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# Digital Spectrometer Autocorrelator 1- 18 GHz Down Converter, EMS Automation, Rohn Tower Repair, and TV Action Updates

VLA/VLBA INTERFERENCE MEMO NO. 21

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January 3rd through July 31st, 2001

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National Radio Astronomy Observatory
VLA/VLBA Electronics Division
Interference Protection Group

New Mexico Institute of Mining and Technology
Department of Electrical Engineering

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Co-op Period: January 3, 2001 through July 31, 2001

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## Table of Contents

## List of Appendixes

**List of Figures**

**Summary**

In my 7 months as a co-op, working under the supervision of Raul Armendariz, I was able to accomplish three major tasks. The first was designing a down converter that down converts 1-18 GHz to 4 DC-50MHz channels to use with the Digital Spectrometer Autocorrelator.

The Second was to write automation software for the Environment Monitoring System, so that monitoring between 1-18 GHz would be divided into 19 different bands with each band being surveyed at different times.

Repairs on a Rohn Tower that had collapsed during my co-op was my third task. Failure's were observed and determined that the tower had be worn out and fatigued which cause the tower to collapse. The tower was replace with a non-folding tower for safety reasons.

There were several other little things that were also accomplished during my co-op such as TV Action Updates, and repairing of the NM67.

## Introduction

In my term working as a co-op student for NRAO in the Interference Protection Group (IPG), I had several projects that I took part in. I finished off the stack of Action Updates. My second task was to build a down converter for the Digital Spectrometer Autocorrelator (DSA) that would convert signals from 1 to 18 GHz down to base band. My third big task was suppose be, to help survey 50 MHz to 18 GHz for radio frequency interference (RFI) to find signals that might interfere with the Very Large Array (VLA). This turned into a much bigger project than originally planned due to problems that came up along the way. I also helped with a few other tasks. I worked under the supervision of Raul Armendariz, along with another student from New Mexico Institute of Mining and Technology, Ryan Schmidt and later on worked with a Physics graduate, Luis Velarde.

## Section 1
## Action Updates

An action update is a weekly newsletter, published by Warren Communications, that contains a list of the new television stations and modifications to existing television stations. The listings include, where they are being transmitted from, the power they are being transmitted at, what channel, and the frequency. With all this information, I had to find out if the power levels where going to harm VLA observations. These are the steps that were used while doing this procedure.

1. Browse through the Action Update and locate any stations that are within 150 miles of a VLA or VLBA (Very Long Baseline Array) antenna. Use Street Atlas USA to determine if the stations are within range. The map has three concentric circles around all of the antennas, with radiuses of 50, 100, and 150 miles. This map can be found on the ipggroup computer, in the IPG lab, on drive D, in the action updates folder, labeled map.SA4.

2. If the station (transmitter) is within 150 miles, check the frequency against the IPG frequency table ("Television Channels and Frequencies and Harmonics") to see if the station has harmonics which fall in the VLA or the VLBA bands; check up to the fifth harmonic. Frequencies that harm the VLA and the VLBA stations are highlighted on the IPG frequency table. Note that Frequencies are not always given and might need to be determined from the Station number using the chart in the IPG office.

3. If the transmitter is within 150 miles and the frequency harmonics fall in VLA/VLBA bands, then the following information needs to be looked up in the "FactBook," if it is not listed in the action update.
    i. Antenna Height above ground
    ii. Latitude/ longitude coordinates
    iii. ERP (effective radiated power)

4. If information is not in the action update or the FactBook then check the FCC web site at www.fcc.gov.

5. A program called Prop97 will calculate the propagation loss due to land for you. You need to login on a Unix PC, and then type the following commands to log you into the directory you need to be in to run the program.

rlogin electra –l coord

Here you need to type in the password, which you can obtain from the IPG offcice.

After logged in, run the prop97 program by typing prop97.

6. There is a certain format that we try to use. As you run the prop97 program, you will be prompted with the following commands. By each command there is a description or and example that contains the format that must be used.

    - State: Type the number corresponding to the antenna close to the Action update entry.
    - Site: <4-letter call sign>ch<channel#>@<Place>
    - Latitude: 041 32 49.0000 (example)
    - Longitude: 090 28 35.0000 (example)
    - Elevation: Always leave blank
    - Height: Height that antenna is above the ground in feet, **not** above sea level
    - Frequency: Lowest frequency circled or yellow highlighted for that channel. See chart on the IPG office corkboard.
    - ERIP: Always 1
    - Filename: <4-letter call sign>ch<channel #>

    This will create two files (filename.log and filename.plot) to see results type more <filename.log>.

7. Print both of the files out. To do this type in these commands.
    - lpr –Ppselec ch7.plot (example)
    - lpr –Ppselec ch7.log (example)

8. Take the result called rounded and plug it into an excel file located in the jmares directory in the action updates folder on the ipggroup computer. Open the file called prop.xls. There are several entries in each tab (DTV, Analog, Low Power,

Translator). Make a copy of any entry in the tab you are using and use it to plug all the new info into.

- Enter power
- Dipole conversion always 2.15
- Attenuation mask: DTV = 110 / Analog = 60
- The rounded value is the Langley-Rice value, just plug it in.
- The Spectral spreading value for DTV will not change. However, with analog it will change depending on the harmonic. The harmonic value will change the spectral spreading value; make sure to test the harmonic that could be harming the VLA/VLBA.
- The SPFD is the Spectral Power Flux Density that the antenna sees. If this value is higher that the harmful threshold you have a problem.

9. Print the excel spreadsheet. You only need to print the entry that you are working on, not the whole document.

10. If you are not sure of the threshold levels, page 23 of the ITU handbook can be of help. There should be a print out on the IPG office corkboard.

Keep all antenna print outs together and give them to the IPG Manager/Engineer. This will allow IPG to get an idea if someone is broadcasting in places they are not suppose to, as well as if their harmonics are harming the VLA or VLBA antennas. The IPG engineer will determine if a letter should be sent to the transmitting company telling them that their emissions are stronger than levels determined to harmful to Radio Astronomy.

## Section 2
## Getting to Know the Lab Equipment

The HP8559A spectrum analyzer measures frequencies from 10 MHz to 21 GHz. It can be used over the range of –111 dBm to +30 dBm. The receiver has lots of different options such as bandwidth, frequency span/div, video filter, and a sweep function.

The Giga-Tronics 1018 signal generator generates signals between 1 MHz and 18 GHz. There are options were you can sweep the signal across a frequency range rather than having a single continuous wave (cw) signal. Signals can be modulated. This signal generator is very useful for testing different radio frequency (RF) equipment. It is possible to use this as the local oscillator input to the digital Autocorrelator down converter (see Section 3) and, control the frequency and power output through the GPIB port.

The HP436A power meter is a very simple but very useful meter. The meter measures the total power levels coming in through the RF input. It measures power levels between –30 dBm and +20 dBm.

The HP5342A Frequency counter is also a very simple and discrete tool. Plug a line into it and it will tell you the frequency of the signal coming into it. This counter works between 10 Hz and 18 GHz.

I used a couple different oscilloscopes. They are very similar in how they work. This tool has many functions. It would take a whole other report to describe all of its uses. The O-Scope basically shows what the signal looks like in the time or frequency domain (i.e. Square wave, Sine wave…).

The logic analyzer that I used was an older one, but still did the job. This machine will tell you whether a DC electric line is high or low and at what time. The analyzer I used accepts over 200 simultaneous inputs.

The network analyzer was very helpful in determining exactly where the frequency cut off points were on low pass filters and band pass filters. It was also helpful in determining the gain of an amplifier to find out exactly what its gain (or attenuation) was and any given frequency. Measurements of cables were taken to determine what frequencies the cable worked for, and what the attenuation was at any frequency.

The STV camera was somewhat helpful with the satellite tracking system (STS) group. I was "nominated" to learn how to use the camera and most of its options. The STV is capable of many things. It is basically a highly sensitive digital video camera. It has the option of being auto-guided by a satellite. It can also store digital images, and has captured some good pictures.

## Section 3.1
## DSA and the Down Converter

DSA is an abbreviation that we use for the Digital Spectrometer Autocorrelator. The DSA is a very sensitive receiver that receives instantaneous bandwidth rather than sweeping like a normal spectrum analyzer. Due to its variable integration the feature allows monitoring at lower power levels. It is currently set up to only observe from DC to 25 MHz. With a higher sampler clock speed, 100 MHz rather than 50 MHz, it can be changed to observe from DC to 50 MHz with a lower frequency resolution. However, there are more canaries chips in the IPG storage locker that can be mounted into the DSA and the resolution will be as high as it was with a 50 MHz sampler clock. There may have to be some programming changes in the DSA software and/or hardware before the canaries chips can be added. More information on the DSA itself can be found in ***Appendix A***, where a preliminary presentation of the DSA and the Down Converter can be found.

## Section 3.2
## Final Proposal for a Down Converter

The proposed down converter would cost $10,500. However, the down converter can be built in stages. To build one stage that is capable of 50 MHz on one channel, that is expandable to 200 MHz over 4 channels, this would cost $4487. The final proposal and design for the down converter and pictures of the DSA can be found in ***Appendix B.***

## Section 3.3
## Filter Shapes and Design Theory

The final design of the down converter located in ***Appendix B*** contains the schematic, which is described here. Please note that all part numbers and manufactures bidding on the parts are located in ***Appendix C*** along with their estimated prices. Quotes for most components can be found in a folder in the lab labeled DSA down converter project or in a folder labeled DSA –Old Quotes.

The first part of the proposed down converter is a 1 to 18 GHz image rejection mixer. This would allow for a broad range of monitoring without limiting the bandwidth of the system. A yig preselector would have worked better for filtering images with more image attenuation, but would have limited the system to only 40 MHz of bandwidth and increased costs. A sketch has been drawn to show sample inputs and outputs of the mixer, it can be found in ***Appendix C.*** The mixer will need an LO of 400 MHz above the desired frequency. With this, the signal will be mixed down from the desired frequency to 400 MHz.

The band pass filter after the mixer was put there to protect the amplifier, however, this may not be necessary. If used, it needs to be centered at 400 MHz with a 200 MHz bandwidth. With the 3dB bandwidth of the filter being more than 20% (it is 50%) of the center frequency, it is considered a special filter but still fairly easy to obtain.

The preamplifier after the band pass filter needs a center frequency of 400 MHz and a bandwidth of at least 200 MHz. The amplifier should have around 30 dB of gain. There is currently an amplifier that was tested (Results are in ***Appendix C***) and stored in the box reserved for the down converter located in the IPG Lab area. The required gain of the amplifier was determined by adding all of the losses due to the other down converter components.

Requirements for the 4-way power splitter were not determined. One might be able to be obtained from another group in the electronics division. It only needs to work over 300-500 MHz. Each channel will probably be attenuated by 6 dB. This will split the 200 MHz wide signal into four different channels. This is necessary because the DSA only has four 50 MHz wide sections. Currently the DSA is set up to only observe over 1 or 2, 25 MHz band passes. More on changing the DSA to observe differently in section 3.4.

The band pass filters in each channel after the 4-way power splitter in each channel need the identical specifications other than frequency range. Each channel should look at a different 50 MHz range. 300-350, 350-400, 400-450, 450-500 It was decided that 40 MHz bandwidth per channel would maximize the use of the DSA. Each channel on the DSA can accept a bandwidth of half the sampler clock rate. The clock rate will be maximized at 100 MHZ, as discussed in section 3.4, so that each channel can observe over 50 MHz. However, the DSA can only take in so much power over the whole 50 MHz span. It was decided that up to 1% of the power attained through each channel could be from outside the 50 MHz span. Otherwise with a higher percentage, folding would occur. Folding is where everything that is outside the bandwidth limits, gets folded over at the ends and laid on top of the signals that are already there. A deeper discussion of folding, also called undersampling, and a sketch are located in ***Appendix C.*** The document that is included is from Analog Devices web sight.
http://www.analog.com/support/standard_linear/seminar_material/highspeed/4.pdf

If folding occurs, the DSA could saturate thus corrupting the results. To prevent this from happening each channel will need a band pass filter to protect it from folding effects. First a 3 dB bandwidth of 45 MHz and a 20 dB bandwidth of 50 MHz was tried. Only one company was able to come up with a quote for such a filter and the price was very high. So, the requirements were made a little easier to achieve by asking for quotes on filters with

20 dB attenuation at ± 25 MHz and 3 dB bandwidths at 35 and 40 MHz. There were a lot more responses when asking for quotes on such filters; however, there wasn't much price difference between the two. With this, it was decided that 40 MHz 3 dB bandwidth would be satisfactory.

The amplifiers after the band pass filters were placed there in case there wasn't enough amplification before the power splitter. However, with a 30 dB gain amplifier, these should not be necessary and a quote or part number was never obtained.

The next mixers are pretty simple. They are low frequency and only need to work to do the last stage of the down conversion. To reduce costs, it was decided that two mixers could share one local oscillator (LO). For the first two channels, an LO of 350 MHz would be needed and for the second two channels an LO of 450 MHz. This would make the output of the first and third channels backwards or reversed. This could be adjusted later in software. For the time being, it will need to be remembered that channels 1 and 3 will appear backwards. Quotes were obtained on LO's but were never evaluated because a signal generator was going to be used until more funds were available to purchase the LO's, which cost around $1200 each. However, with only two LO's, there will be gaps between each channel. This is due to the fact that the bands are actually 40 MHz wide where we are setting the LO's and 50 MHz apart. This implies that there will be 5 MHz missing on each of end of every channel. To keep this from happening, the LO's need to be set where the 3 dB points on each channel touch each other.

Last and not least, low pass filters are needed after the mixers. These prevent any spikes that the mixers may generate going into the DSA. It was decided that these could have as slow a roll to prevent the price from going to high. Mini Circuits have such filters for around thirty dollars that have sufficient roll offs.

## Section 3.4

## Speeding up the Sampling Clock

To maximize the use of the DSA to observe 200 MHz of instantaneous bandwidth, the sampler clock must be changed from 50 MHz to 100 MHz. Rather than buying a new oscillator for the DSA and trying to keep the phase, and power the same, a frequency doubler was looked into. At a fraction of the cost of a new oscillator, this is a cost effective option.

The roll of the low pass filter (LPF) after the noise floor on the DSA was looked at. The filter allowed only 1% of the power to come from outside the 25 MHz bandwidth allowed by the DSA. This agrees with filters specified for the down converter as well. This would need to be replaced with a 50 MHZ low pass filter that will only allow 1% of the power to come from outside the 50 MHz bandwidth. Once again the cost of this filter, like the previous band pass filters, is based on bandwidth. With a 3 dB point at 46 MHz and 20 dB point at 50 MHz, the cost of this is over a thousand dollars. This LPF should be looked into in more detail before purchasing.

## Section 4.1

## NM-67 Receiver #148

The Ailtech NM-67 Receiver is a 1-18 GHz superhetorodyne dual-conversion receiver that down-converts the intermediated Frequency (IF) to 400 MHz with 20 MHz bandwidth. It was decided that it could be used for the first stage of the DSA down converter that was to be built even though it would limit us to a narrow bandwidth. However, the receiver was not working and there were many things that needed to be fixed before it could be used. The final proposal of the down converter did not include the use of the Ailtech receiver, however the DSA Down Converter presentation in ***Appendix A*** does. The receiver could be used as an LO in the final proposal of the down converter, with minimal effort and a lot of calibration.

## Section 4.2:

## Problems with the Ailtech receiver: LNA

This receiver had an excessive amount of problems. I inserted a signal from a signal generator and tried to find the signal coming out of the 400 MHz down converted IF output. However, no signals were detected. Several input frequencies were tried, and still nothing. I checked the output of the local Oscillator (LO) generated by the Ailtech receiver, which should be 400 MHz above the tuned frequency. It seemed to be working fine with correct power levels. After testing the radio frequency (RF) path, it was determined that the 400 MHz amplifier was defective and was actually attenuating the down converted signal. A 400 MHz amplifier was borrowed from the LO/IF group and placed in the receiver. This corrected the problem and proved that the original amplifier was bad. The original amplifier was tested again later and determined to have 2 dB attenuation where it was suppose to have 20 dB gain.

The RF assembly was tested to find out exactly what each component's attenuation or amplification was. Notice that the total power coming out is 2.5 dB higher than the incoming signal. This is due to removing the attenuator and the attenuator switch, otherwise, the input power should be equal the output power.

| | |
|---|---|
| Yig Oscillator | -7 dB |
| 3 dB attenuator | -2 dB |
| Mixer | -7.5 dB |
| 6" cable (Mixer -> Amp) | -.5 dB |
| Preamp | +20 dB |
| Band Pass Filter | -.5 dB (Insertion Loss) |
| Total | +2.5dB |

**Problems with the Ailtech receiver: A1A29 & A1A30**

Sam Field used board A1A29 (Tuning control #2 board) from S/N#148 for parts for the other Ailtech receiver, S/N #196. A couple of transistors were cross-referenced and replaced. Transistor E-112 was cross-referenced to J112, which was then cross-referenced to 2N4092 and to ecg4066. They were ordered and replaced. The drive voltages for the band selector assembly, A1A30, were tested after transistors were replaced and they work properly. When installing the new transistors, it was very important to note that the pin outs on the new transistors are different than the old ones. One of the "legs" must be twisted around the other with protective covering. A data sheet for the transistor is located in ***Appendix D.***

**Problems with the Ailtech receiver: A1A26**

Sam Field, a previous co-op student, deemed board A1A26 unreliable. The A1A26 board is the YIG Voltage Regulator Assembly. Test pins were tested and their levels were below the tolerance levels. With more testing board A1A29 was also a problem. Swapping these boards with the working ones from NM67 #196 allowed a carrier signal to be seen, where previously it wasn't. This problem was eventually solved by replaced a voltage regulator, U5, on board A1A26. After the new voltage regulator was installed, test pin 15 went from 1.6 volts to an expected 10.5 volts. All resistors were tested and R26 was replaced with a 4.75K ± 1% ¼ watt resistor. U4, an op-amp was also replaced and a voltage was then found on TP2. The board works perfectly now.

**Problems with the Ailtech receiver: A2S1 Switch**

As mentioned before it was decided that the A2S1 switch and the attenuator could be bypassed and were removed from the RF assembly. This was fortunate as Sam Field tested the attenuator and the motor was not working. For future reference the pin outs and wiring diagram are in ***appendix D.***

## Problems with the Ailtech receiver: A1A25

Board A1A25 had a bad relay, K3, and a replacement was found in the extra NM7A #227. Please note that relays only last for so many switches and then ware out. There are a couple more replacements in still in the NM7A.

## Problems with the Ailtech receiver: LED Board

The LED driver board was tested. The display was tuned to 1.47 GHz and the voltage was tested at the pins (Pin T in the communication port on the back of the receiver.) and should have been equal to 0.147 Volts. However, it was equal to 1.5 Volts. The LED driver board is basically a voltmeter with a digital display, with 1GHz equaling 0.1 volts. After turning pots to try to calibrate the voltage, it was decided that it could not be calibrated. An Oscilloscope was used at the test points and it showed that one of the op-amps was not working properly, See ***Appendix D*** for printouts from the O-scope of the working and non-working boards. It was replaced with an equivalent part. The display worked properly overnight and power was then recycled through the receiver. After recycling power, the display board stopped working completely. Nearly all of the IC's were socketed for ease of testing. It was determined that a capacitor went bad and was shorting to ground. It was replaced and Test pin 3 started working properly. It was decided to stop working on the display board and was never fixed. The problem on the board is unknown.

## Problems with the Ailtech receiver: Bands 4 & 5

It was believed that the 8-12.4 GHz and the 12.4 –18.4 yig's were bad. The problem was first believed to be the missing transistors on board A1A29 but they were replaced and still no signal. This lead to a problem on boards A1A15, A1A16, the Yig driver cards, or another problem on A1A29, band select board. All three cards were removed and replaced with the cards from the working NM67 receiver. The 8 –12.4 yig started working properly; allowing signals to go through. However, the 12.4 –18.4 yig still did not work, leading to a bad yig. The A1A29 card was replaced with the original one to determine if there was a problem on that board. The board seems to work properly, proving that the problem is with the 12.4 –18.4 GHz yig. If the down converter is not going to be used above 12.4 GHz, then it does not need to be replaced.

A decision was made to take the 400 MHz output right out of the band pass filter. This bypassed more down conversions (To 60 MHz) and a lot of other components. With this change, the Ailtech Receiver cannot be used for power measurements or anything else. This will also disable the power level display on the front of the Ailtech Receiver.

After evaluating the NM67 receiver, we decided that it was too much work. The receiver was used for parts for the current working receiver used by the EMS system. This left the broken parts from both receivers in this receiver and it needs a lot more attention. We decided that it was not worth our time and we started looking into a new yig or more options rather than using the receiver.

## Section 5.1:
## Introducing the Environment Monitoring System (EMS)

The EMS system was made so that RFI observations from 1 to 18 GHz could be preformed. The systems consists of two antennas, an omni-directional antenna, and a horn antenna set at a 45 degree angle to allow vertical and horizontal signals to be monitored. The antennas are mounted on rotator so that signals can be detected from any and all directions. Next the Front End that filters out known strong signals and amplifies areas of weak or no known signals. The system was built to find radio frequency interference (RFI). This is necessary to protect the VLA from harmful signals. It allows NRAO to determine where signals are and when they are there.

## Section 5.2:
## EMS Automation Software

The RFI W8 monitoring system at NRAO uses data control software like the EMS system and makes daily plots. However, the W8 Monitor is limited to 1.25 GHz – 1.75

GHz. The EMS monitor covers 1-18 GHz which created the need for an automation program that would change between bands and obtain different data as required. A shell script called "dailychange" was written. This program, located in /home/electra2/ailmon, will change between 19 different bands. See ***Appendix E*** for the frequency ranges and other information about each band. This program will change several files everyday. It will change the /home/snow/etc/ail.dfl file, needed by the EMS software. This one-line file tells the EMS system which channel to use in the Front End, what bands to observe on the receiver, and in general how to set up the system. It will also update where2savepeak.sv and where2savepfd.sv. These are also one-line files that contain a directory of where to save the data. These are read as inputs to the daily routine software the EMS system uses and tell it where to save the data; this way the data is sorted by band.

When the where2save files were created, it meant that the ktransfer_plot needed to be changed to read the files. The ktransfer_plot program creates plots of the data and then saves them to their prospective directories. It will also link the plots to an additional folder so that it is easy to locate plot files by date or by band. Later when the software is updated to create average data and plots, this program will also need to be updated to write to the file where2saveavg.sv.

The pgsail and pgsail2 programs where updated to accept new input parameters: where to find the data files and where to store the plots.

The automation program, dailychange, will also sort the data files on snow (The EMS computer) the same way the plots are saved and linked. This will make future reference to these files easy. This program writes to a file called bandcounter. This file contains the number of the band that the automation program is on. This was made so that when the computer restarts or the power shuts off, or some other quirky thing happens, it will not effect the counter and will allow observing to continue without starting over.

After testing, the dailychange change program was placed in the vlarfi's crontab on electra so that it would be ran everyday.

## Section 5.3:
## Making the information Available on the Web

Now that the plots are saved in sorted directories and by date, the scientists and researchers need to be able access the information. It was decided to make the plots available online. An shtml page was written that contains links to all of the plots. A link to this new page was added from the rfi.shtml web page. The web address of the new page is http://www.aoc.nrao.edu/vla/html/ems_plots.shtml. A copy of the code is in ***Appendix E.***

## Section 5.4:
## Backup of Files

All files were backed up onto a disk and saved under a dos format by using the following command.

**mcopy** *<filename>* a:

This will save a Linux file as a dos file on the A: drive with the same filename. Make sure that you have the directory in front of the filename or be in the directory of the file and us the ./ command. These files were then burned onto a CD and labeled Nathan Thomas Backups. It should be located in the CD rack in the IPG office. All software I developed for the EMS system is located in ***Appendix E***.

## Section 5.5:
## Restoring the Files

To restore any of the files make a copy of the CD onto a disk and put the disk into the EMS computer and type the following command.

**mcopy** a:*<filename>* /home/somedirectory/

This command will change the dos file back into a Linux file automatically. Kind of nice; isn't it? The **mdir** command will allow you to see the contents on the disk.

## Section 6:
## Tower Repair

The EMS system uses the antennas that are located on the RFI tower. The Rohn tower is triangularly shaped with the sides about eighteen inches wide. The tower folds at nineteen feet above the ground. This made for really easy access to the antennas and Front End on the tower. The towers total length is almost 55 feet.

On June 25, 2001 while at the VLA with Luis Velarde, a NMT student working with IPG, I was in the RFI shack setting up test equipment to do some line loss measurements on the RF cable going to the antennas, I heard a really loud bang. I ran outside to see what the clatter was all about. While Luis was lowering the tower, it had collapsed.

The tower needed to be repaired as soon as possible to allow interference monitoring to continue. Within one day of the tower falling, the tower was completely dismantled. There were three damaged ten-foot tower sections and a broken hinge section.

While trying to find replacement parts for the tower, it was discovered that Rohn, the tower company, did not make folding towers any more. Pictures of the broken tower were emailed to the manager at Rohn Towers also included in ***Appendix F***. He replied with a quote for a replacement hinge, see ***Appendix F***. The cost of the replacement hinge was more than a thousand dollars, so we looked into the pros and cons of having a non-folding tower instead.

There were a lot more reasons to go with a non-folding tower than a folding tower. A non-folding tower is much safer and can handle more weight. The main reason for a folding tower is ease of maintenance. With a straight tower, trying to do maintenance is a little harder. A cherry picker will be needed to do any maintenance on the tower.

It was decided to go with a non-folding tower. The antenna sections were replaced as well as the RF cable from the shelter to the Front End. The repaired tower cost less than a thousand dollars. Purchase requisitions can be found in ***Appendix F***.

## Section 7:
## Place's To Be If You're In IPG

*Appendix G* contains pictures of my desk, the IPG Lab area, the VLA, the EMS Tower, the RFI shelter, and even the STS dish. The lab area changed sizes and layouts several times during my co-op. Space was needed for the new ALMA employees so the lab area was divided in two. The pictures were taken after we were finally happy with the way the lab was laid out.

## Conclusion

To sum up my experience as a co-op student for the National Radio Astronomy Observatory, it was definitely a learning experience. I think that I have picked the right career. Not only enjoying the environment, but I also enjoyed the work. I have never worked so hard to learn things that I did not know how to do. I took advantage of the knowledge that was there to learn from and the people who were willing to give the knowledge away. I absorbed as much of the knowledge as I could, and hopefully gave some away too.

In the past 7 months, I learned how to do RF engineering, Project Management, shell programming, and most of all, how to work in the engineering environment. Before starting this co-op, I had no idea what a mixer was much less what it did. Now, I feel comfortable with a lot more RF components than just a mixer. And with my minuet experience in programming, and even smaller knowledge about the Unix/Linux operating system, it was an accomplishment to work my way through the tasks at hand. I am now comfortable using the Unix/Linux operating systems and writing simple shell programs within them.

Overall, I feel that I can make it in the work place after graduating. To sum it up in one sentence… I enjoyed working for NRAO funded by the NSF in the IPG group, at the AOC monitoring for RFI, at the VLA and the VLBA, with the EMS system, and building a down converter for the DSA.

Nathan Thomas typed this report and took all photos except the one he is in.

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# Appendix A:

# Presentation of the DSA and the Down Converter

# What is the DSA?

DIGITAL SPECTROMETER AUTOCORRELATOR

Receiver that is able to receive instantaneous bandwidth rather than sweeping.

# Why Finish the DSA?

- Wide band instantaneous monitoring
- Monitor radar, DME, and other intermittent signals.
- Broadband RFI power levels

# Digital Spectrometer Autocorrelator Capabilities and Current Setup

| | Equation | Min | Current | Max |
|---|---|---|---|---|
| Integration time: | (counter size * Clock Period)/2 | ~~300ns~~ 1ms | 1s | 21.5 s |
| # of Lags | N/A | 1 | 2048 (512 per channel) | 4096 |
| # 0f Channels | N/A | 1 | 4 | 4 |
| Clock Speed | N/A | 50 MHz | 50 MHz | 100 MHz |
| Resolution Bandwidth | Instantaneous Bandwidth/ Lags | 6.1 kHz (With additional Canaris Chips Sampling at 50 MHz) | 12.2 kHz | 50 MHz |
| Instantaneous Bandwidth Per Channel | Clock Speed/2 | 25 MHz | 25 MHz | 50 MHz |
| Total Instantaneous Bandwidth | (Instantaneous Bandwidth Per Channel)* (# of Channels) | 100 MHz | 100 MHz | 200 MHz |

# Designing the Down Converter

## Project Description:

To build a down converter that will convert 1 - 18 GHz to base band (dc – 25 or 50 MHz) so that we can use the Digital Spectrometer Autocorrelator to monitor RFI over a broad range.

## NM67 Receiver Available for Use

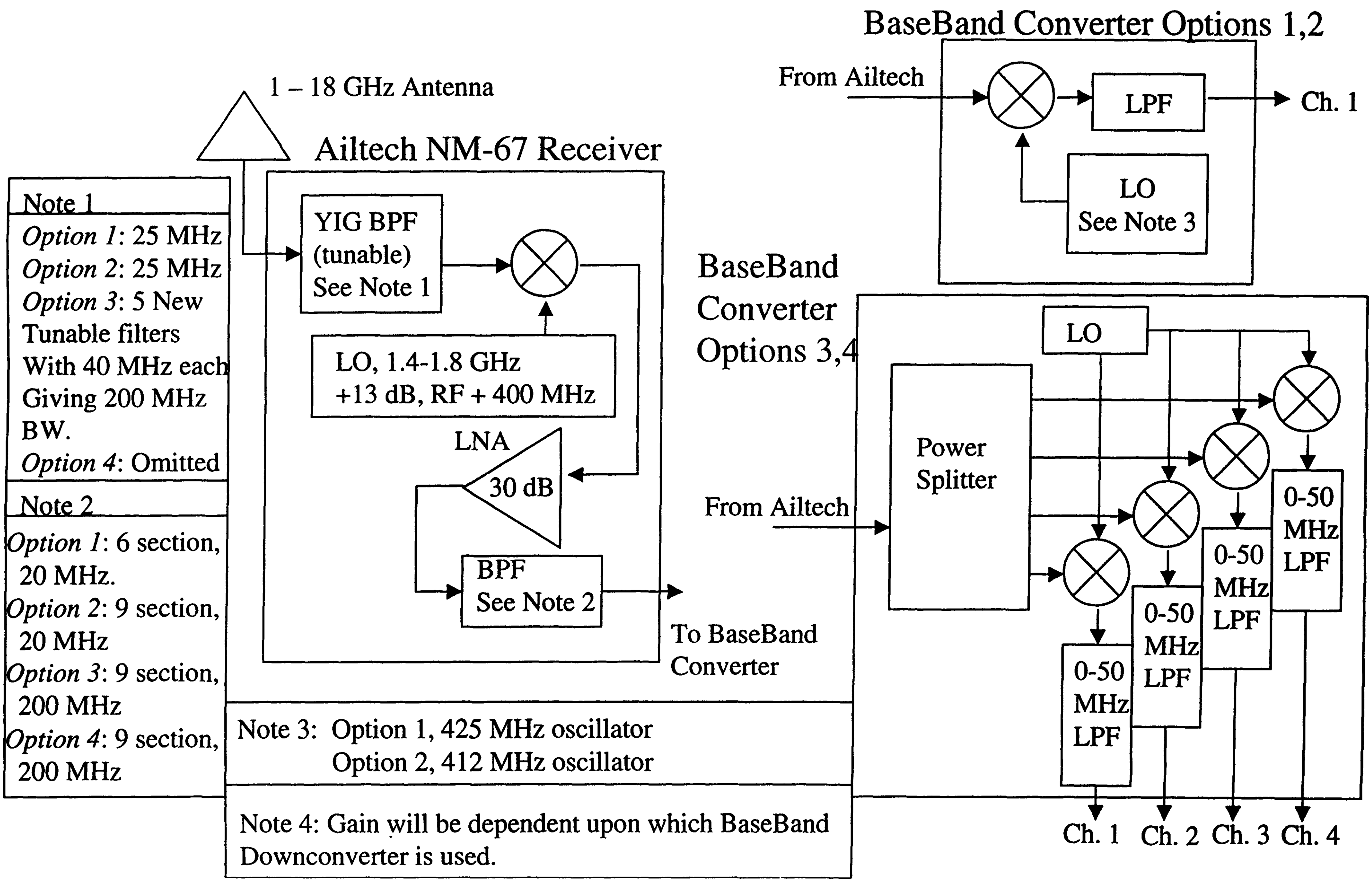
| | |
|---|---|
| Function: | Down converts 1 - 18 GHz to 400 MHz. |
| Limitations: | 25 MHz tunable band pass filter (YIG) |
| Work needed: | Calibration and Frequency Display Card |

# Design Specifications and Costs

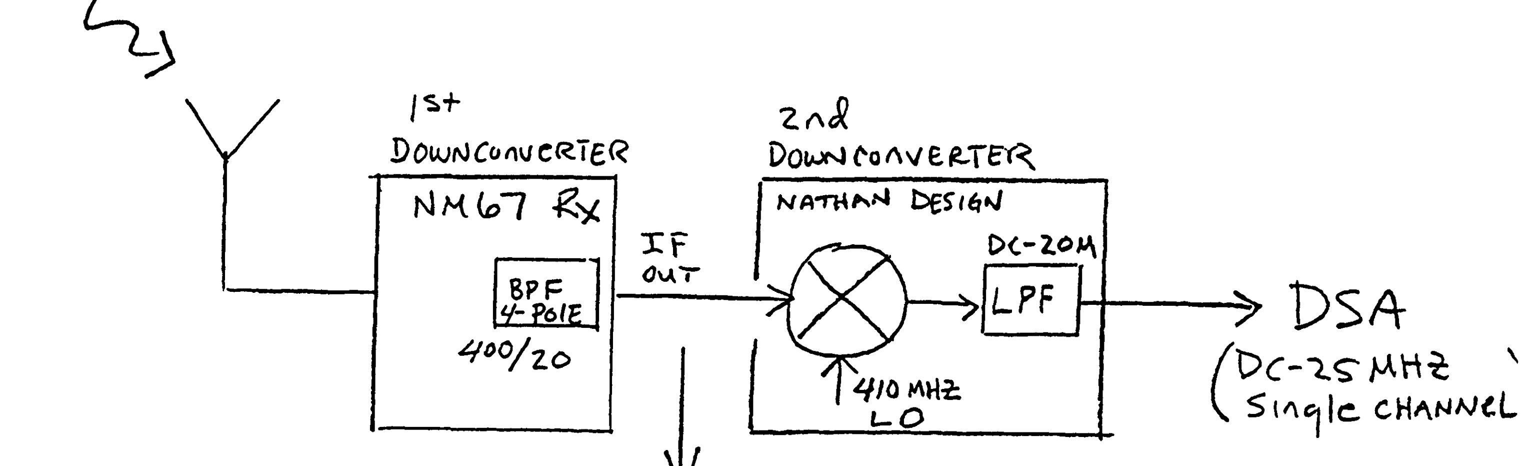
DSA Sampling rate is currently 50 MHz

| | Option 1 | Option 2 | Option 3 | Option 4 |
|---|---|---|---|---|
| Description | Use Ailtech | Replace BPF in Ailtech | Replace tunable BPF in Ailtech | Omit tunable BPF in Ailtech |
| Estimated Cost For Entire System | $7,600 + (3) Ailtech's | $9,400 + (3) Ailtech's | $24,000 | $9250 |
| Clock Speed | 100 MHz | 50 MHz | 100 MHz | 100 MHz |
| Resolution Bandwidth | 24.4 kHz | 12.2 kHz | 24.4 kHz | 24.4 kHz |
| Instantaneous Bandwidth | 50 MHz / Channel | 25 MHz / Channel | 50 MHz / Channel | 50 MHz / Channel |
| Total Bandwidth used per channel | 20 MHz | 20 MHz | 40+ MHz | 40+ MHz |
| Total BW with 4 channels | 200 MHz | 100 MHz | 200 MHz | 200 MHz |
| Pros | No change in Ailtech<br>No expensive filter | High Resolution<br>No change to DSA | Maximizes DSA<br>Protects Mixer | Maximizes DSA |
| Cons | Lower Resolution<br>Not using full 50 MHz on each channel | Limited to 100 MHz band width | Lower Resolution<br>Cost | Lower Resolution<br>No protection for Mixer |

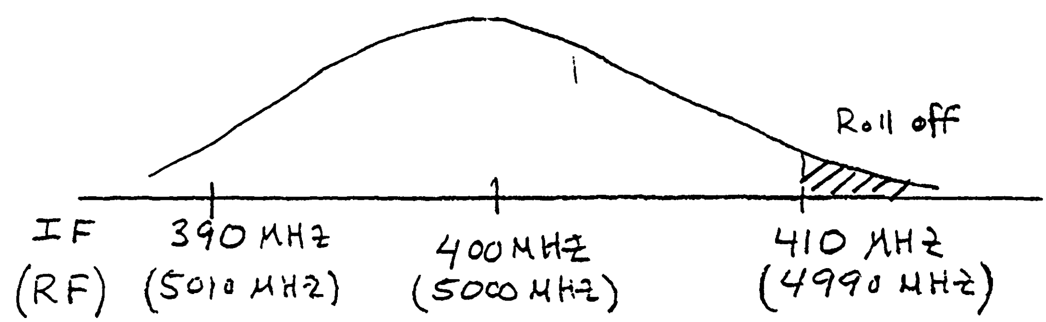
# Downconverter Stages



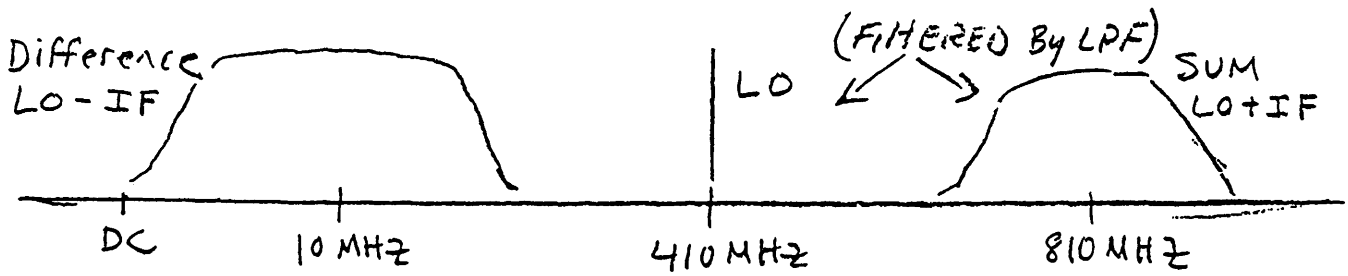
# EXAMPLE SYSTEM AND FILTERS REQUIRED



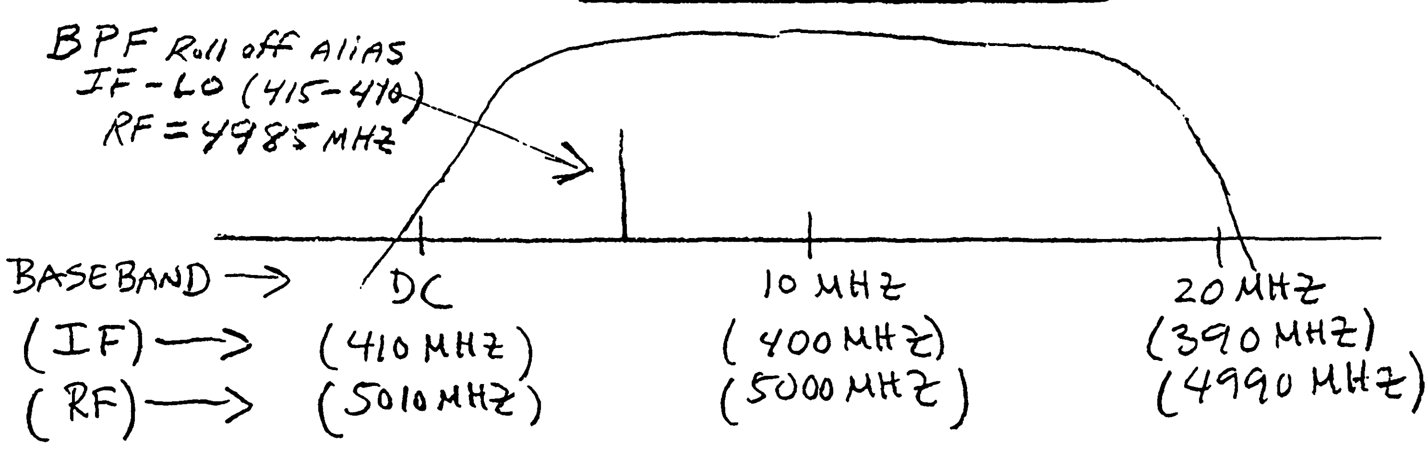

## IF SPECTRUM




## SPECTRA AFTER MIXER




## SPECTRA INPUT TO DSA




**CONCLUSION:** VERY SHARP 400/20 BPF NEEDED IN NM67 to REMOVE ALIASES.

OMNIYIG INC.

## *YIG FILTER RF SPECIFICATIONS*

*TYPE:* Yig Filter with Integrated 12 Bit Digital Driver

*Model Nbr:* M2122DD

| | | |
|---|---|---|
| *Frequency Range* | *GHz* | 1.0 to 18.0 |
| *Insertion Loss – maximum* | *dB* | 7.0 |
| *Bandwidth @ 3 dB - minimum* | *MHz* | 40 Typically 50 |
| *Off Resonance Isolation – minimum* | *dB* | 50 |
| *Off Resonance Response – minimum (Note 1)* | *dB* | 25 |
| *Passband Spurious & Ripple* | *dB* | 2.8 |
| *Number of Stages* | *No.* | 2 |
| *Limiting Level – minimum* | | |
| *From: 1.0 to 2.0 GHz* | *dBm* | -20 |
| *From: 2.0 to 18.0 GHz* | *dBm* | +5 |
| *Freq. Drift v/s Temp. (0 °C to +55 °C)* | *MHz* | ±10 |
| *Driver Voltage (±15 Volts) @ Current* | *mA* | +50 and -900 |
| *Control Driver - Digital* | *Bits* | 12 |
| *Heater Voltage* | *Volts* | 24 ±4 Unregulated |
| *Heater Current* | | |
| *@ Surge for 5 Seconds* | *mA* | 800 |
| *@ Steady State* | *mA* | 100 |
| *Linearity* | *MHz* | ±14 |
| *Coil Resistance - typical* | *Ohms* | 10 |
| *Coil Inductance - typical* | *mh* | 110 |
| *Sweeping Speed* | *ms* | 15 |
| *Connectors* | *RF* | 3mm (female) |
| *Connectors* | *DC* | 25 Pin |
| *Size* | *Inches* | 1.7 x 1.95 x 4.0 |
| *Outline Drawing* | *Nbr* | 82,377 |

*Note 1: 210 mode is located below the main tuning response. Approximately 300 MHz. All other spurious response will be 60 dB minimum.*

*Customer:* National Radio Astronomy Observatory
*Proposal:* P-8377-1 *Rev.:* ______ *Date:* February 8, 2001
*kjs*

OMNIYIG, INC. ☐ 3350 Scott Blvd., Bldg. #66 ☐ Santa Clara, California 95054-3125 ☐ (408) 988-0843 ☐ Fax (408) 727-1373

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YOUR FULL SERVICE COMPANY

02/20/2001

National Radio Astronomy Obser
Aoc Building
1003 Lopezville Road
Socorro, NM 87801

Attn: Nathan Thomas nthomas@nrao.edu
505-835-7151
FAX: (505) 835-8027

**Quote #534377**

Dear Nathan:

Tucker Electronics is pleased to present this quotation as you requested for the purchase of the equipment listed:

| Qty | Description | Type | Item Cost | Extended Cost |
|---|---|---|---|---|
| 1 | AILNM67<br>RFI METER | R | 6,675.00 | 6,675.00 |

*In Stock

N = New; R = Reconditioned or Rental; F = Factory Reconditioned; U = As Is - No Warranty, No Return

All new equipment is shipped unopened in the manufacturer's packaging and includes the full manufacturer's warranty.

All reconditioned equipment will be calibrated to the manufacturer's specifications and will include certificate of compliance traceable to NIST. Reconditioned items include a 180 day parts and labor warranty .

All equipment is shipped FOB origin. All items are subject to prior sale and availability is subject to change without notice.

If you have any questions, you may call me or you may reach me via FAX or E-mail.

Yours Truly,

*Craig Leong x8385*
Sales Engineer
(800) 527-4642
FAX 214-348-0367

cleong@tucker.com

# Conclusion & Recommendation

I recommend to build a down converter that will utilize the maximum bandwidth of the DSA.

**Option 4:**

200 MHz bandwidth
Resolution of 24.4 kHz
Estimated cost of $10,000
Mixer will not be protected
Further investigation is necessary

**Option 2:**

100 MHz bandwidth
Resolution of 12.2 kHz
Each channel can be built at different times.
Estimated cost of $2,400/channel ($10,000 + 3 Ailtech's)

# Appendix B:

# Final Proposal of the Down Converter For the DSA

# DSA Down Converter Proposal

Nathan Thomas

April 16, 2001

The Digital Spectrometer Autocorrelator (DSA) will allow IPG to observe frequencies between 1 – 18 GHz with nearly 200 MHz of instantaneous bandwidth and with greater sensitivity than a spectrum analyzer receiver. This will allow RFI monitoring for radar, DME, and other intermittent signals, enabling total power measurements over wide bandwidths. Coupled with the satellite tracking system (STS), it will give IPG the capabilities of RFI monitoring closer to the levels determined harmful to Radio Astronomy via ITU RA-769 and will aide in the policy protection of the Radio Astronomy Service bands.

The following schematic (Next page) is a proposed down converter that will maximize the bandwidth of the DSA. The sampling rate of the DSA will be increased from 50 MHz to 100 MHz by using a frequency doubler and a low pass filter with a higher cut off frequency.

The down converter that I am proposing will cost $10,500. However, the downconverter can be built in stages. To build one stage that is capable of 50 MHz on one channel, that is expandable to 200 MHz over 4 channels, will cost $4487. Later we can expand as quickly as our budget will let us. The cost is broken down in the table below.

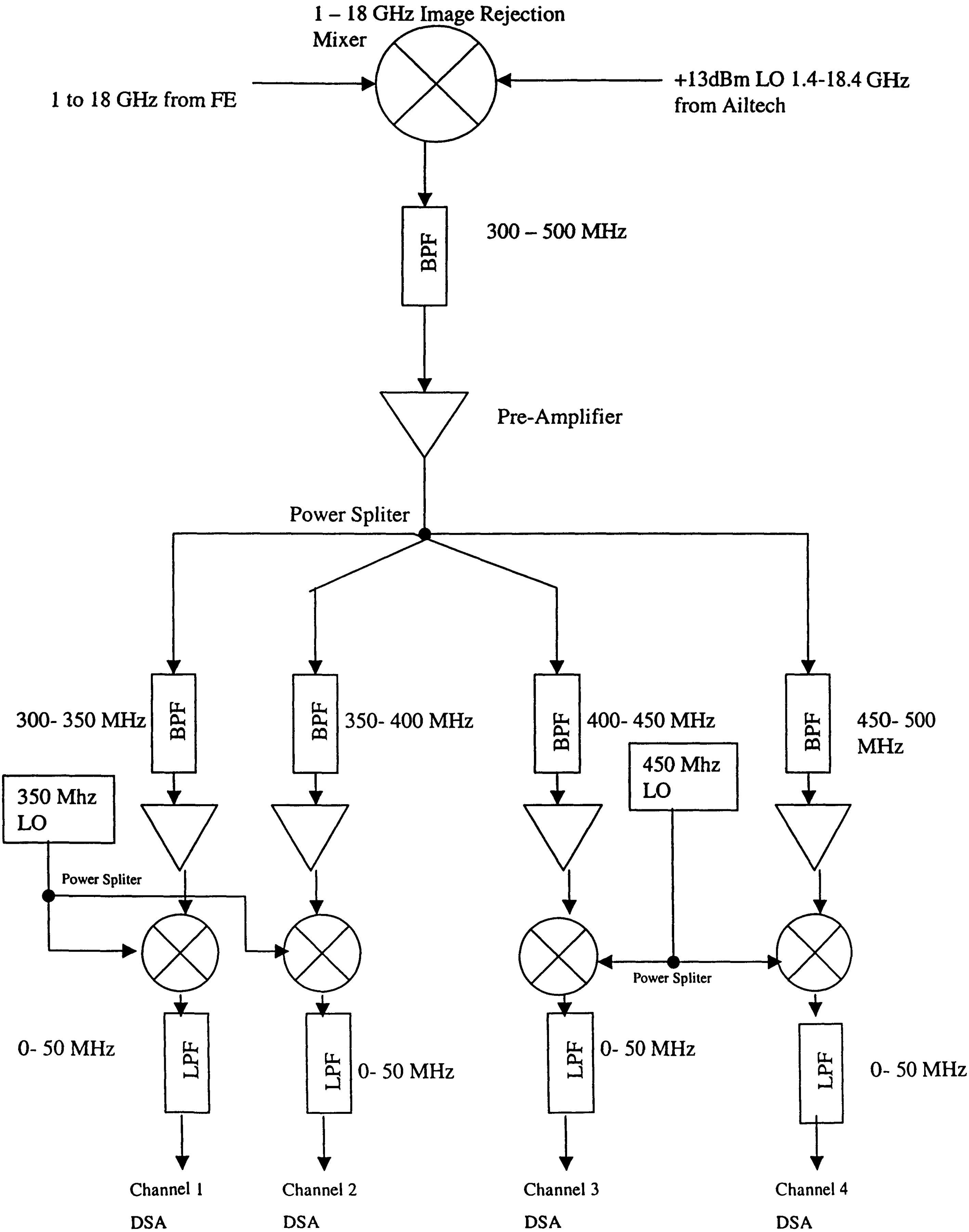
Another cheap option that can get us started would only cost $1187. However, to upgrade this to use all four channels would take 3 more Ailtech Receiver and more money. This down converter will limit the use of the DSA to 80 MHz of instantaneous bandwidth after expansion to 4 channels. Note, that the cost is not shown for the expansion of this down converter.

I recommend that we build one channel of the down converter that will maximize the use of the DSA. This will cost around $4,500 and will allow us to use all of the components for the complete down converter later. With this down converter, the DSA will be at its maximized bandwidth fulfilling the requirements of the down converter.

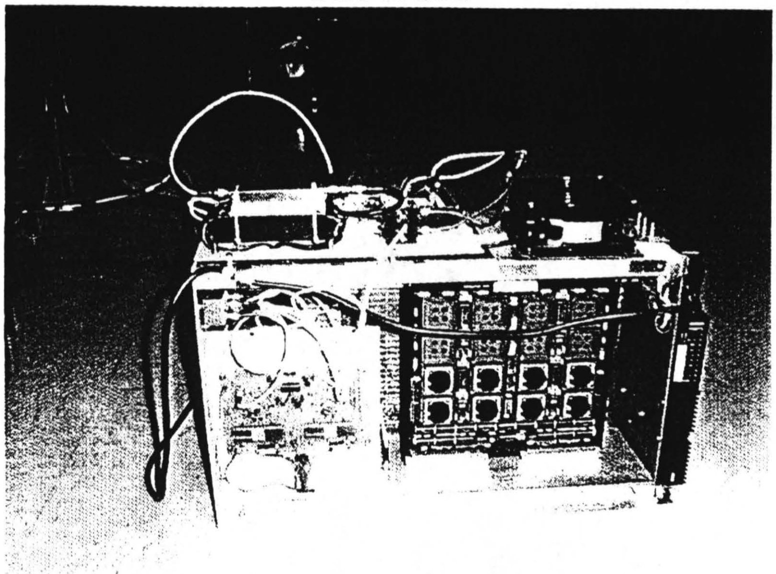
| $1,187 | | $4,487 | | $6,011 | |
|---|---|---|---|---|---|
| 1 Channel | | 1 Channel | | Expansion to 4 Channels | |
| 20 MHz | | 50 MHz | | 200 MHz | |
| Limited to 100 MHz | | Expands to 4 Channels | | Total Cost- 4 channels = $10,500 | |
| 9 Pole BPF | $900.00 | Image Rejection Mixer | $2,450.00 | Power Splitter | Can Attain |
| Pre-Amp | Stock | 300-500 MHz BPF | $300.00 | (3) 9 Pole filters | $2,700.00 |
| Mixer | $51.95 | Pre-amp | Stock | (3) Amplifiers | $750.00 |
| LPF | $34.95 | 9 Pole BPF** | $900.00 | (3) Mixers | $155.85 |
| Misc. | $200.00 | Amplifier | Stock | (3) LPF's | $104.85 |
| Schematic not shown | | Mixer | $51.95 | (2) LO's | $2,300.00 |
| | | LPF | $34.95 | Schematic on following page | |
| | | LO | SG | | |
| | | Frequency Doubler | $300.00 | | |
| | | LPF (Noise Floor) | $250.00 | | |
| | | Misc. | $200.00 | | |

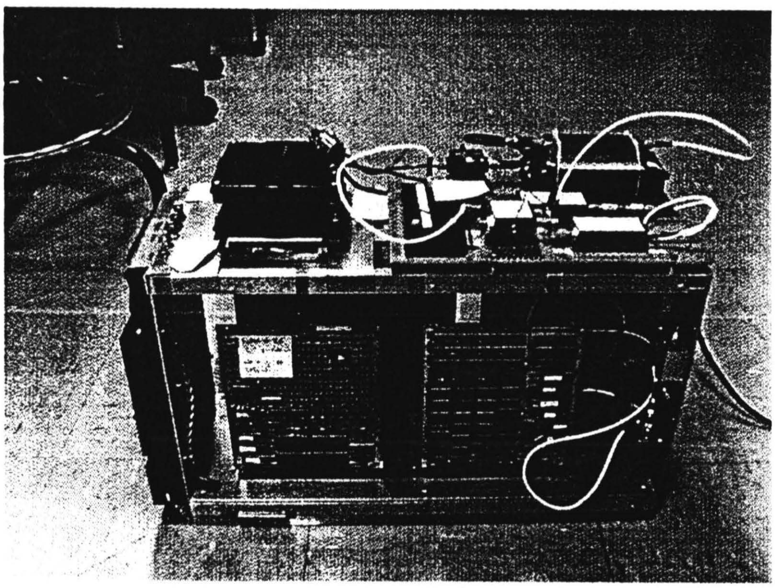
** This cost is adjustable, however, the lower the cost, the less BW attained. With 9 section filters (Around $900 each), we can get 180 MHz instantaneous bandwidth.

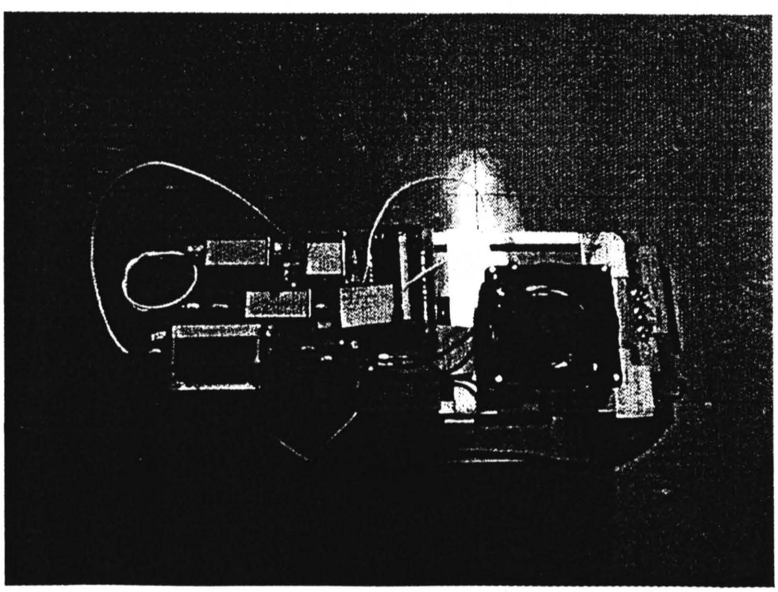
# 1-18 GHz Downconverter Schematic



# The DSA







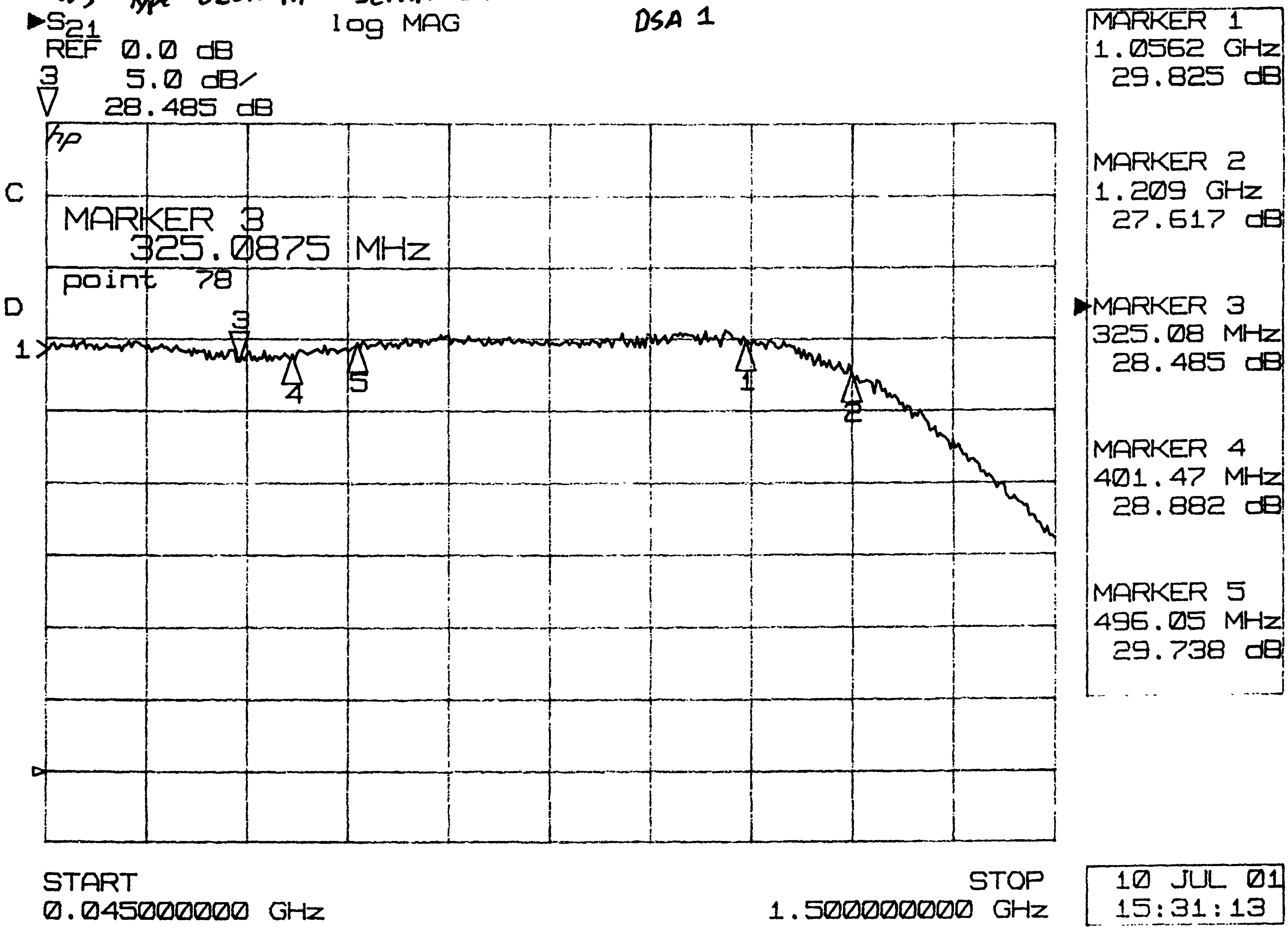
# Appendix C:

# Image Rejection Mixer Drawings and Parts List

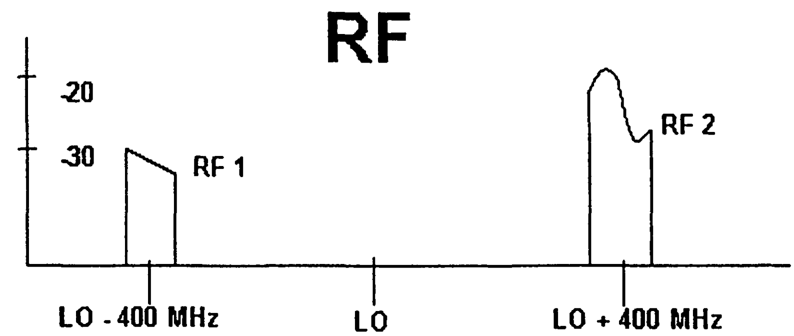
# Part Numbers, Prices, and Competing Manufacturers

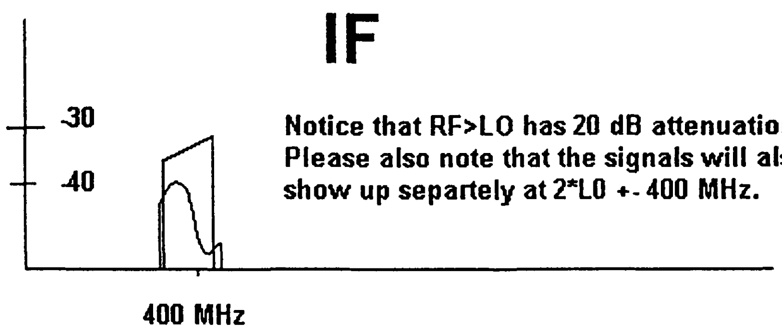
| Part Discription | Company | Part No. | Cost | Competitor 1 | Part No. | Cost | Competitor 2 | Part # | Cost | notes |
|---|---|---|---|---|---|---|---|---|---|---|
| 1- 18 GHz Image Rejection Mixer | Miteq | 1R0118LC1Q | $2,450.00 | None | | | | | | |
| 300-350 MHz Band Pass Filter | | | | | | | | | | |
| With 35 MHz Bandwidth | RLC | F-15564 | $685.00 | Not worth looking into | | | | | | To narrow bandwidth |
| With 40 MHz Bandwidth | RLC | F-15558 | $715.00 | K&L | 7IB10-325/T40-O/O | $715.00 | TTE | can't produce | | This is the best option |
| With 45 MHz Bandwidth | RLC | F-15557 | $1,900.00 | No one else can make this | | | | | | This costs too much |
| Frequency Doubler | Willmanco | WHM-S-50-100 | $275.00 | None | | | | | | |
| 400/200 | K & L | 3IB40-400/T200-O/O | $270.00 | RLC | BPF-500-400-200-2RF | $480.00 | | | | Don't Think we need this |
| LPF 50 MHz for DSA | RLC | L-2605 | $1,140.00 | Needs to be looked into | | | | | | |
| LPF - Slow rolloff | Mini-circuits | SLP-50 | $34.95 | Not worth looking into | | | | | | Need One for each channel |
| Mixer- 400MHz -> Baseband | Mini-Circuits | ZFM-1W | $51.95 | Not worth looking into | | | | | | Need One for each channel |

Amplifier for DSA Downconverter.
WJ Type 6201-411 serial-Z388



# Input (RF) and Output (IF) of an Image Rejection Mixer

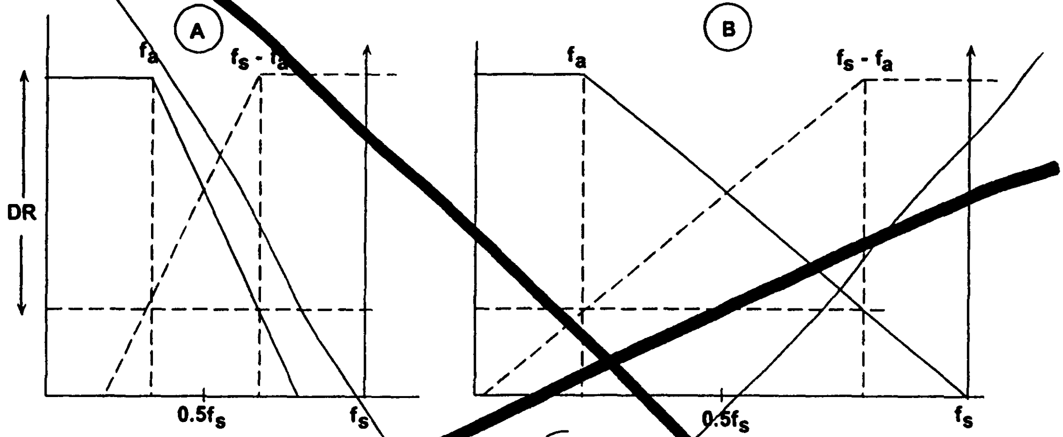



**Notice that RF>LO has 20 dB attenuation. Please also note that the signals will also show up separtely at 2*LO +- 400 MHz.**

increasing the sampling frequency while maintaining the same analog corner frequency, $f_a$, and the same dynamic range, DR, requirement.

**INCREASING SAMPLING FREQUENCY RELAXES REQUIREMENT ON ANTIALIASING FILTER**




LOWPASS FILTER SPECIFICATIONS:

ANALOG DEVICES

4.5

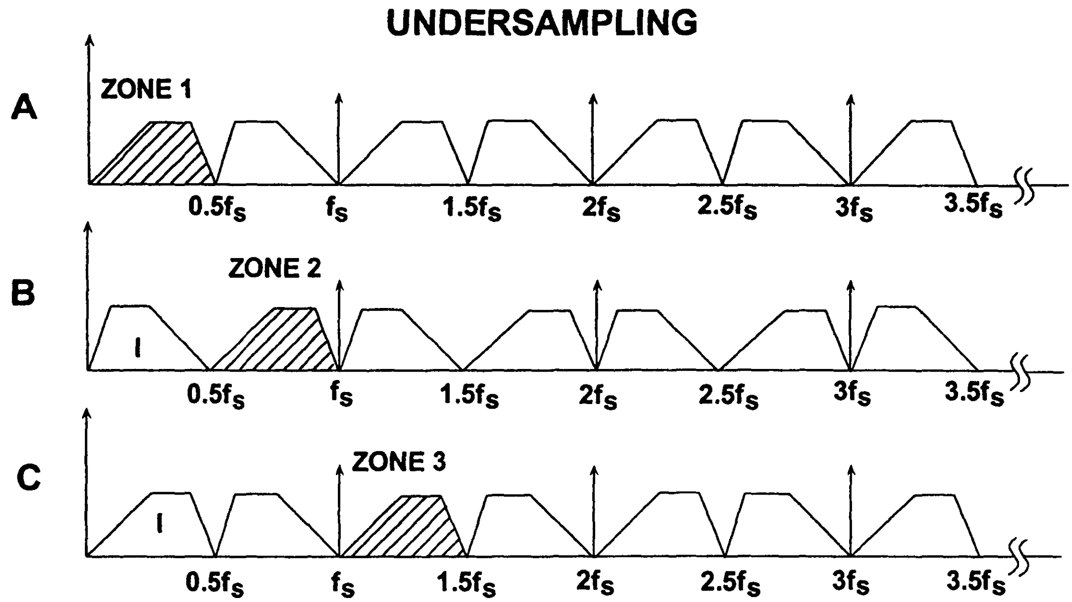
The above design process is started by choosing an initial sampling rate of 2 to 4 times $f_a$. Determine the filter specifications based on the required dynamic range and see if such a filter is realizable within the constraints of the system cost and performance. If not, consider a higher sampling rate which may require using a faster ADC.

The antialiasing filter requirements can be relaxed somewhat if it is certain that there will never be a fullscale signal at the stopband frequency $f_s - f_a$. In many applications, it is improbable that fullscale signals will occur at this frequency. If the maximum signal at the frequency $f_s - f_a$ will never exceed XdB below fullscale. Then, the filter stopband attenuation requirement is reduced by that same amount. The new requirement for stopband attenuation at $f_s - f_a$ based on this knowledge of the signal is now only DR – XdB. When making this type of assumption, be careful to treat any noise signals which may occur above the maximum signal frequency $f_a$ as unwanted signals which will also alias back into the signal bandwidth.

## UNDERSAMPLING (HARMONIC SAMPLING, BANDPASS SAMPLING, IF SAMPLING, DIRECT IF TO DIGITAL CONVERSION)

Thus far we have considered the case of baseband sampling, i.e., all the signals of interest lie within the first Nyquist zone. Figure 4.6A shows such a case, where the band of sampled signals is limited to the first Nyquist zone, and images of the original band of frequencies appear in each of the other Nyquist zones.

Consider the case shown in Figure 4.6B, where the sampled signal band lies entirely within the second Nyquist zone. The process of sampling a signal outside the first Nyquist zone is often referred to as *undersampling*, or *harmonic sampling*. Note that the first Nyquist zone image contains all the information in the original signal, with the exception of its original location (the order of the frequency components within the spectrum is reversed, but this is easily corrected by re-ordering the output of the FFT).




ANALOG DEVICES

4.6

Figure 4.6C shows the sampled signal restricted to the third Nyquist zone. Note that the first Nyquist zone image has no frequency reversal. In fact, the sampled signal frequencies may lie in *any* unique Nyquist zone, and the first Nyquist zone image is still an accurate representation (with the exception of the frequency reversal which occurs when the signals are located in even Nyquist zones). At this point we can clearly state the Nyquist criteria:

*A signal must be sampled at a rate equal to or greater than twice its* ***bandwidth*** *in order to preserve all the signal information.*

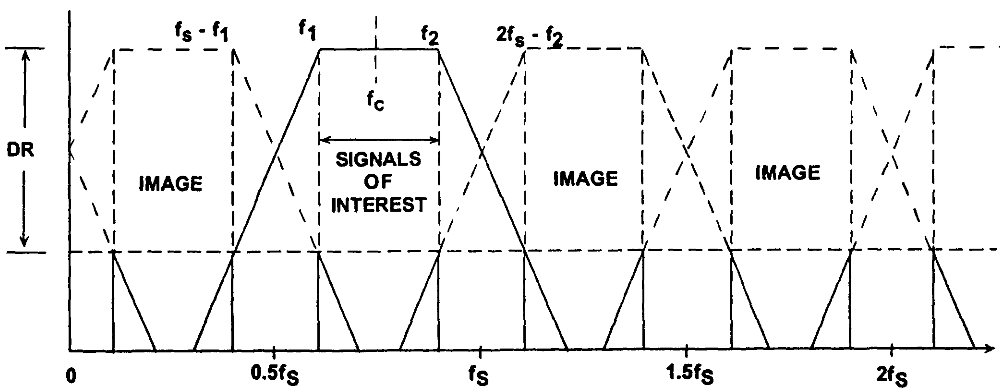
Notice that there is no mention of the absolute *location* of the band of sampled signals within the frequency spectrum relative to the sampling frequency. The only constraint is that the band of sampled signals be restricted to a *single* Nyquist zone, i.e., the signals must not overlap any multiple of $f_S/2$ (this, in fact, is the primary function of the antialiasing filter).

Sampling signals above the first Nyquist zone has become popular in communications because the process is equivalent to analog demodulation. It is becoming common practice to sample IF signals directly and then use digital techniques to process the signal, thereby eliminating the need for the IF demodulator. Clearly, however, as the IF frequencies become higher, the dynamic performance requirements on the ADC become more critical. The ADC input bandwidth and distortion performance must be adequate at the IF frequency, rather than only baseband. This presents a problem for most ADCs designed to process signals in the first Nyquist zone, therefore an ADC suitable for undersampling applications must maintain dynamic performance into the higher order Nyquist zones.

## ANTIALIASING FILTERS IN UNDERSAMPLING APPLICATIONS

Figure 4.7 shows a signal in the second Nyquist zone centered around a carrier frequency, $f_c$, whose lower and upper frequencies are $f_1$ and $f_2$. The antialiasing filter is a bandpass filter. The desired dynamic range is DR, which defines the filter stopband attenuation. The upper transition band is $f_2$ to $2f_s - f_2$, and the lower is $f_1$ to $f_s - f_1$. As in the case of baseband sampling, the antialiasing filter requirements can be relaxed by proportionally increasing the sampling frequency, but $f_c$ must also be increased so that it is always centered in the second Nyquist zone.

**ANTIALIASING FILTER FOR UNDERSAMPLING**




**BANDPASS FILTER SPECIFICATIONS:**
- **STOPBAND ATTENUATION = DR**
- **TRANSITION BAND: $f_2$ TO $2f_s - f_2$**
  **$f_1$ TO $f_s - f_1$**
- **CORNER FREQUENCIES: $f_1$, $f_2$**

ANALOG DEVICES **4.7**

Two key equations can be used to select the sampling frequency, $f_s$, given the carrier frequency, $f_c$, and the bandwidth of its signal, $\Delta f$. The first is the Nyquist criteria:

$$f_s > 2\Delta f \qquad \text{Eq. 1}$$

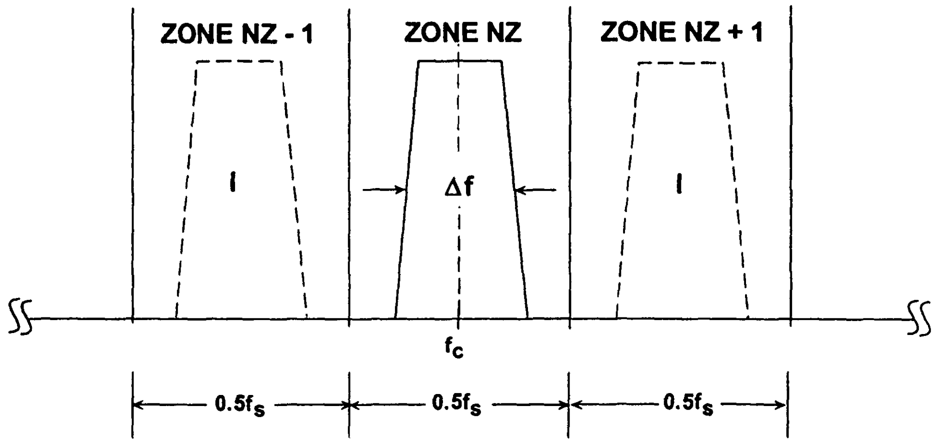
The second equation ensures that $f_c$ is placed in the center of a Nyquist zone:

$$f_s = \frac{4f_c}{2NZ - 1}, \quad \text{Eq. 2}$$

where NZ = 1, 2, 3, 4, .... and NZ corresponds to the Nyquist zone in which the carrier and its signal fall (see Figure 4.8).

NZ is normally chosen to be as large as possible while still maintaining $f_S > 2\Delta f$. This results in the minimum required sampling rate. If NZ is chosen to be odd, then $f_C$ and it's signal will fall in an odd Nyquist zone, and the image frequencies in the first Nyquist zone will not be reversed. Tradeoffs can be made between the sampling frequency and the complexity of the antialiasing filter by choosing smaller values of NZ (hence a higher sampling frequency).

**CENTERING AN UNDERSAMPLED SIGNAL WITHIN A NYQUIST ZONE**




- $f_S > 2\Delta f$
- $f_S = \dfrac{4f_C}{2NZ - 1}$, NZ = 1, 2, 3, . . .

ANALOG DEVICES

4.8

As an example, consider a 4MHz wide signal centered around a carrier frequency of 71MHz. The minimum required sampling frequency is therefore 8MSPS. Solving Eq. 2 for NZ using $f_C$ = 71MHz and $f_S$ = 8MSPS yields NZ = 18.25. However, NZ must be an integer, so we round 18.25 to the next lowest integer, 18. Solving Eq. 2 again for $f_S$ yields $f_S$ = 8.1143MSPS. The final values are therefore $f_S$ = 8.1143MSPS, $f_C$ = 71MHz, and NZ = 18.

Now assume that we desire more margin for the antialiasing filter, and we select $f_S$ to be 10MSPS. Solving Eq. 2 for NZ, using $f_C$ = 71MHz and $f_S$ = 10MSPS yields NZ = 14.7. We round 14.7 to the next lowest integer, giving NZ = 14. Solving Eq. 2 again for $f_S$ yields $f_S$ = 10.519MSPS. The final values are therefore $f_S$ = 10.519MSPS, $f_C$ = 71MHz, and NZ = 14.

The above iterative process can also be carried out starting with $f_S$ and adjusting the carrier frequency to yield an integer number for NZ.

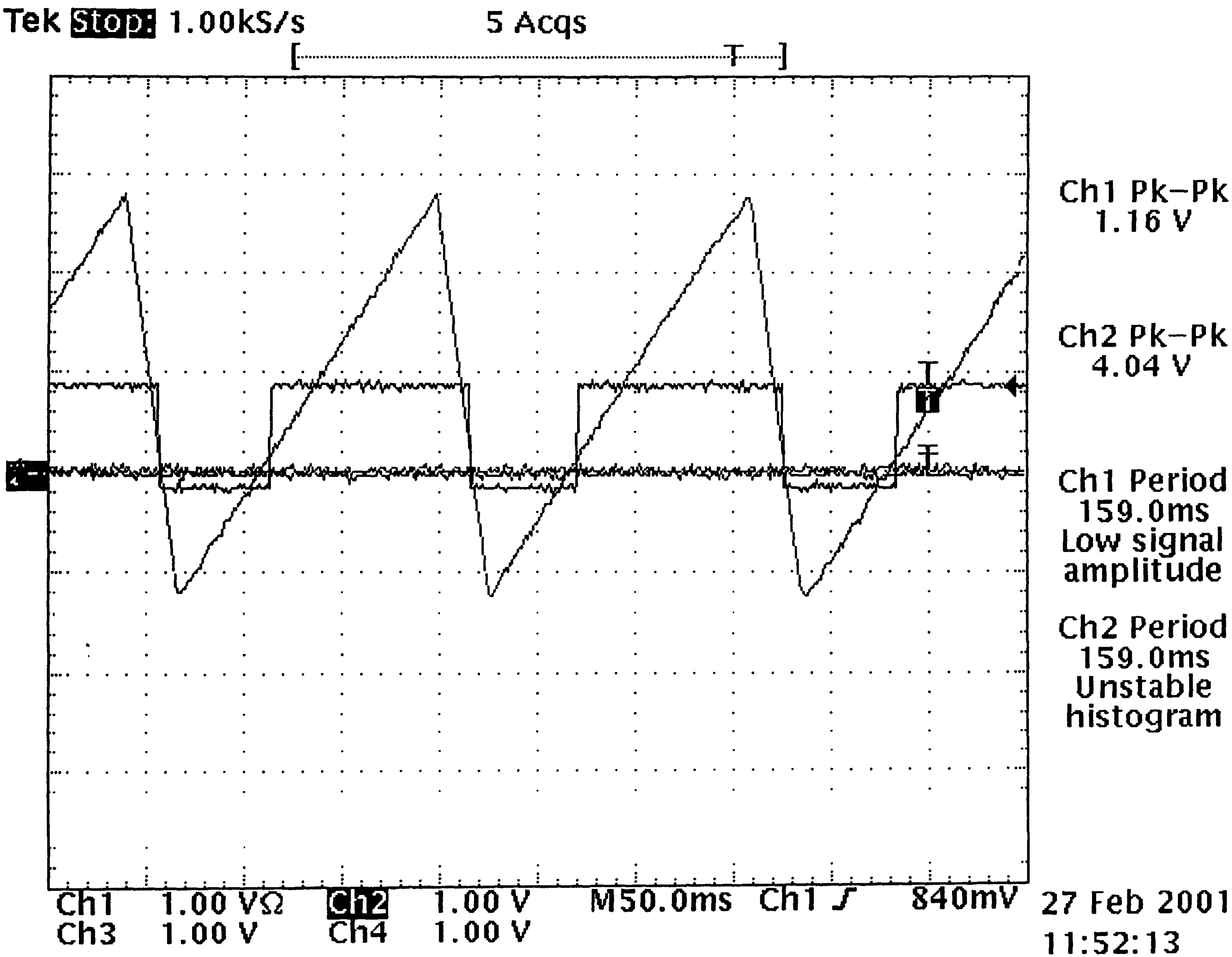
## DISTORTION AND NOISE IN AN IDEAL N-BIT ADC

# Appendix D:

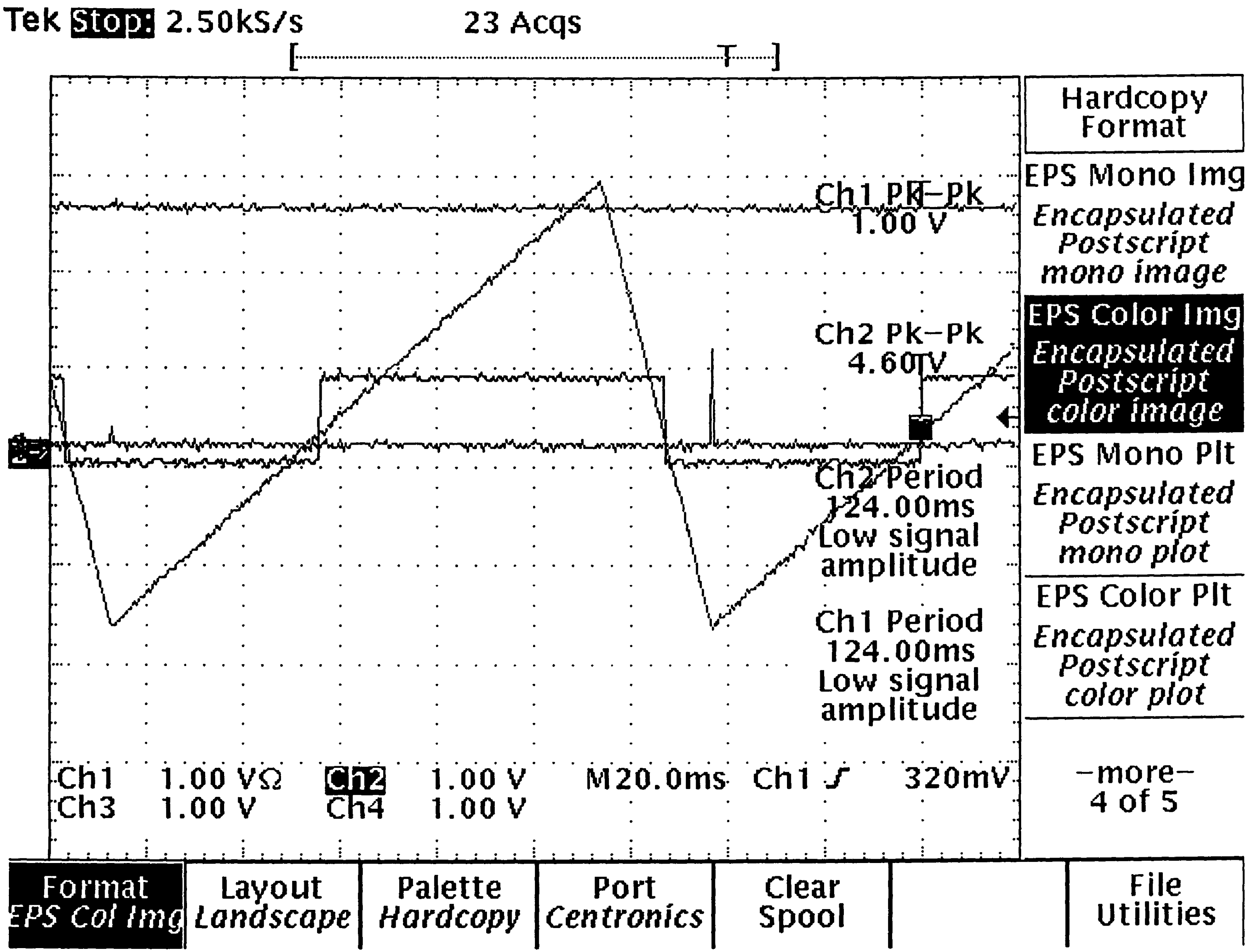
# NM67 Information

Problems:

Channel 1 period too short
Chan. 3 should be a 2.5V
Chan. 4 should have spikes.



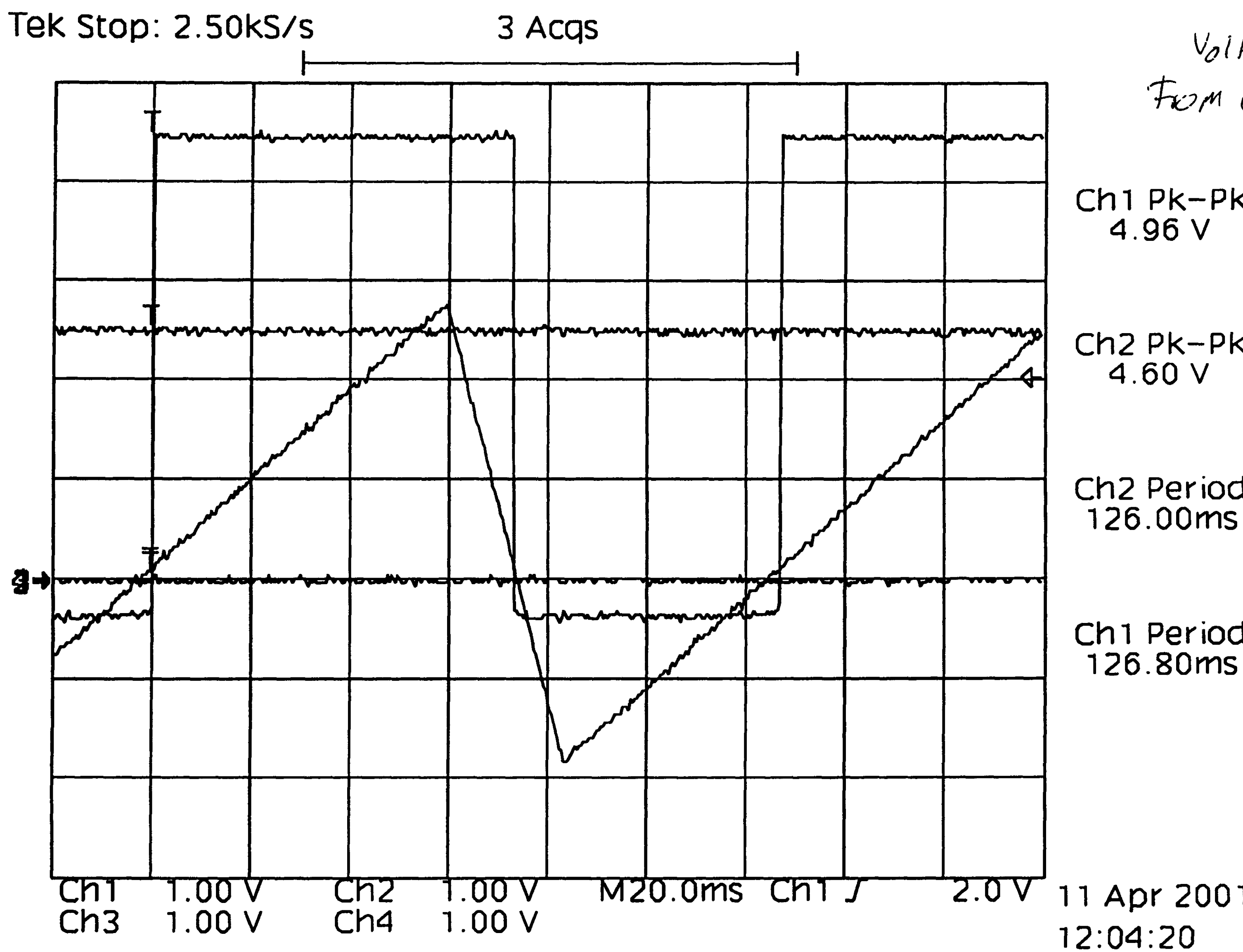
NM 61 Display

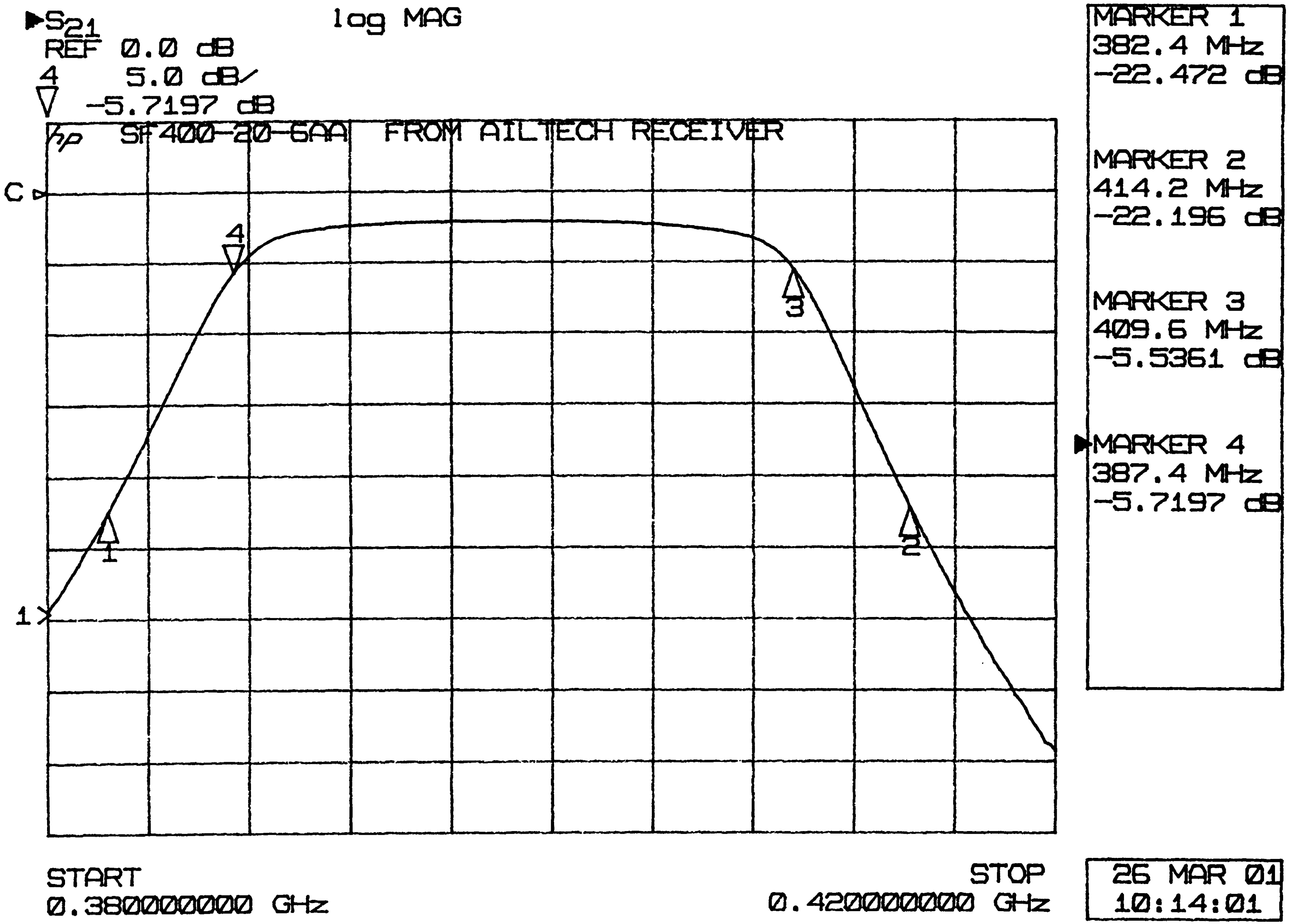


#146 ... display board

Bad Board display seems to work.

Voltages are diff. From working Board.





S21
log MAG
REF 0.0 dB
4 5.0 dB/
-5.7197 dB
SF400-20-6AA FROM AILTECH RECEIVER
C
1
4
3
1
2
MARKER 1
382.4 MHz
-22.472 dB
MARKER 2
414.2 MHz
-22.196 dB
MARKER 3
409.6 MHz
-5.5361 dB
MARKER 4
387.4 MHz
-5.7197 dB
START
0.380000000 GHz
STOP
0.420000000 GHz
26 MAR 01
10:14:01

Lark Engineering

Signal Filtech BP Filter SF400-20-6AA

# STOPBAND ATTENUATION

The graphs on the following pages define the normal specification limits on attenuation for Lark bandpass filter series HP, HQ, and SM. The minimum level of attenuation in dB is shown as a "number of 3dB bandwidths from center frequency".

Since the frequency characteristics vary for differing bandwidths, it is necessary to establish specifications for each bandwidth filter. The different graphs represent various 3dB percentage bandwidths. Intermediate values should be interpolated. The 3dB percentage bandwidth is defined as follows:

$$\frac{\text{3dB Bandwidth (MHz)} \times 100}{\text{Center Frequency (MHz)}}$$

The exact relationship is as follows:

1. 3dB Bandwidths From Center Frequency $= \dfrac{\text{Rejection Frequency (MHz)} - \text{Center Frequency (MHz)}}{\text{3dB Bandwidth (MHz)}}$

Example:
Given:

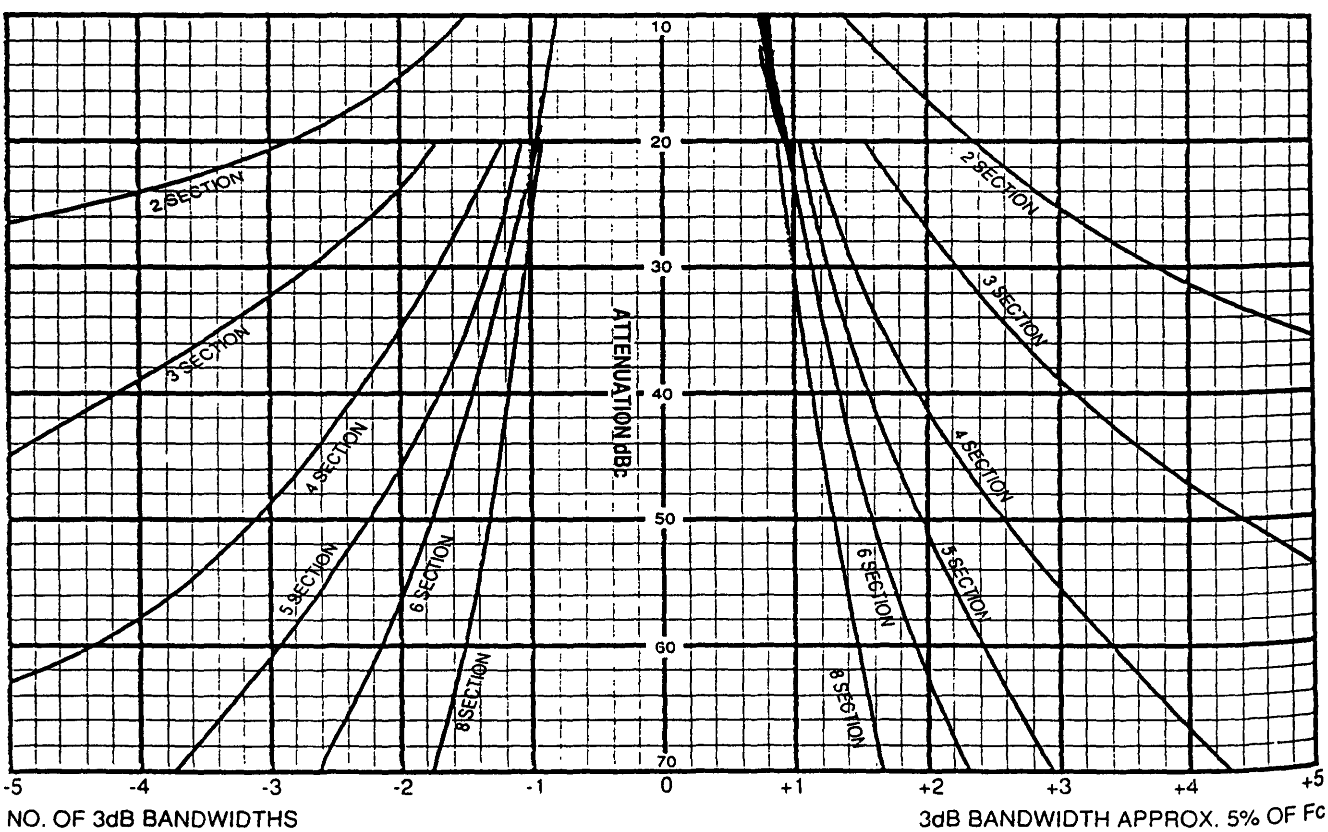
2. Center Frequency = 300 MHz
   Minimum 3dB Bandwidth = 30 MHz
   Number of Sections = 5

   Find: Minimum attenuation levels at 255 MHz and 348 MHz.

$$\text{3dB BW's from Fc} = \frac{255 - 300}{30} = -1.5$$

$$\text{and } \frac{348 - 300}{30} = +1.6$$

As the 3dB bandwidth is exactly 10% of the center frequency, the answer can be read directly from the 10% graph. Using the 5 section curve at the point -1.5 (255 MHz) we find the minimum level of attenuation is 36dB. At +1.6 (348 MHz) the minimum level of attenuation is 48dB.
For special requirements, please contact our Application Engineering Department.






48

E210 E211 E212

# n-channel JFETs designed for . . .

**Performance Curves NZF**
**See Section 4**

## ■ General Purpose Amplifiers

replace with
PN 4392
or J112

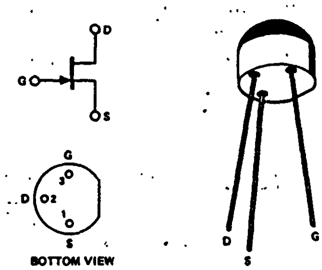
**BENEFITS**

- High Gain
  $G_{FS}$ = 7000 µmho Minimum (E211, E212)
- High Input Impedance
  $I_{GSS}$ = 100 pA Maximum
  $C_{iss}$ = 5 pF Typical

### ABSOLUTE MAXIMUM RATINGS (25°C)

Gate-Drain or Gate-Source Voltage .............. -25 V
Gate Current .............................. 10 mA
Total Device Dissipation
  (25°C Free-Air Temperature) ............... 350 mW
Power Derating (to +125°C) ................ 3.5 mW/°C
Storage Temperature Range ............. -55 to +125°C
Operating Temperature Range ............ -55 to +125°C
Lead Temperature
  (1/16" from case for 10 seconds) ............. 300°C

TO-106
See Section 5




### ELECTRICAL CHARACTERISTICS (25°C unless otherwise noted)

| | | | Characteristic | E210 Min | E210 Typ | E210 Max | E211 Min | E211 Typ | E211 Max | E212 Min | E212 Typ | E212 Max | Unit | Test Conditions | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | STATIC | $I_{GSS}$ | Gate Reverse Current (Note 1) | | | -100 | | | -100 | | | -100 | pA | $V_{DS}$ = 0, $V_{GS}$ = -15 V | |
| 2 | | $V_{GS(off)}$ | Gate-Source Cutoff Voltage | -1 | | -3 | -2.5 | | -4.5 | -4 | | -6 | V | $V_{DS}$ = 15 V, $I_D$ = 1 nA | |
| 3 | | $BV_{GSS}$ | Gate-Source Breakdown Voltage | -25 | | | -25 | | | -25 | | | V | $V_{DS}$ = 0, $I_G$ = -1 µA | |
| 4 | | $I_{DSS}$ | Saturation Drain Current (Note 2) | 2 | | 15 | 7 | | 20 | 15 | | 40 | mA | $V_{DS}$ = 15 V, $V_{GS}$ = 0 | |
| 5 | | $I_G$ | Gate Current (Note 1) | | -10 | | | -10 | | | -10 | | pA | $V_{DG}$ = 10 V, $I_D$ = 1 mA | |
| 6 | DYNAMIC | $g_{fs}$ | Common-Source Forward Transconductance (Note 2) | 4,000 | | 12,000 | 7,000 | | 12,000 | 7,000 | | 12,000 | µmho | $V_{DS}$ = 15 V, $V_{GS}$ = 0 | f = 1 kHz |
| 7 | | $g_{os}$ | Common-Source Output Conductance | | | 150 | | | 200 | | | 200 | µmho | $V_{DS}$ = 15 V, $V_{GS}$ = 0 | f = 1 kHz |
| 8 | | $C_{iss}$ | Common-Source Input Capacitance | | 5.0 | | | 5.0 | | | 5.0 | | pF | $V_{DS}$ = 15 V, $V_{GS}$ = 0 | f = 1 MHz |
| 9 | | $C_{rss}$ | Common-Source Reverse Transfer Capacitance | | 1.5 | | | 1.5 | | | 1.5 | | pF | $V_{DS}$ = 15 V, $V_{GS}$ = 0 | f = 1 MHz |
| 10 | | $\bar{e}_n$ | Equivalent Short-Circuit Input Noise Voltage | | 10 | | | 10 | | | 10 | | $\frac{nV}{\sqrt{Hz}}$ | $V_{DS}$ = 15 V, $V_{GS}$ = 0 | f = 1 kHz |

NOTES:
1. Approximately doubles for every 10°C increase in $T_A$.
2. Pulse test duration = 2 ms.

NZF

© 1977 Siliconix incorporated



n-chann
designed

■ Audio and
Amplifiers

ABSOLUTE MAXIMU

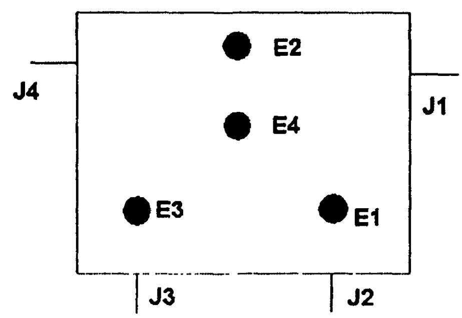
Gate-Drain or Gate-Sou
Gate Current ......
Total Device Dissipatic
(25°C Free-Air Tem
Power Derating (to +1
Storage Temperature F
Operating Temperatur
Lead Temperature
(1/16" from case fo

ELECTRICAL CHAR

| | | | Characteristic |
|---|---|---|---|
| 1 | STATIC | $I_{GSS}$ | Gate Revers (Note 2) |
| 2 | | $V_{GS(off)}$ | Gate-Source Voltage |
| 3 | | $BV_{GSS}$ | Gate-Source Voltage |
| 4 | | $I_{DSS}$ | Saturation I Current (Nc |
| 5 | | $I_G$ | Gate Currer |
| 6 | DYNAMIC | $g_{fs}$ | Common-S Transcondu |
| 7 | | $g_{os}$ | Common-S Conductan |
| 8 | | $C_{iss}$ | Common-S Capacitanc |
| 9 | | $C_{rss}$ | Common-S Transfer C |
| 10 | | $\bar{e}_n$ | Equivalent Input Nois |
| 11 | | | |

NOTES:
1. Geometry is symmetrical.
2. Approximately doubles fc
3. Pulse test duration = 2 ms

# A2S1 Switch and Pin Out




E1 – Orange/Blue/White Wire
E2 – Orange/White Wire
E3 – Red/Orange/White Wire
E4 – Black Wire

# Appendix E:

# Software – New and Updated

# Bands for "dailychange" software --EMS

| Band Number | Frequency Range (GHz) | FE Band (GHz) | Ailtech Band | File to Save to | | getAilm | default | dir | Az | El | Band | BW | Zero | Span | FreqC | IFGain | Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1-2 | 1-2 | 1-2 | lband_high | | getAilm | 0 | 4 | 0 | 0 | 18 | 1 | 0 | 231 | 1914 | 35 | lband_high |
| 2 | 1-2 | 1-2 | 1-2 | lband_low | | getAilm | 0 | 0 | 0 | 0 | 18 | 1 | 0 | 152 | 2808 | 36 | lband_low |
| 3 | 2-3.022 | 2-4 | 2-3.6 | sband_2_3 | | getAilm | 0 | 0 | 0 | 0 | 19 | 1 | 151 | 89 | 2808 | 33 | sband_2_3 |
| 4 | 3.014-3.601 | 2-4 | 2-3.6 | sband_3_3.6 | | getAilm | 0 | 0 | 0 | 0 | 19 | 1 | 0 | 62 | 2964 | 45 | sband_3_3.6 |
| 5 | 3.600-4.623 | 2-4 | 3.6-7.6 | cband_3.6_4.6 | | getAilm | 0 | 0 | 0 | 0 | 20 | 1 | 63 | 61 | 2964 | 86 | cband_3.6_4.6 |
| 6 | 4.592-5.60 | 4-10 | 3.6-7.6 | cband_4.6_5.6 | | getAilm | 0 | 0 | 0 | 0 | 20 | 1 | 121 | 61 | 2964 | 35 | cband_4.6_5.6 |
| 7 | 5.597-6.602 | 4-10 | 3.6-7.6 | cband_5.6_6.6 | | getAilm | 0 | 0 | 0 | 0 | 20 | 1 | 180 | 62 | 2964 | 34 | cband_5.6_6.6 |
| 8 | 6.593-7.601 | 4-10 | 3.6-7.6 | cband_6.6_7.6 | | getAilm | 0 | 0 | 0 | 0 | 20 | 1 | 0 | 56 | 2872 | 32 | cband_6.6_7.6 |
| 9 | 7.600-8.615 | 4-10 | 7.6-12 | cxband_7.6_8.6 | | getAilm | 0 | 0 | 0 | 0 | 21 | 1 | 56 | 56 | 2872 | 34 | cxband_7.6_8.6 |
| 10 | 8.608-9.620 | 4-10 | 7.6-12 | xband_8.6_9.6 | | getAilm | 0 | 0 | 0 | 0 | 21 | 1 | 111 | 56 | 2872 | 35 | xband_8.6_9.6 |
| 11 | 9.576-10.587 | 4-10 | 7.6-12 | xband_9.6_10.6 | | getAilm | 0 | 0 | 0 | 0 | 21 | 1 | 163 | 57 | 2872 | 36 | xband_9.6_10.6 |
| 12 | 10.580-11.601 | 10-18 | 7.6-12 | xband_10.6_11.6 | | getAilm | 0 | 0 | 0 | 0 | 21 | 1 | 220 | 23 | 2872 | 37 | xband_10.6_11.6 |
| 13 | 11.591-12.004 | 10-18 | 7.6-12 | xband_11.6_12 | | getAilm | 0 | 0 | 0 | 0 | 21 | 1 | 0 | 41 | 2872 | 16 | xband_11.6_12 |
| 14 | 12.000-12.994 | 10-18 | 12-18 | uband_12_13 | | getAilm | 0 | 0 | 0 | 0 | 22 | 1 | 41 | 41 | 3148 | 22 | uband_12_13 |
| 15 | 12.983-13.977 | 10-18 | 12-18 | uband_13_14 | | getAilm | 0 | 0 | 0 | 0 | 22 | 1 | 80 | 41 | 3148 | 13 | uband_13_14 |
| 16 | 13.962-14.956 | 10-18 | 12-18 | uband_14_15 | | getAilm | 0 | 0 | 0 | 0 | 22 | 1 | 121 | 42 | 3148 | 22 | uband_14_15 |
| 17 | 14.945-15.964 | 10-18 | 12-18 | uband_15_16 | | getAilm | 0 | 0 | 0 | 0 | 22 | 1 | 160 | 42 | 3148 | 28 | uband_15_16 |
| 18 | 15.956-16.974 | 10-18 | 12-18 | uband_16_17 | | getAilm | 0 | 0 | 0 | 0 | 22 | 1 | 203 | 42 | 3148 | 25 | uband_16_17 |
| 19 | 16.970-17.983 | 10-18 | 12-18 | uband_17_18 | | getAilm | 0 | 0 | 0 | 0 | 22 | 1 | 224 | 20 | 3148 | 16 | uband_17_18 |

dailychange

```
"bin/sh
 'ile name and location

   /home/electra2/ailmon/dailychange

 Shell script to change what ailmon observes everyday.
 nis adjusts or makes changes to the following files

 /home/ailmon/where2savepfd.sv and /home/ailmon/where2savepeak.sv
    This file tells npgsail and npgsail2 where to store
     the data plots.

 /home/electra2/ailmon/ail.dfl
    This file is the data input for the ailmon program
     and tells the ailtech receiver where to observe.

    This files format can be found in the folowing file

       /home/snow/usr/src/ailmon/ver4/getAilmKey.txt


version 1.0
NRAO
 une 2001

*****  Program Starts Here   ******
 ar

ho "Please wait... making daily changes"
nort BAND="`cat /home/electra2/ailmon/bandcounter`"


The following case statement will do the following
  The first line  will set peramiters for
  ailtech reciever and set what band to scan through
- The second line will set the file
  location for the peak plots that were made today.
  The third line  will set the file location
  for the PFD plots that were made today.
- Increase the number in bandcounter to tell getAilm
  to generate data for a different frequency range
  for the next day.


 autologfile.new autologfile.old

ho "Log file for automation program." > autologfile.new
 o "ail.dfl file was last updated on "  >> autologfile.new
.te >> autologfile.new
ho "It was changed from band $BAND to $(($BAND+1))" >> autologfile.new

.e "$BAND" in


   printf "getAilm 0 4 0 0 18 1 0 231 1914 35 1_band_high_gain" > /home/snow/et
'ail.dfl
   printf "/home/electra2/ailmon/data/ems_plots/peak/uband_17_18" > /home/elect
 /ailmon/where2savepeak.sv
   printf "/home/electra2/ailmon/data/ems_plots/pfd/uband_17_18" > /home/electr
/ailmon/where2savepfd.sv
   printf "/home/snow/data/ailm/sorted_data/peak/uband_17_18" > /home/electra2/
 mon/where2savedata.sv
```

```
printf "/home/snow/data/ailm/sorted_data/peak/sband_4.6_5.6" > /home/electra
ilmon/where2savedata.sv
 printf 8 > /home/electra2/ailmon/bandcounter ;;


 printf "getAilm 0 0 0 0 20 1 0 56 2872 32 c_band_6.6_7.6" > /home/snow/etc/ai
ifl
 printf "/home/electra2/ailmon/data/ems_plots/peak/cband_5.6_6.6" > /home/elec
2/ailmon/where2savepeak.sv
 printf "/home/electra2/ailmon/data/ems_plots/pfd/cband_5.6_6.6" > /home/elect
/ailmon/where2savepfd.sv
  printf "/home/snow/data/ailm/sorted_data/peak/sband_5.6_6.6" > /home/electra
ilmon/where2savedata.sv
 printf 9 > /home/electra2/ailmon/bandcounter ;;


) printf "getAilm 0 0 0 0 20 1 56 56 2872 34 cx_band_7.6_8.6" > /home/snow/etc/
.dfl
 printf "/home/electra2/ailmon/data/ems_plots/peak/cband_6.6_7.6" > /home/elec
a2/ailmon/where2savepeak.sv
 printf "/home/electra2/ailmon/data/ems_plots/pfd/cband_6.6_7.6" > /home/elect
/ailmon/where2savepfd.sv
  printf "/home/snow/data/ailm/sorted_data/peak/sband_6.6_7.6" > /home/electra
ailmon/where2savedata.sv
 printf 10 > /home/electra2/ailmon/bandcounter ;;


 ) printf "getAilm 0 0 0 0 21 1 111 56 2872 35 x_band_8.6_9.6" > /home/snow/etc
 l.dfl
  printf "/home/electra2/ailmon/data/ems_plots/peak/cxband_7.6_8.6" > /home/el
tra2/ailmon/where2savepeak.sv
  printf "/home/electra2/ailmon/data/ems_plots/pfd/cxband_7.6_8.6" > /home/ele
ra2/ailmon/where2savepfd.sv
  printf "/home/snow/data/ailm/sorted_data/peak/sband_7.6_8.6" > /home/electra
ilmon/where2savedata.sv
  printf 11 > /home/electra2/ailmon/bandcounter ;;


 ) printf "getAilm 0 0 0 0 21 1 163 57 2872 36 x_band_9.6_10.6" > /home/snow/et
ail.dfl
  printf "/home/electra2/ailmon/data/ems_plots/peak/xband_8.6_9.6" > /home/ele
a2/ailmon/where2savepeak.sv
  printf "/home/electra2/ailmon/data/ems_plots/pfd/xband_8.6_9.6" > /home/elec
ra2/ailmon/where2savepfd.sv
  printf "/home/snow/data/ailm/sorted_data/peak/sband_8.6_9.6" > /home/electra
ilmon/where2savedata.sv
  printf 12 > /home/electra2/ailmon/bandcounter ;;


 ) printf "getAilm 0 0 0 0 21 1 220 23 2872 37 x_band_10.6_11.6" > /home/snow/e
/ail.dfl
  printf "/home/electra2/ailmon/data/ems_plots/peak/xband_9.6_10.6" > /home/el
ra2/ailmon/where2savepeak.sv
  printf "/home/electra2/ailmon/data/ems_plots/pfd/xband_9.6_10.6" > /home/ele
ra2/ailmon/where2savepfd.sv
  printf "/home/snow/data/ailm/sorted_data/peak/sband_9.6_10.6" > /home/electr
/ailmon/where2savedata.sv
  printf 13 > /home/electra2/ailmon/bandcounter ;;


 ) printf "getAilm 0 0 0 0 21 1 0 41 2872 16 x_band_11.6_12" > /home/snow/etc/a
.dfl
  printf "/home/electra2/ailmon/data/ems_plots/peak/xband_10.6_11.6" > /home/e
```

```
    printf "/home/electra2/ailmon/data/ems_plots/pfd/uband_16_17" > /home/electr
:/ailmon/where2savepfd.sv
    printf "/home/snow/data/ailm/sorted_data/peak/sband_16_17" > /home/electra2/
ilmon/where2savedata.sv
    printf 1 > /home/electra2/ailmon/bandcounter  ;;


  echo "Something went amuck";;
sac

cho "Finished"


xit 0
```

ktransfer_plot

```
.n/sh
:ll script to transfer and plot getAilm data
-sion 1, 18 Oct 00
:LL=/usr/bin/csh

l nthomas20010605 - changed output perameters for the plot file
 have an additional output (i.e.: different input and output locations)

 s will also delete the data file from electra2 once plots have been made



:s and reformats current year
late '+%y'`
:`date '+%Y'`

:s the current month, day as one quantity
:`date '+%m%d'`

eates the logfile

home/electra2/nlogfile.new /home/electra2/nlogfile.old
 "Logfile for data renaming, plotting" > /home/electra2/nlogfile.new
 "The shell used is "$SHELL >> /home/electra2/nlogfile.new
 "The year is "$yy >> /home/electra2/nlogfile.new
 "The month/day is "$mmdd >> /home/electra2/nlogfile.new


home/electra2/npfdlog.new /home/electra2/npfdlog.old
 "Logfile for data renaming, plotting" > /home/electra2/npfdlog.new
 "The year is "$yy >> /home/electra2/npfdlog.new
 "The month/day is "$mmdd >> /home/electra2/npfdlog.new

*************************************************************

es the transfer
:p -r snow.aoc.nrao.edu:/home/snow/data/ailm/peak/1$yy$mmdd /home/electra2/ail
'data >> /home/electra2/nlogfile.new

-r /home/snow/data/ailm/peak/1$yy$mmdd /home/electra2/ailmon/data >> /home/ele
a2/nlogfile.new

-r /home/electra2/ailmon/data/1$yy$mmdd /home/electra2/ailmon/data/PFD >> /hom
.ectra2/npfdlog.new

*************************************************************

rt the data on snow (Make links in sorted folders)

here0="`cat /home/electra2/ailmon/where2savedata.sv`"
 "Data files on snow being sorted" >> /home/electra2/nlogfile.new

-s /home/snow/data/ailm/peak/1$yy$mmdd $savehere0/1$yy$mmdd >> /home/electra2/
file.new

*************************************************************
 names the files, need to insert variable center freq.
cho "$0 <current-prefix> <new-prefix>" >> /home/electra2/nlogfile.new
 $# -ne 2 ] && exit 1

efix=$mmdd
ix=0406
```

usr/bin/sh

Pgsn.1

```
 set up environment for IDL RF Data plotting
 3-D grayscale for ailmon receiver data

 dmertely May 1998

 od dmertely20000302: Fix bug of finding data files in
 irectory--Had to add "-type f" to exclude the directory "./"
from the list.
 : old= DATA_FILE_LIST=`find $DATA_PATH -name "*$DATA_DATE????"`
   new= DATA_FILE_LIST=`find $DATA_PATH -type f -name "*$DATA_DATE????"`



..od - nthomas2001: Changed input so that input data file and output/plots
do not have to be in the same directory


TH=/usr/ucb:/usr/bin:/bin:/usr/local/bin


.LLER=$0
ER=`whoami`
 TNAME=`uname -n`
 [ "$PWD" = "" ]; then
PWD=`pwd`
 xport PWD


:age_message()

echo "usage:"
echo " $CALLER data-path data-date [plot-Title]"
:cho " $CALLER --help"


-heck for number of arguments.
 ho "nargs = $#"
: [ $# -eq 1 ] && [ "$1" = "--help" ]; then
   usage_message
   echo
   echo " $CALLER  data-path  YYMMDD"
   echo " $CALLER  data-path  YYMMDD  plot-title"
   echo
   echo "examples:"
   echo "   $CALLER  /home/electra2/ailmon/data/ 980505  \"test plot\" "
   echo "   $CALLER  /home/electra2/ailmon/data/ 980505 "
   echo
   exit 1
i

L [ $# -lt 2 ] ; then
 usage_message
 xit 1
:

ata_path=$1
: ER_PATH=$2
ATA_DATE=$3
LOT_TITLE=$4

  ıo "zeroplace = $0"
```

58

```
:port USER HOSTNAME DATA_PATH PLOT_TITLE CALLER OUT_PATH DATA_DATE DATA_FILE
:port DATA_FILE_LIST
il << EOF
RINT, 'user     =', GETENV('USER')
RINT, 'hostname =', GETENV('HOSTNAME')
RINT, 'path     =', GETENV('DATA_PATH')
PATH = EXPAND_PATH("+$IDL_MODULES:"+!PATH)
rint, 'new path:'
rint, !PATH
RINT, 'compiling: $BASE_CALLER.pro'
BASE_CALLER
OF
cho "cleaning up . . ."
ıset CALLER DATA_PATH PLOT_TITLE OUT_PATH DATA_DATE DATA_FILE DATA_FILE_LIST


 EOF pgsail
```

pgsail2

```
:/usr/bin/sh

  set up environment for IDL RF Data plotting
  3-D grayscale for ailmon receiver data

  dmertely May 1998

 Mod dmertely20000302: Fix bug of finding data files in
 directory--Had to add "-type f" to exclude the directory "./"
 from the list.
ie: old= DATA_FILE_LIST=`find $DATA_PATH -name "*$DATA_DATE????"`
    new= DATA_FILE_LIST=`find $DATA_PATH -type f -name "*$DATA_DATE????"`

PATH=/usr/ucb:/usr/bin:/bin:/usr/local/bin

echo "In pgsail2"

 ALLER=$0
 SER=`whoami`
HOSTNAME=`uname -n`
if [ "$PWD" = "" ]; then
  PWD=`pwd`
  export PWD
fi

 sage_message()
{
  echo "usage:"
  echo " $CALLER data-path data-date [plot-Title]"
  echo " $CALLER --help"
}

# check for number of arguments.
#echo "nargs = $#"
 f [ $# -eq 1 ] && [ "$1" = "--help" ]; then
    usage_message
    echo
    echo " $CALLER  data-path  YYMMDD"
    echo " $CALLER  data-path  YYMMDD  plot-title"
    echo
    echo "examples:"
    echo "  $CALLER  /home/electra2/ailmon/data/ 980505  \"test plot\" "
    echo "  $CALLER  /home/electra2/ailmon/data/ 980505 "
    echo
    exit 1
 i

if [ $# -lt 2 ] ; then
  usage_message
  exit 1
fi

 ata_path=$1
USER_PATH=$2
 ATA_DATE=$3
 LOT_TITLE=$4

DATA_MOUNT=/home/electra2/ailmon/data/PFD

DATA_PATH=$USER_PATH/$DATA_DATE
DATA_FILE=""

 ILMON_HOME=~ailmon
```

```
)L_MODULES="$AILMON_HOME/bin/idl"

UT_PATH="$data_path"


f [ "$PWD" = "$AILMON_HOME/src/plot/idl" ]; then
   IDL_MODULES=$PWD
i

f [ ! -d $DATA_PATH ] ; then
 echo "error:  cannot find directory: $DATA_PATH"
 exit 1
i

 find first "$DATA_PATH/*$DATA_DATE????" file
  set DATA_FILE= this file
ATA_FILE_LIST=`find $DATA_PATH -type f -name "*$DATA_DATE????"`

cho "DATA_DATE: $DATA_DATE"
cho "DATA_FILE_LIST: $DATA_FILE_LIST"
or i in $DATA_FILE_LIST; do
 check if filename exists and is readable
 if [ -r $i ]; then
   DATA_FILE=`basename $i`
   echo "found basename i: `basename $i`"
   echo "i: $i"
   echo "found datafile: $DATA_FILE"
   break
 fi
one

f [ "$DATA_FILE" = "" ]; then
 echo "error:  cannot find a valid data file in "
 echo "        $DATA_PATH"
 exit 1
i

cho "caller: $CALLER"
cho "date  : $DATA_DATE"
cho "path  : $DATA_PATH"
cho "file  : $DATA_FILE"
cho "title : \"$PLOT_TITLE\""
cho "output: $OUT_PATH"
echo "data-file-list: $DATA_FILE_LIST"

ASE_CALLER=`basename $CALLER`
DIR_CALLER=`dirname $CALLER`

xport USER HOSTNAME DATA_PATH PLOT_TITLE CALLER OUT_PATH DATA_DATE DATA_FILE
export DATA_FILE_LIST
idl << EOF
RINT, 'user     =', GETENV('USER')
RINT, 'hostname =', GETENV('HOSTNAME')
PRINT, 'path     =', GETENV('DATA_PATH')
PATH = EXPAND_PATH("+$IDL_MODULES:"+!PATH)
rint, 'new path:'
print, !PATH
PRINT, 'compiling: $BASE_CALLER.pro'
BASE_CALLER
EOF
echo "cleaning up . . ."
nset CALLER DATA_PATH PLOT_TITLE OUT_PATH DATA_DATE DATA_FILE DATA_FILE_LIST
```

**EOF npgsail2**

rfi.shtml

```
TML>
-- Updated June 5 2001 by Nathan Thomas -->
!-- Updated to include link to new EMS Monitoring Page-->

HEAD>

title>VLA Radio Frequency Interference</title>

/HEAD>


H3 align=center>
 Radio Frequency Interference at the VLA
 </H3>

P>

table cellpadding=4 border=0 valign=center>
align=center>
tr>
td>Radio Frequency Interference (RFI), both internally and
xternally generated, is an increasingly significant problem at the
LA, particularly at wavelengths of 18cm and longer.  This page points
ou to information on known RFI, current developments, and plans for
andling the problem in the future.
/P>
p>
or each band surveyed, current and past postscript and giff
nterference plots show signal power vs. frequency. Overlay plots
dentify the known emitters in each band. </p>
p>
lick for more information on <a
href="../interference/README.1ST">SYSQUICK</a> plots; on <a
href="../interference/gsplots/README.1ST">W8 Monitor Grayscale</a> plots.</p>
p>
his is a picture of our new 60ft RFI Tower. With the help of directional
antenna on top we will be able to determine from which direction we
re receiving RFI. This will help us to better identify the source of
ome interference.</p>
<center><b>This page is currently under development.</b><br>
<font color=red>If an error is displayed next to a link, that plot is
urrently unavailable.</font></center>
/th>
td>
img src="../interference/rfitower.jpg" width="257" height="364"
lign=right>
</th>
/table>
HR width=100%> <P> <DL>
  <DT><STRONG><A HREF="../interference/VLA-RFI-Report-link.ps">VLA RFI Survey</A
</STRONG>   A VLA site survey of RFI and potential RFI from 50 MHz to 71 GHz (Bi
 file!).
  <P>
  <DT><STRONG><A HREF="../interference/rfireports.shtml">RFI Bulletins</A></STRO
 >   Current announcements and Bulletins on RFI at the VLA.
  <P>
  <DT> <A HREF="./Memos/rfimemolist.shtml"><STRONG>RFI Memoranda</STRONG></A>   R
ent VLA memoranda related to RFI.
  <P>
  <DT><STRONG><a href="../interference/survey.shtml">Satellite
Survey</a></STRONG>  A Survey of Satellite Constellations that could effect RFI
  the VLA.
  <p>
```

```
<DT> <A HREF="rfa.htm"><STRONG> World Radio Astronomy Frequency
    Allocations</STRONG></A>
  <DD>List of frequencies allocated and footnote-protected by the
    International Telecommunications Union (1994)
<P>
—
DT> <a href="./ems_plots.shtml"><STRONG>Environmental Monitoring System(EMS) Plc
:</STRONG></a>
<DD>Plots made by the EMS system range from 1 to 18 GHz.
—
?> 
'>
:P><P>
:DT> <H2><STRONG><CENTER>SYSQUICK RFI plots and W8 Monitor L band plots:</CENTER>
'STRONG></H2>
—

<DT> <STRONG>K-band (22.1-26.0GHz) RFI</STRONG>
  <DL>
    <DT> <A HREF="../interference/kband/CurrentPlot.ps">
      Latest "SYSQUICK" interference plot</A>
      <!--#config timefmt="%d%b%y"-->
      (<!--#flastmod virtual="/doc/vla/interference/kband/CurrentPlot.ps"-->)
    <DT><A HREF="../interference/kband/CurrentOverlay.jpg">
      Latest overlay plot</A>
      <!--#config timefmt="%d%b%y"-->
      (<!--#flastmod
        virtual="/doc/vla/interference/kband/CurrentOverlay.jpg"-->)

    <DT><A HREF="../interference/kband/">
      All interference plots</A>
      <DD> plots of RFI from 22.1 to 26.0GHz; the overlay files show
        known sources of RFI, together with band assignments from the FCC.
    </DL>
<P>

<DT> <STRONG>U-band (14.4-14.9GHz) RFI</STRONG>
  <DL>
    <DT> <A HREF="../interference/uband/CurrentPlot.ps">
      Latest "SYSQUICK" interference plot</A>
      <!--#config timefmt="%d%b%y"-->
      (<!--#flastmod virtual="/doc/vla/interference/uband/CurrentPlot.ps"-->)
    <DT><A HREF="../interference/uband/CurrentOverlay.jpg">
      Latest overlay plot</A>
      <!--#config timefmt="%d%b%y"-->
      (<!--#flastmod virtual="/doc/vla/interference/uband/CurrentOverlay.jpg"--
>)
    <DT><A HREF="../interference/uband/">
      All interference plots</A>
      <DD> plots of RFI from 14.4 to 14.9GHz; the overlay files show
        known sources of RFI, together with band assignments from the FCC.
    </DL>
<P>

<DT> <STRONG>X-band (8345-8605MHz) RFI</STRONG>
  <DL>
    <DT> <A HREF="../interference/xband/CurrentPlot.ps">
      Latest "SYSQUICK" interference plot</A>
      <!--#config timefmt="%d%b%y"-->
      (<!--#flastmod virtual="/doc/vla/interference/xband/CurrentPlot.ps"-->)
    <DT><A HREF="../interference/xband/CurrentOverlay.jpg">
      Latest overlay plot</A>
      <!--#config timefmt="%d%b%y"-->
```

Added on June 5th 2001 by Nathan Thomas

6

```
        (<!--#flastmod
          virtual="/doc/vla/interference/xband/CurrentOverlay.jpg"-->)
      <DT><A HREF="../interference/xband/">
        All interference plots</A>
        <DD> plots of RFI from 8345 to 8605MHz; the overlay files show
          known sources of RFI, together with band assignments from the FCC.
      </DL>
  <P>

  <DT> <STRONG>C-band (4600-5000MHz) RFI</STRONG>
    <DL>
      <DT> <A HREF="../interference/cband/CurrentPlot.ps">
        Latest "SYSQUICK" interference plot</A>
        <!--#config timefmt="%d%b%y"-->
        (<!--#flastmod virtual="/doc/vla/interference/cband/CurrentPlot.ps"-->)
      <DT><A HREF="../interference/cband/CurrentOverlay.jpg">
        Latest overlay plot</A>
        <!--#config timefmt="%d%b%y"-->
        (<!--#flastmod
          virtual="/doc/vla/interference/cband/CurrentOverlay.jpg"-->)
      <DT><A HREF="../interference/cband/">
        All interference plots</A>
        <DD> plots of RFI from 4600 to 5000MHz; the overlay files show
          known sources of RFI, together with band assignments from the FCC.
      </DL>
  <P>

  <DT> <STRONG>L-band (1200-1800MHz) RFI</STRONG>
    <DL>
      <DT> <A HREF="../interference/lband/CurrentPlot.ps">
        Latest "SYSQUICK" interference plot</A>
        <!--#config timefmt="%d%b%y"-->
        (<!--#flastmod virtual="/doc/vla/interference/lband/CurrentPlot.ps"-->)
      <DT> <A HREF="../interference/lband/CurrentOverlay.jpg">
        Latest overlay plot</A>
        <!--#config timefmt="%d%b%y"-->
        (<!--#flastmod
          virtual="/doc/vla/interference/lband/CurrentOverlay.jpg"-->)
      <DT><A HREF="../interference/lband/">
        All interference plots</A>
        <DD> plots of RFI from 1200 to 1800MHz; the OVERLAY files show
          known sources of RFI, together with band assignments from the FCC.
      <DT>Pre-made W8 Monitor Grayscale Plots (<A
href="../interference/gsplots/">Peak</a> / <a
ref="../interference/gsplots/avg/">Average</a>) for past few
onths.  Average data available after 1/13/98.
      <DT><table border=0>
tr>
td>Interactive W8 Monitor Grayscale Plots. </td>
<FORM ACTION="http://www.aoc.nrao.edu/cgi-bin/RFGen.cgi" METHOD="POST">
<td>YY<input name="YEAR" Size=2> MM<input name="MONTH" size=2> DD<input
ame="DAY" size=2> # of days<input name="NDAYS" size=2 value="1"> <input
ype="SUBMIT" value="Submit"></td>
/table>

      </DL>
  <P>

  <DT> <STRONG>P-band (300-350MHz) RFI</STRONG>
    <DL>
      <DT> <A HREF="../interference/pband/CurrentPlot.ps">
        Latest "SYSQUICK" interference plot</A>
        <!--#config timefmt="%d%b%y"-->
```

```
        (<!--#flastmod virtual="/doc/vla/interference/pband/CurrentPlot.ps"-->)
      <DT><!-- VLADATE -->
        <A HREF="../interference/pband/CurrentOverlay.jpg">
        Latest overlay plot</A>
        <!--#config timefmt="%d%b%y"-->
        (<!--#flastmod
          virtual="/doc/vla/interference/pband/CurrentOverlay.jpg"-->)
      <DT><A HREF="../interference/pband/">
        All interference plots</A>
        <DD> plots of RFI from 300 to 350MHz; the overlay files show
          known sources of RFI, together with band assignments from the FCC.
      </DL>
  <P>

  <DT> <STRONG>4-band (74MHz) RFI</STRONG>
    <DL>
      <DT> <A HREF="../interference/4band/CurrentPlot.ps">
        Latest interference plot</A>
        <!--#config timefmt="%d%b%y"-->
        (<!--#flastmod virtual="/doc/vla/interference/4band/CurrentPlot.ps"-->)
      <DT><!-- VLADATE -->
        <A HREF="../interference/4band/CurrentOverlay.jpg">
        Latest overlay plot</A>
        <!--#config timefmt="%d%b%y"-->
        (<!--#flastmod
          virtual="/doc/vla/interference/4band/CurrentOverlay.jpg"-->)
      <DT><A HREF="../interference/4band/">
        All interference plots</A>
        <DD> plots of RFI at 74MHz; the overlay files show
          known sources of RFI, together with band assignments from the FCC.
      </DL>
  <P>

  <DT> <STRONG>RFI People</STRONG>
    <DD>
    <DT>
      <P>Raul Armendariz (505-835-7187,
        <A HREF="mailto:rarmenda@aoc.nrao.edu">rarmenda@aoc.nrao.edu</A>) --
        Interference Protection Group (IPG) Engineer      </P>

  </DL>


<HR>

 P>
<A HREF="./VLAhome.shtml"><STRONG>VLA Home Page</STRONG></A>
-/P>

<HR>


 /HTML>
```

Ems_plots.shtml

```
:ML>
:AD>
ITLE>
·ironmental Monitoring System at the VLA
:ITLE>

--*******************************-->
.-*                              *-->
--*  Written by Nathan Thomas    *-->
--*  IPG CO-OP Student           *-->
--*  June 2001                   *-->
.-*                              *-->
--*  File lists folders of all   *-->
--*  ems Plots, including PFD    *-->
--*  average, and peak.          *-->
--*                              *-->
--*******************************-->

3 align=center>
Environment Monitoring System at the VLA
  </H3>

  <P>

  <table cellpadding=4 border=0 valign=center>
  <align=center>
  <tr>
  <td>The Environmental Monitoring System (EMS), was created by students
   doing co-op's or senior design, with supervision from Raul Armendariz.
   The system currently works from 1 to 18 GHz and with the addition to
   new equipment, the system will work down to 50 MHz in the near future.
  </P>
  <p>


     Like the W8 Monitor, each band surveyed, current and past
  postscript and giff interference plots show signal power vs.
  frequency. Overlay plots identify the known emitters in each band. </p>
  <p>

  This is a picture of our 60ft RFI Tower. With the help of directional
  antenna on top we will be able to determine from which direction we
  are receiving RFI. This will help us to better identify the source of
  some interference.</p>

  <center><b>This page is currently under development.</b><br>
  <font color=red>If an error is displayed next to a link, that plot is
  currently unavailable.</font></center>
>
 <center> <font color=red>NOTE: </font> Our software is currently
 not creating average plots.  There shouldn't be any plots in the
 average directories.</center>
>

  Photo By: Nathan Thomas

  <p>

  </th>
  <td>
  <img src="../interference/towersketch.jpg" width="257" height="364"
  align=right>
```

```
      <DT><A HREF ="../interference/ems_data/pfd/cband_3.6_4.6/">
       S to C-Band 3.6-4.6 GHz PFD plots</A>

      <DT><A HREF ="../interference/ems_data/peak/cband_4.6_5.6/">
       C-Band 4.6-5.6 GHz peak plots</A>

      <DT><A HREF ="../interference/ems_data/avg/cband_4.6_5.6/">
       C-Band 4.6-5.6 GHz average plots</A>

      <DT><A HREF ="../interference/ems_data/pfd/cband_4.6_5.6/">
       C-Band 4.6-5.6 GHz PFD plots</A>

      <DT><A HREF ="../interference/ems_data/peak/cband_5.6_6.6/">
       C-Band 5.6-6.6 GHz peak plots</A>

      <DT><A HREF ="../interference/ems_data/avg/cband_5.6_6.6/">
       C-Band 5.6-6.6 GHz average plots</A>

      <DT><A HREF ="../interference/ems_data/pfd/cband_5.6_6.6/">
       C-Band 5.6-6.6 GHz PFD plots</A>

      <DT><A HREF ="../interference/ems_data/peak/cband_6.6_7.6/">
       C-Band 6.6-7.6 GHz peak plots</A>

      <DT><A HREF ="../interference/ems_data/avg/cband_6.6_7.6/">
       C-Band 6.6-7.6 GHz average plots</A>

      <DT><A HREF ="../interference/ems_data/pfd/cband_6.6_7.6/">
       C-Band 6.6-7.6 GHz PFD plots</A>

    </DL>
  /P>

<DT> <STRONG>X-Band (8-12 GHz) RFI</STRONG>
     <DL>
      <DT><A HREF ="../interference/ems_data/peak/cxband_7.6_8.6/">
       C to X-Band 7.6-8.6 GHz peak plots</A>

      <DT><A HREF ="../interference/ems_data/avg/cxband_7.6_8.6/">
       C to X-Band 7.6-8.6 GHz average plots</A>

      <DT><A HREF ="../interference/ems_data/pfd/cxband_7.6_8.6/">
       C to X-Band 7.6-8.6 GHz PFD plots</A>

      <DT><A HREF ="../interference/ems_data/peak/xband_8.6_9.6/">
       X-Band 8.6-9.6 GHz peak plots</A>

      <DT><A HREF ="../interference/ems_data/avg/xband_8.6_9.6/">
       X-Band 8.6-9.6 GHz average plots</A>

      <DT><A HREF ="../interference/ems_data/pfd/xband_8.6_9.6/">
       X-Band 8.6-9.6 GHz PFD plots</A>

      <DT><A HREF ="../interference/ems_data/peak/xband_9.6_10.6/">
       X-Band 9.6-10.6 GHz peak plots</A>

      <DT><A HREF ="../interference/ems_data/avg/xband_9.6_10.6/">
       X-Band 9.6-10.6 GHz average plots</A>

      <DT><A HREF ="../interference/ems_data/pfd/xband_9.6_10.6/">
       X-Band 9.6-10.6 GHz PFD plots</A>

      <DT><A HREF ="../interference/ems_data/peak/xband_10.6_11.6/">
```

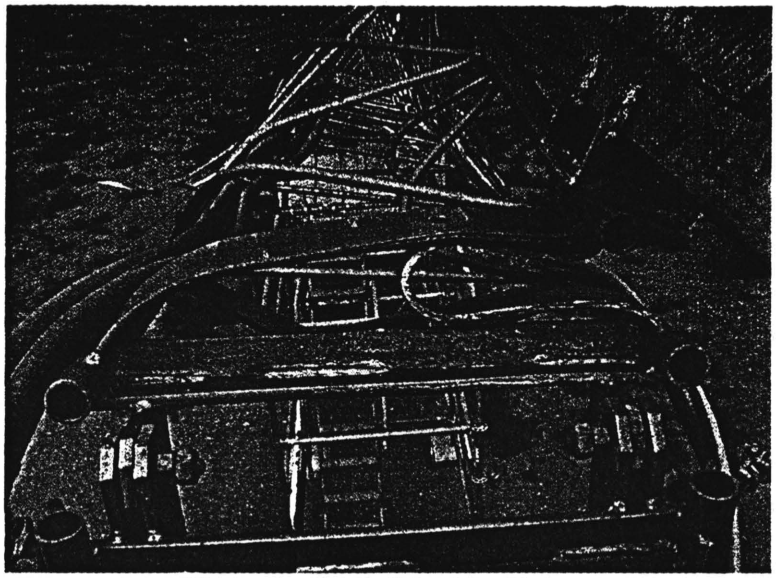
```
      X-Band 10.6-11.6 GHz peak plots</A>

     <DT><A HREF ="../interference/ems_data/avg/xband_10.6_11.6/">
      X-Band 10.6-11.6 GHz average plots</A>

    <DT><A HREF ="../interference/ems_data/pfd/xband_10.6_11.6/">
      X-Band 10.6-11.6 GHz PFD plots</A>

     <DT><A HREF ="../interference/ems_data/peak/xband_11.6_12/">
      X-Band 11.6-12 GHz peak plots</A>

     <DT><A HREF ="../interference/ems_data/avg/xband_11.6_12/">
      X-Band 11.6-12 GHz average plots</A>

     <DT><A HREF ="../interference/ems_data/pfd/xband_11.6_12/">
      X-Band 11.6-12 GHz PFD plots</A>
 </DL>
/P>

DT> <STRONG>U-Band (12-18 GHz) RFI</STRONG>
    <DL>
      <DT><A HREF ="../interference/ems_data/peak/uband_12_13/">
       U-Band 12-13 GHz peak plots</A>

      <DT><A HREF ="../interference/ems_data/avg/uband_12_13/">
       U-Band 12-13 GHz average plots</A>

      <DT><A HREF ="../interference/ems_data/pfd/uband_12_13/">
       U-Band 12-13 GHz PFD plots</A>

      <DT><A HREF ="../interference/ems_data/peak/uband_13_14/">
       U-Band 13-14 GHz peak plots</A>

      <DT><A HREF ="../interference/ems_data/avg/uband_13_14/">
       U-Band 13-14 GHz average plots</A>

      <DT><A HREF ="../interference/ems_data/pfd/uband_13_14/">
       U-Band 13-14 GHz PFD plots</A>

      <DT><A HREF ="../interference/ems_data/peak/uband_14_15/">
       U-Band 14-15 GHz peak plots</A>

      <DT><A HREF ="../interference/ems_data/avg/uband_14_15/">
       U-Band 14-15 GHz average plots</A>

      <DT><A HREF ="../interference/ems_data/pfd/uband_14_15/">
       U-Band 14-15 GHz PFD plots</A>

      <DT><A HREF ="../interference/ems_data/peak/uband_15_16/">
       U-Band 15-16 GHz peak plots</A>

      <DT><A HREF ="../interference/ems_data/avg/uband_15_16/">
       U-Band 15-16 GHz average plots</A>

      <DT><A HREF ="../interference/ems_data/pfd/uband_15_16/">
       U-Band 15-16 GHz PFD plots</A>

      <DT><A HREF ="../interference/ems_data/peak/uband_16_17/">
       U-Band 16-17 GHz peak plots</A>

      <DT><A HREF ="../interference/ems_data/avg/uband_16_17/">
       U-Band 16-17 GHz average plots</A>
```

```
      <DT><A HREF ="../interference/ems_data/pfd/uband_16_17/">
       U-Band 16-17 GHz PFD plots</A>

      <DT><A HREF ="../interference/ems_data/peak/uband_17_18/">
       U-Band 17-18 GHz peak plots</A>

      <DT><A HREF ="../interference/ems_data/avg/uband_17_18/">
       U-Band 17-18 GHz average plots</A>

      <DT><A HREF ="../interference/ems_data/pfd/uband_17_18/">
       U-Band 17-18 GHz PFD plots</A>
   </DL>
</P>
<P>
 )T> <STRONG> Plots by date</STRONG>
 <DL>

   <DT><A HREF ="../interference/ems_data/peak/bydate/">
    Peak Plots by Date</A>

   <DT><A HREF ="../interference/ems_data/avg/bydate/">
    Average Plots by Date</A>

   <DT><A HREF ="../interference/ems_data/pfd/bydate/">
    PFD Plots by Date</A>

   <DT><A HREF ="../interference/ems_data/avg/bydate/">
    Signle (Unique) Plots by Date</A>

  </DL>
</P>


  <DT> <STRONG>RFI People</STRONG>
   <DD>
    <DT>
     <P>Raul Armendariz (505-835-7187,
      <A HREF="mailto:rarmenda@aoc.nrao.edu">rarmenda@aoc.nrao.edu</A>) --
       Interference Protection Group (IPG) Engineer
    </P>
</DL>

 <HR>
    <P>
     <A HREF="./VLAhome.shtml"><STRONG>VLA Home Page</STRONG></A>
    </P>

 <HR>


</HTML>
```

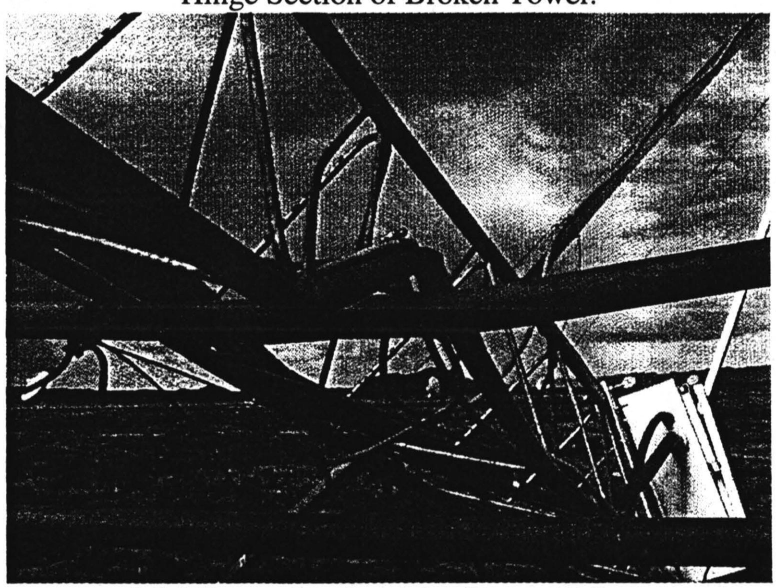
# Appendix F:

# Tower Repair – Pictures and Purchase Requisition's

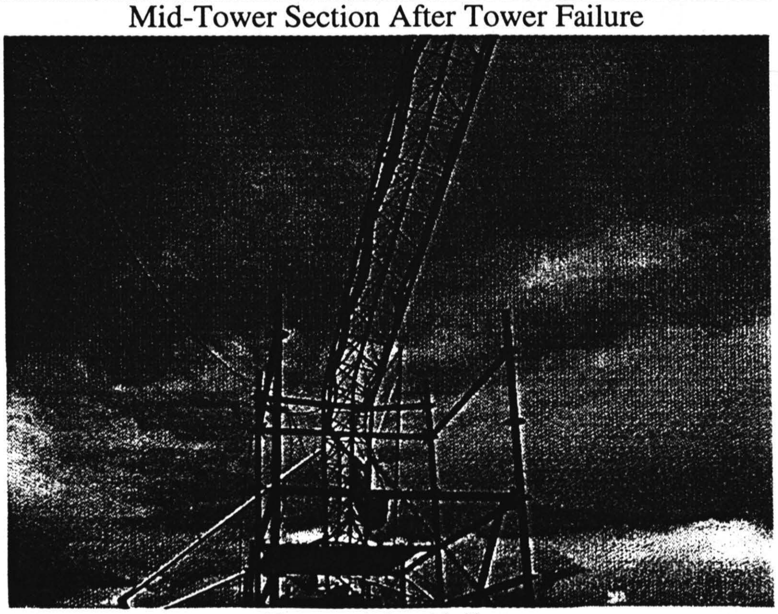
# Pictures of Failed Tower



Hinge Section of Broken Tower.



Mid-Tower Section After Tower Failure



Tower After Failure

NATIONAL RADIO ASTRONOMY OBSERVATORY
ASSOCIATED UNIVERSITIES, INC.

# PURCHASE REQUISITION 30657

REC. PURCHASING 06/28/2001 DATE

SUCCESSFUL VENDOR: Talley Communications

NEED DATE: 05 July 01

ACCOUNT NO.: 46301 - 7271

DELIVER TO: Raul Armendariz LOCATION: AOC - Rm 144

TECHNICAL INSPECTION REQUIRED: YES ☐ NO ☒

CONTACT:
PHONE: FAX:
PURCHASE ORDER NO. 62069

DELIVERY DATE: 7/12 or sooner

TERMS:

F.O.B. POINT:

SHIP VIA:

TRANSPORTATION CHARGES:

SHADED AREAS FOR BUYER USE ONLY

| ITEM NO. | QUANTITY | DESCRIPTION | ESTIMATED UNIT PRICE | ESTIMATED TOTAL PRICE | CONFIRMED UNIT PRICE | CONFIRMED TOTAL PRICE | REMARKS |
|---|---|---|---|---|---|---|---|
| 1 | 100 ft. | LDF2-50 3/8" Heliax Coaxial Cable 50Ω | $1.15 | $115.00 | 1.15/ft | 115.00 | |
| 2 | 2 | L2PNM Andrew, Type 'N' plug connectors for 3/8" Heliax Coax. | $18.73 | $37.46 | 18.73 | 37.46 | |

CPO. 6/28/ Will

REQUISITIONER / DATE [signature] 6/27/01 APPROVAL / DATE [signature] 6/26

TOTAL ▶ $152.46 152.46

NOTE: REQUISITIONER KEEP 3rd COPY

The Items Listed Are Not ☐ Available From Stock

SUGGESTED VENDORS – USE OTHER SIDE FOR JUSTIFICATION

(ANDREW) Talley Communications
1-800-949-7069

REV. 11/99

REQUISITIONER'S COPY

NATIONAL RADIO ASTRONOMY OBSERVATORY
ASSOCIATED UNIVERSITIES, INC.

PURCHASE REQUISITION 20147

DATE

| SUCCESSFUL VENDOR | NEED DATE | ACCOUNT NO. | |
|---|---|---|---|
| Nott limited | 7/6/01 | 46301 - 7271 | |
| | | DELIVER TO: Raul Armendariz | LOCATION: AOC - leave in Docking Room |
| CONTACT: PHONE: FAX: 325-1142 | DELIVERY DATE | TERMS | F.O.B. POINT / SHIP VIA / TRANSPORTATION CHARGES |
| PURCHASE ORDER NO. 62076 | | | |

TECHNICAL INSPECTION REQUIRED YES ☐ NO ☒

SHADED AREAS FOR BUYER USE ONLY

| ITEM NO. | QUANTITY | DESCRIPTION | ESTIMATED UNIT PRICE | ESTIMATED TOTAL PRICE | CONFIRMED UNIT PRICE | CONFIRMED TOTAL PRICE | REMARKS |
|---|---|---|---|---|---|---|---|
| 1 | 3 | Rohn 45G 10' straight tower section | $188.00 | $564.00 | 188.00 | | |
| 2 | 1 | Rohn GA45GD guy bracket assembly | $73.50 | $73.50 | 73.50 | | |
| CPO 7/2 | | Ordy | | | | | |
| | | Shipping via RAC Transport to NRAO | $84.00 | $84.00 | | | |
| | | 1-2 day delivery JPG - Raul Armendariz | | | | | |
| | | 1003 Lopezville Road | | | | | |
| | | Socorro, NM 87801 | | | | | |

REQUISITIONER / DATE [signature] 7/2/01 APPROVAL / DATE [signature]

TOTAL ▶ 721.50

NOTE: REQUISITIONER KEEP 3rd COPY

The Items Listed Are Not ☐ Available From Stock

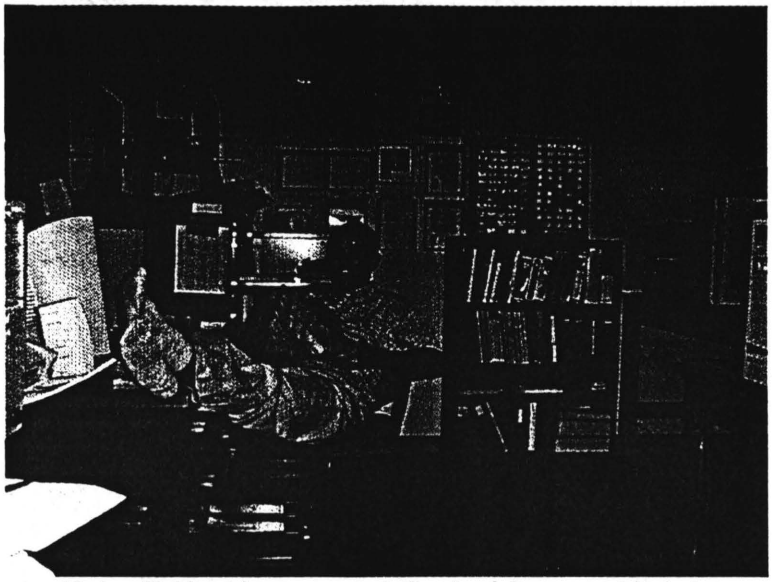
SUGGESTED VENDORS – USE OTHER SIDE FOR JUSTIFICATION

Nott limited
4001 La Plata Highway
Farmington, NM 87401
(505) 327-5646

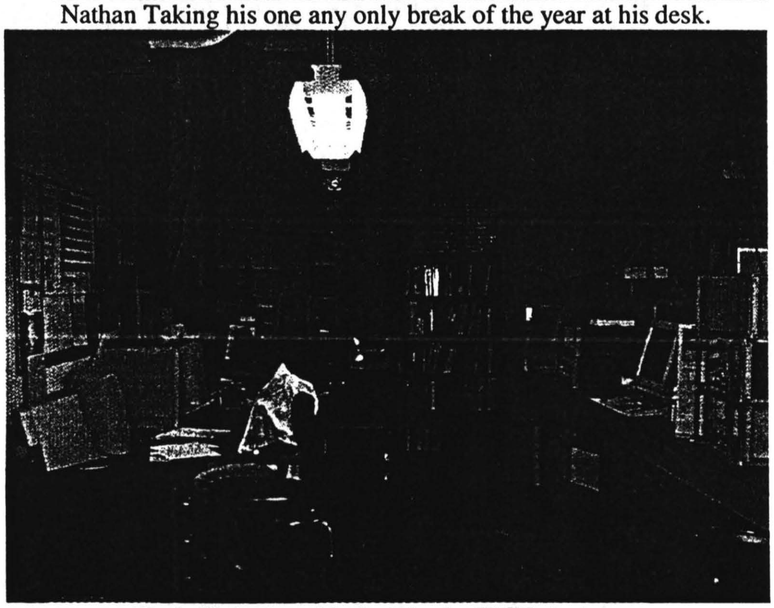
REV. 1/00

DIVISION COPY

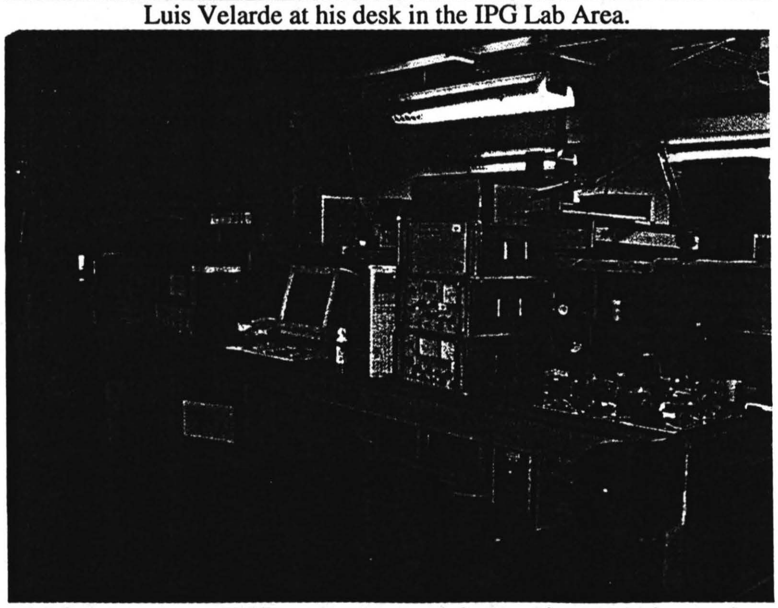
# PLACES TO BE IF YOU ARE IN IPG



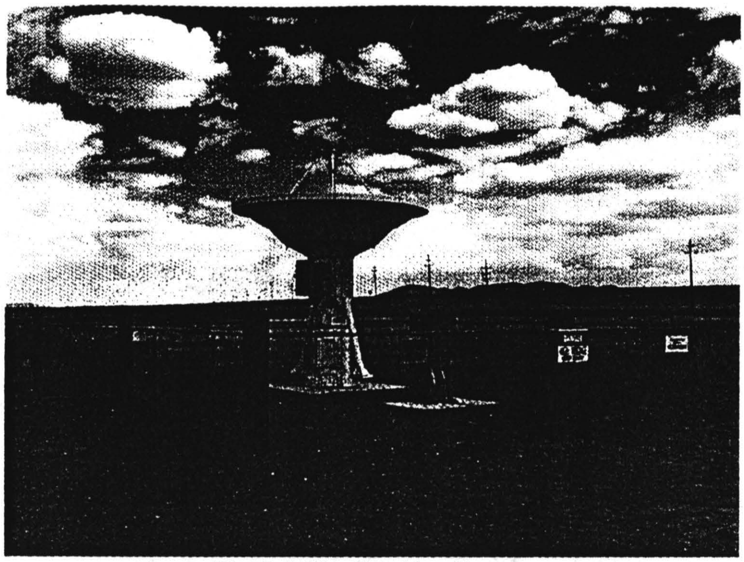
Nathan Taking his one any only break of the year at his desk.



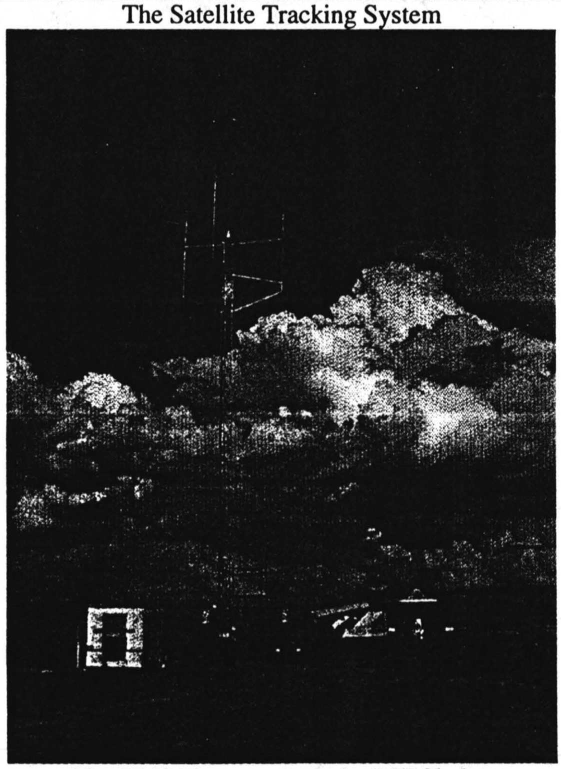
Luis Velarde at his desk in the IPG Lab Area.



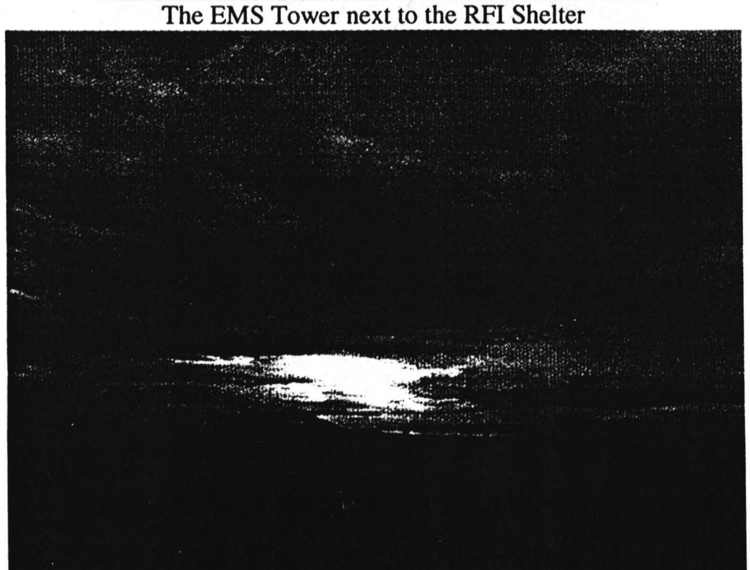
IPG Lab benches. EMS system on the right most bench during testing.



The Satellite Tracking System



The EMS Tower next to the RFI Shelter



The VLA at its best.