VLA/VLBA INTERFERENCE MEMO #16

National Radio Astronomy Observatory Student Cooperative Education Program

Environmental Monitoring Station: Ailtech-Stoddart Receiver Calibration & Integration of NM-67 and CCI-7
AND
Satellite Tracking Station: Implementation

Ryan John Schmidt
New Mexico Institute of Mining and Technology Undergraduate
Socorro, New Mexico
November 27, 2000

National Radio Astronomy Observatory (NRAO)
Very Large Array (VLA) / Very Long Baseline Array (VLBA) Electronics Division
Interference Protection Group (IPG)

New Mexico Institute of Mining and Technology (NMIMT)
Department of Electrical Engineering

Environmental Monitoring Station: Ailtech-Stoddart Receiver Calibration & Integration of NM-67 and CCI-7
AND
Satellite Tracking Station: Implementation

Ryan John Schmidt
Co-op Period: January 17, 2000 through September 26, 2000

Mr. Raul Armendariz, EE

NRAO Project Supervisor

Mr. Daniel Mertely, EE

NRAO Project Committee

Dr. Stephen Bruder, EE

NMIMT Project Advisor

Acknowledgements

I would like to thank everyone that helped me with my work during the co-op period. I would like to thank the VLA machine shop, especially Pat Madigan and Don Ellis, for producing the necessary parts to get the projects done. I am greatful to Everett Calan for his specialties and help. The antenna mechanics were very patient and understanding when I bothered them, and I thank them for it. I would like to thank the Data Acquisition Group and the Front End Division for their supply of parts as they were needed. Special thanks goes to Dr. Bill Brundage for his untiring efforts to help me understand antennas and antenna theory, and I would like to thank Dr. Robert Bond for aiding me in this task as well. I am grateful to Raul Armendariz for his understanding and supervision of the tasks. I am thankful for Clint Janes' support and interest in the projects. Additional thanks goes to Dan Mertely, Raul Armendariz, Clint Janes, and the National Science Foundation for this opportunity to participate in the cooperative education program.

Ryan John Schmidt

Socorro, New Mexico

November 27, 2000

Summary

This document covers the work done during my co-op employment with NRAO. It discusses the theory that I learned while I worked on the radio frequency (RF) systems. This document includes all major discoveries made and where possible it discloses the motives for the work done. The sections discuss the Environmental Monitoring System and the Satellite Tracking System. Each system is introduced and then the specifics of my work are discussed.

Table of Contents

List of Figures

List of Tables

1 Introduction

This section will discuss the purpose, scope, and the background RF theory needed to work on the systems.

1.1 Purpose

The purpose of this document is to report on my cooperative education employment at the VLA facilities of the NRAO so that the parties involved with my coop experience may be informed and have a document that can be referenced to.

1.2 Scope

This document provides a detailed description of the work done during my co-op experience. Included within this report are an account of the specific tasks performed, documentation on all modifications made, and an overview of any pertinent theory that was used and unfamiliar to me.

1.3 Antenna and Radio Frequency Theory

Many new ideas were encountered while working for NRAO. Radio frequency interference (RFI) brought with it many new theorems and ideas that my studies at NMIMT had not introduced to me, or the material had been briefly covered.

1.3.1 Astronomy Frequency Band

The frequency spectrum, for convenience purposes, is broken up into several bands. The astronomy community uses letters to denote the bands of interest. Table 1 shows the band designations that the NRAO uses.

TABLE 1: Frequency Labeling Convention within Astronomical Community

Band	Center Frequency [GHz]	Frequency Range [GHz]
L	1.5	1.0 – 2.0
S	3.0	2.0 – 4.0
C	6.0	4.0 – 8.0
X	10.0	8.0 – 12.0
U	15	12.0 – 18.0
K	22	18.0 – 26.5
K_a	33	26.5 – 40.0
Q	45	40.0 – 50.0

1.3.2 Power / dB Scale

Power measurements in radio frequency (RF) systems traverse a large linear scale. The ratio between signals, other signals, and the background noise can be on the order of 1000. A logarithmic scale for power is used to emphasize the difference between these signals and the noise. The dB scale is the most common and is calculated by:

$$Power_{dB} = 10 * \log(\frac{P_1}{P_2})$$

In this equation, P_2 is the reference power level. If P_2 is 1 Watt then the calculated value is labeled a dBW. If P_2 is a milliWatt then the result of the calculation is a dBm. For instance if P_1 = 1000 W and P_2 = 1 W then

$$x = 10 * \log(\frac{1000\_W}{1\,W})$$

$$x = 30\_W$$

If P_2 were changed to 1 mW (10^{-3} W) then

$$x = 10 * \log(\frac{1000\_W}{10^{-3}\_W})$$

$$x = 60\_dBm$$

The denominator, P_2, is typically a normalized value. Therefore the units of power in the equation are typically in milliWatts. P_2 is 1 mW and P_1 is in milliWatts for unit conservation. For the previous example

$$x = 10 * \log(\frac{10^6\_mW}{1\ \_mW})$$

$$x = 60\_dBm$$

1.3.3 Noisefloor Effects on Detected Signals in a Receiver

The power that the receiver detects and reports is composed of both the signal and the noise contribution. The power measurements described in 1.3.2 deal only with the total power (P_1) in reference to an absolute reference power (P_2). The total power is actually a combination of signals from multiple sources. The equipment being used will generate noise and contribute to the power being detected. The contribution of the noise is negligible if the signal power is ten dB higher than the noisefloor. For example if the signal power is 100 W and the noisefloor of the system is 10 W then:

$$Power_S = 10 * \log(\frac{10^5\_mW}{1\_mW})$$

$$Power_S = 50\_dBm$$

And the total power is:

$$Power_T = 10 * \log(\frac{10^5\_mW + 10^4\_mW}{1\_mW})$$

$$Power_T = 50.41\_dBm$$

As one can see the contribution to the measured power is quite small (it doesn't even double the power measured – 3 dB). The situation is different if the signal being injected is equal to the system noisefloor. If the signal power

$$Power_S = 10 * \log(\frac{10^4\_mW}{1\_mW})$$

and the noisefloor power were both 10 W then:

$$Power_S = 40\_dBm$$

And the total power is:

$$Power_T = 10 * \log(\frac{10\_mW + 10\_mW}{1\_mW})$$

$$Power_T = 43.00\_dBm$$

Since the power is doubled (10 W signal + 10 W noisefloor) there is a 3 dB increase is measured power.

1.3.4 Receiver Headroom Before First Filter

As part of the Expanded VLA (EVLA) design there are three areas of interest when studying the harmful effects of RFI on the telescope. RF can interfere with the astronomical data within the digital system, the correlator A/D, and the front end (FE) amplifiers. The front end is particularly sensitive before the first filters. All components before the filters must be designed to operate with enough dynamic range so that they do not saturate, create intermodulations, or fail. This headroom can be calculated, and is typically done with respect to the 1% compression point of the amplifier being designed. The headroom is the ratio of the power at reference linearity level (1% compression point) to the total system noise power (P_{TSN}).

$$P_{TSN} = K * T_{SYS} * B$$

Where K is Boltman's Constant (1.38 x 10^{-23}Joules/Kelvin), T_{SYS} is the noise temperature of the system in Kelvin, and B is the bandwidth in Hertz. One should design the system so that the power of the system multiplied by the headroom is less than the 1% compression point.

$$P_{1\%} \geq P_{RFI} = K * T_{SYS} * B * HR$$

1.3.5 Parabolic Antenna Characteristics

Parabolic antennas are a very directional and powerful system. Directionality creates an antenna that has more gain compared to an isotropic antenna. The gain of a paraboloid is composed of two parts, the directivity and the aperture efficiency. The directivity deals with the dimensions of the paraboloid and how different frequencies are magnified at the focal point of the antenna, whereas the aperture efficiency takes into account the feed position and sensitivity to RF at different angles. The maximum theoretical directivity (which the term "gain" is typically referenced to) can be calculated by

$$D_o = \left(\frac{\pi d}{\lambda}\right)^2$$

For the specific case of the NRAO STS antenna that is designed to track birds such as Iridium, the diameter (d) is 3.086 m and $\lambda = c/f$ (f = 1.625 GHz), λ = 0.1846 m. The theoretical gain is $D_o = 2757.8$. In terms of dB, $D_o = 34.4$ for the ideal situation where the effective aperture is unity. Everyday antennas have antenna efficiency values between 0.7 and 0.55. This means that the actual directivity of the specified paraboloid antenna is between 32.9 and 31.8 dB at 1.625 GHz (remember that the efficiency factors operate on the value in Watts not in dBm).

Directionality of a paraboloid will also limit the angular sensitivity of the antenna. Paraboloid antenna operates by reflecting the incident waves, that are parallel to the axis of the paraboloid, and converging them on the focal point. Any incident waves that are off axis will not be reflected properly. If one were to analyze the declining gain of the antenna as a function of angle within a plane containing the maximum at a reference angle of 0^o, then the half-power beamwidth is the angle between the points on each side of 0^o where half the power is received (3 dB loss of signal strength). The half-power beamwidth for a circular aperture, paraboloid antenna is

$$HPBW = \frac{58^0 * \lambda}{D}$$

The STS dish has a diameter, D, of 3.086 m. Tracking an Iridium bird with the STS dish and being within the 3 dB lobe of the antenna requires that the dish be aimed at the target within $\pm$ 1.734° (HPBW/2).

Paraboloid antennas, like all other antenna, have frequency limitations to their operation. The lower end of the operational frequency span is based on the dish diameter, and the upper limit of the frequency span is set by the surface roughness of the reflector dish. The lowest frequency that a paraboloid antenna should operate, as a rule of thumb, is

$$D = 10 * \lambda_{min}$$

For the STS dish, where D = 3.086 m, $\lambda_{min} = 3.086/10$; $f_{min} = c/0.3086 = 972$ MHz. This rule of thumb is used because the gain of the antenna drops too low for effective use.

The maximum frequency that a reflecting antenna can operate at is set by the surface roughness (σ). If the frequency exceeds this value the dish will scatter

$$\lambda_{max} = 4 * \pi * \sigma$$

the incoming RF and leave little to be focused on the feed. The frequency can be calculated by
Or in more straight forward terms

$$f_{max} = \frac{c}{4 * \pi * \sigma}$$

The STS dish has a surface roughness of 0.015 milli-inches (3.81×10^{-4} meters). Therefore f_{max} is 63 GHz. One last noteworthy situation with a reflector antenna is that the sense of a nonlinearly polarized signal will change sense every time it is reflected.

1.3.6 Mismatched Polarization Between Transmitter and Receiver

Matching the polarization of the antenna and the incident wave is critical to maximizing the detected power. The most basic case of polarization matching occurs when the incident wave and the antenna are both of the linear polarization sense. Placing the antenna in the same plane of oscillation as the wave is extremely important. The percent of the power received is dependant on the angle between the antenna and the wave orientation. If τ represents the change in rotation between the incident wave and the antenna then the power should be scaled by

$$p = \cos^2(\tau)$$

Note that if there is no alignment mismatch then there is no power loss, and if the antenna is 90° off then theoretically no power is received. In actuality, antennas are sensitive to cross polarization of 90° and this value can be obtained from the data sheet. Circularly polarized antennas have to be matched as well. The receiving antenna and the incident wave must be of the same sense of polarization. Rotation of the antenna will not affect the power received, but if the antenna's lobe is not parallel to the incident wave then the beam will be squinted and seem elliptical. Squinted beams will not transfer all the power to the antenna. The worst case of mismatching is when the antenna and the incident wave are of opposite senses of polarization (left-hand vs. right-hand circular polarization). Theoretically if antennas are of opposite sense then no power is transmitted from one to the other. Realistically there is some sensitivity between the two and the expected gain of the antenna to the difference in polarization should be determined from the manufacturer's specifications.

A very important mismatch situation is when a circular polarized wave and a linear polarized antenna exist. Here the power received is one half the actual magnitude ($p' = ½ p$). The same situation occurs whether the wave is linearly polarized and the antenna is circularly polarized, or if the wave is circularly polarized and the antenna is linearly polarized.

1.3.7 Digitizing Analog Information and Sampling Issues

Automated RF monitoring requires that a receiver's information be recorded. Most instruments communicate with PCs via the general purpose interface bus (GPIB, also known as the Hewlett Packard Interface Bus – HPIB, and the IEEE 488 bus – adopted in 1978 from HP). No matter how the data is retrieved from an instrument the digitization process will limit the application of the device being used.

If all the data being detected is to be saved, then certain criteria must be met when setting up the instrument. For instance, in the NRAO memo *Performance Characterization of the 1-18 GHz Ailtech-Stoddart NM67-CCI7 Receiver System used as part of the Continuous RFI Environmental Monitoring Station (EMS) at the VLA* (found in Appendix A), it was discovered that the frequency span, resolution bandwidth (RBW), and the number of sampling points are interrelated if all the data is to be recorded. To capture all the information detected the number of points being recorded must be greater than or equal to the frequency span divided by the RBW.

One must be careful to not over sample the information being saved. Filter shapes become visible if the sampling rate is twice as fast as needed for the above criteria (even though the filter shape only becomes easily apparent when sampling is done at ten times the necessary rate). Many sample points within one span of the RBW will show the shape of the filter being used. One can notice the gaussian filter shape in Plot 23 of the memo where the filter span of 10 MHz is sampled ten times.

The opposite of over sampling the information is under sampling. Under sampling will miss information as can be seen between plots 24 and 24.1 of the NRAO memo. The first plot shows that the signal at frequency 1163 MHz is not recorded whereas the frequency of 1171.875 MHz is recorded. The scanning and digitizing setup of the equipment for both plots is identical. This clearly shows that if all the information detected is to be saved in the digitized version then under sampling should be avoided.

1.3.8 EMI Receiver Functions and Application Notes

The Ailtech-Stoddart Electromagnetic Interference (EMI) / Field Intensity (FI) Receivers are versatile. The NM-67 receiver and other accompanying models were built to meet military specifications such as MIL-STD-461A and MIL-STD-826A. The main purpose of the specifications is to separate control of the different operational aspects. In particular the scan rate, RBW, and frequency span are not interconnected. The user must be aware of the implications when changing settings; these receivers will not compensate or automatically adjust for optimal performance.

Scan rate must be properly set for calibrated operation. A continuous wave (CW) signal that is applied to a receiver requires a specific amount of time for the full deflection (amplitude detection) to be displayed/detected. The minimum scan time (T_s in seconds) is determined by the frequency span (Δf in Hertz) and the 3 dB bandwidth (BW in Hertz) of the filter being adjusted (in a super heterodyne receiver) and can be calculated as follows

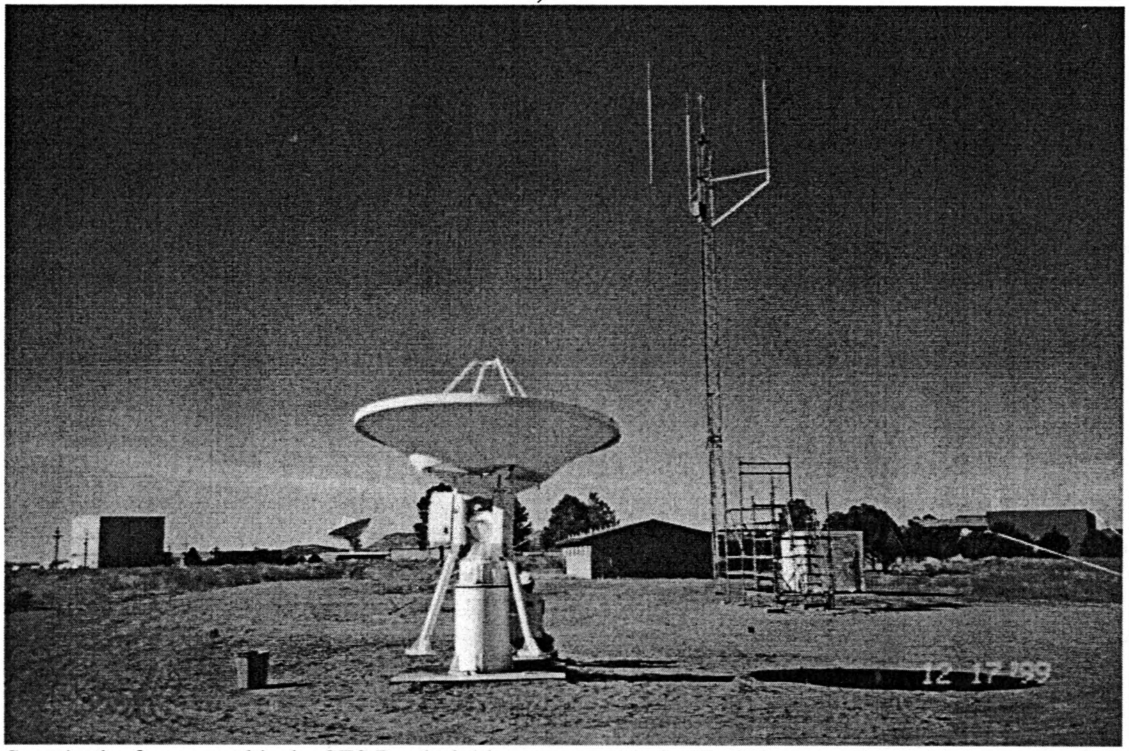
$$T_S = \frac{\Delta f}{BW^2}$$

The Ailtech-Stoddart receivers can be programmed to use one of four functions while in remote mode. The receivers have a Field Intensity, Calibrate, Peak Hold (3.0 sec), and Special Peak detection modes available when being controlled by the CCI-7. The Calibrate mode is used manually to get very precise amplitude measurements while tuned to a specific frequency. The implementation of Calibrate in remote mode can be used in a similar fashion to obtain the IFGain value, but this value can only be set once before each scan (and the value is only accurate for a specific frequency, not a range of frequencies). Field Intensity mode will detect the amplitude of a signal at the frequency it is tuned to. This mode is added to the receiver for maintenance purposes and to meet military specification MIL-STD-461 & MIL-STD-462. Peak Hold is used to detect amplitudes of frequencies as the receiver is swept through a range of frequencies. In manual mode, Peak Hold has three separate settings for the length of the charging circuitry (0.03, 0.3, 3.0 seconds). Remote mode through the CCI-7 allows only the 3.0 second Peak Hold function to be used even though the programming interface to the receiver itself allows for any one of the three settings to be selected. The hold length for Peak Hold is not the actual length that the peak value is held (see Test 25 in Appendix A), but how fast the needle reacts to the signal (how fast it will deflect to the proper amplitude) in remote mode, but in local mode hold length/time is the length that a peak value is held. This is the standard remote control function. Radar or other sweeping sources of RF will not be detected properly unless Special Peak function is used. Special Peak will charge the amplitude driving circuitry to the detected amplitude, but will not quickly discharge after the signal passes. This function is built to exponentially decay the amplitude so that the value can be held for a small amount of time (until the source sweeps again). This function is most useful with radar sources. For further information on receiver use please read *Instruction Manual for Electromagnetic Interference / Field Intensity Meter Model NM-67.*

2 Environmental Monitoring Station

This section will discuss the initial capabilities of the EMS system and the improvements and investigations that I worked on as a cooperative education hire for the Interference Protection Group in Socorro, New Mexico. The RFI site at the VLA, NM can be seen in Figure 1.

FIGURE 1: RFI Site at the VLA, NM



Seen in the foreground is the STS Paraboloid Antenna with the EMS Tower and RFI Shelter to the right

2.1 Background

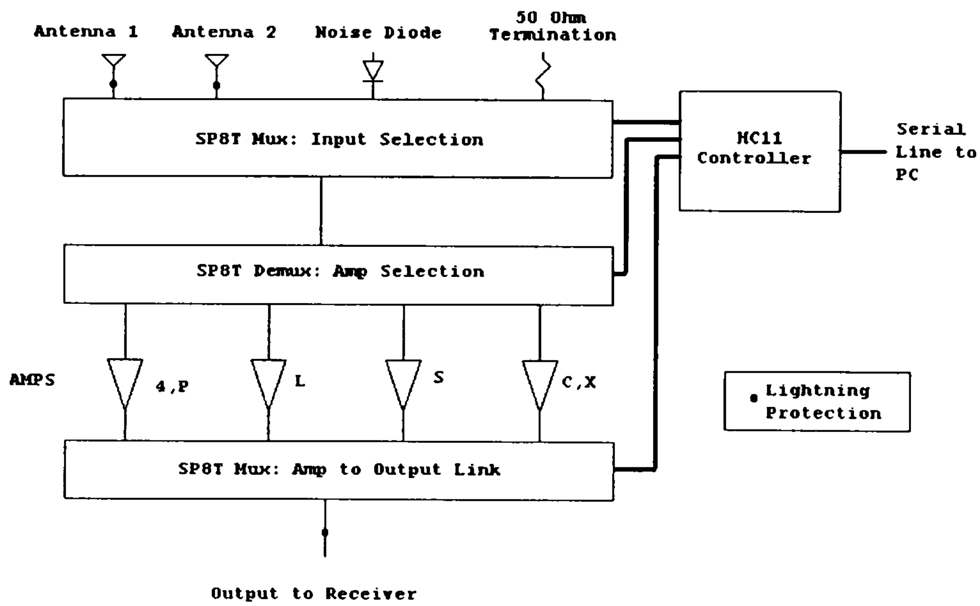
The Environmental Monitoring Station has been a student project for five years. The 54' Rohn tower and the RF shelter were installed under Dan Mertely and Zac Barnes. Zac wrote the Java code that allows for web communication to the receivers, and the C code that controls the receivers through the general purpose interface bus (GPIB). Leo Porta, under the cooperative education program, built a band switching front end. Raul, Sam, and I created a document showing the timeline for observing the 1 to 40 GHz frequency range with the current equipment (this task is currently in the charter for IPG). This document can be found in Appendix B.

2.1.1 EMS Front End

The front end is designed to handle a wide range of frequencies. Since an extremely broadband amplifier is extremely expensive, if it exists at all, the front end is designed to switch between amplifiers to cover the frequency range (see Figure 2). Using a single pull eight throw RF switch, Dynatech/U-Z Inc. Model N8-4135S28, as the three mux/demux RF switches. The front end is capable of selecting between up to eight input signals (only four are being used currently: noise diode, 50 Ohm termination, and two antenna inputs). The next stage of the front end handles the amplifier selection. The RF switches direct the signal to either a 10 MHz to

1 GHz (1002), 1 GHz to 2 GHz (Miteq: AM-2A-1020), 2 GHz to 4 GHz(JCA24-F01), or a 4 GHz to 12 GHz amplifier (Miteq: AFD3-4012). The control of the front end is achieved with a modified Motorola 68HC11 (MMT-HC11).

FIGURE 2: Block Diagram of EMS Front End



2.1.2 Ailtech-Stoddart EMI/FI Receiver

The Interference Protection Group obtained the Ailtech-Stoddart receivers as surplus from White Sands Missile Range. The system is designed so that a GPIB controller (a PC in this case) can select and control one of four receivers connected to the CCI-7 (Counter Controller Interface; see figure 3). The CCI-7 has all the digital and analog controlling circuitry built into the receiver cards. There are four receiver controller cards inside the CCI-7, and can control any of the NM series receivers (NM-7, NM-17/27, NM-37/57: 10 MHz to 1 GHz, NM-67: 1 to 18 GHz). Within the CCI-7 is the sampling and controlling circuitry that records the amplitude information as the receiver is swept across the frequency span. The NM-67 (figure 4) is the primary receiver for the EMS system. This receiver is the only RF receiver that can help IPG survey the spectrum from 1 GHz to 50 GHz. The FC-67 is a down converter attachment to the NM-67 and is operational from 18 GHz to 40 GHz, and it must be connected to the NM-67 for control. The NM series receiver is a super heterodyne receiver. These receivers have four functions that enable the user to detect different types of signals. The functions are Field Intensity, Peak Hold, Special Peak, and Calibrate (for internal testing procedures).

FIGURE 3: CCI-7 Front Panel

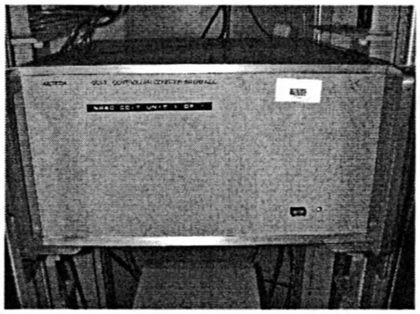
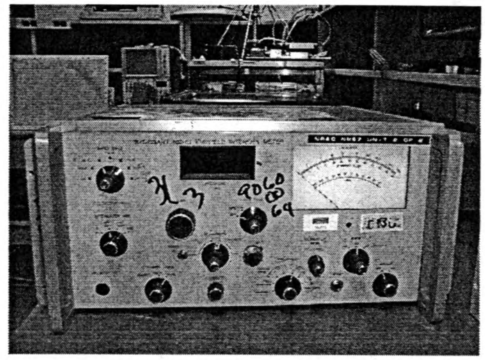


FIGURE 4: NM-67 Receiver



2.1.3 Computer Software

Two software programs are running the EMS system. Each of them handles a different task of the automated system. The communications and control is done with a *C* based program and the interface is a *Java* program.

The communication and control of the CCI-7 is done through a *C* language program called *getAilm*. This program takes user entered inputs and sets the parameters on the receiver controller card to the desired task. The inputs are in machine units, not user friendly. The code sets the receiver, sends the scan signal, and then records the amplitude information into a file on the hard drive. The files are recorded at /data/ailm/peak/(year 100 = 2000; month; day) [i.e. for May 10, 2000 the files would be saved in the directory /data/ailm/peak/1000510]. Each file is a five-minute sample of the peak values detected. The *C* code will, after a 5-minute interval, save the data in the above directory as a (year 100 = 2000; month; day; hour; min) filename. The CCI-7 commands across the GPIB link can be found in table 2.

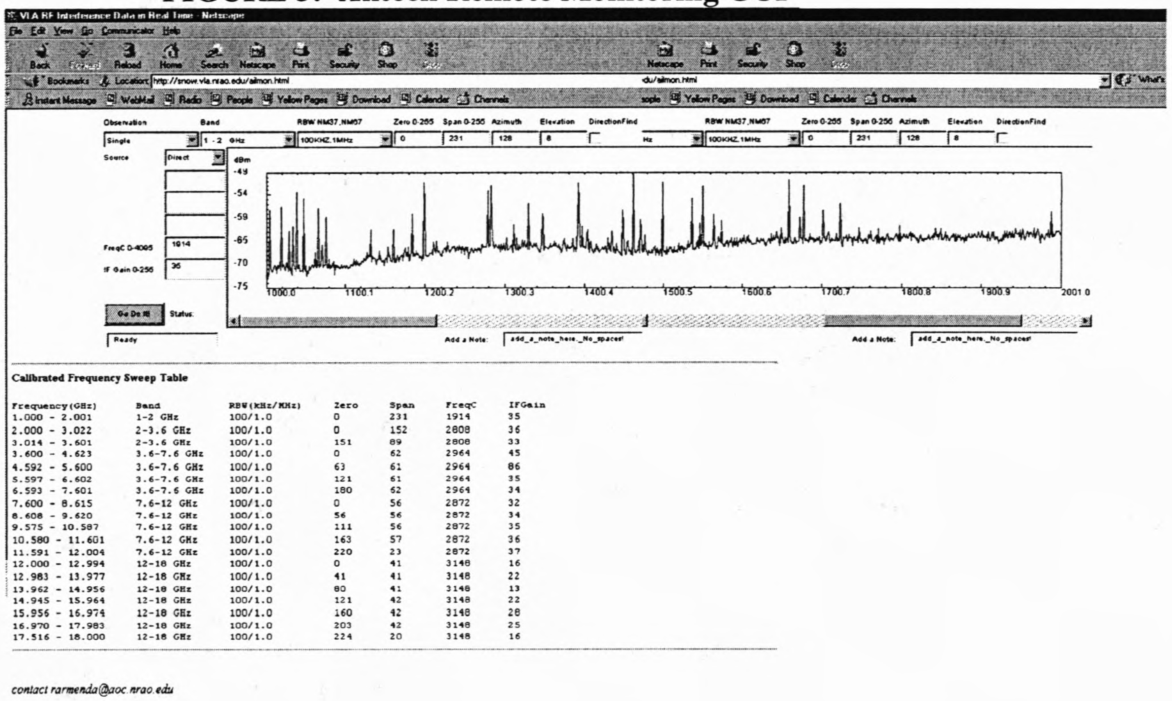
TABLE 2: CCI-7 Command Structure

Command					
11,A,W,address1,address2,word1,word2,word3,word4,word5,word6					
	address1,address2: receiver card addresses (A1A1 - A1A4)				
	address1	address2	Receiver Card		
	0x40	0x30	A1A4		
	0x40	0x20	A1A3		
	0x40	0x10	A1A2		
	0x40	0x00	A1A1		
	word1: Resolution Bandwidth				
	Control byte		RBW Selection	NM67 RBW	
	0x01		Narrowest RBW	0.1 MHz	
	0x02		2nd Narrowest	1.0 MHz	
	0x03		2nd Widest	1.0 MHz	
	0x04		Widest	10.0 MHz	
	word2: Band Selection				
	Control byte		Band Selection	NM67 Band	
	0x01		1st	1 - 2 GHz	
	0x02		2nd	2 - 3.6 GHz	
	0x04		3rd	3.6 - 7.6 GHz	
	0x08		4th	7.6 - 12 GHz	
	0x10		5th	12 - 18 GHz	
	0x20		6th	18 - 26 GHz	
	0x40		7th	26 - 40 GHz	
	0x80		8th	NA	
	word3: Receiver Function				
	Control byte		Function		
	0x01		Calibrate		
	0x02		Field Intensity		
	0x04		Special Peak		
	0x08		Peak Hold		
	word4: Attenuator Settings				
	Control byte		Attenuation		
	0x0e		0 dB		
	0x0d		20 dB		
	0x0b		40 dB		
	0x07		60 dB		
	word5: IFGain				
	eight bits control gain (see chart)				
	word6: GPIB Digital Outputs				
	4 LSB		Output Array		
	1011		Tuning Voltage		
	1101		Detector Output		
	1001		Both (above 2)		
12,T,word1,word2,word3,word4,word5,word6,word7,word8,word9,word10					

	word1,word2: Number of Points to be Sampled					
		range: 2^4 to 2^10, factor of 2				
		word1	word2	# of Points		
		0	16	16		
		0	32	32		
		0	64	64		
		0	128	128		
		1	0	256		
		2	0	512		
		4	0	1024		
	word3: Band to be Scanned					
		Control Byte		Frequency Range		
		10		30 - 57 MHz		
		11		55 - 105 MHz		
		12		101 - 192 MHz		
		13		186 - 292 MHz		
		14		285 - 445 MHz		
		15		430 - 620 MHz		
		16		600 - 825 MHz		
		17		800 - 1000 MHz		
		18		1.0 - 2.0 GHz		
		19		2.0 - 3.6 GHz		
		20		3.6 - 7.6 GHz		
		21		7.6 - 12.0 GHz		
		22		12.0 - 18.0 GHz		
		23		18.0 - 26.0 GHz		
		24		26.0 - 40.0 GHz		
	word4: N (number of 1024 sample counts between current counts)					
		N = 1024 / (Number of Points decided by word1,word2)				
	word5: Scan Rate					
		Control Byte		Scan Length (Time)		
		129		1.5 sec		
		65		3 sec		
		33		6 sec		
		17		12 sec		
		9		24 sec		
		5		48 sec		
		32		80 sec		
		16		160 sec		
		8		320 sec		
		4		640 sec		
	word6: Zero (value is always 0)					
	word7: Span (percentage of Band's Span to be Traversed)					
		Control Byte		Effect		
		0-255		(Control Byte)*Span/255 + Start Frequency		
	word8: Start Point (Starting Frequency within Band)					
		Control Byte		Effect		
		0-255		(Control Byte)*Span/255		
	word9: Frequency Calibration #1 (see chart)					
	word10: Frequency Calibration #2 (see chart)					

The web access and remote programming of the EMS system is done through a *Java* application. The website used to talk to the computer is http://snow.vla.nrao.edu/ailmon.html (see figure 5 below).

FIGURE 5: Ailtech Remote Monitoring GUI



Frequency(GHz)	Band	RBW(kHz/MHz)	Zero	Span	FreqC	IFGain
1.000 - 2.001	1-2 GHz	100/1.0	0	231	1914	35
2.000 - 3.022	2-3.6 GHz	100/1.0	0	152	2808	36
3.014 - 3.601	2-3.6 GHz	100/1.0	151	89	2808	33
3.600 - 4.623	3.6-7.6 GHz	100/1.0	0	62	2964	45
4.592 - 5.600	3.6-7.6 GHz	100/1.0	63	61	2964	86
5.597 - 6.602	3.6-7.6 GHz	100/1.0	121	61	2964	35
6.593 - 7.601	3.6-7.6 GHz	100/1.0	180	62	2964	34
7.600 - 8.615	7.6-12 GHz	100/1.0	0	56	2872	32
8.608 - 9.620	7.6-12 GHz	100/1.0	56	56	2872	34
9.575 - 10.587	7.6-12 GHz	100/1.0	111	56	2872	35
10.580 - 11.601	7.6-12 GHz	100/1.0	163	57	2872	36
11.591 - 12.004	7.6-12 GHz	100/1.0	220	23	2872	37
12.000 - 12.994	12-18 GHz	100/1.0	0	41	3148	16
12.983 - 13.977	12-18 GHz	100/1.0	41	41	3148	22
13.962 - 14.956	12-18 GHz	100/1.0	80	41	3148	13
14.945 - 15.964	12-18 GHz	100/1.0	121	42	3148	22
15.956 - 16.974	12-18 GHz	100/1.0	160	42	3148	28
16.970 - 17.983	12-18 GHz	100/1.0	203	42	3148	25
17.516 - 18.000	12-18 GHz	100/1.0	224	20	3148	16

The *Java* applet has three programs that run all the time. These three programs (*ailBGConfServer*, *ailBGViewServer*, and *ailMainServer*) control the interface to the *getAilm* program. The *ailBGViewServer* controls the information given to any client window that is set in "Background View" mode. It will update the data coming out of the CCI-7 as is needed. This stream of data is currently set to come from scans that occur every 1.5 seconds. The *ailBGConfServer* runs the data compilation windows around the left and top edges of the display. It interfaces the user input values from the windows to the definition file on the hard drive at */etc/ail.dfl*. The server *ailMainServer* executes the information in the file *ail.dfl* and then waits for the execution to finish. The server does this task continuously as it runs in an unending loop.

When a client connects to the java servers, an html file executes the interface program, *client_box.class*. This program is the client's interface to the information going to and from the servers. The code processes the data for accurate display and links to the servers as needed for its function.

2.2 NM-67 Hardware Troubleshooting

The Ailtech-Stoddart receivers needed retuning since they were made in the 1970s. Sam Field, a fellow coop employee within the IPG office, worked primarily on calibrating and fixing the NM-67 receiver (S/N 196), but when he left in May of 2000 the receiver still needed some odds and ends to be worked on.

2.2.1 Tuning Card No. 2 Adjustment (Card A1A29)

The NM-67 receiver's tunable range needed adjustment. Tuning Control No. 2 board controlled the range of tuning by supplying a set current for the YIG oscillators. These oscillators control the mixer frequencies that select the frequency of reception. The gain in band three (3.6 GHz to 7.6 GHz) was inadequate right around 5.0 GHz. All the bands were also tuning outside of the labeled frequency range. These two reasons prompted us to adjust the resistor values on card A1A29 to get the problems fixed (see 6.3.18 of the NM-67 Instruction Manual from Carnel Labs).

Adrian Rascon and I changed the YIG driving current tunable range on A1A29. Resistors R7, R13, R14 were changed so that the tuning problems stated above could be calibrated. Changing these resistors without paying attention to the side effects altered the filter synchronization. Realizing that the synchronization was lost, and loosing it nullified any gain we hoped to achieve through the alteration, I replaced the board to the original order.

2.2.2 Remote Function Selector Card Replacement (A1A25)

The Remote Function Selector card is the interface that remotely selects the function of the receiver. Remote control is achieved by energizing relays. The relays were failing to properly close. They had exceeded their lifetime and affecting the functionality of the receiver. The receiver's peak hold function did not have the proper noisefloor, and the charge time for signal detection was grossly longer than manufacturer's specification. We were having to slow the scan time to 320 seconds to properly detect the peak, whereas the specifications showed that the fastest available scan time of 1.5 seconds would be slow enough to operate without scan loss. After talking with Senior Engineer Paul Bender, at Carnel Labs, and Larry Toller, a retired engineer from Eaton, the problem was discovered to be the aging relays. Raul Armendariz replaced the Remote Function Selector card (A1A25) with the board from the spare NM-67 (S/N 148) and the functionality was restored. As of this writing the old relays have not been replaced.

2.2.3 NM67 Frequency Accuracy and Frequency Readout Test

7.3.2 Frequency Accuracy and Frequency Readout Minimum Performance Test found within the instruction manual at page 7-1 investigates the precision of the local oscillator (LO), digital display, and the Programmer receptacle J3 (Pin T carries the frequency voltage). The manufacturer specifications are that the digital readout and the scaled voltage are to be within 1% of the actual frequency detection (the LO). For the test the equipment was tuned to the correct LO (400 MHz above the interested frequency) and then the state of the three outputs was recorded. The chart found in Appendix C shows the results that Sam Field and I obtained on May 5, 2000.

2.2.4 Calibration Factor Procedure and Chart

An extremely useful feature of the NM-67 receivers is that the signal amplitude of any given frequency can be determined if the calibration factor is set. The calibration factor is set by 1) tuning to the desired frequency, 2) putting the receiver into the calibrate function, 3) setting the calibrate value with the calibrate knob, 4) switching the receiver back to the function of choice where the amplitude is accurate to within 2 dB for a CW signal and 3 dB for a impulse signal (see manufacturer's specifications for instrument).

To determine the calibration factor one should follow the procedure found in the instruction manual. Essentially it requires the user to inject a –67 dBm signal into the receiver, tune to the peak detection while in FI mode, move the Cal. Factor knob until the amplitude reading is 40 dBμV switch to Calibrate mode, and record the calibration number on the dBμV scale.

The calibration factor is useful for local operation of the instrument where control of the calibration factor can be done at the user's discretion, but remote control of the device allows the calibration factor to be set only once at the beginning of the scan. Another hindrance of remote controlling the amplitude calibration factor is that the user input for programming the receiver is not in corresponding units. The relationship of the 8 bit control variable and the actual dBμV setting is nonlinear and different for each of the five bands. Appendix D gives the calibration factors found on May 9, 2000 for the three resolution bandwidths.

2.3 Counter Controller Interface 7 (CCI-7)

The CCI-7 allows remote control and recording of the receivers. Sending analog and digital signals to the receiver through the Programmer Cable controls it remotely. The receiver will send back the frequency voltage it is tuned to and the amplitude that it is detecting. The amplitude is digitized and stored in ram until the end of the sweep where it is sent to the CCI-7 programmer across the GPIB connection.

The Data Chain cards digitize the incoming amplitude data. A ramp voltage controls the frequency tuning of the receiver. 0V is the bottom of the frequency span and 10V is the top of the frequency span of a receiver band.

The Data Chain cards use a voltage comparison circuit to dictate the sampling time. The card compares a set reference voltage to the frequency control voltage. Next, the card records the output of the A/D when the voltages are equal and then increments the reference voltage to the next point in the sweep. It seems that every sweep is broken into 1024 "action" points where the amplitude is sampled. The variable "N" in the control strings (see table 2) sets the rate of sampling. The variable "Points" in the same control string sets the total number of points, but if N is left at "1" while Points is set to half the original value then the resulting array of information will be the first half of the original set of information. The same is not true if N is doubled and Points halved. The array elements will now be similar to just the even bins of the original array.

Other miscellaneous notes on the CCI-7 is that the power supply fan has been replaced several times in the past, by Zac Barnes, and that some parts have failed leaving visible burns on the boards, and were fixed before NRAO received the equipment.

2.3.1 Receiver Card Tuning (Cards A1A1 through A1A4)

Analog voltages run the operations within the NM receivers. Calibrated, remote control of the receivers requires that the receiver card be tuned to the analog biases that are individual to the receiver being controlled. The amplitude calibration factor bias is controlled by R11 on the receiver card.

Procedure 8.5.1 in the instruction manual tells a technician how to set R11 if an HP 85 is available with the standard program. IPG has the software and an HP 85, but the HP 85 is not operational. The program on the tape has aged beyond its shelf life. The proposed replacement procedure calls for the user to know the noisefloor levels of the receiver in local mode. Make sure that the input to the receiver is terminated with 50Ω so that there is no induced noise. Record the noisefloor of the band of interest when the Cal. Factor is set to the calibrated position for a set frequency of interest, at the maximum, and at the minimum settings. Set the receiver to remote mode. Next, set the IFGain variable in the program arrays to the maximum value (IFGain = 255, 0xff). Now, program the receiver to tune to the frequency used in local mode (and set the span to zero so that the frequency doesn't change while adjusting R11). Adjust R11 so that the noisefloor during a programmed scan is equal to the noisefloor in local mode at maximum Cal. Factor setting. Finally, check the noisefloor after setting the IFGain to zero (minimum setting) during a remote-controlled sweep versus the noisefloor of the receiver when it was in local mode and the Cal. Factor setting to its lowest value. The noisefloor for a calibrated IFGain value in remote operation should also be compared to the noisefloor for a calibrated operation in local mode if the IFGain for calibrated remote operation is known. This setting will allow for the maximum span of control and set the span similar to the local operational capabilities.

2.3.2 Amplitude (Y-Data) Calibration (Card A1A11)

Data Chain #2 Card within the CCI-7 receives the amplitude signal (Y-Data output) from the receiver and digitizes it. The Y-Data signal can range from 0 V to 2.008 V. The A/D converter on the Data Chain #2 card has an adjustable reference voltage from which the eight-bit range of the A/D is set.

The instruction manual's Y-Data Calibration procedure can be found on page 8-9 of the CCI-7 manual. The given procedure assumes that the operator has access to an HP 85 with the CCI-7 Operation tape. IPG created a new procedure since the current HP 85 is broken and the CCI-7 Operation Tape cannot be read. First thing to be done is set the receiver in local mode. Pin Y of the Programmer Cable carries the amplitude voltage from the receiver to the CCI-7. Set the receiver in Slideback Peak function. Adjust the Slideback control knob until the voltage on pin Y is 2.008 V. Next, run a GPIB program that will control the receiver and record the amplitude output (*gpibtest* is a useful program, and its source code can be found at */usr/src/ailmon/test/gpibtest.c*). Leave the receiver in Local Mode so that the amplitude sent to the CCI-7 is the 2.008 V. Local mode will also ignore the control inputs from the CCI-7. Adjust R11 until the amplitude recorded by the program is alternating between 0xff and 0xfe. 2.008 V now corresponds to the 60 dB dynamic range detectable by the receiver where 0xff is 60 dB on the scale and 0x00 is 0 dB.

2.3.3 CCI-7 Switch Settings

Two types of switches in the CCI-7 must be properly set in order for the CCI-7 to communicate properly with its peripherals. The GPIB card must have the correct address set, and the receiver cards have to be configured for either the NM-67 or any other NM receiver.

The GPIB interface card (A1A12) has a dipswitch that sets the GPIB address for talking to the CCI-7. S1, the address switch, is set to 0h19 (0d25) from the factory and is currently operating with that value.

The receiver cards must behave differently depending on the receiver they are controlling. Each card has a slide switch located to the right of it (if viewed from above with the faceplate pointing toward the viewer) that informs the card whether to control an NM-67 or either an NM-37/57, NM-17/27, or NM-7. The NM-67 must be separated from the rest since the remote functions are different. Receiver cards that control an NM-67 must have the indicator switch thrown toward the back of the CCI-7. This mechanism allows for any of the receiver cards (A1A1 through A1A4) to control any NM receiver; i.e. the CCI-7 can be set to control 2 NM-37/57s and 2 NM-67s.

2.3.4 Power Switch Replacement

Simple parts on the CCI-7 will wear out over time. The on/off power switch on the front panel display failed early in February of 2000. A replacement was found and installed. There is a significant design hindrance to replacing this part. The power supply and the card assembly both block the switch from easy maintenance.

2.3.5 Cables and Peripheral Connections

The receiver system is capable of many operations. The CCI-7 can interface with the CIU units. The CIUs allows for multiple antennas to be used with one receiver setup as long as the setup uses only the receivers NM-7, NM-17/27, NM-37/57, but not the NM-67. As of this writing the CIUs (CIU A and CIU B) have not been tested.

The GPIB cables that accompanied the system from White Sands Missile Range are faulty. Communications between the CCI-7 and the NM-67 failed due to an unmarked, bad cable. No information came from the NM-67 to the CCI-7 during the failure. The cable started working after its middle connection with a second cable was dropped on the ground. None of the cables have been marked or tested.

2.4 EMS Front End (FE)

A FE is an essential and complicated part of any antenna that is being used for broadband purposes.

2.4.1 Design

Amplifiers operate on the incoming signal and the signal noise without discrimination. The signal path acts as an antenna and will pick up more and more signal noise the farther down the signal path one makes measurements at. Placing the amplifier as close to the antenna as possible will minimize the amount of noise induced, and will minimize the attenuation of the desired signal, making the amplifier more effective. Leo Porta designed the front end to be as close to the antenna as possible, protected from the elements, allow the maximum frequency use of the complimentary equipment, give a user the maximum functional capabilities at the beginning of the signal path, and provide complete remote control of the front end.

The FE bandwidth is limited by several components. The FE switches power to the amplifiers only when that amplifier is selected. This eliminates the possibility of damaging all the amps during a power surge or brown out (there is suspicion that a pulse of energy from a passing cloud or lightning can be causing the amps to fail). Currently a user can select between four different amplifiers that combined frequency span is 0.01 GHz to 12 GHz. The transmission line, Andrew Heliax LDF-2, does not limit the bandwidth of the system, but is not wasteful either, since it can operate from DC to 13 GHz. RF microwave switches, single pull eight throw, do not limit the bandwidth either since they operate from DC to 12.4 GHz. Expansion of the system bandwidth to meet the receiver bandwidth will require replacing multiple parts.

A user can configure the front end for different operations through the HC11 serial link. The microcontroller automatically launches the program when power is supplied. The user is prompted to select two different system settings. The first setting is the input selection. Currently the system will switch between a 50Ω termination, a white-noise diode, a directional antenna input, or an omnidirectional antenna. System temperatures can be calculated since the 50Ω termination and the diode is included. The SP8T microwave switch can allow for six antenna inputs to be selected from, but the current system is configured for two antennas maximum. The user's second input will decide the amplifier used by the FE. The system has the capability to distinguish between eight different paths, but only four amplifiers are currently connected and no higher frequencies can be supported by the hardware.

2.4.2 FE Wiring

IPG possesses no good wiring diagram of the front end. The first thing needed to troubleshoot any problems with amplifier power, signal misconnects, or any other failures are a detailed understanding of the wiring. Leo Porta's report did not describe the complete system. The block diagrams, program source code, and RF circuitry are well documented, but the power distribution was not. The power from the incoming 120 VAC down to the 5 V, 12 V, ±15 V, and 28 V DC allocation were traced and marked for future simplicity. The 5 V supply failed during this investigation. A RF switch was shorting the 5 V to ground and was replaced (switch 3). Replacing RF switch 3 brought the number of operational, spare switches to zero. This caused some alarm within IPG.

2.4.3 RF Relay Investigation

The current RF microwave switches are ideal. Their bandwidth is limiting for the current system, but the DC to 12.4 GHz operational range is only 600 MHz shy of the cable bandwidth of DC to 13 GHz. These relays allow control of one signal path to be switched to any of eight other paths (SP8T Design) and the switches have indicator pins that allow the system to monitor the switch's state of operation. The switch is designed to automatically link the common path to path number one if no controlling voltages are applied. One must apply a ground voltage to the desired actuating pin for the switch to operate. The indicator pin of the active path will be driven to 5 VDC whereas the other indicator pins will be at 0 VDC.

The RF relay switches were investigated for replacement. The lack of spare switches and limiting bandwidth (compared to the receiver) spurred an investigation into replacement relays. First, I asked Everett Calan if he knew where some replacements were. Everett knows a lot about the relays and the history of the FE parts of the VLA. He told me that the current switch in the FE was part of an experimental addition to 12 antennas of the VLA. Since the relays were flaky the system had been scrapped. The extra relays should have been in a storage trailer at the site, but when Kris Haskins (a student employee for the Front End Group) and I searched we could not find any extra units.

New RF switches were looked into since the current equipment has no replacements if one fails. Extra RF switches from NRAO stock could not be found to supplement the system. The current switches were used since they were surplus, but they were in the surplus bin because they were faulty. Armed with this new knowledge, I contacted a distributor of the VLA switches that are currently being used (DB Products, Inc.). I priced a single pull six throw switch – model 6SSE2C31. It would be able to support all current functions, and would have two extra ports available for expansion, that had the indicator pins (just like the current switches) and ran at 28 VDC and can operate from DC to 22 GHz. These parts would take about 45 days to deliver and cost $488 each. $1,952, plus shipping, minimum would be needed to get the three required switches plus a backup switch.

Other surplus RF switches do exist for IPG use. The Dynatech switches currently being used in the FE replaced a SP4T switch in the VLA configuration. There is a lot of DB Products, Inc. SP4Ts, model 4SL2003. These switches lack certain functions that make the Dynatech appealing. They do not have any indicators that will allow for monitoring, expansion ability since four paths are already used on all three switches, and they are not failsafe – the switches will not automatically disengage when the controller circuitry is broken. More precisely, the switching mechanism must be reset by a separate signal before switching to a different path otherwise the first setting will continue to operate when the next switch is activated. The difference in operations would mean editing the code within the MMT-HC11, but if the SP6T were implemented then the switch could be wired into the system without any code alterations.

2.4.4 Front End Amplifiers

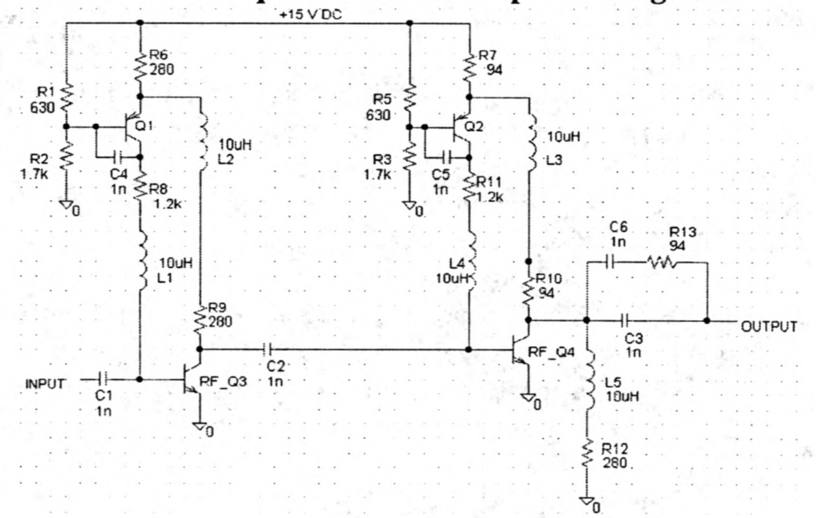
The front end is designed so that a user can select a desired amplifier and have it applied close to the antenna so that the amplified signal to noise ratio is at its maximum. The EMS FE contains four amplifiers. These amplifiers give at least 15 dB gain across the frequency span of 0.01 MHz to 12 GHz.

The 4, P band amplifier has very little documentation. The only external marking on the case is "1002". Investigation shows that the amplifier box is a standard, machined box for in-house amps. The amplifier housed inside is a stand-alone package with the markings "AVANTEK UTO-1002, MICamp". The amplifier gives 15 dB gain across the frequency range of 10 MHz to 1 GHz. Leo Porta gives the only documentation on the amplifier, and it agrees with a specification sheet for the Watkins-Johnson WJ-A12. The WJ-A12 amp operates with the same gain across the same frequency as the 1002, and has a specified ±0.7 dB gain flatness, 3.5 dB noise figure, and +7.0 dBm output at 1 dB gain compression.

The L band amplifier is Miteq's AM-2A-1020. These amplifiers are the center of the system since L band concerns IPG the most. The amplifiers kept losing amplification ability, and NRAO employees had observed this occurrence before Raul Armendariz and I were employed. The gain is specified at 19 dB, but after a few months, weeks, or days the amp would attenuate the signal rather than amplify it. Two things needed to be addressed: 1) What is failing in the amps and can it be fixed in-house at a lower price and 2) Why are the amps breaking and can they be protected from the problem?

I reverse engineered the amplifiers to understand how they worked, and to figure out which part(s) were failing. The amplifier is a simple two-stage bipolar junction transistor (BJT) amplifier. The housing separates the amplifier into two circuit boards that have different functions. One board consists of two 2N3906 (Q1 and Q2) transistors and their supporting resistor networks that create the biasing voltages for the RF transistors on the other board. The second board contains the RF amplification stages, two RF BJTs (RF_Q3 and RF_Q4), and the necessary capacitors and inductors that isolate the RF stages from each other and their biasing circuitry (see figure 6).

FIGURE 6: Miteq AM-2A-1020 Amplifier Diagram

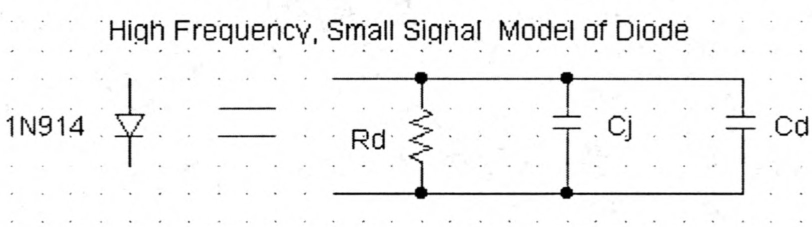


Testing several different points within the amplifier gave a good picture about their failure points. Applying the DC voltage to the amplifier and then checking the biasing voltages of the RF BJT can easily show if the BJT has failed. The RF BJT in most cases is the failing component. They are designed so that the input path (the base) is biased at 0.7 V, the output path (the collector) is biased around 9.5 V, and the emitter is grounded. The typical readings for a broken amplifier will give the base voltage about 13.5 V and the collector voltage around 13.5 V as well. The RF transistor was replaced by Agilent's AT-41486. The replacement transistor has a noise figure of 1.4 dB at 1.0 GHz and 1.7 dB at 2.0 GHz whereas the Miteq amp is rated at 1.8 dB at 1.0 GHz and 2.4 dB at 2.0 GHz. The AT-41486 gain is not ideal for the amplifier either. The transistor gives 17.5 dB gain at 1.0 GHz and only 11.5 dB gain at 2.0 GHz. It is a close match to the original, but if a better transistor can be found then it should be used since this replacement is not quiet enough. The AT-41486 cost $1.47 per part that makes it more economical than sending the amp to Miteq where the handling fee is $75.

The L Band amplifiers need protection. The BJTs are failing and nobody knows why. The amps would give approximately 20 dB gain when first installed, but after operating continuously for a week the amplifier would act as a 20 dB attenuator. Several different scenarios suggest how these amplifiers are being damaged. Near-by lightning strikes, AC coupled spikes, or charge build-up on the antenna as clouds passed overhead can possibly damage the amplifiers. Suggested protection for the amplifiers varied greatly. Phoenix Contact demonstrated that a combination of MOV (metal oxide varistor), arch chopping spark gaps, and silicone avalanche diodes should be used for surge protection. These three elements in parallel to ground will protect against impulse surges because some of them act quickly, but cannot handle a lot of power, while other components are slow to activate, but will handle a large amount of power. The unfortunate problem with this type of protection is that above 3 GHz the components either act as capacitors (and short the signal to ground) or fail to act fast enough. This leaves the system above the L band amps unprotected. Another suggested protection against an impulse is having a 90^0 bend on the connector to the amplifier since higher frequencies (in the impulse signal) cannot travel around the sharp bend. This was not tried due to time constraints.

The adapted protection for the amplifier is a simple 1N914 diode with an air core inductor. The diode was placed from the input to ground in both directions to protect the input from voltages above 0.7 V, but the small signal model of the diode (figure 7) indicates that at the high frequencies of operation the diode becomes a short from input to ground. The inductor was placed in series to create a high pass filter so that the signals of interest can be blocked from the capacitive effects of the diode. It is feared that the inductor will also block the high frequency components of an impulse from utilizing the diode and therefore cancel the protection. At this time there is no other information about protecting the amplifiers except for switching relays when lightning is detected by an independent system.

FIGURE 7: Diode Considerations for Surge Protection



The Miteq AM-2A-1020 amplifier is the backbone of the front end, but there are other amplifiers in IPG's possession. The JCA12-F01 amplifier is a 1 to 2 GHz amplifier from JCA. It has a minimum gain of 22 dB, gain flatness of ±1.0 dB max, a noise figure of 1.2 dB max, an output power of +10 dBm at the 1 dB compression point, an input and output VSWR of 2.0:1 max, and cost $395. The amplifier found in the lab does not work. The JCA24-F01 is very similar to the JCA12-F01 except that the operating frequency range is 2 to 4 GHz and the noise figure is 1.5 dB max. This amplifier does work, and can give a similar gain from 1 to 2 GHz. The other characteristics of this amp between 1 and 2 GHz are unknown.

The MITEQ AFD3-4012 amplifier operates through the frequency range of 4 to 12 GHz. This amplifier gives 19 dB of gain across the frequency range of 4 to 12 GHz with a gain flatness of ±1.25 dB, its 1 dB gain compression occurs at +10 dBm, and a noise figure of 3.0 dB. This amplifier is the limiting device for the EMS bandwidth. One final note: this amplifier runs very hot to the touch. A heat sink was added to the amplifier, but is only held on by a rubber band.

2.4.5 Lightning Protection System

An active lightning protection system is used to protect the amplifiers and receiver of EMS. The system is set up to actively open several Dowkey 401-3308 microwave relays. These relays operate on a 28Vdc signal. When a predetermined field potential is reached between earth-ground and the antenna, the system activates the relays. The relays are kept open for 10 seconds (time is controllable by the user through a knob). This design approach hopes that during the length of time that the relays are activated the danger of a lightning strike will dissipate. The relays are placed at the input to the receiver, the input and output of the front end, along the antenna input path and receiver output path.

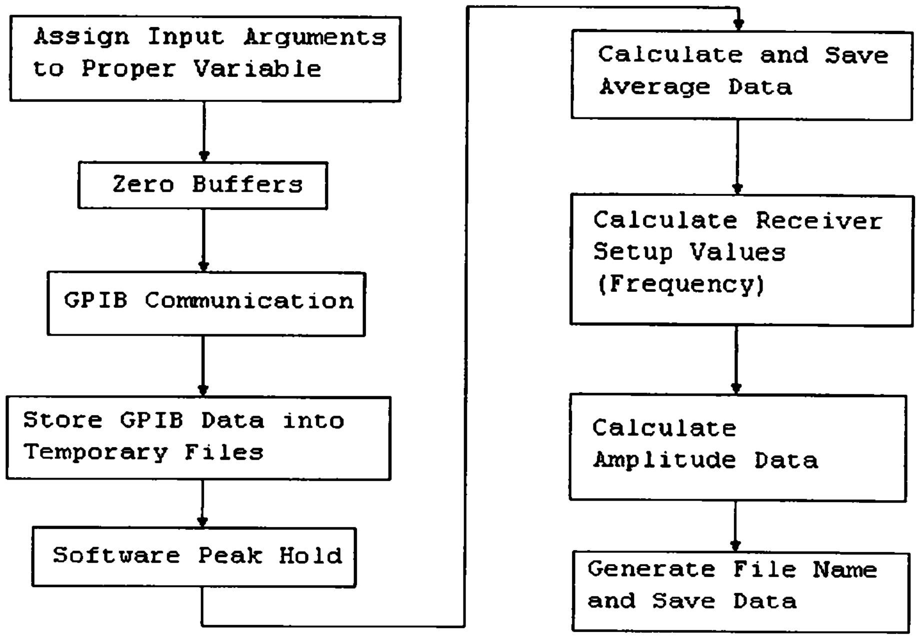
2.5 EMS Code

The Environmental Monitoring Station depends on computer control. The system is based on two software sets. The receiver control and communication is done through a *C* language program (*getAilm*) and a series of *Java* programs (*ailBGViewServer, ailBGConfServer,* and *ailMainServer*) dictate the continuous operation of the receiver and create a remote interface for the user. The system had several problems when I was hired in January of 2000. The GPIB board was not properly communicating with the receiver controller (CCI-7), and the software was not controlling the receiver in a calibrated state.

2.5.1 Introduction to Receiver Control

GetAilm is a simple code that controls the CCI-7 through the GPIB bus. The code accepts external values and sets the instructions for the instrument accordingly. After the instrument runs its single operation, the code receives the digital data across the GPIB and then proceeds to save the information. The data is saved to hard drive every five minutes. There is an unused section of code that allows for positioning the Yaesu rotator, but this section is commented out of operation since the rotator is not operating. The code execution path is shown in figure 8, a block diagram of the code.

FIGURE 8: Software Flowchart



2.5.2 GPIB Miscommunication

The GPIB protocol differs in operation from one instrument to another. The bus has several explicit lines used to communicate the end of statements (EOS) and end of instructions (EOI). The protocol allows for service requests to be conveyed to the controller from a "slave" device, and for polling of the bus to determine the device of concern. Other than this set communication hierarchy the bus allows for the instruments to use the data bus for any desired operation. The CCI-7 needed a set sequence of EOS, EOI signals to be conveyed for operation. Zac Barnes, who had set the original system up, revisited in March and discovered the flaw in communication procedure and fixed it.

2.5.3 Receiver Function Interrelation

I learned the control program of the CCI-7 while Sam Field and Adrian Rascon repaired the receiver. Every time I used the CCI-7 to control the receiver the output was different from earlier experiences. Progress on receiver calibration, characterization, and user understanding was greatly hindered by the frequent shifting of its performance. I performed a study on how/if settings for one function impacted the control of another function on the receiver and its output data across the GPIB link. Specifically, the frequency span seemed to be related to switching either the receiver function or the scan time. In one session I characterized the receiver's frequency response, switched through all the attenuator settings, switched through every mode of the receiver, tested all the resolution bandwidths, and receiver scan rates. The only effects of dependency happened when the scan time was increased to its three fastest settings. Under these conditions the frequency span of the receiver decreased with the increasing scan rate. All other settings did not affect the frequency range of the receiver while in remote control. The decreasing frequency range was tested with Field Intensity Mode and Peak Hold Mode. Neither function detected an injected signal of –27 dBm at the fastest scan rate of 1.5 seconds. Besides amplitude deviation, the frequency range began to shrink when the scan time was set to 6 seconds.

The test conclusively show that for most, if not all settings, the receiver's frequency range is unaffected by the other settings. The FI mode is not designed for scanning. This mode is mainly for calibration procedures. The lack of frequency performance in Peak Hold mode was traced to the failing relay (K3) on the remote interface board in the NM-67 (see section 2.2.2). The only source for the shifting behavior of the receiver, since the function toggling did not affect it, is the fact that when I was not using the system, Sam and Adrian were calibrating the hardware.

2.5.4 Frequency Characterization

The relationship between frequency and sample numbers must be recorded if any calibrated data is going to be taken from this system. Four variables control the frequency range that the receiver sweeps through. *Frequency Tune 1* and *Frequency Tune 2* set the lowest possible frequency that the receiver can be tuned to. These two eight bit variables actually program a single 12-bit D/A that biases the tuning voltage. *Frequency Tune 2 (FTune2)* sets the eight most significant bits and *Frequency Tune 1 (FTune1)* casts the four least significant bits. The lowest tunable frequency shifts inversely to the values of *FTune1* and *FTune2*; i.e. when *FTune2* = 255_D and *FTune1* = 15_D then the 12 bit value is at its maximum value and the frequency range is at its lowest. The third variable is the *Zero* value. *Zero* is an 8-bit variable. This variable controls the beginning of the tuning voltage ramp that drives the receiver. The receiver will start at the beginning of the band when *Zero* = 0, and it will start at the highest frequency of the band when *Zero* = 255. The ramp that tunes the receiver runs a range from 0 V to 10 V and its relationship with the frequency domain is linear. The final variable is the *Span*, and is an 8-bit variable. *Span* sets the percent of the selected band that the receiver tunes through after starting that the start frequency (that is determined as described above). For example, if the band had a frequency span of 1 GHz and *Span* = 255 then the frequency that the receiver tunes through will be f_{start} to $f_{start} + f_{span}$. More precisely, if the receiver band starts at 500 MHz, has a range of 1000 MHz, *Zero* = 128, and *Span* = 127 then:

$$f_{start} = \frac{Zero * 1000MHz}{255} + 500MHz$$

$$f_{start} = 1001.96 \text{ MHz}$$

$$f_{span} = \frac{Span * 1000MHz}{255}$$

$$f_{span} = 498.04 \text{ MHz}$$

The resulting scan will start at 1001.96 MHz and end at 1500 MHz.

The receiver does not behave in an ideal, linear fashion. All actual frequency parameters must be empirically found. The above equations are a guideline for the theoretical behavior, but the analog components of the system have irregularities. Empirically discovering the frequency settings of a particular scan can be done with a signal generator and the control station. The *FTune* values should be set for each band of the receiver and any changes in the sweep range should be done with *Zero* and *Span*. To get the *FTune* values, set the signal generator to broadcast a continuous wave (CW) signal to the beginning frequency of the band and at a respectable power level so that the receiver is sensitive to it. Leave *Zero* = 0, and set *Span* so that the range is not over-sampled or under-sampled. Now adjust the *FTune* values until the CW signal is detected at either the first or second sample. Once at this point repeat the process several different times so that it can be determined if the CW is repeatable and still in the first couple bins.

Determination of the frequency span for a constant variable set is similar to finding the *FTune* values. First, program the receiver as is desired. Now, inject a CW signal of appropriate amplitude. Next, run the remote control operation and identify which sample (if any) detected the signal. Adjust the signal generator up or down until the first bin samples the signal. The end frequency can be discovered in a very similar fashion. All these procedures assume that there is no over sampling or under sampling issues with the receiver setup (see section 1.3.6). Appendix E contains several different charts of the frequency control values as the receiver changed its operation characteristics over time.

2.5.5 Amplitude Calibration

Amplitude characterization / calibration is equally as important as frequency characterization. The control variable *IFGain* sets the calibration factor for amplitude at a certain frequency. Local control of the receiver allows for the *Calibration Knob* to be adjusted asynchronously. Remote control allows the *IFGain* to be set once at the beginning of the scan. For this reason the amplitude results are not as accurate when compared to manual operation.

The amplitude calibration procedure is simple. First, inject a signal at a frequency of importance and at a calibrated power. The frequency chosen is important since the calibration factor can only be set once per scan. All other frequencies in the scan will not be accurately reported in power. The center frequency is chosen by default if no particular frequency is of interest, but if a source in the frequency range is being sought for observation then this frequency should be used for calibration. The power of the injected signal should be more than 10 dB above the noise floor of the receiver, and within the sensitivity of the receiver. Run a GPIB program that will retrieve the data from the receiver and make it available to the user (i.e. *gpibtest* or *gpibcal*). The *IFGain* is linearly and proportionally interpreted. Adjust the value up or down to get the detected peak to the proper level. Note: the digital value of the amplitude should be converted to dBm by

$$Power_{dBm} = \frac{value_{digital} * 60}{255} - 107 + attenuator$$

i.e. if $value_{digital}$ is 127 and the attenuator is set to 20 dB then

$$Power_{dBm} = \frac{127 * 60}{255} - 87$$

$$Power_{dBm} = -57.12 dBm$$

The gain flatness of the any band should be ±3 dB. A table of the current *IFGain* values for the 1 GHz frequency spans desired for IPG surveying can be found in Appendix E (see August 14th). Also, it should be noted that before the data is saved to file the program calculates the amplitude into dBm from the digital word value. The equation that does this operation can be found at line 494 of the *getAilm* code and this code does not account for the attenuator setting.

2.5.6 Intranet Access Calibration (Frequency)

The *Java* program needed adjustment for calibrated data display. The equations for calculating the frequency were incorrectly written. The original assumed ideal operating conditions and had a incorrect multiplier. The *case* statement that calculates the frequency values can be found at line 345 for *userClient.java*. The structure was expanded to recognize the set of 1 GHz frequency spans and interpolate any other setup from one of the calibrated equations from the set. This interpolation must be done since there is no first order equation that accurately describes the *FTune* effects on the frequency. The best guess comes from using a calibrated scan setup and changing that for any arbitrary setup.

2.6 Receiver Performance Characterization Memo for NRAO

Raul Armendariz and I generated an internal memo on the characterization of the NM-67. This document can be found in Appendix A. It discusses the different effects that the receiver functions have on its output and its quotability. The tests were setup with the Gigatronics 1018 (S/N 1804A00291) signal generator and checked by the Agilent Power Meter (S/N GB40201637). The data was collected with the program *collector.c* and the resulting plots were produced with MatLab.

2.7 EMS Survey Investigation

IPG is chartered to investigate 1 to 50 GHz for interference. An equipment impact report was drafted to show a timeline for the investigation. Part of the report showed the difference in time when more optimal equipment is used. My particular responsibility was to demonstrate the front end and receiver limitations and possible improvements. The timeline should not be seen as anything more than speculation since the receiver had not been investigated for operational characteristics. The report was generated based on Sam Field's, Raul Armendariz's, and my research.

3 Satellite Tracking Station

Kerry Shores stared the Satellite Tracking Station as his coop task. IPG had several unfinished tasks when this project was started, and the management of NRAO felt that the previous projects should have been given the attention rather than starting another project that did not get finished. Engineers fought to keep STS since it promises to give extra monitoring capabilities for the expanding interference issues of satellites. Management and the engineers came to an agreement that STS had to track a satellite by March 13 of 2000. It was because of this deadline that Sam Field and I were moved from EMS to STS in early February.

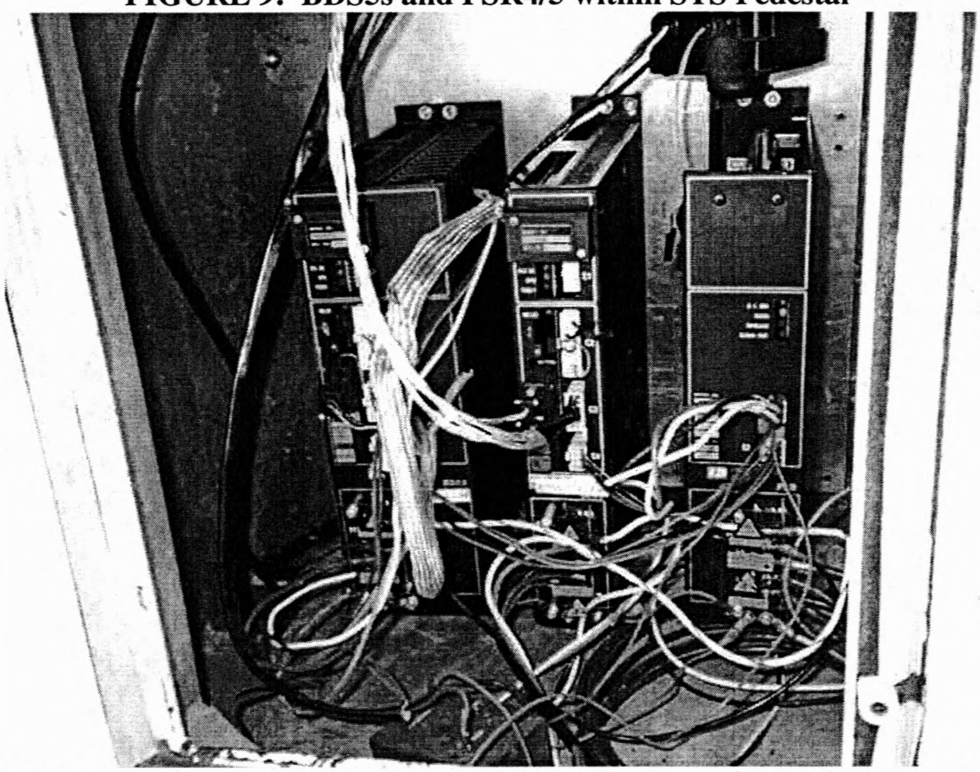
3.1 Initial Status

STS was not operational when Sam and I started work on it. Kerry Shores had installed the dish at the site, ran the power (and set up a convenient power distribution box), installed the power supply (PSR4/5), installed the elevation motor and control unit (BDS5), implemented a commercial off the shelf (COTS) satellite tracking package – NOVA, and wrote some LabVIEW code that would communicate with the BDS5. The system did not have any provisions for the azimuth control system. The azimuth gearbox, under advise from Dan Mertely, was not investigated for maintenance, and the gear ratio was not accurately measured for the control equations (it was believed to be 450:1 but is actually 350:1). There was no communication line installed for the azimuth controller. The elevation communication line was eight single ended wires that were 160 feet in length. Three of these lines were used for elevation communication through the RS232 interface (that does not reliably work over more than a 50 foot span). The azimuth motor was on back order, and was not fitted to accept the current gear or mount to the STS pedestal. Another obstacle to be overcome was the fact that no feed or front end had been designed for STS's permanent use.

3.2 Hardware Modifications and Installations

Many tasks needed to be completed before STS could be controlled. There was and still is a lot of items to be installed or modified. The wiring needed to be inspected, a motor needed to be installed along with its controller, the feed needed to be attached, and the physical limits needed to be investigated. Figure 9 shows the two BDS5 motor controllers and the PSR4/5 power supply, and figures 10 and 11 show the azimuth and elevation motors and gearboxes respectively.

FIGURE 9: BDS5s and PSR4/5 within STS Pedestal



Left to Right: Azimuth BDS5, Elevation BDS5, PSR4/5 (bottom of Azimuth Motor can be seen above the PSR4/5 in upper-right corner of picture)

FIGURE 10: Azimuth Motor and Gearbox

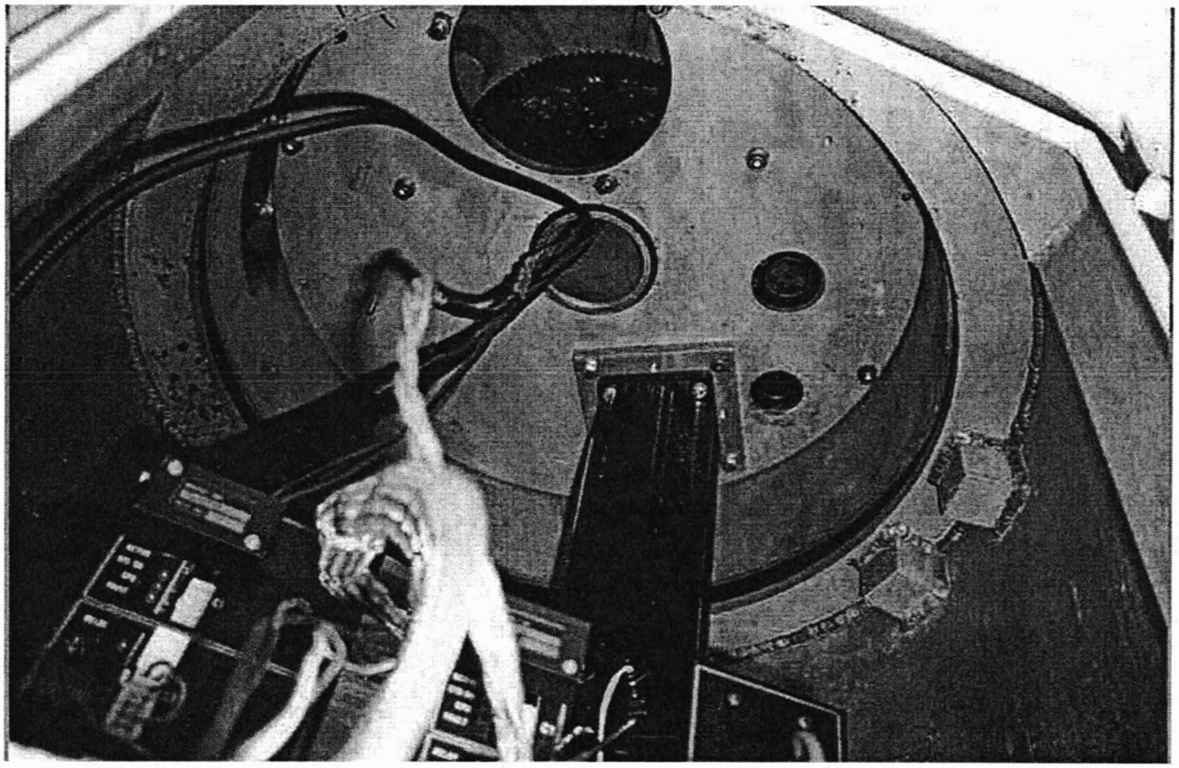
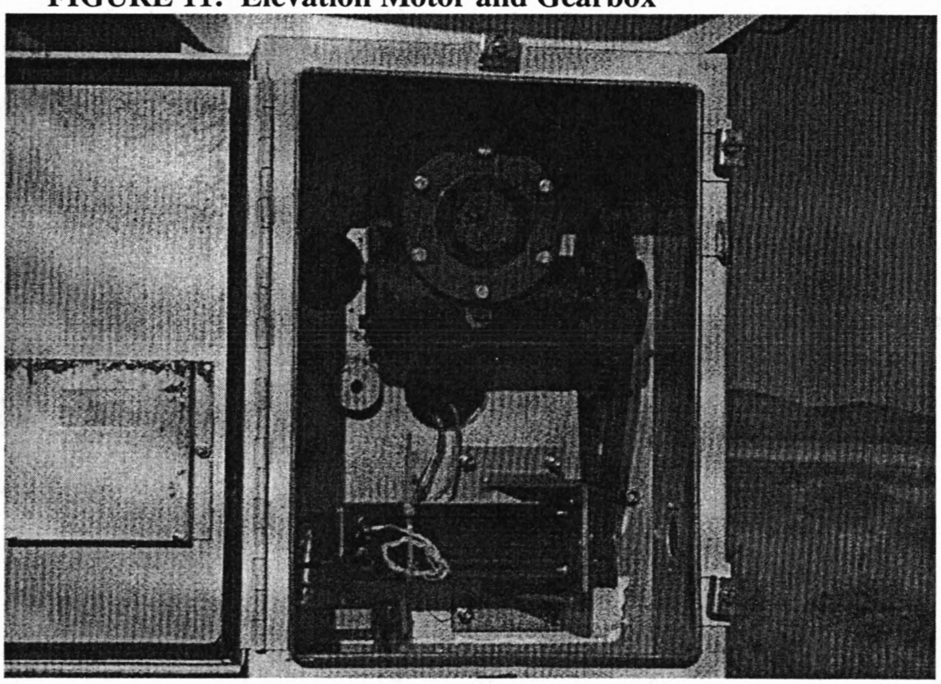


FIGURE 11: Elevation Motor and Gearbox



3.2.1 Wire Diagram

The Kollmorgen BDS and PSR system requires 220 V three phase and 120 VAC. The power distribution and emergency cut-off boxes were wired up, but there was no documentation for reference. The task of documenting this setup was left to Mark Sullivan, Sam Field and myself. The diagram for the wiring (including the later addition of the azimuth BDS) can be seen in the following figures. The power is brought in from the main lines and ran through a relay before getting to the controllers. An emergency shutoff switch was added for the 220 three phase so that motor power can be interrupted whenever necessary.

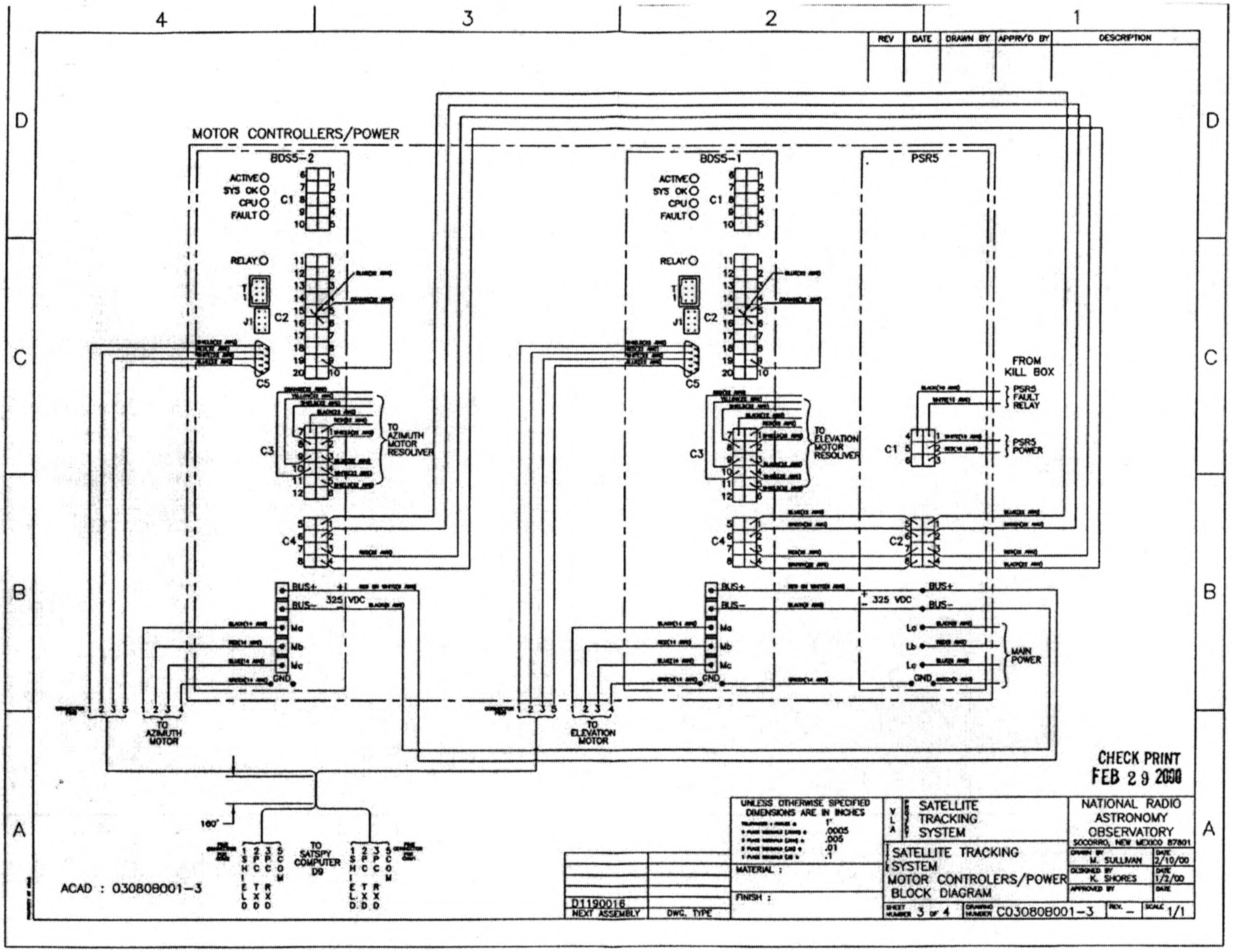


FIGURE 12: BDS5 Wiring

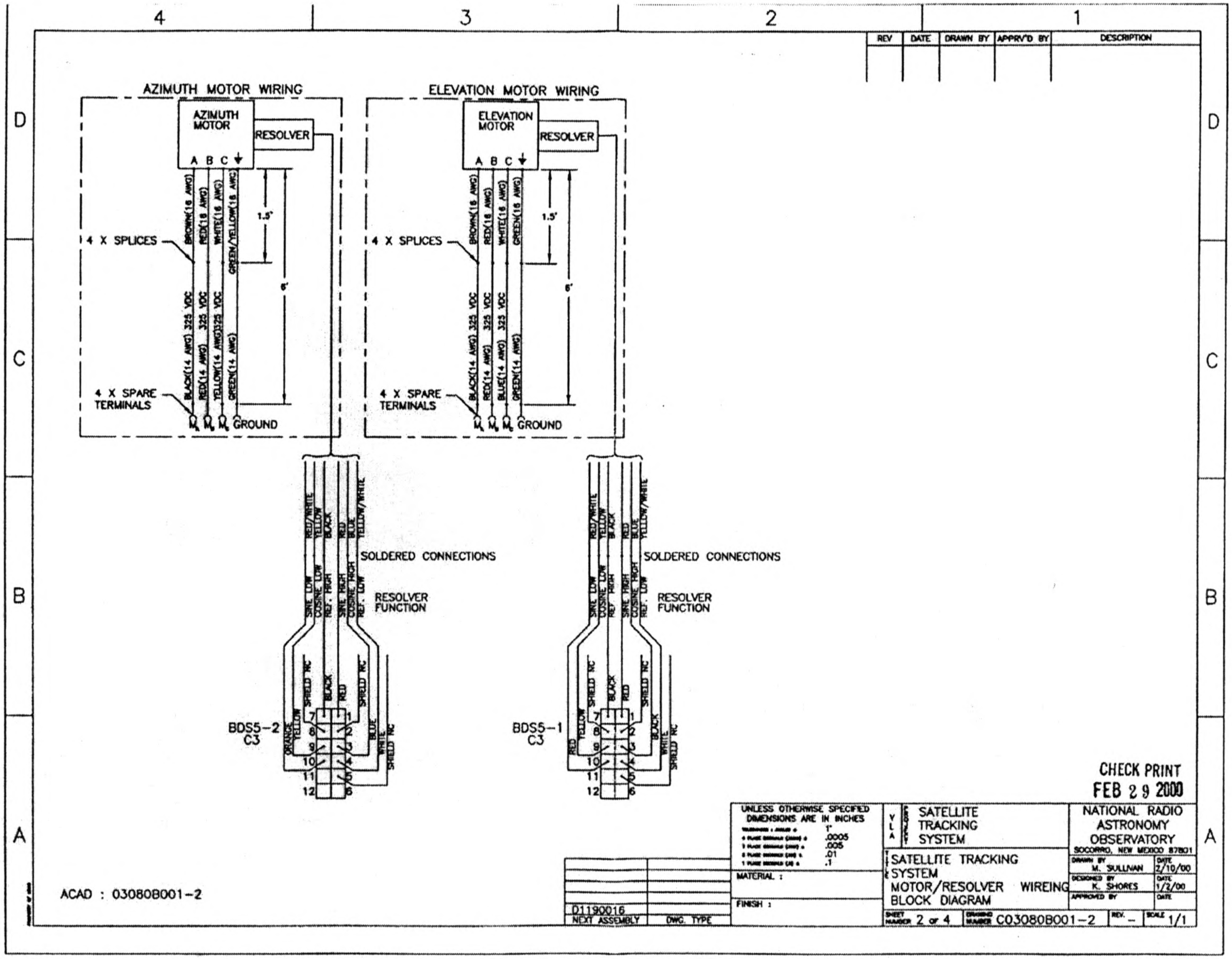
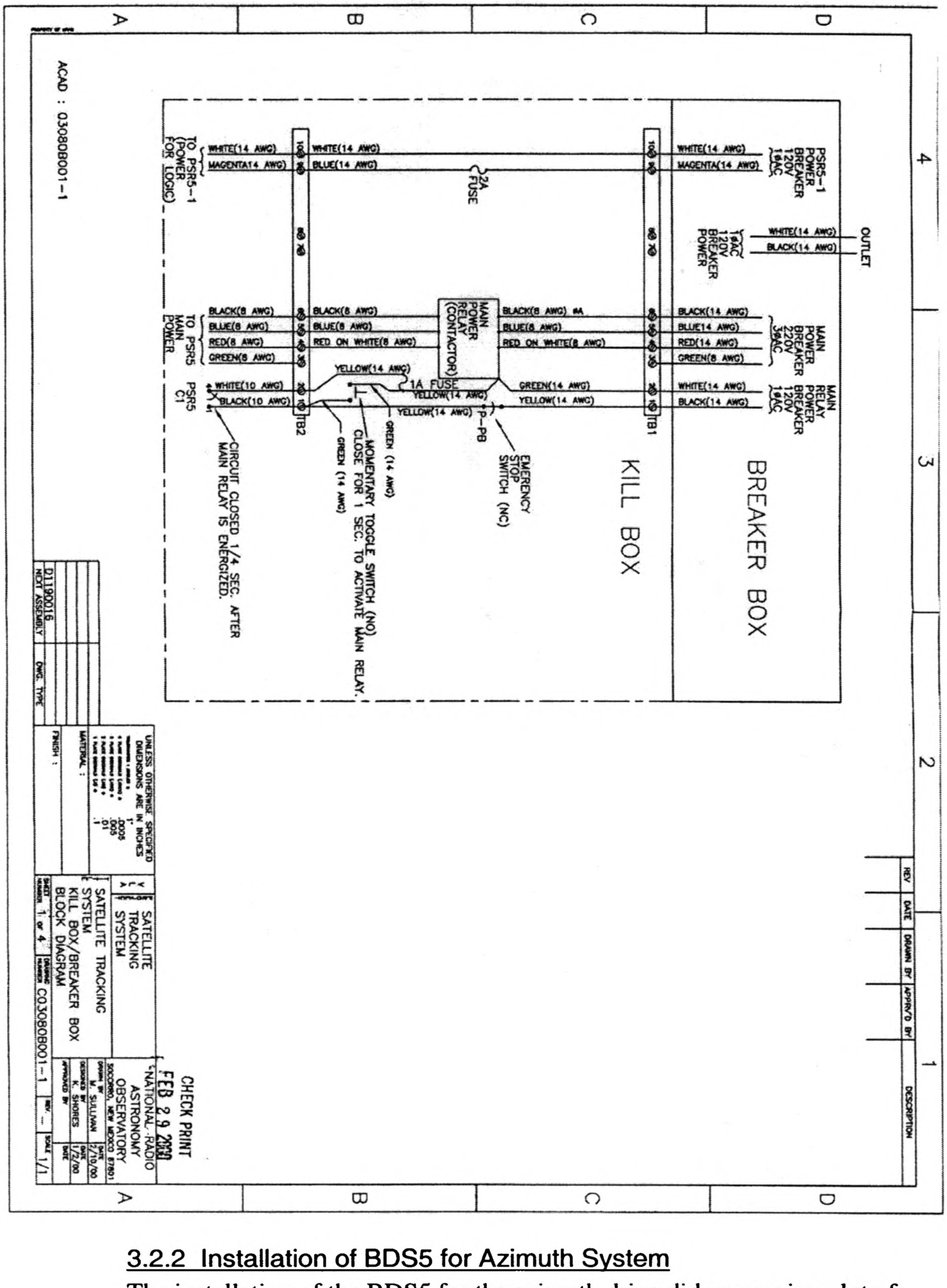


FIGURE 13: BDS5 to Motor Connection

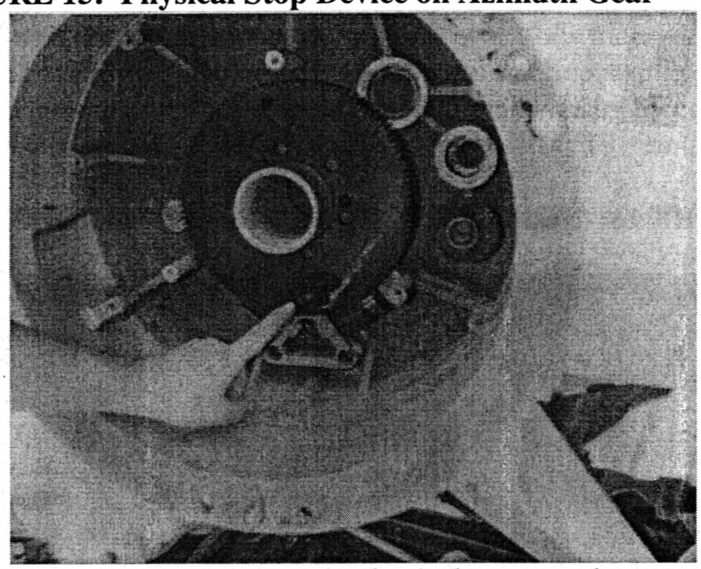
FIGURE 14: Power Distribution and Kill Box



3.2.2 Installation of BDS5 for Azimuth System

The installation of the BDS5 for the azimuth drive did no require a lot of maintenance. The PSR bus was daisy chained to the BDS5, the motor wiring was attached to the correct ports, and other miscellaneous connections were made as the installation documentation in the BDS5 manual indicated on page B-6. The motor adaptation plate and gear fitting was left to the Machine Shop. I removed the physical limit device while the azimuth gear box was being repaired (see figure 15). It was feared that since the azimuth was limited to $\pm 200^{\circ}$ and it was not known where the center of this range is, the control would be extremely complicated. The implication of removing the stop is that the gimble will not stop before the wires can be tangled together and be destroyed. The BDS5 position limit was enabled and set to $\pm 370^{\circ}$ to prevent damage, but this software solution does not account for user error over time where the system might become entangled.

FIGURE 15: Physical Stop Device on Azimuth Gear



The removed item is being pointed to (and mounts on the opposite side of the device)

3.2.3 Feed Mounting and Antenna Pattern Measurement

The feed and front end used for the system was a temporary addition to show that the system could work. The feed was a Watkins-Johnson AR7-18. This line of antennas was sold to Condor Systems. The salesperson in charge of the line is Helen White. She informed me that this antenna is now called the AS-48015. This model needs to have its tip placed at the focal point of the dish since the tip is the phase center of the feed. The antenna was mounted to an existing front end box (that came with the dish from the military). The front end amplifier is a Miteq AM-2A-1020. This system was used to measure an antenna pattern. Raul and I went into the field with a signal generator and the 1 – 10 GHz tensor horn and broadcast a signal toward the dish. Sam operated the dish and HP spectrum analyzer (Model 8559A – display unit is the 853A) and recorded the gain while pointed at the source. There is no exact measurement for the pointing of the dish. This uncertainty plus the uncalibrated broadcasting source nullifies any ability to calculate a quotable gain value. The preliminary estimates can be found in Appendix F.

3.2.4 Azimuth Gear Box Maintenance

The initial status of STS included a non-operational azimuth gearbox. Sam and I spent several afternoons trying to get an accurate reading of the gear ratio by installing the azimuth motor and trying to spin the azimuth through several elementary motor commands. We were unable to get the dish to rotate any more than a fraction of a degree before the motor was unable to move the dish. The dish was disassembled and the Antenna Maintenance department took an afternoon to inspect our problem. The problem (as was feared by Sam and I when we noticed debris in the motor mounting hole) was an ancient rodent's nest within the gearbox (see figure 16) and poorly maintained gears where the teeth were filled with an orange, solid residue (see figure 17).

FIGURE 16: Nest in Gearbox

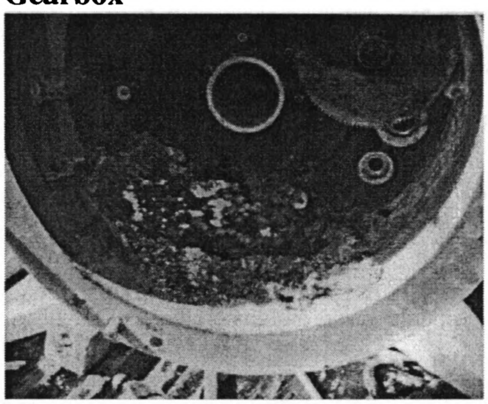
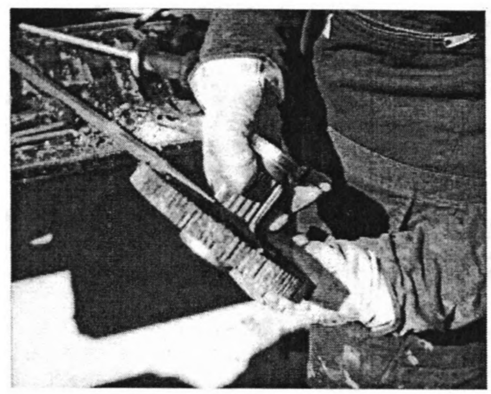


FIGURE 17: Residue on Gear



3.3 Software Design

The software initially only used the elevation control. Many functions had to be added so that the azimuth and elevation could be controlled at the same time. NOVA was already sending the azimuth data to LabVIEW, but LabVIEW was ignoring it.

3.3.1 BDS5 Code and Tuning

The control / gain constants were obtained by putting the system at the greatest inertial load (elevation angle = 0^{o}) and then executing the command *tune 30 3*. The tune command allows for the system to be set for critically damped, underdamped, and overdamped responses with a varying set of bandwidth. The constants were programmed into the code as a set of initialized values that would be set every time the code executed. This made sure that the constants were not lost in volatile memory. The code itself was adopted from the elevation code, except that the scaling and rescaling factors had to be independently determined for azimuth since the gear ratio is different. Ideally the scaling factor should be (gear ratio) * (resolver counts per revolution), but with the registers only being 32 bits large (and having to deal with signed numbers) this value had to be scaled down to insure that the register would not overflow. For this same reason, the rescaling factor (which should have been $10*360^{o}$) is smaller. This difference in values induces error in the system since the registers have to use integers, but the factors cannot be proportionally reduced.

3.3.2 LabVIEW Expansion

Azimuth functions and user friendly control was completely missing from the LabVIEW vi (vi is the programs generated by LabVIEW). The functionality was as easy as copying text in a word document. The graphic programming environment allowed the azimuth system to be copied and initialized without a problem. The initial vi did not have any means for stowing the dish to 0^{o} azimuth and 90^{o} elevation while it was running. The vi did not even communicate at the same baud rate as the hyperterminal. This made manual mode to automated mode switching a nightmare since the only way to get the systems back into an autobauding stage required a cycling of the power. These functions were added and the system became easy to use, but was still not tracking properly.

3.3.3 Serial Communication Problem

The communications to the BDS5s deteriorated to a useless state as soon as the azimuth system was implemented. The dish would track fine, but about once a minute the system would run to an incorrect angle and then come back as if a single, incorrect angle was communicated to the BDS5. At first it was thought that the problem was a lack of processor speed, but when an Athlon 900 MHz system was used to run the software the problem intensified. Switching back to the old 486 computer reduced the problem back to its original issue. The vi was then set to only communicate the angles when either of them changed. This made the problem less frequent (occurring once an hour), but it was still there plus now the system would hang during the stowing process. It was not discovered until late October of 2000 that the error laid within the RS232 cable. The RS232 protocol is only good at 9600 baud or faster when the cable length is 50 feet or less. The STS length is 160 feet and the programs were running at 19200 baud. As of this writing the problem remains, but has been identified.

3.4 Uncalibrated Tracking of Iridium Birds

With the system having the occasional glitch Raul, Sam, and I tracked several Iridium satellites. The same HP spectrum analyzer that was used to measure antenna pattern monitored the power off the satellites and their frequencies. These plots can be found in Appendix G. Unfortunately these plots do not give any information about the satellite's track across the sky (its azimuth and elevation angles or its distance from the tracking station).

4 Miscellaneous Equipment Characterization

The HP8559A, HP8640B, and Gigatronics 1018 were all characterized at a small set of their operating values and tables of the findings against a "reliable" source are taped to their tops. There is no absolutely calibrated device in the Array Operations Center, so nothing is quotable.

APPENDIX A
VLA-VLBA Interference Memo No. 15

Performance Characterization of the 1-18 GHz Ailtech-Stoddart NM67-CCI7 Receiver System used as part of the Continuous RFI Environmental Monitoring Station (EMS) at the VLA

Raul Armendariz, Ryan Schmidt
VLA RFI Interference Protection Group
October 2, 2000

Abstract:
Calibrated CW signals were injected into the remote controlled NM67 scanning receiver to determine its accuracy and repeatability for both frequency and amplitude detection. Intermediate frequency (IF) Gain and frequency Fine Tune controls are used to adjust for power and frequency error respectively; these pre-scan adjustments are limited to a flat power correction per scan, and frequency corrections to band edges only; because of these limitations errors are larger for wider scans. For 1 GHz scans over 1-18 GHz the amplitude error was typically less than 2.5 dB, except at 1.9 GHz where the error was 4.5 dB, and at 5.5 GHz where the error was 7.5 dB. Maximum frequency error over 1-2 GHz was 8 MHz. For 1 GHz scans over 2-18 GHz the maximum frequency error was 22 MHz. Calibrated results for this system are therefore known to within +/- 2.5 dB, and frequency accuracy to within +/- 22 MHz worst case. Errors in power and frequency are non-constant and non-linear across all 1 GHz bands, thus the application of post-processing correction factors would be difficult. A way to produce tighter results would be to run smaller scans, on the order of 100 MHz; however any range scanned requires prior determination of IF Gain and frequency Fine Tune values. At various frequency bands over 1-18 GHz 50 consecutive scans were run, each over a 30 minute period to determine detection repeatability. The receiver system is repeatable up to +/- 1 MHz in frequency and +/- 1 dB in power. Repeatability on scales from days to weeks was not tested. This receiver system is a practical tool for continuous omnidirectional RFI monitoring for 1 GHz scans over 1-18 GHz, and for direction finding. Once direction of incidence for strong sources are determined a calibrated, high-resolution spectrum analyzer should be used for signal identification.

Section 1: Description of Receiver System and Performance Tests

The Stoddart NM67 receiver (S/N 196) is an ambient operated superheterodyne 1-18 GHz RFI/EMI analog receiver expandable via an associated downconverter up to 40 GHz, with 120 dB of dynamic range over –107 dBm to +13 dBm (figure 1). The RBW settings are limited to 100 kHz, 1 MHz, and 10 MHz. The unit is typically used scanning over frequency and in rms peak detection mode; in peak mode at a 100 kHz RBW the internal noise floor is –90 dBm +/- 3 dB. The Stoddart controller-counter interface (CCI-7) is a digital device, which allows remote PC control, and data download over a GPIB 488 bus. The receiver and controller date from the 1960's to the 1970's, and many functions are recently repaired.[1]

This study was performed in order to quantify the error both in frequency and amplitude in CW signal detection over 1-18 GHz. Most of the study was conducted on August 18, 2000. Calibrated CW signals at various frequencies were injected into the scanning receiver while in rms peak mode and under remote CCI-7 control (figure 2). The data presented here are CCI-7 digital output converted to units of MHz and dBm via software in the control PC. Before performance tests could begin it was necessary to determine the accurate receiver settings for both the frequency and amplitude controls while under remote operation. The receiver controls of "Zero," "Fine Tune 1," and "Fine Tune 2" determine the start frequency, and the "Span" control determines the end frequency for any given scan range. Accurate values for these controls were determined by injecting calibrated signals at the desired start and end frequencies, for each scan range, and tweaking the controls until the beginning and end frequencies were defined by the detected signals, values listed in table 1. The response to input power is adjustable via the "IF Gain" control which adjusts for internal receiver error; the IF Gain has a 20 dB swing and adjustments effect both the receiver noise floor and injected signals. Accurate IF Gain values for each scan range were determined by injecting CW signals of known power into the receiver and remotely adjusting the Gain control until the detected power output from the CCI-7 was equal to the input power to the receiver. The IF Gain values applied were determined either near the scan center frequency, or at a VLA default frequency range, values listed in table 1.

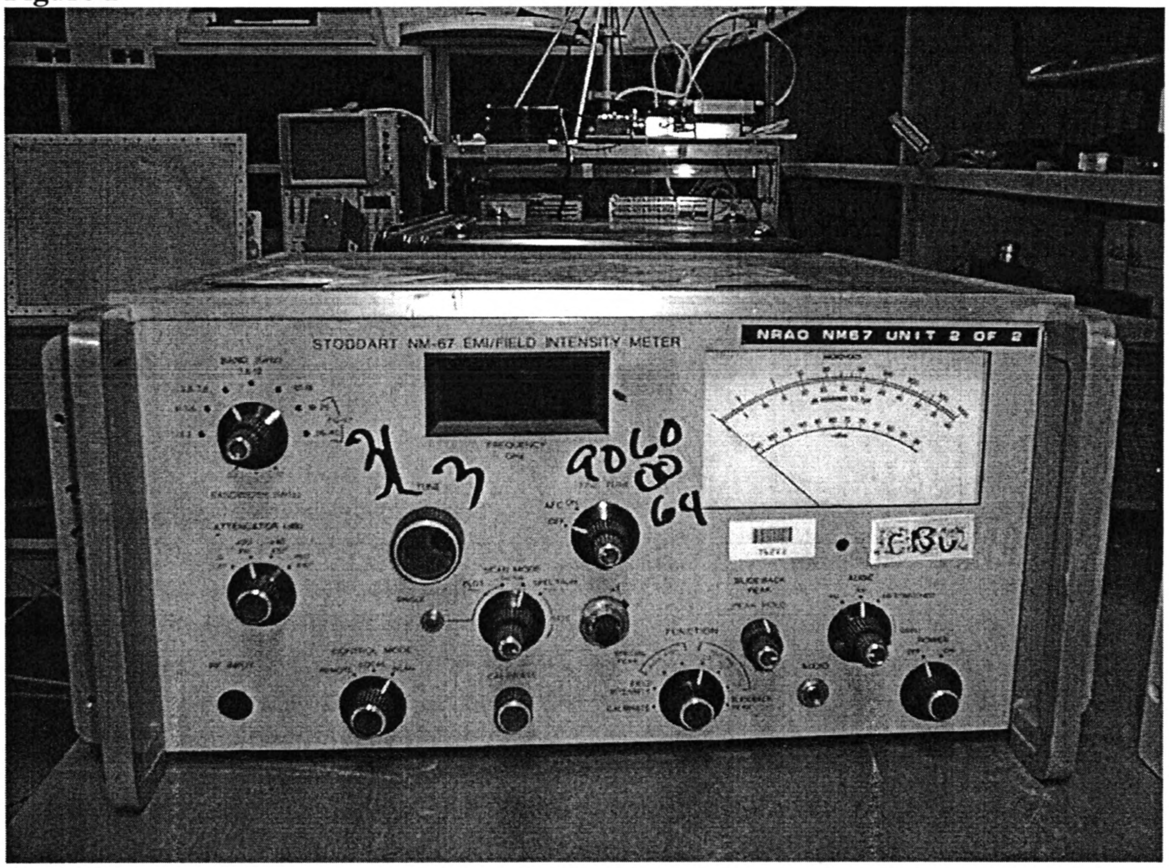
The digital controller samples the receiver DC volt output; moderate care should be taken to not oversample nor undersample the receiver; oversampling results in tracing out the RBW filter, and undersampling creates the possibility for missing narrow-band signals (see tests 24 and 25). Calibration signals used were exponentially stronger than the receiver internal noise power and thus the noise floor contribution to signal + noise was systematically ignored. Before these tests were performed the following control and data lines between controller and receiver were characterized. Frequency: 1) CCI 0-10 Vdc tuning ramp to YIG oscillator tuning drivers, 2) determined that 1st CCI data acquisition pulse occurs approximately at beginning of scans, 3) YIG tuning drivers in the receiver were found to be off and NOT corrected: the ZERO, Fine Tune 1, 2 and SPAN settings adjust for this. POWER: 1) Slideback peak control for 60 dB receiver dynamic range matched to 0-2.008 Vdc receiver output (A1A4 pin 19) and matched to CCI 0-255 byte range ADC output (A1A11), 2) CCI IF Gain byte range matched to Vdc output (range and offset) and adjusted (A1A4 R11) till receiver remote and local mode noise floors correspond.

The receiver-controller setups for all tests are listed in tables 1 and 2. No post processing correction factors were applied to the data neither in frequency or amplitude.

---

[1] *RFI Environmental Monitoring Station (EMS): Repair and Calibration of Ailtech NM67 Receiver*, IPG Student Co-op Report, Sam Field, May 19, 2000

Figure 1



(S/N 148 SHOWN HERE; S/N 196 CHARACTERIZED IN REPORT)

Figure 2: TEST SETUP FOR PERFORMANCE CHARACTERIZATION OF RECEIVER-CONTROLLER SYSTEM

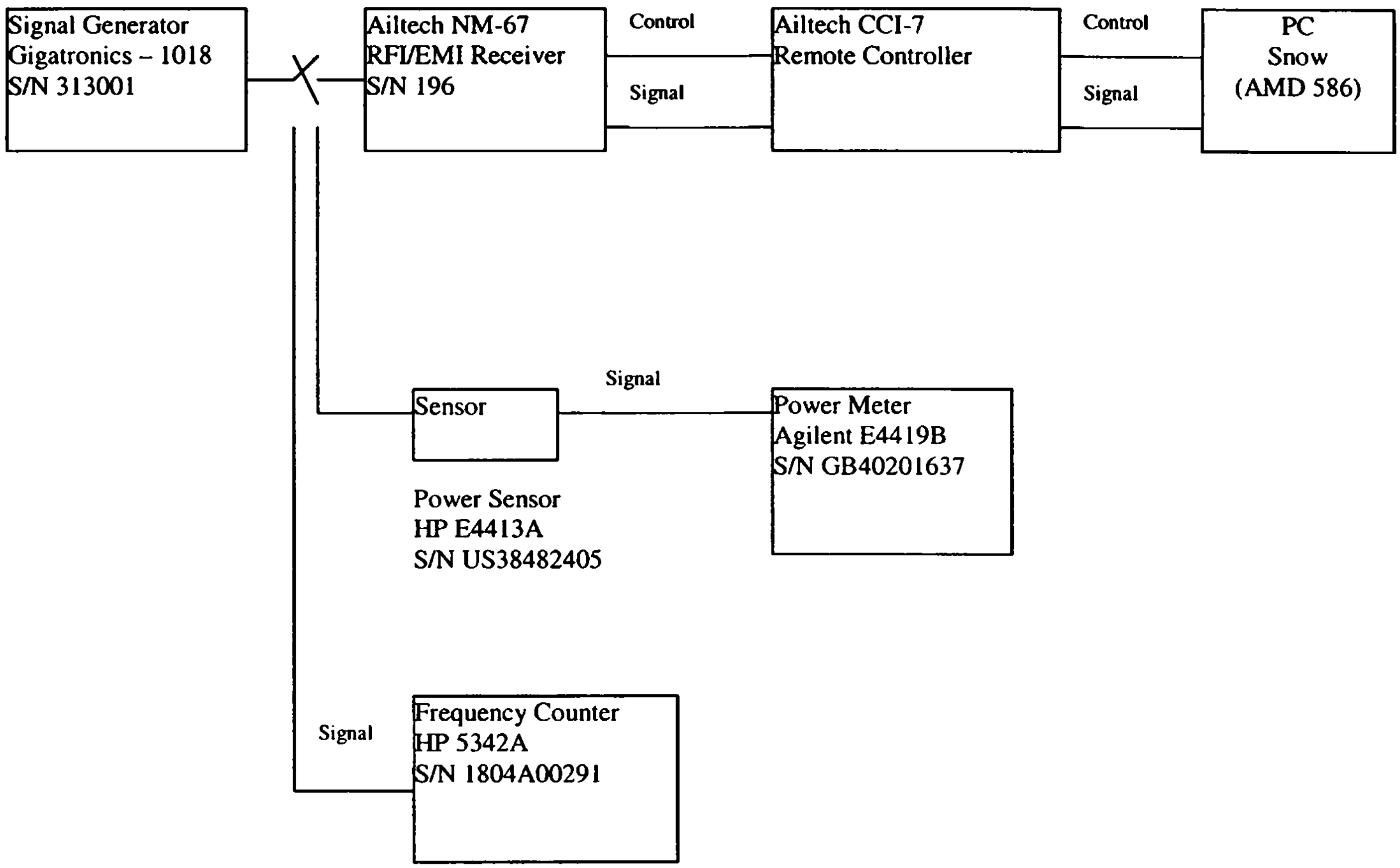


Table 1: Frequency Tuning and IF Gain Control Settings, August 2000

Frequency Scan (GHz)	RBW used (MHz)	---------- Binary values ------------ Zero	Span	Fine Tune 1 + 2	IF Gain	IF Gain determined at (MHz)
1.000 - 2.001	1.0	0	231	1914	35	1500
1.437 – 1.539	0.1	104	22	1914	35	1500
2.000 - 3.022	1.0	0	152	2808	36	2200
3.014 - 3.601	1.0	151	89	2808	33	3308
3.600 - 4.623	1.0	0	62	2964	45	4111
4.592 - 5.600	1.0	63	61	2964	86	4850
5.597 - 6.602	1.0	121	61	2964	35	6100
6.593 - 7.601	1.0	180	62	2964	34	7099
7.600 - 8.615	1.0	0	56	2872	32	8450
8.608 - 9.620	1.0	56	56	2872	34	9114
9.575 - 10.587	1.0	111	56	2872	35	10081
10.580 - 11.601	1.0	163	57	2872	36	11087
11.591 - 12.004	1.0	220	23	2872	37	11798
12.000 - 12.994	1.0	0	41	3148	16	12497
12.983 - 13.977	1.0	41	41	3148	22	13480
13.962 - 14.956	1.0	80	41	3148	13	14930
14.945 - 15.964	1.0	121	42	3148	22	15454
15.956 - 16.974	1.0	160	42	3148	28	16465
16.970 - 17.983	1.0	203	42	3148	25	17477
17.516 - 18.000	1.0	224	20	3148	16	17758
12.000 - 18.000	10.0	0	245	3320	37	12000

Table 2: Receiver-Controller System Setup

(Unless otherwise stated the following system setup was used for all tests)

Remote control mode via CCI-7
RMS Peak detection mode
CCI-7 frequency resolution = 1024 points
RBW = 1 MHz
Attenuator setting = 0 dB
Peak-hold time same for all tests and set by CCI-7 controller (not selectable)
IF Gain used from table 1
Frequency start, fine tune 1, 2, and scan ranges from table 1
Receiver frequency sweeping scan time = 35 seconds measured (byte = 9)
PC control software: collector.c for accuracy tests, cycle.c for repeatability tests.

Section 2: Performance Results

Test 1, Plots 1.1-1.3: Effects of frequency sweeping scan time on performance
Setup: scan times of 1.5 s, 35 s, and 320 s used for scans over 1-2 GHz.
Result: The system works equally as well at the fastest scan time of 1.5 s, and a slower scan time of 320 s; there was no scan loss in amplitude or increased error in frequency as a function of scan time. Any scan time chosen faster than (frequency scan range) / (0.7 x RBW)^2 will suffer scan loss in amplitude. For the fastest CCI-7 scan time of 1.5 s and narrowest RBW of 100 kHz, this corresponds to a maximum frequency span of 7.35 GHz. For scans much larger than 1 GHz this test should be performed.

Test 2, Plots 2.1-2.3: RBW performance
Setup: all 3 RBW settings of 100 kHz, 1 MHz, and 10 MHz were used.
Result: Remote control scans using RBW filters of 100 kHz, 1 MHz, and 10 MHz were performed, and found to be functional. In local mode the RBW filters were tested by tuning the receiver to +/- 0.5 x RBW away from injected signal frequency, where the detected signal strength was 6 dB down from peak, as expected.

Test 3, Plots 3.1-3.3: Attenuator performance
Setup: attenuator settings of 20 dB, 40 dB, and 60 dB were used.
Result: all three attenuator settings are functional. It is important to note that all three attenuator settings attenuate the receiver internal noise floor by 20 dB, but attenuate injected signals by 20 dB, 40 dB, and 60 dB accordingly. For injected signals the response (needle deflection and CCI-7 output) will be the input value minus attenuation, and as such this control works differently then typical spectrum analyzers.

Test 4, Plots 4.1-4.2: Dynamic range performance
Result: The receiver's response to power was tested at –52 dBm and –66 dBm at 1420 MHz and found to be functional to within 2.5 dB.

Test 5, Plots 5-5.1b: 1-2 GHz performance, detection accuracy and repeatability
Results A: In Plot 5 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 6 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 4.5 dB and also varies over the band.
Results B: In plots 5.1a and 5.1b 47 scans over 1-2 GHz were run and detections are shown for a single injection of 1420 MHz at –59 dBm; detection repeatability were +/- 1 MHz and +/- 0.5 dB.

Test 6, Plots 6a-6.1b: 2-3.6 GHz performance, detection accuracy and repeatability
Results A: In Plot 6a and 6b three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 9.8 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 0.71 dB and varies over the band.

Results B: In plots 6.1a and 6.1b 47 scans over 2-3 GHz were run, and detections are shown for a single injection of 2200 MHz at –59 dBm; detection repeatability were +/- 1 MHz and +/- 0.5 dB.

Test 7, Plot 7.1: 3.6-4.6 GHz performance, detection accuracy
Results: In Plot 7.1 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 18 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.41 dB and varies over the band.

Test 8, Plots 8-8.1b: 4.6-5.6 GHz performance, detection accuracy and repeatability
Results A: In plot 8 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 22 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 7.53 dB and varies over the band.
Results B: In plots 8.1a and 8.1b 47 scans over 4.6-5.6 GHz were run, and detections are shown for a single injection of 4850 MHz at –59 dBm; detection repeatability were +/- 1 MHz and +/- 1 dB.

Test 9, Plot 9: 5.6-6.6 GHz performance, detection accuracy
Results: In plot 9 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 14 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.88 dB and varies over the band.

Test 10, Plot 10: 6.6-7.6 GHz performance, detection accuracy
Results: In plot 10 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 12 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.88 dB and varies over the band.

Test 11, Plots 11-11.1b: 7.6-8.6 GHz performance, detection accuracy and repeatability
Results A: In plot 11 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 12 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.88 dB and varies over the band.
Results B: In plots 11.1a and 11.1b 47 scans over 7.6-8.6 GHz were run, and detections are shown for a single injection of 8450 MHz at –59 dBm; detection repeatability were +/- 1 MHz and +/- 0.5 dB.

Test 12, Plots 12: 8.6-9.6 GHz performance, detection accuracy
Results: In plot 12 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 11 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.65 dB and varies over the band.

Test 13, Plot 13: 9.6-10.6 GHz performance, detection accuracy
Results: In plot 13 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 21 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.18 dB and varies over the band.

Test 14, Plot 14: 10.6-11.6 GHz performance, detection accuracy
Results: In plot 14 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 14 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.41 dB and varies over the band.

Test 15, Plot 15: 11.6-12 GHz performance, detection accuracy
Results: In plot 15 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 15 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.41 dB and varies over the band.

Test 16, Plot 16: 12-13 GHz performance, detection accuracy
Results: In plot 16 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 16 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.18 dB and varies over the band.

Test 17, Plot 17: 13-14 GHz performance, detection accuracy
Results: In plot 17 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 15 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 0.84 dB and varies over the band.

Test 18, Plots 18-18.1b: 14-15 GHz performance, detection accuracy and repeatability
Results A: In plot 18 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 9 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.65 dB and varies over the band.
Results B: In plots 18.1a and 18.1b 47 scans over 14-15 GHz were run, and detections are shown for a single injection of 14.956 GHz at –59 dBm; detection repeatability were +/- 1 MHz and +/- 1 dB.

Test 19, Plot 19: 15-16 GHz performance, detection accuracy
Results: In plot 19 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 7 MHz, and the error is

non constant and non linear across the band. The amplitude error was a maximum of 2.12 dB and varies over the band.

Test 20, Plot 20: 16-17 GHz performance, detection accuracy
Results: In plot 20 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 3 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.65 dB and varies over the band.

Test 21, Plot 21: 17-18 GHz performance, detection accuracy
Setup: IF Gain set at ?? GHz
Results: In plot 21 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 9 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.65 dB and varies over the band.

Test 22, Plot 22: 17.5-18 GHz performance, detection accuracy
Results: In plot 22 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 9 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 2.59 dB and varies over the band.

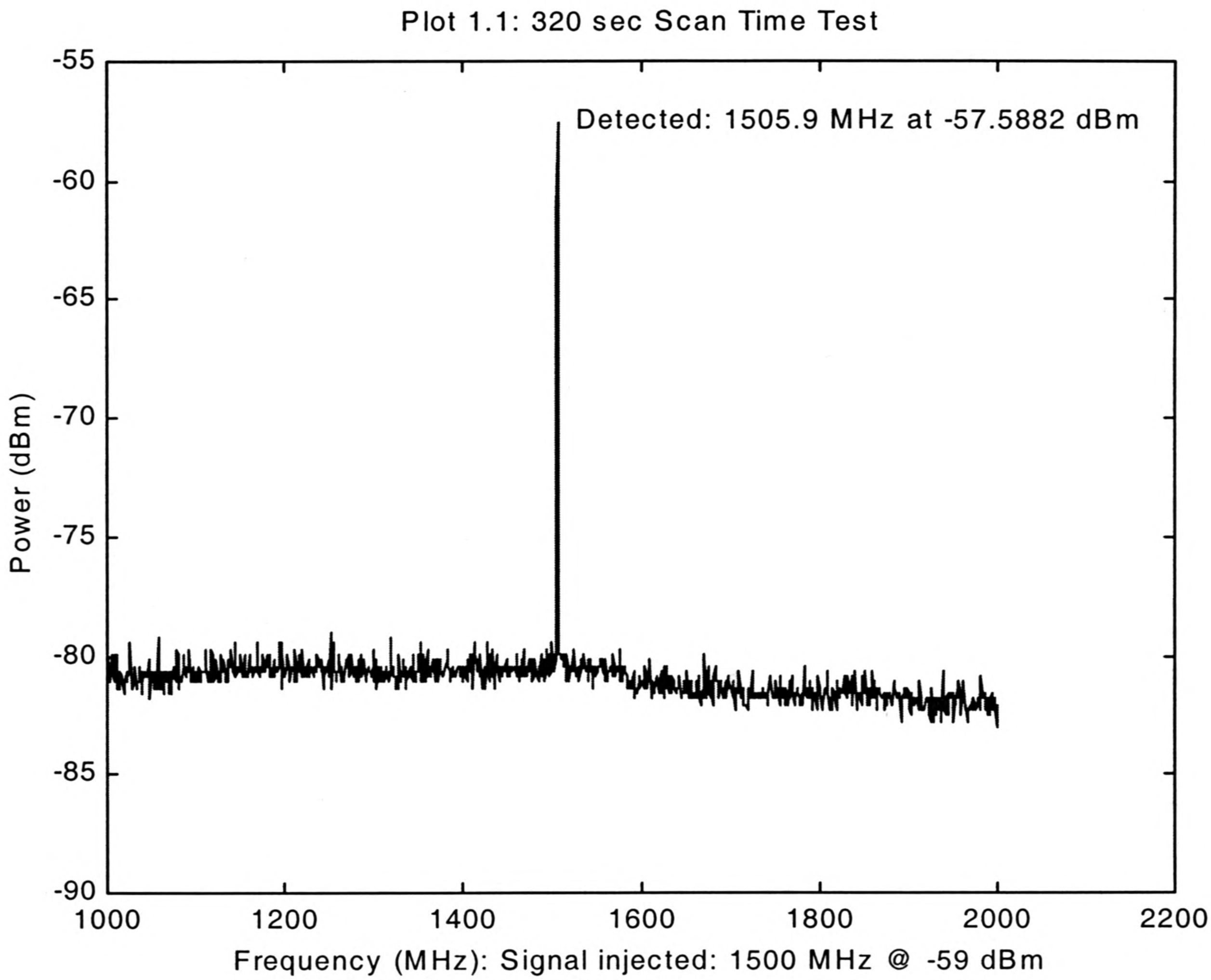
Test 23, Plots 23: Oversampling the receiver with the CCI-7 controller
Setup: RBW 10 MHz, span = 1000 MHz, # CCI points = 1024
Results: Oversampling the receiver by choosing a small value for [(frequency span) / (RBW)], results in tracing out the RBW filter shape in the controller output. Setting the span/RBW large will prevent tracing out the filter, and hence misinterpreting the filter shape for broad band RFI. For (#sampled points) >> [(frequency span) / (RBW)], the RBW filter shape is more defined in the controller output.

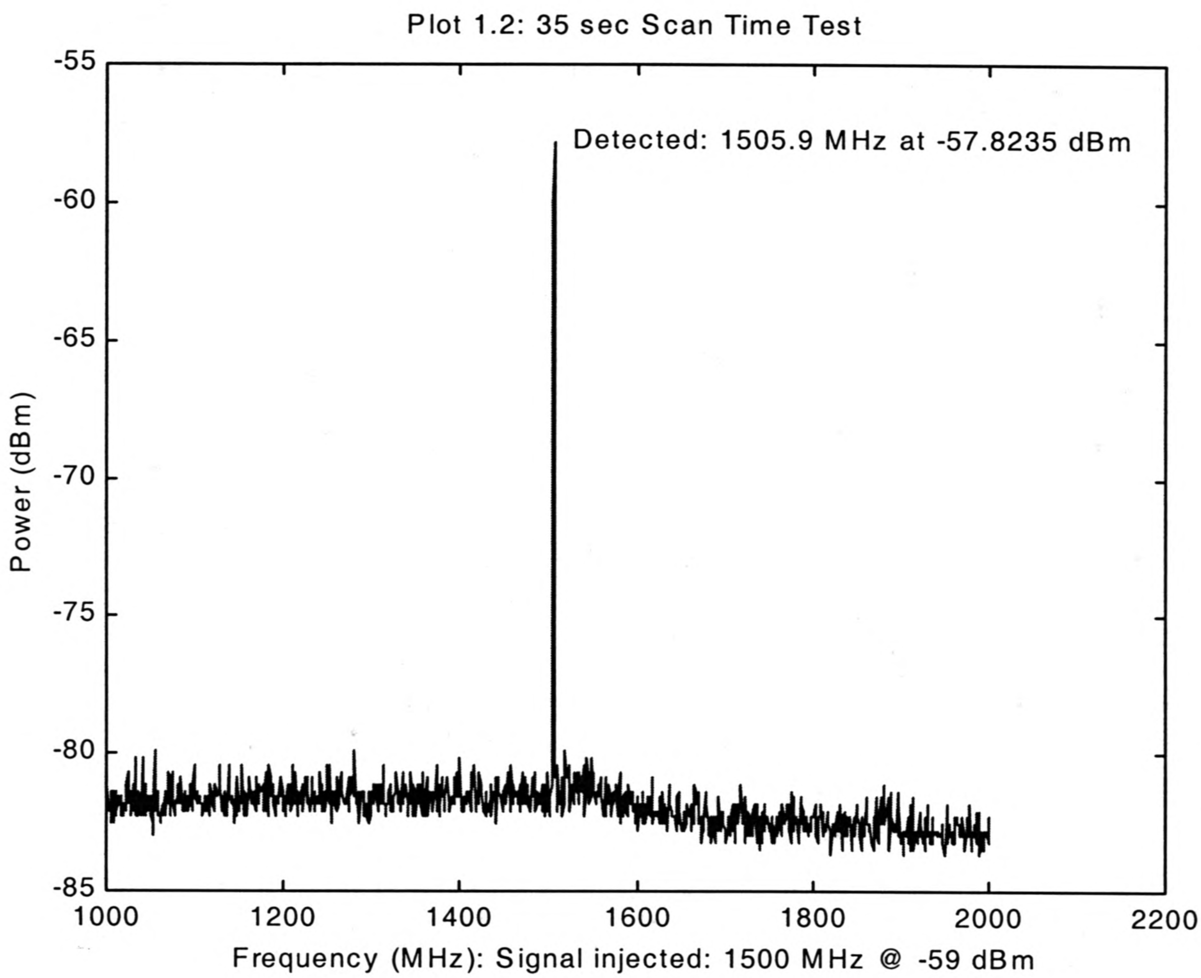
Test 24, Plots 24-24.3: Undersampling the receiver with the CCI-7 controller, missing CW signals
Setup: RBW 0.1 MHz, # CCI frequency bins = 64, scan times of 320s and 35s used
Objective: To demonstrate that if the number of times the controller discretely samples the receiver is small compared to the ratio of (frequency span) / (RBW), and an injected signal is between sampled points, and the sampling period is longer than the receiver peak-hold time, the controller will miss CW signals.
Results: Undersampling the receiver can result in missing CW signals. Also see plots 25a and 25b.

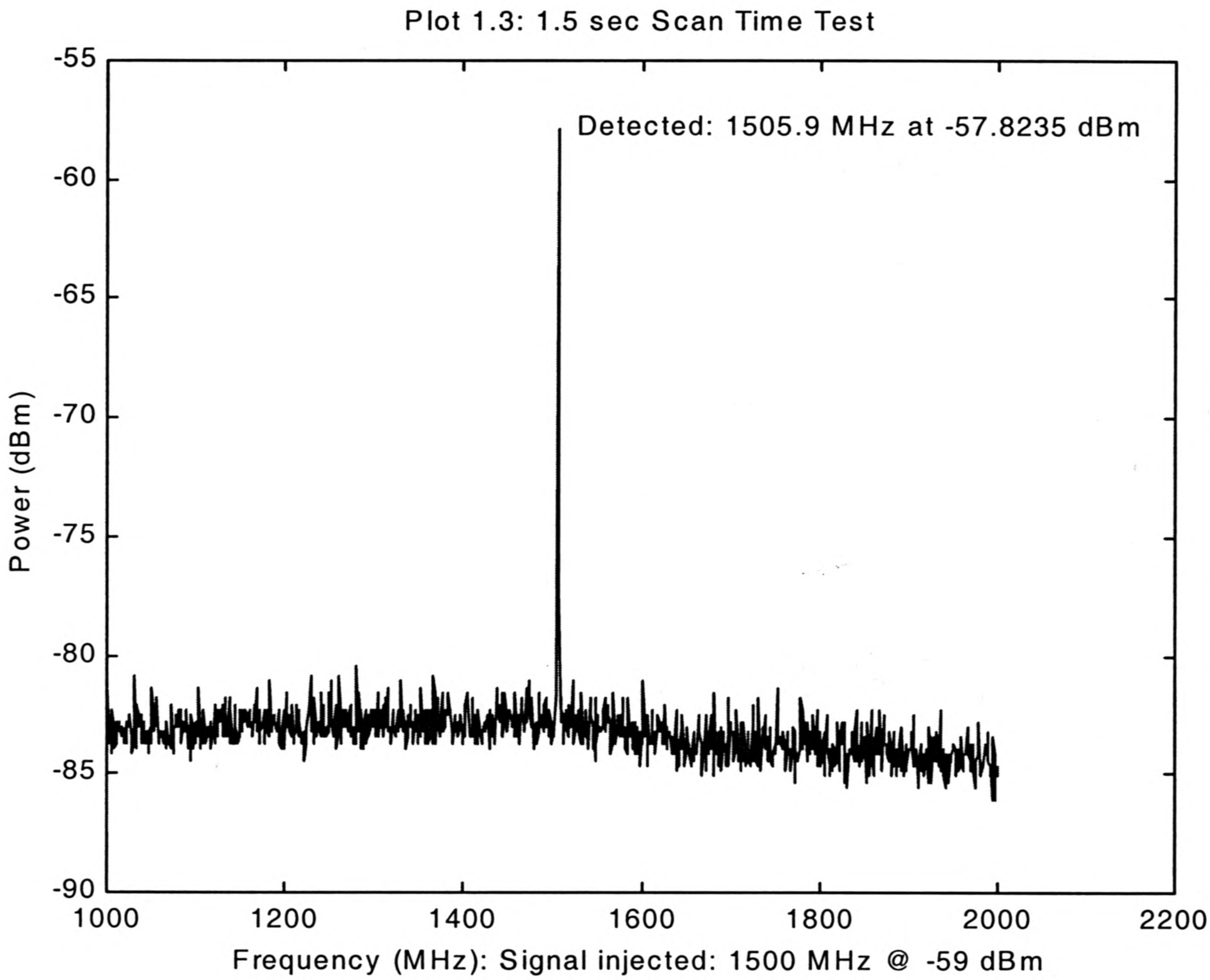
Test 25, Plots 25a and 25b: Effects of receiver Peak-hold time on CCI-7 output
Setup: In plot 25.a # CCI frequency bins = 1024, in plot 25b # CCI frequency bins = 64.
Objective: The peak-hold is the amount of time the receiver power gauge needle is held at maximum deflection while responding to the strongest signal in a scan. This test was to

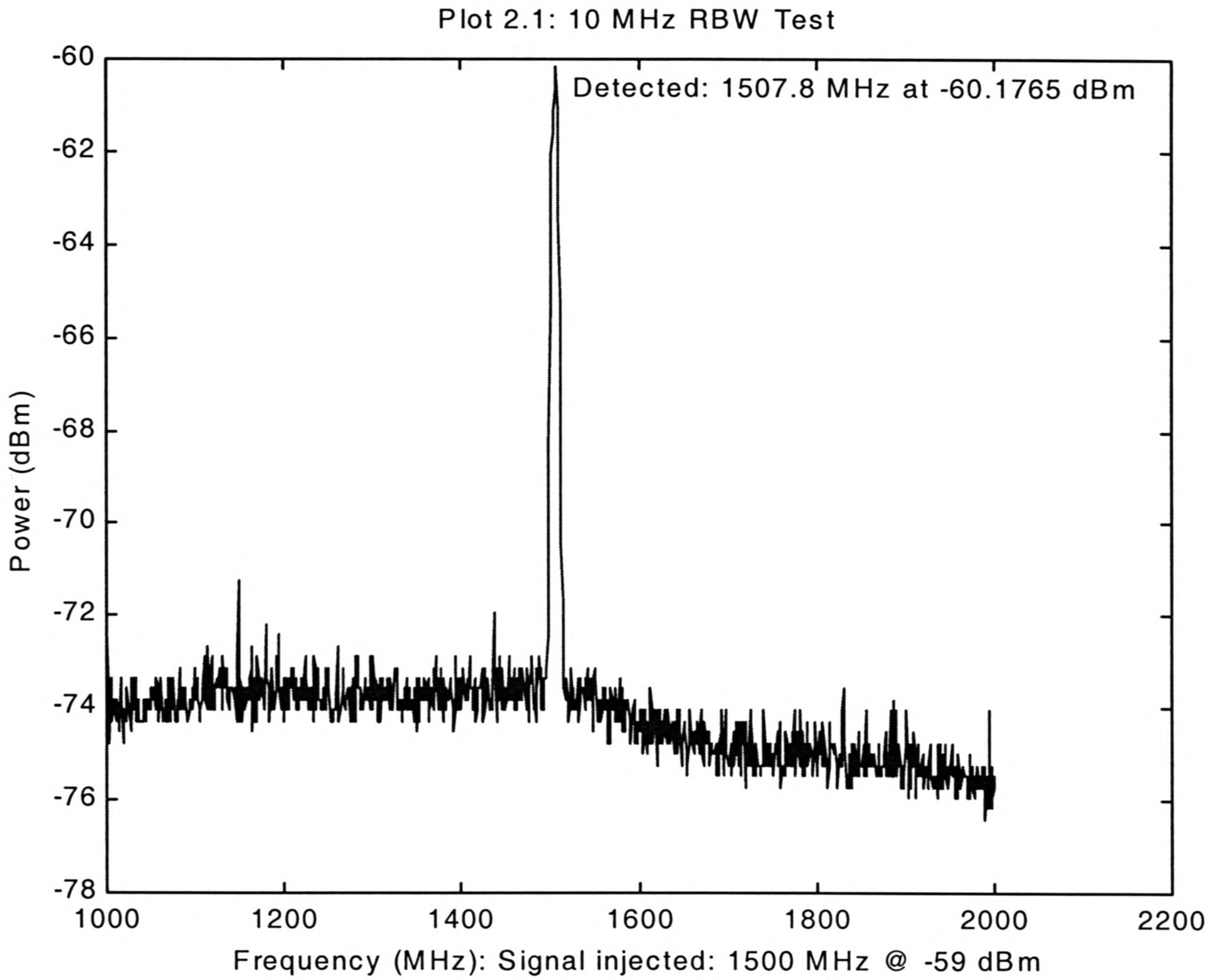
determine if while in remote mode the peak-hold time shows up in the controller output, possibly distorting the shape of the signal. For this test, the specified period at which the controller samples the receiver defined by [scan time / # CCI frequency samples], was chosen small compared to the peak-hold time (which is fixed in remote mode).

Result: For peak-hold time long compared to the sampling period the peak-hold effects are not significantly present in the controller output, regardless of the rate at which the controller samples the receiver and hence does not distort the data. These two setups were chosen such that had a 3 sec peak-hold time been reflected in the CCI output the peak would have been repeated over 90 MHz (90 bins in 25a and 5 bins in 25b); the peak appeared in 3 consecutive frequency bins in 25a, and only 1 frequency bin in 25b, suggesting a very short peak-hold as seen by the controller. Also see plots 24-24.3.

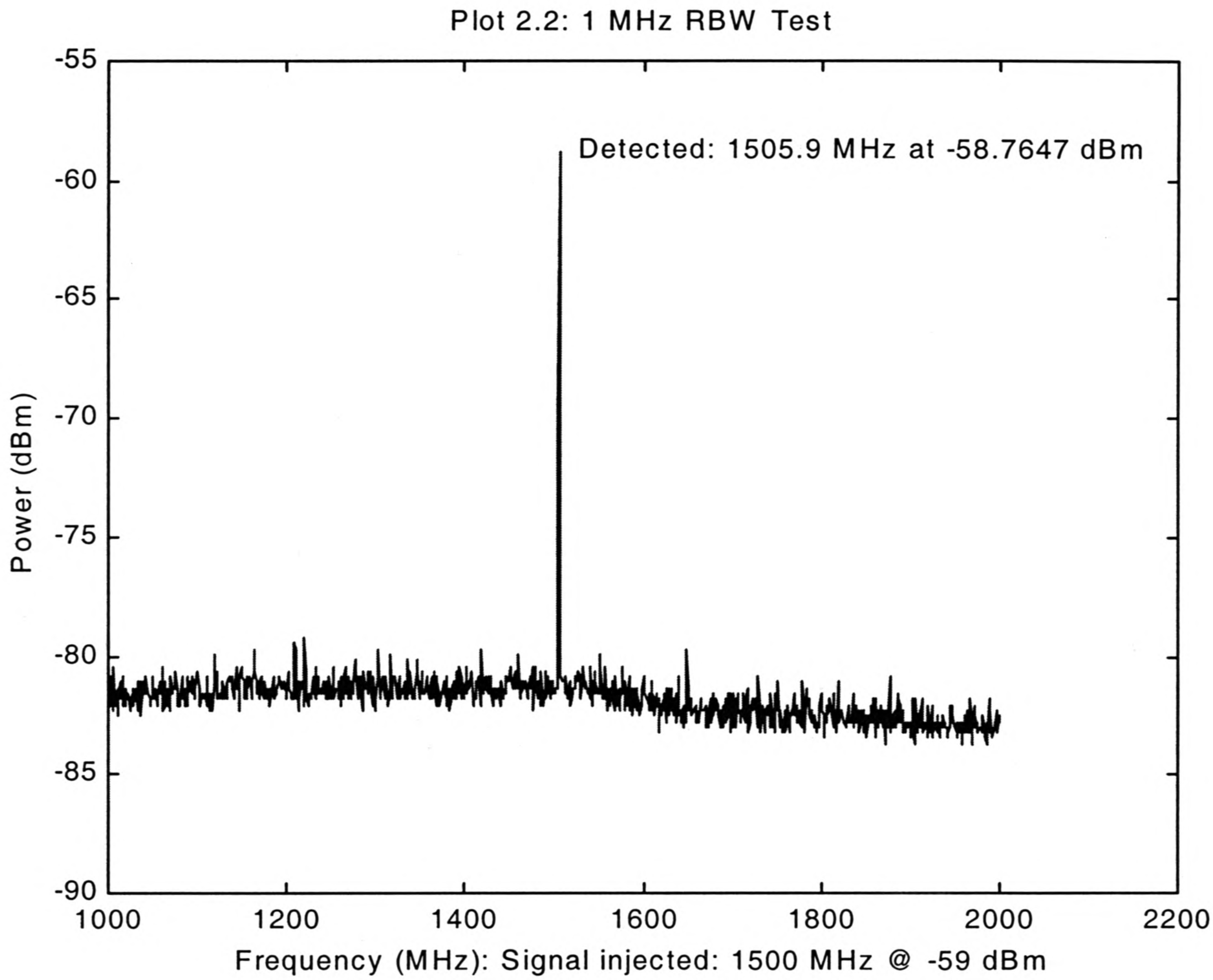

Plot 1.1: 320 sec Scan Time Test
Detected: 1505.9 MHz at -57.5882 dBm
Power (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Signal injected: 1500 MHz @ -59 dBm

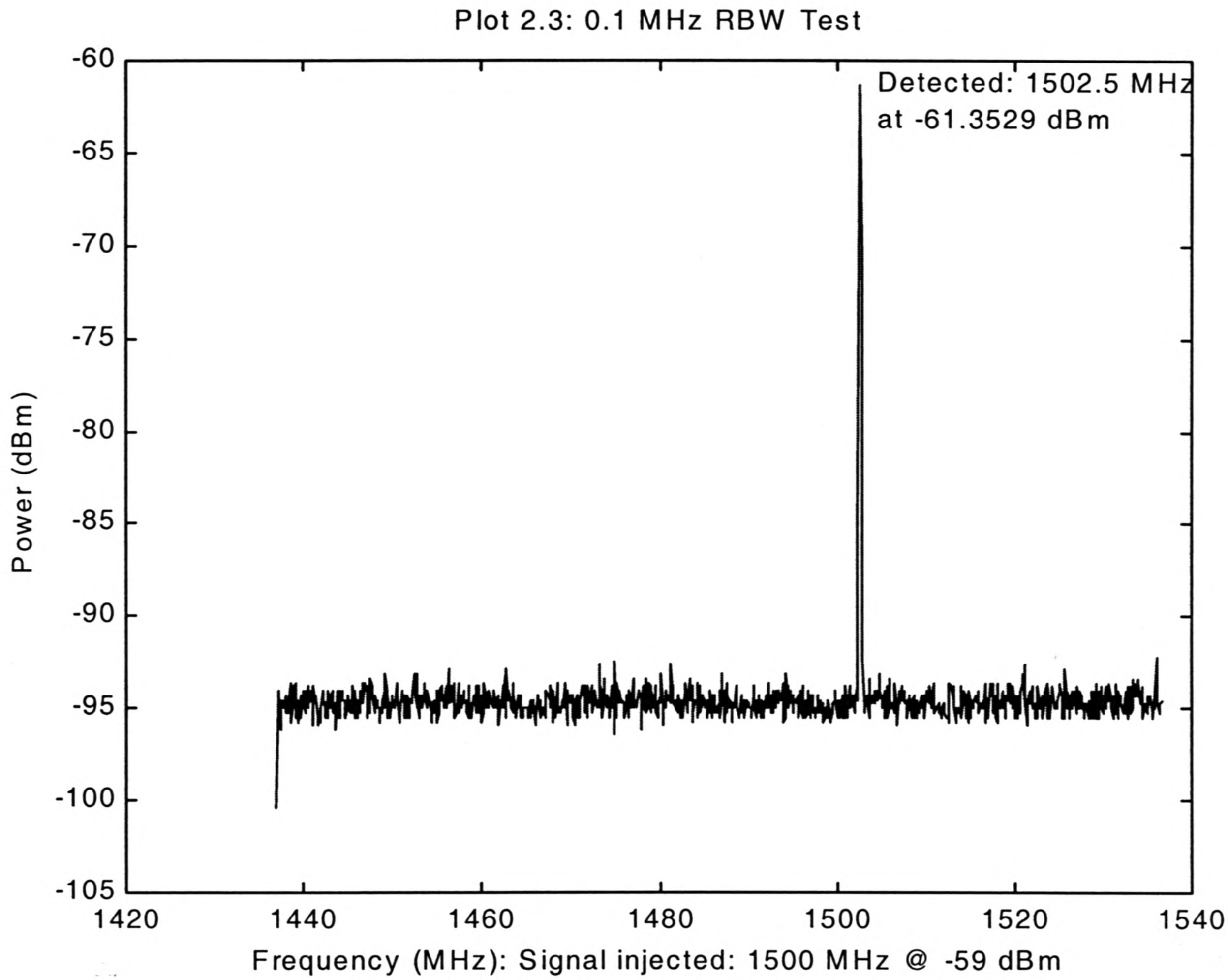

Plot 1.2: 35 sec Scan Time Test
Detected: 1505.9 MHz at -57.8235 dBm
Power (dBm)
-55
-60
-65
-70
-75
-80
-85
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Signal injected: 1500 MHz @ -59 dBm


Plot 1.3: 1.5 sec Scan Time Test
Detected: 1505.9 MHz at -57.8235 dBm
Power (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Signal injected: 1500 MHz @ -59 dBm

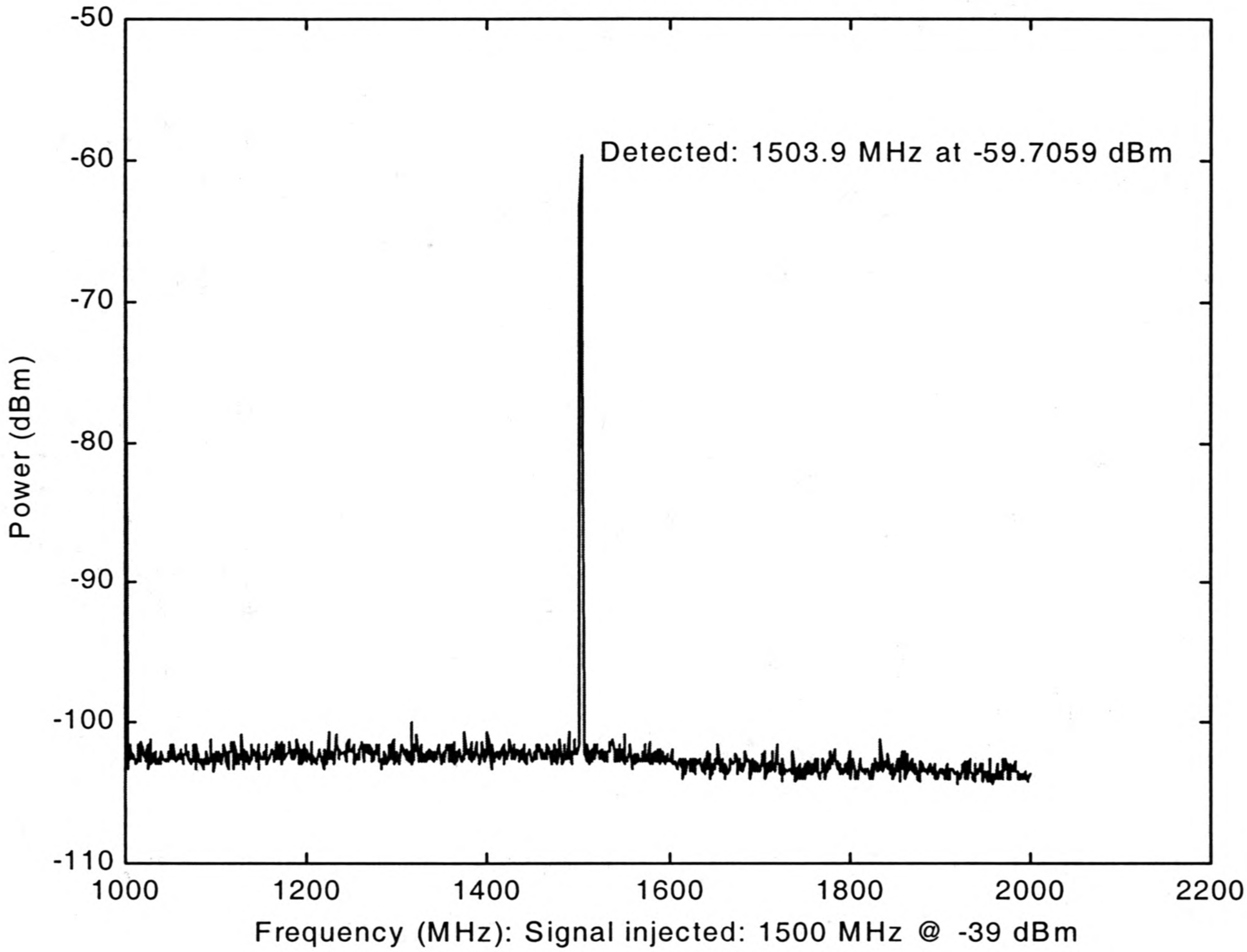


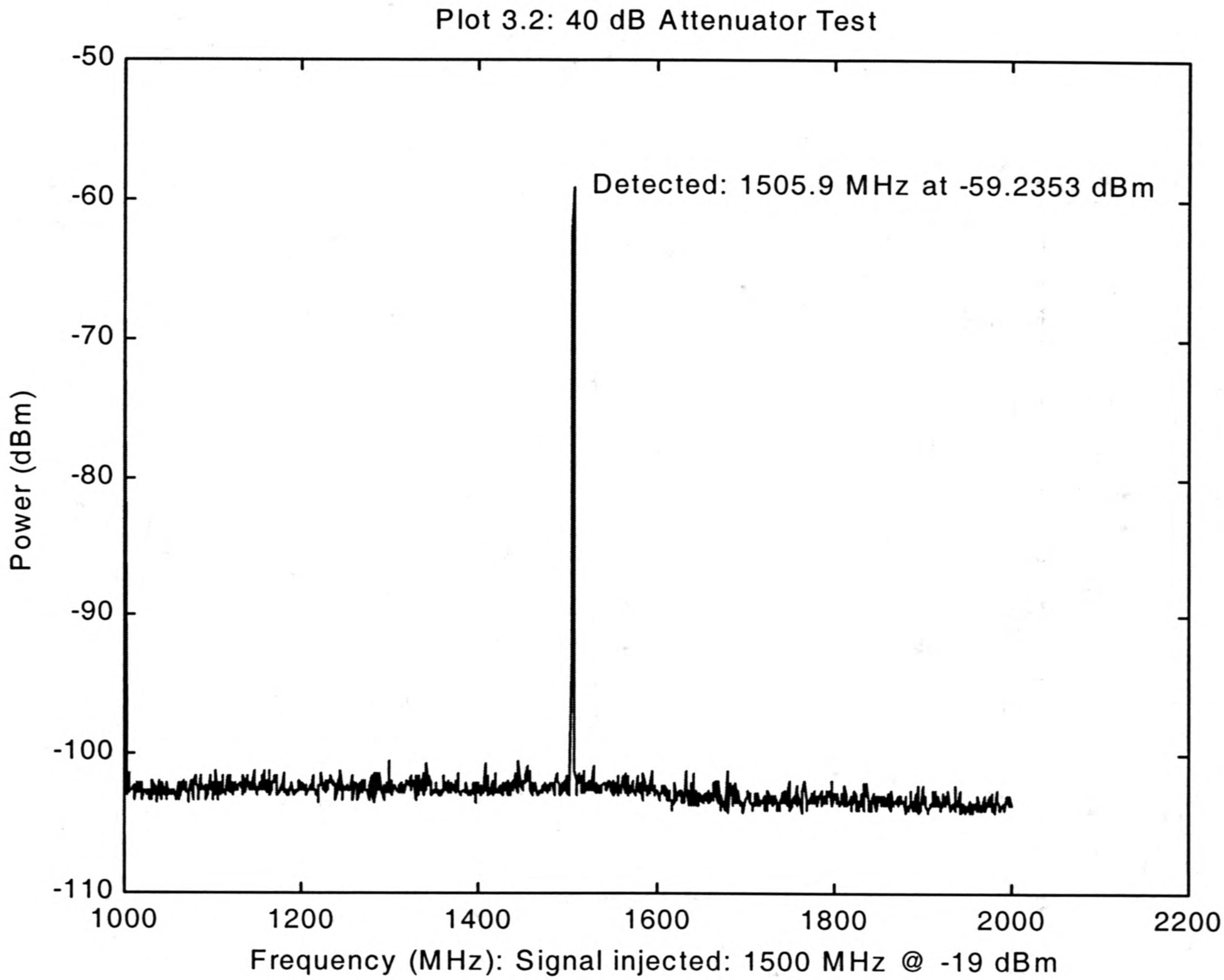
Plot 2.1: 10 MHz RBW Test
Detected: 1507.8 MHz at -60.1765 dBm
-60
-62
-64
-66
-68
-70
-72
-74
-76
-78
Power (dBm)
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Signal injected: 1500 MHz @ -59 dBm

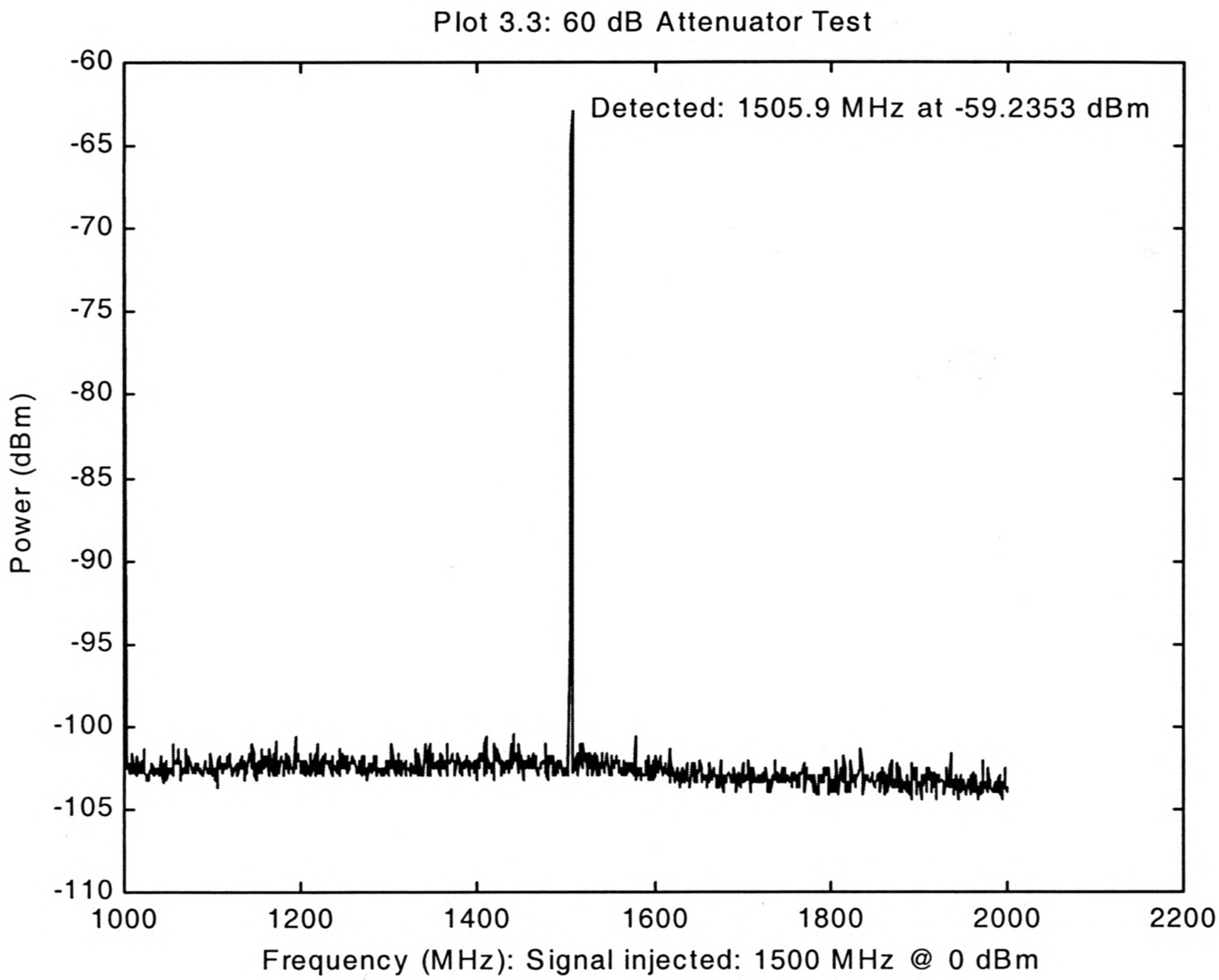

Plot 2.2: 1 MHz RBW Test
Detected: 1505.9 MHz at -58.7647 dBm
-55
-60
-65
-70
-75
-80
-85
-90
Power (dBm)
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Signal injected: 1500 MHz @ -59 dBm

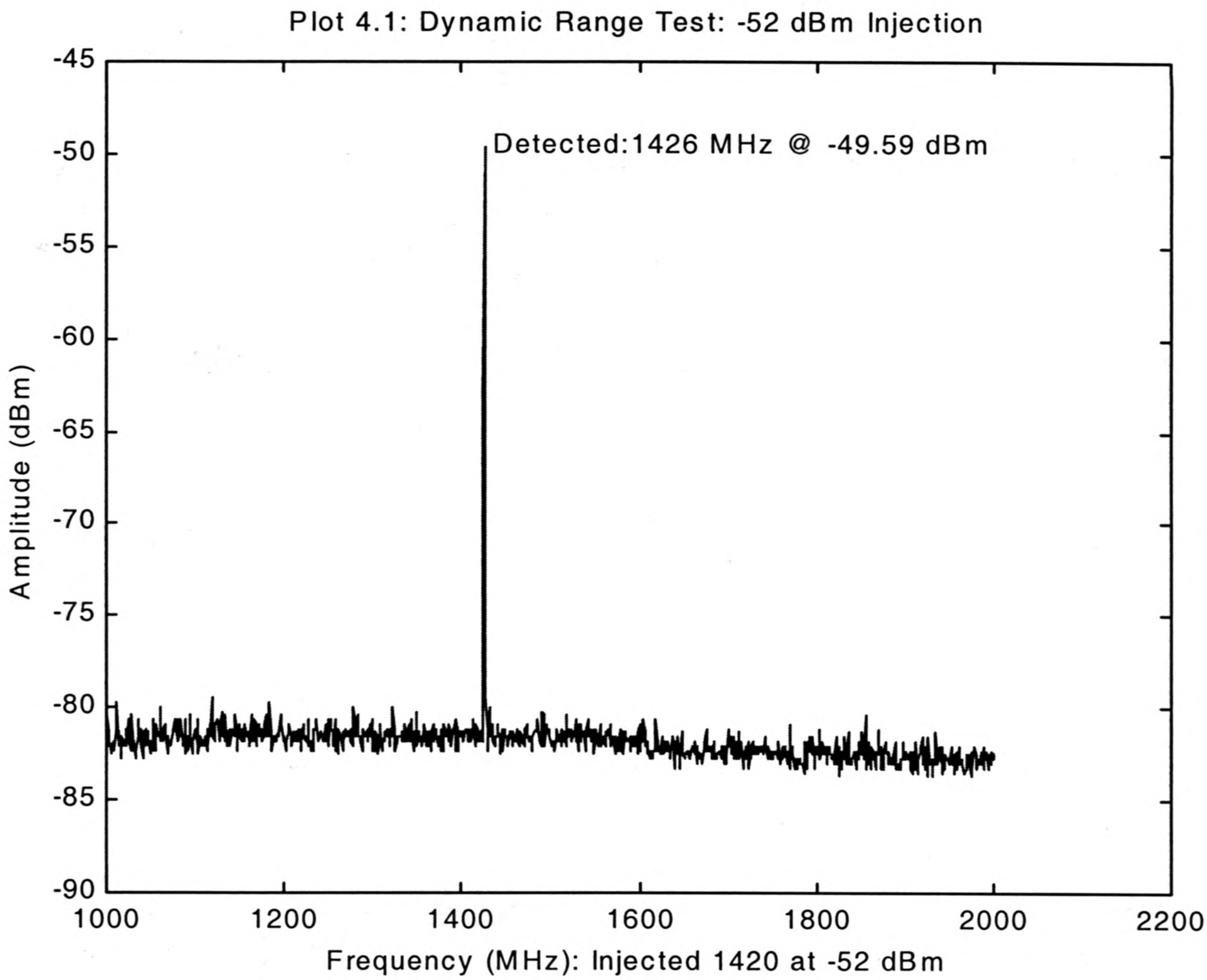

Plot 2.3: 0.1 MHz RBW Test
Detected: 1502.5 MHz
at -61.3529 dBm
Power (dBm)
-60
-65
-70
-75
-80
-85
-90
-95
-100
-105
1420
1440
1460
1480
1500
1520
1540
Frequency (MHz): Signal injected: 1500 MHz @ -59 dBm

Plot 3.1: 20 dB Attenuator Test

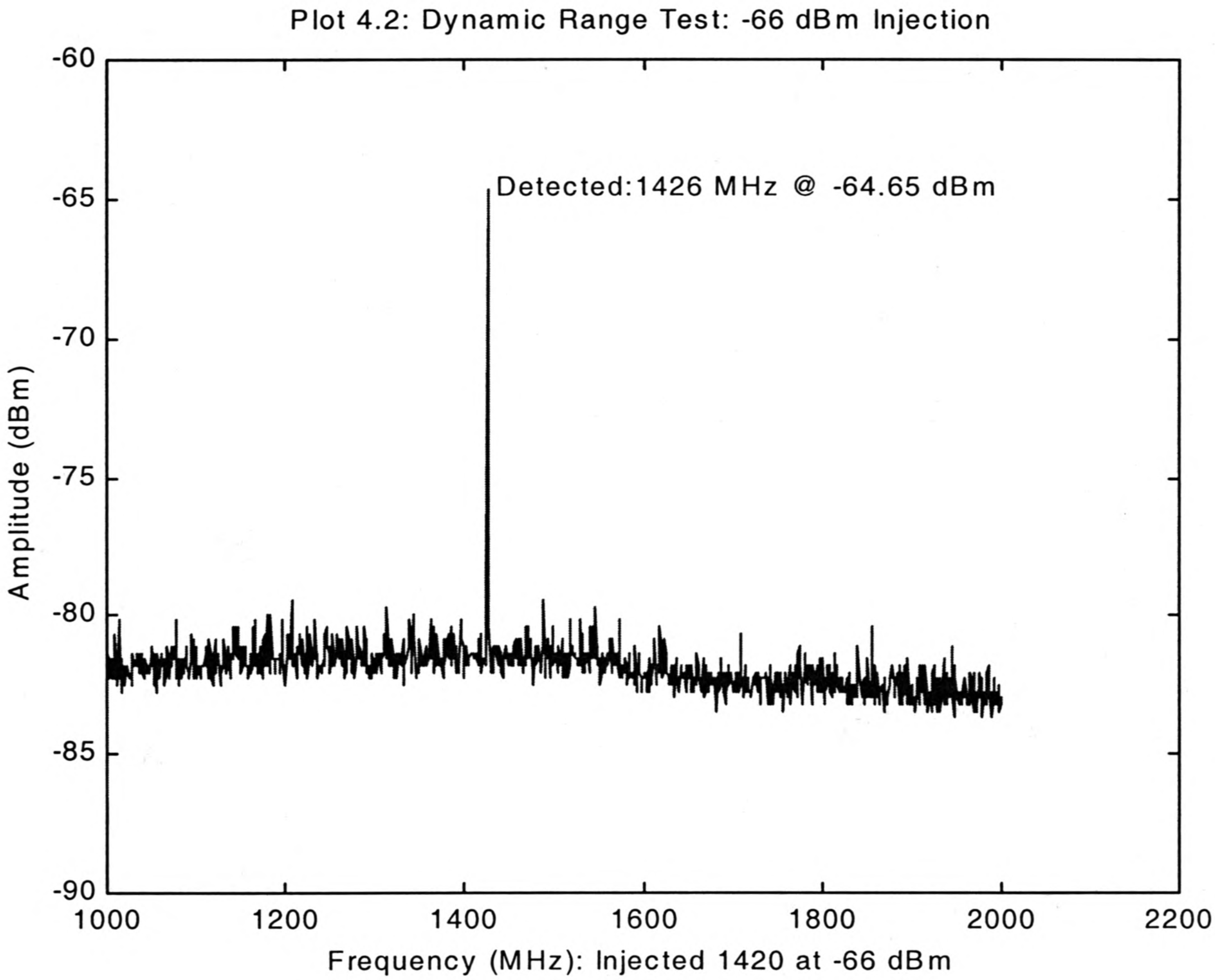


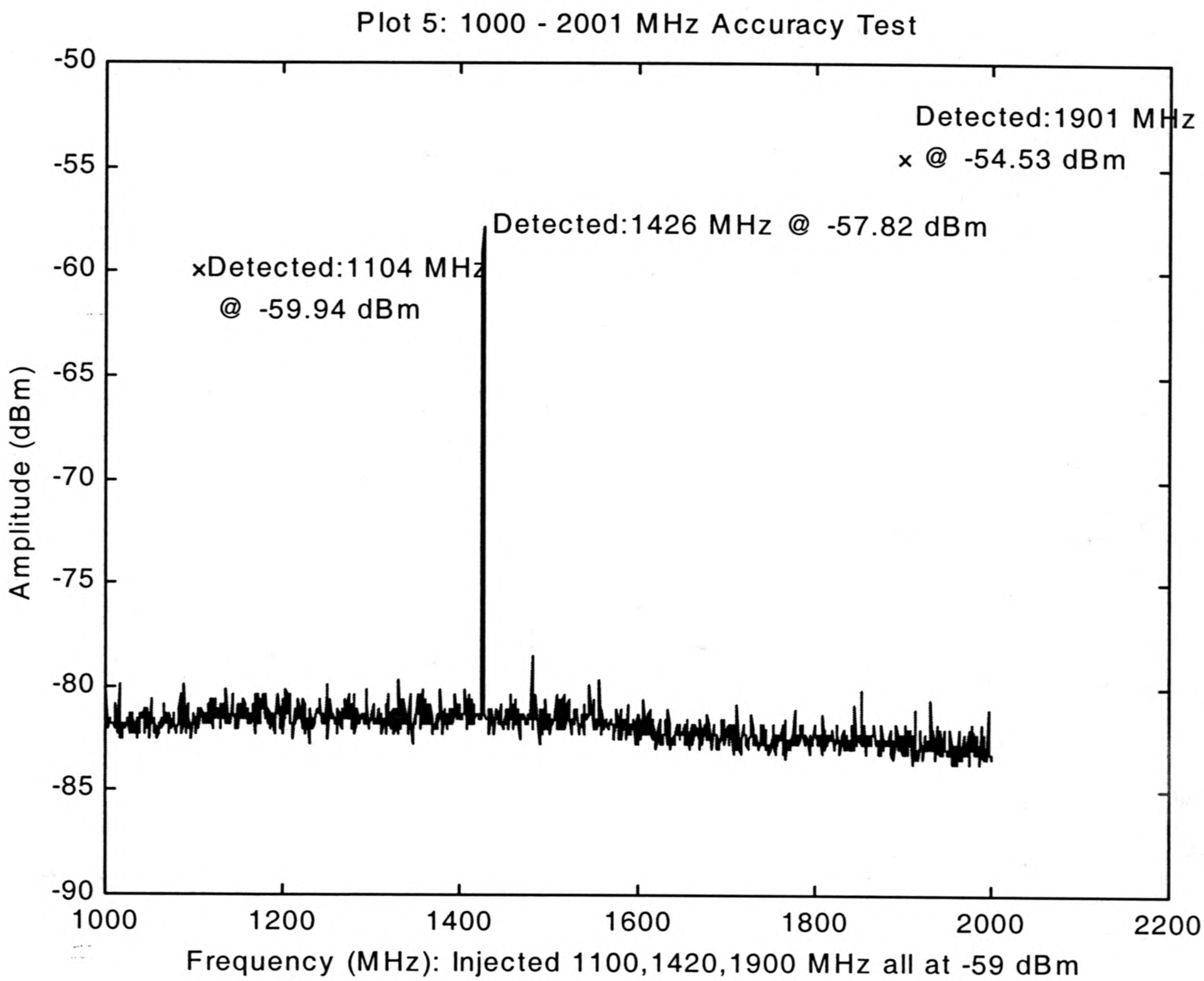

Plot 3.2: 40 dB Attenuator Test
Detected: 1505.9 MHz at -59.2353 dBm
Power (dBm)
-50
-60
-70
-80
-90
-100
-110
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Signal injected: 1500 MHz @ -19 dBm

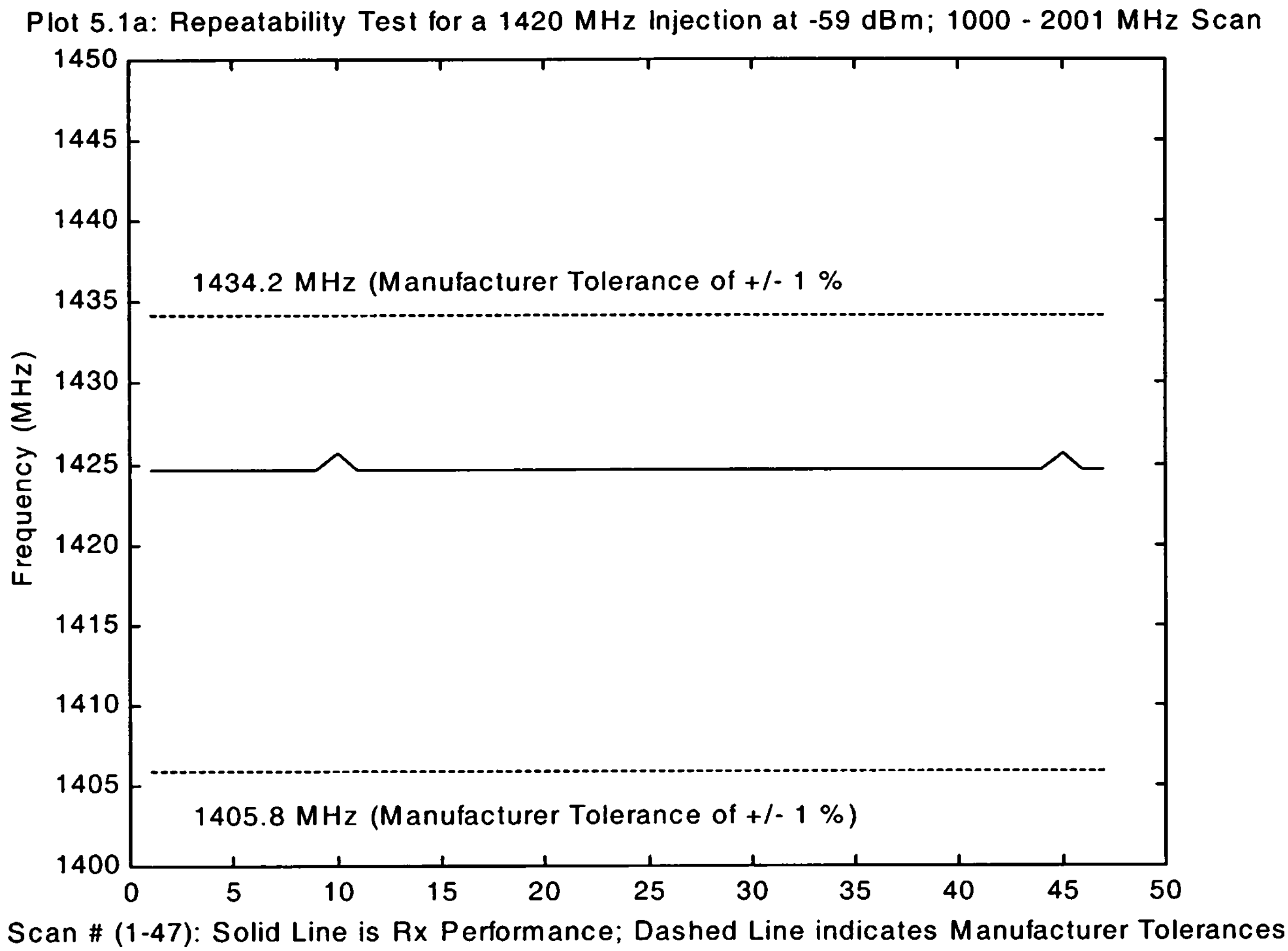

Plot 3.3: 60 dB Attenuator Test
Detected: 1505.9 MHz at -59.2353 dBm
Power (dBm)
-60
-65
-70
-75
-80
-85
-90
-95
-100
-105
-110
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Signal injected: 1500 MHz @ 0 dBm



Plot 4.1: Dynamic Range Test: -52 dBm Injection
Detected:1426 MHz @ -49.59 dBm
Amplitude (dBm)
-45
-50
-55
-60
-65
-70
-75
-80
-85
-90
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Injected 1420 at -52 dBm

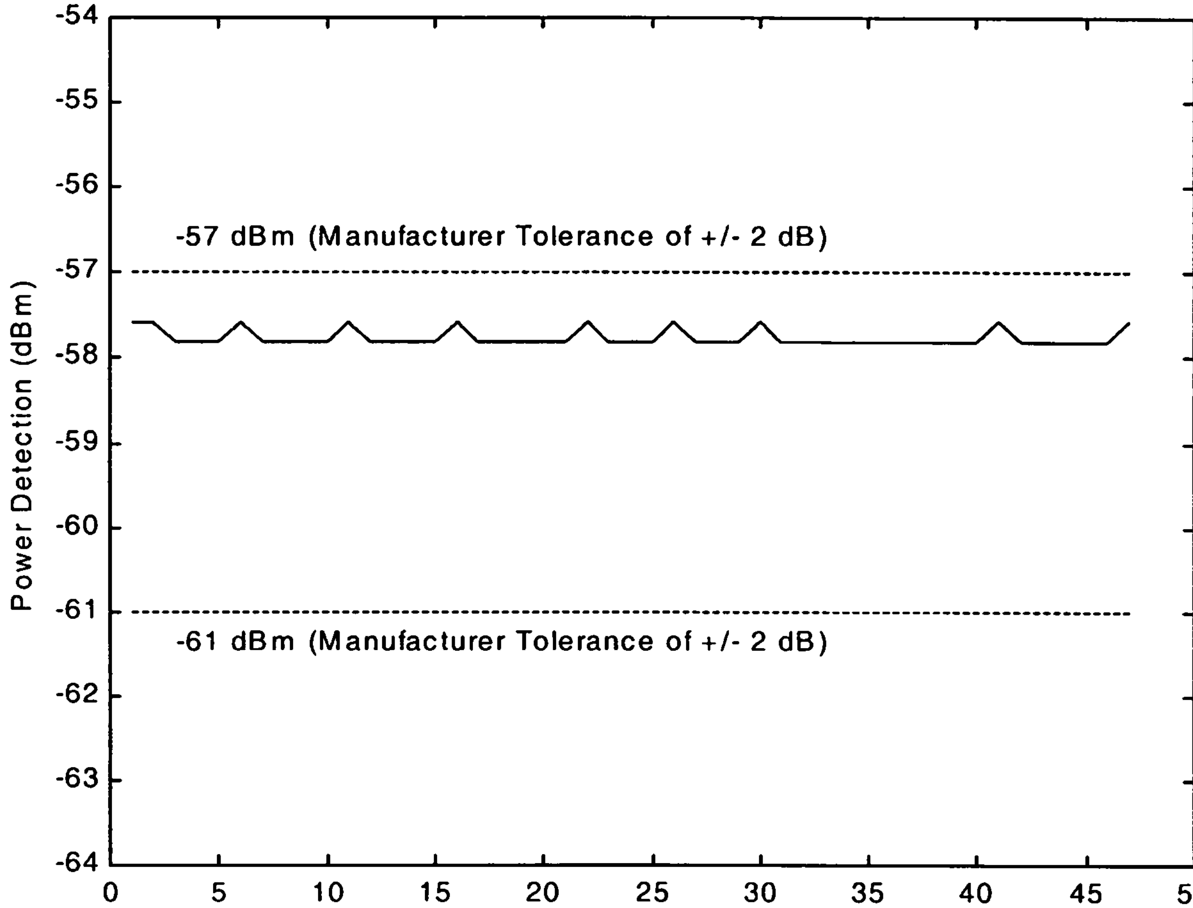

Plot 4.2: Dynamic Range Test: -66 dBm Injection
Detected:1426 MHz @ -64.65 dBm
-60
-65
-70
-75
-80
-85
-90
Amplitude (dBm)
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Injected 1420 at -66 dBm


Plot 5: 1000 - 2001 MHz Accuracy Test
Detected:1901 MHz
x @ -54.53 dBm
Detected:1426 MHz @ -57.82 dBm
xDetected:1104 MHz
@ -59.94 dBm
Amplitude (dBm)
-50
-55
-60
-65
-70
-75
-80
-85
-90
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Injected 1100,1420,1900 MHz all at -59 dBm

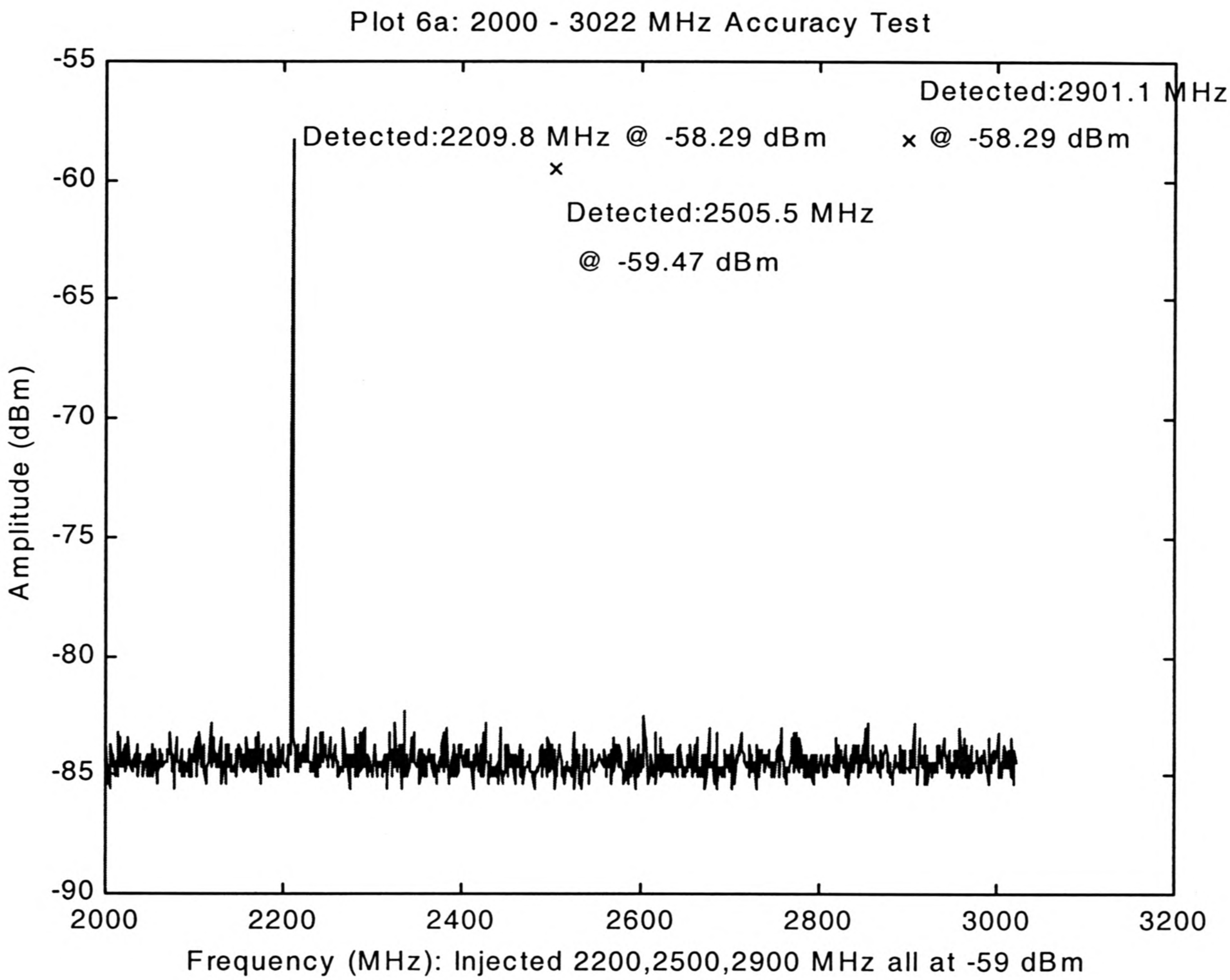


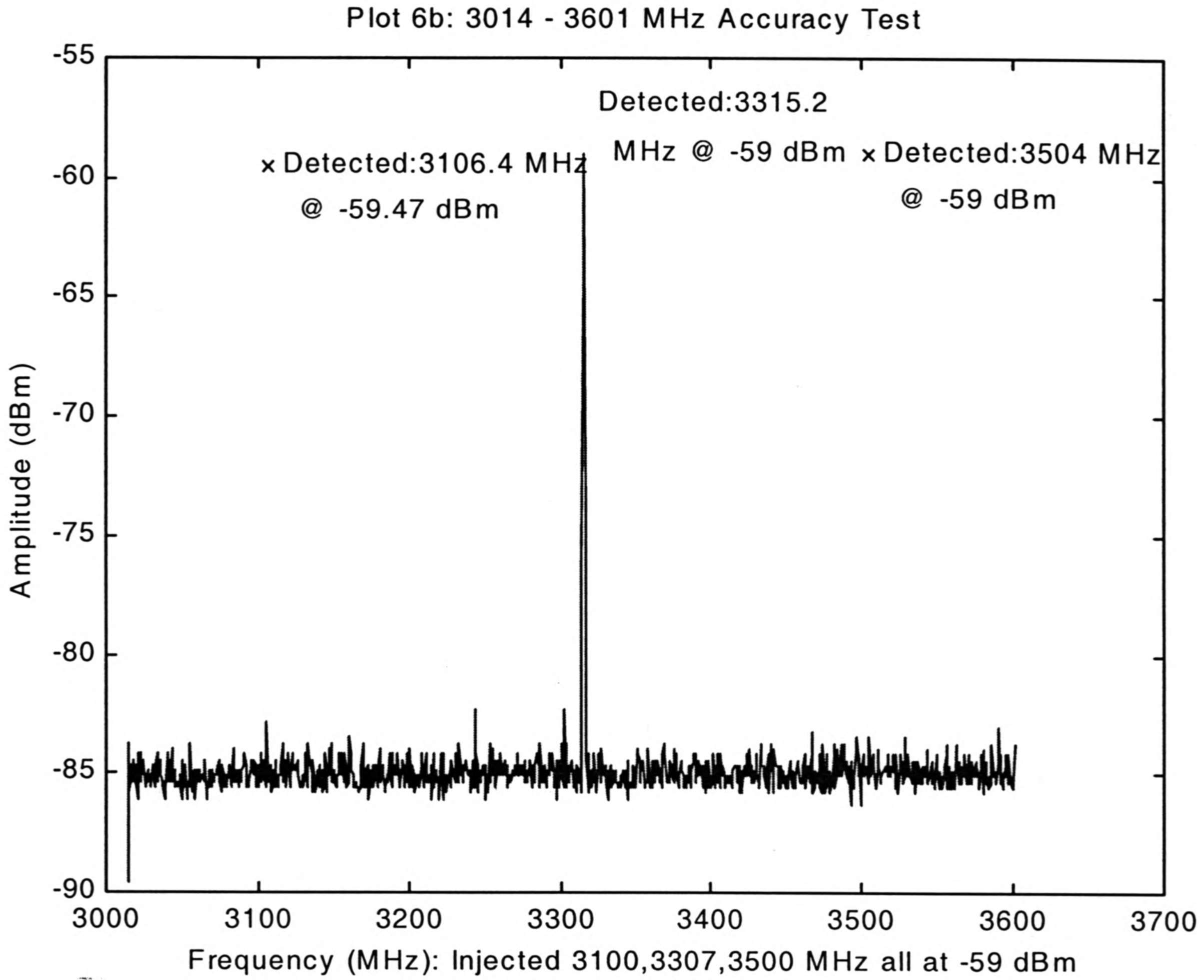
Plot 5.1a: Repeatability Test for a 1420 MHz Injection at -59 dBm; 1000 - 2001 MHz Scan
1450
1445
1440
1435
1430
1425
1420
1415
1410
1405
1400
Frequency (MHz)
1434.2 MHz (Manufacturer Tolerance of +/- 1 %
1405.8 MHz (Manufacturer Tolerance of +/- 1 %)
0
5
10
15
20
25
30
35
40
45
50
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerances

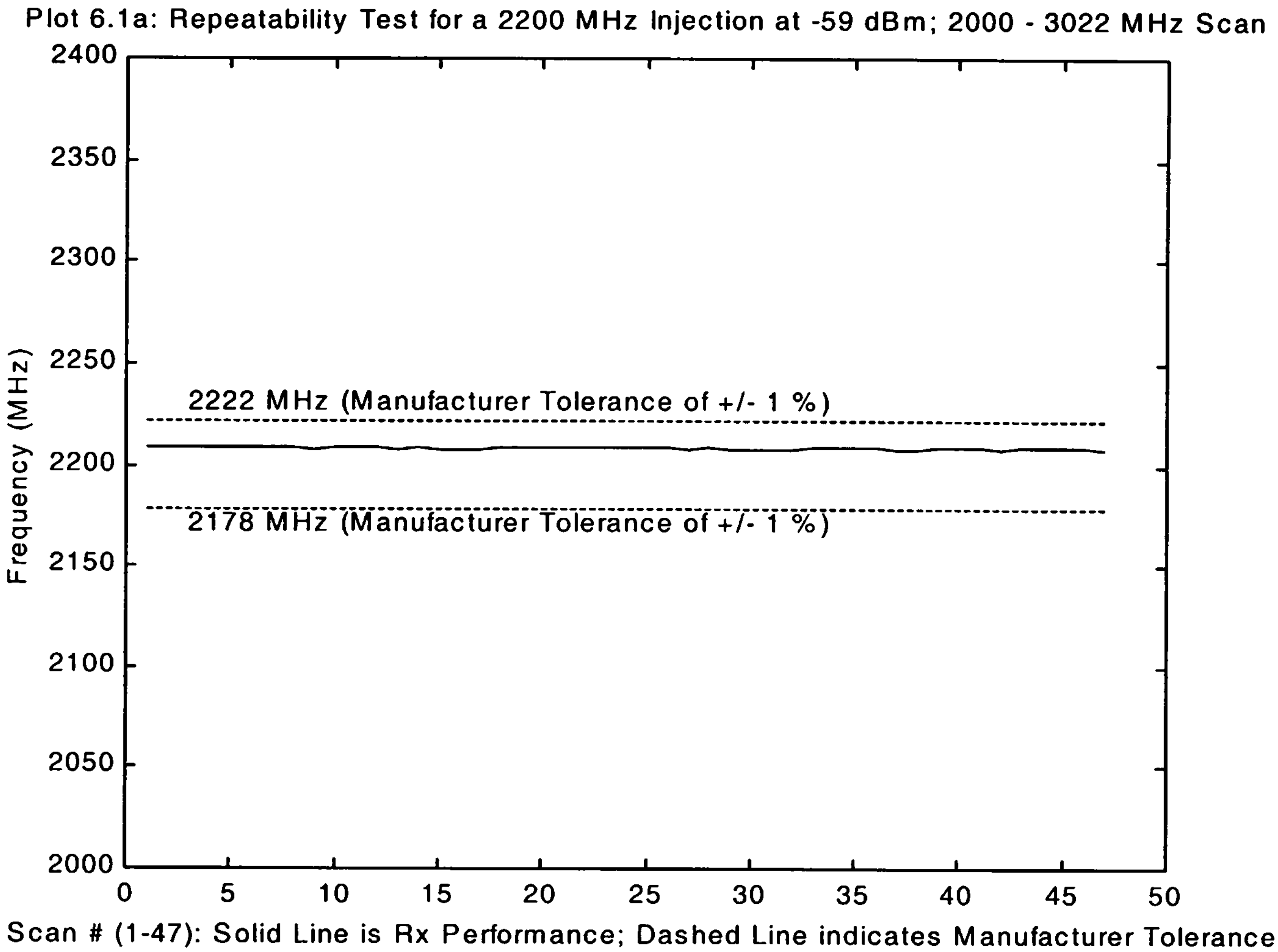
Plot 5.1b: Repeatability Test for a 1420 MHz Injection at -59 dBm; 1000 - 2001 MHz Scan



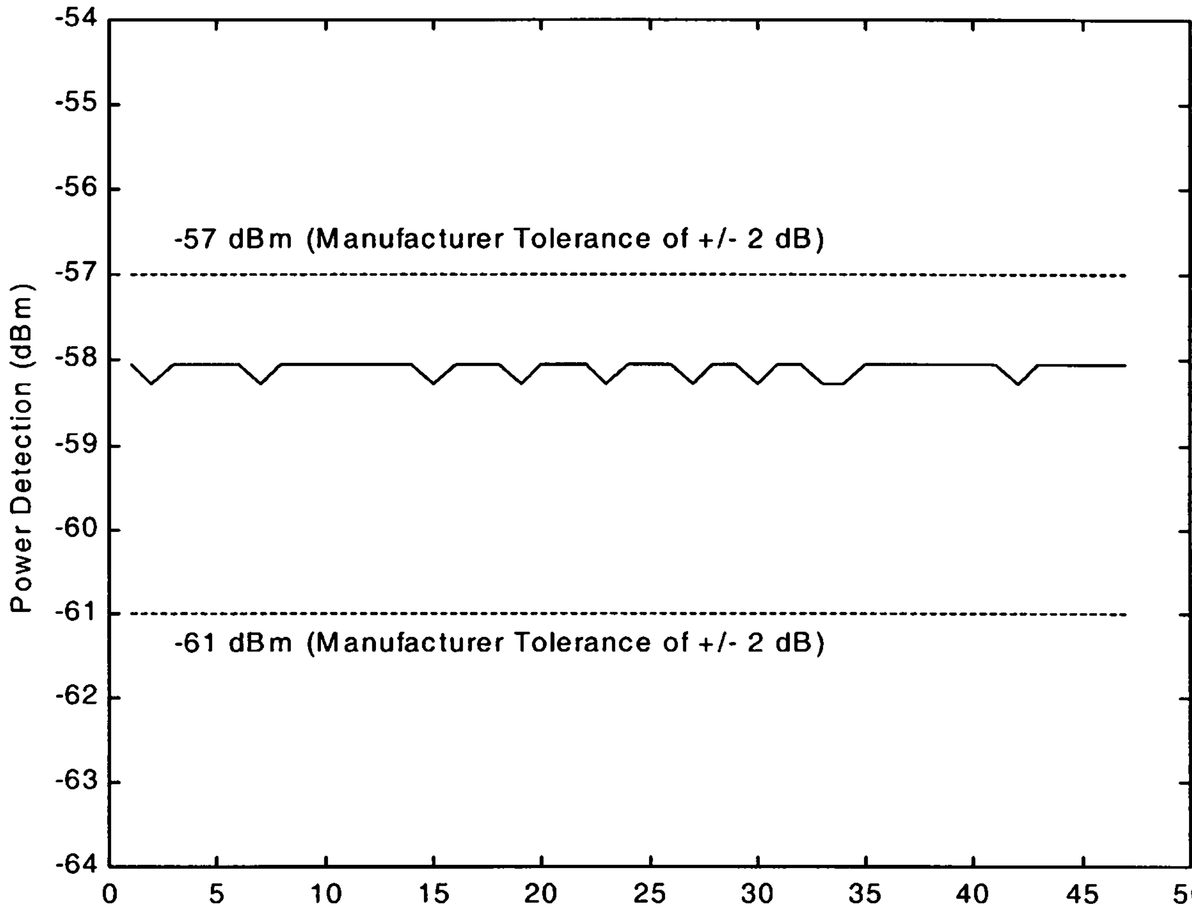
Scan #-(1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance


Plot 6a: 2000 - 3022 MHz Accuracy Test
Detected:2209.8 MHz @ -58.29 dBm
Detected:2505.5 MHz
@ -59.47 dBm
Detected:2901.1 MHz
@ -58.29 dBm
-55
-60
-65
-70
-75
-80
-85
-90
Amplitude (dBm)
2000
2200
2400
2600
2800
3000
3200
Frequency (MHz): Injected 2200,2500,2900 MHz all at -59 dBm


Plot 6b: 3014 - 3601 MHz Accuracy Test
Detected:3315.2
MHz @ -59 dBm
× Detected:3106.4 MHz
@ -59.47 dBm
× Detected:3504 MHz
@ -59 dBm
Amplitude (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
3000
3100
3200
3300
3400
3500
3600
3700
Frequency (MHz): Injected 3100,3307,3500 MHz all at -59 dBm

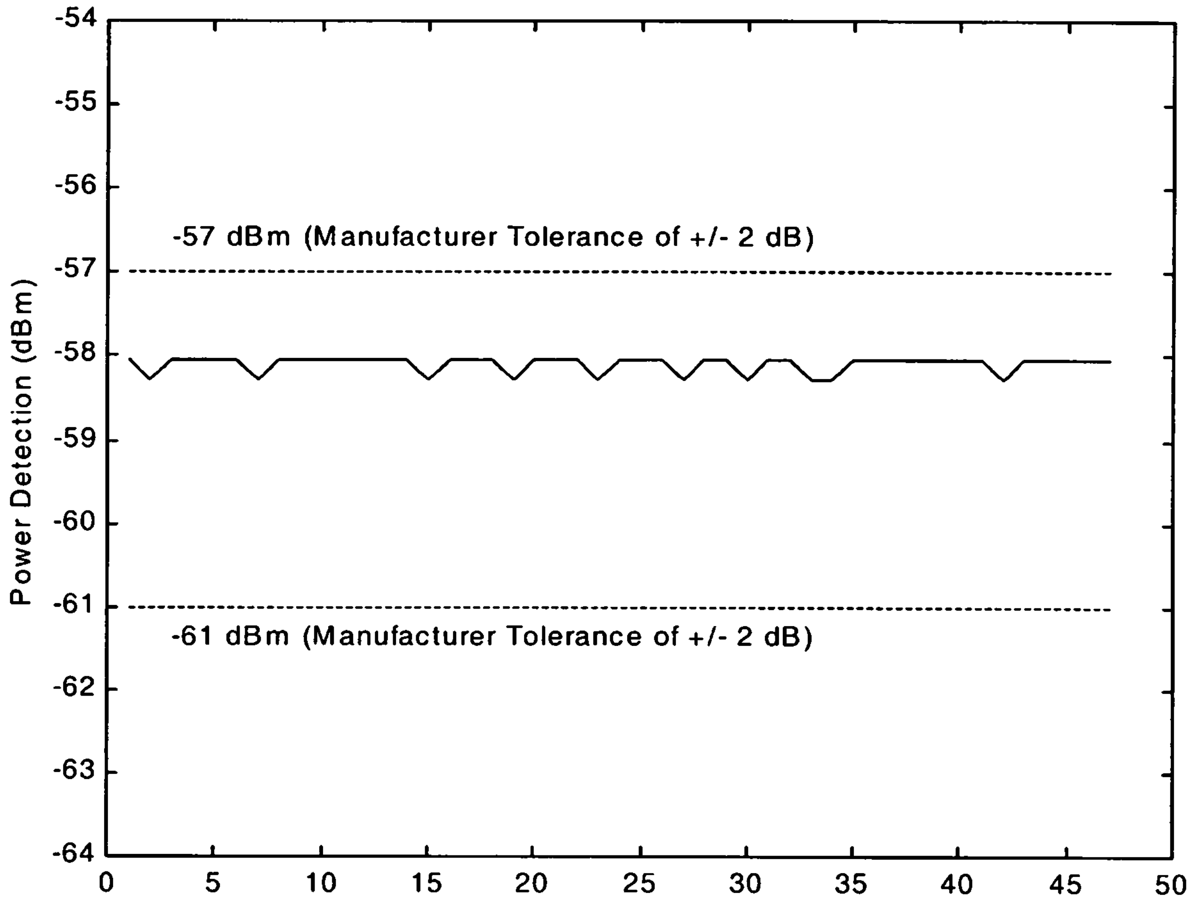

Plot 6.1a: Repeatability Test for a 2200 MHz Injection at -59 dBm; 2000 - 3022 MHz Scan
2222 MHz (Manufacturer Tolerance of +/- 1 %)
2178 MHz (Manufacturer Tolerance of +/- 1 %)
Frequency (MHz)
2400
2350
2300
2250
2200
2150
2100
2050
2000
0
5
10
15
20
25
30
35
40
45
50
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

Plot 6.1b: Repeatability Test for a 2200 MHz Injection at -59 dBm; 2000 - 3022 MHz Scan



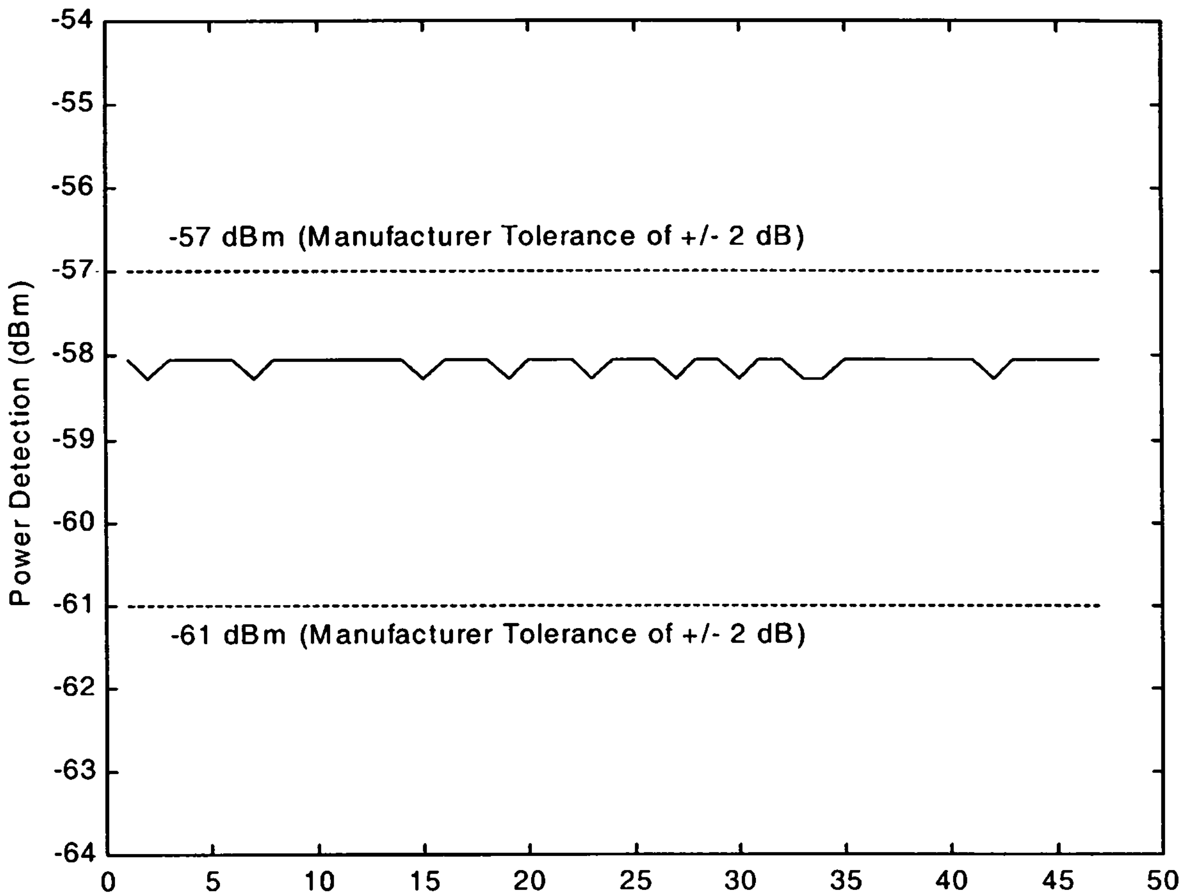
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

Plot 6.1b: Repeatability Test for a 2200 MHz Injection at -59 dBm; 2000 - 3022 MHz Scan



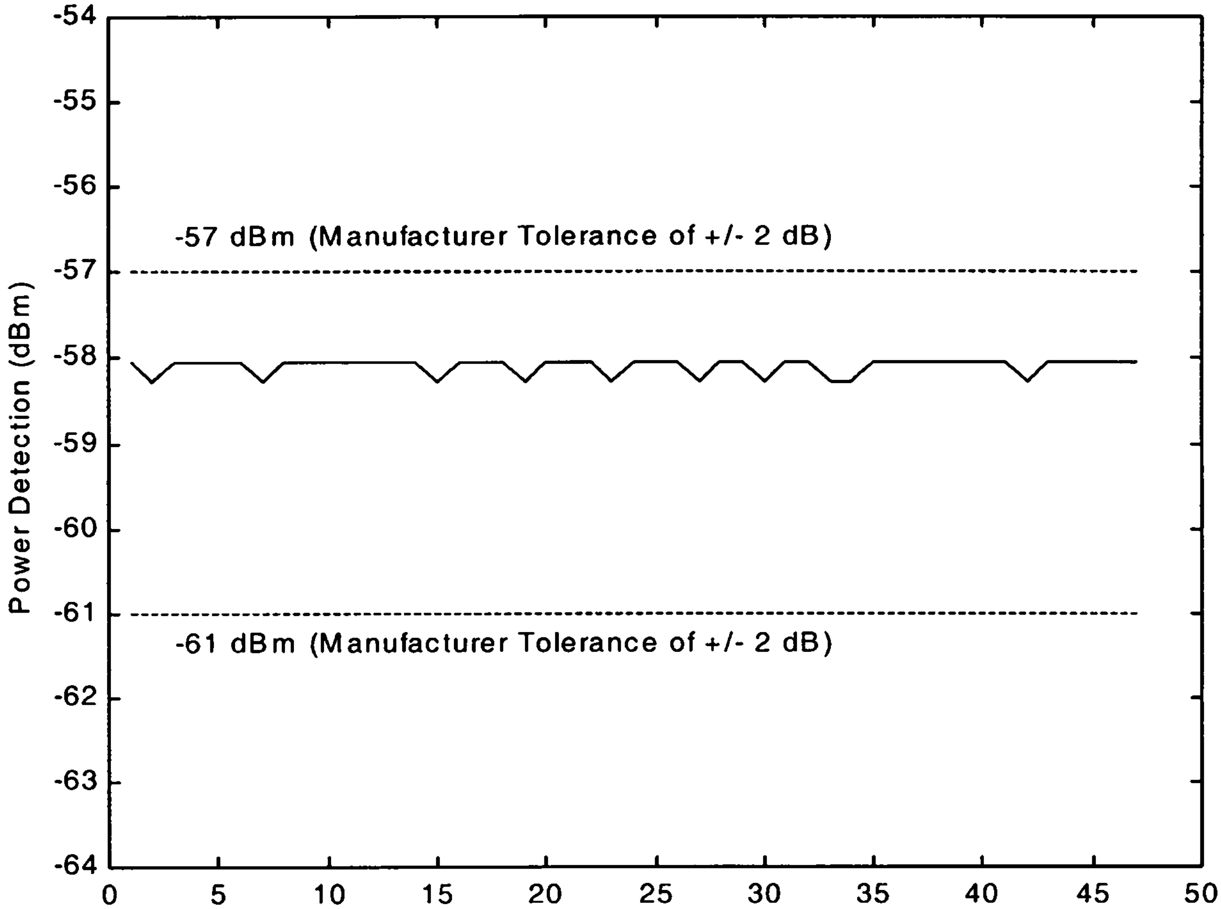
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

Plot 6.1b: Repeatability Test for a 2200 MHz Injection at -59 dBm; 2000 - 3022 MHz Scan



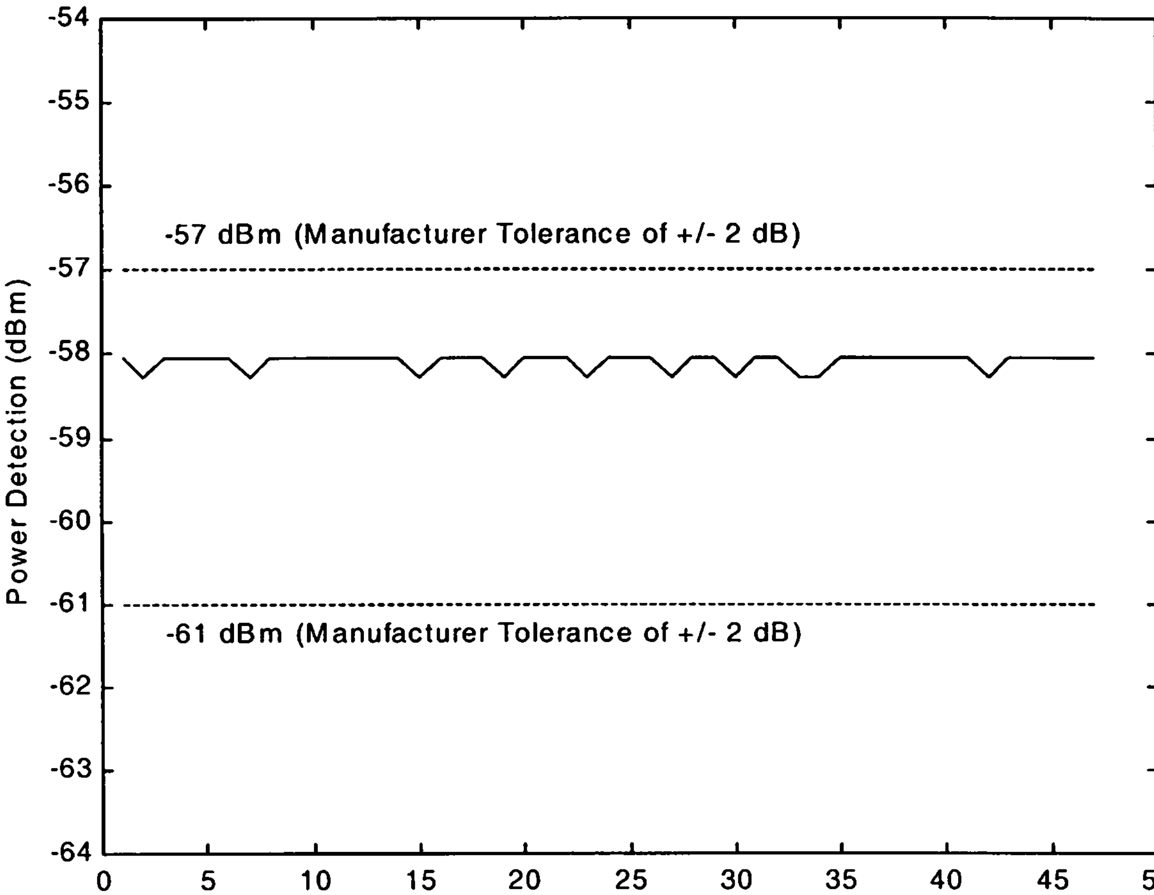
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

Plot 6.1b: Repeatability Test for a 2200 MHz Injection at -59 dBm; 2000 - 3022 MHz Scan



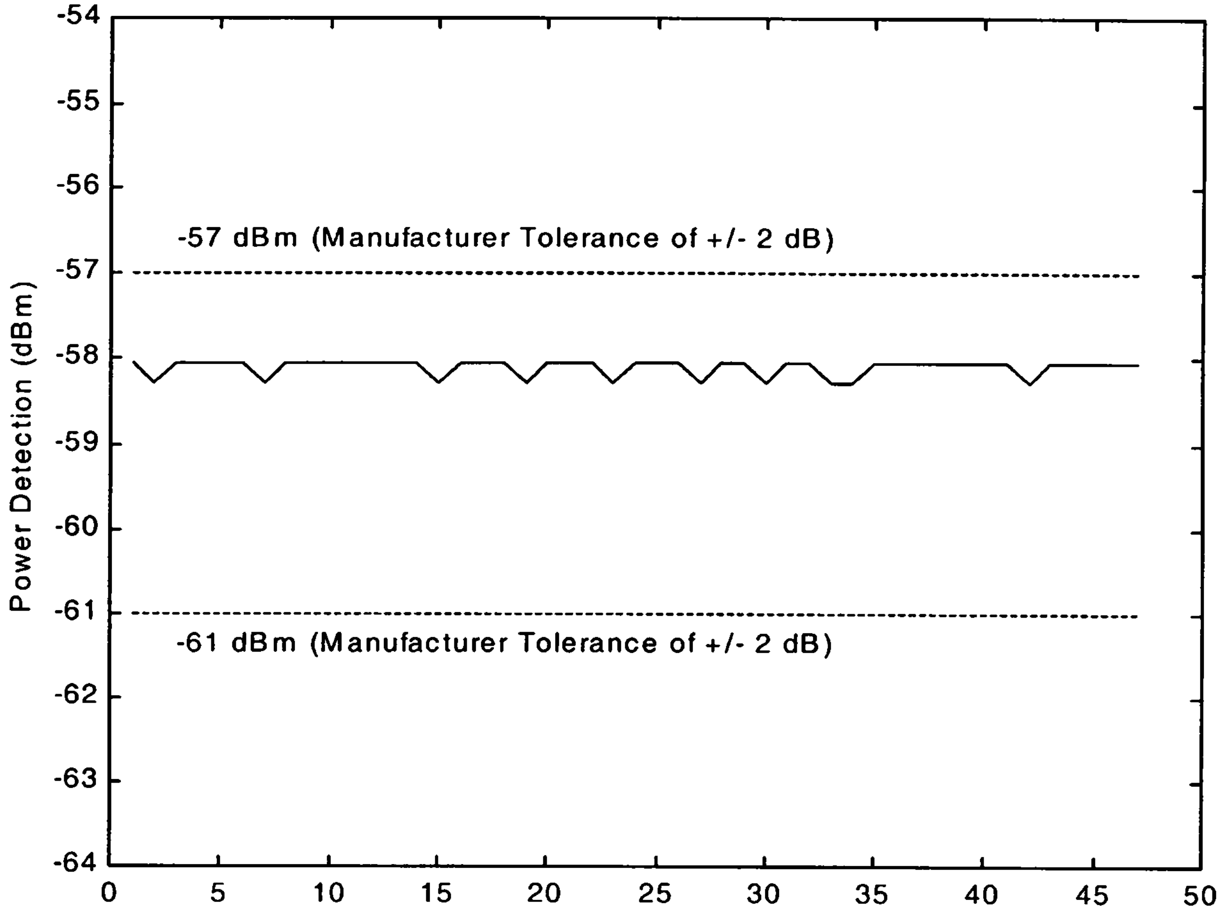
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

Plot 6.1b: Repeatability Test for a 2200 MHz Injection at -59 dBm; 2000 - 3022 MHz Scan

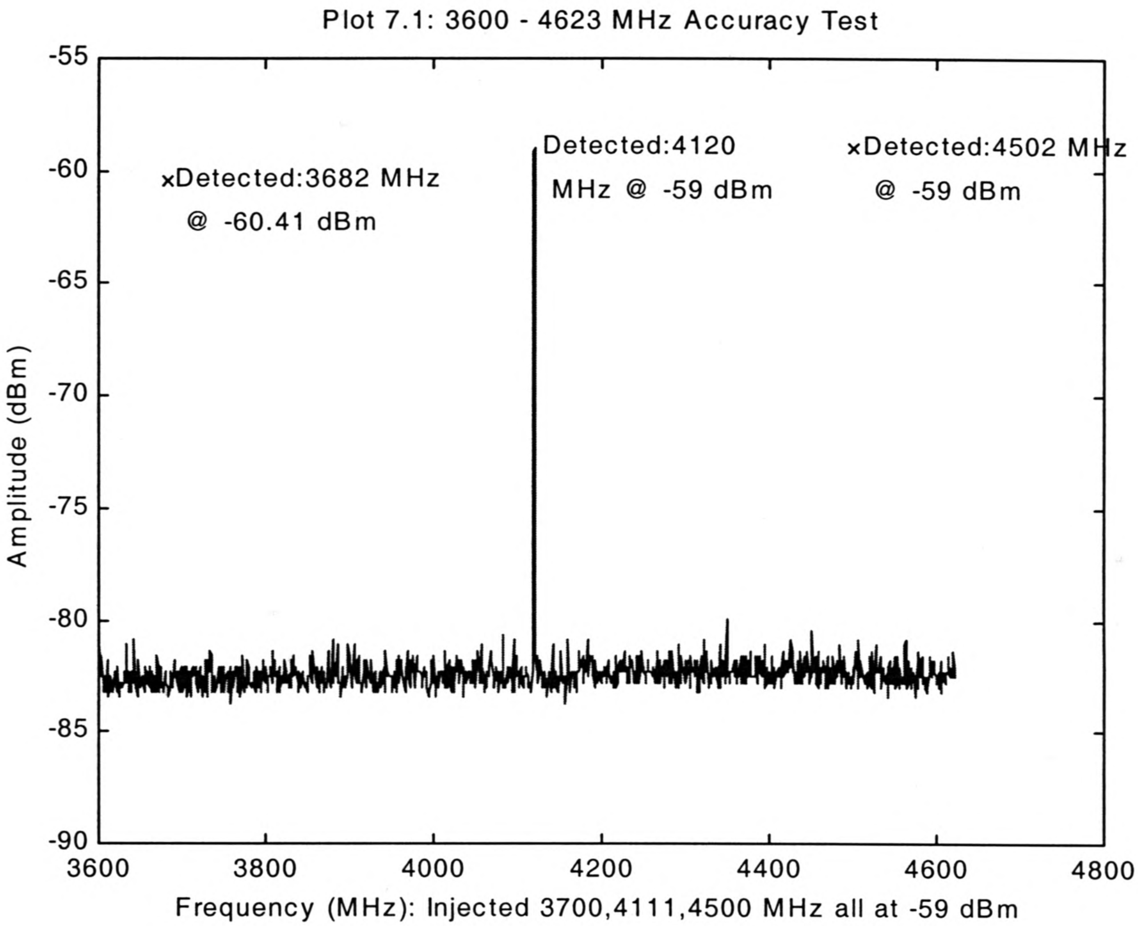


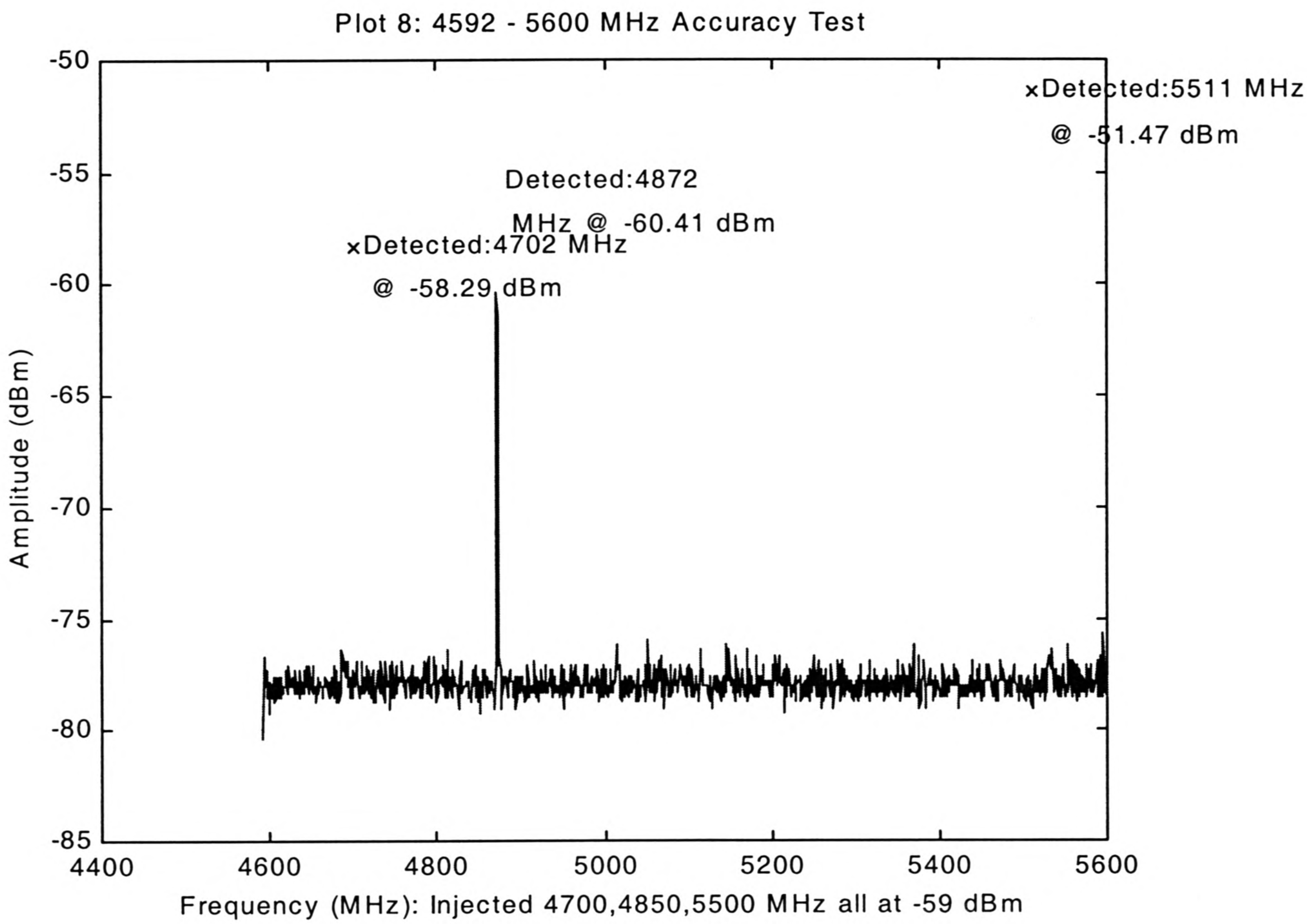
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

Plot 6.1b: Repeatability Test for a 2200 MHz Injection at -59 dBm; 2000 - 3022 MHz Scan

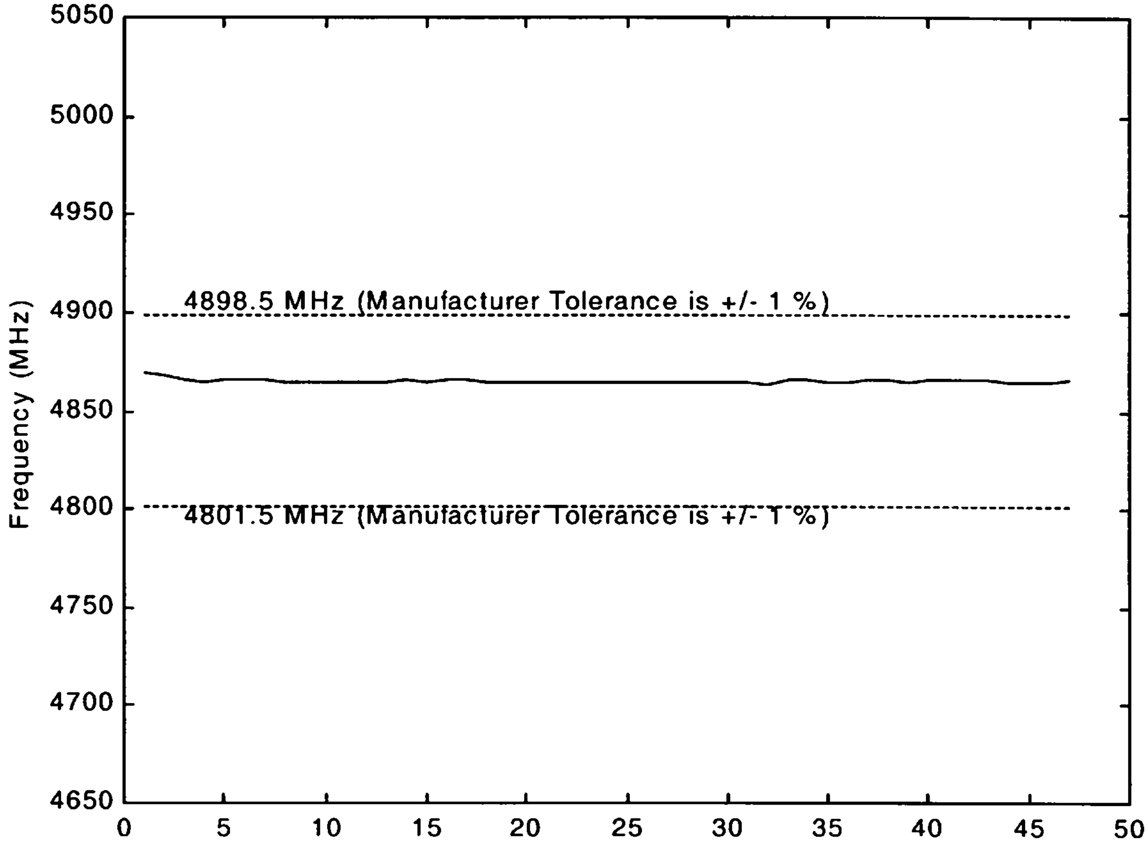


Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance


Plot 7.1: 3600 - 4623 MHz Accuracy Test
-55
-60
-65
-70
-75
-80
-85
-90
Amplitude (dBm)
×Detected:3682 MHz
@ -60.41 dBm
Detected:4120
MHz @ -59 dBm
×Detected:4502 MHz
@ -59 dBm
3600
3800
4000
4200
4400
4600
4800
Frequency (MHz): Injected 3700,4111,4500 MHz all at -59 dBm

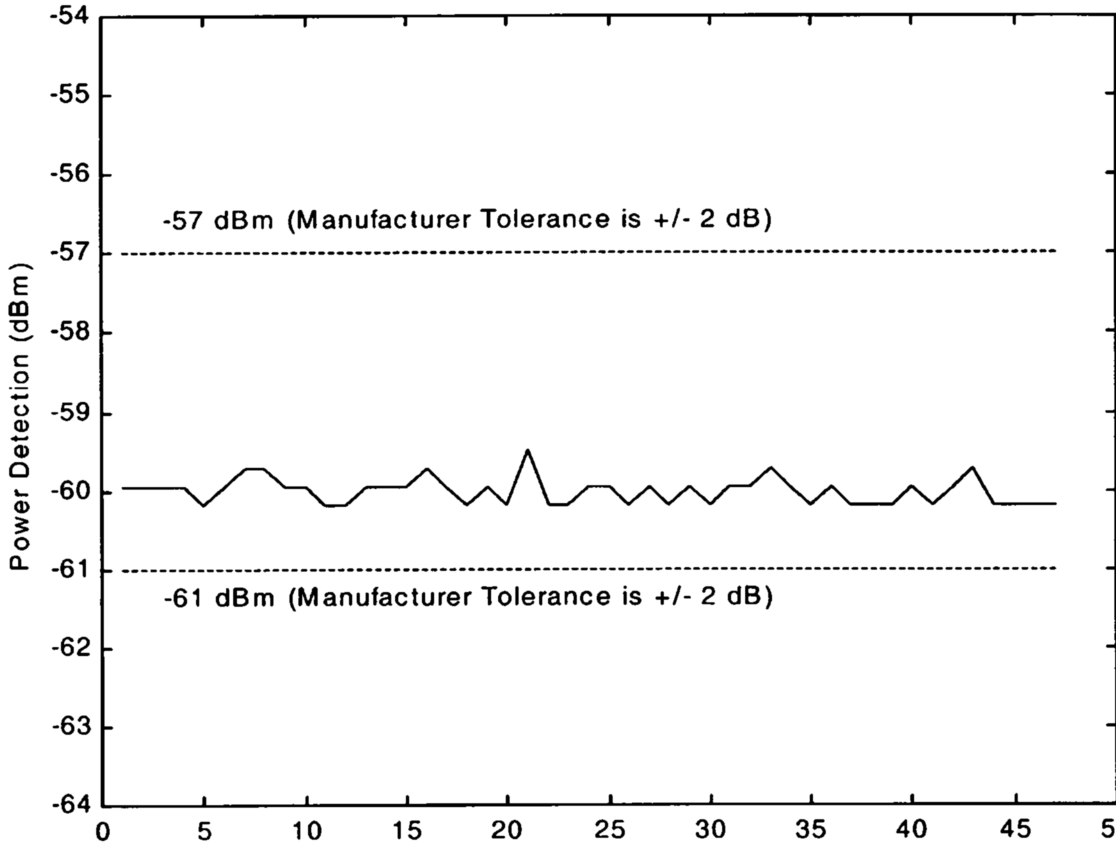

Plot 8: 4592 - 5600 MHz Accuracy Test
-50
-55
-60
-65
-70
-75
-80
-85
Amplitude (dBm)
×Detected:5511 MHz
@ -51.47 dBm
Detected:4872
MHz @ -60.41 dBm
×Detected:4702 MHz
@ -58.29 dBm
4400
4600
4800
5000
5200
5400
5600
Frequency (MHz): Injected 4700,4850,5500 MHz all at -59 dBm

Plot 8.1a: Repeatability Test for a 4850 MHz Injection at -59 dBm; 4592 - 5600 MHz Scan)

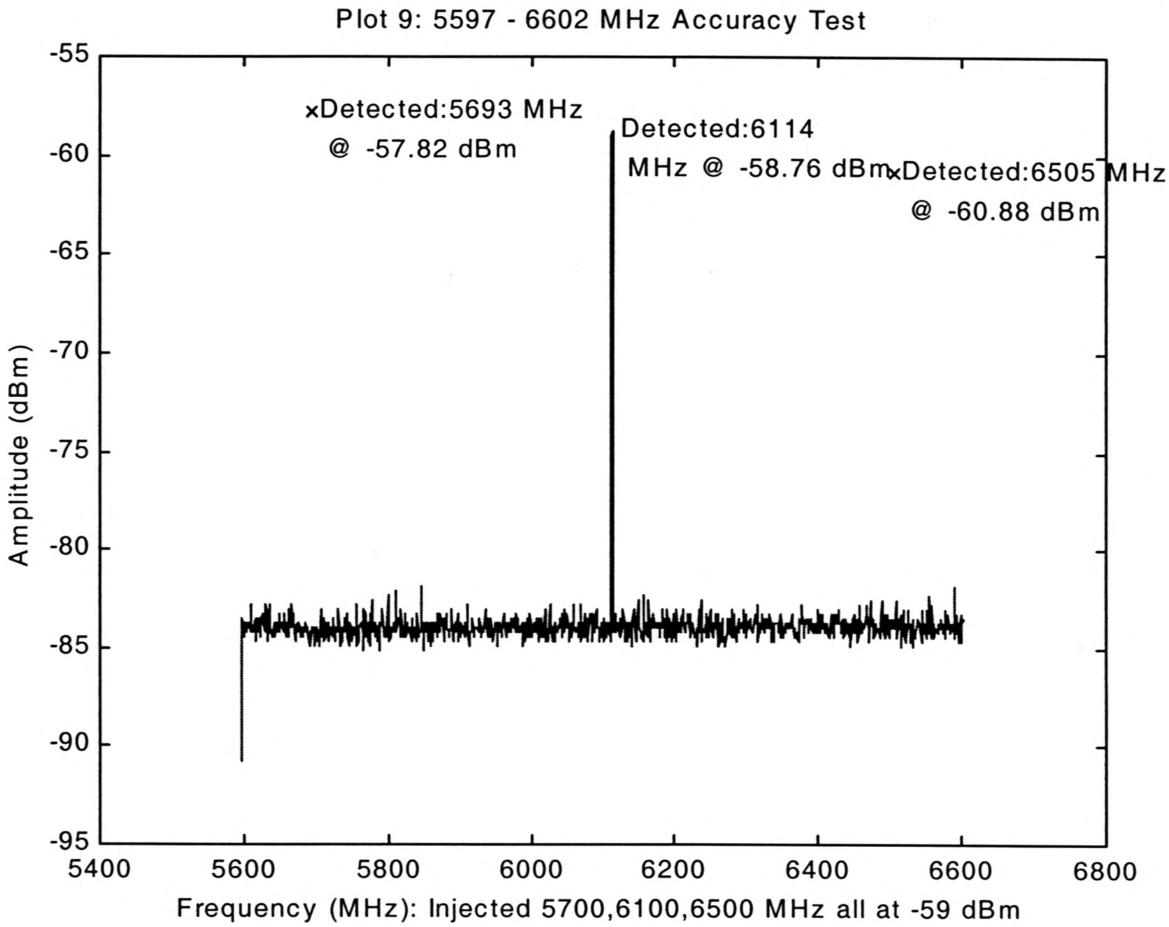


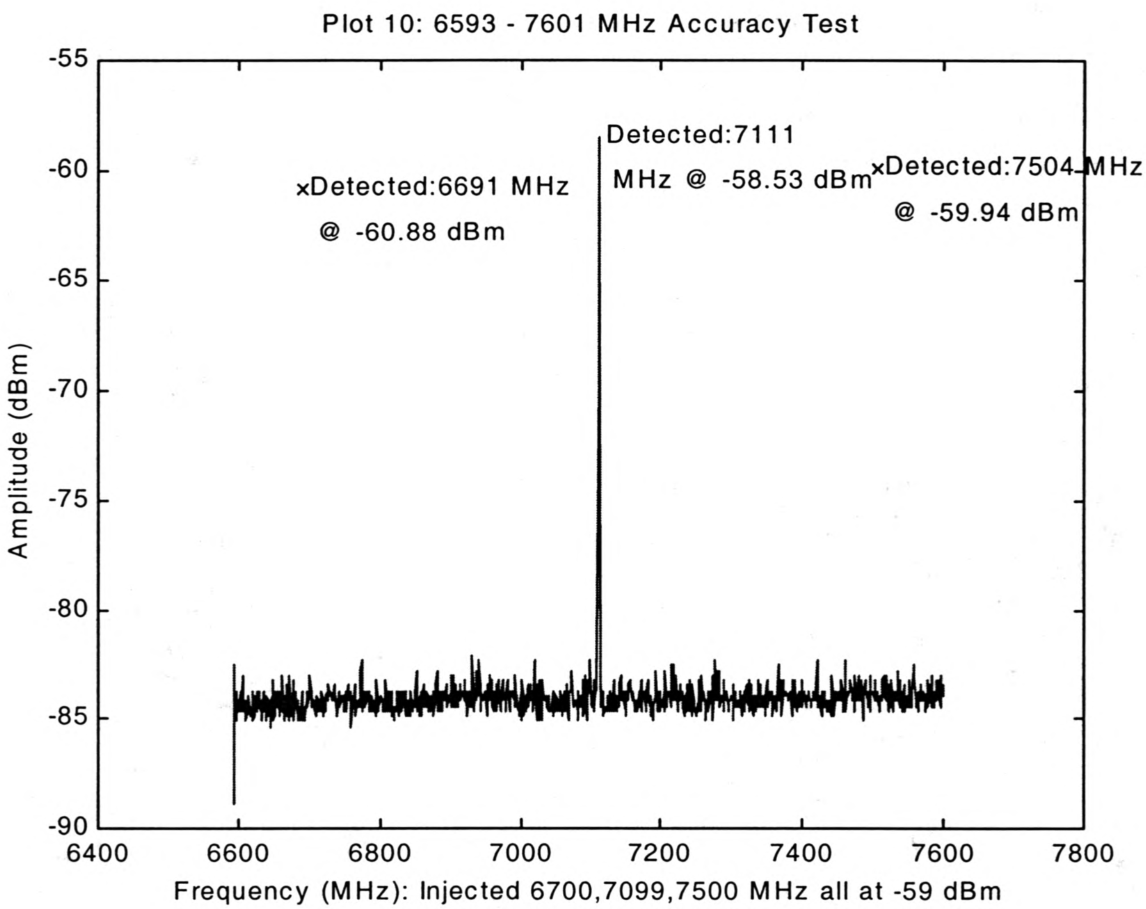
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

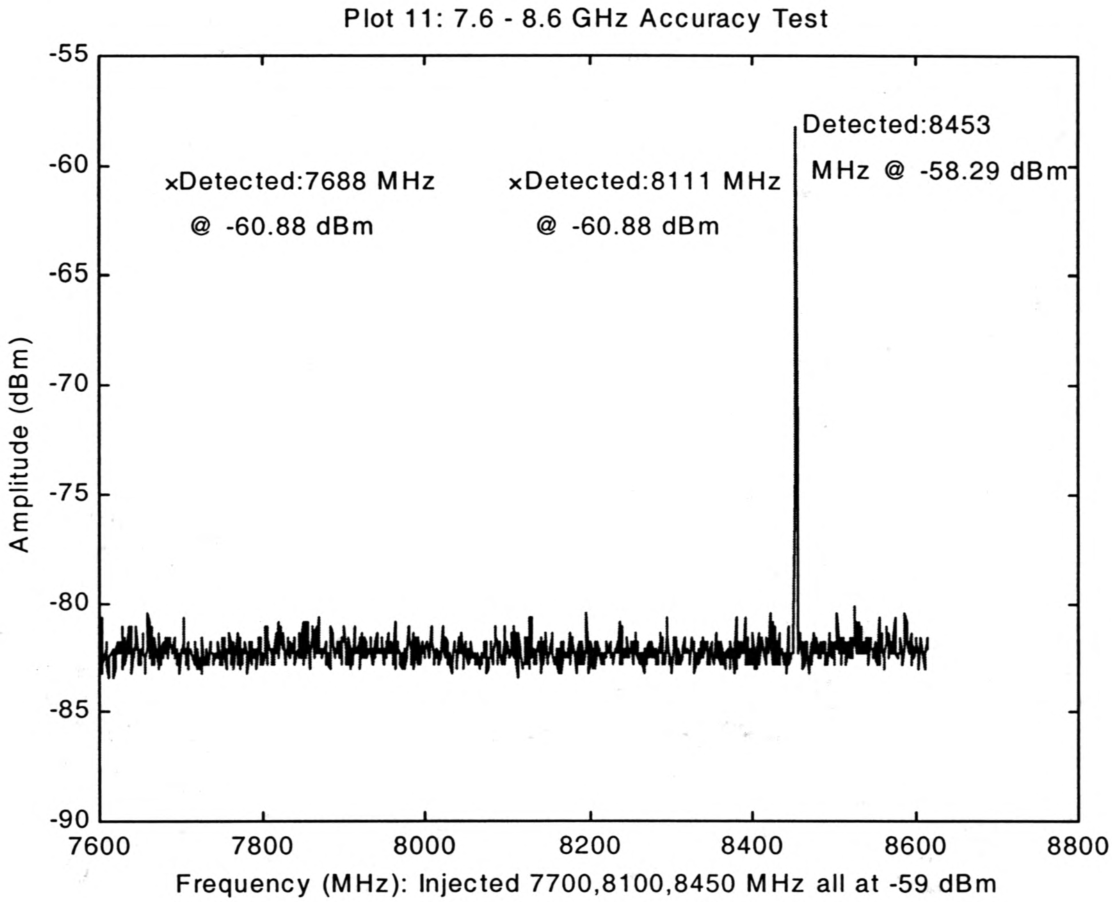
Plot 8.1b: Repeatability Test for a 4850 MHz Injection at -59 dBm; 4592 - 5600 MHz Scan)



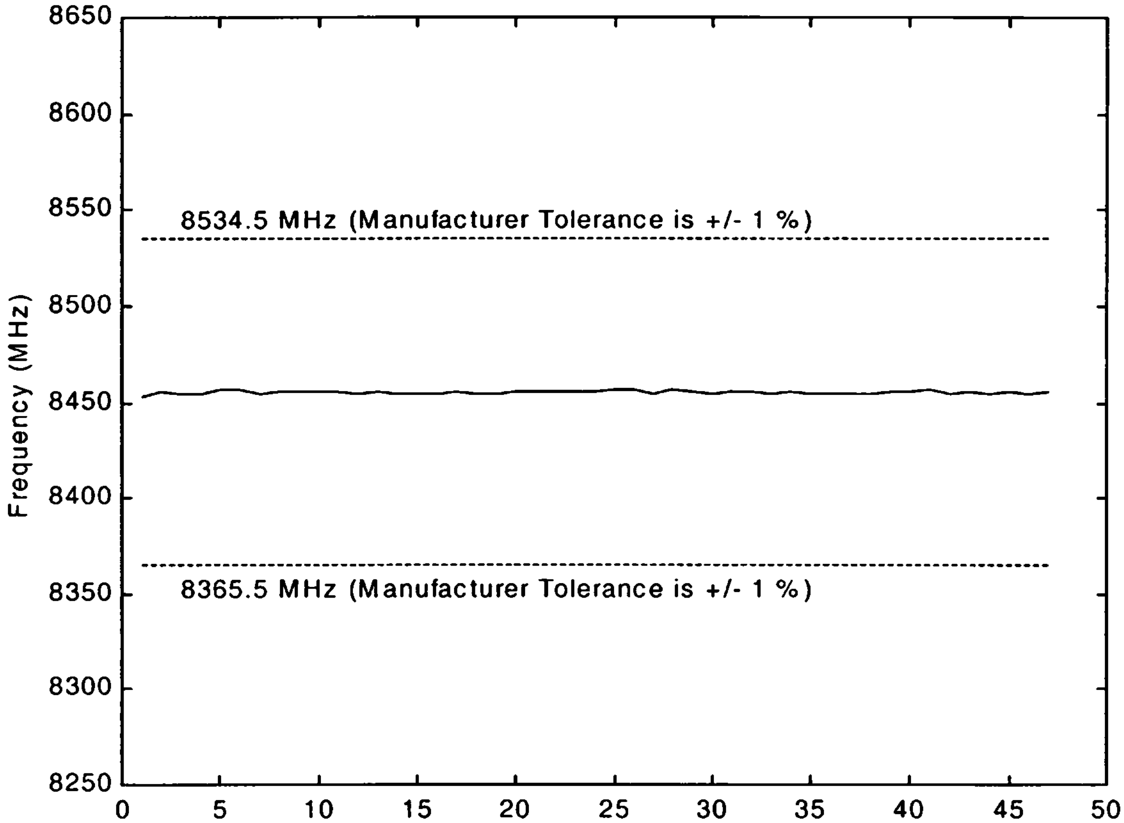
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance


Plot 9: 5597 - 6602 MHz Accuracy Test
xDetected:5693 MHz
@ -57.82 dBm
Detected:6114
MHz @ -58.76 dBm
xDetected:6505 MHz
@ -60.88 dBm
Amplitude (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
-95
5400
5600
5800
6000
6200
6400
6600
6800
Frequency (MHz): Injected 5700,6100,6500 MHz all at -59 dBm

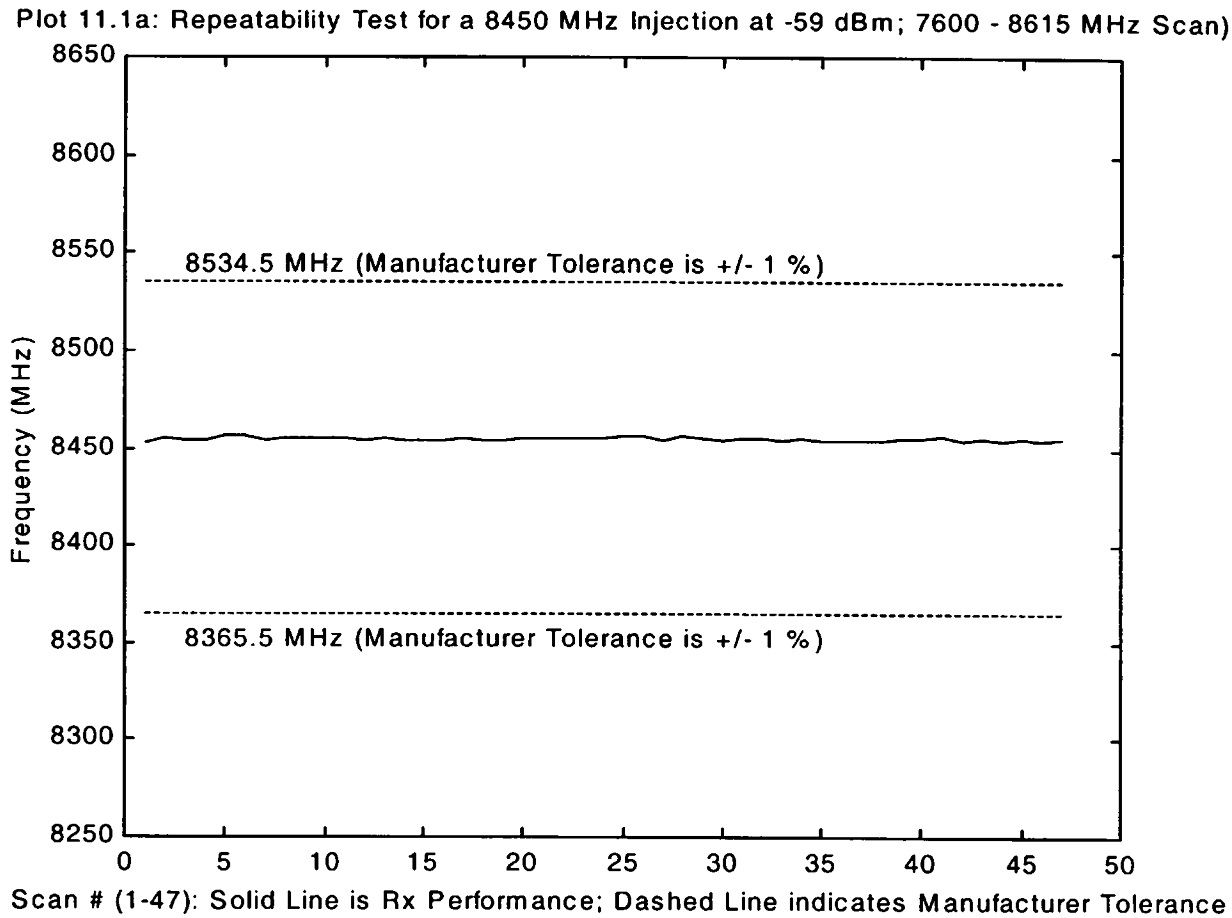

Plot 10: 6593 - 7601 MHz Accuracy Test
Amplitude (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
Detected:7111
MHz @ -58.53 dBm
xDetected:6691 MHz
@ -60.88 dBm
xDetected:7504 MHz
@ -59.94 dBm
6400
6600
6800
7000
7200
7400
7600
7800
Frequency (MHz): Injected 6700,7099,7500 MHz all at -59 dBm


Plot 11: 7.6 - 8.6 GHz Accuracy Test
-55
-60
-65
-70
-75
-80
-85
-90
Amplitude (dBm)
×Detected:7688 MHz
@ -60.88 dBm
×Detected:8111 MHz
@ -60.88 dBm
Detected:8453
MHz @ -58.29 dBm
7600
7800
8000
8200
8400
8600
8800
Frequency (MHz): Injected 7700,8100,8450 MHz all at -59 dBm

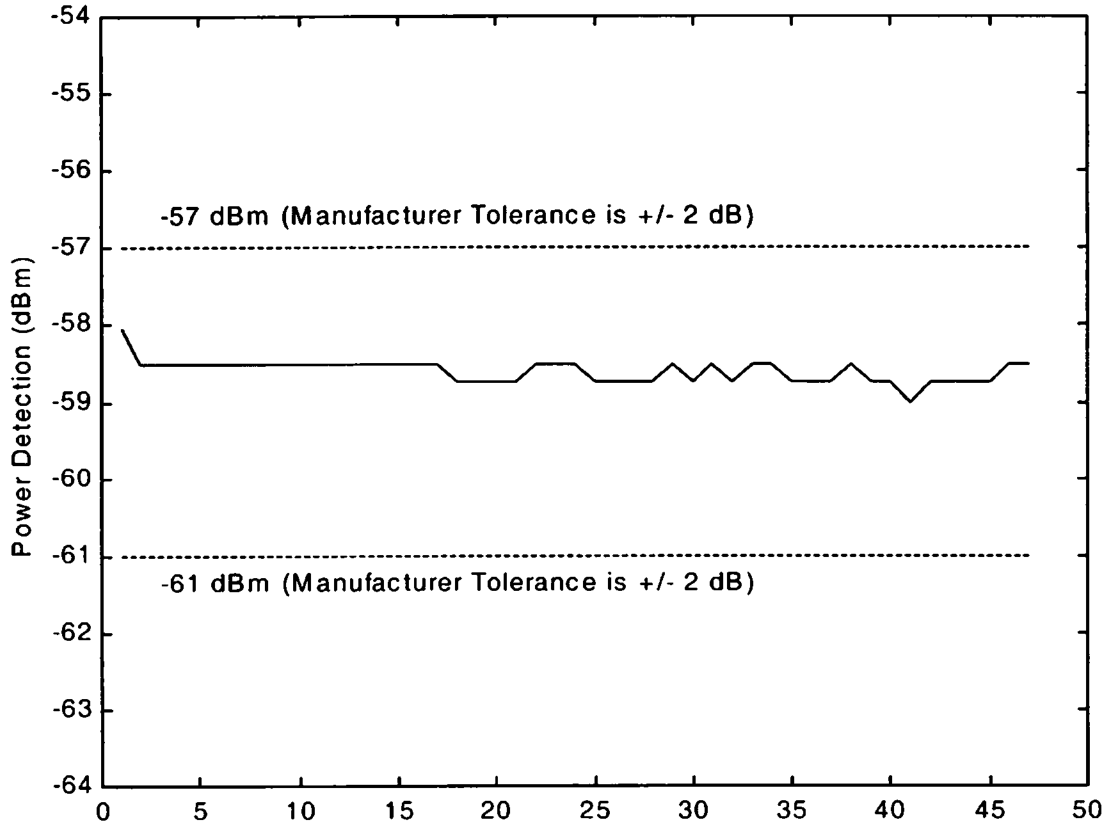
Plot 11.1a: Repeatability Test for a 8450 MHz Injection at -59 dBm; 7600 - 8615 MHz Scan)



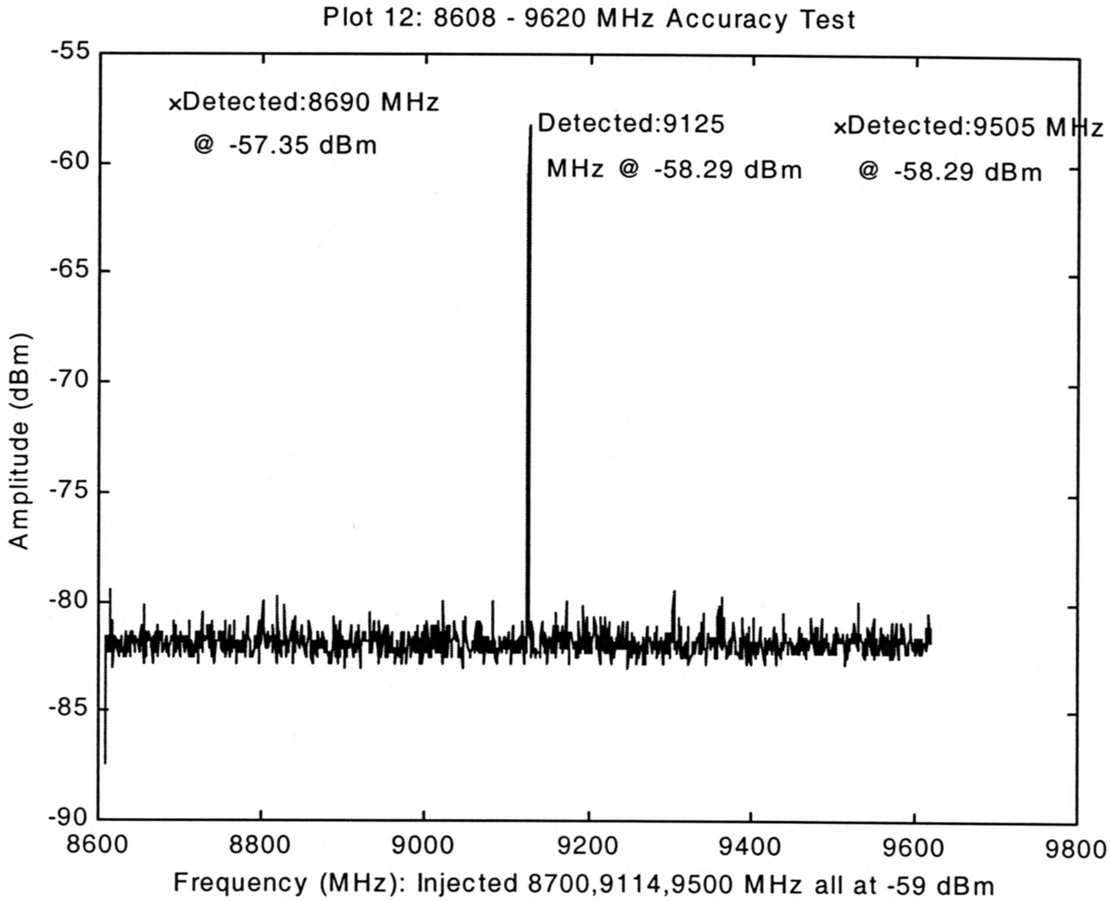
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

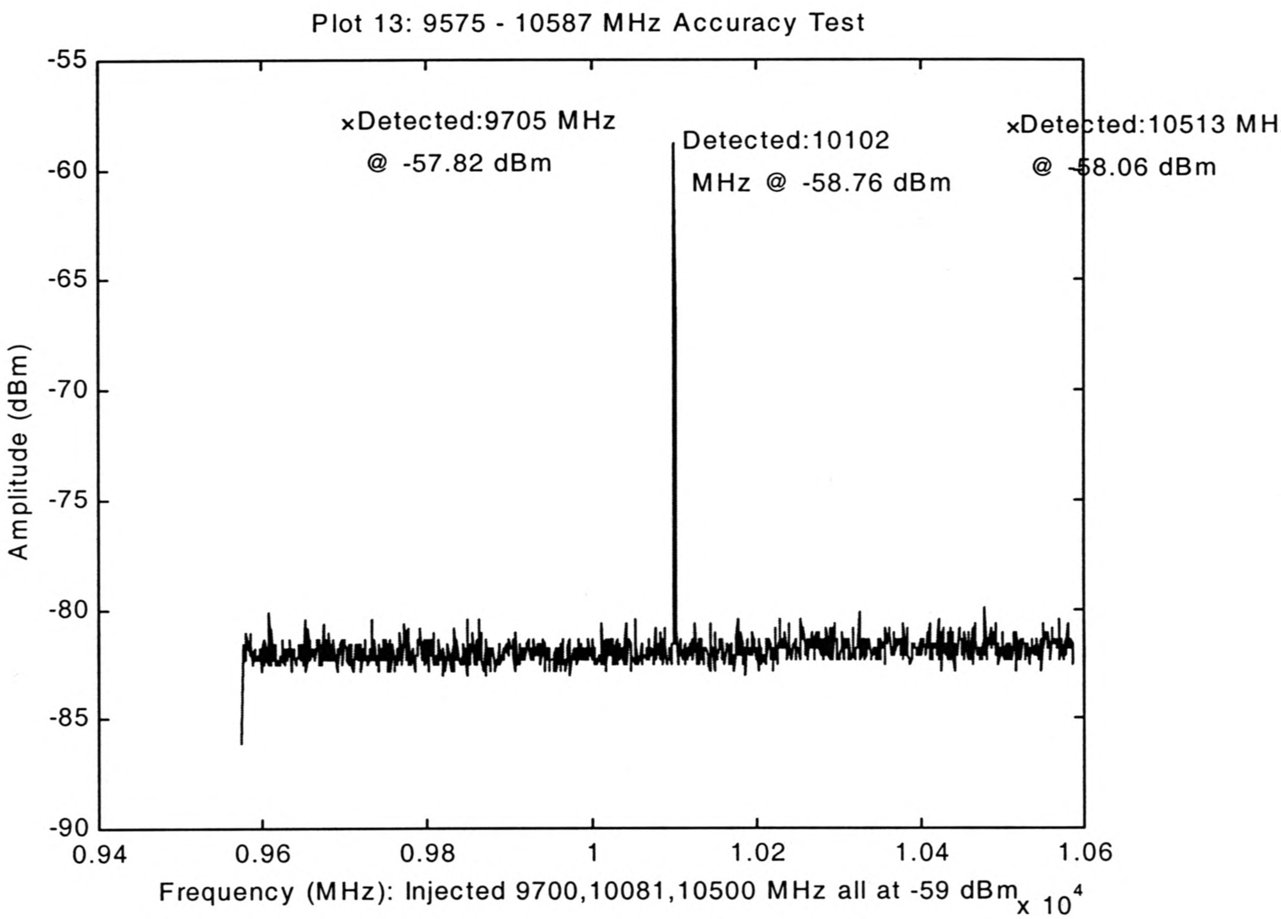

Plot 11.1a: Repeatability Test for a 8450 MHz Injection at -59 dBm; 7600 - 8615 MHz Scan)
8650
8600
8550
8500
8450
8400
8350
8300
8250
Frequency (MHz)
8534.5 MHz (Manufacturer Tolerance is +/- 1 %)
8365.5 MHz (Manufacturer Tolerance is +/- 1 %)
0
5
10
15
20
25
30
35
40
45
50
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

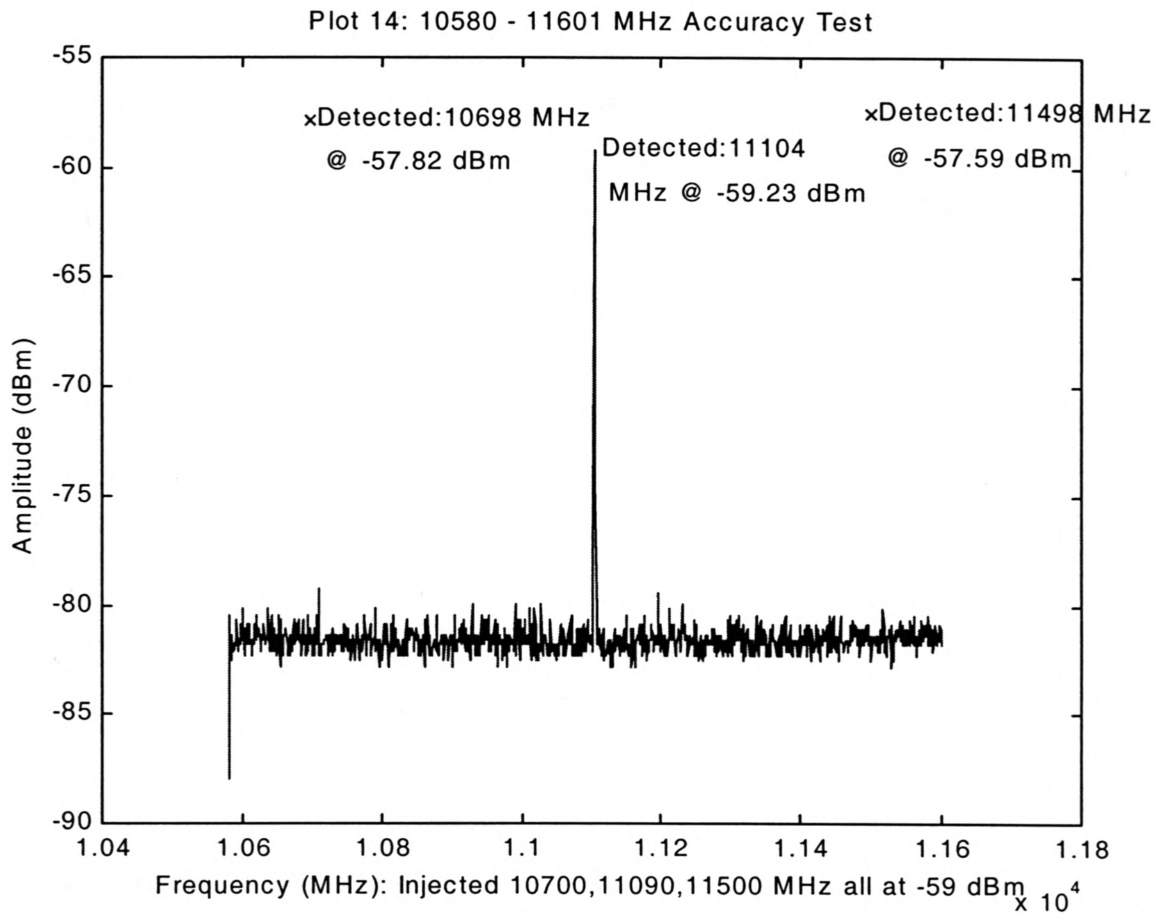
Plot 11.1b: Repeatability Test for a 8450 MHz Injection at -59 dBm; 7600 - 8615 MHz Scan)

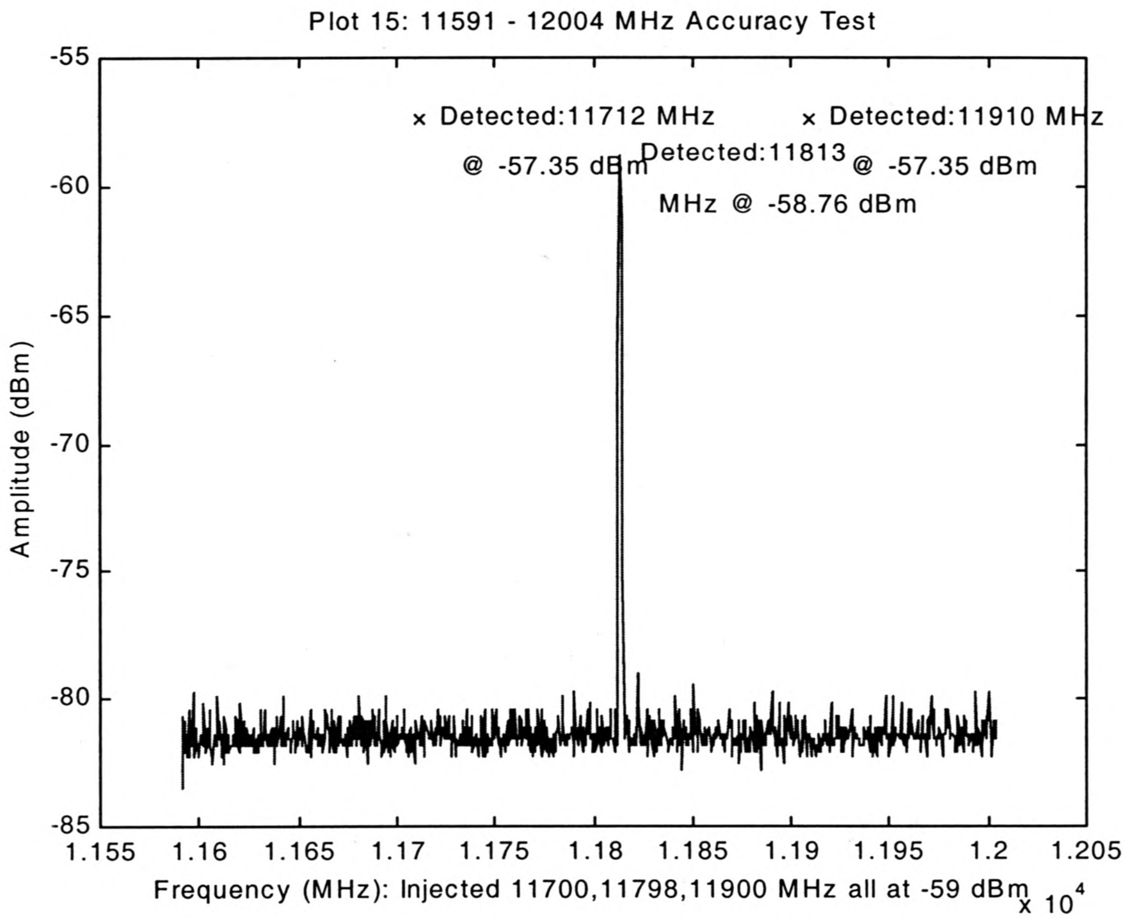


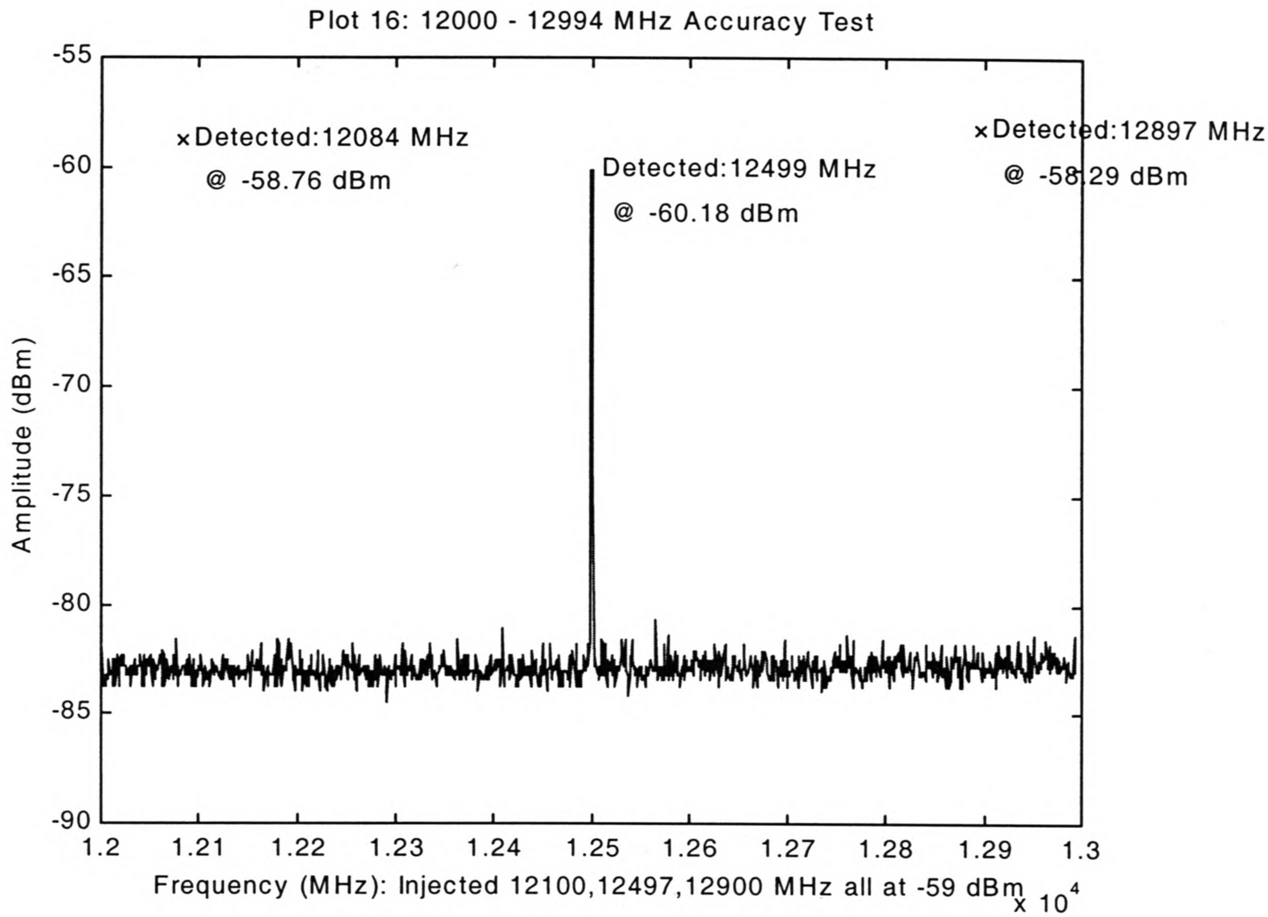
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance


Plot 12: 8608 - 9620 MHz Accuracy Test
xDetected:8690 MHz
@ -57.35 dBm
Detected:9125
MHz @ -58.29 dBm
xDetected:9505 MHz
@ -58.29 dBm
Amplitude (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
8600
8800
9000
9200
9400
9600
9800
Frequency (MHz): Injected 8700,9114,9500 MHz all at -59 dBm

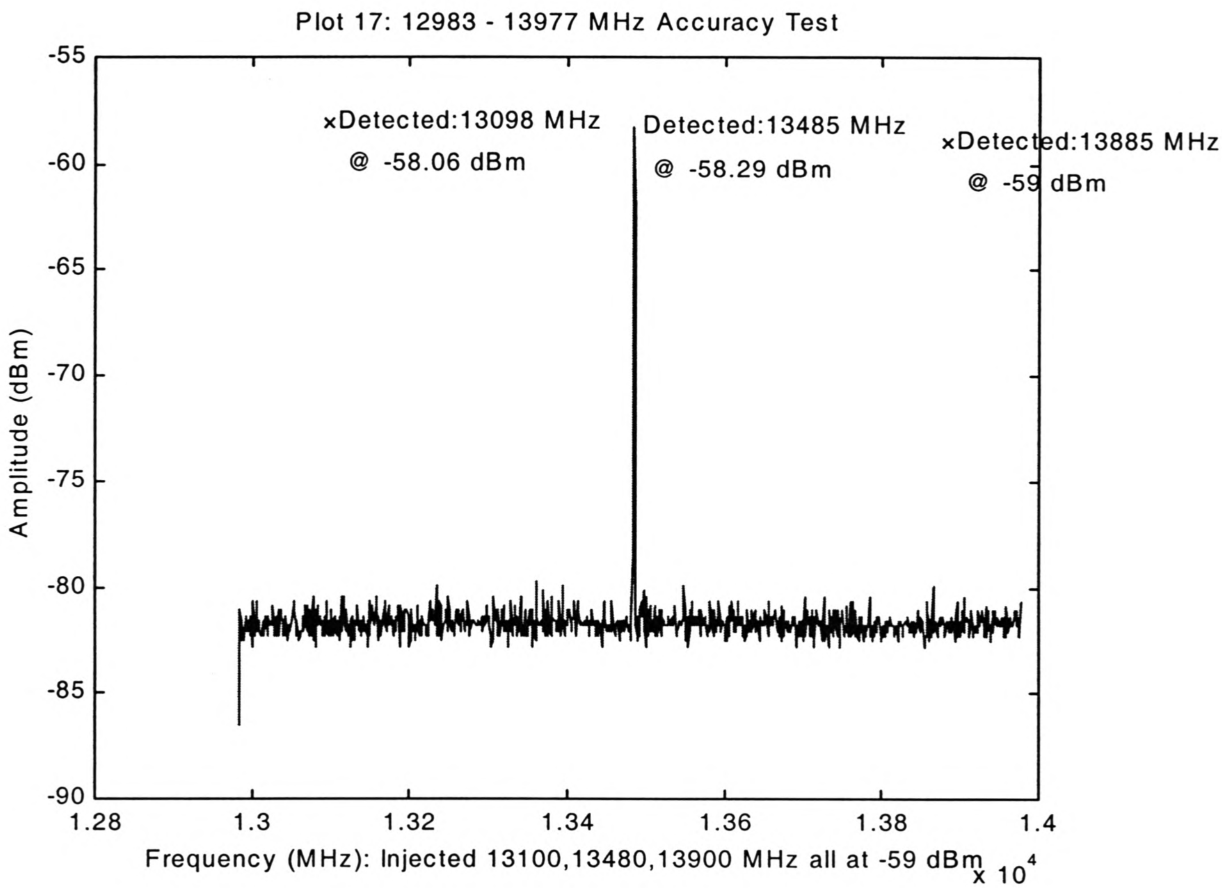

Plot 13: 9575 - 10587 MHz Accuracy Test
xDetected:9705 MHz
@ -57.82 dBm
Detected:10102
MHz @ -58.76 dBm
xDetected:10513 MHz
@ -58.06 dBm
Amplitude (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
0.94
0.96
0.98
1
1.02
1.04
1.06
x 10^4
Frequency (MHz): Injected 9700,10081,10500 MHz all at -59 dBm

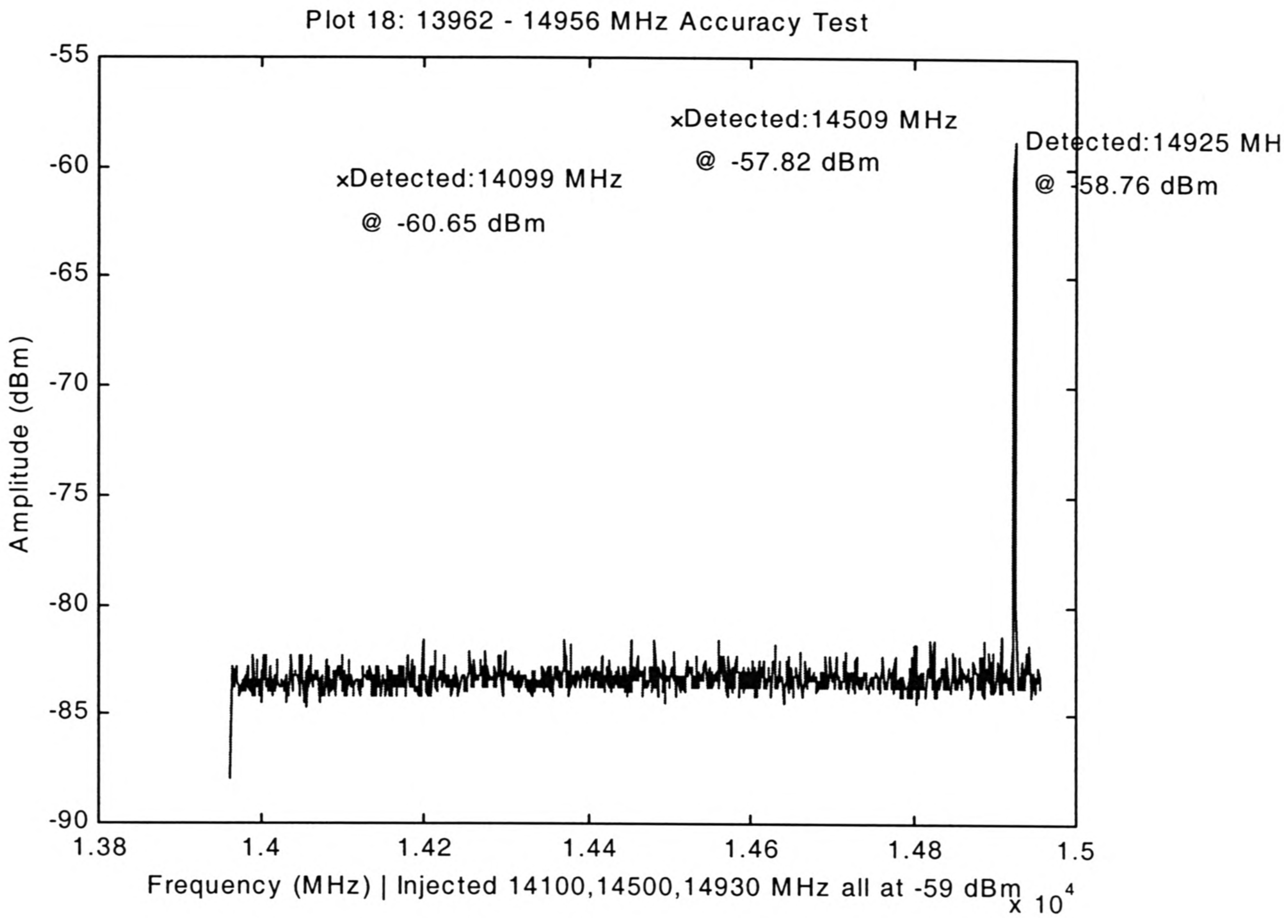

Plot 14: 10580 - 11601 MHz Accuracy Test
xDetected:10698 MHz
@ -57.82 dBm
Detected:11104
MHz @ -59.23 dBm
xDetected:11498 MHz
@ -57.59 dBm
Amplitude (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
1.04
1.06
1.08
1.1
1.12
1.14
1.16
1.18
x 10^4
Frequency (MHz): Injected 10700,11090,11500 MHz all at -59 dBm

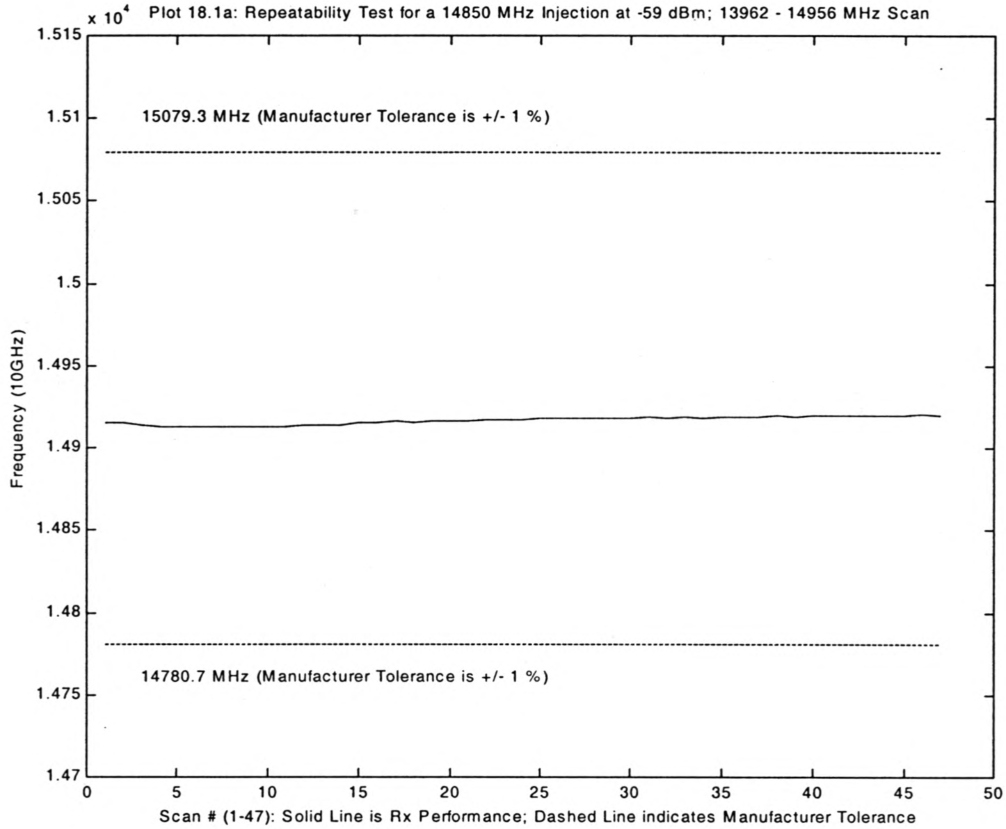

Plot 15: 11591 - 12004 MHz Accuracy Test
-55
-60
-65
-70
-75
-80
-85
Amplitude (dBm)
× Detected:11712 MHz
@ -57.35 dBm
Detected:11813
MHz @ -58.76 dBm
× Detected:11910 MHz
@ -57.35 dBm
1.155
1.16
1.165
1.17
1.175
1.18
1.185
1.19
1.195
1.2
1.205
x 10^4
Frequency (MHz): Injected 11700,11798,11900 MHz all at -59 dBm



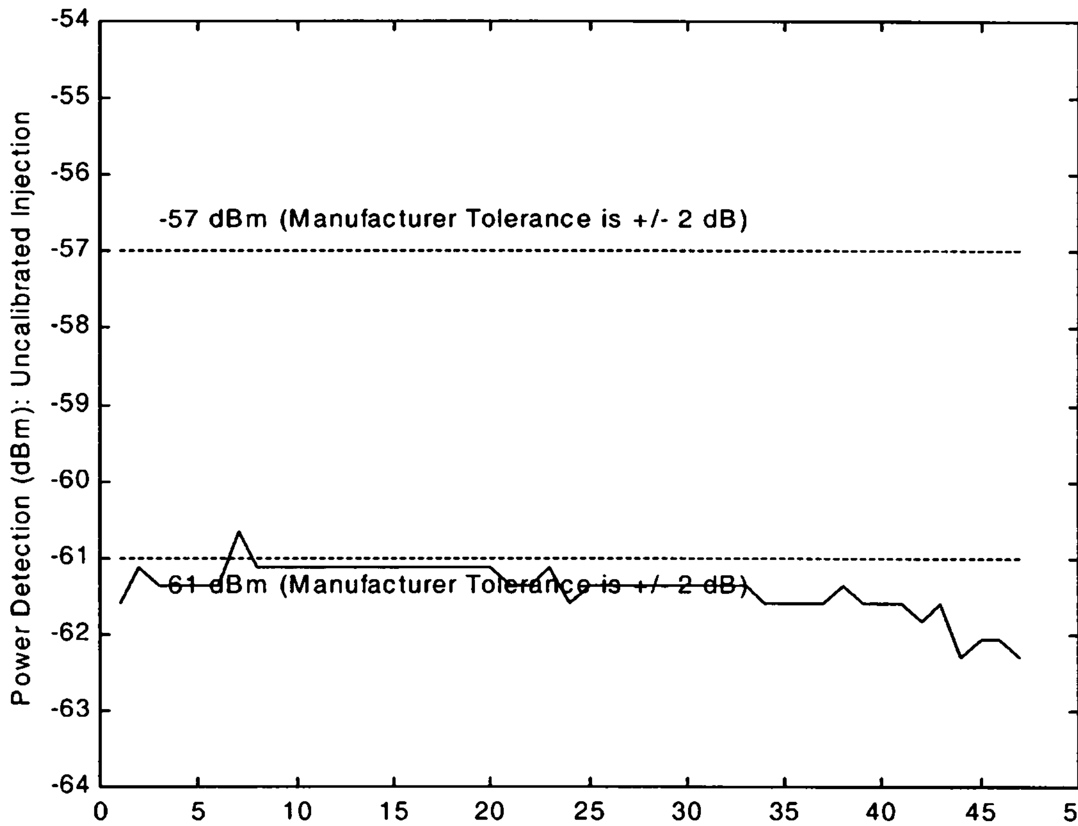
Plot 16: 12000 - 12994 MHz Accuracy Test
×Detected:12084 MHz
@ -58.76 dBm
Detected:12499 MHz
@ -60.18 dBm
×Detected:12897 MHz
@ -58.29 dBm
Amplitude (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
1.2
1.21
1.22
1.23
1.24
1.25
1.26
1.27
1.28
1.29
1.3
Frequency (MHz): Injected 12100,12497,12900 MHz all at -59 dBm
x 10^4


Plot 17: 12983 - 13977 MHz Accuracy Test
-55
-60
-65
-70
-75
-80
-85
-90
Amplitude (dBm)
×Detected:13098 MHz
@ -58.06 dBm
Detected:13485 MHz
@ -58.29 dBm
×Detected:13885 MHz
@ -59 dBm
1.28
1.3
1.32
1.34
1.36
1.38
1.4
Frequency (MHz): Injected 13100,13480,13900 MHz all at -59 dBm
x 10^4

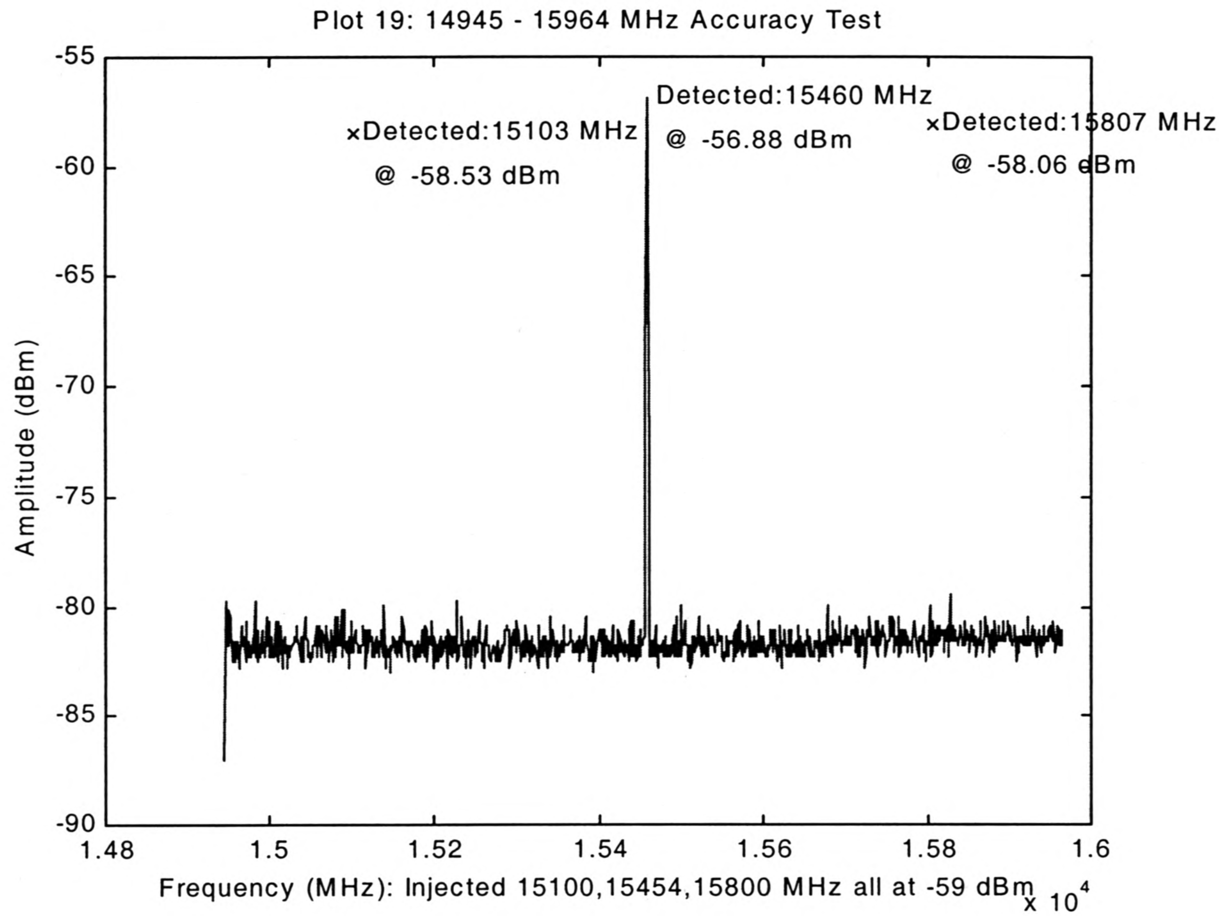

Plot 18: 13962 - 14956 MHz Accuracy Test
xDetected:14099 MHz
@ -60.65 dBm
xDetected:14509 MHz
@ -57.82 dBm
Detected:14925 MH
@ -58.76 dBm
Amplitude (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
1.38
1.4
1.42
1.44
1.46
1.48
1.5
x 10^4
Frequency (MHz) | Injected 14100,14500,14930 MHz all at -59 dBm

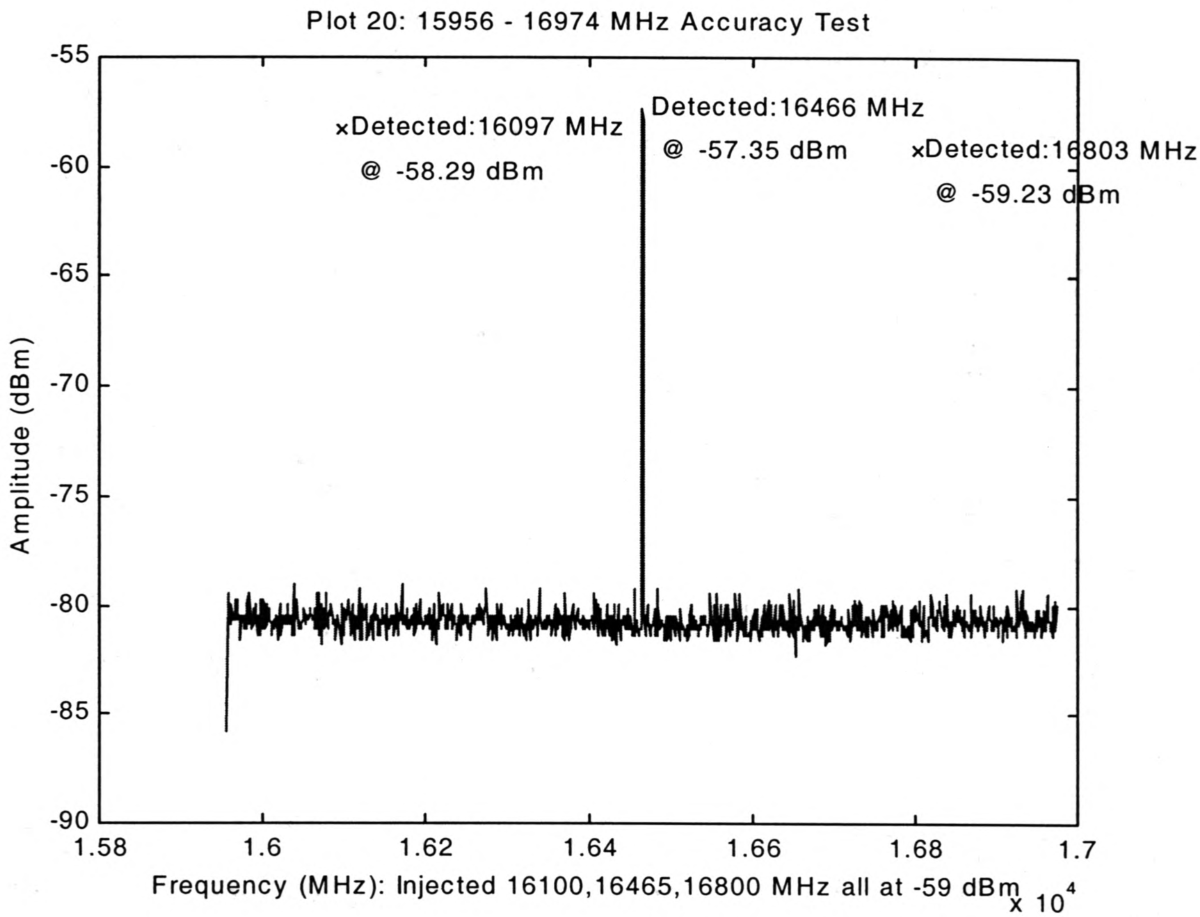

x 10^4
Plot 18.1a: Repeatability Test for a 14850 MHz Injection at -59 dBm; 13962 - 14956 MHz Scan
1.515
1.51
1.505
1.5
1.495
1.49
1.485
1.48
1.475
1.47
Frequency (10GHz)
15079.3 MHz (Manufacturer Tolerance is +/- 1 %)
14780.7 MHz (Manufacturer Tolerance is +/- 1 %)
0
5
10
15
20
25
30
35
40
45
50
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

Plot 18.1b: Repeatability Test for a 14850 MHz Injection at -59 dBm; 13962 - 14956 MHz Scan

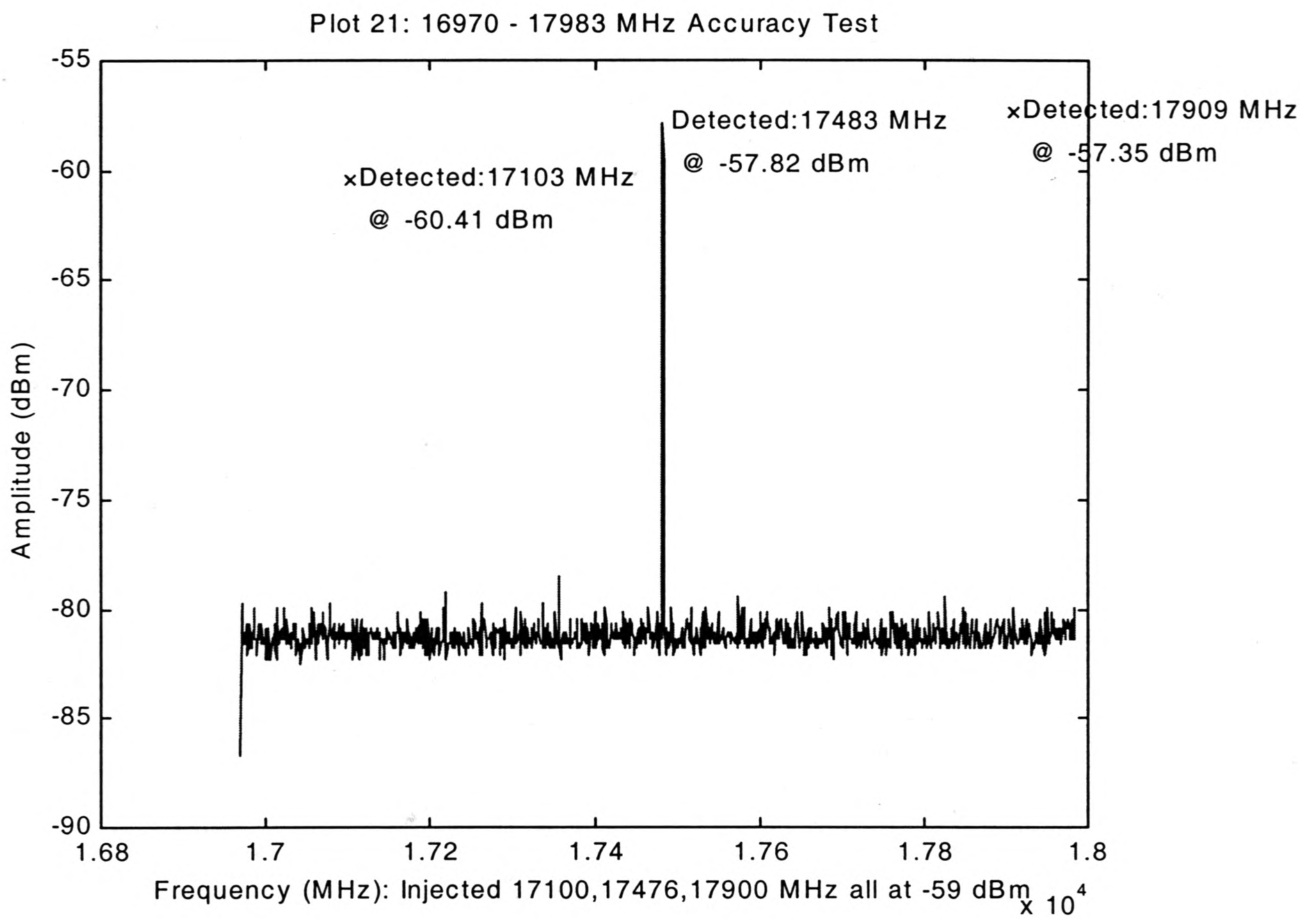


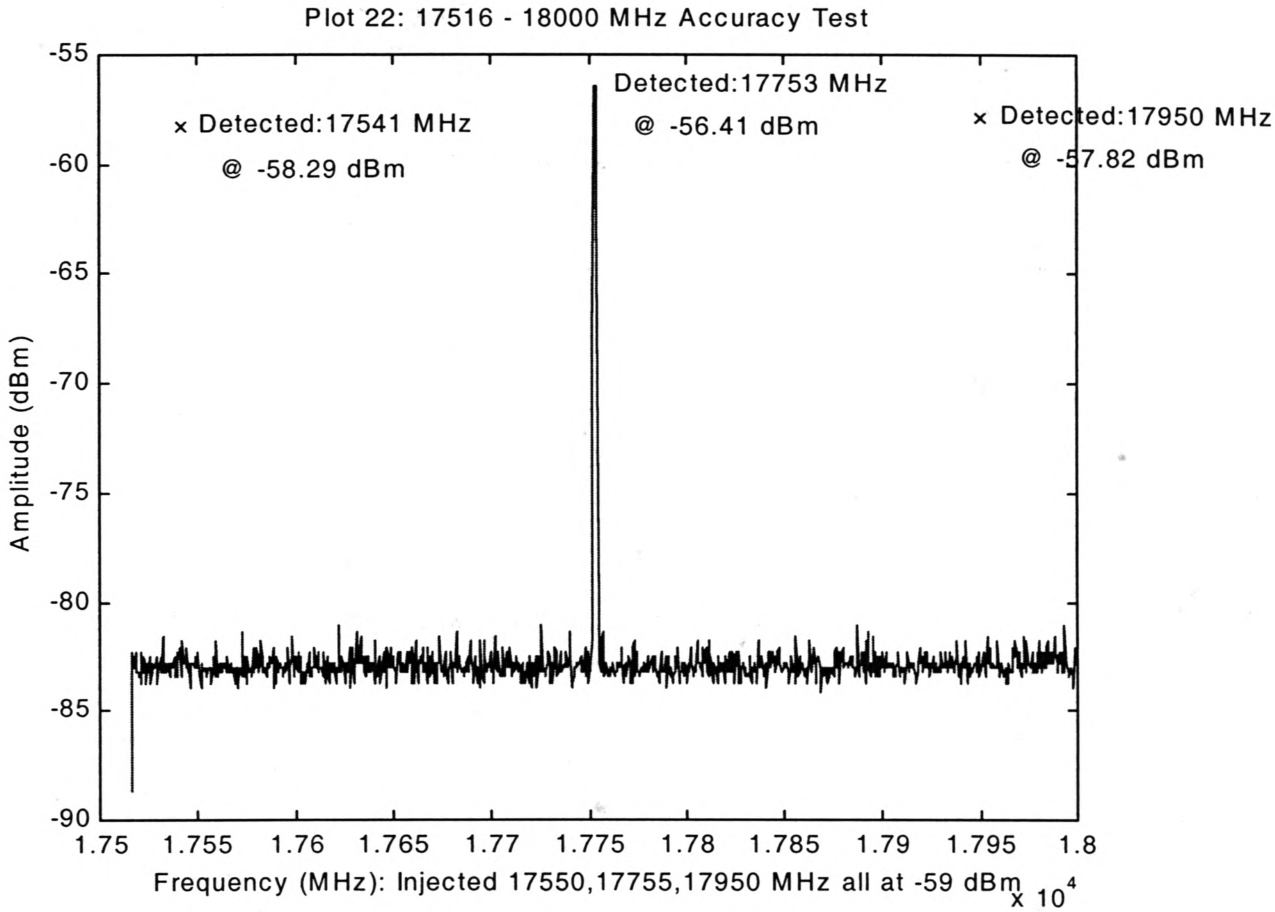
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

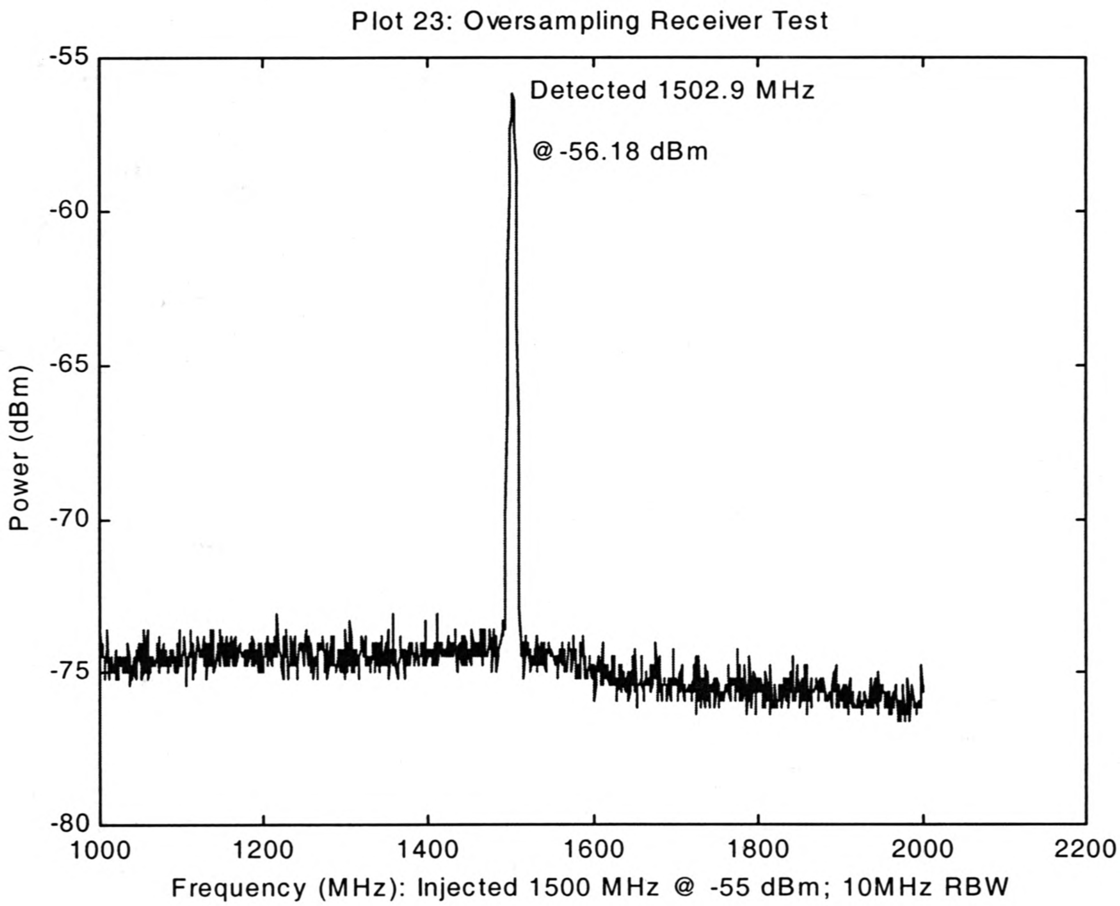

Plot 19: 14945 - 15964 MHz Accuracy Test
Amplitude (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
Detected:15460 MHz
@ -56.88 dBm
×Detected:15103 MHz
@ -58.53 dBm
×Detected:15807 MHz
@ -58.06 dBm
1.48
1.5
1.52
1.54
1.56
1.58
1.6
x 10^4
Frequency (MHz): Injected 15100,15454,15800 MHz all at -59 dBm

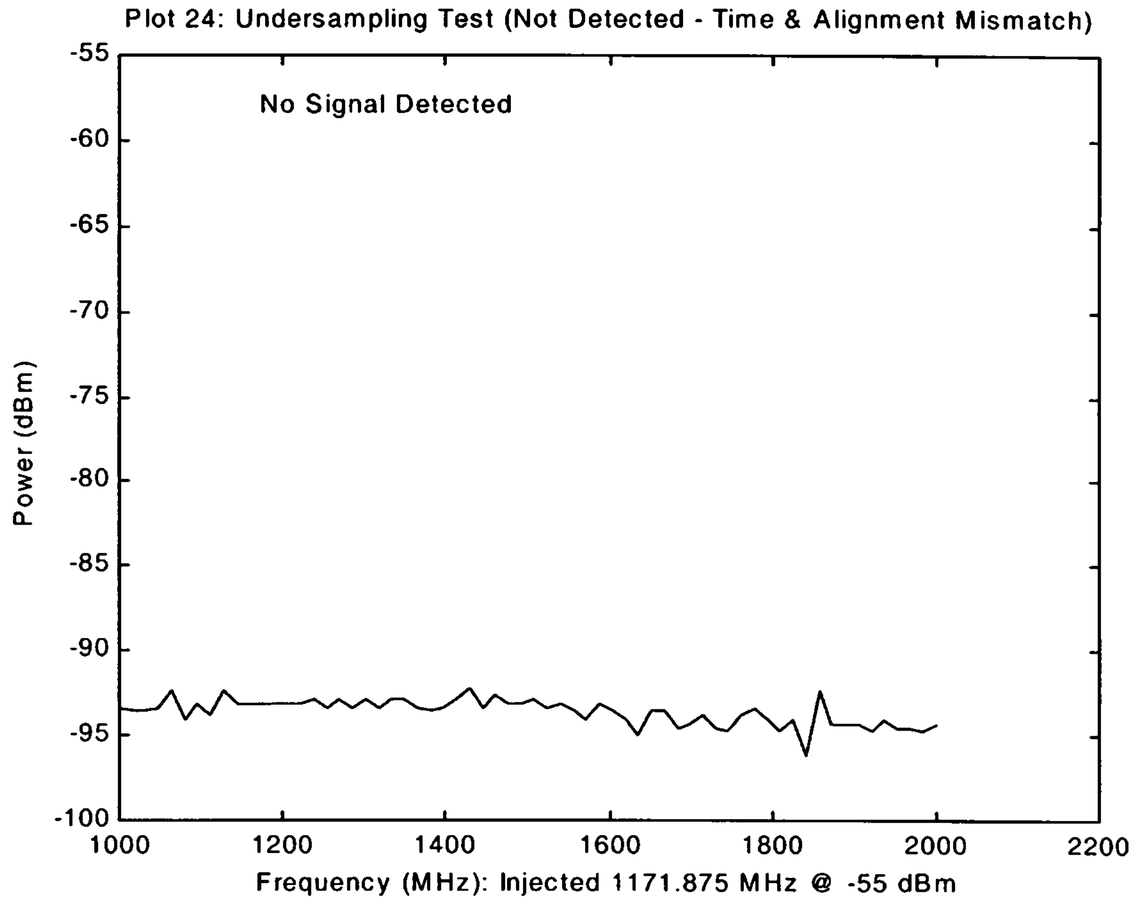


Plot 20: 15956 - 16974 MHz Accuracy Test
×Detected:16097 MHz
@ -58.29 dBm
Detected:16466 MHz
@ -57.35 dBm
×Detected:16803 MHz
@ -59.23 dBm
Amplitude (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
1.58
1.6
1.62
1.64
1.66
1.68
1.7
x 10^4
Frequency (MHz): Injected 16100,16465,16800 MHz all at -59 dBm


Plot 21: 16970 - 17983 MHz Accuracy Test
Amplitude (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
Detected:17483 MHz
@ -57.82 dBm
×Detected:17909 MHz
@ -57.35 dBm
×Detected:17103 MHz
@ -60.41 dBm
1.68
1.7
1.72
1.74
1.76
1.78
1.8
Frequency (MHz): Injected 17100,17476,17900 MHz all at -59 dBm
x 10^4

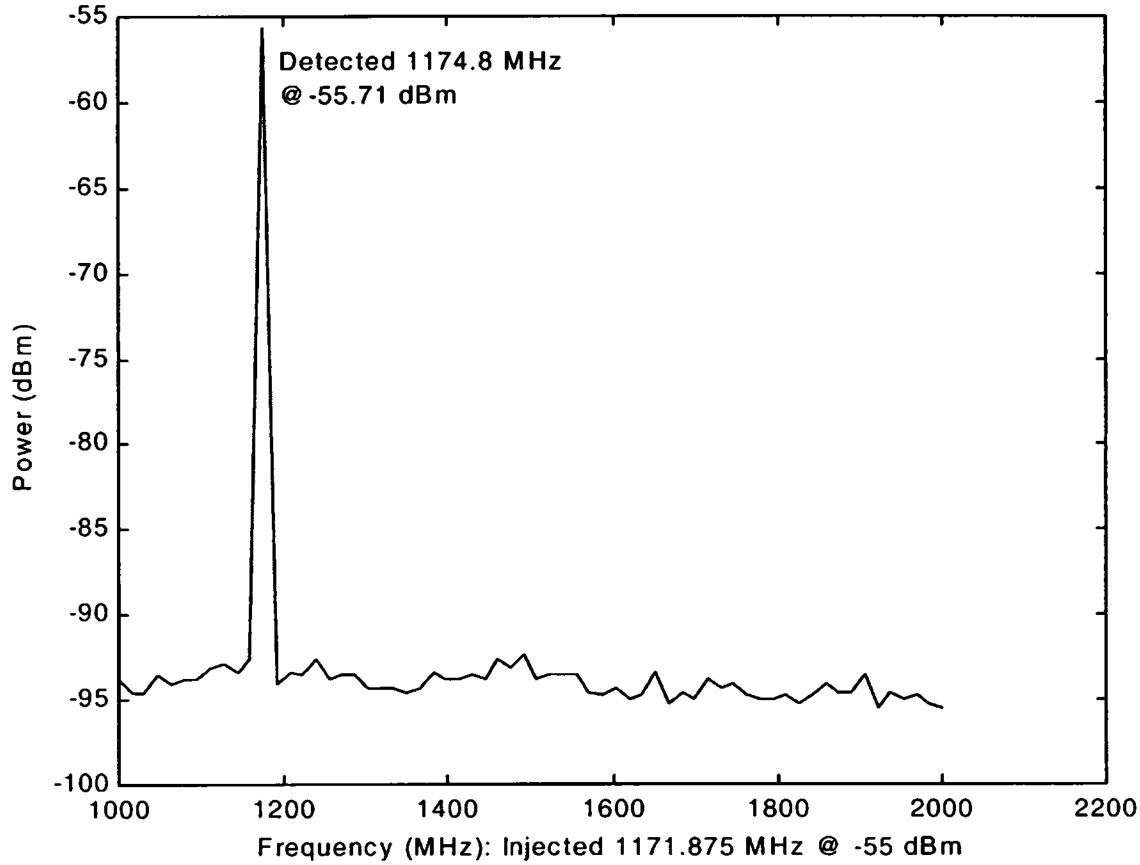

Plot 22: 17516 - 18000 MHz Accuracy Test
Detected:17753 MHz
@ -56.41 dBm
Detected:17541 MHz
@ -58.29 dBm
Detected:17950 MHz
@ -57.82 dBm
-55
-60
-65
-70
-75
-80
-85
-90
Amplitude (dBm)
1.75
1.755
1.76
1.765
1.77
1.775
1.78
1.785
1.79
1.795
1.8
Frequency (MHz): Injected 17550,17755,17950 MHz all at -59 dBm
x 10^4


Plot 23: Oversampling Receiver Test
Detected 1502.9 MHz
@-56.18 dBm
Power (dBm)
-55
-60
-65
-70
-75
-80
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Injected 1500 MHz @ -55 dBm; 10MHz RBW

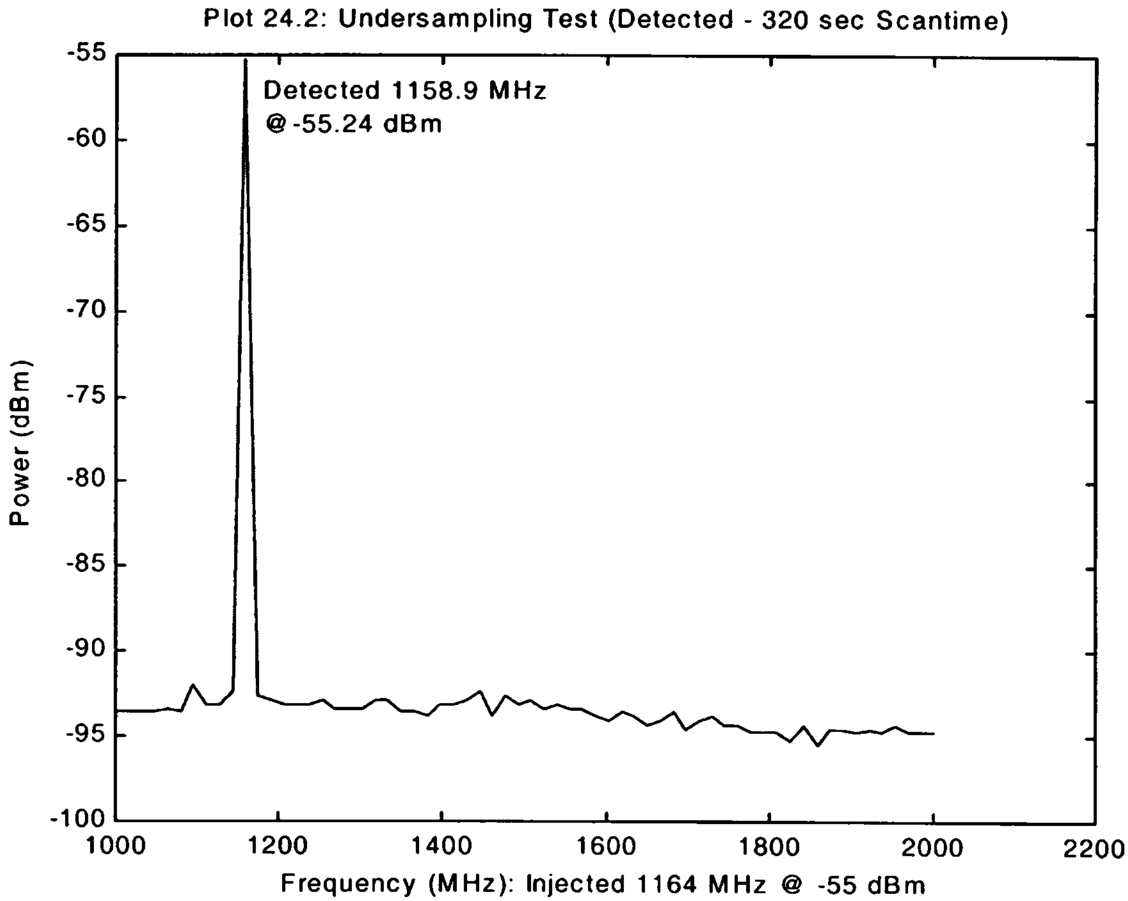


100 kHz RBW, 320 sec scan time, CCI bins

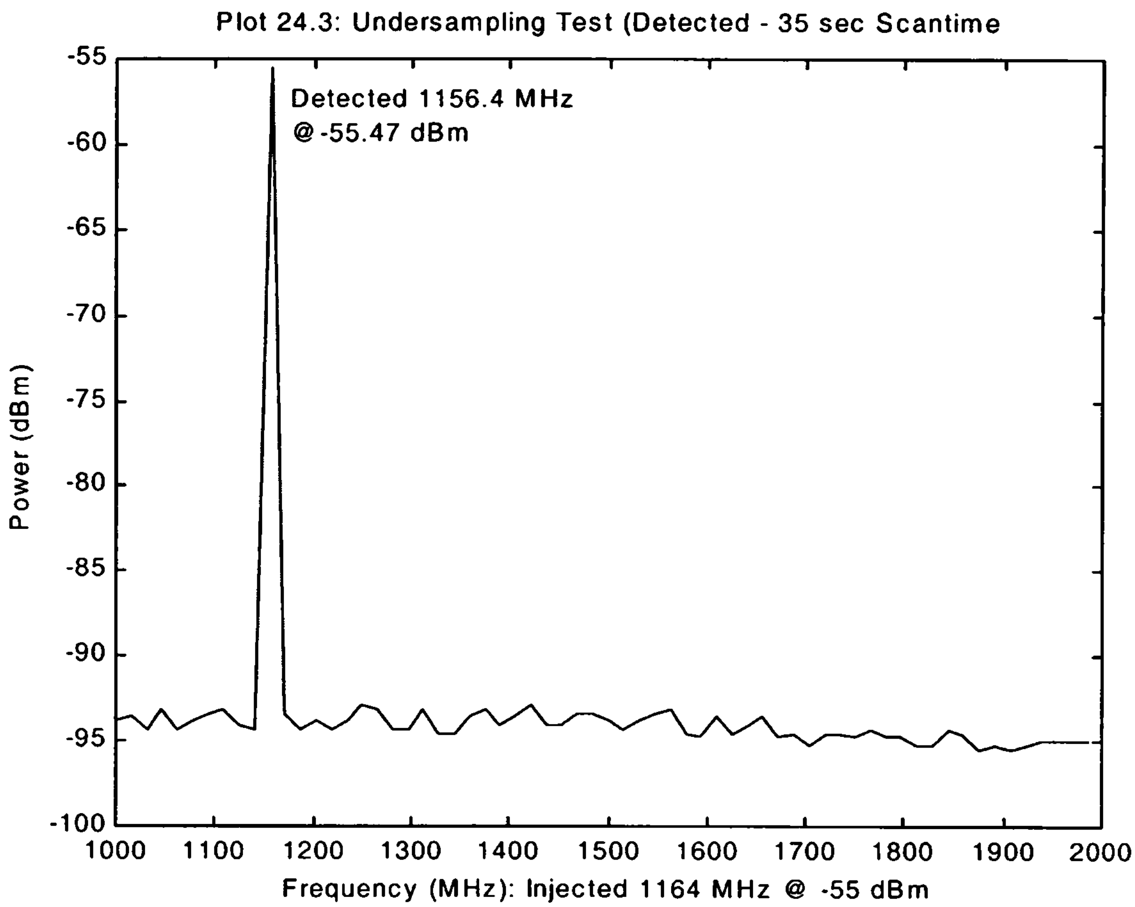
Plot 24.1: Undersampling Test (Detected - Sufficient Hold Time)



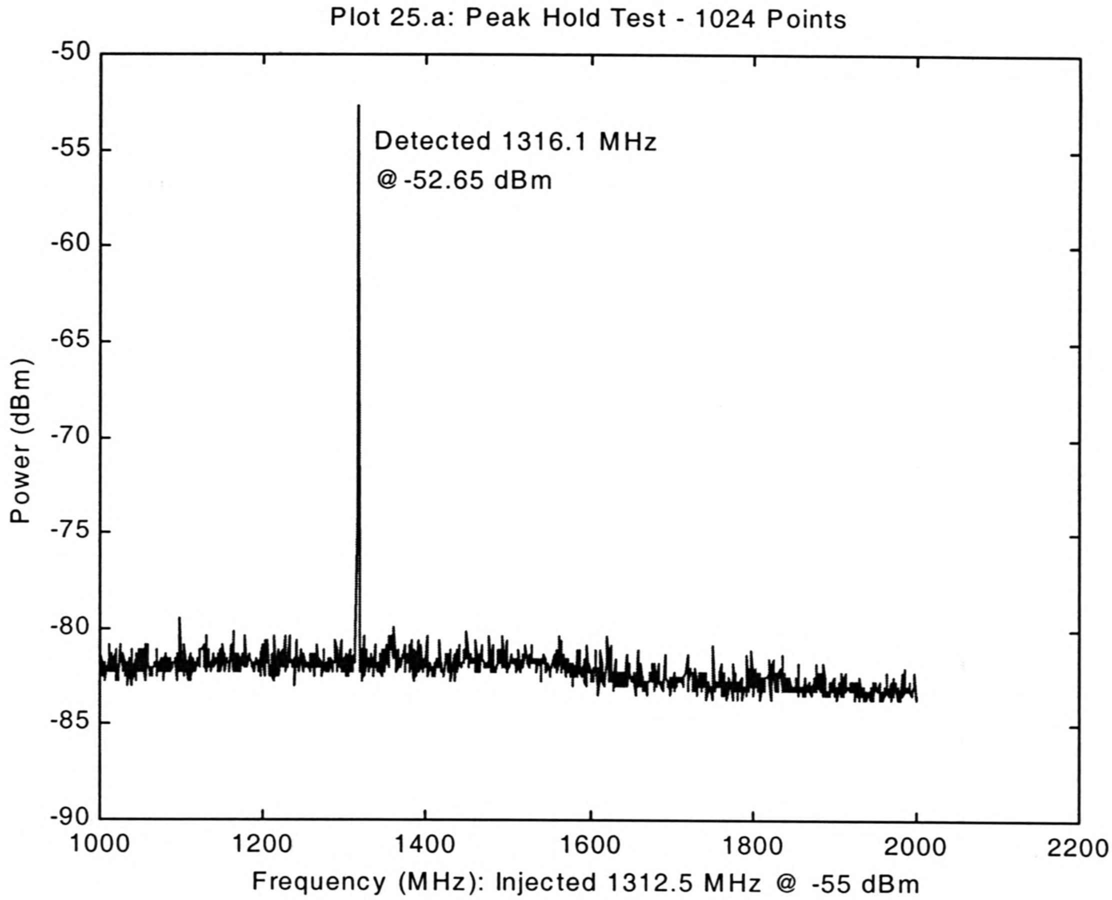
100 kHz RBW, 35 sec scan time, 64 CCI bins



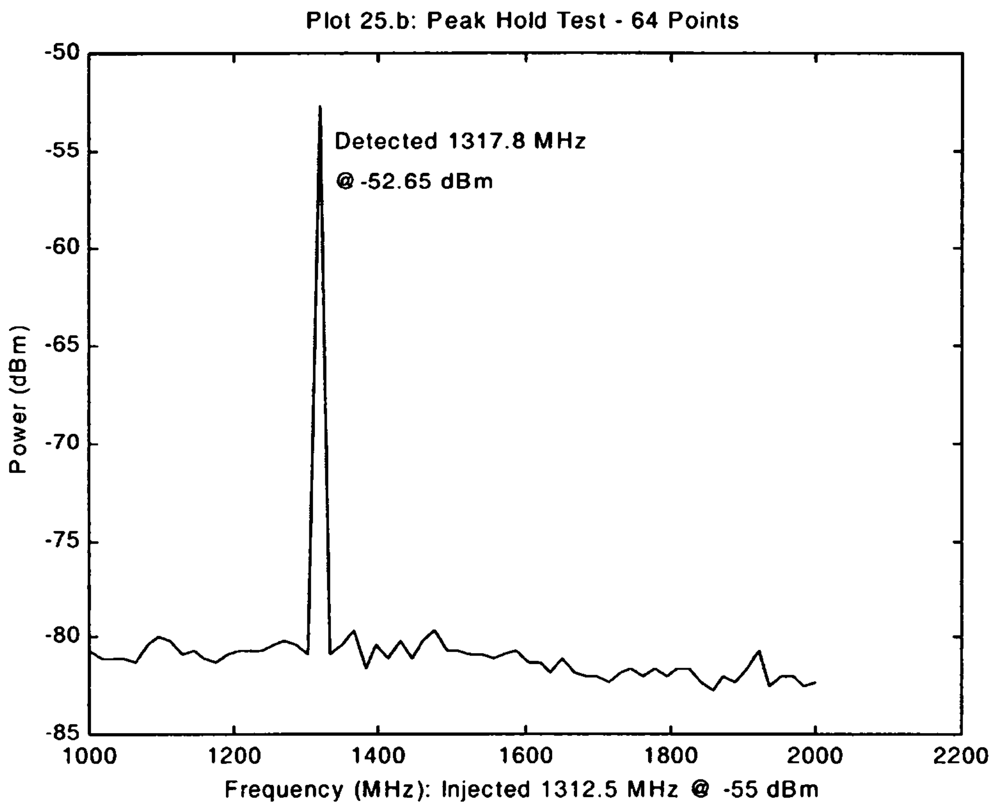
100 kHz RBW, 320 sec scan time, 64 CCI bins



100 kHz RBW, 35 sec scan time, 64 CCI bins



Plot 25.a: Peak Hold Test - 1024 Points
Detected 1316.1 MHz
@ -52.65 dBm
Power (dBm)
-50
-55
-60
-65
-70
-75
-80
-85
-90
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Injected 1312.5 MHz @ -55 dBm


Plot 25.b: Peak Hold Test - 64 Points
Detected 1317.8 MHz
@ -52.65 dBm
Power (dBm)
-50
-55
-60
-65
-70
-75
-80
-85
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Injected 1312.5 MHz @ -55 dBm

APPENDIX B
IPG Survey Plan To Measure Levels Of External RFI The EVLA System Will Have To Accommodate

Raul Armendariz, Sam Field, Adrian Rascon, Ryan Schmidt
May 5th, 2000

NRAO Internal Document

Discussion

The IPG office in Socorro has been given the assignment to establish specifications for the level and characteristics of external RFI the EVLA system will have to accommodate; this specification will be used in the design of 8 EVLA receivers. The IPG RFI Environmental Monitoring Station (EMS) equipment should be used to identify the 6 to 12 strongest RFI emitters in each of the eight EVLA receiver bands, starting with L-band, then S, C, X, and so on up the spectrum. The specifications are to include power levels in absolute calibration of RFI flux densities, frequencies, bandwidth, duty cycle, and rep rate (Sramek/Janes March 28, 2000). The proposed EVLA receivers will cover 1-50 GHz continuously. The IPG EMS equipment has functional limitations, and additional equipment and engineering design are required to survey at frequencies higher than 12 GHz.

Section I lists the EMS equipment which will be used to survey 1-12 GHz, its limitations, and what remains to get it working.

Section II lists equipment IPG has and intends to use for surveying above 12GHz, additionally needed equipment to survey above 12 GHz.

Section III preliminary survey time lines.

Section IV specification sheets and pricing on recommended equipment.

Remaining to do:

A theoretical discussion of how the EMS equipment will be used to determine power levels in absolute calibration of RFI spectral power flux densities, and limits set by the internal noise floor of the Ailtech receiver system. The discussion should focus on RFI power levels causing 1% gain compression in the current VLA receivers, and levels causing a 10% increase in measurement errors above that due to VLA receiver system noise (ITU thresholds). In addition, a discussion of what advantages would be gained by using the IPG Digital Spectrum Analyzer (DSA) versus the Ailtech receiver, and the requirements to do so.

Note:

RFI Sysquick plots demonstrate that interference at the VLA from C through K-bands is much less than in L-band, therefore the majority of surveying time is planned for 1GHz to 5 GHz. Some of the strongest emitters in L-band are satellites, therefore the IPG Satellite Tracking Station (STS) may be needed.

SECTION I: Surveying 1 GHz to 12 GHz

Antennas Positioned on top of 50 feet Rohn tower

1) Discone antenna, omni-directional in azimuth, Sigma Euro-Com SE2200, 800MHz-2.2GHz, vertical polarization,
Remaining to do: Characterize antenna gain pattern vs. frequency. Determine sensitivity to horizontal polarized RF.

2) Directional Horn antenna, GTE Sylvania AN-10F, 2GHz-18GHz, vertical polarization, will be used in slant orientation to receive both vertical and horizontal polarized RF. Gain vs. frequency chart completed at VLA (1976?): 5-20 dBi. Directional antenna will be situated on an azimuth rotator.
Remaining to do: build an antenna mounting plate. Characterize antenna gain pattern vs. frequency.

Possibly use the STS for satellites in L-band.

3) Satellite Tracking Station, Tecom, dish specified range 1GHz-60GHz, feed antenna limits range to 1GHz-18GHz.
Remaining to do: characterize dish gain vs. frequency; determine pointing accuracy.

Low Noise Pre-Amplifiers Positioned on tower ~ 10 feet from antenna
Features:

1) Ambient low noise amplifier coverage 10MHz-12GHz,
4 amplifiers: 10MHz-1GHz, 1GHz-2GHz, 2GHz-4GHz, 4GHz-12GHz
2) Band select relays, specified up to 12 GHz.
3) Noise diode and RF power detector for receiver calibration.

Remaining to do:
Determine if noise diode works.
Determine if lightning protection (Corona Field Detector) works.
Rewire circuit to make more manageable.

Signal Path 3/8 inch foam Heliax, ~ 60 feet

Receiver RFI/EMI Field Intensity Meter, superheterodyne, dual conversion, operates at ambient. Main advantages over a Spectrum Analyzer are its internal 25 MHz bandpass Preselector which prevents intermods from strong out of band signals leaking in and corrupting data; scan time and RBW are independently selectable; has three RFI surveying modes for CW vs. radar signals. Main disadvantage is its potential for missing narrow band signals when remote controller used.

Type:	Ailtech (Stoddart) NM67, serial # 196, designed for MIL STD 461-462
Freq. Range:	1GHz-40GHz; 18GHz-40GHz with frequency downconverter FC67. +/- 1% accuracy
Bands (GHz):	1-2, 2-3.6, 3.6-7.6, 12-18, 18-26, 26-40; sub-band scans allowable.
RBW, 6dB:	100kHz, 1MHz, 10MHz +/- 10% accuracy
Sensitivity:	Receiver noise floor ~ -80 dBm.

Receiver range is −107dBm to +13dBm (includes 60dB attenuator range).
+/- 2dB accuracy for CW signals.
+/- 3dB accuracy for impulse signals.

Scan time: range is 1.5sec-640sec if controller used (else 0.03 to 300 seconds).

Modes: Field Intensity: gives the average value of output.
Special Peak: responds to peak value, exponential decay.
Peak: responds to peak value, calibrated in RMS of equivalent sine wave.

Remaining to do:

Calibrate and repair receiver as necessary:

Determine receiver output inaccuracies in frequency, amplitude, and RBW. For amplitude this is to be done in the form of an IF gain calibration table measuring analog voltages at output receptacle (as outlined in the manual, ~200 MHz increments); for frequency accuracy this is to be done through the controller. For RBW follow manual guidelines.

Possibly write a software correction factor for receiver inaccuracies.

Determine receiver noise floor stability.

Determine relationship between RBW, scan time, and video bandwidth, and how to setup these functions correctly.

Understand which receiver modes are to be used: Field Intensity, Peak, Special Peak.

Transducer correction factor.

Determine how Repetition Rate to be incorporated into data analysis.

Receiver Controller

Type: Ailtech (Stoddart) CCI-7.
Allows PC control of receiver and data download through GPIB-488.
Converts analog data output from receiver to digital.

Specifications:

Frequency scale resolution is selectable with max = 10-bit: 2E10 = 1024 incremental resolution of frequency range. The controller accesses data from the receiver non continuously, thus has the potential to miss data; to avoid the loss of narrow band signals the receiver scan range and RBW will be chosen properly: (scan range)/(RBW) = 1024.

Amplitude scale resolution is selectable with max = 8-bit: 2E8 = 256 incremental resolution of amplitude range. Dynamic range is 60 dB, thus resolution is 60/256 = 0.234dB.

Remaining to do:

Calibrate and repair as necessary.

Determine Controller output inaccuracies in frequency and amplitude.

Determine how the remote IF gain feature for amplitude inaccuracies works.

Computer

Current setup: PC network name "Snow;" AMD 133 MHz, 64Mb RAM, 1.2 Gb hard drive, dual boot Linux 2.0.36 and W95. GPIB card configured for Linux.

Alternative: PC network name "Ra;" Pentium 133 MHz, 64Mb RAM, 3.9 Gb hard drive (includes slave), dual boot Linux 2.0.35 with Redhat 5.0, and WNT. No GPIB card.

Remaining to do:

Linux upgrade (requested by network administrator); determine if change effects receiver control.

Software

1) C-code, ~ 200 lines; software for receiver control and data acquisition. Setup to save peak values over five minute intervals, where each interval consists of multiple scans.
2) Java code, ~ 700 lines; software providing an Applet viewer in Netscape for receiver control and data acquisition. Launches C-program.
3) HC11 microcontroller code, ~ 300 lines; operates amplifier band select, antenna input, and noise diode calibration.
4) IDL code; software for plotting RFI data.
5) Remaining to do:

Add Java program to allow selection of receiver scan time, and scan repetition rate.
Adjust IDL program to plot data easily.

SECTION II: Surveying Above 12 GHz

12 GHz – 18 GHz

Surveying 12GHz-18GHz can be done mostly with the equipment listed above, but requires additional items and design work to the Front End:

Add relays to band select 12GHz-18GHz.
Acquire and add ambient amplifier 12GHz-18GHz.
Possibly change type-N connectors to SMA for 12GHz-18GHz.
Make necessary revisions to HC11 band select controller.

Other issues: determine if 3/8" Heliax signal path losses over 12-18 GHz is tolerable.

18GHz - 50GHz

Surveying above 18 GHz will require additional equipment and engineering design; below is a list of equipment IPG has and intends to use, and what else is needed.

Antennas:

1) Directional Horn antenna, DeMornay-Bonardi E-520 E1007, 18GHz-26GHz, vertical polarization, will be used in slant orientation to receive both vertical and horizontal polarized RF. Directional antenna will be situated on azimuth rotator. Remaining to do: build an antenna mounting plate. Characterize antenna gain pattern vs. frequency.

2) IPG does not have any antennae operating above 26GHz.

Amplifiers:

The IPG does not have any amplifiers, which operate above 12GHz. Depending on distance of antenna from downconverter, amplifiers may or maynot be required.

Receiver:

The Ailtech FC67 frequency downconverter which covers the range 18GHz-40GHz will be used in conjunction with the NM67 receiver. IPG does not have a receiver operating above 40GHz. The FC67 antenna inputs are for WR-42 (18-26GHz), and WR-28 (26-40GHz) waveguide.

Signal path:

If it is determined that the 18-40GHz antennae can be situated near the ground, then waveguide is not needed. If the 18-40 GHz antennas need to be situated on the 50-foot Rohn tower, then a suitable low-loss signal path needs to be constructed. This can be done either by 1) determining Heliax losses and acquiring/installing required amplifier, 2)-acquiring/installing low-loss waveguide along the tower, or 3) situating the FC67 downconverter on the tower.

SECTION III: Survey Time

Equipment (Current)

Front End: Amps range from 0.01 GHz to 12 GHz, Heliax cable usable to 13 GHz, RF Switch SP8T usable to 12.4 GHz

Field Intensity Receiver: NM67 1-18 GHz; RBW 10MHz, 1MHz, 0.1MHz
FC67 Frequency Converter for NM67 18-26GHz and 26-40 GHz

Computer Controller Interface: CCI-7; 1024 recordable bytes

PC: Linux Based, Pentium 133MHz, GPIB link to CCI-7

Antennae: 1-2.2 GHz Omnidirectional
2-18 GHz Directional Horn w/ 45^0 View Sensitivity
18-26 GHz Directional Horn w/ 20^0 View Sensitivity

Equipment (Optimal)

Front End: Amps: 12-18 GHz or 0.1-18 GHz

Field Intensity Receiver: Same as Above

Computer Controller Interface: Same as Above

PC: Same as Above

Antennae: 1-18 GHz Omnidirectional
4-40 GHz Omnidirectional

Survey Width

1024 bytes @ 10MHz resolution = 10.24 GHz span
1024 bytes @ 1MHz resolution = 1.024 GHz span
1024 bytes @ 0.1 MHz resolution = 0.1024 GHz span

Initial Survey Sets

1-12 GHz

Equipment	RBW	# Sets	Time/Set (hours)	Total Time (days)
Current	10 MHz	25	6.00	6.2500
	1 MHz	89	6.00	22.2500
	0.1 MHz	810	6.00	202.5000
Optimal	10 MHz	4	6.00	1.0000
	1 MHz	12	6.00	3.0000
	0.1 MHz	110	6.00	27.5000

12-18 GHz

Equipment	RBW	# Sets	Time/Set (hours)	Total Time (days)
Current	10 MHz	8	6.00	2.0000
	1 MHz	48	6.00	12.0000
	0.1 MHz	480	6.00	120.0000
Optimal	10 MHz	1	6.00	0.2500
	1 MHz	6	6.00	1.5000
	0.1 MHz	60	6.00	15.0000

18-26 GHz

Equipment	RBW	# Sets	Time/Set (hours)	Total Time (days)
Current	10 MHz	18	6.00	4.5000
	1 MHz	144	6.00	36.0000
	0.1 MHz	1440	6.00	360.0000
Optimal	10 MHz	1	6.00	0.2500
	1 MHz	8	6.00	2.0000
	0.1 MHz	80	6.00	20.0000

26-40 GHz

Equipment	RBW	# Sets	Time/Set (hours)	Total Time (days)
Current	10 MHz	72	6.00	18.0000
	1 MHz	504	6.00	126.0000
	0.1 MHz	5040	6.00	1260.0000
Optimal	10 MHz	2	6.00	0.5000
	1 MHz	14	6.00	3.5000
	0.1 MHz	140	6.00	35.0000

Suggested Survey

Band	RBW	# Sets (C)	# Sets (O)	Time/Set (C) hrs	Time/Set (O) hrs
L	0.1 MHz	10	10	3	3
S	0.1 MHz	128	16	3	3
C	1 MHz	40	5	3	3
X	1 MHz	32	4	3	3
U	1 MHz	NA	6	NA	3
K	10 MHz	NA	1	NA	3
Ka	10 MHz	NA	2	NA	3
			total time (days)	26.25	5.5

C = Current Equipment O = Optimal Equipment

SECTION IV

Recommended Equipment Purchase for EMS EVLA
RFI Surveying

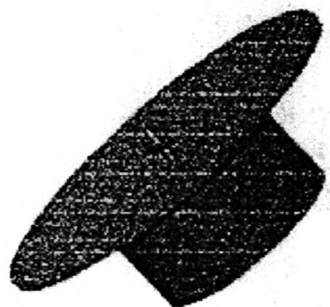
Antenna Research Associates CMA-118/A Specifications

Type:	**Omnidirectional Discone Antenna**
Polarization:	**Vertical (slant linear available)**
Frequency Range:	**1-18 GHz**
Gain:	**3dBi typ.**
Cost:	**$1722**
Lead Time:	**30 days**
VSWR:	**2.0:1 typ.**
Connector:	**SMA Female**
Size:	**8"x2.8"**
Weight:	**3 lbs.**

The CMA-118/A is a discone omnidirectional antenna which works from 1-18 GHz. It is vertically polarized, but can be supplied with slant linear polarization as a no cost option, allowing it to receiver both vertical and horizontal polarization. It comes with a radome that allows it to withstand 100 mph winds.

A.R.A Antenna Research

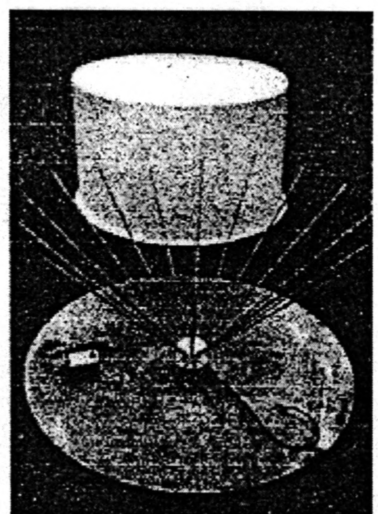
CONICAL MONOPOLES



CMA-118/A

CMA-118/A Typical VSWR and Gain		
FREQUENC Y (GHz)	VSWR	GAIN (dBi)
1.0	1.5	2.9
2.0	1.25	3.0
3.0	1.5	2.0
4.0	2.1	3.0
5.0	1.8	4.2
6.0	1.5	3.6
7.0	1.4	3.4
8.0	1.4	3.3
9.0	2.0	6.1
10.0	2.1	5.7
11.0	2.2	5.1
12.0	2.1	4.7
18.0	1.9	4.5

TYPICAL E-FIELD ANTENNA FACTOR AND GAIN						
FREQUENCY MHz	CMA-750		CMA-350A/A		CMA-710	
	AFE dB M^{-1}	GAIN dBi	AFE dB M^{-1}	GAIN* dBi	AFE dB M^{-1}	GAIN dBi
30			-0.5	0.3		
40			-5.0	7.3		
50			-5.9	10.1		
60			-6.8	12.6	Long Elements	
70	7.3	-0.2	-5.5	12.6	7.3	-0.2
80	7.7	0.6	-4.4	12.7	7.7	0.6
100	9.4	0.8	-3.0	13.2	9.4	0.8
125	11.1	1.1		13.2	11.1	1.1
150	12.8	1.0	0.3	13.4	12.8	1.0
					Short Elements	
200	15.2	1.1	2.6	13.6	15.5	0.8
300	20.0	-0.2	6.4	13.4	18.8	1.0
400	22.5	-0.2	9.3	12.9	21.3	1.0
500	25.0	-0.8	11.6	12.6	23.4	0.8
600			13.5	12.3	24.5	1.3
700			15.1	12.0	22.7	4.4
800			16.8	11.5	26.0	2.3
900			18.1	11.2	28.6	0.7
1000			19.2	11.0	29.7	0.5



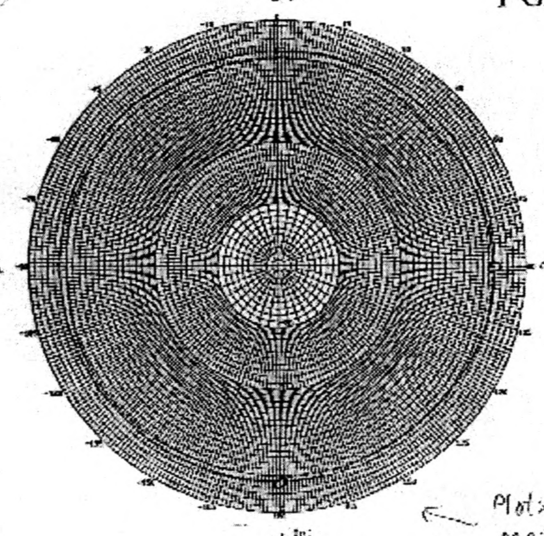
CMA-350A/A

*with pre-amplifier

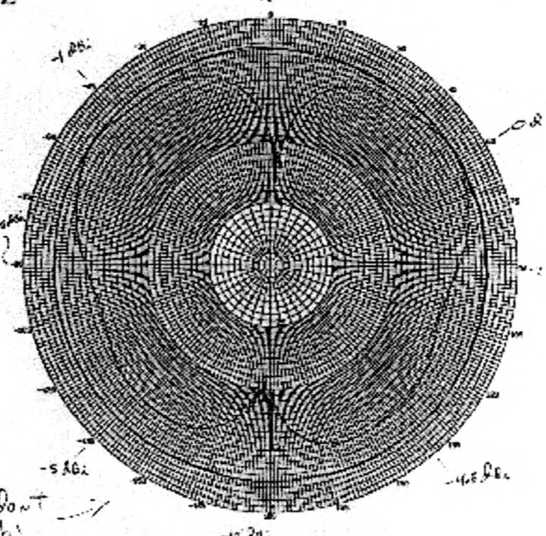
Phone: 301-937-8888 • Fax: 301-937-2796 • http://www.ara-inc.com • sales@ara-inc.com

Antenna Research Associates CMA-118/A Gain Patterns

1 GHz



Azimuth



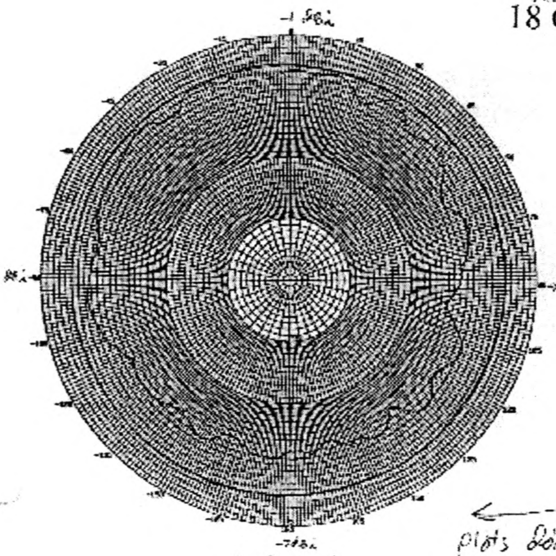
Elevation

Plots don't match!

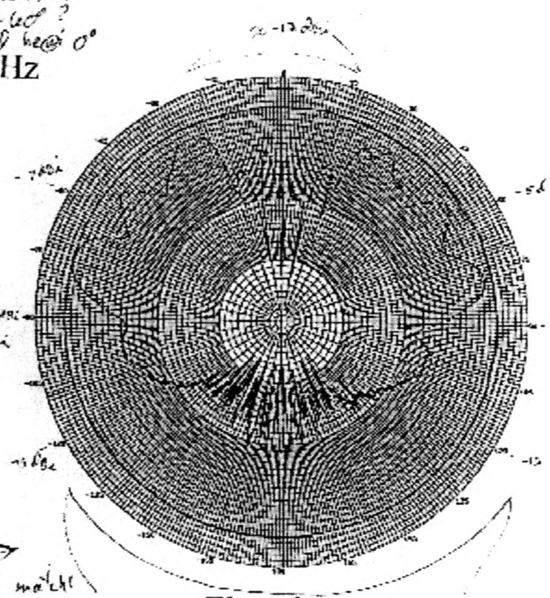
see below also.

is Az a slice @ El = 0? should be @ 0°

18 GHz



Azimuth



Elevation

≈ −15 dBi

plots don't match!

– where in El plot was a slice made generating this Az plot?

Condor Systems AS-48957 Specifications

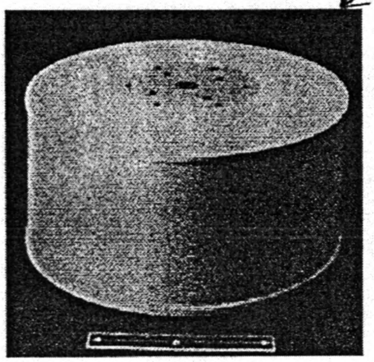
Type:	**Omnidirectional Biconical Antenna**
Polarization:	**Slant Linear**
Frequency Range:	**4 – 40 GHz**
Gain:	**0 dBi**
Cost:	**$9,346**
VSWR:	**3.0:1 max**
Connector:	**SMA Female**
Weight:	**2.5 lbs.**

The Condor Systems AS-48957 is an Omnidirectional Biconical antenna with very wide frequency coverage. Its Omnidirectional coverage from 4 – 40 GHz could be useful for initial RFI surveying.

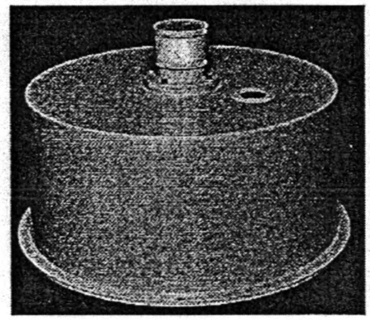
Biconical Omnidirectional Antennas - Slant Linear Polarization

- ***0.5 GHz TO 40 GHz FREQUENCY COVERAGE***
- ***SLANT LINEAR POLARIZATION***
- ***SEALED RADOMES***

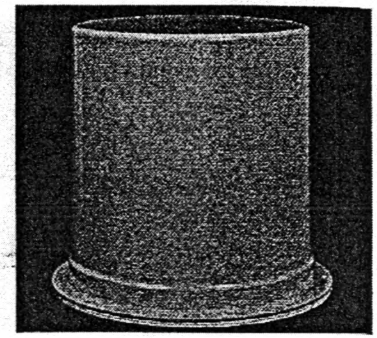
Similiar Design to the AS-48957



AS-48988



AS-48963



AS-48951

These broadband antennas, operating between 0.5 and 40 GHz, provide excellent omnidirectional performance in slant linear polarization.

All models are sealed in low-loss dielectric radomes and have mounting flanges.

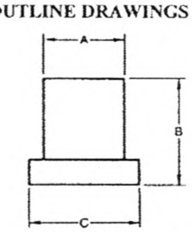
Outstanding performance features include omnidirectional patterns optimized for the reception of signals on the horizon and small deviation from omnidirectionality. Typical performance curves showing properties well above specified limits are shown.

The AS-48951, when equipped with a heavy duty radome, will withstand air speeds of over 600 mph.

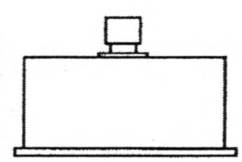
PHYSICAL SPECIFICATIONS

Model Number	Config-uration	"A" in.	(cm)	"B" in.	(cm)	"C" in.	(cm)	Weight lb.	(kg.)	Connector Type
AS-48951	1	4.6	(12.0)	5.5	(14.0)	5.8	(14.7)	2.5	(1.2)	SMA Female
AS-48956	1	3.16	(8.0)	3.10	(7.9)	4.12	(10.5)	0.63	(0.28)	SMA Female
AS-48957	1	4.6	(12.0)	5.5	(14.0)	5.8	(14.7)	2.5	(1.2)	SSMA Female
AS-48960	1	2.0	(5.1)	4.0	(10.2)	3.0	(7.6)	1.0	(0.45)	SSMA Female
AS-48963	2	17.3	(43.9)	12.5	(31.8)	18.9	(48.0)	16.0	(7.3)	SMA Female
AS-48976	1	8.65	(21.9)	9.6	(24.4)	10.23	(26.0)	8.5	(3.9)	SMA Female
AS-48978	1	12	(31)	6	(16)	15	(38)	10	(4.5)	SMA Female
AS-48987	1	12	(31)	6	(16)	12	(31)	10	(4.5)	SMA Female
AS-48988	1	3	(7.6)	2.2	(5.6)	3	(7.6)	0.6	(0.3)	K Female
AS-48989	1	17.3	(44.0)	9.0	(23)	19.0	(48.0)	10	(4.5)	SMA Female

OUTLINE DRAWINGS



Configuration 1



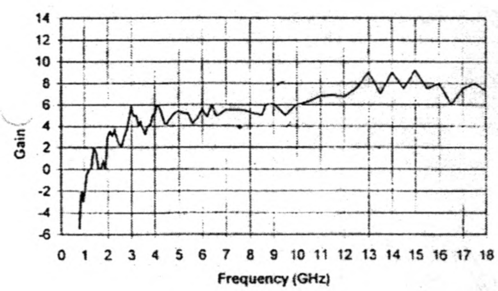
Configuration 2

PERFORMANCE SPECIFICATIONS

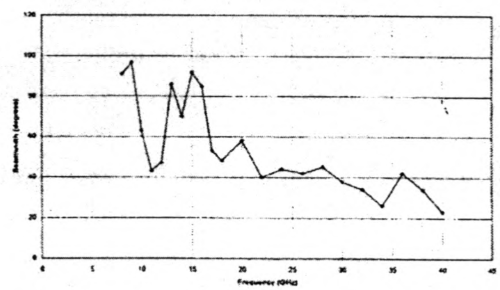
Model Number	Frequency Range	Polarization	Typical Gain (dBi)	VSWR (Max.)		Typical Deviation From Omni[1]
[illegible]51	0.5–18.0 GHz	Slant Linear	-2.0	3.0:1 6.0:1 9.0:1	(2.0–18.0 GHz) (1.0–2.0 GHz) (0.5–1.0 GHz)	±6 dB max. ±3 dB
AS-48956	4.0–26.0 GHz	Slant Linear	0	3.0:1		±3 dB
AS-48957	4.0–40.0 GHz	Slant Linear	0	3.0:1		±3 dB
AS-48960	12.0–40.0 GHz	Slant Linear	0	3.0:1	(12.0–36.0 GHz)	±3 dB
AS-48963 (Stack)	0.5–1.0 GHz 1.0–8.0 GHz 8.0–18.0 GHz	Slant Linear	-0.5 +2.0 0	3.0:1		±3 dB
AS-48976	2.0–18.0 GHz	Slant Linear	3	3.0:1		±3 dB
AS-48978	1.0–8.0 GHz	Slant Linear	0	3.0:1		±2 dB
AS-48987	0.8–18 GHz	Slant Linear	See Curve	2.5:11		±1.5 dB
AS-48988	8–40 GHz	Slant Linear	1.5	3.0:1		±2.0 dB
AS-48989	0.5-18 GHz	Slant Linear	See Curve	3.0:11		±2.5 dB

[1] Specification applicable over 90% of full operating frequency bandwidth.

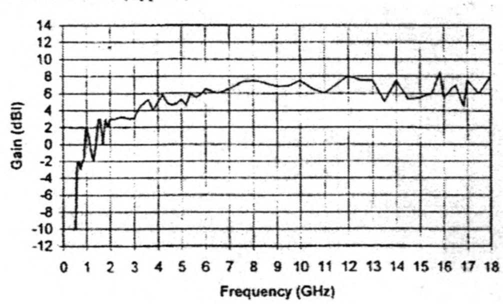
AS-48987 Gain (Typical)



AS-48988 Elevation Beamwidth



AS-48989 Gain (Typical)



OMNIDIRECTIONAL ANTENNAS

Antenna Research Associates MWH 2640/B Specifications

Type:	**Directional Horn Antenna**
Polarization:	**Linear**
Frequency Range:	**26 – 40 GHz**
Gain:	**25 dBi typ.**
Cost:	**$1775**
Lead Time:	**90 days**

The MWH 2640/B is a directional horn antenna that detects linearly polarized signals.

HORN ANTENNAS

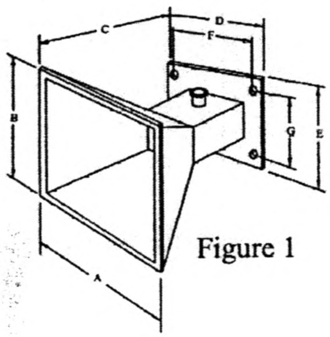


Figure 1

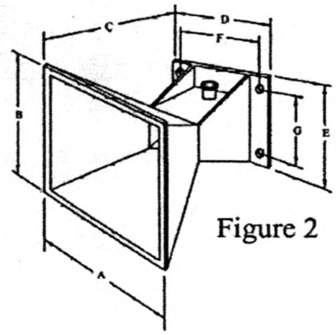


Figure 2

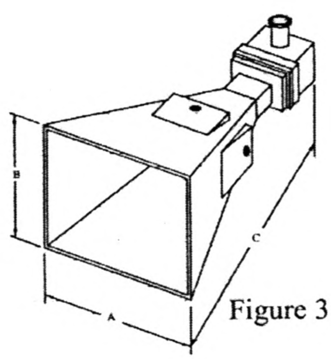
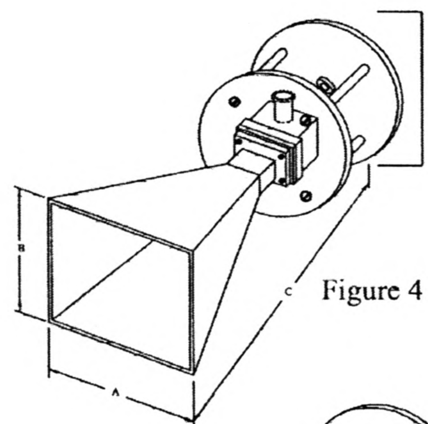


Figure 3



Optional

Figure 4

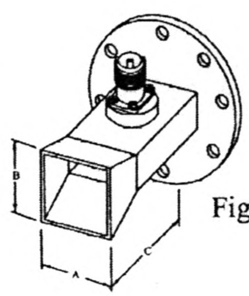


Figure 5

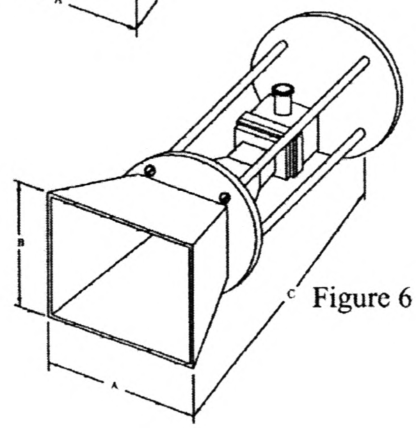
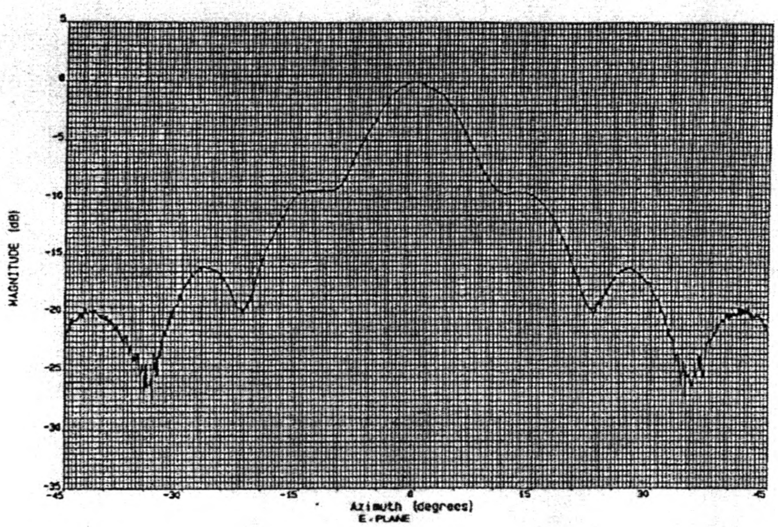


Figure 6

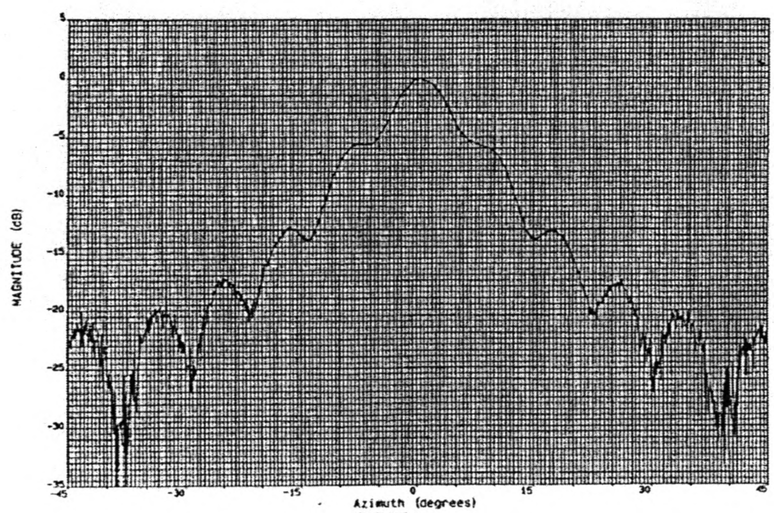
WHEN ORDERING WAVEGUIDE FLANGE OUTPUT, ADD "WG" FOLLOWING THE MODEL NUMBER

Antenna Research Associates MWH 2640/B Gain Patterns

26 GHz



40 GHz



A.R.A Antenna Research

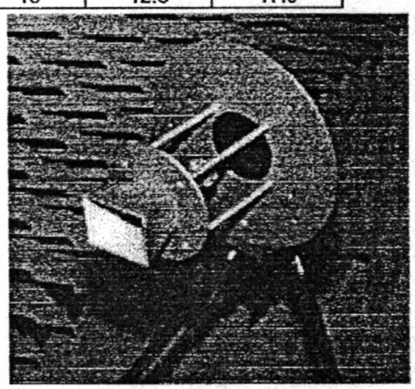
HORN ANTENNAS

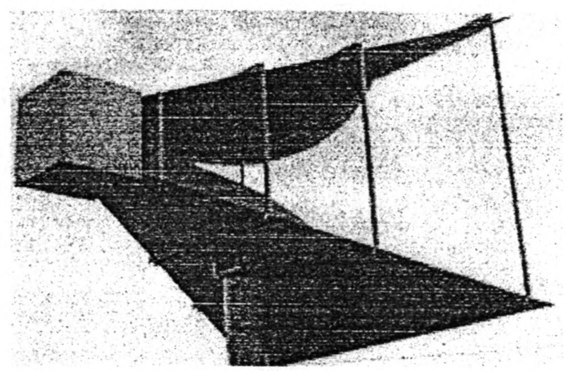
Typical Antenna Gain for Wideband Horns

Frequency (GHz)	Model DRG - 118/A Gain (dBi)	Model DRG-5018/A Gain (dBi)
1	7.3	
2	6.1	
3	9.1	
4	12.3	
5	11.4	10.9
6	12.8	12.1
7	11.8	12.7
8	11.5	12.7
9	13.1	14.0
10	12.2	13.9
12	14.0	14.4
14	10.8	15.8
16	15.8	17.0
18	12.8	17.9

Model DRG - 2020/A Frequency (MHz)	Gain (dBi)
200	7.0
400	9.3
600	11.5
800	10.4
1000	12.7
1200	10.6
1400	10.1
1600	9.3
1800	10.3
2000	10.3

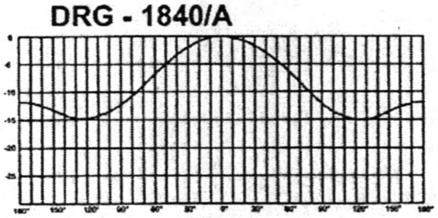
Frequency (GHz)	Model DRG - 1840/A Gain (dBi)	Model MWH-1826/B Gain (dBi)	Model MWH-2640/B Gain (dBi)
18	19.0	23.5	
19	19.5	23.7	
20	20.6	24.2	
22	21.9	24.6	
24	22.4	24.9	
26	23.4	25.1	23.2
28	24.1		23.6
30	25.5		24.1
32	23.1		24.3
34	22.8		24.4
36	22.3		24.7
38	20.8		24.9
40	19.0		25.0





DRG - 1840/A

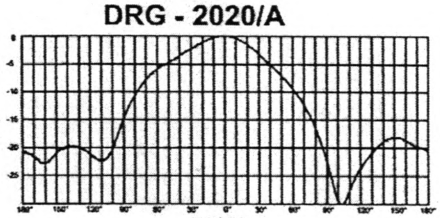
Relative Gain (dBi)



200 MHz

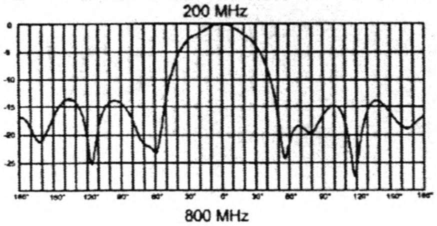
DRG - 2020/A

Relative Gain (dBi)



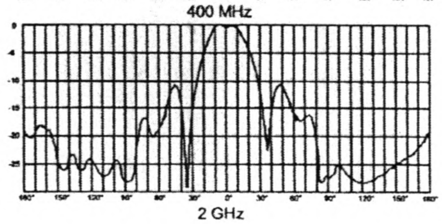
400 MHz

Relative Gain (dBi)



800 MHz

Relative Gain (dBi)



2 GHz

DRG - 2020/A Antenna Patterns

DIMENSIONS FOR HORN ANTENNAS

ANTENNA MODEL	CONFIGURATION (SEE FIGURES)	DIMENSIONS (INCHES)						
		A	B	C	D	E	F	G
MWH - 2550/A	1	68.0	50.3	69.0	36.0	36.0	18.5	24.0
MWH - 5010/A	1	34.0	25.3	33.3	18.0	18.0	16.0	16
MWH - 7511/A	3	35.7	24.3	32.0				
MWH - 9614/A	3	27.5	18.8	25.0				
MWH - 1117/A	3	23.5	16.0	22.5				
MWH - 1422/A	3	18.2	12.3	18.5				
MWH - 1726/A	3	14	10.5	25.0				
MWH - 24/A	2	14	10.9	23.0	7.12	6.0	4.0	4.0
MWH - 2233/A	4	12.0	8.2	14.1				
MWH - 2639/A	4	9.5	6.9	22.0				
MWH - 3349/A	4	8.0	5.6	12.1				
MWH - 48/A	5	2.0	1.6	3.2	3"dia.	8 on 2.5" BC		
MWH - 3958/A	3	6.5	5.0	15.0				
MWH - 4970/A	4	5.5	3.7	13.0				
MWH - 5882/A	3	5.0	3.5	12				
MWH - 7010/A	4	3.8	2.6	7.5				
MWH - 8212/A	3	3.0	2.5	9.0				
MWH - 812/A	5	1.3	1.3	3.2	3" dia.	8 on 2.5" BC		
MWH - 1015/A	4	2.6	1.8	6.0				
MWH - 1218/A	3	2.0	1.5	5.5				
MWH - 1218/B	5	0.7	0.7	3.2	3" dia.	8 on 2.5" BC		
MWH - 1522/A	4	1.8	1.2	4.0				
MWH - 1826/B	6	4.3	3.4	11.9	9" dia.	6 on 5.5" and 8 on 7.06" BC		
MWH - 2233/A	3	1.2	.82	3.0				
MWH - 2640/B	4	3.1	2.5	8.9				
DRG - 2020/A	See picture (Page 57)	38.0	27.0	36.8				
DRG - 118/A	See picture (Page 56)	9.5	5.63	7.85				
DRG - 1020/A	1	17.0	12.6	16.9	9.0	5.4	8.25	4.64
DRG - 1020/B	2	13.5	9.4	19.3	7.0	6.0	4.0	4.0
DRG - 2040/A	2	12.0	8.0	10.3	7.12	6.0	4.0	4.0
DRG - 2678/A	4	6.5	4.4	14.5				
DRG - 3582/A	4	5.4	3.7	13.7				
DRG - 4010/A	4	5.1	3.7	7.0				
DRG - 4711/A	4	5.1	3.7	7.0				
DRG - 5018/A	4	3.4	2.5	6.25				
DRG - 6518/A	4	2.7	1.8	6.2				
DRG - 7518/A	4	2.5	1.7	6.2				
DRG - 1126/A	4	1.7	1.2	4.3				
DRG - 1840/A	6	2.8	2.2	7.4	9" dia	6 on 5.5" and 8 on 7.06" BC		

Apr-21-00 08:29A miteq 516 439 9433 P.01

MITEQ

100 Davids Drive, Hauppauge, New York 11788
TEL : (631) 439-9288
FAX : (631) 439-9433

TO :	NRAO	FAX MSG. NO. :	1123
ATTN :	Ryan Schmidt	DATE :	April 21, 2000
FROM :	Leon Chetuck	FAX NO. :	(505) 835-7027
RE :	Quote # 45000421 . 1 *As per your phone calls of 20-Apr-00.*	TEL. NO. :	(505) 835-7151
		PAGES :	2

Quote # 45000421 : 1

As per your request, Miteq is pleased to quote the following catalog amplifier:

Specifications apply at +25 °C case temperature unless otherwise specified.

Miteq Model Number	AMF-4D-001180-24-10P
Frequency Range	0.1 to 18.0 GHz
Gain	30.0 dB, minimum
Gain Flatness	± 1.50 dB, maximum
Noise Figure	2.40 dB, maximum *(0.2 - 18.0 GHz)* 2.90 dB, maximum *(below 0.2 GHz)*
Power Output at 1 dB Compression	+ 10.0 dBm, minimum
VSWR : Input / Output	2.20 : 1, maximum / 2.20 : 1, maximum
Max Input Handling Capability	+ 10.0 dBm CW
DC Power	+15 VDC @ 150 mA, nom
RF Connectors	SMA - Female
Outline Drawing	121623-4 *(attached)*
Price : 1 - 4 pieces	$ 3,450 each
Delivery : 1 - 4 pieces	60 - 90 days ARO

This quote is valid for 60 days.
TERMS : Net 30 days, FOB Hauppauge, NY

Thank you for the opportunity to quote your requirements.

Best Regards,
Leon Chetuck, Design Engineer
AMF Amplifier Department

F4

MITEQ

100 Davids Drive, Hauppauge, New York 11788
TEL : (631) 439-9288
FAX : (631) 439-9433

TO :	N R A O	**FAX MSG. NO. :**	1054
ATTN :	Ryan Schmidt	**DATE :**	April 17, 2000
FROM :	Leon Chetuck	**FAX NO. :**	(505) 835-7027
RE :	Quote # 45000417 . 5 *(As per your e-mail of 14-Apr-00.)*	**TEL. NO. :**	(505) 835-7151
		PAGES :	2

Quote # 45000417 . 5 CORRected

As per your request, Miteq is pleased to quote the following amplifiers that should suit your requirement:

Specifications apply at +25 °C case temperature unless otherwise specified.

Miteq Model Number	**AMF-4F-120180-25-10P**	**AMF-4D-120260-45-8P**
Frequency Range	12.0 to 18.0 GHz	12.0 to 26.0 GHz
Gain	28.0 dB, minimum	25.0 dB, minimum
Gain Flatness	± 1.50 dB, maximum	± 2.50 dB, maximum
Noise Figure	2.50 dB, maximum	4.50 dB, maximum
Power Out at 1 dB Compression	+ 10.0 dBm, minimum	+ 8.0 dBm, minimum
VSWR : Input / Output	2.00 : 1, max / 2.00 : 1, max	2.30 : 1, max / 2.30 : 1, max
Max Input Handling Capability	+ 10.0 dBm CW	+ 10.0 dBm CW
DC Power	+15 VDC @ 125 mA, nom	+15 VDC @ 225 mA, nom
RF Connectors	SMA - Female	SMA - Female
Outline Drawing	121623-4 *(attached)*	121623-4 *(attached)*
Price & Delivery : 1 - 4 pieces	$ 1,650 each at 60 days ARO	$ 1,950 each at 60 days ARO

Please note that other suitable models will be quoted at your request. Also, a delivery faster than "60 days ARO" is available with the imposition of a premium payment. That, too, will be quoted upon request.

This quote is valid for 60 days. TERMS : Net 30 days, FOB Hauppauge, NY

Thank you for the opportunity to quote your requirements.

Best Regards,
Leon Chetuck, Design Engineer
AMF Amplifier Department

MITEQ
100 Davids Drive, Hauppauge, New York 11788
TEL : (631) 439-9288
FAX : (631) 439-9433

TO :	N R A O	FAX MSG. NO. :	1124
ATTN :	Ryan Schmidt	DATE :	April 21, 2000
FROM :	Leon Chetuck	FAX NO. :	(505) 835-7027
RE :	Quote # 45000421 . 2	TEL. NO. :	(505) 835-7151
	As per your phone calls of 20-Apr-00.	PAGES :	3

Quote # 45000421 . 2

As per your request, Miteq is pleased to quote the following amplifiers:

Specifications apply at +25 °C case temperature unless otherwise specified.

Miteq Model Number	AMF-4D-260400-45-6P	AMF-5D-260400-55-15P
Frequency Range	26.0 to 40.0 GHz	26.0 to 40.0 GHz
Gain	20.0 dB, minimum	30.0 dB, minimum
Gain Flatness	± 2.00 dB, maximum	± 2.00 dB, maximum
Noise Figure	4.50 dB, maximum	5.50 dB, maximum
Power Out at 1 dB Compression	+ 6.0 dBm, minimum	+ 15.0 dBm, minimum
VSWR : Input / Output	2.50 : 1, max / 2.50 : 1, max	2.50 : 1, max / 2.50 : 1, max
Max Input Handling Capability	+ 10.0 dBm CW	+ 10.0 dBm CW
DC Power	+15 VDC @ 160 mA, nom	+15 VDC @ 400 mA, nom -15 VDC @ 50 mA, nom
RF Connectors	K - Female	K - Female
Outline Drawing	125292 *(attached)*	125294 *(attached)*
Price : 1 - 4 pieces	$ 1,850 each	$ 2,150 each
Delivery : 1 - 4 pieces	60 - 90 days ARO	60 - 90 days ARO

This quote is valid for 60 days.
TERMS : Net 30 days, FOB Hauppauge, NY

Thank you for the opportunity to quote your requirements.

Best Regards,
Leon Chetuck, Design Engineer
AMF Amplifier Department

APPENDIX C
Frequency Accuracy and Frequency Readout Minimum Performance Test (7.3.2)

The minimum performance test for frequency can be found at section 7.3.2 in the NM-67 User's Manual. It details the procedure for testing the tuning circuitry of the receiver. The specific test done on May 5, 2000 had the HP 5342A Frequency Counter and the Keithley 191 Digital Multimeter connected to the I.F. output and pin T on the programmer jack, respectively. Just as a caution the I.F. is designed to be 400 MHz above the tuned frequency. Here are the findings:

Frequency Accuracy Test on NM-67 (S/N 196) on May 5, 2000		
Display Readout	Frequency Counter	Voltage Output
0.999	1.40002	0.10003
1.099	1.50002	0.11001
1.199	1.60001	0.11997
1.299	1.70001	0.12996
1.399	1.80000	0.13987
1.500	1.90000	0.14997
1.600	2.00000	0.15998
1.700	2.10000	0.17003
1.801	2.20001	0.18007
1.901	2.29999	0.19007
2.001	2.40001	0.20006
2.001	2.40001	0.19997
2.100	2.50001	0.20994
2.200	2.60000	0.21989
2.300	2.70001	0.22984
2.400	2.80001	0.23978
2.499	2.90001	0.24973
2.599	3.00001	0.25969
2.699	3.10000	0.26966
2.799	3.20002	2.79600
2.898	3.30002	0.28953
2.998	3.40003	0.29950
3.098	3.50001	0.30951
3.199	3.60002	0.31952
3.299	3.70000	0.32957
3.401	3.80002	0.33967
3.502	3.90000	0.34983
3.606	4.00002	0.36010
3.600	NA	NA
3.708	4.10000	0.37030
3.809	4.20003	0.38037
3.910	4.30000	0.39044
4.011	4.39999	0.40049
4.112	4.49999	0.41053
4.212	4.59999	0.42055
4.312	4.70001	0.43055
4.412	4.80002	0.44050
4.512	4.90001	0.45044
4.611	5.00001	0.46039
4.711	5.10002	0.47031
4.810	5.20002	0.48024
4.910	5.30001	0.49015
5.009	5.40001	0.50008
5.108	5.50000	0.51001
5.208	5.60000	0.51993
5.308	5.70000	0.52987
5.407	5.80001	0.53981
5.507	5.90002	0.54975
5.607	6.00006	0.55972
5.707	6.10002	0.56968
5.807	6.20002	0.57965
5.903	6.30001	0.58961
6.005	6.40004	0.59945
6.104	6.50001	0.60935
6.204	6.60001	0.61929
6.304	6.70003	0.62925
6.404	6.80003	0.63921
6.504	6.90000	0.64916
6.604	7.00020	0.65918
6.704	7.10006	0.66919
6.805	7.20001	0.67919
6.906	7.30003	0.68924
7.006	7.40002	0.69929
7.107	7.50004	0.70936

7.208	7.60001	0.71949
7.310	7.70004	0.72961
7.412	7.80000	0.73979
7.515	7.90004	0.75005
7.618	8.00001	0.76037
7.591	8.00000	0.75909
7.695	8.10000	0.76922
7.797	8.20000	0.77931
7.897	8.30001	0.78936
7.998	8.40000	0.79939
8.097	8.50000	0.80933
8.197	8.60000	0.81931
8.297	8.70000	0.82930
8.397	8.80000	0.83426
8.496	8.90000	0.84920
8.596	8.99998	0.85911
8.696	9.10001	0.86915
8.796	9.20003	0.87914
8.896	9.30001	0.88914
8.997	9.40000	0.89924
9.093	9.50001	0.80911
9.194	9.60001	0.91890
9.294	9.70000	0.92890
9.394	9.80000	0.93890
9.495	9.90000	0.98900
9.595	9.99999	0.95890
9.695	10.09999	0.96559
9.795	10.20001	0.97890
9.895	10.30000	0.98879
9.997	10.40000	0.99893
10.097	10.50003	1.00897
10.197	10.60000	1.01896
10.298	10.70001	1.02902
10.398	10.80001	1.03902
10.497	10.90001	1.04894
10.597	11.00002	1.05888
10.697	11.10003	1.06885
10.797	11.20000	1.07886
10.898	11.30001	1.08892
10.998	11.40004	1.09892
11.098	11.50000	1.10893
11.199	11.59999	1.11899
11.300	11.70001	1.12908
11.400	11.80002	1.13911
11.501	11.90006	1.14917
11.603	12.00001	1.15950

11.704	12.10002	1.16946
11.804	12.20000	1.17945
11.904	12.30001	1.18945
12.005	12.40000	1.19950
12.007	12.40000	1.19797
12.106	12.50000	1.20784
12.205	12.60000	1.21778
12.305	12.70000	1.22776
12.406	12.80000	1.23777
12.506	12.90000	1.24777
12.606	13.00000	1.25775
12.706	13.10000	1.26773
12.806	13.20005	1.27769
12.906	13.29993	1.28765
13.006	13.40000	1.29765
13.106	13.50000	1.30763
13.205	13.60000	1.31755
13.306	13.70000	1.32757
13.406	13.79997	1.33752
13.506	13.90008	1.34754
13.606	14.00003	1.35752
13.707	14.10007	1.36750
13.807	14.20004	1.37751
13.907	14.30000	1.38749
14.006	14.40003	1.39743
14.107	14.50003	1.40743
14.207	14.60044	1.41747
14.307	14.70031	1.42740
14.407	14.80010	1.43735
14.507	14.90012	1.44730
14.607	15.00011	1.45727
14.707	15.10014	1.46726
14.806	15.20000	1.47721
14.907	15.30001	1.48722
15.007	15.40005	1.49729
15.107	15.50006	1.50725
15.208	15.60006	1.51725
15.308	15.70009	1.52725
15.409	15.80063	1.53729
15.509	15.90009	1.54726
15.609	16.00030	1.55730
15.709	16.10000	1.56727
15.809	16.19998	1.57726
15.910	16.30015	1.58729
16.011	16.40015	1.59730
16.111	16.49997	1.60729

16.212	16.60025	1.61734
16.312	16.70019	1.62735
16.412	16.80007	1.63735
16.513	16.90000	1.64737
16.613	17.00001	1.65734
16.713	17.10002	1.66735
16.813	17.20010	1.67736
16.914	17.30028	1.68740
17.014	17.40002	1.69739
17.114	17.49999	1.70740

17.215	17.59999	1.71743
17.315	17.70017	1.72748
17.415	17.79993	1.73743
17.517	17.90002	1.74755
17.617	18.00010	1.75758
17.718	18.10003	1.76760
17.879	18.20013	1.77772
17.920	18.29997	1.78779
18.021	18.40004	1.79787

APPENDIX D
Calibration Factors for Manual Operation of NM-67 S/N196
(May 9, 2000)

Calibration Values found on May 9, 2000 by injecting a –47 dBm signal at the given frequency. The attenuator was set to 20 dB and any **bold** values indicate out-of-range (necessary gain was more than could be applied).

Calibration Values (dBμV)			
Frequency Display	10 MHz RBW	1.0 MHz RBW	0.1 MHz RBW
1.0000	36.0	35.0	37.2
1.1000	34.0	34.1	36.8
1.2000	33.9	35.0	37.1
1.3000	34.8	34.9	37.8
1.4000	32.0	33.8	36.0
1.5000	33.6	34.1	36.9
1.6000	35.1	36.0	38.5
1.7000	32.7	34.5	36.5
1.8000	30.9	33.9	36.3
1.9000	28.5	32.2	34.5
2.0000	27.1	31.0	33.2
2.0000	27.0	31.0	33.0
2.1000	27.3	31.4	33.3
2.2000	28.0	31.5	34.0
2.3000	27.8	31.0	33.1
2.4000	27.9	31.8	34.1
2.5000	29.1	33.0	35.5
2.6000	28.2	32.0	34.9
2.7000	28.0	32.0	34.5
2.8000	27.4	31.3	33.8
2.9000	28.5	32.5	34.5
3.0000	29.0	32.0	35.0
3.1000	30.0	32.5	34.5
3.2000	28.0	32.0	35.0
3.3000	28.0	32.0	35.0
3.4000	28.5	32.5	35.0
3.5000	30.5	33.0	35.5
3.6000	29.9	32.1	34.4
3.6000	32.6	33.5	
3.7000	32.2	33.5	
3.8000	32.0	33.0	
3.9000	31.0	33.0	
4.0000	31.5	33.0	
4.2000	30.0	33.0	
4.4000	32.0	34.5	
4.6000	35.0	38.0	
4.8000	***35.0***	***35.5***	
5.0000	***36.0***	***36.5***	
5.2000	***36.0***	***37.5***	
5.4000	31.0	34.0	
5.6000	30.0	33.5	
5.8000	31.5	35.5	
6.0000	32.0	34.5	
6.2000	33.0	36.0	
6.4000	32.5	35.0	
6.6000	33.0	34.5	
6.8000	33.0	35.0	
7.0000	32.0	34.0	
7.2000	32.0	34.5	
7.4000	32.0	34.0	
7.6000	33.0	35.0	
7.6000	33.0	35.0	
7.8000	33.0	35.0	
8.0000	34.5	35.5	
8.2000	36.5	37.5	
8.4000	37.5	33.0	
8.6000	38.0	38.0	
8.8000	35.5	35.5	
9.0000	34.5	36.0	
9.2000	37.5	38.0	
9.4000	36.5	37.0	
9.6000	36.0	36.0	
9.8000	37.0	37.0	
10.0000	36.5	36.9	
10.2000	37.0	37.5	
10.4000	37.0	37.5	
10.6000	37.5	38.0	
10.8000	37.5	38.0	
11.0000	38.0	38.0	
11.2000	37.0	37.0	

11.4000	37.0	36.5	
11.6000	36.0	37.0	
11.8000	35.0	36.0	
12.0000	35.0	37.5	
12.0000	36.5	37.5	
12.4000	36.5	37.0	
12.8000	38.0	38.0	
13.2000	38.0	37.5	
13.6000	37.5	37.0	
14.0000	39.0	38.0	
14.4000	39.5	38.5	

14.8000	39.0	38.5	
15.2000	39.0	38.0	
15.6000	40.0	39.0	
16.0000	40.0	39.0	
16.4000	39.5	38.5	
16.8000	39.0	38.0	
17.2000	39.0	38.5	
17.6000	38.0	37.0	
18.0000	38.5	38.0	

APPENDIX E
Program-Oriented Frequency Stability over Time

The following charts show the movement of the limits of the frequency tuning that occurred within the CCI-7 and NM-67 during characterization investigations.

Total Frequency Span (Span = 255, Zero = 0)			
	Frequency Tune Max	Frequency Tune Min.	
11-May			
Band 1	0.956 - 2.078	1.067 - 2.196	
Band 2	1.967 - 3.703	2.138 - 3.876	
Band 3	3.519 - 7.802	3.946 - 8.214	
Band 4	7.518 - 12.206	7.981 - 12.660	
Band 5	11.930 - 18.250	12.557 - 18.879	
15-May			
Band 1	0.950 - 2.058	1.062 - 2.174	
Band 2	1.958 - 3.667	2.129 - 3.842	
Band 3	3.498 - 7.723	3.920 - 8.147	
Band 4	7.494 - 12.125	7.958 - 12.597	
Band 5	11.898 - 18.143	12.523 - 18.775	
22-May			
Band 1	0.947 - 2.054	1.058 - 2.169	
Band 2	1.955 - 3.671	2.126 - 3.841	
Band 3	3.494 - 7.723	3.916 - 8.142	
Band 4	7.489 - 12.132	7.952 - 12.594	
Band 5	11.891 - 18.157	12.515 - 18.773	
Gigahertz Frequency Sets			
Span	Frequency Start	Frequency Span	
30-May			
1.000 - 2.001	0	230	
2.000 - 3.022	0	152	
3.007 - 3.605	151	90	
3.600 - 4.607	0	61	
4.589 - 5.602	63	61	
5.597 - 6.606	123	61	
6.604 - 7.615	181	62	
7.600 - 8.619	0	56	
8.607 - 9.625	56	56	
9.573 - 10.590	111	56	
10.590 - 11.601	164	56	
11.594 - 12.008	220	23	

12.000 - 12.998	0	41	
12.996 - 13.993	42	41	
13.991 - 14.989	82	41	
14.984 - 15.982	124	41	
15.982 - 16.978	162	41	
16.965 - 17.955	203	41	
17.946 - 18.018	243	3	
2-Jun			
1.000 - 2.000	0	230	
2.000 - 3.025	0	152	
3.009 - 3.606	151	90	
3.600 - 4.607	0	61	
4.579 - 5.593	63	61	
5.591 - 6.601	121	61	
6.598 - 7.608	181	62	
7.600 - 8.617	0	56	
8.605 - 9.621	56	56	
9.566 - 10.580	111	56	
10.576 - 11.584	163	56	
11.584 - 12.016	220	24	
12.000 - 12.996	0	41	
12.980 - 13.975	41	41	
13.960 - 14.956	80	41	
14.936 - 15.929	121	41	
15.835 - 16.828	159	41	
16.826 - 17.815	198	41	
17.794 - 18.008	239	9	
14-Jun			
1.000 - 2.000	0	230	
2.000 - 3.023	0	152	
3.004 - 3.601	151	90	
3.600 - 4.608	0	61	
4.576 - 5.586	63	61	
5.579 - 6.588	120	61	
6.584 - 7.609	180	63	
7.600 - 8.616	0	56	
8.600 - 9.616	56	56	
9.558 - 10.571	111	56	
10.571 - 11.581	163	56	
11.578 - 12.008	220	24	
12.000 - 12.996	0	41	
12.985 - 13.981	42	41	
13.966 - 14.962	81	41	
14.954 - 15.977	123	42	

15.974 - 16.995	162	42	
16.993 - 18.008	206	42	
30-Jun			
1.000 - 2.000	0	230	
2.000 - 3.023	0	152	
3.003 - 3.601	151	90	
3.600 - 4.605	0	61	
4.576 - 5.586	63	61	
5.585 - 6.596	121	61	
6.592 - 7.605	181	62	
7.600 - 8.616	0	56	
8.612 - 9.628	57	56	
9.560 - 10.573	111	56	
10.573 - 11.580	163	56	
11.578 - 12.008	220	24	
12.000 - 12.994	0	41	
12.985 - 13.980	42	41	
13.969 - 14.964	81	41	
14.960 - 15.982	123	42	
15.978 - 16.999	162	42	
16.997 - 18.013	206	42	
14-Aug			IFGain
1.000 - 2.001	0	231	35
2.000 - 3.022	0	152	36
3.014 - 3.601	151	89	33
3.600 - 4.623	0	62	45
4.592 - 5.600	63	61	86
5.597 - 6.602	121	61	35
6.593 - 7.601	180	62	34
7.600 - 8.615	0	56	32
8.608 - 9.620	56	56	34
9.575 - 10.587	111	56	35
10.580 - 11.601	163	57	36
11.591 - 12.004	220	23	37
12.000 - 12.994	0	41	16
12.983 - 13.977	41	41	22
13.962 - 14.956	80	41	13
14.945 - 15.964	121	42	22
15.956 - 16.974	160	42	28
16.970 - 17.983	203	42	25
17.516 - 18.000	224	20	16

APPENDIX F
STS Gain Characterization at 1.5 GHz

Setup

Transmitter: Gigatronics 1018 (S/N 320508) – Characterized, CW Signal, Frequency = 1.5 GHz; $\lambda = 0.1993$ m, power = 0 dBm

Transmitting Horn: Tensor 1 – 10 GHz (S/N 2043) – Vertically Polarized, 6 dBi Gain at operating frequency (assumed)

Distance: 100 m (estimated)

Receiver: Spectrum Analyzer – HP 8559A (S/N 2347403428), Scan Mode – Peak Hold, Signal Recorded through GPIB Port, VBW and Scan time not recorded, RBW = 100 kHz, scan 1.45 – 1.55 GHz, noisefloor = -82 dBm/100 kHz

Feed: Watkins-Johnston AR7-18 (S/N 007), 1 – 18 GHz, Single Linear Polarization, -10 dB angle approximately matches dish illumination angle of 74°, Gain at operating frequency is 6 dBi (assumed)

Calculation

Transmitted Signal Power (EIRP) = Generated Signal Power + Horn Gain

$$\begin{array}{r} 0dBm \\ +6dBi \\ \hline +6dBm \end{array}$$

Propagation Loss

$$10\log\left(\frac{1}{4\pi(100)^2}\right) = -51\_dBm$$

SPFD at Dish

$$\begin{array}{r} +6dBm \\ -51dB/m^2 \\ \hline -45dBm/m^2 \end{array}$$

Received Power out of Antenna (SP) = Receiver Measured Power – Lineloss

$$\begin{array}{r} -37dBm \\ +6dBi \\ \hline -31dBm \end{array}$$

Effective Aperture (A_e) = Received Power / SPFD

$$Ae = \frac{10^{-3.1}}{10^{-4.5}} = 25.119\_m^2$$

Gain (dB) = 10*log(Gain isotropic)

$$Gain = 10\log\left(\frac{4\pi Ae}{\lambda^2}\right) = 39.0dB$$

Notes

EIRP: Effective Isotropic Radiated Power – the power out of the transmitting antenna

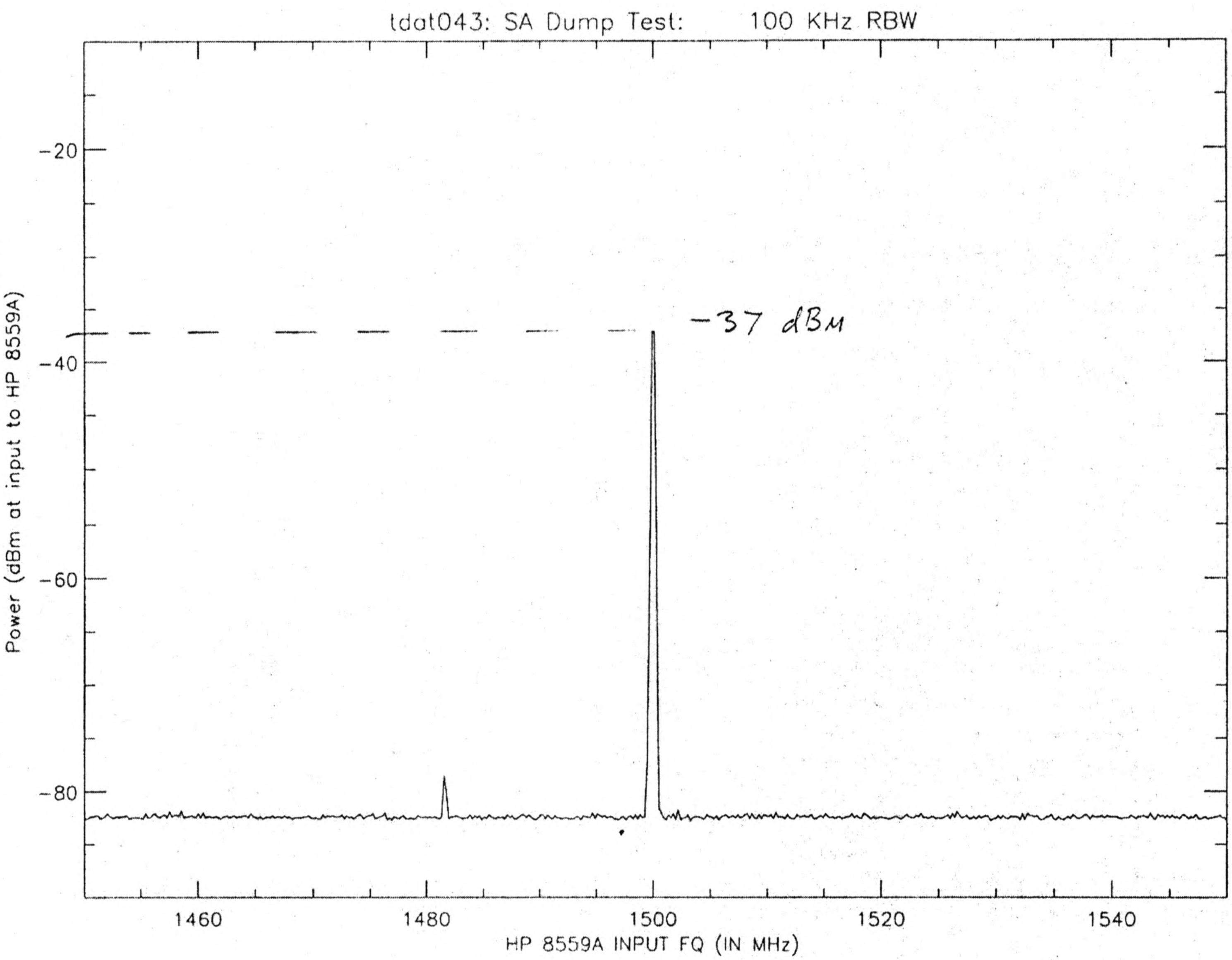
SPFD: Spectral Power Flux Density – the power at the receiving antenna (in space) per unit Hertz

SP: Spectral Power – either in the receiver or the line right after the feed

A_e: Effective Aperture of Receiving Antenna – For parabolic dish the effective aperture depends on the geometry of the dish and the effect of matching the feed sensitivity to the dish geometry (i.e. how well the –11 dB rule is implemented).

Issues Which May Have Affected Gain Calculation

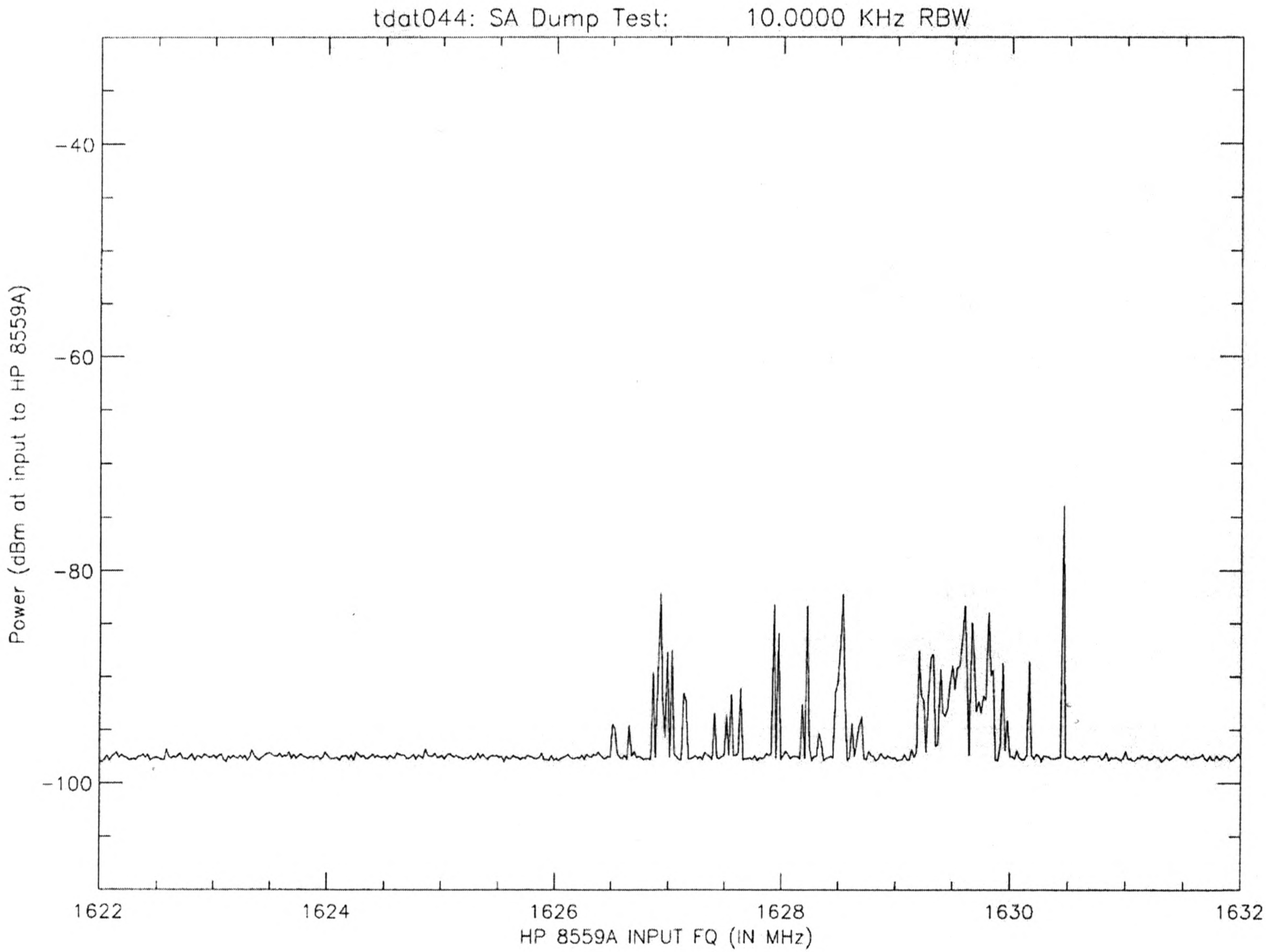
1) Transmitting Horn's Gain of 6 dBi at 1.5 GHz is interpolated from manufacturer's specification sheet
2) Positioning of the feed on the dish put the feed's center point at the focus, not the phase center (the tip of the feed). This will impact the antenna efficiency value.
3) The feed orientation with respect to the incident wave (vertically polarized) was not recorded – the actual incident power cannot be determined without this factor.
4) The spectrum analyzer's reception characteristics is unknown (it may have reported rms, peak, or averaged power).
5) The spectrum analyzer is uncalibrated.
6) Pointing accuracy of the parabolic dish toward the transmitting source was approximated with binoculars (human interaction).
7) No loss was assumed between the signal generator and the transmitting horn (the three feet of cable was assumed ideal – no line loss).
8) Noisefloor contributions were ignored since the level is expected to be less than 0.1dB

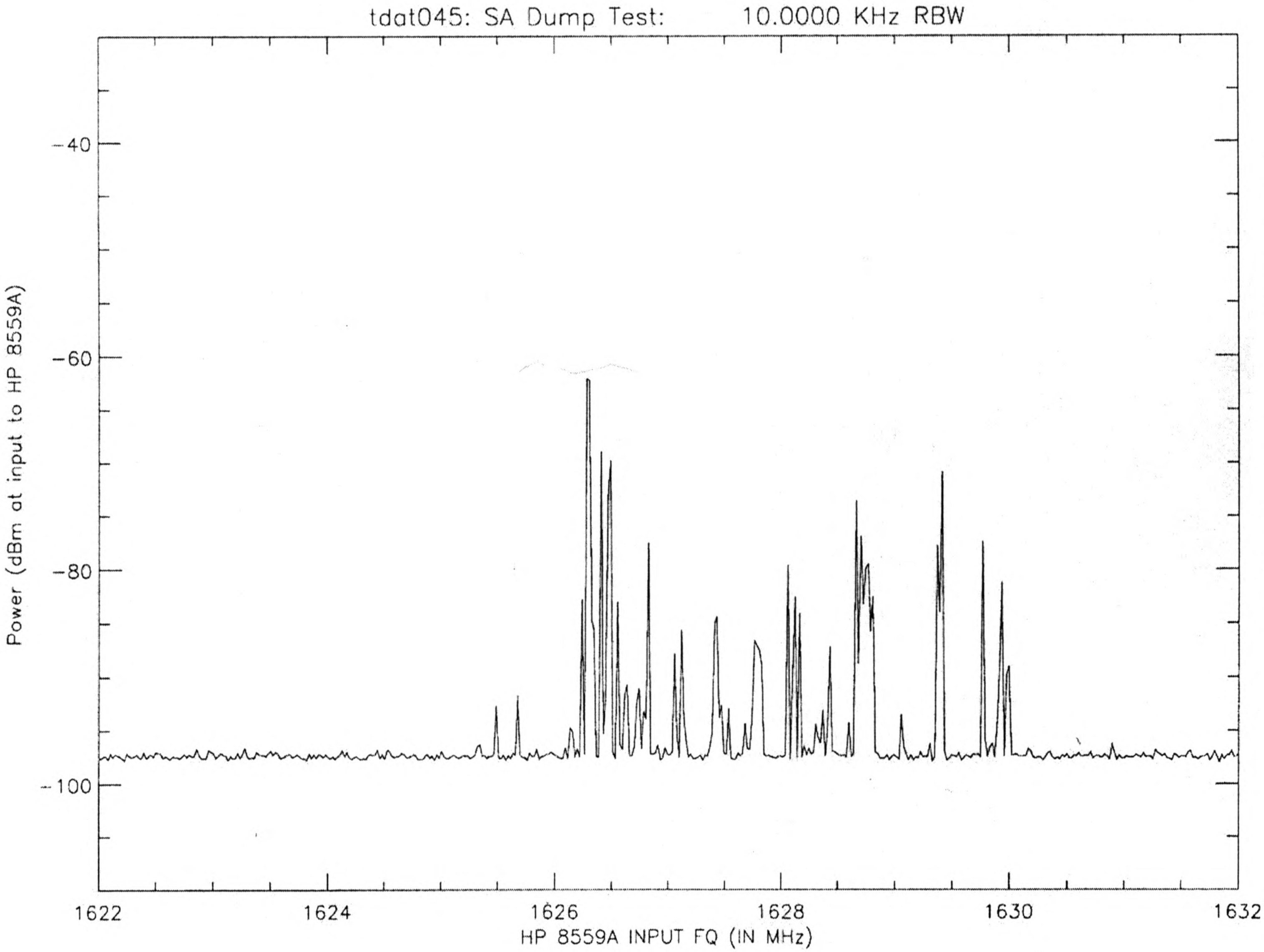


Note: Signal detected at 1481 MHz is a miscellaneous signal; not a part of the experiment

APPENDIX G

Track of Iridium 74 with one amplifier in the FE





Track of Iridium 74 with two amplifiers in the FE