
14.11	(Establish baseline)	200 kHz ± 20 kHz			

15.0 IMAGE REJECTION

Reference Number	Requirement	Results		Findings	
		Required Value	Measured Value	Met	Not Met
15.5	(No Image Detected)	N/A			
15.7	IF Level (dBm)	TBD			
15.10	RF Equivalent Level (dBm)	TBD			
15.11	Image rejection (dBc)	TBD			

16.0 FIRST I.F. REJECTION

Reference Number	Requirement	Results		Findings	
		Required Value	Measured Value	Met	Not Met
15.5	(No Image Detected)	N/A			
15.7	IF Level (dBm)	TBD			
15.10	RF Equivalent Level (dBm)	TBD			
15.11	Image rejection (dBc)	TBD			

17.0 INTERNALLY GENERATED SPURS

Reference Number	Receiver Frequency (MHz)	Generator Frequency (MHz)	Spurious Frequency (MHz)	Spurious Level (dBc)
17.11				
17.11				
17.11				
17.11				
17.11				
17.11				
17.11				
17.11				
17.11				

18.0 PHASE NOISE

Offset (Hz)	P_{-1db}	IF Signal Level	1 Hz Noise Level (dBm)	Phase Noise (dBc / Hz)
Reference Number	18.2	18.4	18.8	18.9
5 kHz				
100 kHz				
1 MHz				

19.0 NOISE FIGURE AND RF-TO-IF GAIN

		Results		NF < 7 dB	
Reference Number	Frequency	Noise Figure	Gain	Met	Not Met
20.15	435.000				
20.15	435.100				
20.15	435.200				
20.15	435.300				
20.15	435.400				
20.15	435.500				
20.15	435.600				
20.15	435.700				
20.15	435.800				
20.15	435.900				
20.15	436.000				
20.15	436.100				
20.15	436.200				
20.15	436.300				
20.15	436.400				
20.15	436.500				
20.15	436.600				
20.15	436.700				
20.15	436.800				
20.15	436.900				
20.15	437.000				
20.15	437.100				
20.15	437.200				
20.15	437.300				
20.15	437.400				
20.15	437.500				
20.15	437.600				
20.15	437.700				
20.15	437.800				
20.15	437.900				
20.15	438.000				

20.0 RF INPUT VSWR

Reference Number	Requirement	Results		Findings	
		Required Value	Measured Value	Met	Not Met
20.3	Measured highest VSWR				

21.0 IF OUTPUT VSWR

Reference Number	Requirement	Results		Findings	
		Required Value	Measured Value	Met	Not Met
21.3	Measured maximum return loss				

22.0 FIRST LOCAL OSCILLATOR LEAKAGE

Reference Number	Requirement	Results		Findings	
		Required Value	Measured Value	Met	Not Met
22.3	635.500 MHz leakage level				

23.0 OUTPUT 3rd ORDER IM and IP at P_{-1db} – 10 dB BACK-OFF

Calculate IP_3 using the formula:

$$OIP_3 = \frac{3*(P_A) - P_{IM3}}{2}$$

Where: OIP_3 = Third order intercept point in dBm

P_A = Average test tones power in dBm (from step 23.8)

P_{IM3} = Average IM_3 power dBm (from step 23.19 and 23.21)

Reference Number	23.8	23.19	23.21		
	P_A (dBm)	$2f_1-f_2$ (dBm)	$2f_2-F_1$ (dBm)	Average P_{IM3} (dBm)	OIP_3 (dBm)
1 MHz					
100 kHz					

23.0 OUTPUT 3rd ORDER IM and IP at -44 dBm (PAVE PAWS EMI LEVEL)

Calculate IP_3 using the formula:

$$OIP_3 = \frac{3*(P_A) - P_{IM3}}{2}$$

Where: OIP_3 = Third order intercept point in dBm

P_A = Average test tones power in dBm (from step 23.8)

P_{IM3} = Average IM_3 power dBm (from step 23.19 and 23.21)

Reference Number	23.8	23.19	23.21		
	P_A (dBm)	$2f_1$-f_2 (dBm)	$2f_2$-F_1 (dBm)	Average P_{IM3} (dBm)	OIP_3 (dBm)
1 MHz					
100 kHz					

24.0 INPUT 3rd ORDER INTERCEPT POINT

	Frequency Spread	Results		Findings	
		Required Value	Measured Value	Met	Not Met
Subtract receiver gain in step 23.17 from OIP_3 in previous test.	1 MHz	TBD			
	100 kHz	TBD			

25.0 PAVE PAWS INTERFERENCE

Ref. Number	PAVE PAWS Frequency (MHz)	Uplink Level (dBm)	Noise Level (dBm)	S/N Ratio (dB)	Uplink Signal Degradation (db)
25.16 - .18					
25.16 - .18					
25.16 - .18					
25.16 - .18					
25.16 - .18					
25.16 - .18					
25.16 - .18					
25.16 - .18					
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25.16 - .18					
25.16 - .18					
25.16 - .18					

20.0 POWER SUPPLY NOISE TEST

Reference Number	Requirement		Results		Findings	
	DC Input Voltage varied from 10.8 to 16.8 VDC	No noise correlated with the power supply appears above the noise floor	IF Frequency	Measured EMI Level	Met	Not Met
20.3	10.8					
20.3	11.0					
20.3	11.2					
20.3	11.4					
20.3	11.6					
20.3	11.8					
20.3	12.0					
20.3	12.2					
20.3	12.4					
20.3	12.6					
20.3	12.8					
20.3	13.0					
20.3	13.2					
20.3	13.4					
20.3	13.6					
20.3	13.8					
20.3	14.0					
20.3	14.2					
20.3	14.4					
20.3	14.6					
20.3	14.8					
20.3	15.0					
20.3	15.2					
20.3	15.4					
20.3	15.6					
20.3	15.8					
20.3	16.0					
20.3	16.2					
20.3	16.4					
20.3	16.6					
20.3	16.8					

27.0 AN/FPS-123 PAVE PAWS ADDENDUM

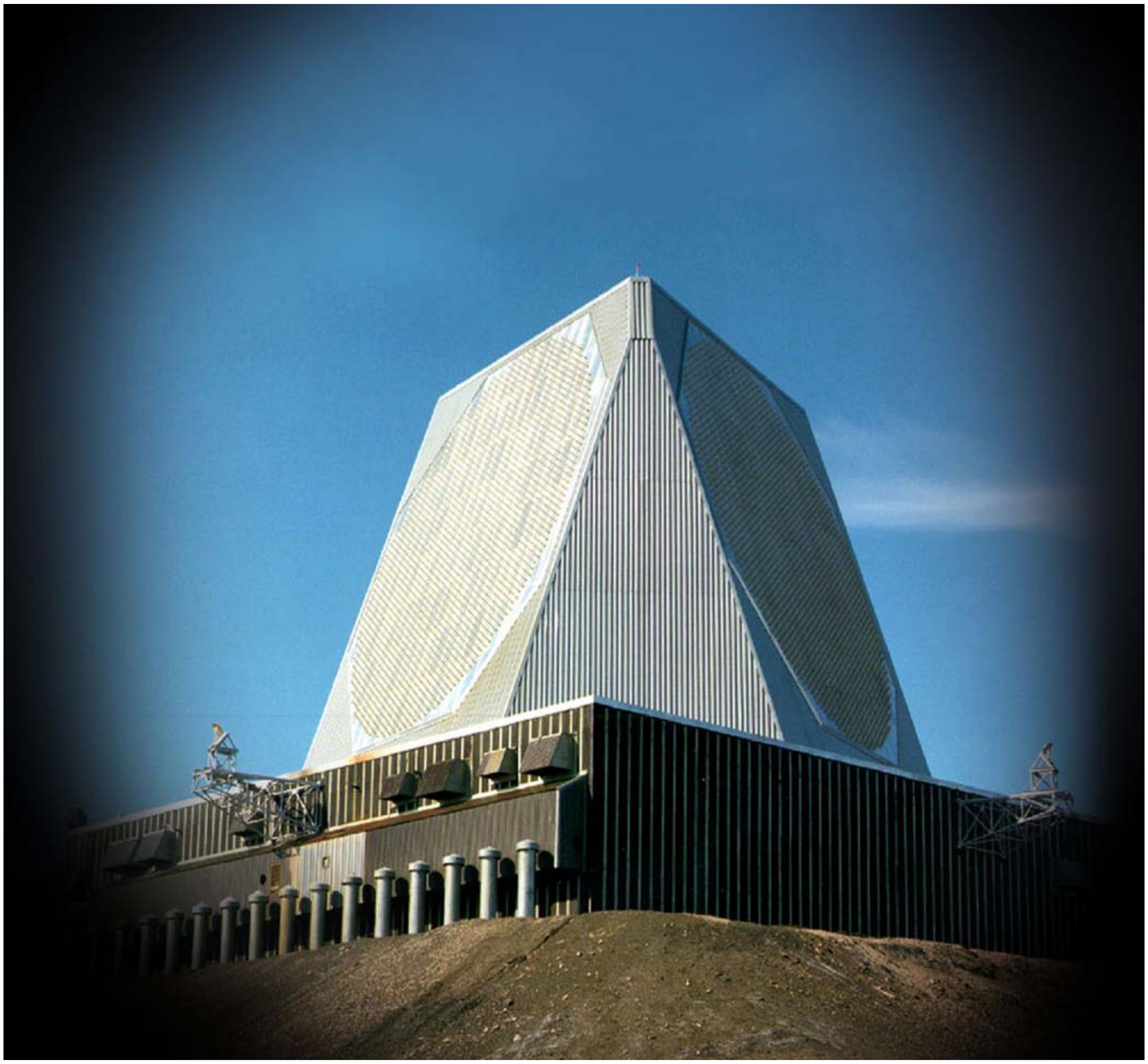

Figure 27-1. AN/FPS-123 PAVE PAWS Radar Antenna[1]

- PAVE PAWS Radar and Power Plant
- Building is 105 feet high with two antenna faces
- Faces are 120° apart and transmit in parallel

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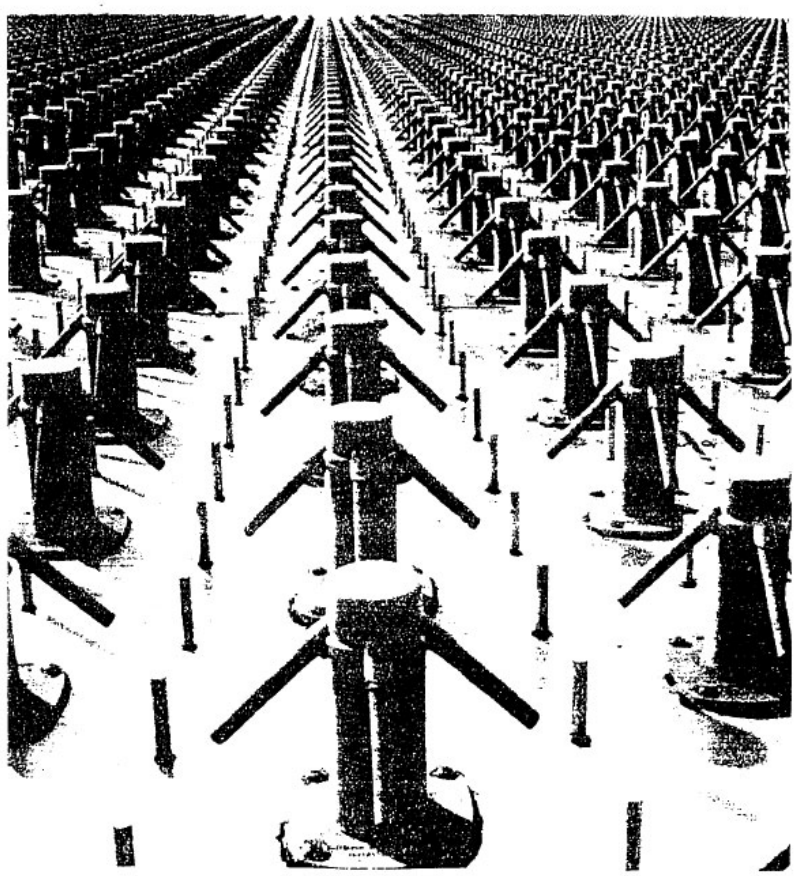
[1] http://www.raytheonmissiledefense.com/matrix/pdfs/dis/uewr.pdf

One Face of the PAVE PAWS Radar

- **An array of 5,354 elements**
- **Of these 2,677 are inactive (reserved for a future power upgrade)**
- **1,792 elements are powered at ~322 watts each (1,792 x ~322 watts = 580,000 watts)**



Reference:
"Radiation Intensity of the Pave Paws Radar System"
National Academy of Sciences, 1979, Fig. 2, pages 7 & 8

Figure 27-2. One Face of PAVE PAWS Radar[2]

[2] http://pavepaws.com/Pavepawsradardescription1.pdf

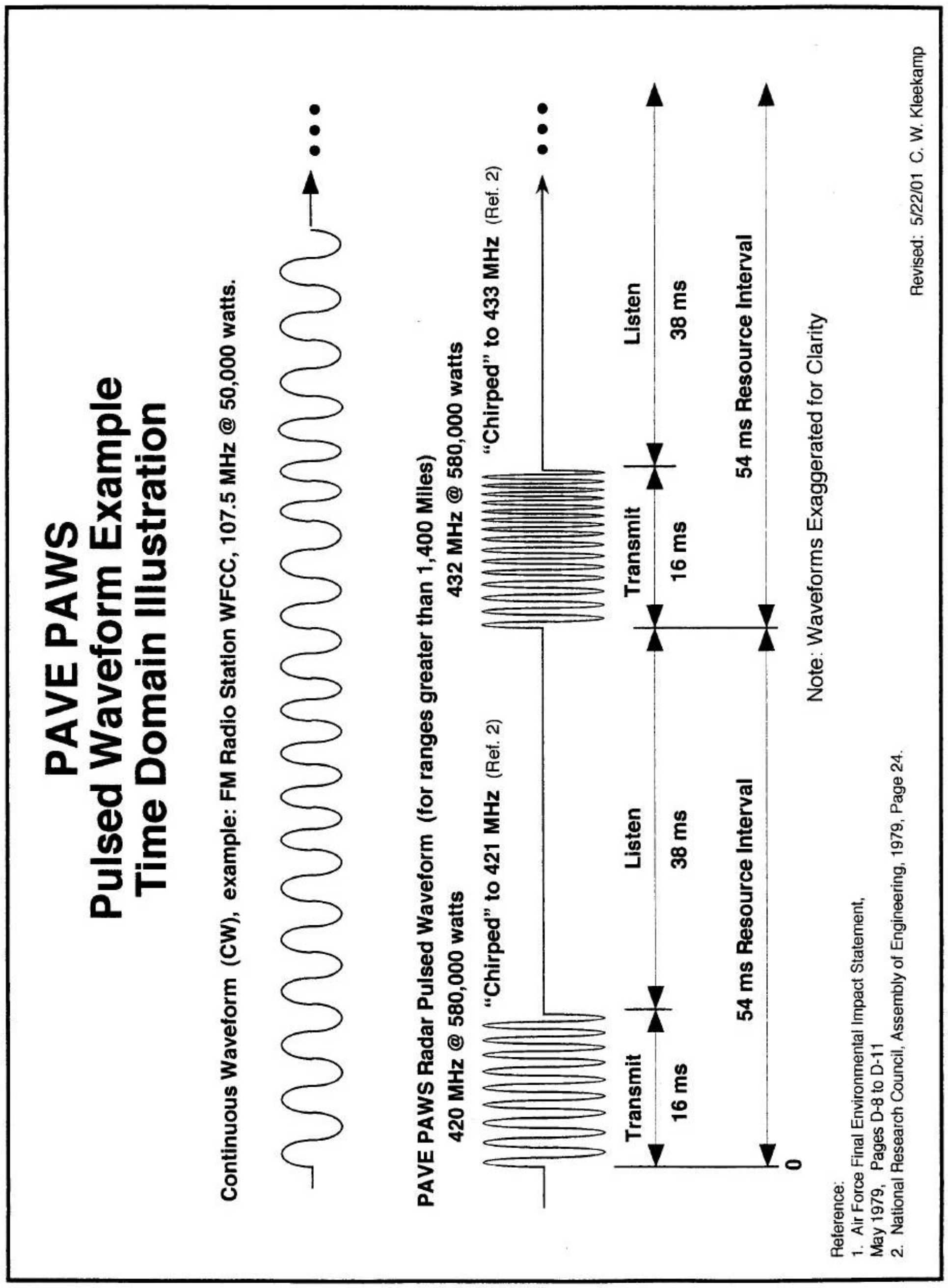


Figure 27-3. Pulsed Waveform Time Domain Representation[3]

[3] http://pavepaws.com/Pavepawsradardescription1.pdf

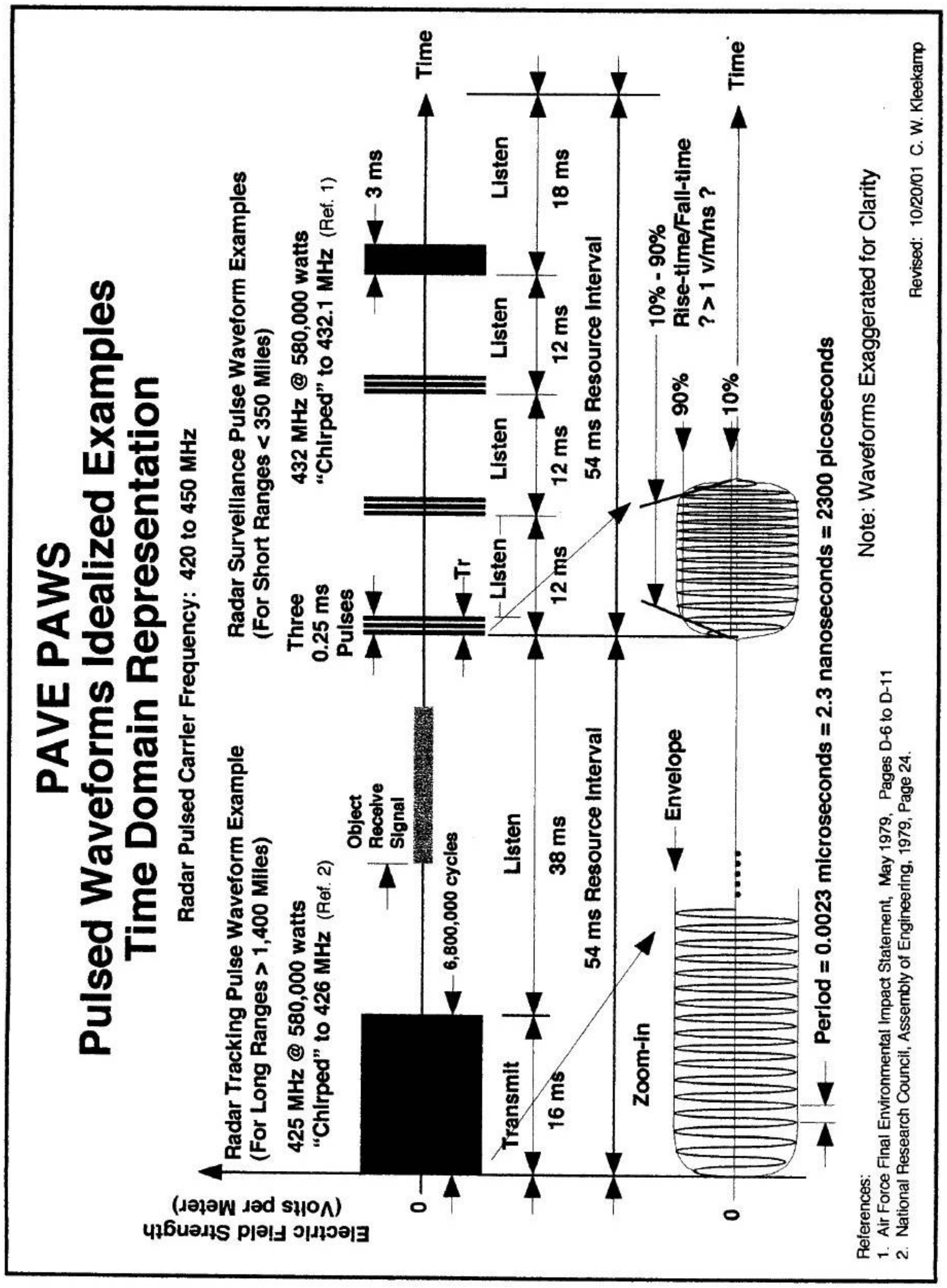


Figure 27-4. Pulsed Waveform Time Domain Representation (Cont.)[4]

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[4] http://pavepaws.com/Pavepawsradardescription1.pdf

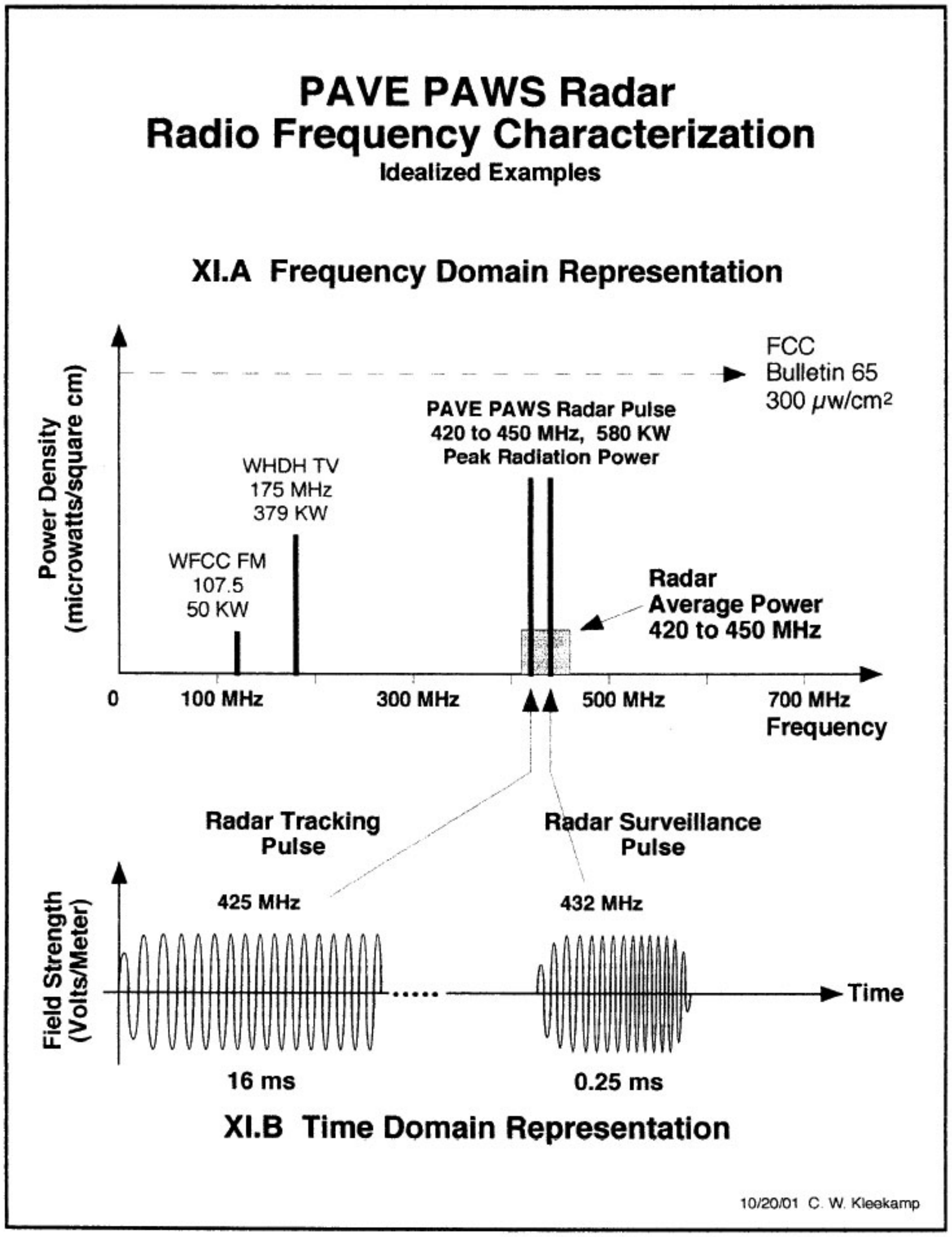

Figure 27-5. PAVE PAWS Frequency Characterization[5]

[5] http://pavepaws.com/Pavepawsradardescription1.pdf

Table D-2

PAVE PAWS FREQUENCIES

Channel Number	Center Frequency (MHz)	Frequency Set
1	421.3	A
2	422.5	B
3	423.7	C
4	424.9	A
5	426.1	B
6	427.3	C
7	428.5	A
8	429.6	B
9	430.8	C
10	432.0	A
11	433.2	B
12	434.4	C
13	435.6	A
14	436.8	B
15	438.0	C
16	439.2	A
17	440.4	B
18	441.5	C
19	442.7	A
20	443.9	B
21	445.1	C
22	446.3	A
23	447.5	B
24	448.7	C

Figure 27-6. PAVE PAWS Channel Assignments[6]

[6] http://pavepaws.com/Pavepawsradardescription2.pdf

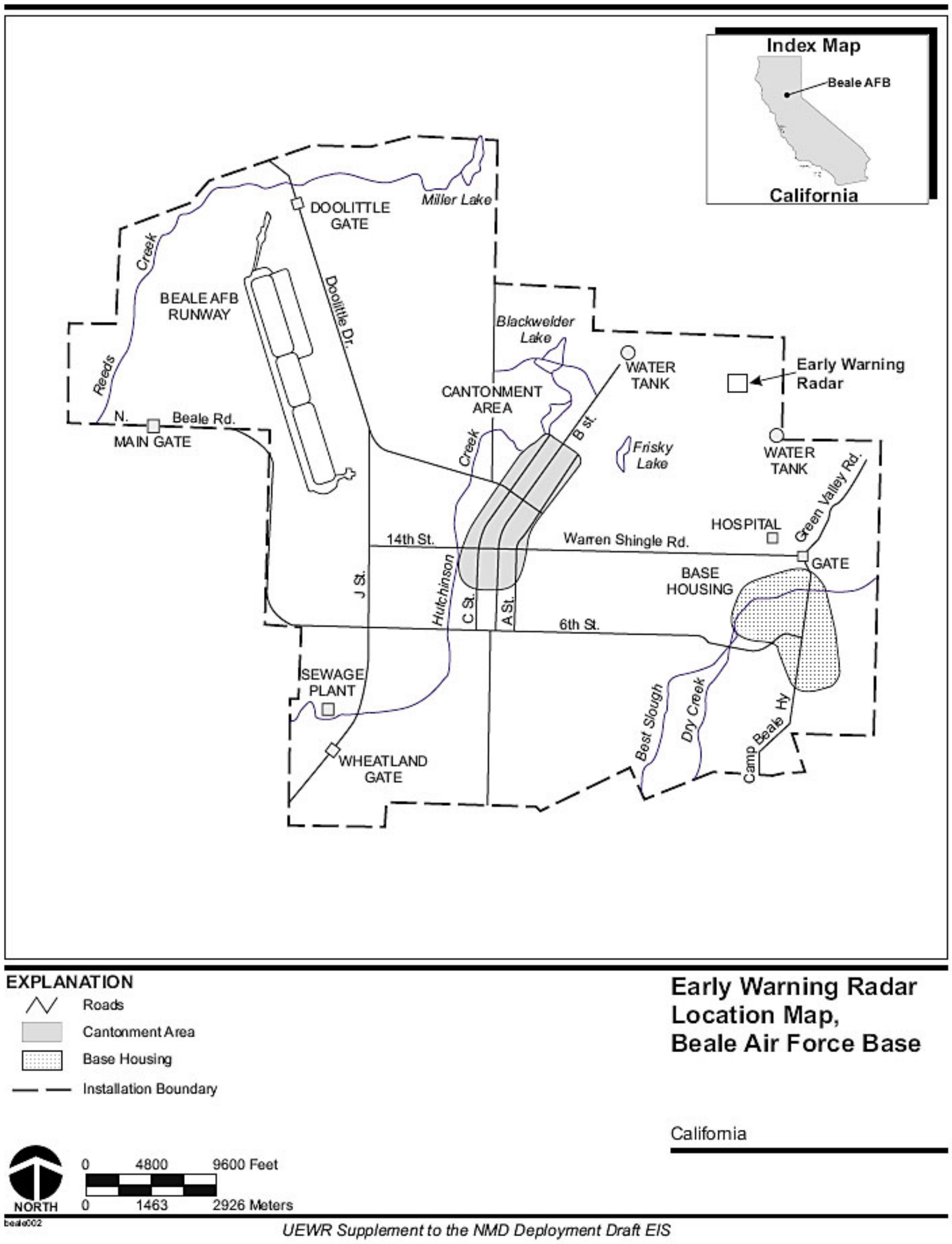

Figure 27-7. Beale Air Force Base Site Location Map[7]

[7] Upgraded Early Warning Radar Supplement to the National Missile Defense (NMD) Deployment Draft Environmental Impact Statement – January 2000 – U.S. Army Space and Missiles Defense Command – Huntsville, Alabama

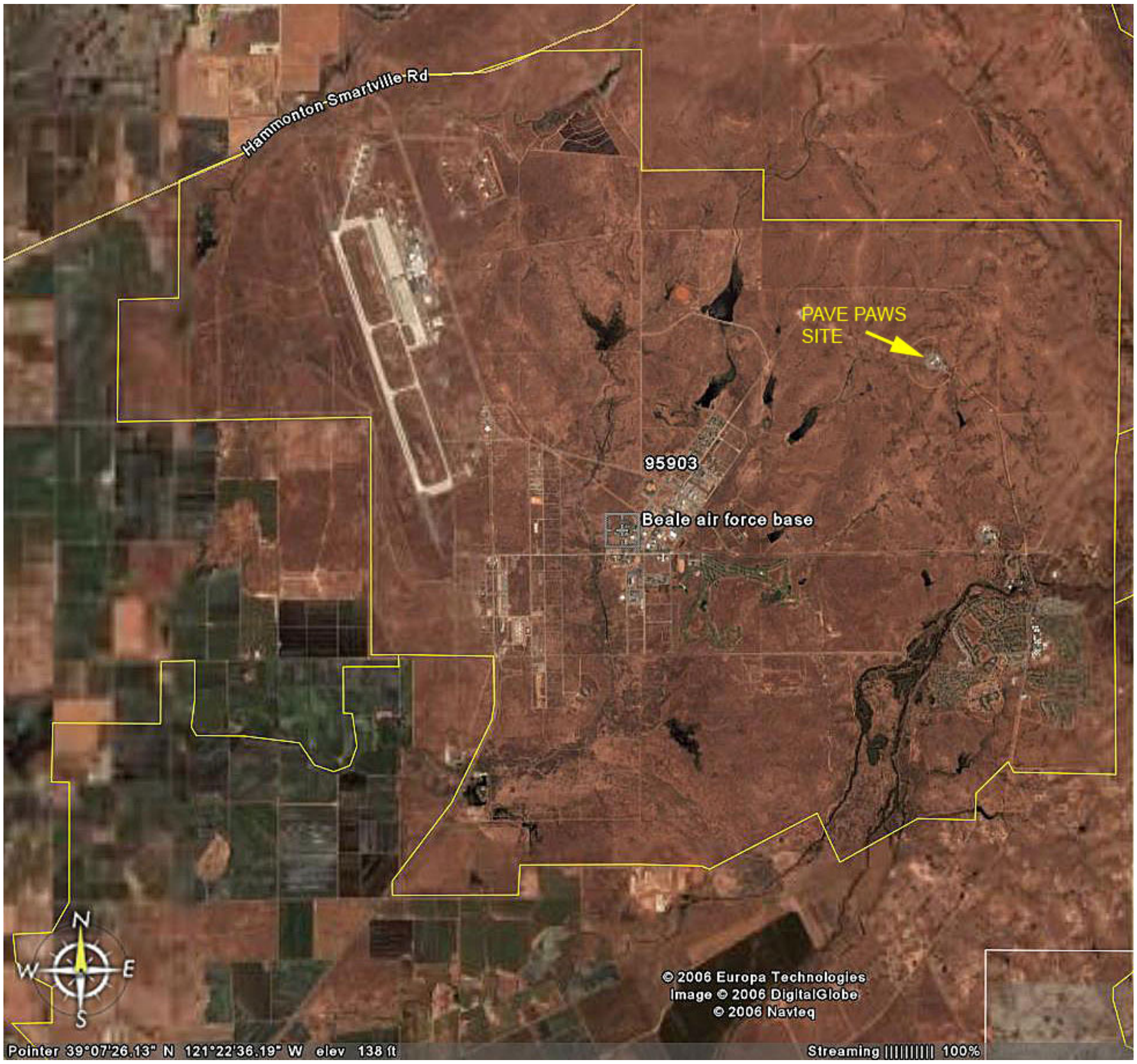

Figure 27-8. Beale Air Force Base Overhead Imagery[8]

[8] Google Earth

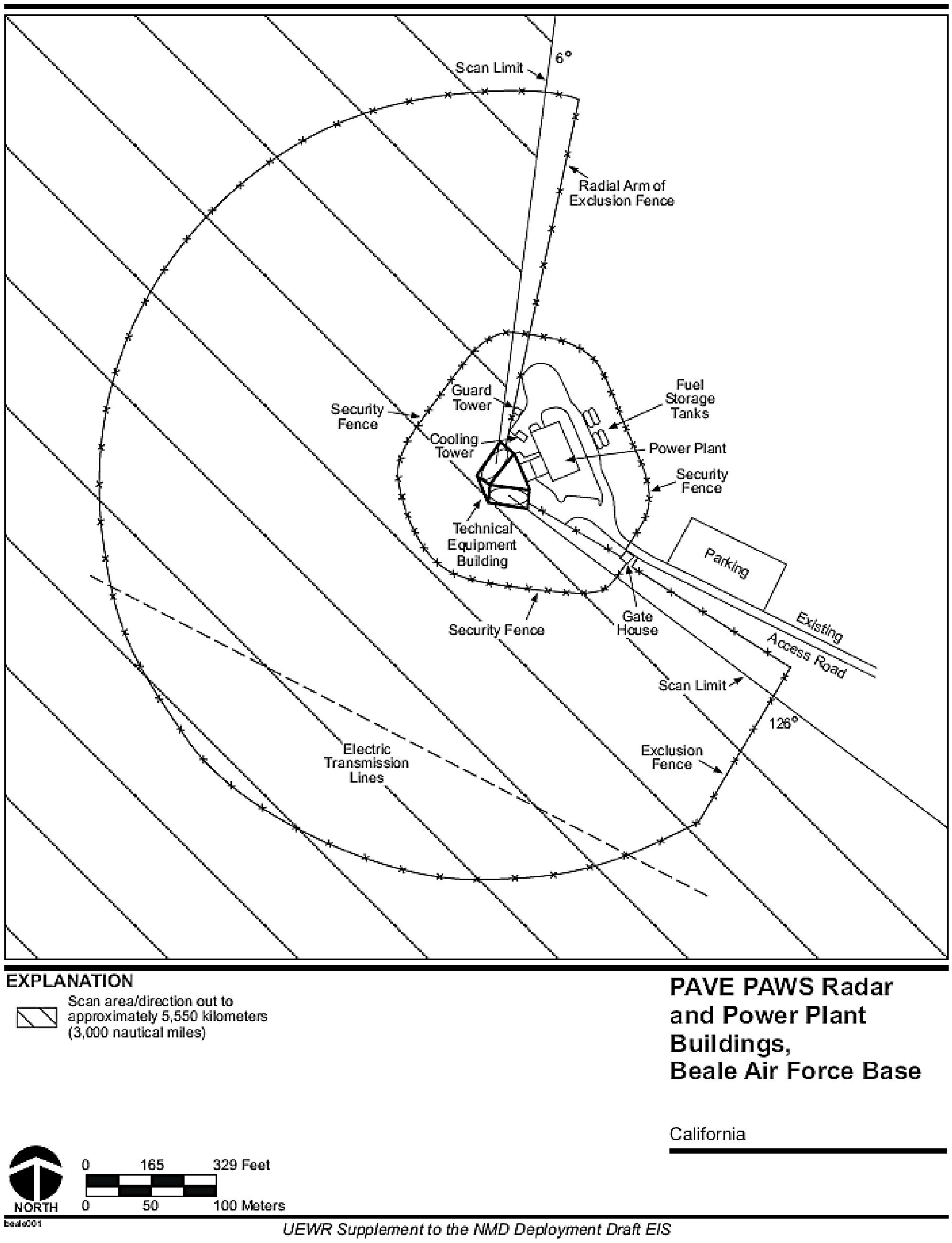

Figure 27-9. Beale AFB PAVE PAWS Site Plan[9]

[9] Upgraded Early Warning Radar Supplement to the National Missile Defense (NMD) Deployment Draft Environmental Impact Statement – January 2000 – U.S. Army Space and Missiles Defense Command – Huntsville, Alabama

Figure 27-10. Beale AFB PAVE PAWS Radar Site Overhead Imagery[10]

[10] Google Earth