COMPUTATION BOOK

NAME Jack Welch

Course ATA #4

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AMPAD

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HS76 Kissing Hour

(X)

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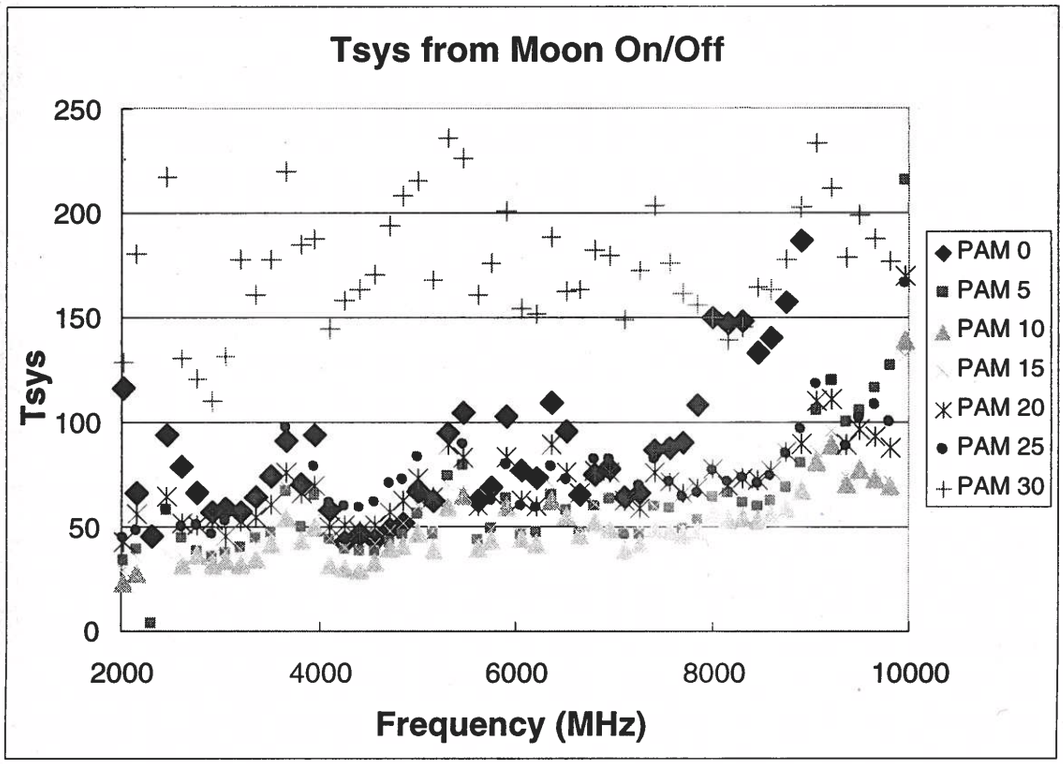
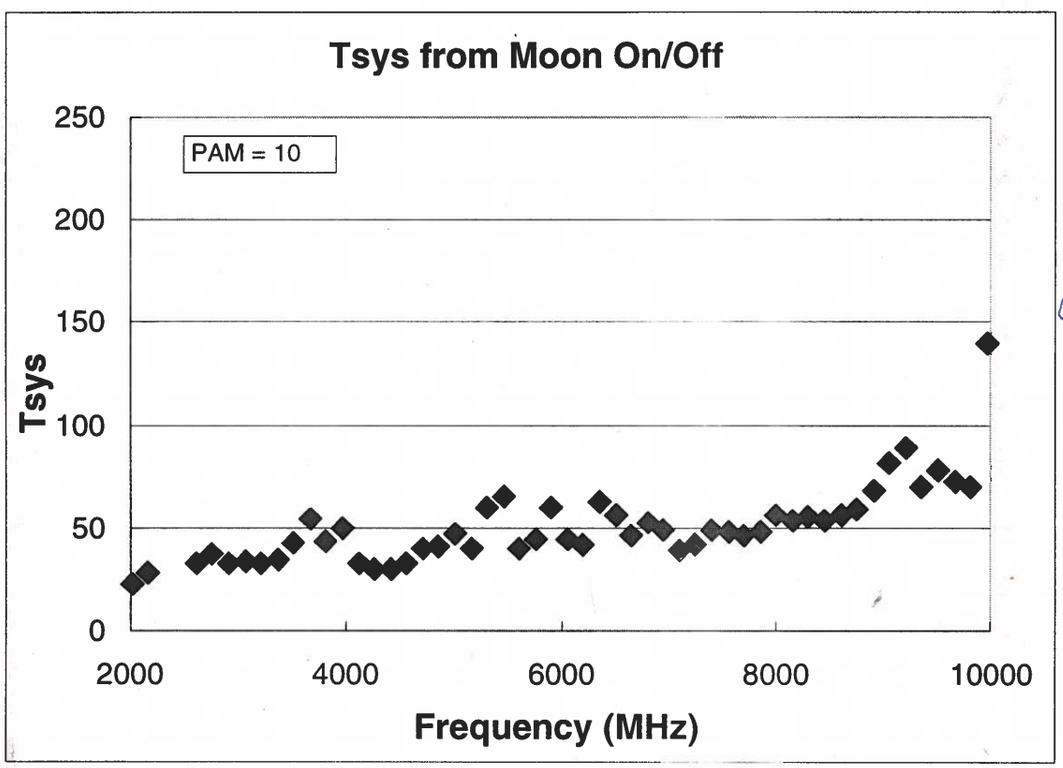


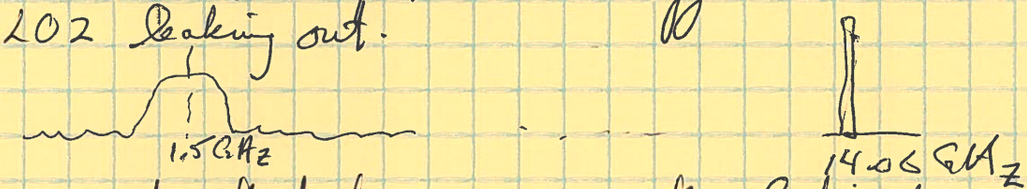


??

Gerry's Tsys measurements on the mean moon, showing ~~about~~ result at a PAM attenuator setting of 10db, 5db and 15db are slightly worse. For 2K

☆ The Tsys measurements of III (pp. 148-149) were made with the RFCB driving the HP power meter. So we now study one of the RFCB's to find out why it makes a slightly noisier result.

I. An HP power meter on one output of the RFCB showed a steady output that only dropped by 1 db if the output from the input power splitter box was disconnected. The Spectrum Analyzer showed that it is LO2 leaking out.

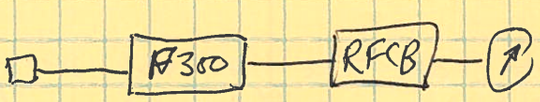


This suggests that the power of the leaking LO2 is about 7 db greater than ~~expected~~ the power in the output band. When the input power from the front end is added at the level of ~ 20db so that it dominates the back-end noise, the LO power is relatively small. However, its presence confuses measurements made with a power detector. It's constant presence makes the system seem non-linear with variations of the PAM attenuators. It might affect slightly the A/D converter as well and maybe should be filtered out.

☆

II. Noise figure measurements of the RFCB were made with both ⓐ lab oscillators and lab power supplies and ⓑ lab oscillators feeding the LO distribution unit and a DC/DC converter supplying power to the RFCB. There was no difference in noise figure. So the use of the DC/DC converter is not a problem.

For the noise figure measurements we use an HP excess noise unit which looks like a 50 Ω room temp. load when off ① and becomes ~ 15db stronger when turned on.



F = 1 with it off F ≅ 20 when it is turned on.

The anti-aliasing filter should eliminate the leaking LO2. Does it? Put the SA out to check this. 12/01/11: Yes. It lowers

R is the ratio of the two measurements: $R = \frac{T_R + T_N}{T_R + 300} = \frac{T_R + F300}{T_R + 300}$

so $T_R = \frac{(F-1)300}{R-1}$

$R(T_R + 300) = T_R + F300$

$T_R = (N-1)300$

The input band is tuned with 201.

ν (MHz)	R	F	T_R	on, off	Δ	N-1
1000	6.9	17.1	818	-49.8, -58.4	8.44	2.7
3000	6.9	17.4	830			2.8
5000	5.0	18.4	1300	-51.8, -58.8	7.0	4.3
7000	3.3	20	2500	-52.0, -57.2	5.2	8.3
10,000	3.5	23.8	2700	-51.9, -57.2	5.5	9.0

III. Linearity tests with a CW signal from 8350B.

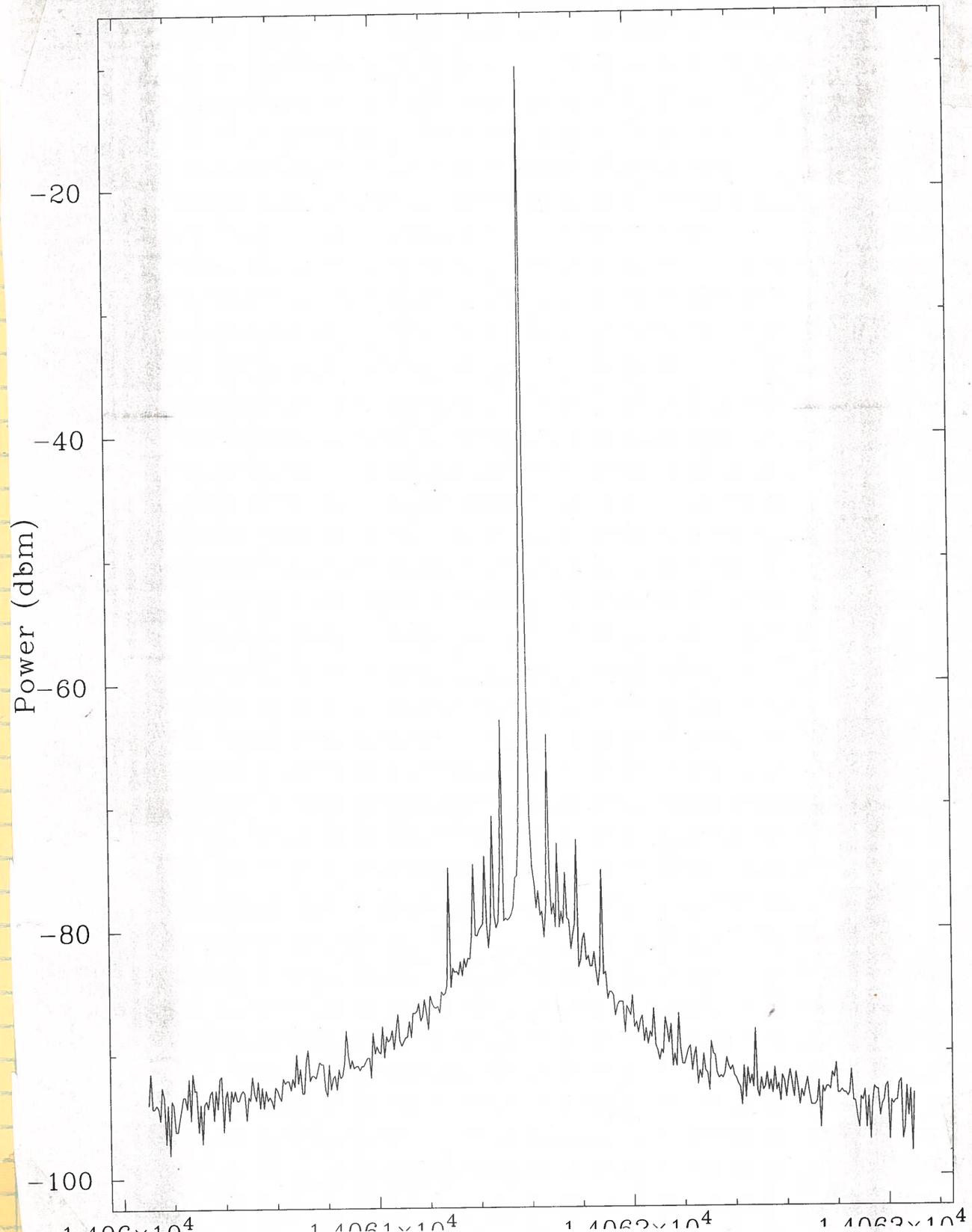
Osc. Input	Output
-2.0 dbm	-15.3 dbm
0 dbm	-13.2 dbm
+10	-3.1
+20	+7.3 dbm ← This is the advertised P1 point for the amp.
+22	+8.8 dbm

Calvin's measurements on the PAM detector with the HP noise diode for input.

PAM attenuator	output power	detector volts
0	+6.49	2.60 VDC
7		
10	-4.36	0.461
13	-7.40	0.246
16	-10.71	0.118
19	-13.65	.065
22	-17.00	.032

(Rob)? → The scale on the PAM read-out needs to be expanded.

ATA LO2 spectrum – 29 Nov 06

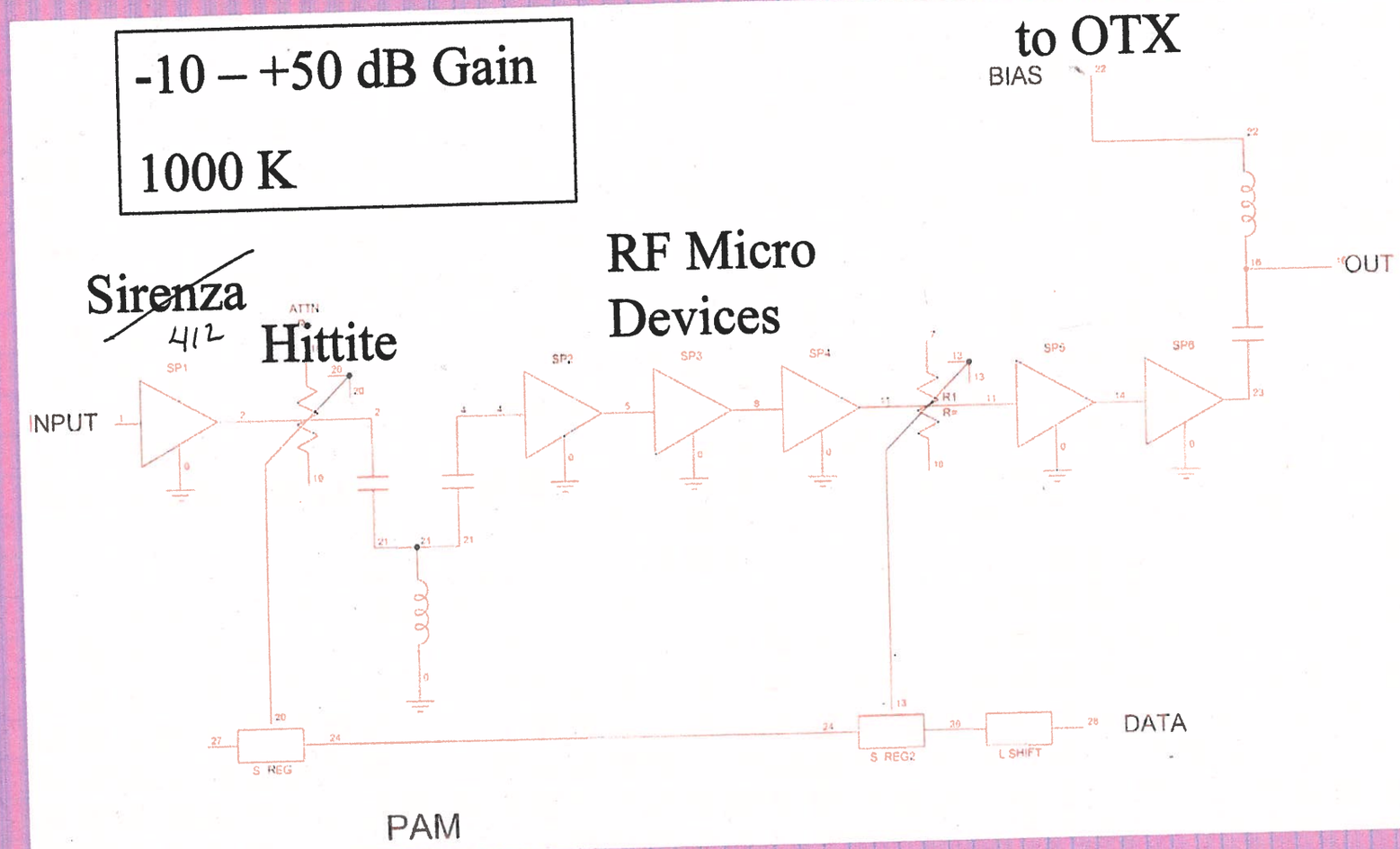


This LO noise evidently causes no extra noise in the RFCBs. See above. The band is narrow, but there will be weak sideband on strong signals.

Post-Amplifier Module

-10 – +50 dB Gain

1000 K



Measurements of one PAM unit 12/8/00

Overall gain w/o attenuators in is 61.5 db to 10 GHz
It is flat within ±1 db, but drops to ~50 db at 11 GHz

The broadband noise figure is: $\frac{T_{sys} + T_N}{T_{sys}} = 8.4\,db = F = 6.9$

where $\langle T_N \rangle = 20 \times 300 = 6000°$

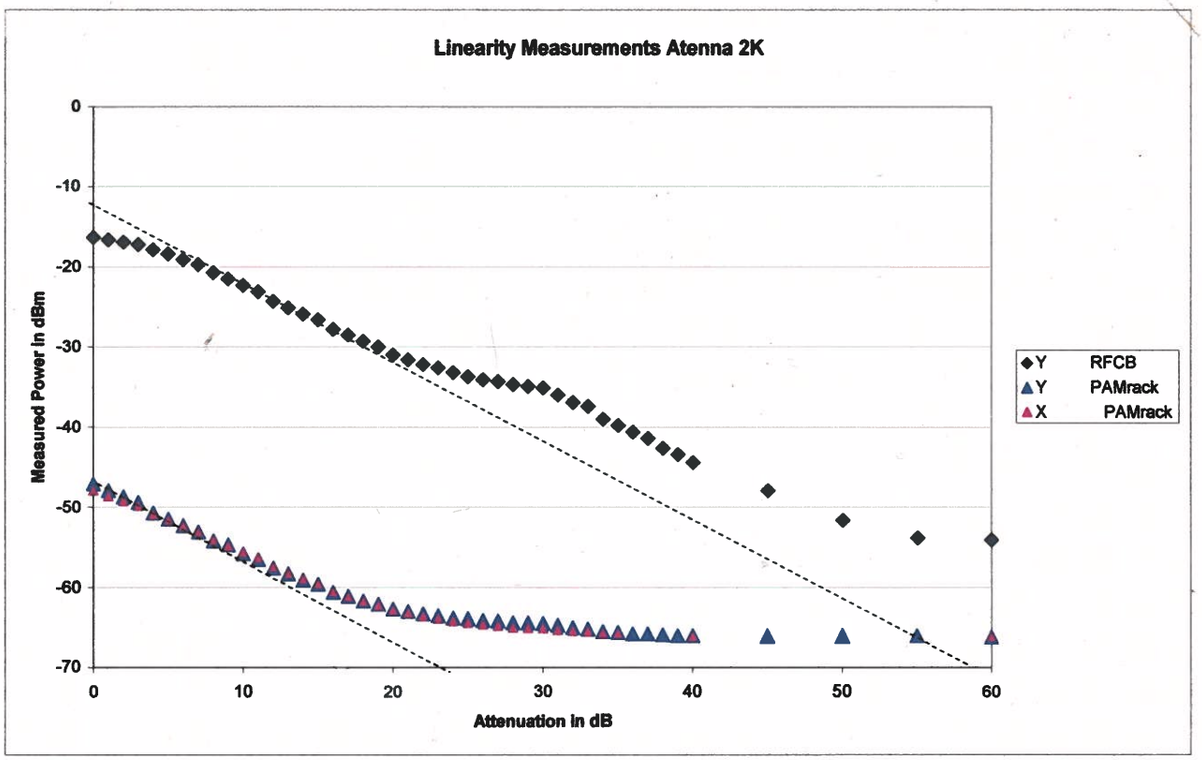
$$T_s = \frac{T_N}{F-1} = \frac{6000°}{5.9} \cong \underline{\underline{1000°}}$$

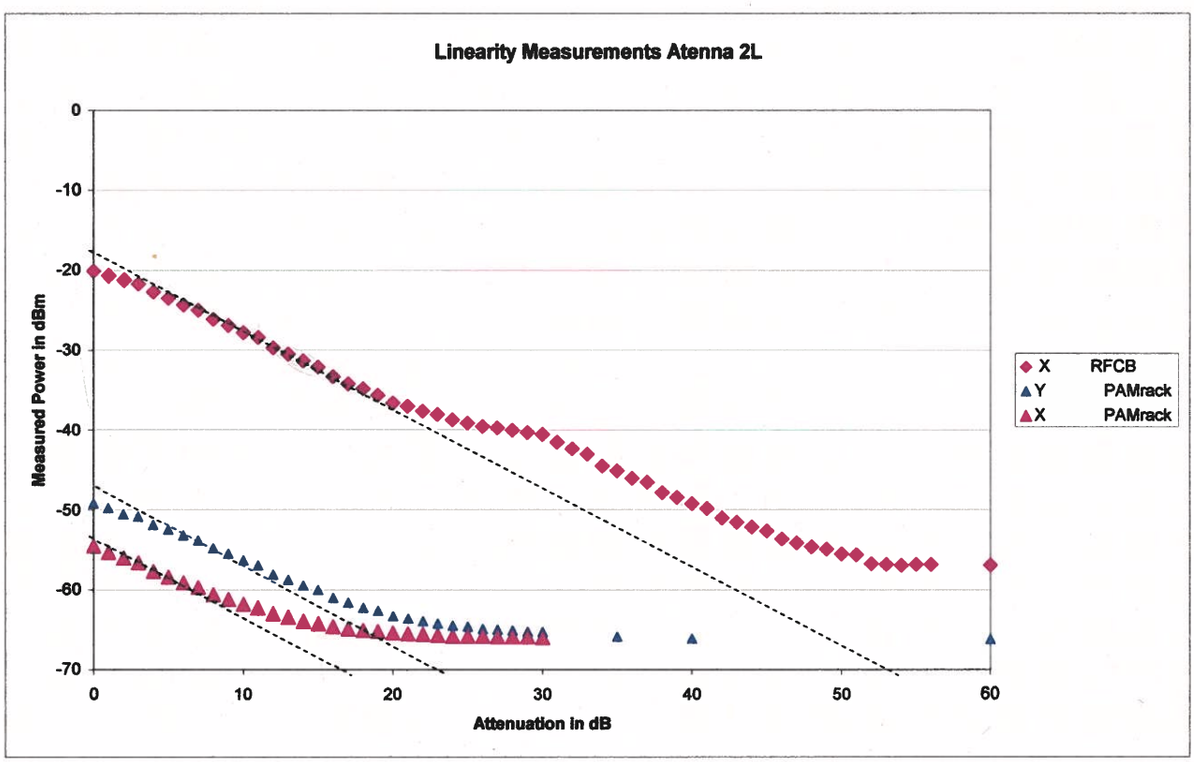
Putting 10 db into the second attenuator makes no difference, as expected.
Putting 10 db into the first attenuator gives F = 5.8 db, 3.8, worse as expected $T_s' = \frac{6000}{3.8-1} = 2100°K$

Measurements of output power from 2 different antennas as a function of the attenuator settings for both the PamRack back-end and the RFCB. A band pass filter of 220 MHz width centered at 4835 MHz was used on the PamRack output. A band at the same frequency was used for the RFCB. The spectrum analyzer was used as detector in both cases.

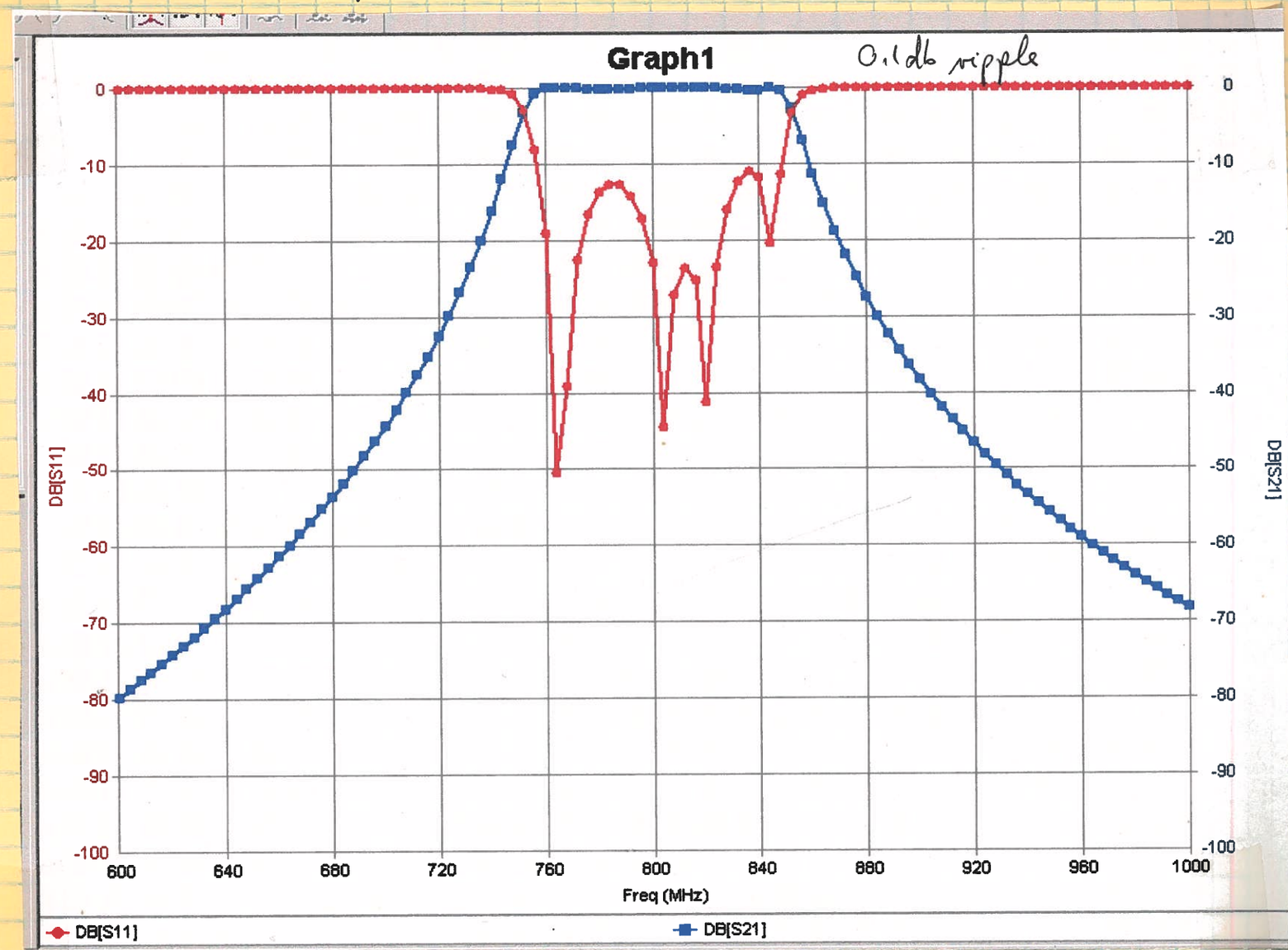
Rick and Jim 12/6-8/06

now known to have 1.1 dB inaccuracy
(old spectrum analyzer)

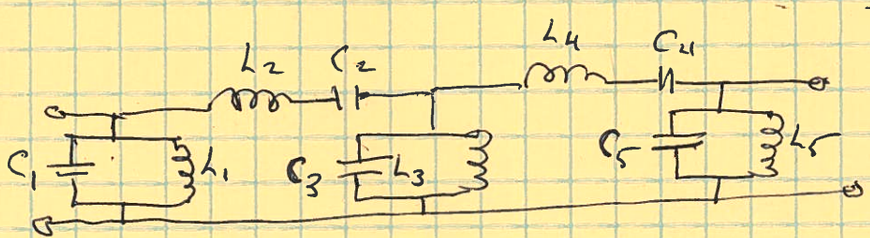

Linearity Measurements Atenna 2K
Measured Power in dBm
Attenuation in dB
0
-10
-20
-30
-40
-50
-60
-70
0
10
20
30
40
50
60
Y RFCB
Y PAMrack
X PAMrack


Linearity Measurements Atenna 2L
Measured Power in dBm
Attenuation in dB
0
-10
-20
-30
-40
-50
-60
-70
0
10
20
30
40
50
60
X RFCB
Y PAMrack
X PAMrack

Bandpass filter - candidate anti aliasing filter



Scaling the filter of VI p.54-55 from p.318 of Zverev
$\underline{n=5}$ & 0.1 db ripple



$R_r = 50\Omega$

$f_0 = 800\,MHz$ Band $= 100\,MHz$ $a = \frac{800}{100} = 8$

$L_r = \frac{R_r}{\omega_0} = 9.95\,nH$ $C_r = \frac{1}{R_r \omega_0} = 3.98\,pf$

Normalized Values from Zverev (p. 318)

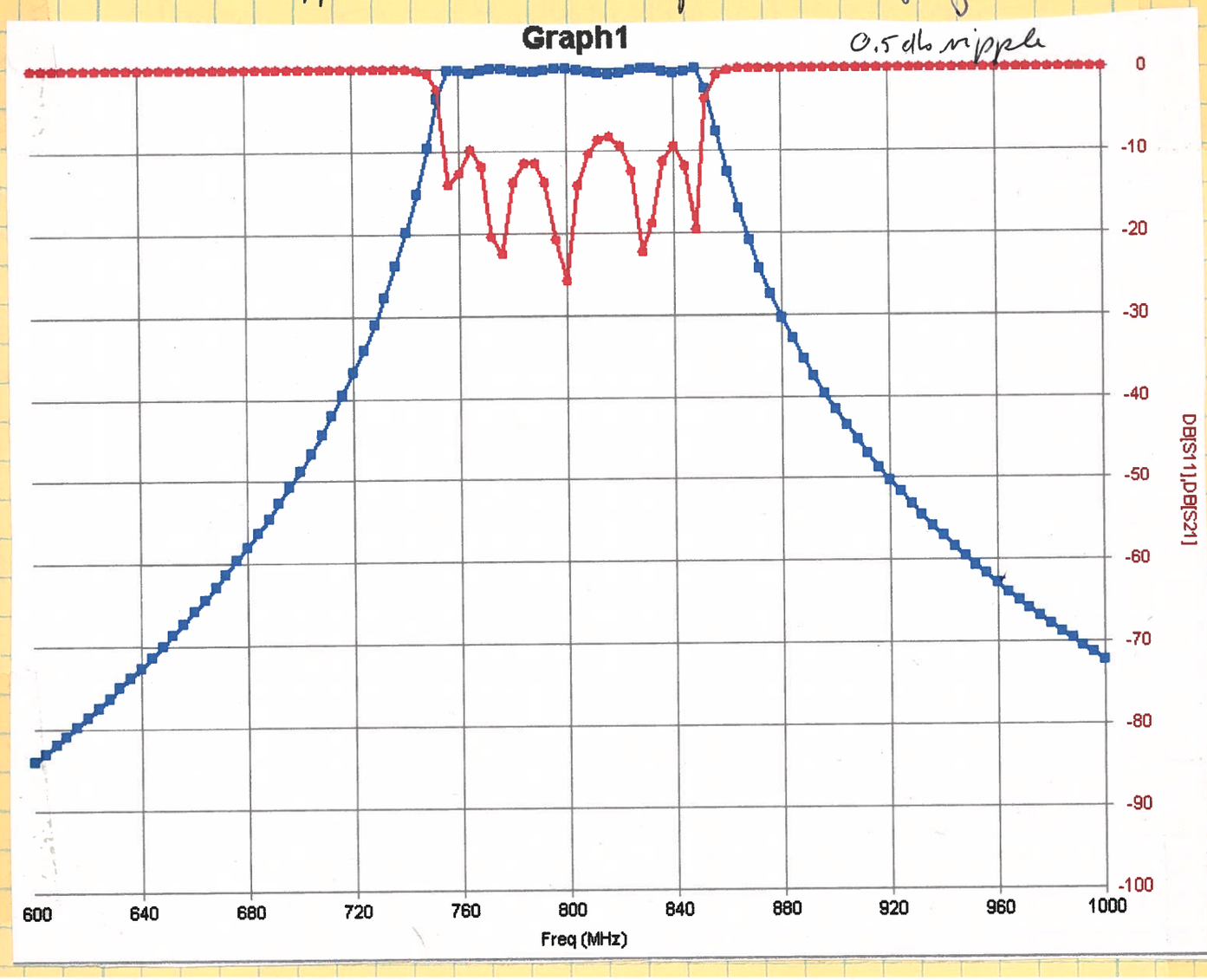
(p. 321)

		0.1db ripple	0.5db ripple
0.1db ripple	$C_1' = 1.3013$	$C_1 = aC_1'C_r = 41.43$ pf	57.53 pf
	$L_2' = 1.5559$	$L_1 = [aC_1']^{-1}L_r = .956$ nH	.688 nH
	$C_3' = 2.2411$	$C_2 = [aL_2']^{-1}C_r = .32$ pf	.38 pf
	$L_4' = 1.5559$	$L_2 = [aL_2']L_r = 123.8$ nH	103.68 nH
	$C_5' = 1.3013$	$C_3 = [aC_3']C_r = 71.36$ pf	85.69 pf
0.5db ripple	$C_1' = 1.8068$	$L_3 = [aC_3']^{-1}L_r = .555$ nH	.462 nH
	$L_2' = 1.3025$	$C_4 = .32$ pf	.38 pf
	$C_3' = 2.6914$	$L_4 = 123.8$ nH	103.68 nH
	$L_4' = 1.3025$	$C_5 = 41.43$ pf	57.53 pf
	$C_5' = 1.8068$	$L_5 = .96$ nH	.688 nH

S_{11} and S_{21} appear in the graph

It should be realizable. We have .25–.7pf Johanson caps.

A 0.5db ripple would have steeper sides (slightly)



annual report

Sensitivity loss with non-flat passbands

From TMS p.198 (first version) 2.9 db peak-peak gives a 2.5% loss of sensitivity; 2.0 p-peak gives 1% loss in sensitivity. This assumes the whole band is summed. With the separate channels calibrated before summing, there would be no loss in sensitivity.

Schedule to Finish ATA-42

2/4/98

I. E-shop RFCBs and Paxes (also Danny Zhao's Shop)

RFCBs – no changes needed. The 2nd LO output signal will not bother either the IBOB ADC or the ATA ADC (mid-end January)

Everything in hand here except 5 photodiodes (includes 3 spares)
All built here 5@750 = $3750
50TX 5@2600 = 13,000 (includes 3 spares)

PAXes / PAMs no further changes – to be built here. Get a few more done before X mas for Artyom.

Including contingency: 13,000 + 3750 + 8250 = $\boxed{25,000}$
[note: possible need L.O. ~$14K for 12.5 GHz 2nd LO for IBOB system]

II. Matt: Nearly nothing more to buy, except foam insulation
Refurbish PTAS,

Artyom: ≤$5,000 for miscellaneous (including ion pump controllers)
13 receivers and feeds ready to go, waiting for PAXes Boxes and ion pump controllers

SETI

(mid-end January) Total Contingency $\boxed{\$20,000}$

III. Hat Creek $\boxed{\$20,000}$ for misc., including trenching for PTAS

IV. 8 correlator x 2 (Appears to be running end-end now)

IBOBs and ADC's for correlator $\boxed{\$160,000}$
42 Correlator ready by March
Beam former maybe within a month of March 1.

Jon Anderson on antennas. For 40 @ 17,500 = 700,000
50 @ 17,000 = 850,000

Observing the Moon for T_{sys} calibration

The average of the table of p. 119 (III) is 62.2 K, a little more than $\langle T_{sys} \rangle$. So going to the moon gives about 4db more total input noise power. It is important to have that amount of overhead with the PAM attenuator settings. Look at the curves of p. 7.

Other effects: The lunation effect: At λ3cm the first harmonic is about (1/4) th of the average. This ratio is proportional to wavelength [Troitskii] p. 481. The residual variation is delayed relative to the surface illumination, nearly 1/4 period @ 3 cm.

Diameter change: 14.75' to 16.32' 16.2/14.75 = 1.098
about 5% on each side of the average, ~ 15.5', for a total quasi change of 10% away from the average. I used 15.0 in my calculations 3% low or 6% lower in signal.

Troitskii's numbers are corrected for the emissivity. The accuracy in the Russian data is claimed to be 5%

12/2002 The Cost per antenna for 40 antennas

Matt one antenna

Large component & casting costs

Part	Process	$ process	$ total each	Lead time
Primary & Secondary			$18,000.00	EPL est
	Pri struts		$700.00	EPL est
	Sec struts		$350.00	EPL est
Alidade hub+upper+lower+all -encoder-relay-limits			$5,500.00	
Azimuth drive			$2,150.00	EPL est
Elevation Drive			$1,250.00	EPL est
Az Encoder & Limits & relay			$700.00	EPL est
Elevation Encoder			$550.00	
Drive Box+amps+trans			$910.00	est
Control Box-boards			$150.00	est
Motors 2			$950.00	
Pedestal			$3,659.80	
Frame			$2,408.90	
Feed focus mech + motor			$635.00	
Raydome ????			$1,350.00	
Rim box+brackets			$300.00	
			$39,563.70	

Several rows are hidden

Artyom's total 12,109.00 for one feed and receiver.

Niklas Wadefalk

Cryotest results expected "Tomorrow" with new chips from Fraunhofer. Told him of our immediate interest.

9/13/2008 LNA cost Niklas + Fraunhofer is $1350 each.

Total antenna parts cost. This is a recent revision based mostly on a better understanding of Hat Creek parts costs 1/23/02.

Matts total for antenna parts	39,564	
Node cost 32,000/10	3,200	
Artyom's feed and receiver	12,100	
Antenna Foundations	5,000	
All other Hat Creek components	2,672	
Signal Processor (not correlator)	10,000	back end part
Remaining electronic parts up to ADC	15,420	
	87,956	

So parts for 40 = 3.5M $
30 = 2.6M $
20 = 1.7M $

Salaries of all employees, fully burdened, 208,016 /month

I. Construction over two years

40: 12 X 208K = ~~2.5M $, 1.5~~
5.0M $, + 3.5 = 8.5M $

30: 5.0 + 2.6 = 7.6M $

20: 5.0 + 1.7 = 6.7M $

Survey Summary Comparisons: nD, relative sensitivity for an observation of a fixed duration

Antenna	nD	
Arecibo	240	
GBT	110	
Parkes	70	effective diameter for a mapping observation
Bonn	100	
Westerbork	350	low frequency bands
Cambridge	120	
VLA	→ 675	with multiple pointing
ATA-42	252	
ATA-62	372	
ATA-82	492	
ATA-200	1200	
ATA-350	2100	

What's the cost per antenna [construction only]

For just the construction crew, the monthly salaries are 124k/month. (excludes programmers + scientists)

time needed a) antennas – Matt says 3 days each, the Hat Creek guys say 1 week (5 days)
For 40 antennas 40 weeks is 0.8 year
b) feeds and receivers (Artyom) one per week also
c) RFCB ≈ 5 months
d) PAMs ~ 4 months
e) other electronics 3 months

Trenching can be done by Hat Creek group with back hoe
This time is additional to antenna erection ~10 weeks.

It looks like about one year is needed

12 × 124 = 1.488 M$

Cost per antenna is 37k.

Parts and labor / antenna 37 + 88 = 125 k$

Re-examination of the labor costs 2/25/07

After a few months of actual construction, it is clear that we are undermanned. Getting both the PAX units and the RFCBs completed and properly tested, beginning in November shows that having just three electronics techs is inadequate to complete 40 more antennas in a year.

Adds 2 more etecs (full time) @ 68k/year = 136K
1 analog engineer @ 108K = 108 K
1 digital engineer @ 110K = 110 K
354k /year

For a one year construction of 40 antennas, that's 8.5k/antenna
The cost per antenna is now 45.5 k
The total parts + labor per antenna is now 45.5 + 88 = 133.5k
For 40 ants that's 5.35 M$

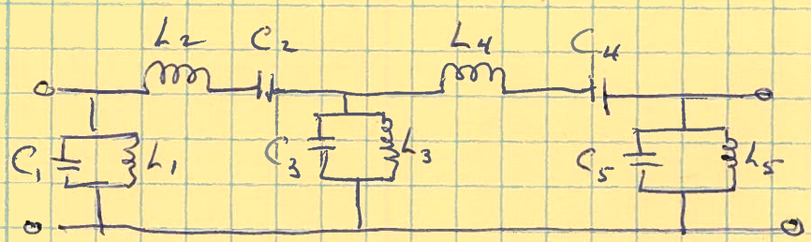
An antialiasing filter for 1400 MHz for the IBOB
sampling @ ~~1400 MHz~~ 800 MHz for a band at ~1400 MHz.

Plan: BW = 200 MHz centered at 1425 MHz.
We can use the filter of pp. 8-9
Use the 0.1 db version for best match (impedance) $S_{11} \lesssim -17$ db

$f_0 = 1425$, $BW = 200$; $a = \frac{1425}{200} = 7.125$
$R_r = 50\,\Omega$, $L_r = R_r/\omega_0 = 5.58$ nh (5.5444), $C_r = 1/R_r\omega_0 = 2.23$ pf. (2.2338)

$C_1' = 1.3013$
$L_2' = 1.5559$
$C_3' = 2.2411$
$L_4' = 1.5559$
$C_5' = 1.3013$

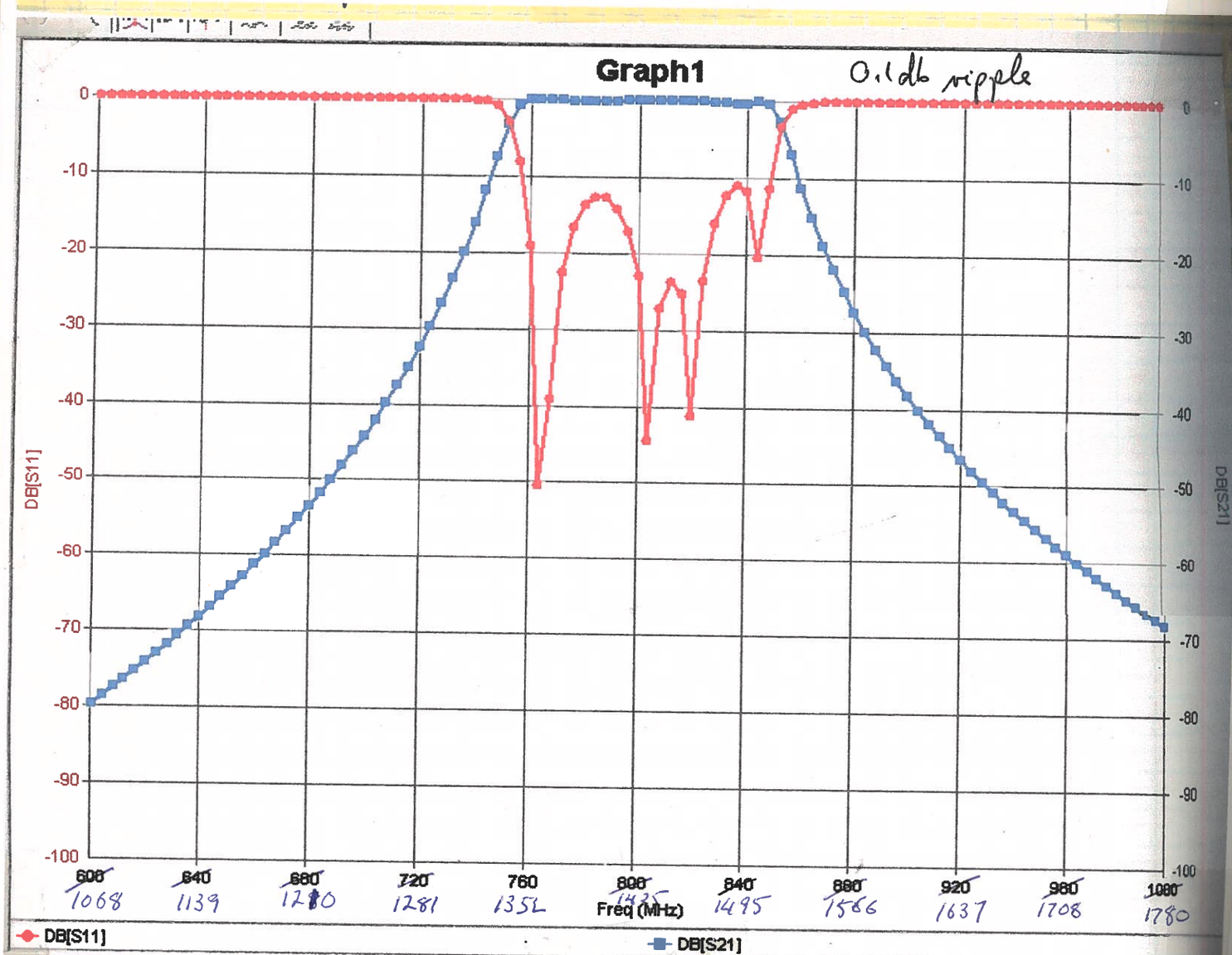
$C_1 = (aC_1')C_r = 20.7$ pf (20.7113)
$L_1 = [aC_1']^{-1}L_r = .6023$ nH
$C_2 = [aL_2']^{-1}C_r = .2015$ pf
$L_2 = [aL_2']L_r = 61.9075$ nh
$C_3 = [aC_3']C_r = 35.669$
$L_3 = [aC_3']^{-1}L_r = .3497$
$C_4 = .2015$ pf
$L_4 = 61.9075$ nh
$C_5 = 20.7113$
$L_5 = .6023$ nH



NB: This assumes 10K/antenna for the processor cost. Since we're not now certain about how we will expand the processor (correlator and beam former), it might be better to use 20K/ant. as the number. For 10K, the expansion by 300 antennas is 3M$. ⇐ For 20K/ant the total would be 6M$ which may be more realistic. That brings the 134K up to 144K$/ant. (This is the same as Dave's cost per antenna for 50 antennas).

Could we temporarily observe at 10GHz with rapid dumps and a lot of computer storage (temporary) → $\boxed{\text{delay + fringe corr.}}$ →
long time series ?

An approximate spectrum of the filter ~~scaled~~ of the previous page which is scaled from p. 8 by the factor 1.78.
100 MHz BW → 178 MHz (~200 MHz)



Can we move IF2 to 600 MHz for a 200 MHz band?

The Band pass filter at 15.2 – 15.8 GHz shows no spurious out of-band transmission greater than −90 db for $f < 15$ GHz. There is one weak feature at −86 db at ~ 20 GHz; nothing other up to 40 GHz.

So the output band is totally isolated from the input, and the only signal that comes out of the RFCB comes from mixing the 15.2 – 15.8 band with LO2.

☆ Having a band centered at 600 MHz requires that LO2 = 14.9 GHz. The answer is "yes".

Is the FR2 Board of the ADC sufficiently thermally stable in amplitude and phase, or do we have to make the board out of a better material?

From BVI pp 120–123, we find variations of the Correlator Room Temperature by 1–1.5°F due to the cycling of the Air Conditioner. There are ~ 2.5 cycles per hour. So one cycle is about 20 minutes.

From BVI-113 For FR4 $\frac{\Delta P}{P} = -.0000188\,\Delta T(°C)\,l(in)\,f(GHz)$

For frequencies above 1.5 GHz the curve of absorption with frequency deviates sharply from being a straight line.

☆ see next page

For $\Delta T = 1$, $f = 0.9$ GHz, and $l = 6''$, $\Delta P/P = .001$ db $= 2\times10^{-4}$

It might eventually be useful to have better than that gain stability. The TMM4 board is better by an order of magnitude.

Time stability for the 800 MHz clock.

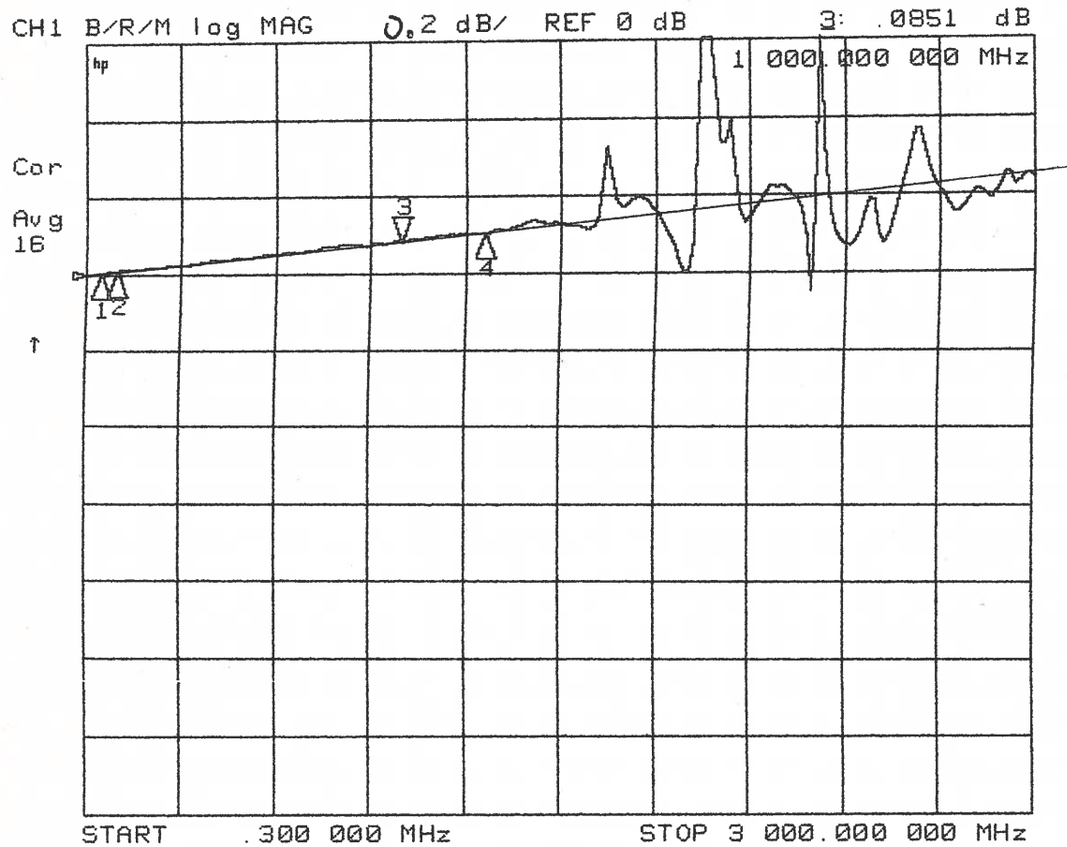
$\Phi = \frac{2\pi l}{\lambda} = \frac{2\pi\sqrt{K}\,l}{\lambda_0}$; $\frac{d\Phi}{\Phi} = \frac{d\sqrt{K_e}}{\sqrt{K_e}} = \frac{1}{2}\frac{K_e^{-1/2}}{K_e^{1/2}}dK_e = \frac{1}{2}\frac{dK_e}{K_e}$

so $d\Phi = \frac{1}{2}\frac{dK_e}{K_e}\Phi = \frac{1}{2}[250\times10^{-6}]\Phi$; For 900 MHz, $\lambda_0 \cong 13$ inches and $\lambda = 6''$, about the board size. so $\Phi \cong 360°$.

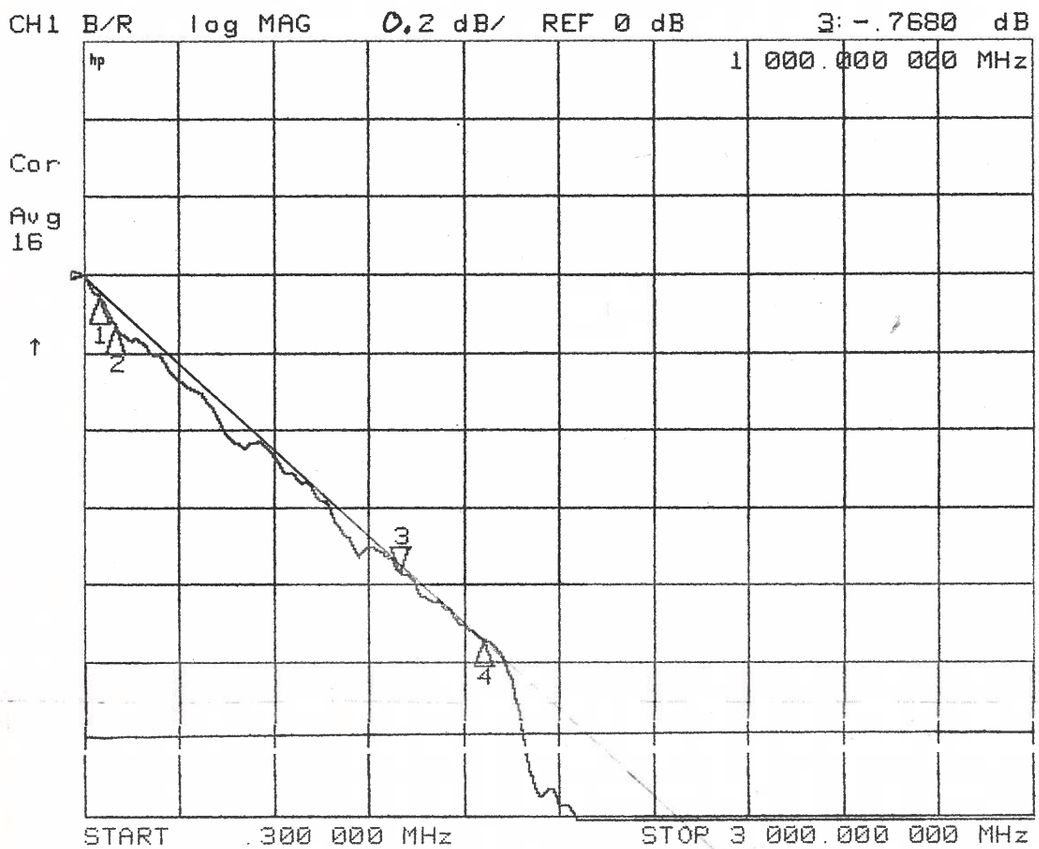
$d\Phi = 125\times10^{-6}\times360° = .05°$ (in 1°K).

One cycle is ~ 10^{-9} seconds long. .05° phase drift in $\frac{.05}{360}\times10^{-9} = 1.25\times10^{-13}$ secs. = .125 psec per degree.

Transmission through fiberglass microstrip line; 9.5" long $\epsilon_r = 4.8$
Trace = 108 mils wide, 9.5" long, Thickness 62 mils. ($Z_0 = 50\Omega$)
from BVI (p. 112) The board is bad above ≈ ~~1.4 GHz~~ 1.0 GHz

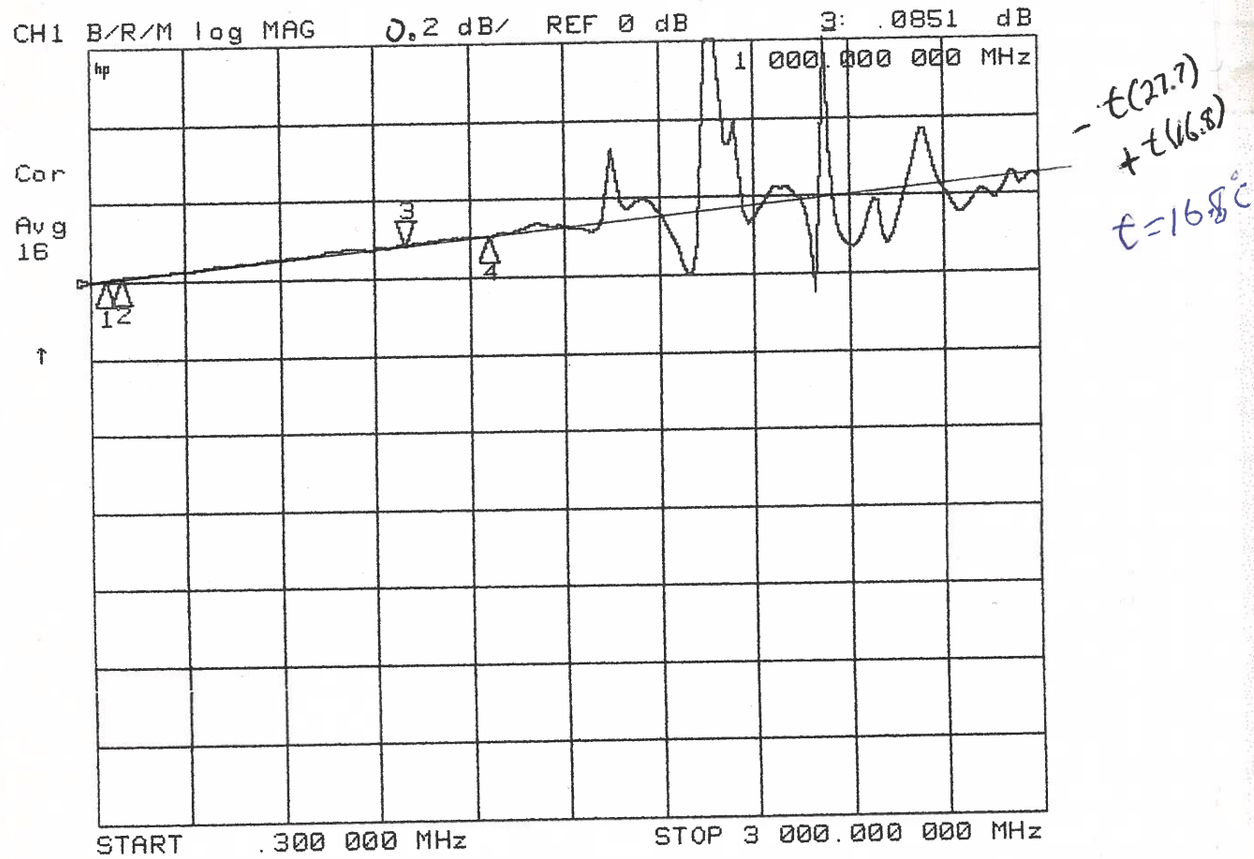


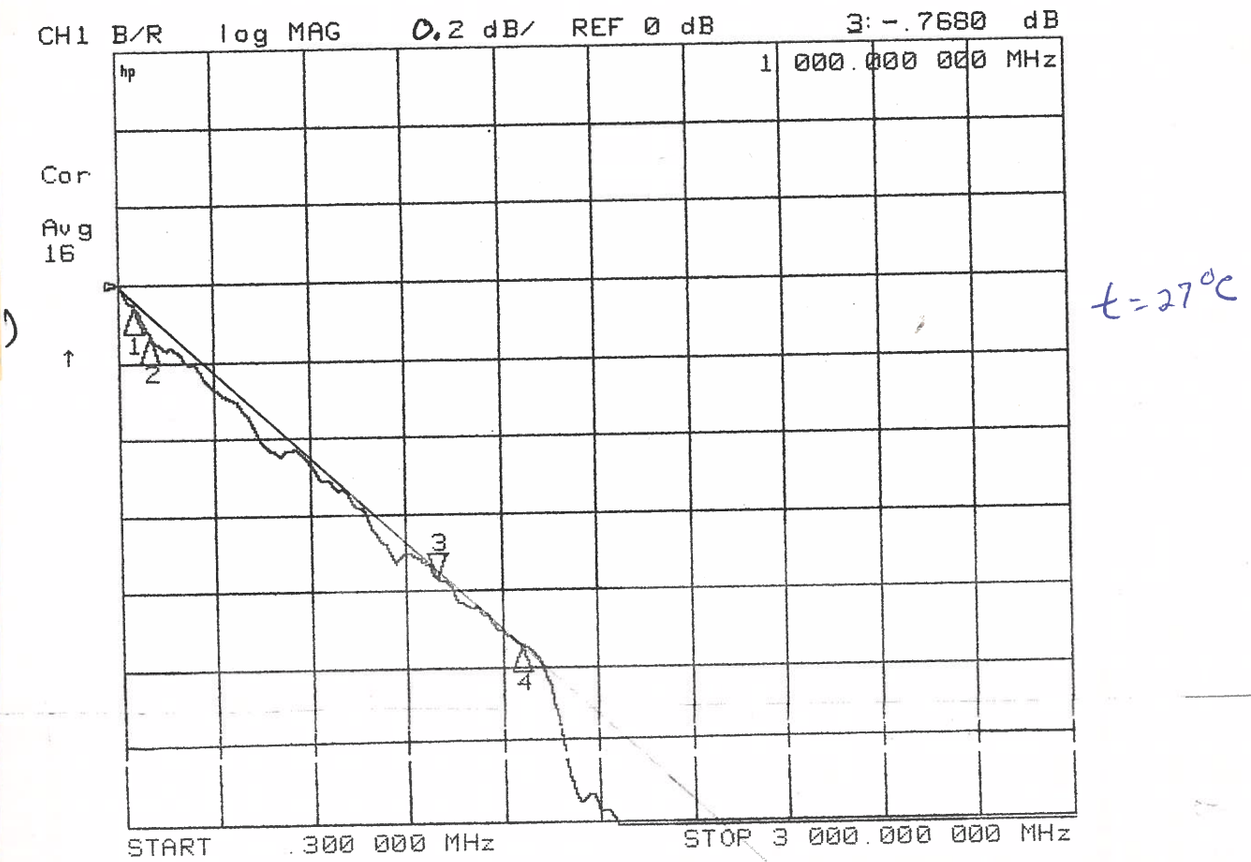
$-t(27.7)$
$+t(16.8)$
$t = 16.8°C$



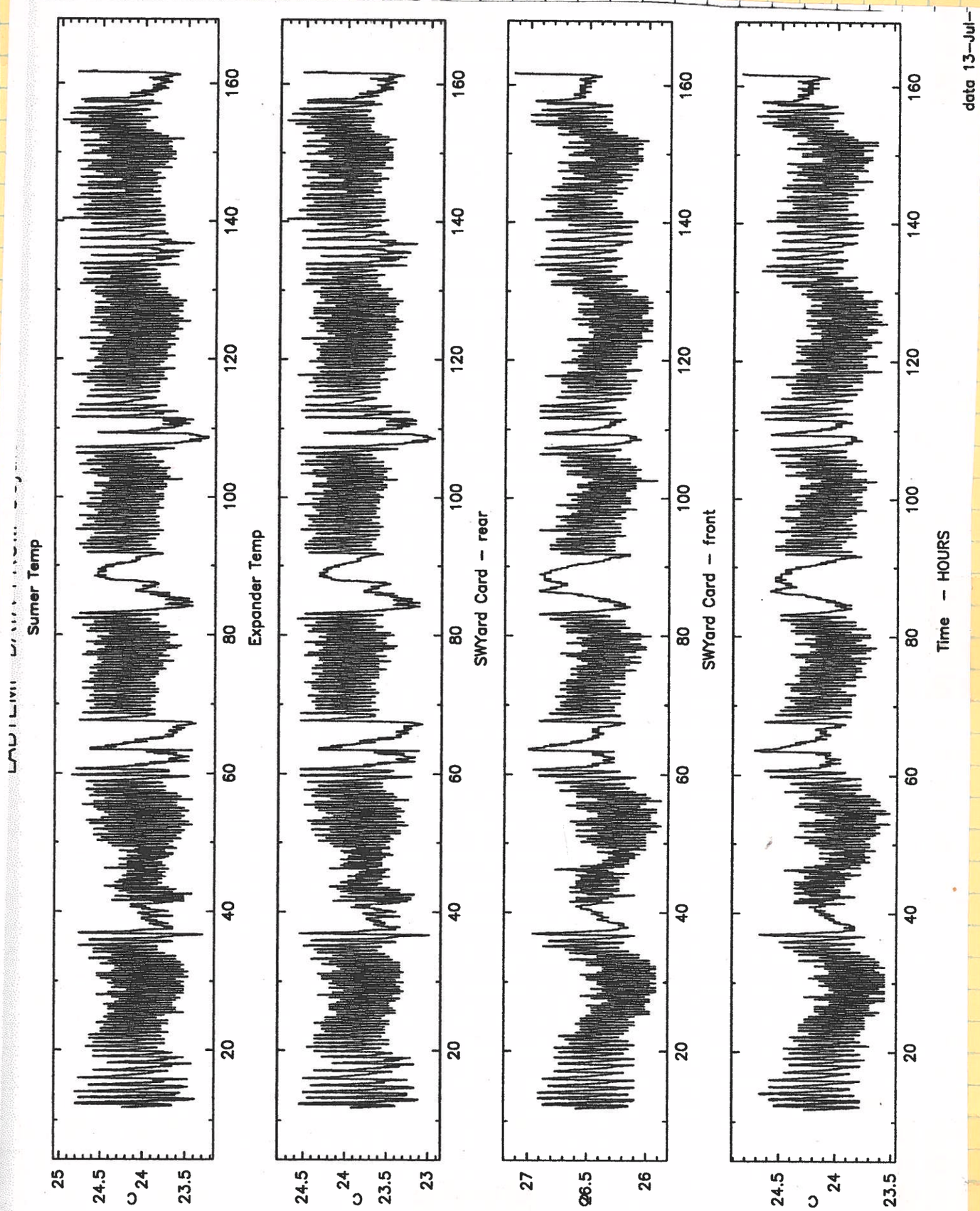
$t = 27°C$

Transmission through fiberglass microstrip line: 9.5" long $\epsilon_r = 4.8$
Trace = 4/108 mils wide, 9.5" long, Thickness 62 mils. ($Z_0 = 50\Omega$)
from BVI (p. 112) The board is bad above ≈ ~~1.4 GHz~~ 1.0 GHz





Temperatures in the Correlator Room at Hat Creek
from BVI p. 121

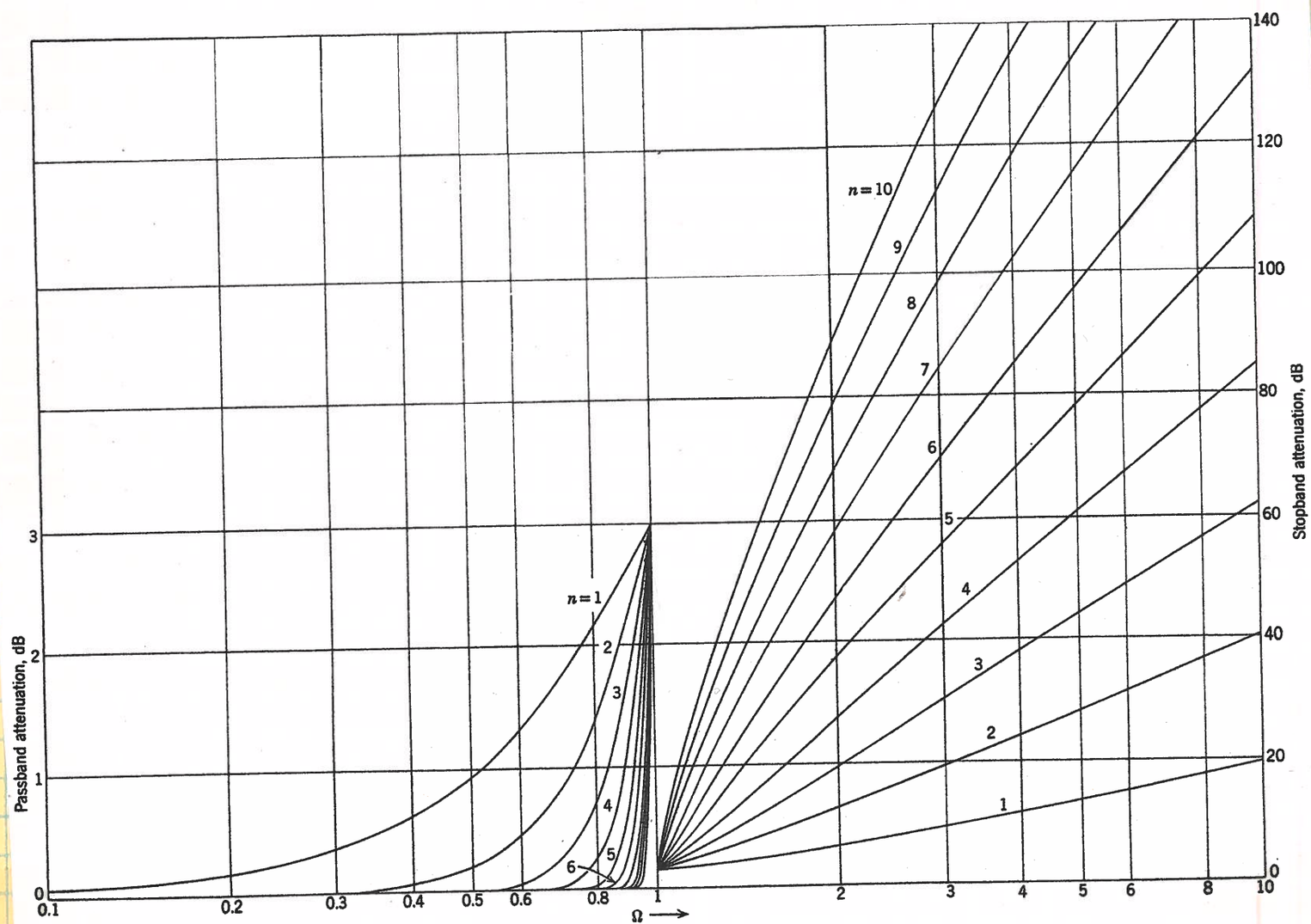


Attenuation characteristics for Chebychef Filters

For different numbers of L,C elements (for low pass)
or different number of resonators for Band pass

.01db ripple here

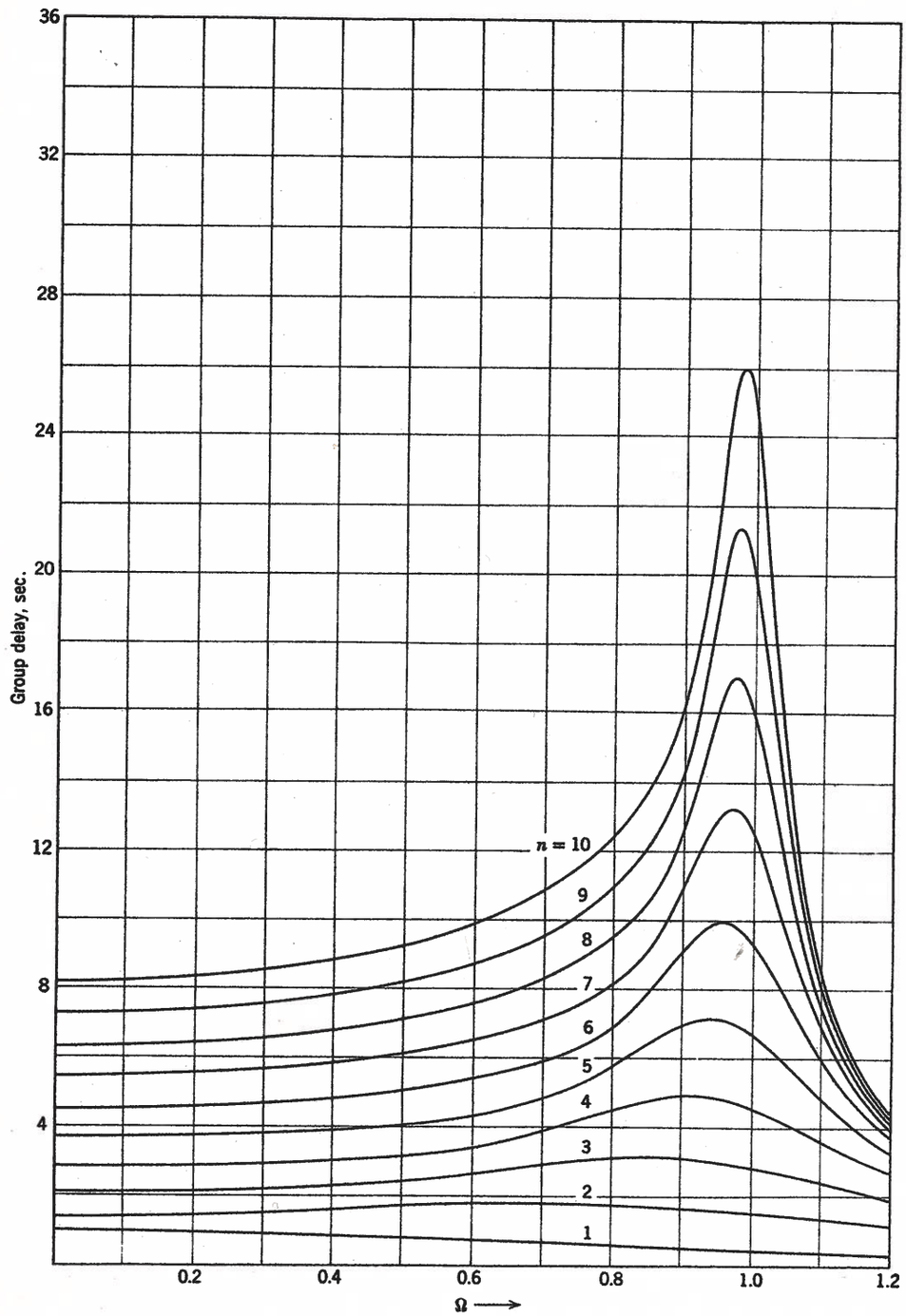
from Zverev



Low pass model

Curve 3. Attenuation characteristics for Chebyshev filter with 0.01 dB ripple.

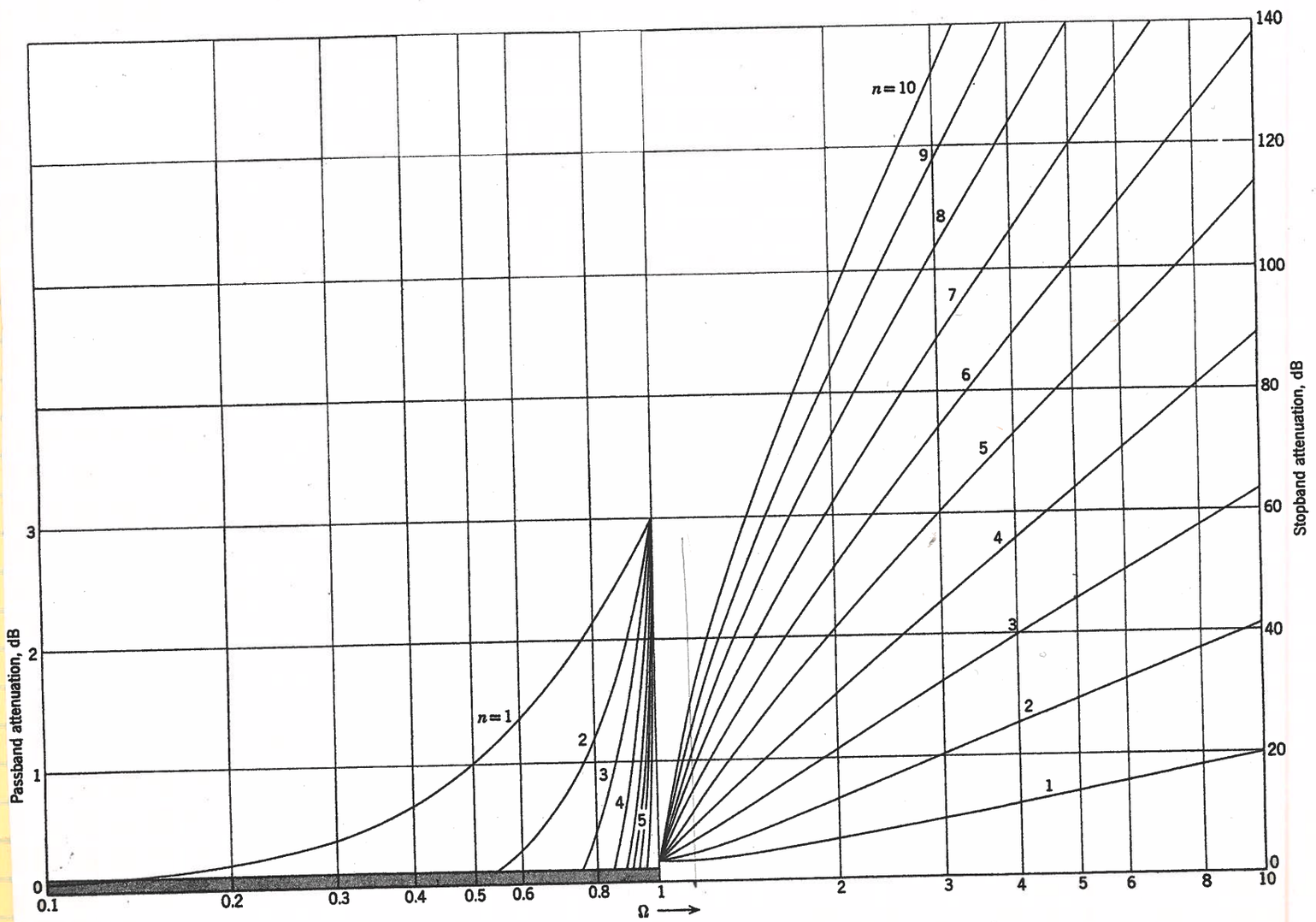
Group delay characteristics for 0.01db ripple



Curve 4. Group-delay characteristics for Chebyshev filter with 0.01 dB ripple.

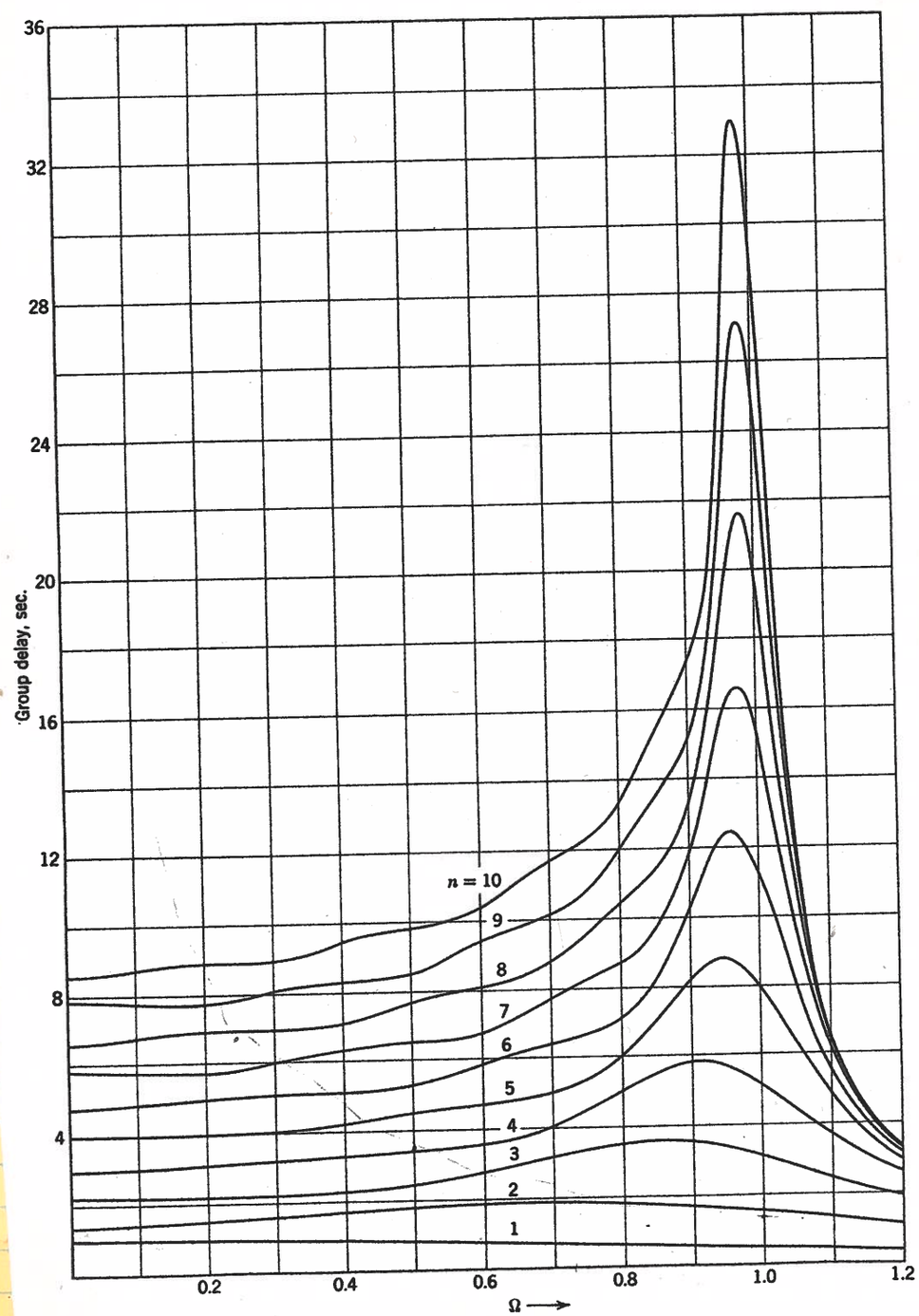
0.1 db ripple

Amplitude



Curve 5. Attenuation characteristics for Chebyshev filter with 0.1 dB ripple.

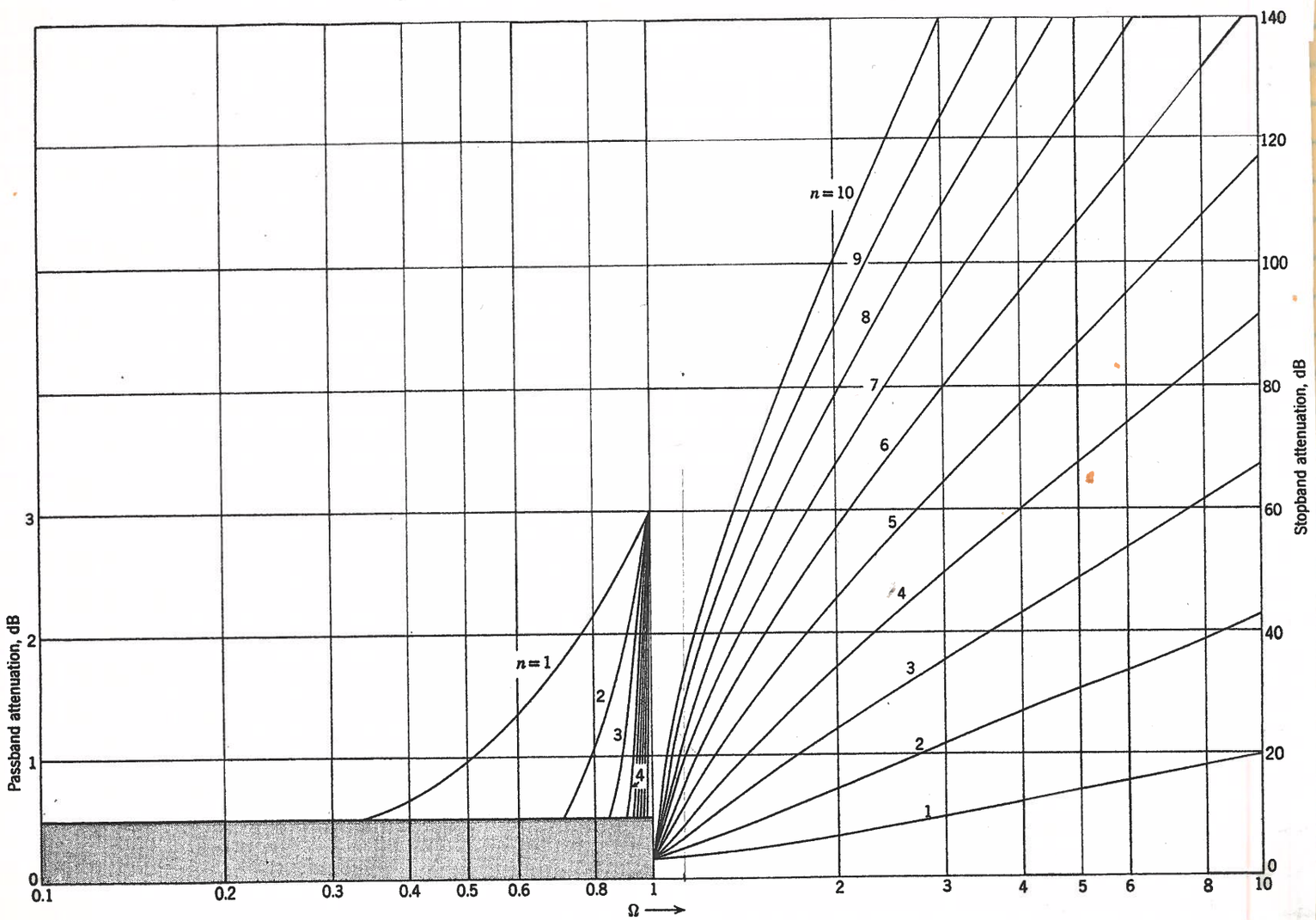
Group delay for 0.1db ripple



Curve 6. Group-delay characteristics for Chebyshev filter with 0.1 dB ripple.

0.5db ripple

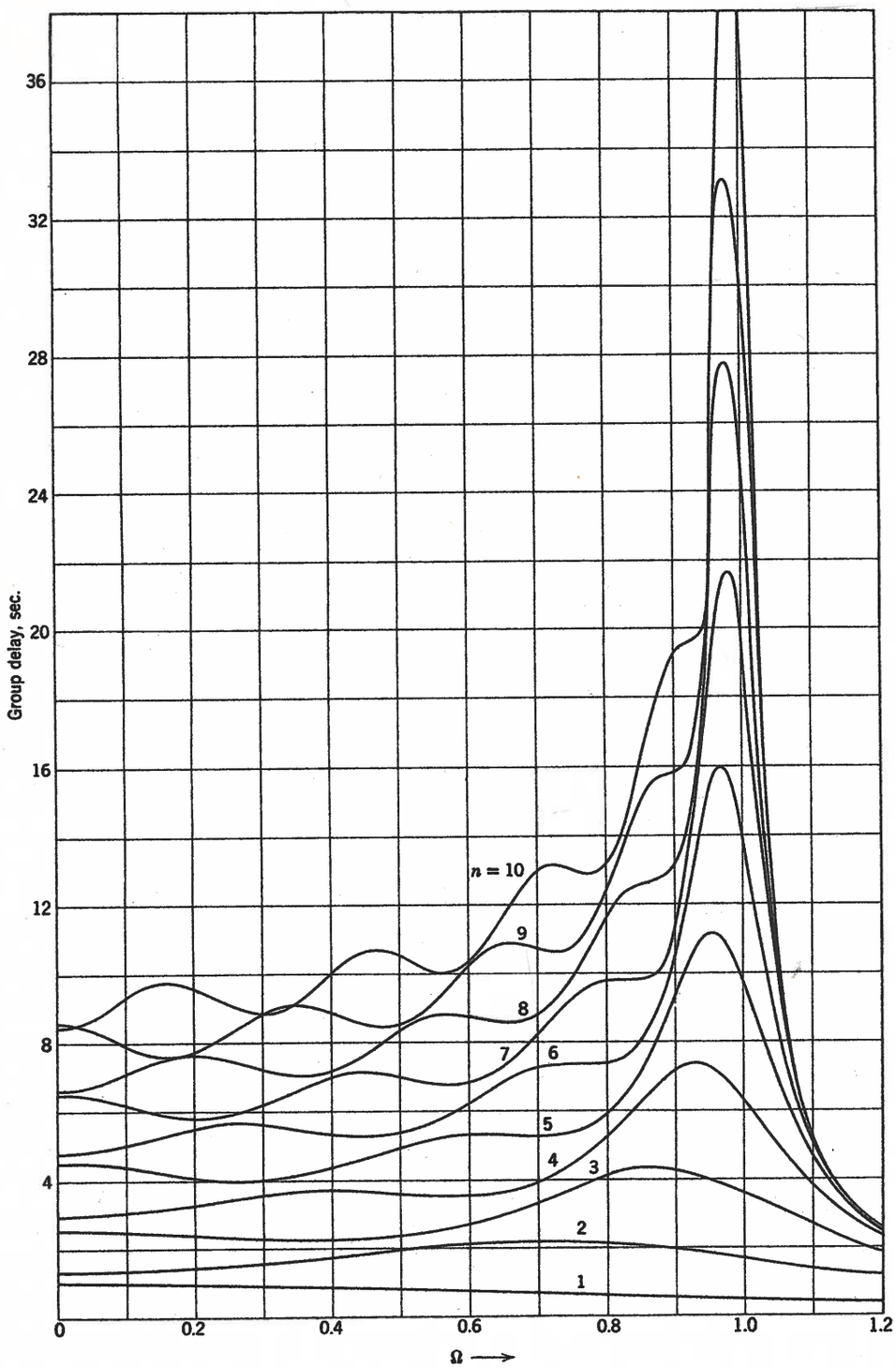
amplitude



Curve 7. Attenuation characteristics for Chebyshev filter with 0.5 dB ripple.

0.5db ripple

delay



Curve 8. Group-delay characteristics for Chebyshev filter with 0.5 dB ripple.

Stopband attenuation, dB

Filter options: Use the filter of page 15, but with $f_p = 600\,MHz$ and $BW = 200\,MHz$, $a = \frac{600}{200} = 3$; 0.1 db ripple [Zverev p.319]

for n=5

$C_1' = 1.3013$
$L_2' = 1.5559$
$C_3' = 2.241$
$L_4' = 1.5559$
$C_5' = 1.3013$

$L_r = R_r/\omega_0 = 50/2\pi\,600\times10^6 = 13.26\,nH$

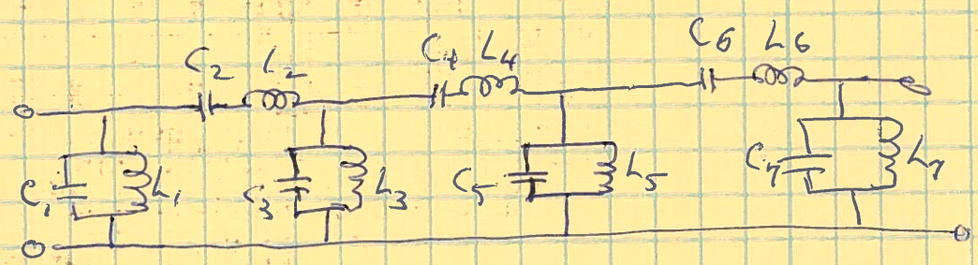
$C_r = 1/R_r\omega_0 = 1/(50)(2\pi\times600\times10^6) = 5.304\,pf$

$C_1 = (aC_1')C_r = 20.706 = C_5$ (18+)
$L_1 = (aC_1')^{-1}L_r = 3.397\,nH = L_5$ (3.3)
$C_2 = (aL_2')^{-1}C_r = 1.1363\,pf = C_4$ (1.2)
$L_2 = (aL_2')L_r = 61.894\,nH = L_4$ (56, 68)

$C_3 = (aC_3')C_r = 35.660\,pf$ (33+)
$L_3 = (aC_3')^{-1}L_r = 1.9722\,nH$ (2.8 chip)

for n=7 0.1 db ripple

$C_1' = 1.2615$
$L_2' = 1.5196$
$C_3' = 2.2392$
$L_4' = 1.6804$
$C_5' = 2.2392$
$L_6' = 1.5196$
$C_7' = 1.2615$



$C_1 = (aC_1')C_r = 20.073\,pf = C_7$ (18+)
$L_1 = (aC_1')^{-1}L_r = 3.5038\,nH = L_7$ (3.3 chip)
$C_2 = (aL_2')^{-1}C_r = 1.1635\,pf = C_6$ (1.2 pf)
$L_2 = (aL_2')L_r = 60.450\,nH = L_6$ (56, 68)
$C_3 = (aC_3')C_r = 35.630\,pf = C_5$ (33 chip)
$L_3 = (aC_3')L_r = 1.974\,nH = L_5$ (2.8 chip)
$C_4 = (aL_4')^{-1}C_r = 1.0521\,pf$ (1.0 pf)
$L_4 = (aL_4')L_r = 66.846\,nH$ (68 nH chip)

The issue between n=5 or 7 is the alias skirts. If a narrow (polyphase) digital filter is used after the ADC, then n=5 is probably more than sufficient!

Some available chip inductors from Coilcraft

Document 100-1

Chip Inductors - 0805CS Series (2012)

These compact inductors provide exceptional Q values, even at high frequencies. They have a ceramic body and wire wound construction to provide the highest SRFs available in 0805 size.

Coilcraft **Designer's Kit C103** contains samples of all 5% inductance tolerance parts. Kits with 2% tolerance are also available. To order, contact Coilcraft or purchase on-line at **http://order.coilcraft.com.**

Part number[1]	Inductance[2] (nH)	Percent tolerance[3]	Q min[4]	SRF min[5] (MHz)	DCR max[6] (Ohms)	Irms[7] (mA)	Color code
0805CS-020X_B_	2.8 @ 250 MHz	20,10,**5**	80 @ 1500 MHz	7900	0.06	800	Gray
0805CS-3N0X_B_	3.0 @ 250 MHz	20,10,**5**	65 @ 1500 MHz	7900	0.06	800	White
0805CS-030X_B_	3.3 @ 250 MHz	20,10,**5**	50 @ 1500 MHz	7900	0.08	600	Black
0805CS-050X_B_	5.6 @ 250 MHz	20,10,**5**	65 @ 1000 MHz	5500	0.08	600	Orange
0805CS-060X_B_	6.8 @ 250 MHz	20,10,**5**	50 @ 1000 MHz	5500	0.11	600	Brown
0805CS-070X_B_	7.5 @ 250 MHz	20,10,**5**	50 @ 1000 MHz	4500	0.14	600	Green
0805CS-080X_B_	8.2 @ 250 MHz	20,10,**5,2**	50 @ 1000 MHz	4700	0.12	600	Red
0805CS-100X_B_	10 @ 250 MHz	20,10,**5,2**	60 @ 500 MHz	4200	0.10	600	Blue
0805CS-120X_B_	12 @ 250 MHz	20,10,**5,2**	50 @ 500 MHz	4000	0.15	600	Orange
0805CS-150X_B_	15 @ 250 MHz	20,10,**5,2**	50 @ 500 MHz	3400	0.17	600	Yellow
0805CS-180X_B_	18 @ 250 MHz	20,10,**5,2**	50 @ 500 MHz	3300	0.20	600	Green
0805CS-220X_B_	22 @ 250 MHz	20,10,**5,2**	55 @ 500 MHz	2600	0.22	500	Blue
0805CS-240X_B_	24 @ 250 MHz	20,10,**5,2**	50 @ 500 MHz	2000	0.22	500	Gray
0805CS-270X_B_	27 @ 250 MHz	20,10,**5,2**	55 @ 500 MHz	2500	0.25	500	Violet
0805CS-330X_B_	33 @ 250 MHz	20,10,**5,2,1**	60 @ 500 MHz	2050	0.27	500	Gray
0805CS-360X_B_	36 @ 250 MHz	20,10,**5,2,1**	55 @ 500 MHz	1700	0.27	500	Orange
0805CS-390X_B_	39 @ 250 MHz	20,10,**5,2,1**	60 @ 500 MHz	2000	0.29	500	White
0805CS-430X_B_	43 @ 200 MHz	20,10,**5,2,1**	60 @ 500 MHz	1650	0.34	500	Yellow
0805CS-470X_B_	47 @ 200 MHz	20,10,**5,2,1**	60 @ 500 MHz	1650	0.31	500	Black
0805CS-560X_B_	56 @ 200 MHz	10,**5,2,1**	60 @ 500 MHz	1550	0.34	500	Brown
0805CS-680X_B_	68 @ 200 MHz	10,**5,2,1**	60 @ 500 MHz	1450	0.38	500	Red
0805CS-820X_B_	82 @ 150 MHz	10,**5,2,1**	65 @ 500 MHz	1300	0.42	400	Orange
0805CS-910X_B_	91 @ 150 MHz	20,10,**5,2,1**	65 @ 500 MHz	1200	0.48	400	Black
0805CS-101X_B_	100 @ 150 MHz	10,**5,2,1**	65 @ 500 MHz	1200	0.46	400	Yellow
0805CS-111X_B_	110 @ 150 MHz	20,10,**5,2**	50 @ 250 MHz	1000	0.48	400	Brown
0805CS-121X_B_	120 @ 150 MHz	10,**5,2,1**	50 @ 250 MHz	1100	0.51	400	Green
0805CS-151X_B_	150 @ 100 MHz	10,**5,2,1**	50 @ 250 MHz	920	0.56	400	Blue
0805CS-181X_B_	180 @ 100 MHz	10,**5,2,1**	50 @ 250 MHz	870	0.64	400	Violet
0805CS-221X_B_	220 @ 100 MHz	10,**5,2**	50 @ 250 MHz	850	0.70	400	Gray
0805CS-241X_B_	240 @ 100 MHz	20,10,**5,2**	44 @ 250 MHz	690	1.00	350	Red
0805CS-271X_B_	270 @ 100 MHz	10,**5,2**	48 @ 250 MHz	650	1.00	350	White
0805CS-331X_B_	330 @ 100 MHz	10,**5,2**	48 @ 250 MHz	600	1.40	310	Black
0805CS-391X_B_	390 @ 100 MHz	10,**5,2**	48 @ 250 MHz	560	1.50	290	Brown
0805CS-471X_B_	470 @ 50 MHz	10,**5,2**	33 @ 100 MHz	375	1.76	250[8]	Violet
0805CS-561X_B_	560 @ 25 MHz	10,**5,2**	23 @ 50 MHz	340	1.90	230	Orange
0805CS-681X_B_	680 @ 25 MHz	10,**5,2**	23 @ 50 MHz	188	2.20	190	Green
0805CS-821X_B_	820 @ 25 MHz	10,**5,2**	23 @ 50 MHz	215	2.35	180	Blue

1. Specify tolerance and packaging codes:

0805CS-821X G B C

Tolerance: F = 1% G = 2% J = 5% K = 10% M = 20% (Table shows stock tolerances in bold.)

Packaging: C = 7" machine-ready reel. EIA-481 embossed plastic tape (2000 parts per full reel).
B = Less than full reel. In tape, but not machine ready. To have a leader and trailer added ($25 charge), use code letter C instead.
D = 13" machine-ready reel. EIA-481 embossed plastic tape. Factory order only, not stocked (7500 parts per full reel).

2. Inductance measured using Coilcraft SMD-A fixture in an Agilent/HP 4286A impedance analyzer with Coilcraft-provided correlation pieces. For recommended test procedures, contact Coilcraft.
3. Tolerances in bold are stocked for immediate shipment.
4. Q measured using an Agilent/HP 4291A with an Agilent/HP 16193 test fixture and on an Agilent/HP 8753D with Coilcraft SMD-D test fixture.
5. SRF measured using Agilent/HP 8720D network analyzer and Coilcraft SMD-D test fixture.
6. DCR measured on Cambridge Technology micro-ohmmeter and Coilcraft CCF858 test fixture.
7. Average current for a 15°C rise above 25°C ambient.
8. Operating temperature range –40°C to +125°C.
9. Electrical specifications at 25°C.

See Qualification Standards section for environmental and test data.

COILCRAFT PRECISION ACCURATE REPEATABLE MEASUREMENTS SEE INDEX TEST FIXTURES

Coilcraft

Specifications subject to change without notice. Document 100-1 Revised 12/18/02

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available components in the bins

Johanson Trim caps: .25–.7, .5–1.3, .6–2.5, 1–5, 2.5–10, 5–15, 5–18, 6–35, 8–50

chip caps: 2.2 pf, 3.3, 0.2, 8.2, 10, 43, 7.5, 12 ; 1.0 pf, 2.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0

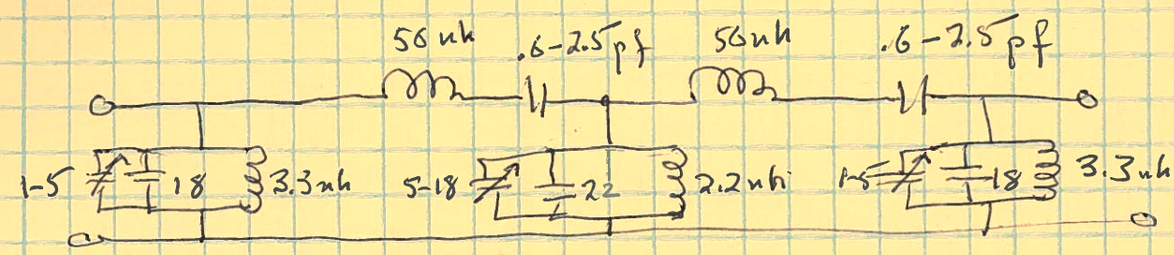
coilcraft chip inductors: 2.2 uh, 8.2, 6.8, 22 in bins, plus designer kits

other chip caps: 1.5, 3.3, 3.9, 4.7, 5.6, ..., 15, 18, 22

boards are available for n=5 filters

boxes are 2.25" x 0.5" x .05" and fit the boards, leaving room for end fit connector

The 800 MHz BP filter n = 5 BW = 200 MHz 3/4/07



We can use the pc board and box from the PTA 200 MHz filter. The series resonators should go on the top of the microstrip line. They will need to be tuned up with SMA end fire connectors on the ends. Then these can be removed for connecting the filter onto the ADC board.

The effect of the LO2 sidebands from the DC/DC converters on a very strong interfering signal. (see page 6 II). 3/4/07

$\phi_{LO} = 2\pi\nu_0 t + \phi_n(t)$ signal: $\cos 2\pi\nu_s t$

mixing: $\cos 2\pi\nu_s t \cdot \cos(2\pi\nu_0 t + \phi_n(t))$
$= \frac{1}{2}\cos\{2\pi(\nu_0 - \nu_s)t + \phi_n(t)\}$ no upper sideband.

$$S(t) = \frac{1}{2}\left[\cos 2\pi(\nu_0-\nu_s)t \cos\phi_n(t) - \sin 2\pi(\nu-\nu_0)t \sin\phi_n(t)\right]$$

Assume $\phi_n(t) << 1$ (from p. 6)

Then $\cos\phi_n(t) \cong 1$ and $\sin\phi_n(t) \cong \phi_n(t)$

$$S(t) \cong \frac{1}{2}\cos 2\pi(\nu_0-\nu_s)t - \frac{\phi_n}{2}(t)\sin 2\pi(\nu_0-\nu_s)t$$

It looks like AM with the spectrum of the LO sidebands of p. 6 at the level of $|\phi_n(t)|$ relative to the strong tone. These sidebands added to the input noise spectrum should be negligible. For a very strong interfering tone, they will add interference at the level of ~ -60 db of the strong tone. over a band of ~ 1 MHz.

Power Cooling in the Correlator Room at Hat Creek

The Liebert AC is 10 tons = 35,190 watts ~ 35 kW

A conservative estimate of the digital load from the Correlator and the beam former is 9 kW.
One rack full of PDMs is 2.2 kW, x 5 = 11 kW
The control computers and RFCB's add up to ~ 1 kW

So the Liebert should work.

In the summer, the west wall feels warm, even though there is insulation in the wall. Possibly an awning could be put up outside to decrease that effect

---

Space: Beamformer rack is 38 u total: 38 x 1.75" = 66.5" ~ 5½'

There will be two of these and one more for the correlator.

The effects of sampling and filtering 3/11/07

The input signal is $I(t)$ and it's transform is $\mathcal{I}(\nu)$.

Filter it with a filter with impulse response $h(t)$ and frequency response $H(\nu)$

The filtered output is $O(t) = I(t) * h(t)$; $O(\nu) = \overbrace{I(\nu)H(\nu)}^{\mathcal{I}(\nu)}$

Sample it at intervals T, i.e. multiply it by $s(t) = \sum_{n=-\infty}^{\infty} \delta(t - nT)$.

$$s(t) \longleftrightarrow S(\nu) \qquad \text{where} \quad S(\nu) = \sum_{m=-\infty}^{\infty} \delta\left(\nu - \frac{m}{T}\right)$$

The spectrum of the sampled filtered signal:

$$s(t)\,O(t) \longleftrightarrow O(\nu) * S(\nu)$$

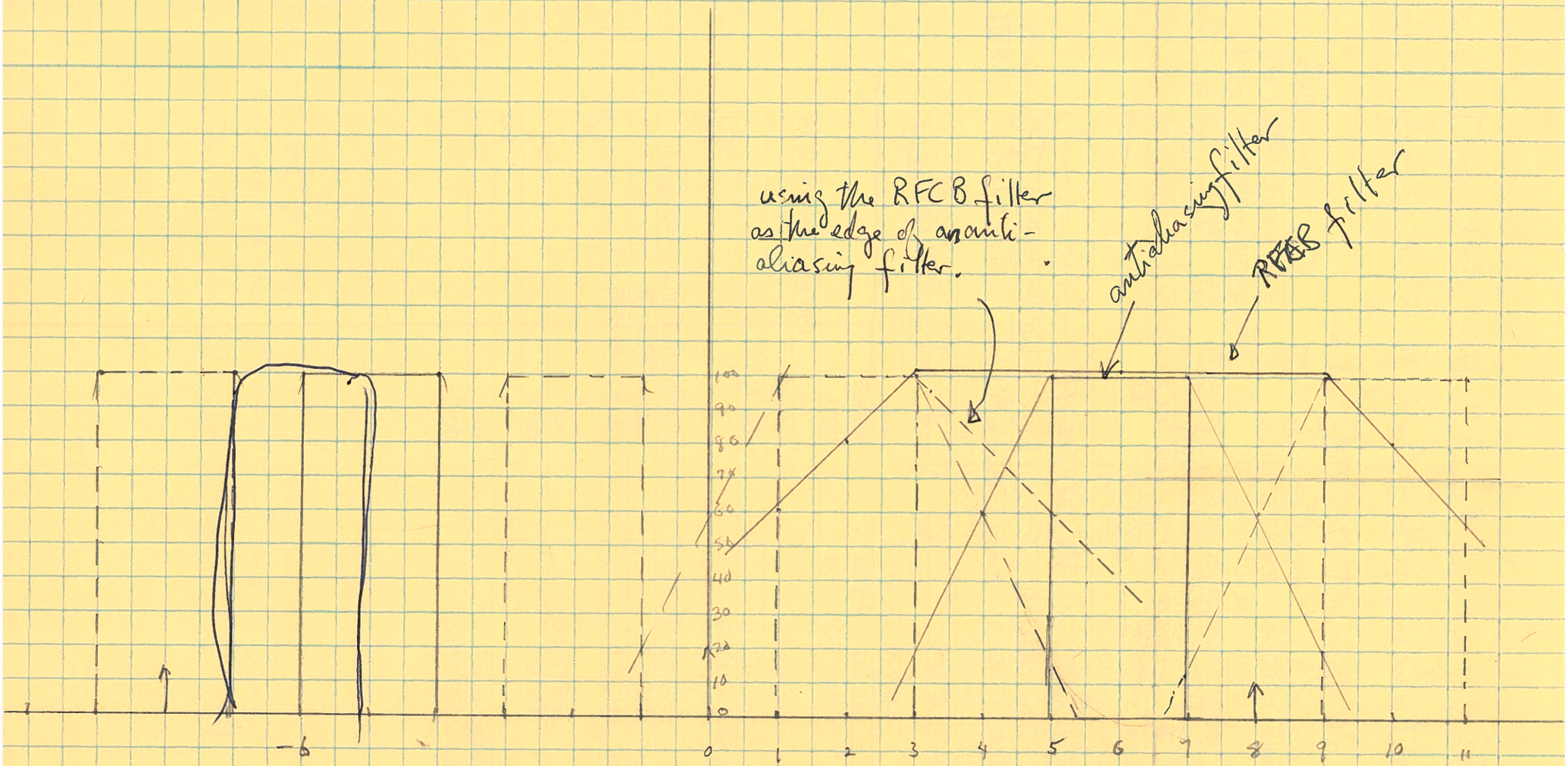
$$O(\nu) * S(\nu) = \int_{-\infty}^{\infty} O(\nu - f) \sum_{m=-\infty}^{\infty} \delta\left(f - \frac{m}{T}\right) df$$

$$= \sum_{m=-\infty}^{\infty} \int_{-\infty}^{\infty} O(\nu - f)\,\delta\left(f - \frac{m}{T}\right) df = \sum_{m=-\infty}^{\infty} O\left(\nu - \frac{m}{T}\right)$$

$$= \sum_{m=-\infty}^{\infty} \mathcal{I}\left(\nu - \frac{m}{T}\right) H\left(\nu - \frac{m}{T}\right) \approx \sum_{m=-\infty}^{\infty} H\left(\nu - \frac{m}{T}\right) \quad \text{for a flat input spectrum.}$$

The sampling produces the sum of replicas of the filtered output, spaced at intervals of the sampling frequency.

The plan is to sample at 800 MHz and receive in a band of width 200 MHz centered at 600 MHz. The band pass filter in front of this has a bandwidth of 600 MHz. There will be a digital filter of width 100 – 200 MHz for the processor, and we put an antialiasing filter of width 200 MHz in front of the digitizer. This will be an $n = 5$ 0.1 db ripple Chebychev filter.



The spillover from the sampling replicas of the antialiasing filter are at the -85db level if the width of the digital processing filter is just 200MHz with no tails.

If the edge of the RFCB filter is used (in conjunction with a low pass filter for the upper edge) the overlap with a perfect dpfilter will be at the level of ~ -40db. If the dpfilter width is 100MHz, instead of 200 MHz, the overlap will occur at the -50db level.

These rejections are for signals that don't stand out above the noise.

The rejection of a Low Pass filter used as the upper edge of an antialiasing filter (using the RFCB filter for the low freq)

It's edge will be at 700 MHz at best.

At 800 MHz it's attenuation is for $n=5$ ~ −13db
$n=7$ ~ −17db −35 at delay edge
$n=9$ ~ −25db

This is less than the RFCB filter, except for $n=9$. The phase/delay ripple is quite high.

Phase stability of the 2nd 600 MHz filter.
Comparison: the BIMA IF Hz box with many Johnson chips in 2 filters plus some amplifiers measured. [BVI 139]

$$\frac{d\Phi}{dT} \sim .01^\circ/^\circ C \quad \text{measured at } 600\ MHz$$

3/15/07

Discussion with Oren Milgrom

He is able to login to the BEE2 board that we have and move data in and out: out on one port and back in on another. He is now familiar with the computer tools developed at BWRC and has been working with Vinayak and his beam forming algorithms. They expect to have a demonstration working very shortly.

We also discussed mounting of the AA filter and gain control on an ADC board. Control of the gain control can be easily connected to the IBOB digital control connector.

Oren believes that filling out the details of the beam former including putting in the input processing filter and Lynn's computer-control FIR filter for delay and phase control should move quickly. The combining of signals on the BEE2 using Vinayak's algorithm should then be straightforward. Perhaps a month or two will be required to debug this software. The version 1.1 ADC boards are ready for testing. Needed for BEE2 programming.

Status of the PAM/PAX units

Problem: the chokes in the PAM, the newer ones, do not work well beyond 10 GHz. There is no time for a redesign so for now it looks like 10 GHz will be our practical upper limit on, probably, the last 10 PAX units. [It does meet spec]

Including these:
a) 9 completed PAXes are at Minex
b) 11 nearly completed units are in Berkeley. The final assembly, including OTX and control cards, should be ready by end April (or sooner)

RFCBs

a) The third box of 12 is complete
b) In the 4th box of 10, 2 are complete, 5 are complete except for the power wiring; the last three need only filters, cables, and power wiring. Completion expected before March 23.

The power distribution box is being completed (by Ed); expected to be done by March 23 (He then leaves on vacation)

Box and layout for Walsh Functions being planned. Maybe this can be finished by WJW before end of March 23. This box can be located at the bottom of the RFCB rack.

Susie

3 PTA antennas ditches close to pedestal are done
old wiring being stripped.
(Les fell off 'a 30' ladder; out for at least a week)
[X-rays? hands, wrists, pulled groin muscle]

Get parts from Matt. Does he want to supervise taking off dish from pedestal? Should they go ahead?
→ Jack bring GPS up next trip

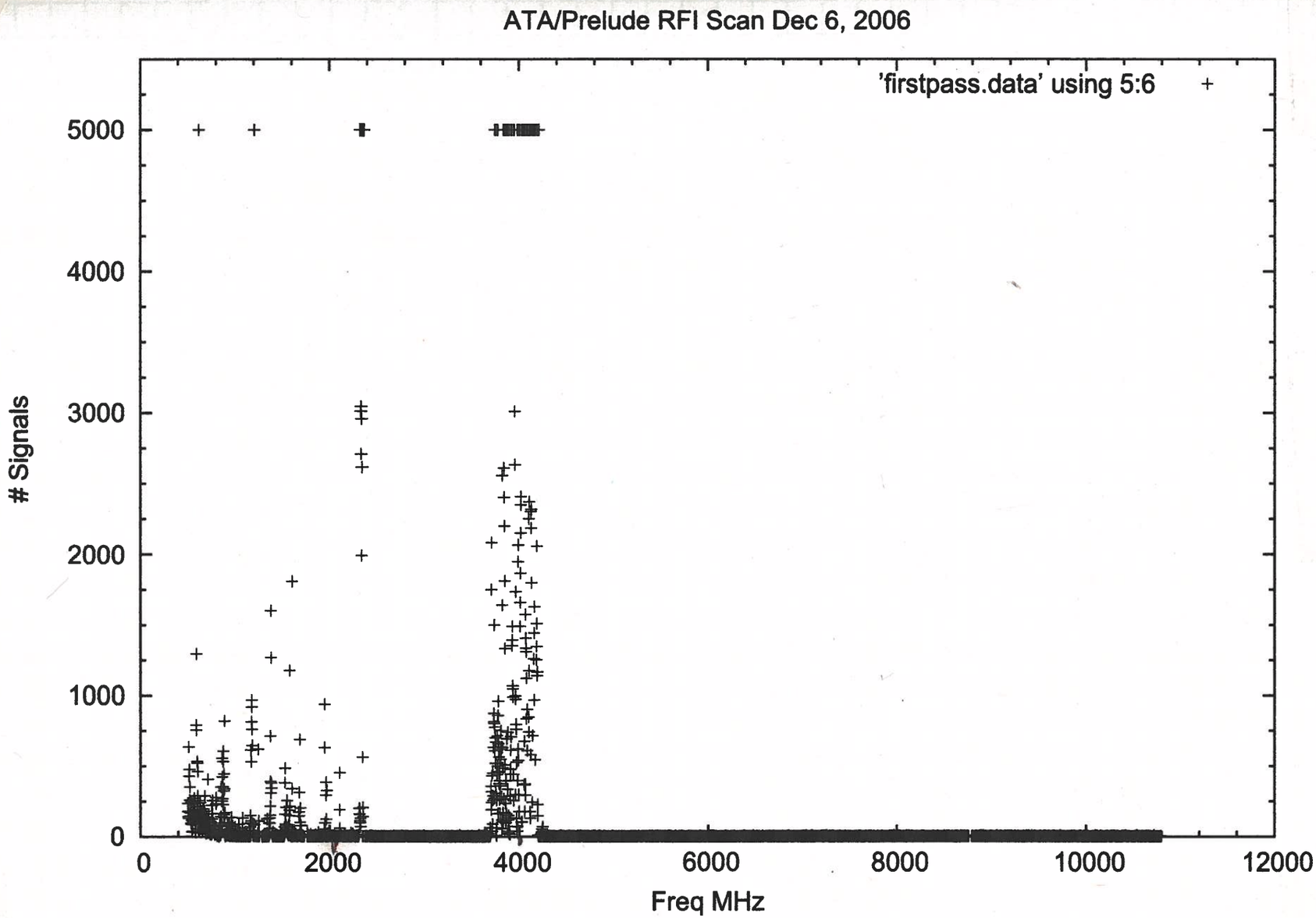
Matt

Priorities for Matt
1. PTA mech. upgrade: moving-parts go up & 3 ale decks
2. Ion pump 10 units done by April 15 } receivers go up by 25th March
3. Rim Box wiring the next sem.
4. 20 Feeds by June 1 or earlier; substantially before May 1

later jobs: A. Insulations of Mounts against sun } in June
B. Soda Blasting antennas against sun }
Plan to buy the equipment.

Rim Box @ cabling new
to monitor board + power dist. for ion pump.

MB next board meeting on May 1.


ATA/Prelude RFI Scan Dec 6, 2006
'firstpass.data' using 5:6
Signals
Freq MHz
0
1000
2000
3000
4000
5000
0
2000
4000
6000
8000
10000
12000

4/12/07

Final version of the anti-alias filter 630/200

The design of p 28 turns up best centered at 580 MHz and has a width of 160 MHz. We begin with the component values on p 26 for $n = 5$.

a) change the a factor to increase the fractional BW
$a = 600/200 = 3$; $600/160 = 3.75$
Decrease a by $3/3.75 = \underline{0.8}$

b) Tuning to 630 MHz from 580 MHz: $\frac{630}{580} = 1.086$
Then $L_r \to 13.26/1.086 = 12.26$, $C_r \to 4.88$ pf.

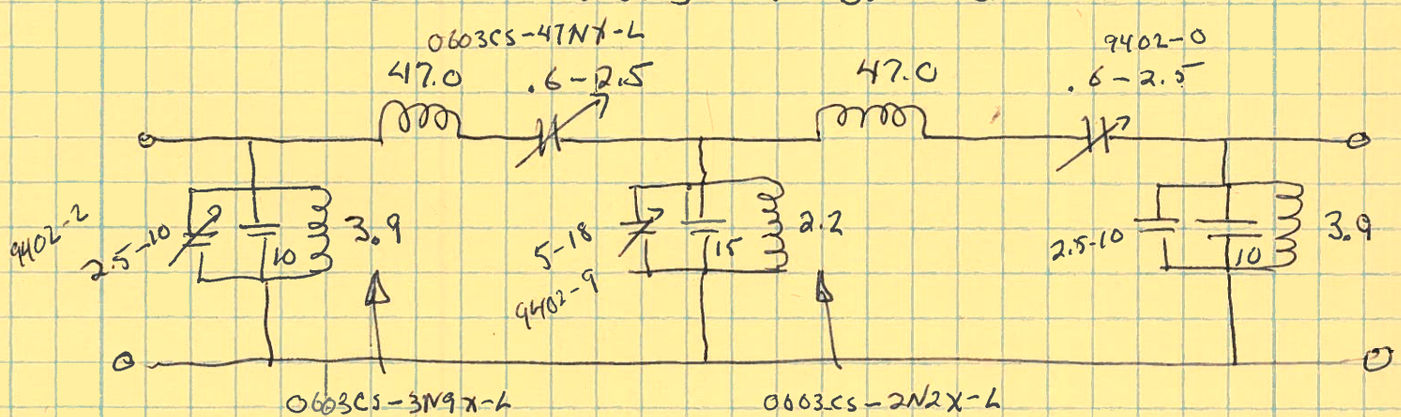
Including both effects:

$C_1 = (aC_1')C_r = (20.7)(0.8)/1.086 = 15.3\text{pf} = C_5$; 10 + (2.5-10) 9402-2
$L_1 = (aC_1')^{-1}L_r = (3.397)(.08)^{-1}/1.086 = 3.91\text{nH} = L_5$; 3.9 (0603)
$C_2 = (aL_2')^{-1}C_r = (1.136)(.8)^{-1}/1.086 = 1.31 = C_4$; .6 – 2.5 9402-0
$L_2 = (aL_2')L_r = (61.9)(0.8)/1.086 = 45.6\text{nH} = L_4$; 47.0 [0603]
$C_3 = (aC_3')C_r = (35.6)(0.8)/1.086 = 26.2$; 15 + (5-18) 9402-9
$L_3 = (aC_3')^{-1}L_r = (1.97)(0.8)^{-1}/1.086 = 2.27\text{nH}$; 2.2 (0603)

Typical turning curves are on the next page.

The asymptotic transmission on the positive frequency side is ~ −60 db.

Transmission loss is −2.6 db at band center.

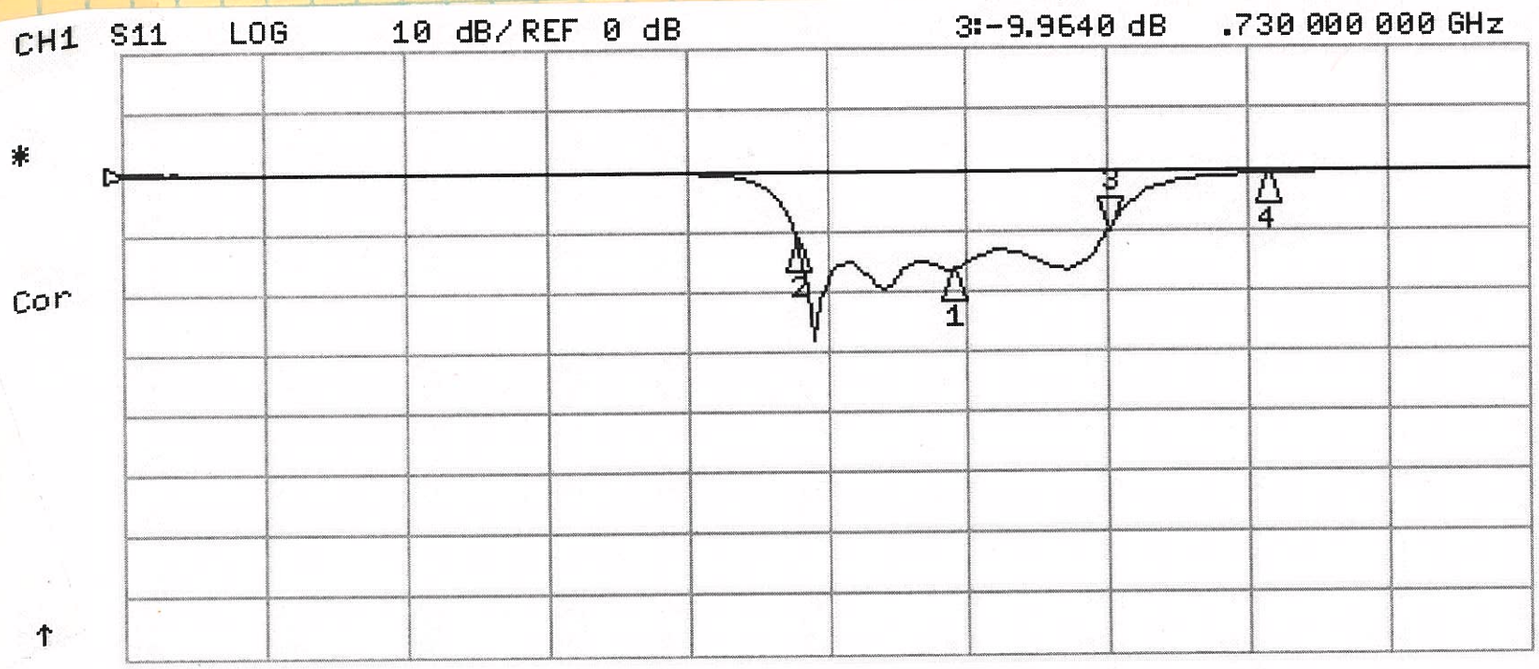


caps 10pf and 15pf NPO

Note: Easier tuning enabled by changing the 5-18pf trimmer to 1-5pf for the central shunt tank.

3db BW ≈ 200 MHz

2db is ~ 320 MHz

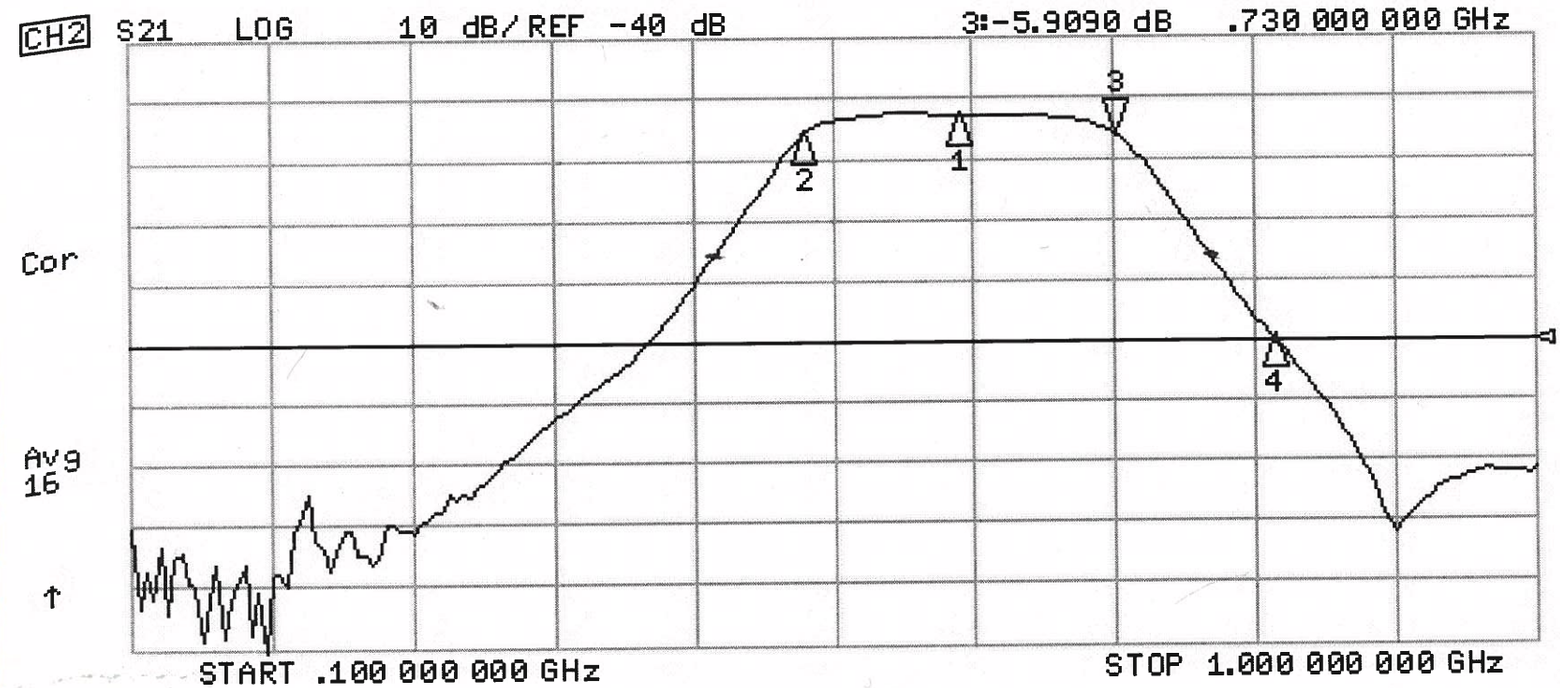


CH1 Markers

1:-16.510 dB
630.000 MHz

2:-11.465 dB
530.000 MHz

4:-.69900 dB
830.000 MHz



CH2 Markers

1:-2.6420 dB
630.000 MHz

2:-5.9670 dB
530.000 MHz

4:-39.423 dB
830.000 MHz

RF Converter Board output match, including the output cable, is ~ -13db with LO2 turned on. Some of this comes from the output connectors and cables that are rolled up. Several were tested. 4/21/07 @ 630 11/12

Rack space for RFCBs 2 crates + power distributer ≅ 34"

Walsh function box is 3½"

Altogether $2 \times (34) + 3\frac{1}{2} = 71\frac{1}{2}$
the rack total is 76"

There is no space for fan trays or air scoops here.

file: ~/obs/help/ATA-control.tutorial 07march07

LOGING IN:

ssh obs@tumulus (pw = b2rk212y) tumulus ip address from inside is 10.3.0.40

HELP FILES: help files are in ~/obs/data/help (use grep keyword *) to find the right file for help on a specific keyword or phrase

atacmds (typing this gives a full list of all available ata commands
atasetazel (typing a specific ata command with no arguments gives help on that command)

DRIVING ANTENNAS: the following commands are helpful:

atasetazel 2a,2b 180 30 (sets ants 2a and 2b to az,el = 180,30)
atagetazel 2a,2b (returns current az,el for ants listed)
ataservostatus 2a (gives status of az & el motors)
ataresetservos 2a (resets servos if something is wrong, like the mstop redbutton was pushed in - it needs to be twisted back out before you can reset the servos)
ataofflimits 2a (drives antenna off az limit - this can happen if you drive through northern transit)

TRACKING:

ataephem moon (makes full day ephemeris for the moon - the source name must be in the default catalog - or a new one added) makes file called moon.ephem
atatrackephem 2a moon.ephem (tracks moon with antenna 2a)

UTILITIES:

atalistants all (lists status of all antennas)
atastatus (puts up 2 graphical displays of ant posns, temps, status, etc)
plottempmon plots temperatures of ants and boxes
atagpstrack interactive gps chooser, plotter, tracker
atagetpams 2a,2f get pam settings
atasetpams 2a,2f set pam settings
atasetskyfreq a 1422 set LO1-A to 1422 MHz
atafx4spectrum --queue fx4b -n plot autocorr spectra from fx4b correlator
atasetrpa 1,2,7,8 5 5 sets rpa dc pams for chanels 1,2,4 & 8
atacheck casa give rise/set times for casa

OBSERVING SCRIPTS (based around Gerry's ata routines) these all live in ~/bin. most need direct editing of at least some of the input parameters (eg. the actual antennas plugged into the correlators)

radpoint.csh does gps pointing using atafx4pointer (currently having java problems)
scan.csh does single interferometer scan on one source
obs.csh alternates between source and cal (both obs and scan are based on atasinglepoint)

FX8 CORRELATOR (see help file "fx8.notes" in help directory)

file: ~/data/help/fx8.notes (obs@tumulus) jrf - 06mar07

PART I

to run the fx8 correlator (from Gerry Harp - 29feb07)
---

on fx8a (ssh obs@fx8a; pw=b2rk2l2y) run xb8netcast
written by Dave MacMahon:

```
xb8netcast.rb tumulus 20000    # emits data packets to
                               tumulus on port 20000
```

run Gerry's server on tumulus to catch those packets

```
FX8Server
```

run Gerry's observing program anywhere to poll the server
and write a miriad file - eg:

```
atafx8 casa-fx8a 2aXD1,2fXD1,2gXD1,2hXD1,2kXD1,2lXD1,3cXD1,3dXD1
       tumulus -duration 60  -noabort -flip
```

(you should be tracking with the antennas and have lo-D set to the right frequency before beginning the scan which lasts 60 seconds)

NOTE: there are some semi-automated scripts written for the fx4 correlators which can be easily converted to call atafx8 instead of 'singlepoint', which is the program used to get data from the fx4 correlators. these obs scripts can be found on tumulus in the obs account at ~/bin/ (eg cals.csh; obs.csh; scan.csh). they all need to be explicitly setup for the current antenna and LO hookup using a text editor.

see also the help files in ~/data/help for more information the interferometer and other equipment.

PART II

to check the health of and setup the fx8 correlator
(from David MacMahon - 28feb07)
---

login to the fx8a correlator:

```
ssh obs@fx8a (pw=b2rk2l2y)

[obs@fx8a obs]$ fxinit          # initialize correlator
0:0x00000000=0x00000000->0x00000010
0:0x00000000=0x0000000e->0x0000001e
Setting initial bit selector values from '/opt/fx/etc/init_bitsel.fx8a'...OK
0:0x00000000=0x0000001e->0x0000000e
0:0x00000000=0x00000010->0x00000000
[obs@fx8a obs]$ fxoff           # turns fx8a off
0:0x00000000=0x00000000->0x00000010
0:0x00000000=0x0000000e->0x0000001e
[obs@fx8a obs]$ fxon            # turns fx8a on
0:0x00000000=0x0000001e->0x0000000e
0:0x00000000=0x00000010->0x00000000

[obs@fx8a obs]$ xaui.rb         # F-board & IBOB integrity check
top_downs: 0
bot_downs: 0                    # this shows health of the
top_syncs: 484                  # top & bottom halves of Fboard
bot_syncs: 484
top_2_bot: 134217727            # this is really -1 (these should
```

you can check the status of the ibob cards leds too. this will tell you if the walshes are synced up or not. the fx8 correlator faces the north wall of the correlator room (toward eshop). the 4 cards below the correlator chasis are the ibobs. just below the blue cables are four rows of 2 leds on each card. the top row should be off; the 2nd row should have all pairs blinking in sync once per second. the next pair down should have one or two leds lit (2nd and 4th counting from the left should have both lit). the 4th row down should be dark. the lone green led at bottom of the card is power. the leftmost one is not lit but that is normal.

here are some commands for changing parameters and getting data from the fx8 correlator.

```
xb8spect.rb      # dumps ascii file
intx.rb 256      # sets integration time (256 frames = 2.68 sec)
fx2mir.rb        # makes miriad file
```

a few diagnostic commands of Davids are also available, if a cable from the ibob board to the fx8 serial input port is connected. this provides a way of obtaining statistics of the levels at the samplers which is useful for correctly setting the input levels from the ants.

```
minicom                    # initialize serial port (ctrl-q to quit)
```

(if it hangs type "/usr/sbin/lsof /dev/ttyS0" to find open files and use kill to stop the process that is hanging up the port).

```
snapibob.sh ibob 1         # takes snapshot of the digitized data
```

use octave to analyze the data -

```
>load -force ibob n0.dat
> std(ibob)      # std of about 15 is good, which corresponds to about
                 # -40dbm on the SA with 5 MHz resolution bw
> max(ibob); mean(std(ibob_in0(1:16383,:)))
```

bit selection

```
--------------
bitsel.rb 1-8 1-1024 4          # sets bitsel 4 on all ants, all chans
```

(bit select values 0-7 picks which four bits in the stack of 8 bits of each word are used in the sampled data. values 8,9,10 are for testing (re,im=0,0 or 1,0 or -1,-1)

```
/obp/fx/etc/init_bitsel.fx8a    # current initialization settings
```

Some Observations of the moon with the FX4B and the FX8A and 8B. ~~at 6 GHz~~ 3C274 for calibrator

4/28/07 Stations 6 GHz

FX4: 2KX, 2LX, 3FX, 3GX

FX8A: 2AX, 2FX, 2GX, 2HX, 3CX, 3DX, 5BX, 5CX

FX8B: ~~2AY, 2DY, 2GY, 3CY, 3DY~~, 2AY, 2DY, 2FY, 2GY, 3CY, 3DY, 5BY, 5CY

lunar diameter: ~~1764.6~~ 1773.2"

4/29/07 FX4: 2HY, 2KY, 2LY, 3EY 6 GHz

FX8A: 2AX, 2FX, 2GX, 3CX, 3DX, 5BX, 5CX (7)

FX8B: 2AY, 2DY, 2FY, 2GY, 3CY, 3DY, 5BY, 5CY (8)

lunar diameter: ~~1766.6~~ 1766.9"

4/30/07 FX4: 2DY, 2HY, 3DY, 5EY 6 GHz

FX8A: 2AX, 2FX, 2GX, 2KX, 2LX, 3JX, 5BX, 5CX

FX8B: 2AY, 2FY, 2GY, 2KY, 2LY, 3EY, 5BY, 5CY

lunar diameter: ~~1765.7~~" 1764.5 @ 6UT

5/01/07 FX4: 5BY, 5CY, 5EY, 5HY

FX8A: 2AX, 2DX, 2FX, 2GX, 2HX, 2KX, 3DX, 5GX

2AY, 2DY, 2FY, 2GY, 2HY, 2KY, 3DY, 5GY

lunar diameter: ~~1765.5~~" 1765.4" @ 6UT

July
John Ross

Hat Creek Beamformer Room

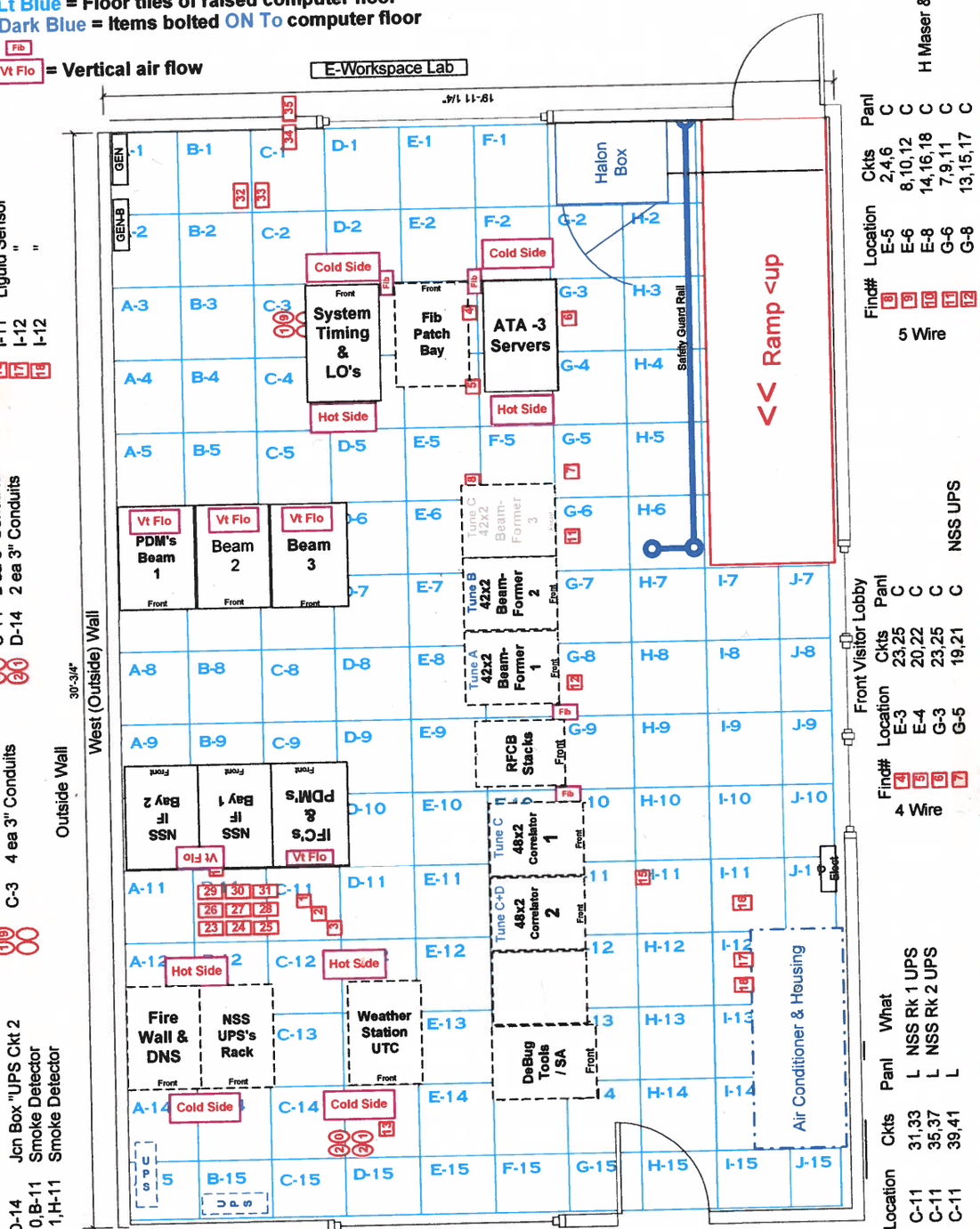
Page 6 by 1 July 2007

Notes:

1. Racks = RFI Shielded Or Non-shielded
2. Red = Items located under Computer floor
3. Lt Blue = Floor tiles of raised computer floor
4. Dark Blue = Items bolted ON To computer floor
6. Vt Flo = Vertical air flow

Grey'ed out = Space reserved. Not installed yet

HatCreekCRoomV10.vsd
Last Mod 5/30/07



Wires	Find#	Location	Ckts	Panl
4	23	B-11	22,24	GEN
3	24	B-11	18,20	GEN
3	25	B-11	14,16	GEN
3	26	B-11	10,12	GEN
3	27	B-11	6,8	GEN
3	28	B-11	2,4	GEN

Wires	Find#	Location	Ckts	Panl
5	29	B-11	13,15,17	GEN
3	30	B-11	9,11	GEN
3	31	B-11	5,7	GEN
4	32	B-1	2,4	GEN-B
4	33	C-1	6,8	GEN-B
3	34	B-0	10	GEN-B
4	35	E-Shp	1,3	GEN

Some rack dimensions 5/31/07

The HP units

a) The top hat sticks out front and back, but not to the side width is 21 3/8"

b) There are short welded square boxes on either side at the top that stick out 1 1/2". That adds 2" for 23 3/8" total, about 24". (They could be cut off)

c) Front to back is 28"

d) Some side shelves exist

e) top-bottom is 73" for rackspace

f) overall dimension is 78" on wheels

The RFCB crates

a) Height is 14"

b) depth is 21 1/4" w/o the extender plates

i) Check out the power connections (120 V) for the new racks

ii) Install the new optical fiber trays

iii) New racks

iv) Order cables for LO's; bring over single cables and use power splitters

v) Batteries for new UPS

vi) UPS for RFCB chassis (what load?) Use a surge suppressor

vii) power supply safety relay for H.C. LO divider chassis

viii) Walsh function cables

LO cable runs: direct under floor: 8.0 cm · 1.2 cm = 2' 13.3' on the floor

half way up the rack is 3' for each rack: 13.3 + 3 + 3 = 19.3'

20 feet should do 5 are needed

note: from [illegible](6) 6' of workhorse is 3.2 db loss @ 10 GHz

20' would be about 10 db @ 10 GHz or ~15 db @ 20 GHz

for db ∝ √f That's a lot of loss

If we put it in the 3rd RFCB slot (for now), the length is 6 + 3 + 3 = 12 feet, for about 2/3 of the loss, ~10 db @ 20 GHz

There is also 3 db loss in the power splitters.

DOMINION RADIO ASTROPHYSICAL OBSERVATORY, PENTICTON

Semflex, Inc.

HPI Series — "Vital Links™"

HIGH PERFORMANCE INTERCONNECT CABLE ASSEMBLY

HPI-190 Group — **Frequency Range: DC-28 GHz**

ELECTRICALS

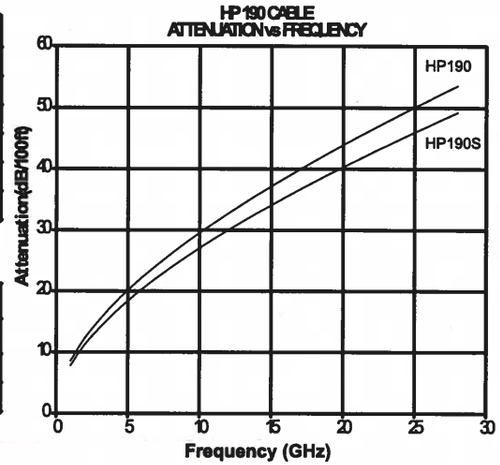
Velocity of Propagation	%	76.5
RF Leakage Min. @ 18GHz	dB/ft	-90
Impedance	Nominal	50
Capacitance	pF/ft (pF/m)	27 (88.58)
Delay	ns/ft (ns/m)	1.34 (4.40)
Breakdown Voltage	kV	>12
Phase Stability vs Flexure	deg/(deg of bend per GHz)	<.003

MECHANICAL/ENVIRONMENTAL

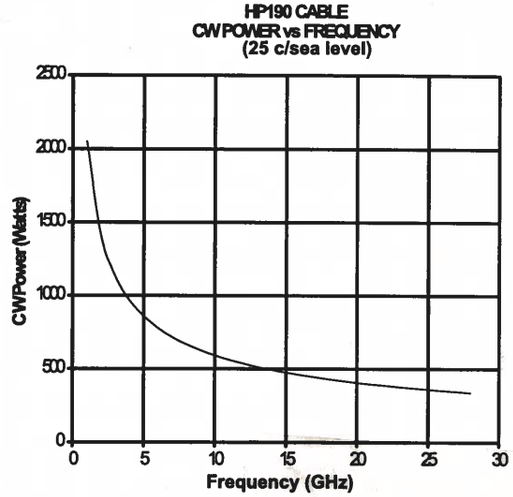
Nominal Diameter	inches (cm)	.205 (.521)
Minimum Bend Radius	inches (cm)	1.1 (2.794)
Temperature	DEG. C	-65/+200
Weight	lb./ft (g/m)	.05 (74.31)

MATERIALS AND FINISHES CONNECTOR

Body	Stainless steel



HP190S is solid center conductor
HP190 is stranded center conductor



5 26' lengths of this cable will be used for the LO's. The HP-190 shows 50db/100 feet @ 25GHz. So a 26' length should be 10.4db of loss.

Power levels

1. At input to LO distribution box
   a. LO1 ~ -10dbm
   b. LO2 ~ -28 dbm
2. To RFCB plates
   a. LO1 +2dbm
   b. LO2 -6 dbm

With available powers at synthesizer outputs of +15dbm the cable has of -10db amp power splitter has of -4db should be no problem. Adjust the pad inside of the LO2 box to get the right power level.

Correlator Room issues (6/7/07)

1. New rack will be shipped on Monday, arrive in Redding Tuesday, someone will drive down to get on Tuesday.

2. Clear out an HP rack on Friday (6/8/07) so a truck can be driven down on Monday to pick it up.

3. With both racks in the Correlator Room, the fiber cable trays can be installed.

4. Get a surge suppressor for the RFCB that could be put in the adjacent Beamformer rack.

5. Put the filters into bands B and C in the RFCBs in Berkeley before bringing them up to Hat Creek.

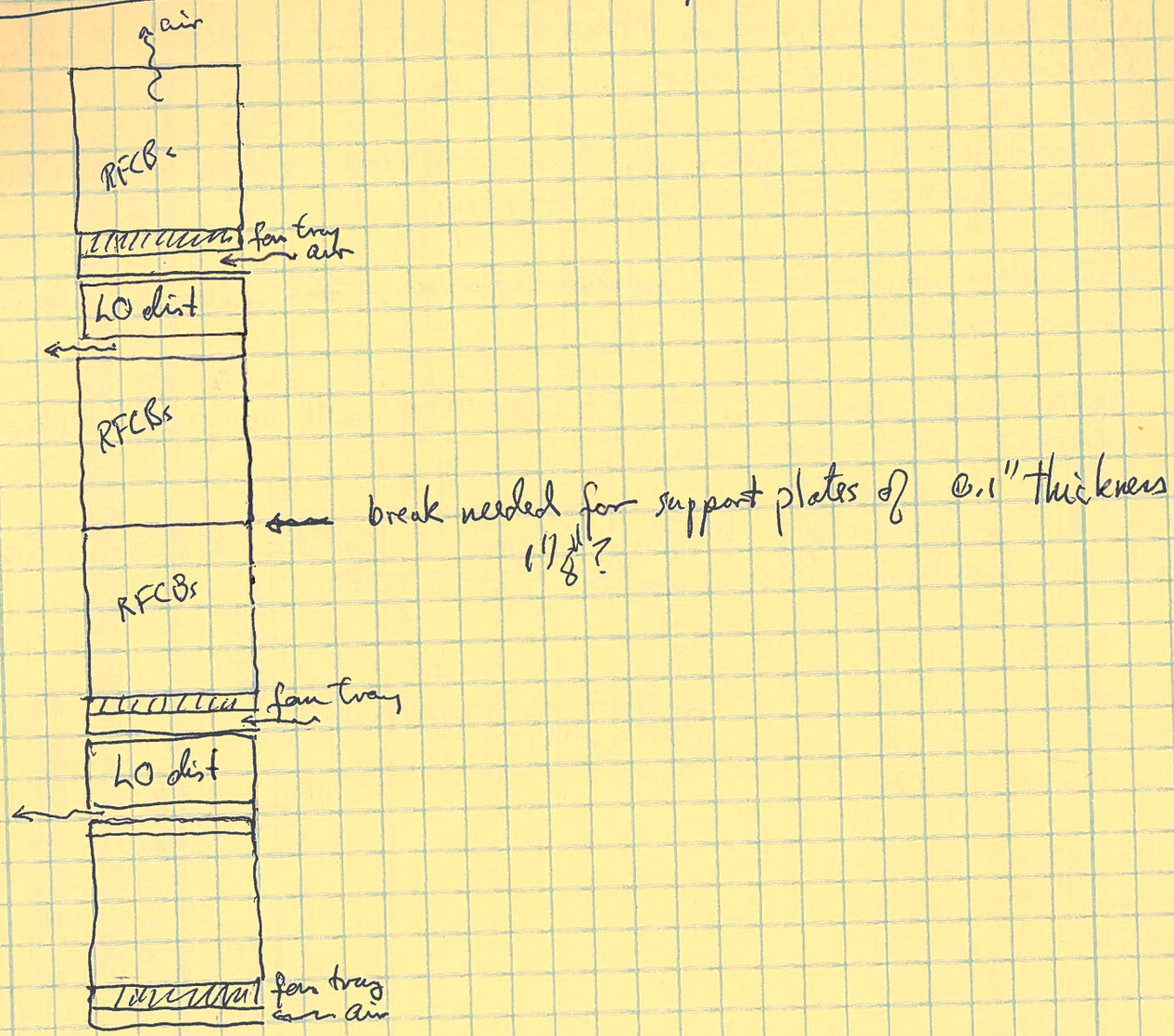
Jill's list of PAM settings

Single Optimal PAM Settings

Antenna	X	Y
2A	17	16
2D	14	12
2F	12	17
2G	16	
2H	17	22
2K	17	12
2L	14	17
3C	15	15
3D	22	22
3E		17
3J	14	15
3L	8	
5B		15
5C	16	16
5E	14	15
5G	18	16
5H		16

DOMINION RADIO ASTROPHYSICAL OBSERVATORY, PENTICTON

The new RFCB Rack with air flow



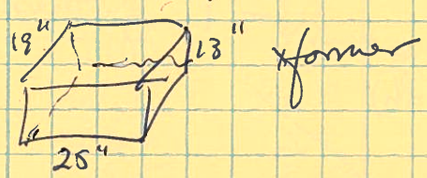
Node Cooling Problems 6/27/07

The node 3 fan motor kicked out its circuit breaker. It was reset, but many high receiver physical temperatures were observed.

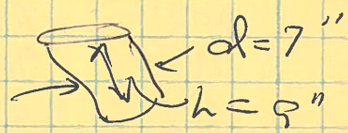
Gary made temperature measurements on the node fan motors:

node	door closed	door open 20 minutes.
1	136°F	125°F
2	170°F	164°F
3	168°F	165°F
4	129°F	125°F
5	122°F	118°F

Some further measurements in node 3: To the touch the transformer box felt substantially hotter than the motor, suggesting that it's temperature is higher ~ 180 - 200°F. This was at 6:30 PM (6/27/07).



motor



Transformer area: $25 \times 3 \times 2 + 19 \times 13 \times 2 + 25 \times 19 \times 2$
$= 2094$ sq. in.

Motor surface area: $\pi \times 7'' \times 9 + \frac{\pi}{4} 7^2 \times 2 = 274$ sq in.

The area of the transformer is 7.6 times greater than that of the motor shell. So it's what's heating the internal air.

Nodes 1, 4, and 5 have reasonable motor temperatures. The 170F temperatures in nodes 2 and 3 are high compared with ambient temperatures of $\lesssim 120$F. So outside air should be able to cool the node interiors.

(a) Blowing air from the plenum i) robs the antennas of air, and ii) does nothing to exhaust the interior warm air.

A simple vent would help. Adding a fan, blowing outside air onto the ~~motor~~ would cool it and force the warm interior air out the vent.

Setting LO powers for cable losses 6/28/07 WJW/RF/DM

I. LO_2 needed a 10 db pad on it's output to get −6 db at the RFCB input

II LO1 Channel c ±1 dbm is needed.

Power settings for +1 dbm at RFCB input.

ν (GHz)	Synth B setting	$4.0\left(\frac{\nu}{16}\right)^{1.5}$	Synth B setting
15	+4 dbm		12 (−3.5 @ RFCB)
15.5	6.0		11.7 (for +1.0)
16.0	4.6	4.0	8.4 "
16.5	3.0		6.5 "
17.0	0 dbm	4.4	2.2
17.5	3.5		5.2
18.0	3.7	4.8	4.0
18.5	4.5		5.3
19.0	5.0	4.7	4.8
19.5	6.2		6.1
20.0	5.0	5.6	5.9
20.5	7.4		12 (−7.2 @ RFCB)
21.0	9.0	6.0	12 (0.5 db)
21.5	6.4		9.0
22.0	6.5	6.5	9.9
22.5	6.4		12.0 (−2.9)
23.0	8.0	6.9	9.8
23.5	9.8		7.6
24.0	5.2	7.4	3.2
24.5	5.5		1.5
25.0	11.0	7.8	11.0
25.5	9.8		8.5
26.0	9.7	8.3	4.5

Problems with the synthesizers

The filter center frequency is 15.5. For an input frequency of 500 MHz, LO1 = 16.0. For 11.2 GHz, it is 26.7.

The scatter is very large. Even so the expression $4.0\left(\frac{\nu}{16}\right)^{1.5}$ fits most of the data pretty well with a few errors of ±3 db. Errors are mostly 1–2 db.

A synthesizer:	HP	83711A	1–20 GHz
B	AG	836302	1–26.5 GHz
C	AG	E8257D	–40 GHz
D	AG	E8247C	40 GHz

7/9/07 #C synthesizer now works

Power settings for +4 dbm at RFCB input

V	Synth C setting	$3.0(V/16)^{1.5}$
15.5	+4.0 dbm	
16.0	+2.0 dbm	3.0
16.5	1.0	3.1
17.0	–0.5 dbm	3.2
17.5	2.8 dbm	3.4
18.0	1.8 dbm	3.6
18.5	3.6 dbm	3.7
19.0	+5.1	3.9
19.5	4.3	4.0
20.0	3.3	4.2
20.5	7.1	4.4
21.0	6.1	4.5
21.5	4.3	4.7
22.0	3.5	4.8
22.5	2.5	5.0
23.0	1.8	5.2
23.5	6.5	5.3
24.0	3.2	5.4
24.5	2.0	5.8
25.0	+10.0	5.8
25.5	8.5	6.0
26.0	+1.5	6.1
GHz	dbm	

It's roughly the same as the other curve. It should be within ±1 db because most of it comes from the LO distributor box.

DOMINION RADIO ASTROPHYSICAL OBSERVATORY, PENTICTON

Receivers needing replacement 7/31/07 Navy

I. one pol dead 2EX, 2MX, 3EX, 3FY, 3L (both) ①, 4EX } ⑥

II. one pol weak 3GY, 3HX, 5AX, 1EY ④

III. cryos not regulating

③ 1f shorted dewar diode
2f dewar diode cathode shorted to shield
✓2J cryo power shorted to shield
5G dewar will not pump down
5e dewar will not pump down

} 15 total

A total of 15 need to be sent back to Minex

4L has just had it's light connection fixed. Both pols are good.

3L has both pols dead. There are five with one pol dead. There are four others with one pol weak. There are five others with cryo problems, mostly poor or non-existent regulation.

Plan Cycle two/week through Minex.

[budget for completion, including parts and labor]

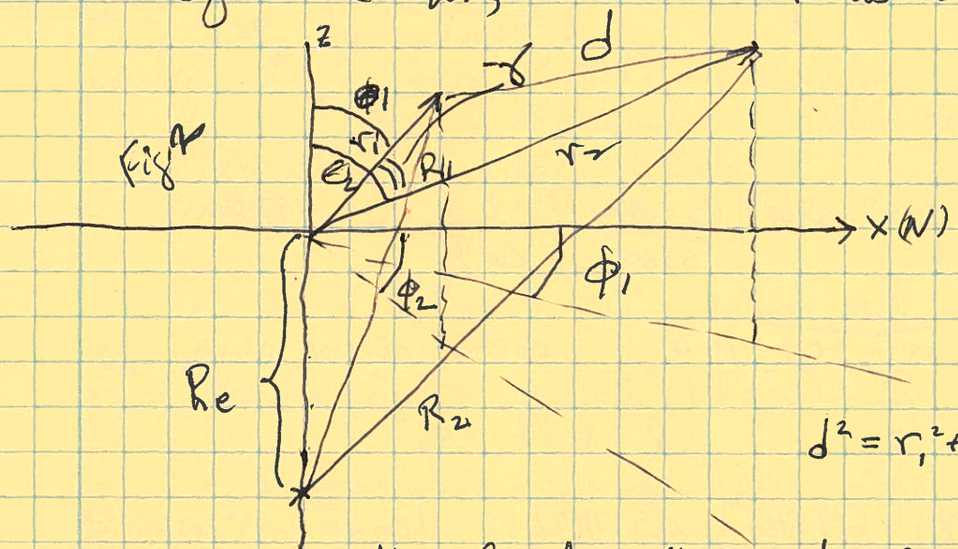
The six antennas for the Navy are: 2J, 2M, 2C, 2E, 2B, 4E

[2E and 4E are the next 2 for revision]

Distances to orbiting space craft in terms of their available ephemerides: Differential delays and Doppler shifts.

Assume the space craft execute circular orbits about the center of the earth, circular orbits as a first approximation.

Fig 4



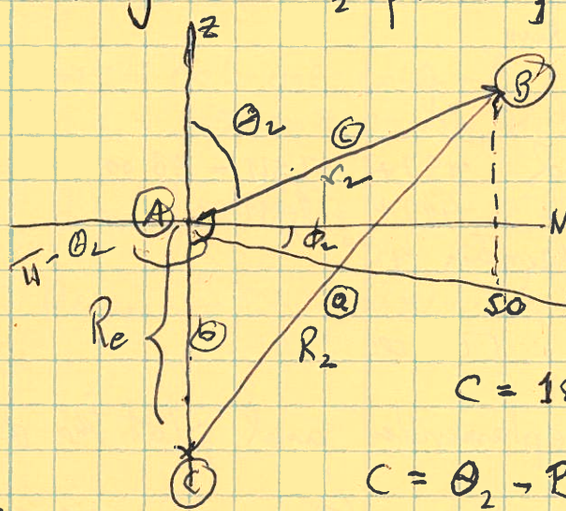
R_1 and R_2 are known constants.

$$d^2 = r_1^2 + r_2^2 - 2r_1 r_2 \cos\gamma$$

r_2 is the direct path; $r_1 + d$ is the scattered path.

For just the r_2 path, a simpler diagram.

Fig 1



The triangle is in a plane which contains the z-axis, r_2, R_2 and θ_2

$$\sin B = \frac{b \sin A}{a} = \frac{R_e \sin(\pi - \theta_2)}{R_2} = \frac{R_e \sin\theta_2}{R_2}$$

so $B = \sin^{-1}\left[\frac{R_e \sin\theta_2}{R_2}\right]$

$$C = 180 - (A+B) = 180 - [(\pi - \theta_2) + B] = \theta_2 - B$$

$$C = \theta_2 - B = \theta_2 - \sin^{-1}\left[\frac{R_e \sin\theta_2}{R_2}\right]$$

$r_e \equiv R_e$

$$r_2 = c = \frac{a \sin C}{\sin A} = R_2 \sin\left\{\theta_2 - \sin^{-1}\left[\frac{r_e \sin\theta_2}{R_2}\right]\right\} \frac{1}{\sin(\pi - \theta_2)}$$

$$\doteq R_2 \sin\left\{\theta_2 - \sin^{-1}\left[\frac{r_e \sin\theta_2}{R_2}\right]\right\} \frac{1}{\sin\theta_2}$$

$$= R_2 \sin\left\{\frac{\pi}{2} - E_2 - \sin^{-1}\left[\frac{r_e \cos E_2}{R_2}\right]\right\} \frac{1}{\cos E_2}$$

A few rough numbers. $r_2 = ?$

$R_2 \cong 42{,}000$ km, $R_e \cong$ ~~6000~~ 6378.2 km, $R_1 = \cong 6360$ km, $E_2 \cong 45°$

$$r_2 = 42{,}000 \sin\left\{45° - \sin^{-1}\left[\frac{6000\,(.707)}{42{,}000}\right]\right\}\frac{1}{.707} = \underline{37{,}548 \text{ km}}$$

For $E_1 = 45°$

$$r_1 = R_1 \sin\left\{45° - \sin^{-1}\left[\frac{R_e \cos \pi/4}{6360}\right]\right\}\frac{1}{\cos \pi/4} = 497 \text{ km}$$

Then $d = \sqrt{r_1^2 + r_2^2 - 2r_1 r_2 \cos\gamma}$; $\cos\gamma = \cos E_1 \cos E_2 \cos(A_{z_1} - A_{z_2}) + \sin E_1 \sin E_2$

For $A_{z_1} - A_{z_2} = 180°$ and $E_1 = E_2 = 45°$

$$d = \left\{(497)^2 + (37{,}548)^2 - 2(497)(37{,}584)\left[\cos 45 \cos 45 \cos 180 + \sin 45 \sin 45\right]\right\}^{1/2}$$

$= 37{,}551$ km

For $A_{z_1} - A_{z_2} = 0°$, $d = 37{,}051$ km

The two paths are r_2 and $r_1 + d$

37,548 and 497 + 37,511 = 38,008

497 + 37,551

$\Delta d \cong 500$ km at this elevation, 45°.

$\Delta t = 500 \text{ km} / 3 \times 10^5 \text{ km/sec} = 1.7$ m sec.

Get the accurate numbers and ephemerides and plot the delay.

These numbers are for two spacecraft, one in geosynch and the other at the orbit of the space station. Or it should work for distances between any two spacecraft. For the radar, the source is assumed to be at r_2.

$$\Delta \text{ delay} = [r_2 - (r_1 + d)]/c$$

Ephemerides for the space craft. [Some are on-line already]

Hat Creek location (Cassel, CA)

West longitude $121°28.4' = 121.4718027$

Latitude $40°49.1' = 40.817361$ N

Approximate location of XM Roll [85° in Geosynch] and XM Rock* [115° in Geosynch] relative to Hat Creek.

XM Rock* $A_z = 170.1°$, $El = 42.3°$

XM Roll $A_z = 131.4°$, $El = 29.9°$

Take r_2 to be fixed at XM Rock, with $A_{z_2} = 170.1°$ $El_2 = 42.3°$ (ok within ~1 degree)

$$r_2 \cong 42{,}000 \sin\left\{\frac{\pi}{2} - E_2 - \sin^{-1}\left[\frac{R_e \cos E_2}{R_2}\right]\right\} \frac{1}{\cos E_2}$$

$$= 42{,}000 \sin\left\{90 - 42.3 - \sin^{-1}\left[\frac{6000 \cos(42.3)}{42{,}000}\right]\right\} \frac{1}{\cos 42.3} = \underline{37{,}726}$$

$$r_1 \cong 6720 \sin\left\{90° - E_1 - \sin^{-1}\left[\frac{\overset{6378.2}{\cancel{6000}} \cos E_1}{6720}\right]\right\} \frac{1}{\cos E_1}$$

$$\cos\gamma = \cos E_1 \cos E_2 \cos(A_{z_1} - A_{z_2}) + \sin E_1 \sin E_2$$

$$= .7396 \cos E_1 \cos(A_{z_1} - 170.1) + .673 \sin E_1$$

$$d = \left[(37{,}726)^2 + (r_1)^2 - 2r_1[37{,}726] \cos\gamma\right]^{1/2}$$

Memo in: /ralf/welch/1HT/DOD/satellite_ephem.pdf
Observations_ISS.pdf (res figures)

from (1986)

RADIO FLUX CALIBRATORS, J2000.0

Source	Right Ascension	Declination	S_{400}	S_{750}	S_{1400}	S_{1665}	S_{2700}	S_{5000}
	h m s	° ′ ″	Jy	Jy	Jy	Jy	Jy	Jy
3C48 [e]	1 37 41.244	+33 09 35.40	39.4	25.6	15.9	13.9	9.20	5.24
3C123	4 37 04.3	+29 40 15	119.2	77.7	48.7	42.4	28.5	16.5
3C147 [e, g]	5 42 36.073	+49 51 07.23	48.2	33.9	22.4	19.8	13.6	7.98
3C161	6 27 12.0	− 4 10 39	41.2	28.9	19.0	16.8	11.4	6.62
3C218	9 18 07.3	−10 19 33	134.6	76.0	43.1	36.8	23.7	13.5
3C227	9 47 46.4	+ 7 25 12	20.3	12.1	7.21	6.25	4.19	2.52
3C249.1	11 04 11.4	+76 59 01	6.1	4.0	2.48	2.14	1.40	0.77
3C274 [f]	12 30 49.5	+12 23 21	625	365	214	184	122	71.9
3C286 [e]	13 31 08.289	+30 30 32.93	25.1	19.7	14.8	13.6	10.5	7.30
3C295	14 11 20.6	+52 12 09	54.1	36.3	22.3	19.2	12.2	6.36
3C348	16 51 08.2	+04 59 26	168.1	86.8	45.0	37.5	22.6	11.8
3C353	17 20 29.4	− 0 57 02	131.1	88.2	57.3	50.5	35.0	21.2
DR 21	20 39 01.1	+42 19 45	—	—	—	—	—	—
NGC7027 [d]	21 07 01.5	+42 14 10	—	—	1.35	1.65	3.5	5.7

Source	S_{8000}	S_{10700}	S_{15000}	S_{22235}	Spec.	Ident.	Polarization (at 5 GHz)	Angular Size (at 1.4 GHz)
	Jy	Jy	Jy	Jy			%	″
3C48 [e]	3.31	2.46	1.72	1.11	C−	QSS	5	<1
3C123	10.6	7.94	5.63	3.71	C−	GAL	2	20
3C147 [e, g]	5.10	3.80	2.65	1.71	C−	QSS	<1	<1
3C161	4.18	3.09	2.14	—	C−	GAL	5	<3
3C218	8.81	6.77	—	—	S	GAL	1	core 25, halo 200
3C227	1.71	1.34	1.02	0.73	S	GAL	7	180
3C249.1	0.47	0.34	0.23	—	S	QSS	—	15
3C274 [f]	48.1	37.5	28.1	—	S	GAL	1	halo 400 [a]
3C286 [e]	5.38	4.40	3.44	2.55	C−	QSS	11	<5
3C295	3.65	2.53	1.61	0.92	C−	GAL	0.1	4
3C348	7.19	5.30	—	—	S	GAL	8	115 [b]
3C353	14.2	10.9	—	—	C−	GAL	5	150
DR 21	21.6	20.8	20.0	19.0	Th	HII	—	20 [c]
NGC7027 [d]	—	6.43	6.16	5.86	Th	PN	<1	10

a) Halo has steep spectral index, so for $\lambda \leq 6$ cm, more than 90% of the flux is in the core. Spectrum curves positively above 20 GHz.
b) Angular distance between the two components.
c) Angular size at 2 cm, but consists of 5 smaller components.
d) Data up to 5 GHz are the direct measurements, not calculated from fit.
e) Suitable for calibration of interferometers and synthesis telescopes.
f) Virgo A.
g) Indications of time variability above 5 GHz.

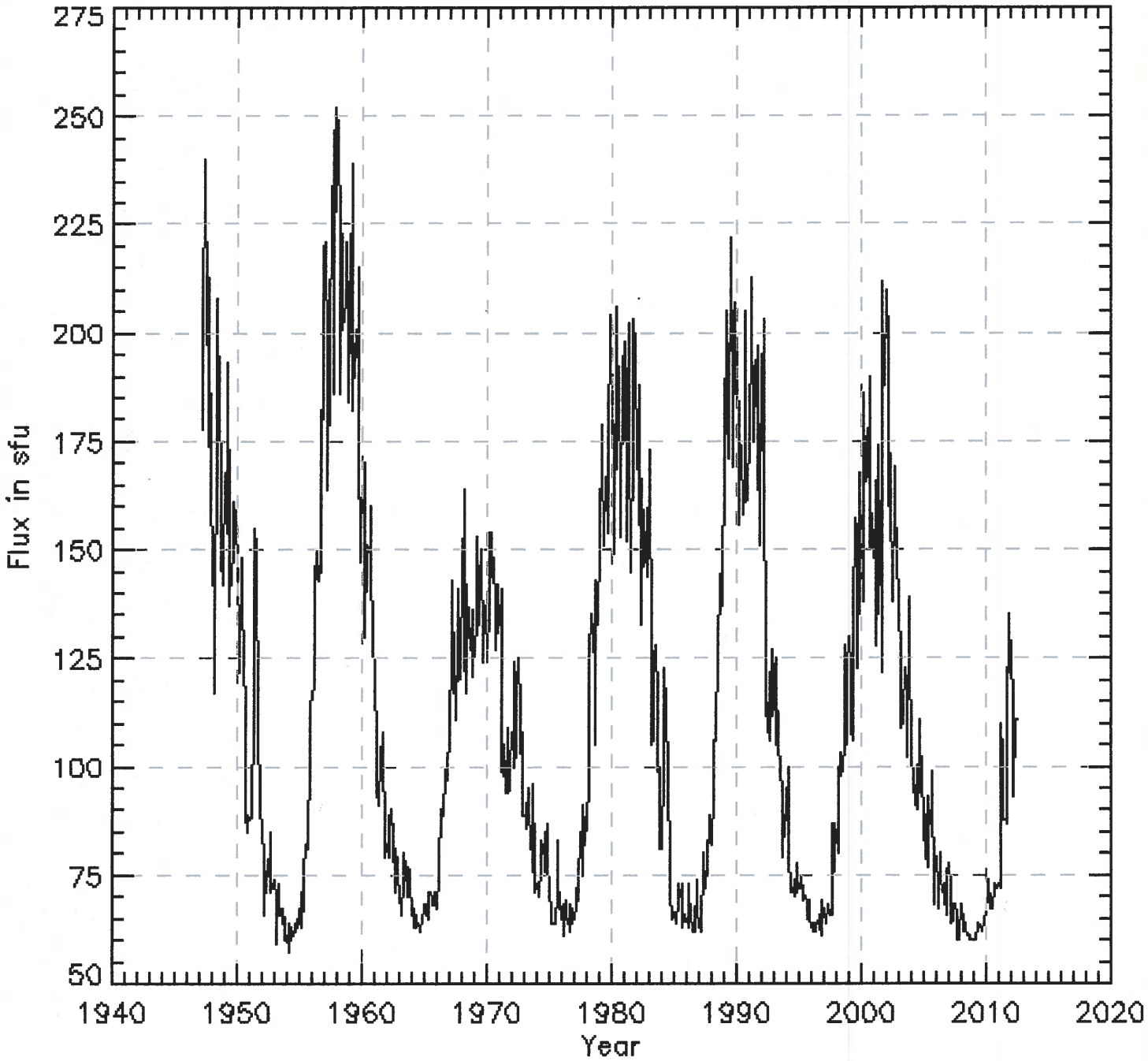
IAU Designation	Name	Right Ascension	Declination	S_{5GHz}
		h m s	° ′ ″	Jy
0003−066		0 06 13.895	− 6 23 35.34	1.5
0016+731		0 19 45.787	73 27 30.07	1.7
0019−000	4C+00.02	0 22 25.43	0 14 56.2	1.1
0022−423		0 24 42.992	−42 02 03.58	1.5
0026+346		0 29 14.241	34 56 32.24	1.2
0056−001	4C−00.06	0 59 05 5143	0 06 51.74	1.4
0107+562	4C+56.02	1 10 57.559	56 32 16.93	0.8
0112−017		1 15 17.094	− 1 27 04.58	0.9
0116+319	4C+31.04	1 19 35.001	32 10 50 03	1.5
0119+041		1 21 56.861	4 22 24.72	1.1
0133+476		1 36 58.5954	47 51 29.114	2.0
0135−247		1 37 38.346	−24 30 53 82	0.7
0138−097		1 41 25.831	− 9 28 43.68	1.2
0146+056		1 49 22.38	5 55 53.5	0.9
0149+218		1 52 18.06	22 07 07.8	1.4
0153+744		1 57 34.976	74 42 43.26	1.1
0202+319		2 05 04 926	32 12 30.05	1.2
0202−172		2 04 57.675	−17 01 19.79	1.2
0212+735		2 17 30.8211	73 49 32.639	2.2
0235+164		2 38 38.928	16 36 59.19	1.4
0237−233		2 40 08.1770	−23 09 15.862	0.9
0256+075		2 59 27.08	7 47 39.6	0.8
0300+470	4C+47.08	3 03 35.2427	47 16 16.293	0.0
0316+161	3C83.1	3 18 57.804	16 28 32.68	2.9
0316+413	3C84	3 19 48.1614	41 30 42.115	56.0
0319+121		3 21 53.101	12 21 14.02	1.1
0332−403		3 34 13.654	−40 08 25.41	1.5
0333+321	4C+32.14	3 36 30.108	32 18 29.350	2.4
0336−019		3 39 30.938	− 1 46 35.859	2.6
0400+258		4 03 05.578	26 00 01.51	1.2
0414−189		4 16 36.546	−18 51 08.28	1.3
0420−014		4 23 15.8016	− 1 20 33.02	3.1
0428+205		4 31 03.753	20 37 34.25	2.3
0430+052	3C120	4 33 11.0959	5 21 15.601	3.3
0438−436		4 40 17.1795	−43 33 08.62	3.9
0440−003		4 42 38.6615	− 0 17 43.43	1.5
0454+844		5 08 42.335	84 32 04.56	1.6
0457+024		4 59 52.048	2 29 31.06	1.2
0458−020	4C−02.19	5 01 12.81	− 1 59 13.8	1.9
0528−250		5 30 07.965	−25 03 29.81	0.8
0552+398		5 55 30.806	39 48 49.16	4.7
0600+442		6 04 29.144	41 13 58.9	0.7
0607−157		6 09 40.9493	−15 42 40.68	2.4
0609+607		6 14 23.859	60 46 21.81	1.1
0615+820		6 26 03.00	82 02 25.64	1.0

3C147/0552+398

Monthly averages of 10.7 cm Solar Radio Flux

REGIONAL WARNING CENTRE CANADA

Generated: 2012-07-16 02:05 UT



Data courtesy of National Research Council of Canada (NRC)

DOMINION RADIO ASTROPHYSICAL OBSERVATORY, PENTICTON

Canada

$Id: beamformer-cal-sources.html,v 1.6 2008/07/31 16:00:18 kilsdonk Exp $

Beamformer cal sources:

==========

Delay cal (bright, possibly extended sources)

Name	Aliases	JY@1.4GHZ
3c144	TauA	875
3c145	OriA,M42	520
3c274	VirA	198
3c292	-	171
3c400	-	576
3c405	CygA	1495
3c461	CasA	2477

==========

Phase cal (nonextended sources)

Note:
(X) = not recommended in VLA catalog for this band
(-) = no flux value in VLA catalog for this band

Name	Aliases	JY@1.5GHZ	JY@5GHZ	JY@8Ghz	Type
3c48		16	5	3	quasar
3c84		24 (X)	23	22	Seyfert galaxy
3c123		47 (-)	16 (-)	10 (-)	galaxy
3c147		23	8	5	quasar
0555+398		2	5	6	quasar
3c161		19 (X)	6 (-)	4 (-)	quasar
0927+390	4C39.25	7 (X)	7	7	Seyfert galaxy
3c286		15	7	5	quasar
3c295		23	6 (X)	3 (-)	galaxy
3c345		8	8	7 (X)	quasar
1733-130		5	5	10	quasar
3c380		14	3 (X)	3 (X)	Seyfert galaxy
3c454.3	2253+161	10	10	11	quasar
	mean (QSO)	12	<7> QSO		

Additional sources from VLA list:

Name	Aliases	JY@1.5GHZ	JY@5GHZ	JY@8Ghz	Type
0025-260		8	3	2	
0240-231		6	3	1	
0318+164		8	3	1	
0359+509		5	10	5	
0410+769		6	3	2	
3c119		8	4	2	
0440-435		5	3	3	
3c138		8	4	2	
0534+194		7	2	- (-)	
0744-064		8	3	1	
0834+555		9	5	3	
1130-148		5	4	3	
1154-350		5	2	1	

1248-199	5	2	1
1311-222	5	1	- (-)
3c287	7	3	2
1347+122	5	3	2
3c298	6	- (-)	- (-)
3c309.1	7	3	2 (X)
1822-096	5	- (-)	1
1830-360	7	1	- (-)
1833-210	11	- (-)	6 (X)
1924-292	6 (X)	6	6
1941-154	6	2 (X)	- (-)
2035-349	5	0 (X)	- (-)
2038+513	6	3 (X)	- (-)
BLLAC	6	5	4
2206-185	6	4 (X)	3 (X)
3C446	6	4	5
2232+117	6	4	3
3C468.1	5	1	- (-)

From:

VLA recommendatiaons:
http://www.vla.nrao.edu/astro/calib/manual/csource.html

Garrett says we're closest to the "D" configuration.
"S" or "P" is usable (P is better), and "X" is right out.

Also:

- ftp://ftp.aoc.nrao.edu/pub/staff/mclausse/calman/csource.mas
- http://adsabs.harvard.edu/abs/1977A&A....61...99B
- Handbook of Space Astronomy & Astrophysics
- Astronomical Almanac
- http://www.gb.nrao.edu/~ykovalev/GBTgain/Cband/

For additional targets see also at HC:
/data/tumulus/obs/schedule/cals.list

20 cm = 1500 MHz
6 cm = 5000 MHz
3.7 cm = 8100 MHz

IAU Designation	Name	Right Ascension	Declination	S_{5GHz}
		h m s	° ′ ″	Jy
0642+449		6 46 32.016	44 51 16.61	0.7
0710+439		7 13 38.19	43 49 17.0	1.6
0711+356		7 14 24.8194	35 34 39.777	1.2
0716+714		7 21 53.449	71 20 36.44	1.1
0727−115		7 30 19.1129	−11 41 12.616	3.0
0733−174		7 35 45.815	−17 35 48.40	1.9
0735+178		7 38 07.3945	17 42 18.993	2.1
0736+017		7 39 18.032	1 37 04.64	2.2
0738+313		7 41 10.7040	31 12 00.230	1.6
0742+103		7 45 33.0601	10 11 12.681	3.6
0748+126		7 50 52.043	12 31 04.70	1.5
0804+499		8 08 39.664	49 50 36.55	1.1
0814+425		8 18 16.0002	42 22 45.424	1.6
0823+033		8 25 50.333	3 09 24.45	1.0
0826−373		8 28 04.7811	−37 31 06.27	1.8
0828+493		8 32 23.217	49 13 21.02	1.5
0831+557	4C+55.16	8 34 54.9044	55 34 21.074	5.5
0833+585		8 37 22.406	58 25 01.88	1.2
0836+710	4C+71.4	8 41 24.367	70 53 42.206	2.5
0839+187		8 42 05.094	18 35 40.97	1.0
0851+202	3C287	8 54 48.8757	20 06 30.628	2.8
0859−140		9 02 16.8317	−14 15 30.895	2.1
0906+015	4C+01.24	9 09 10.11	1 21 34.8	1.4
0917+624		9 21 36.236	62 15 52.14	1.2
0919−260		9 21 29.356	−26 18 43.37	2.1
0923+392	4C+39.25	9 27 03.0149	39 02 20.849	7.6
0941−080		9 43 36.946	− 8 19 30.86	1.0
0954+658		9 58 47.248	65 33 54.813	0.6
1015−314		10 18 09.274	−31 44 14.11	1.3
1030+415		10 33 03.708	41 16 06.17	0.6
1031+567		10 35 07.047	56 28 46.77	1.2
1032−199		10 35 02.156	−20 11 34.35	0.9
1034−293		10 37 16.086	−29 34 02.79	1.9
1039+811		10 44 23.086	80 54 39.45	0.8
1117+146	4C+14.41	11 20 27.806	14 20 54.93	1.1
1127−145		11 30 07.053	−14 49 27.400	4.7
1145−071		11 47 51.558	− 7 24 41.17	1.0
1148−001	4C−00.47	11 50 43.8713	− 0 23 54.219	1.9
1150+812		11 53 12.516	80 58 29.09	1.2
1155+251		11 58 25.793	24 50 17.93	0.9
1213+350	4C+35.28	12 15 55.599	34 48 15.09	0.9
1216+487		12 19 06.421	48 29 56.09	1.0
1219+285		12 21 31.693	28 13 58.43	2.0
1226+023		12 29 06.700	2 03 08.581	45.8
1237−101		12 39 43.066	−10 23 28.76	1.0

IAU Designation	Name	Right Ascension	Declination	S_{408}
		h m s	° ′ ″	Jy
1243−072		12 46 04.235	− 7 30 46.63	1.4
1245−197		12 48 23.8997	−19 59 18.70	2.3
1252+119		12 54 38.254	11 41 05.85	1.0
1255−316		12 57 59.071	−31 55 17.0	1.0
1302−102		13 05 33.018	−10 33 19.5	1.0
1308+326		13 10 28.66	32 20 43.7	2.5
1311+678	4C+67.22	13 13 27.985	67 35 50.368	0.9
1323+321	4C+32.44	13 26 16.514	31 54 09.40	2.3
1328+254	3C287	13 30 37.691	25 09 10.85	3.2
1328+304	3C286	13 31 08.2889	30 30 32.927	7.4
1334−127		13 37 39.784	−12 57 24.710	1.9
1345+125	4C+12.50	13 47 33.358	12 17 24.20	2.7
1354−152		13 57 11.241	−15 27 28.75	1.5
1354+195	4C+19.44	13 57 04.435	19 19 07.37	1.8
1358+624		14 00 28.650	62 10 38.53	1.7
1404+286		14 07 00.394	28 27 14.67	3.0
1418+546		14 19 46.594	54 23 14.72	0.7
1435+638		14 36 45.800	63 36 37.86	0.9
1442+101		14 45 16.462	9 58 36.03	1.1
1502+106	4C+10.39	15 04 24.9800	10 29 39.169	2.1
1504−166		15 07 04.788	−16 52 30.15	2.4
1511+238	4C+23.41	15 13 40.186	23 38 35.19	0.8
1514−241		15 17 41.819	−24 22 19.35	2.4
1519−273		15 22 37.683	−27 30 10.62	2.0
1546+027		15 49 29.436	2 37 01.14	1.3
1547+507		15 49 17.469	50 38 05.769	0.7
1555+001		15 57 51.4337	− 0 01 50.425	1.2
1600+355		16 02 07.262	33 26 53.08	2.1
1607+268		16 09 13.318	26 41 29.0	1.7
1611+343		16 13 41.065	34 12 47.907	2.2
1624+416	4C+41.32	16 25 57.669	41 34 40.58	1.1
1633+382	4C+38.41	16 35 15.494	38 08 04.47	1.9
1637+574		16 38 13.461	57 20 23.9	1.6
1638+124	4C+12.60	16 40 47.932	12 20 02.13	1.0
1638+398	MK501	16 40 29.633	39 46 46.02	0.8
1641+399	3C345	16 42 58.8084	39 48 36.965	7.8
1652+398	4C+39.49	16 53 52.23	39 45 36.5	1.2
1732+389		17 34 20.576	38 57 51.41	1.3
1739+522	4C+51.37	17 40 36.99	52 11 43.5	1.9
1741−038		17 43 58.8578	− 3 50 04.635	2.2
1748−253		17 51 51.263	−25 23 59.80	0.5
1749+701		17 48 32.841	70 05 50.760	1.2
1749+096		17 51 32.815	9 39 00.70	1.6
1751+441		17 53 22.650	44 09 45.68	0.8
1803+784		18 00 45.668	78 28 04.02	2.5

3C286/3C287

IAU Designation	Name	Right Ascension	Declination	S_{5GHz}
		h m s	° ′ ″	Jy
1821+107		18 24 02.849	10 44 23.77	1.1
1921−293		19 24 51.0577	−29 14 30.17	6.8
1928+738	4C+73.18	19 27 48.4908	73 58 01.557	3.0
1933−400		19 37 16.209	−39 58 00.9	0.7
1947+079		19 50 05.538	8 07 13.93	1.2
1958−179		20 00 57.091	−17 48 57.67	1.2
2007+776		20 05 31.002	77 52 43.22	1.0
2021+614		20 22 06.681	61 36 58.802	2.3
2106−413		21 09 33.183	−41 10 20.47	2.2
2113+293		21 15 29.42	29 33 38.2	0.8
2128+048	3CR433	21 30 32.873	5 02 17.47	2.1
2128−123		21 31 35.261	−12 07 04.76	2.4
2131−021	4C−02.81	21 34 10.303	− 1 53 17.27	1.9
2134+004		21 36 38.5851	0 41 54.22	10.3
2136+141		21 39 01.302	14 23 36.00	1.2
2144+092		21 47 10.159	9 29 46.65	0.7
2145+067	4C+06.65	21 48 05.458	6 57 38.614	2.5
2149+056		21 51 37.868	5 52 12.93	1.0
2150+173		21 52 24.813	17 34 37.81	0.7
2200+420		22 02 43.2903	42 16 39.982	2.4
2203−188		22 06 10.413	−18 35 38.76	4.1
2210−257		22 13 02.497	−25 29 30.17	0.9
2216−038	4C−03.79	22 18 52.034	− 3 35 36.91	3.2
2227−088		22 29 40.082	− 8 32 54.44	1.2
2227−399		22 30 40.271	−39 42 52.03	0.6
2230+114	4C+11.69	22 32 36.4089	11 43 50.905	3.6
2234+282		22 36 22.467	28 28 57.40	1.3
2243−123		22 46 18.232	−12 06 51.276	2.4
2245−328		22 48 38.687	−32 35 51.88	1.8
2251+158	3C454.3	22 53 57.748	16 08 53.561	10.2
2254+074		22 57 17.302	7 43 12.28	0.5
2255−282		22 58 05.86	−27 58 23.04	1.6
2318+049		23 20 44.853	5 13 49.96	0.8
2319+272		23 21 59.861	27 32 46.41	0.8
2328+107		23 30 40.851	11 00 18.69	1.1
2329−162		23 31 38.654	−15 56 56.98	0.9
2331−240		23 33 55.28	−23 43 41.9	1.0
2337+264		23 40 29.0281	26 41 56.829	0.8
2344+092		23 46 36.837	9 30 45.51	1.9
2345−167		23 48 02.6089	−16 31 12.037	2.7
2351+456		23 54 21.68	45 53 04.2	1.2
2352+495		23 55 09.458	49 50 08.30	1.6

~~ssh obs@ blake.hcro.org~~

ssh -X welch@blake.hcro.org pw: w3lch [password for chrys]

ssh -X obs@tumulus pw: ~~

Ricks Command Files


```
file ~/archive/schedule/obshelp.txt                    jrf - 21sep07

help     see ~/archive/help:  look for useful help file name, or grep for
----     keywords in all files (eg: grep -i servo *).
         also see "notes" files in dated directories (eg: 0919/notes)
         >>> please keep log of obs problems and any other useful info
             in a "notes" file in the current day's top directory.

scheduling and observing - cd ~/archive/schedule
------------------------
must ssh obs@tumulus (b2rk212y) to run observations. this may change soon.

useful files in ~/archive/schedule:
------------
schedule.2007-09.txt  - graphical description of observations for sept07
catalog.list - add new sources here (make name unique; use j2000)
cals.list - list of recommended phase calibrators
obs.run -  script to run a sequence of observations

 >>> to run the scheduled observations type "obs.run"
     type "killobs"  to interactively kill observing processes running

observing scripts you can use in the obs.run file:
-----------------
obs.csh   (type the command to get the syntax)
mos.csh
scan.csh
radpnt.csh
waittillstart.csh 21.1  (waits until 9:06 pm to begin next project)

scheduling utilities:
--------------------
plotobs m33,3c48 n   (plots az,el of list for todays date)
checkobs             (checks obs.run file - no arguments)

observing utilities:
-------------------
unhook.csh - removes antennas from hookup table so they won't be used
atastatus - produces graphical list of antennae status and positions
allants - produces (comma delimited) list of all antennas
goodants - like allants but may be a subset of all ants
scan.csh 1430 b 3c274 30 - takes 30sec obs of 3c274 at 1430 mzh on lo B.

problems:    (type "atacmds" for full list of available ata commands)
---------
ataservostatus 41 -  lists drive servo status
atareserservos 41 -  resets drive servos
recover - recovers a lits of antennas from drive errors (eg: recover `allants`
)
park.csh `allants` - parks all ants at given az,el
killobs - kills running observing programs (interactive)

if power outage or unexpected delay slopes appear in passbands
---------------
delay0.csh -  (see ~/archive/help/delay0.notes for details)

restart correlator servers (WARNING: Exception from correlator)
--------------------------
tumulus FX servers:  ssh atasys@tumulys (h0tcr22k); restartfx8
fx1.hcro FX servers:  ssh obs@x1.fxa (no pw); fxdump all
```

python ~/pwilliams/calibrators.py

10/5/07

Hat Creek Findings

1. There is a 22k resistor in series with V_g in Rob's setup. to protect the gate. Attempts to increase V_g higher than ~ 0.7 volts (on any LNA) always returns V_g. At lower voltages the returned V_g is about equal to the request. So 0.7 volts must be the breakdown voltage of the gate. A 22k resistor should also be in the supply at Matts.

2. The range of PAM attenuator settings that enable a reasonable dynamic range in the optical fiber system is small. Attempting to optimize S/N astronomically by adjusting LNA bias is difficult (very painfully slow) because any LNA bias adjustment requires a concomitant PAM ~~attenuator~~ adjustment.
   The best way out of this dilema may be to be able to make Tsys optimizations at Matt's place.
   Making hot/cold loads that work at low frequencies proved to be difficult. A possible solution might be just to work on the high frequency part of the Tsys spectrum say 8-10 GHz. This involves only ~ 1% of the short length of the feed. Making hot and cold loads for this may be not so hard.

10/6/07

The effect of being out-of-focus on both the beam width and the gain. The gain effect has been calculated before. It's easier. However, the beam width may also be affected.

Below we calculate the effect at 10 GHz with the focus set for 6 GHz.

NB// The focus phase error is taken from p 19 of the Radio Astronomy class notes. The amplitude illumination is taken from I Cp. 62 and 61. This is for the 6 m aperture

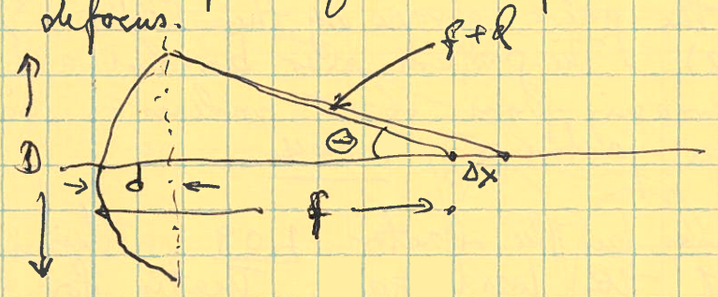
$$E(R) = 0.211 + .786\left[1-(r/a)^2\right]^{1.9} \quad \text{(from the feed)} \begin{cases} -13.5\,\text{dB} \\ \text{at edge} \end{cases}$$

(ok)

This is a convenient form because it allows an analytic pattern calculation, as shown in notebook I.

$$\eta_A = \frac{1}{A}\frac{\left|\int_0^{2\pi} d\phi \int_0^a E(r)\, e^{ik(r/a)^2}\, r\,dr\right|^2}{\int_0^{2\pi}\int_0^a \left|E(r)\, e^{ik(r/a)^2}\right|^2 r\,dr}$$

k is the peak quadratic phase error due to axially symmetric defocus.



Parabola $y^2 = 4fx$ $\quad F = f/D$

focus error $= \Delta x$

$$\cos\theta = \frac{f-d}{f+d}$$

The path difference, center to edge, is $\Delta x(1-\cos\theta)$

and $\Delta x(1-\cos\theta) = \dfrac{2\Delta x}{1+(4F)^2}$

$$K = \text{max phase difference} = \frac{2\pi}{\lambda}\,\frac{2\Delta x}{1+(4F)^2}$$

$F = 0.65$ $\qquad$ Feed phase center is at $s/\lambda = 1.44$

The focus is set for 6 GHz, $\lambda = 5$ cm and $s = 7.2$ cm.

At 10 GHz, $\lambda = 3$ cm and $s = 1.44\lambda = 4.3$ cm ; $F = 0.65$

This means Δx for 3 cm is $7.2 - 4.3 = \underline{2.9\text{ cm}}$, 1.8 cm for 8 GHz

Hence $\Phi^{10}_{max} = K = \frac{2\pi}{\lambda} \frac{2\Delta x}{1+(4F)^2} = 1.56$ radians.

$\Phi^{8}_{max} = .49$ radians

The phase error is quadratic $e^{i\Phi_{max}(r/3)^2} = e^{i\,.1773\,r^2(m)}$

We calculate the pattern with and without the phase error. In both cases the denominator of η will be the same, and we ignore that factor.

In general $E \propto \int_0^a E(r)\, J_0(kr\sin\theta)\, r\,dr$

$$\propto \int_0^3 e^{i.1773r^2}\left[0.211 + .786\left(1-(r/3)^2\right)^{1.9}\right] r\,J_0(kr\sin\theta)\,dr$$

This integral is done numerically with Mathematica, and we plot the square of its magnitude. The plot is first linear in power, showing the two cases, with and without the phase. With the phase error in, the peak drops by the factor 3.99/4.70, just as found before (.82). The pattern also broadens a little with the half width increasing from .00295 radians to .00308. That's an increase by a factor of $\underline{1.044}$.

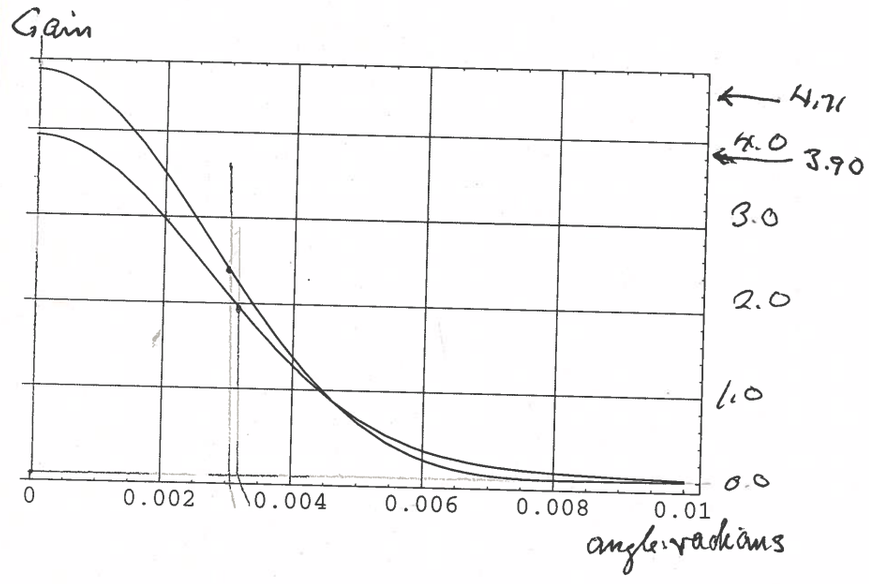
The solid angle increases by the factor $\underline{1.09}$. This is just about half the effect of the loss in gain. That is, for calibration using the moon, it is an additional factor (to the gain) because less of the beam gets on to the moon.

(what about greater overall spillover?)

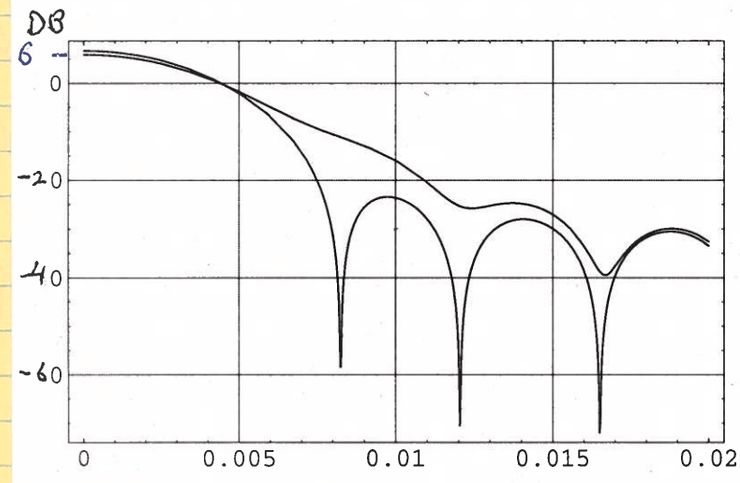
The ~~full~~ half width at half maximum is .00295 radians (20.28'). (At one GHz that's 3.38° degrees (full width) with no focus error)

At 10 GHz the beam is broadened to $\underline{21.17'}$. The out-of-focus error would be about the same at 1 GHz (for focus set for 6 GHz) for a beam of 3.53° @ 1 GHz.

Here's the linear plot



Here's the log power plot.

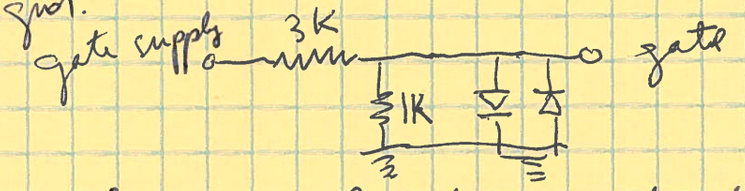


Higher side lobes with the phase error.

10/16/07

From Sandy Weinreb we the LNA gate voltage bias circuit for the current balanced LNA.

There is a 4:1 voltage divider to the gate with backtobback diodes to gnd.



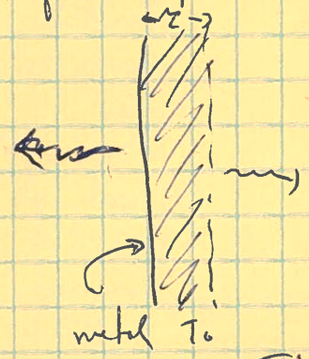
The gate voltage needs to be adjustable up to +.3V. The gate supply needs to able to go upto 1.6 volts and supply 0.5ma to the 4K resistor sum.

Get Jill to print out Sandy's .doc file.

New hot load / cold load plan for Minex 10/20/07

The idea is just to put the high frequency part of the feed into the loads. Much less size is needed for the loads. The cold load will use LN surrounding a polyfoam cup of size 2.5" x 7.5" x 4.6". The rest will be a box or cone of "millimeter" absorber filled with LN backed by the metal. The ambient load will be the same but without the LN or the cup. One piece of the black absorber that is 24" x 24" x 2" has an attenuation of about 14db @ 56 GHz and more at higher frequencies.

I. The effect of the absorbing layer backed by perfectly reflecting metal.



Beam to the right: $T_B = T_0(1-e^{-\tau})$

Moving to the left, the beam is the same $T_B = T_0(1-e^{-\tau})$
This is reflected back through the absorber, and what emerges is $T_0(1-e^{-\tau})e^{-\tau}$

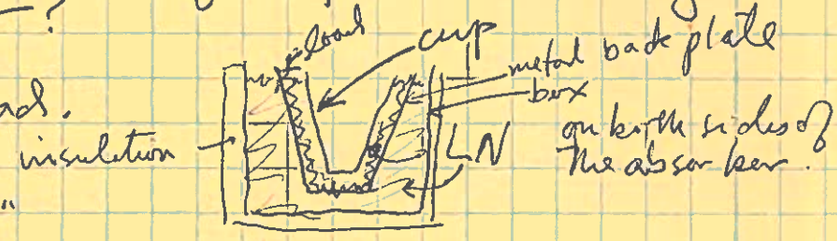
The total radiation to the right is $T_B = T_0(1-e^{-\tau}) + T_0(1-e^{-\tau})e^{-\tau}$

$$T_B = T_0(1-e^{-\tau})(1+e^{-\tau}) = T_0(1-e^{-\tau 2})$$

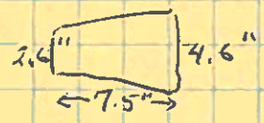
So the metal backing doubles the effective for the absorber.
For $\tau = -14$ db, $2\tau = -28$ db. This is already plenty for 5GHz and more for the higher frequencies!

II. How much of the beam of the feed will be caught by the cold absorber?

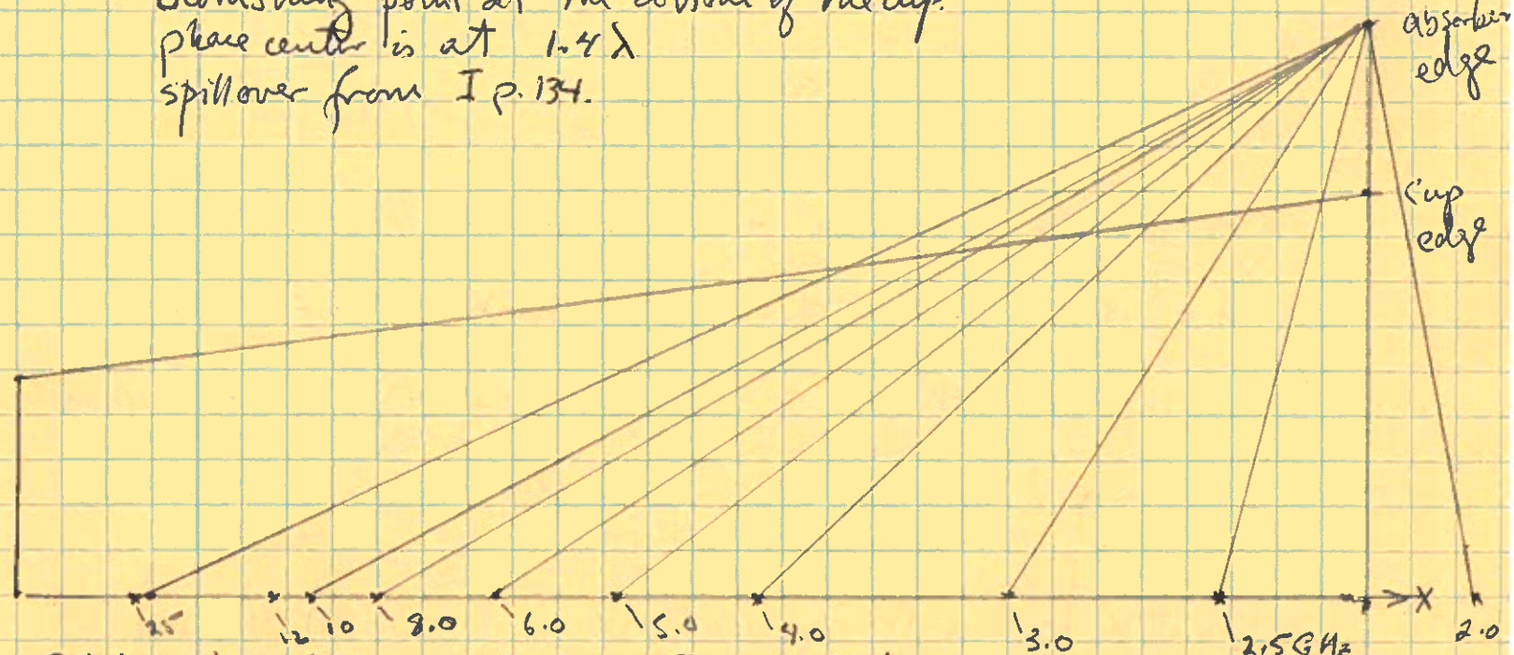
A rough picture of the load.



cup dimensions



vanishing point at the bottom of the cup.
phase center is at 1.4 λ
spillover from I p. 134.



f (GHz)	λ cm (in)	X (in)	θ_c	η_s (fraction)		+.04 for the cup
2	15.0 (5.9)	8.26	79°	.106	(.44 db)	.48 db
4	7.5 (2.95)	4.1	136°	.026	(.11 db)	.15
6	5.0 (1.96)	2.7	146°	.021	(.09 db)	.14
8	3.75 (1.47)	2.0	150°	.019	(.08 db)	.12
10	3.0 (1.18)	1.65	151°	.019	(.08 db)	.12
12	2.5 (.98)	1.4				
25	1.2 (.47)	.66	155°			
2.5	12 (4.72)	6.6	104°	.064		
3.0	10 (3.93)	5.5	121°	.047	(.20)	.25 db
5.0	6 (2.36)	3.3	142	.022		

probably the minimum spillover for all frequencies

echo from the foam cup/LN junction: LN has $n = 1.2053$; $\left|\frac{n-1}{n+1}\right|^2 = .0087$

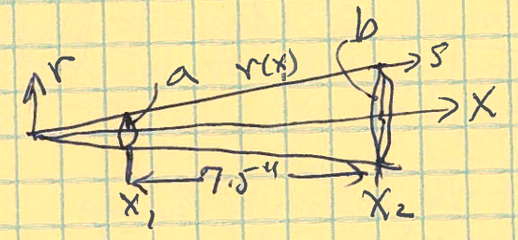
For the foam $\epsilon \sim 1.4$ and $n = \sqrt{1.4} = 1.2$; $\left|\frac{n-1}{n+1}\right|^2 = .014$

At normal incidence $|\rho|^2 = \left|\frac{n-1}{n+1}\right|^2 = .0083 \lesssim 1\%$

It falls in the plane of incidence away from the normal, reaching 0 at the Brewster angle, $\sim 60°$. It slowly rises in the other polarization. Make a 1% average (.04db) correction.

<u>Heat flow through the cup and rate of boiling of LN</u>

<u>Cup surface</u>



$a = 1.3''$
$b = 2.3''$

$r(x) = Ax$

$r(x_1) = Ax_1 = 1.3$ $\qquad \frac{x_1}{x_2} = \frac{1.3}{2.3} = .565$, $x_1 = .565 x_2$

$r(x_2) = Ax_2 = 2.3$

$x_2 = x_1 + 7.5 = .565 x_2 + 7.5$, $x_2 = 7.5/(1-.565) = 17.24$

$x_1 = (.565)(17.24) = 9.74$

$A = 1.3/9.74 = 0.134.$ $\qquad r = .134x$ $\qquad \frac{dr}{dx} = .134$

$(ds)^2 = (dr)^2 + (dx)^2 \qquad ds = dx\sqrt{1+\left(\frac{dr}{dx}\right)^2} = dx\sqrt{1+(.134)^2}$

$ds = dx\ 1.0089$

$dArea = 2\pi r\,ds = 2\pi(1.0089)\,r\,dx$

$$\text{Total Area} = \int_{x_1}^{x_2} 2\pi(1.0089)\,r\,dx = \int_{9.74}^{17.24} 2\pi(1.0089)(.134x)\,dx$$

$= 84.9\ in^2$

Area of bottom end $\pi r^2(x_1) = \pi(1.3)^2 = 5.3\ in^2$

<u>Total area $\cong 90\ in^2$</u> $\rightarrow 90(.0254)^2 = .0581\ m^2$

<u>Heat Flow</u> Cup wall thickness $\Delta z = 1/8'' = 0.125'' = .0032m$

Styrofoam thermal conductivity $K = .034$ watts/mK° (Google)

Temperature drop $\Delta T \cong 280 - 80 = 200K$

Heat flow: $H = \left(\frac{\Delta T}{\Delta Z}\right) K \text{ Area} = \frac{200}{.0032}(.039)(.0581 m^2)$

$= 123$ watts

Heat of vaporization for LN is 2.79 K watt-secs/mol. (Google)

Volume of one mol of LN?

$V_{liq} = N_A 8 r^3$ N_A is Avogadro's number : 6×10^{23}/mole
r is $\sim 1.2\times10^{-8}$ cm

$V_{liq} = (6\times10^{23})(8)(1.2\times10^{-8})^3 = 8.29 \text{ cm}^3/\text{mole} = (2.02)^3$

For 123 watts: $2790/123 = 22.6$ seconds to evaporate one mole

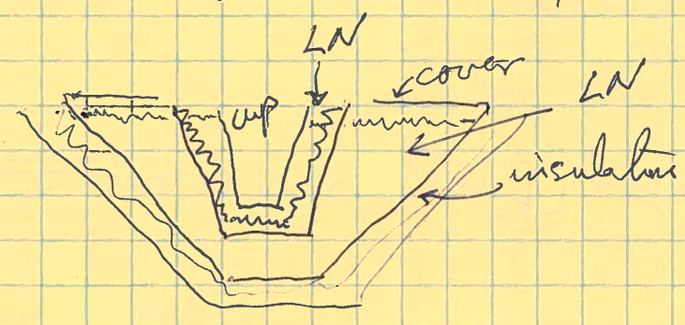
That's ~8 cc of LN

$8/22.6 = 0.35$ cc in one second, or 21 cc in one minute

one cc is $\left(\frac{1}{2.54}\right)^3$ cu in $21\left(\frac{1}{2.54}\right)^3 = 1.28$ cu in/min

Doubling the cup thickness with 2 cups might be a good plan. That would lower the evaporation rate to ~0.6 cu in/minute (or maybe 3 cups)
For 3 cups, find 0.43 cu in/minute ~ 25 cu in/hour

To keep the level high while evaporation is taking place it might be best to have the LN distribution shape be a V, like the load.



10/24/07

Continuation from page 65 on the out-of-focus correction

A table of corrections ; Focus set for 6 GHz ; $X = 1.44\lambda$, $F = .65$

cm λ	GHz f	λ in m $2\pi/\lambda$	focus (cm) X	$\lvert X-7.21\rvert$ ΔX	Φ_{max}	$\Phi_{max}/4$	$\Phi_{max}=0$ $G(0)$	$G(\Delta x)$	FWHM	out of focus FWHM	$G(\Delta x)/G$	$\Delta\theta/\theta$	(in-focus) expected T_A
60	0.5	10.472	86.4	79.2	2.137	.237	4.705	3.346	6.990	7.494	.71	1.07	.6
30	1.0	20.944	43.2	36.0	1.95	.217	4.705	3.547	3.495	3.690	.75	1.056	.6
20	1.5	31.416	28.8	21.6	1.75	.194		3.756	2.330	2.429	.80	1.043	.6
15	2.0	41.888	21.6	14.4	1.55	.172		3.936	1.748	1.800	.84	1.030	.6
7.5	4.0	83.776	10.8	3.6	.78	.087		4.499	.874	.8806	.96	1.008	.6
5.0	6.0	125.664	7.2	0	0	0	4.705	4.705	.583	.583	1.00	1.00	.59
3.75	8.0	167.55	5.4	1.8	.78	.087	4.705	4.499	26.21	26.33	.96	1.0044	.57
3.0	10.0	209.44	4.32	2.88	1.56	0.173		3.936	20.97	21.59	.84	1.030	.56
2.6	11.5	241.66	3.74	3.46	2.15	.239	4.705	3.346	18.17	19.42	.71	1.069	.56
2.5	12.0	251.327	3.600	3.60	2.33	.259	4.7035	3.136			.67		
2.0	15.0	314.159	2.88	4.32	3.499	.3888	4.7035	1.846			.39		

$$\text{FWHM} = 3.495\,\lambda(\text{cm})/30 \qquad \frac{4\pi}{1+(4F)^2} = 1.619$$

$$\Phi_{max} = \frac{2\pi}{\lambda}\frac{2\Delta x}{1+(4F)^2} = \frac{\Delta x}{\lambda}\,1.62$$

$$E(\theta) \propto \int_0^{3m} e^{-i\Phi_{max}(r/3)^2}\left[0.211 + .786\left(1-(r/3)^2\right)^{1.9}\right] J_0\left[\frac{2\pi r}{\lambda}\sin\theta\right] dr\, r$$

$$f_1[r_] = \left(.211 + .786\left(1-(r/3)^2\right)^{1.9}\right) r$$

$$f_2[r_, x_] = f_1[r]\,\text{BesselJ}\left[0, \frac{2\pi r}{\lambda}\text{Sin}[x]\right]$$

$$f_3[r_] = \text{Exp}[I\ .173\ r^2]$$

e.g.

Calculate:

$$\left(\text{Abs}\left[\text{NIntegrate}\left[f_3[r]\, f_2[r,x]\ \cancel{\text{BesselJ}\left[0, \frac{2\pi}{\lambda} r\,\text{Sin}[x]\right]}, \ldots\right]\right)^2$$

10/29/07 Issues for Completion

1. Focus Drives
   a) what software for control (Rick?)
   b) Can they work with lubrication? (Matt/Mike)
   c) What redesign required? (Matt)
   d) schedule

2. Feed/Receiver testing
   a) ambient and LN loads (Matt/Jack) screenroom
   b) Sandy here on Nov. 1 (Jack pick him up
   c) Computer control for LNA biasing (Rob A)
   d) Rebuild of feed #? (Chris)
   e) frame to hold feed (Matt, Peter, Rob S.)
   f) schedule for all feeds: LNA biasing, Tsys opt. Rob A Matt, Jack
   g) more LNA's? (Chris, Matt, Niklas)?

3. Computer Controlled Gain for ADC's
   a) needed for all frequency operation
   b) Hitite connectorized chip (?) (Matt/Chris)
   c) measure match (z) and crosstalk (Jack)
   d) hardware for computer control (Rob A?) Chris
   e) software " (Rob A?)
   f) power range (attenuation) range of attenuators (0-20 db)
   g) what computer for control

4. Beamformer
   a) one needed ASAP in one band Billy Chris
   b) 2-3 needed in one band "
   c) one needed for another band. "
   d) what BW is possible? "
   e) with ~~phase~~ delay needed for passive radar

5. Correlator
   a) completion to 242 (Dave M)
   b) completion to multiple 16's "
   c) phase and delay included (Lynn/Dave.)
   f) other resolutions Dave M
   g) long delay for GPS, etc.

Rick: baselines repeat to ~1mm.

SETI budget contribution

Jack: new hot/cold loads at Mines by Wed // Sandy W will visit for some Tsys tests // also TDP plans
- Rear down -

11/6/07

Continued from p. 69

System assembled and tested with three cup in series. A lot of cold air condensate appears in the cup and moisture formed on the tip of the feed, affecting the measurements.

A possible fix: blow air continuously into the cup to warm the inner wall of the cup.

Convective heat transfer.

From Kreider and Kreith p. 18-19.

$H = h_c \text{Area} (T_s - T_f)$

Free air convection gives $h_c \sim 6-30$ watts/m^2 K°
Forced convection gives $h_c \sim 30-300$ "

Assume $T_s \sim 270$ K and $T_f \sim 290$ K
For $h_c \sim 30$ watts/m^2 K $H \sim (30)(20)$ Area.
Cup area is .06 m^2 so $H \sim (60) \cdot .06 = 3.6$ watts
This is comparable to the heat flow through the LN. (~ 53 watts)

For blowing air through a plastic scoop and if $h_c \sim 300$, we get 360 watts

Now check the heat transport in the wind.

From #III p 66, $P(\text{watts}) = \frac{1}{3}(\text{CFM})\,\Delta T(°F)$

If we could get 40 CFM with $\Delta T = 70-30 = 40°F$,
$P = \frac{1}{3}(40)(40) = 530$ watts. So there is enough heat capacity in the wind. It's ~ 10 times the heat flow from the LN through to the cup. Since the temp drop through the LN is 200 K as compared to 20 K from the wind, the factor of 10 in heat flow is necessary.

Air blowing into the cup with LN surrounding 11/8/07

a) IR sensor { bottom 39°F
edge 44°F

puddles forming on the side/bottom seam.
use toilet paper to dry the cup —
— then with feed down in for 2½ minutes and then retracted with the air turned off, no moisture found on the feed.

Tests on a receiver worked with good reproduction.
no moisture accumulated on the feed tip.
LN level found to be ~ 1½ low on the cup
Y ~ 3db above 3-4 GHz. Not great: T_{sys} ~ 140K
This rcvr known to be weak. No gain or T_{sys} optimization attempted

---

Some test @ Hat Creek 11/11/07

Output of 2CY inspected on Spectrum Analyzer
Res. BW = 3MHz
Peak @ 600MHz is ~ −14dbm 600/3 = 200 (23db)
Peak @ 14.90GHz ~ −36db total power ratio is 46db ok

Inspection of Phase switched second LO that leaks through at high spectral resolution on 2CY.

a) through band A with no antialiasing filter
first sideband peak is at −42dbm
all the other sidebands look very clean. There is no evidence of any modulation cross talk from any other Walsh function
Res BW = 30Hz

b) through band B with antialiasing filter
first sideband peak is now at −54dbm.
the first few sidebands look clean, next @ −64dbm
after that we begin to see other signals appearing weakly that look like the sidebands of the neighboring channels Walsh Functions at ~ double frequency; between harmonic 5 and 6 there is one of these at −78dbm. Maybe the difference is the effect of the filter passband on the phase modulation.

~~Maybe the difference is that~~

S/N on HI W3OH

Sat Nov 10 17:48:45 PST 2007 w3oh (HI)

ant1k.y	1	ant1a.x	28
ant2e.y	1	ant1a.y	37
ant31.x	1	ant1b.x	22
ant2j.y	2	ant1b.y	43
ant2d.y	9	ant1c.y	34
ant2m.y	9	ant1d.x	27
ant5c.x	13	ant1d.y	33
ant1h.y	16	ant1e.x	47
ant2e.x	16	ant1e.y	36
ant3d.x	16	ant1f.x	45
ant41.y	21	ant1f.y	53
ant1b.x	22	ant1g.x	46
ant31.y	22	ant1g.y	42
ant5e.x	23	ant1h.x	36
ant5g.x	23	ant1h.y	16
ant3c.y	25	ant1j.x	33
ant4g.x	25	ant1j.y	46
ant2g.x	26	ant1k.x	42
ant21.y	26	ant1k.y	1
ant1d.x	27	ant2a.y	44
ant2g.y	27	ant2b.x	48
ant3d.y	27	ant2b.y	47
ant1a.x	28	ant2c.x	40
ant3c.x	30	ant2c.y	38
ant3h.x	32	ant2d.y	9
ant1d.y	33	ant2e.x	16
ant1j.x	33	ant2e.y	1
ant5h.y	33	ant2f.y	45
ant1c.y	34	ant2g.x	26
ant1e.y	36	ant2g.y	27
ant1h.x	36	ant2h.x	46
ant2k.y	36	ant2h.y	44
ant1a.y	37	ant2j.y	2
ant2c.y	38	ant2k.y	36
ant2c.x	40	ant21.x	47
ant5b.x	40	ant21.y	26
ant4j.y	41	ant2m.y	9
ant1g.y	42	ant3c.x	30
ant1k.x	42	ant3c.y	25
ant5e.y	42	ant3d.x	16
ant1b.y	43	ant3d.y	27
ant4e.x	43	ant3e.y	49
ant2a.y	44	ant3h.x	32
ant2h.y	44	ant31.x	1
ant4j.x	44	ant31.y	22
ant1f.x	45	ant4e.x	43
ant2f.y	45	ant4f.x	51
ant5b.y	45	ant4f.y	51
ant1g.x	46	ant4g.x	25
ant1j.y	46	ant4j.x	44
ant2h.x	46	ant4j.y	41
ant1e.x	47	ant41.x	47
ant2b.y	47	ant41.y	21
ant21.x	47	ant5b.x	40
ant41.x	47	ant5b.y	45
ant2b.x	48	ant5c.x	13
ant3e.y	49	ant5e.x	23
ant4f.x	51	ant5e.y	42
ant4f.y	51	ant5g.x	23
ant1f.y	53	ant5h.y	33

LNA settings for antennas with no ADC pads.

ants. w/ ⌀ pads into 1b.b:

Vg	ant	pam	rms	AutoPwr
.44	1ey	15	14.2	65.9
.44	1by	20	10.6	63.5
.42	1cy	20	13.3	65.1
.55	1ax	16	9.6	64.6
.44	1bx	20	14.6	65.6
.40	1dx	20	10.9	66.0
0.17	3ey	14	12.3	64.6

Expected level into the ADC is -20dbm.

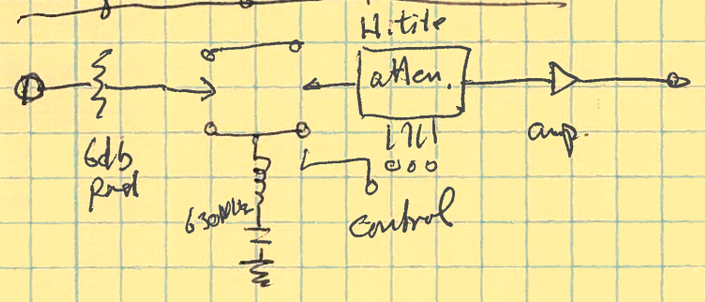
continued from p 73 11/16/07

The additional side bands could result from a non-flat response of the antialiasing filter. Testing one unit showed a pretty flat response @ 14.9 GHz; it's about -10 db transmission.

12/5/07

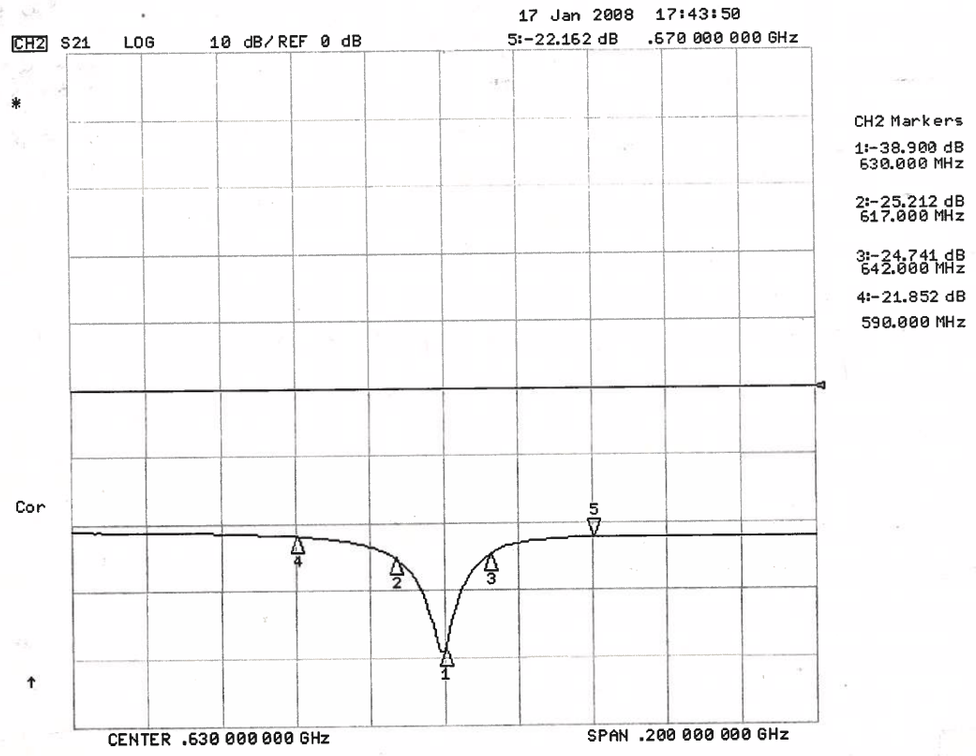
What to use for the notch filter? Doug's single resonator is ~~not~~ available. Fancier filter? What's it's out of-band phase.

Diagram of control unit

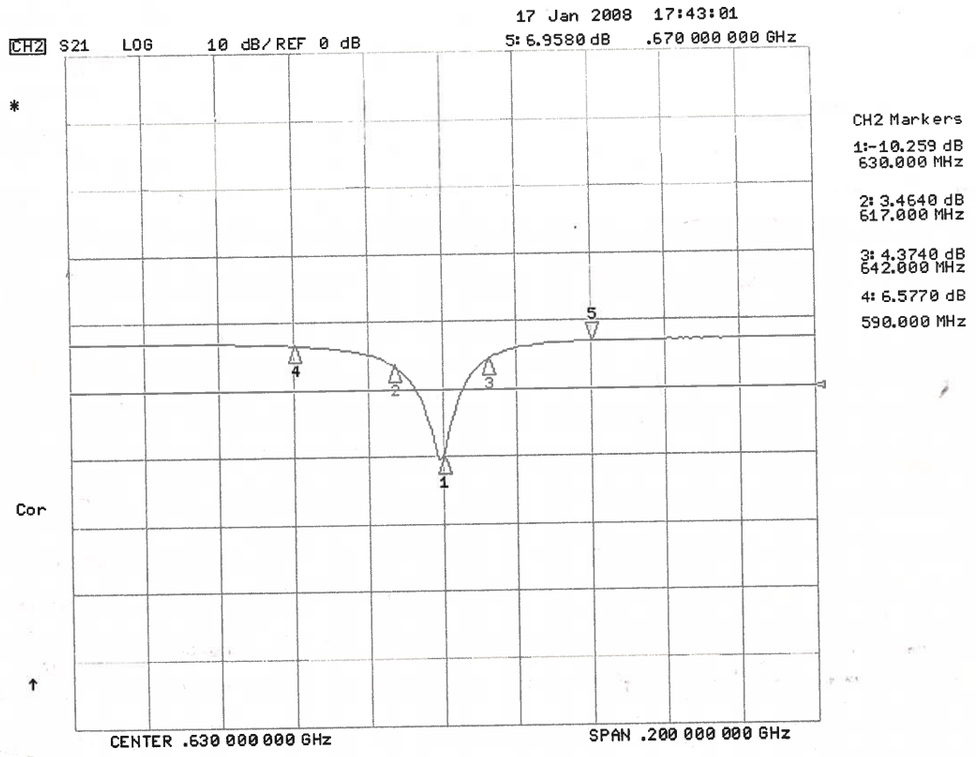


S_{11} and S_{21} spectra appear on the next three pages. These are over the 200 MHz band

Gain and Filter Control Unit



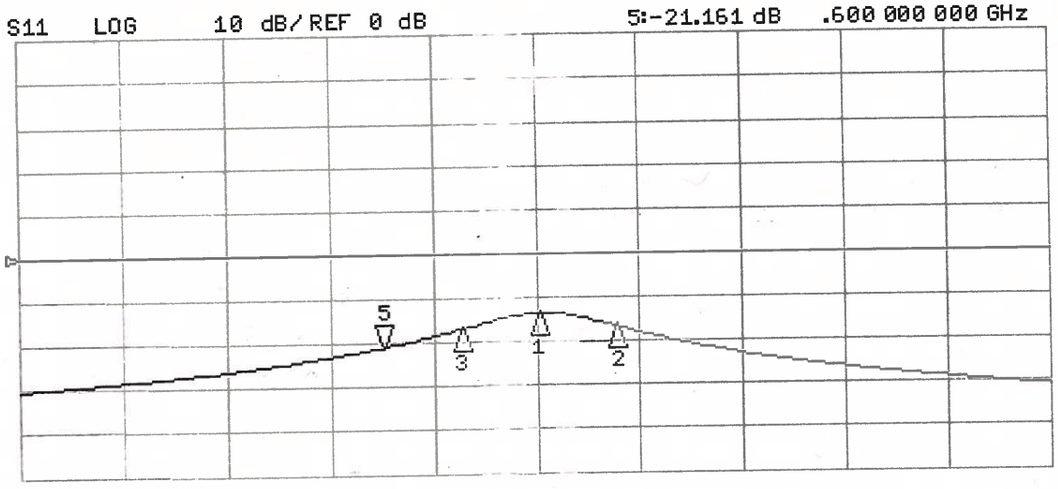
Filter in
Atten @ -29 db



Filter in
atten @ 0 db

22 Jan 2008 10:45:21

CH1 S11 LOG 10 dB/ REF 0 dB 5:-21.161 dB .600 000 000 GHz



CH1 Markers

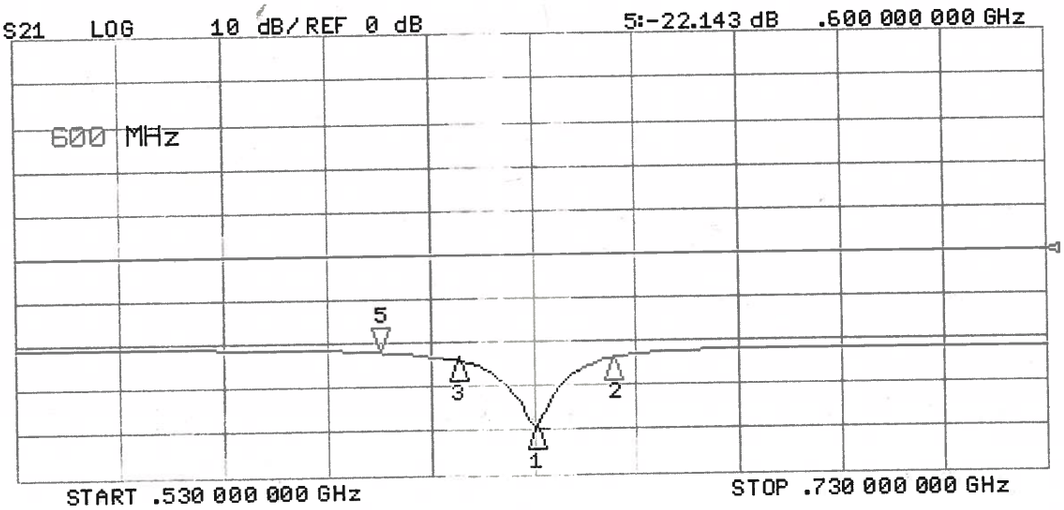
1:-13.404 dB
630.000 MHz

2:-16.424 dB
645.000 MHz

3:-17.096 dB
615.000 MHz

Filter in full attenuation

CH2 S21 LOG 10 dB/ REF 0 dB 5:-22.143 dB .600 000 000 GHz



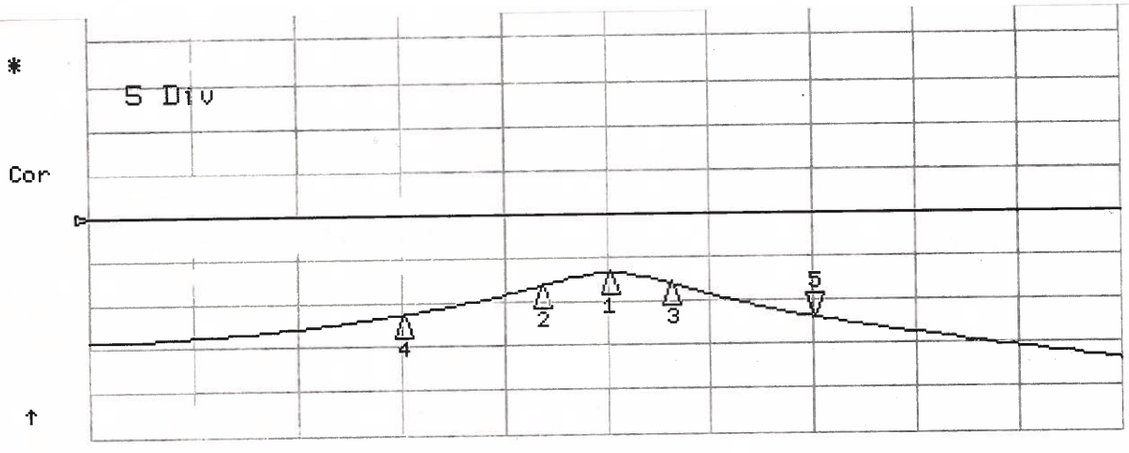
START .530 000 000 GHz STOP .730 000 000 GHz

CH2 Markers

1:-39.322 dB
630.000 MHz

2:-23.828 dB
645.000 MHz

3:-24.157 dB
615.000 MHz



CH1 Markers

1:-13.541 dB
630.000 MHz

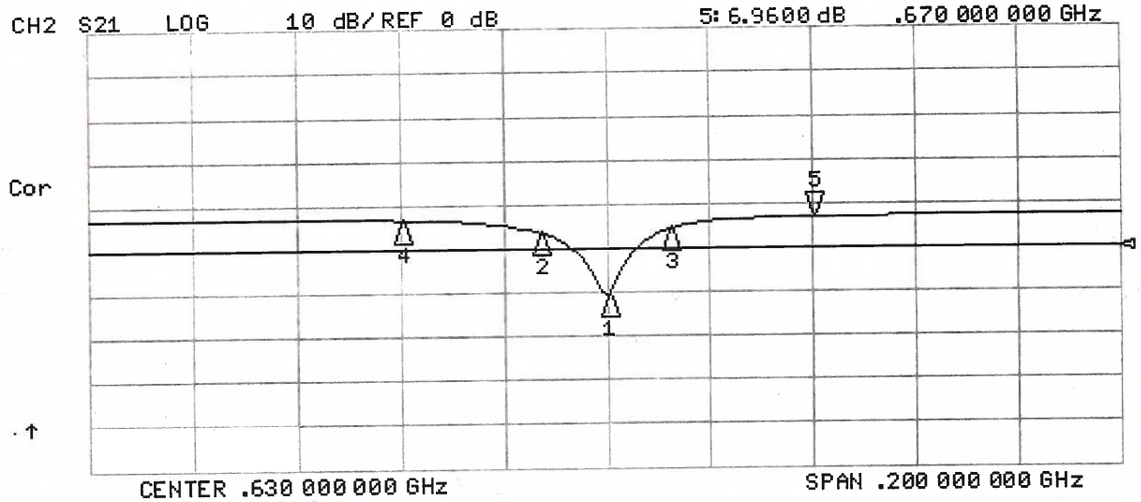
2:-16.411 dB
617.000 MHz

3:-15.925 dB
642.000 MHz

4:-22.732 dB
590.000 MHz

Filter in no attenuation

CH2 S21 LOG 10 dB/ REF 0 dB 5: 6.9600 dB .670 000 000 GHz



CENTER .630 000 000 GHz SPAN .200 000 000 GHz

CH2 Markers

1:-10.678 dB
630.000 MHz

2: 3.5880 dB
617.000 MHz

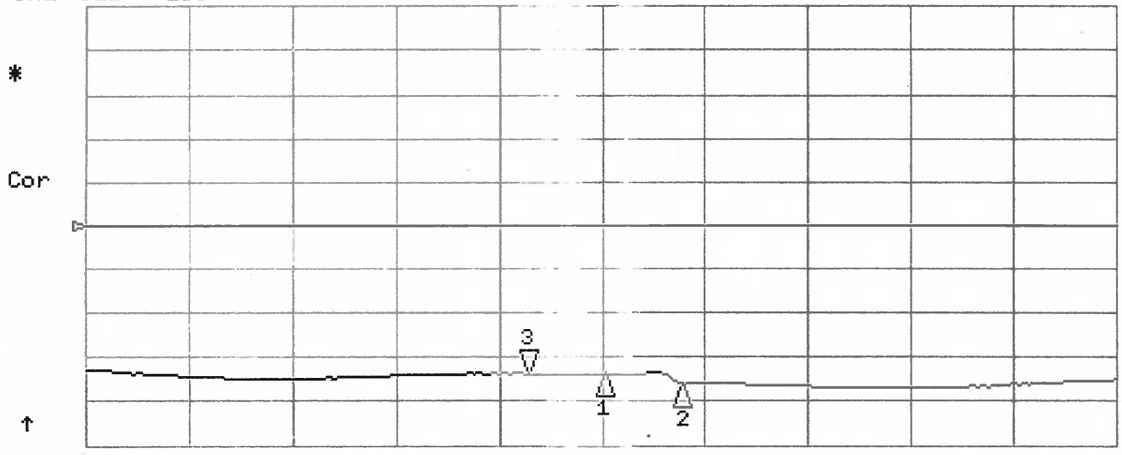
3: 4.2840 dB
642.000 MHz

4: 6.6010 dB
590.000 MHz

22 Jan 2008 10:42:28

CH1 S11 LOG 10 dB/ REF 0 dB 3:-33.573 dB .615 000 000 GHz

Filter Out
0 attenuation

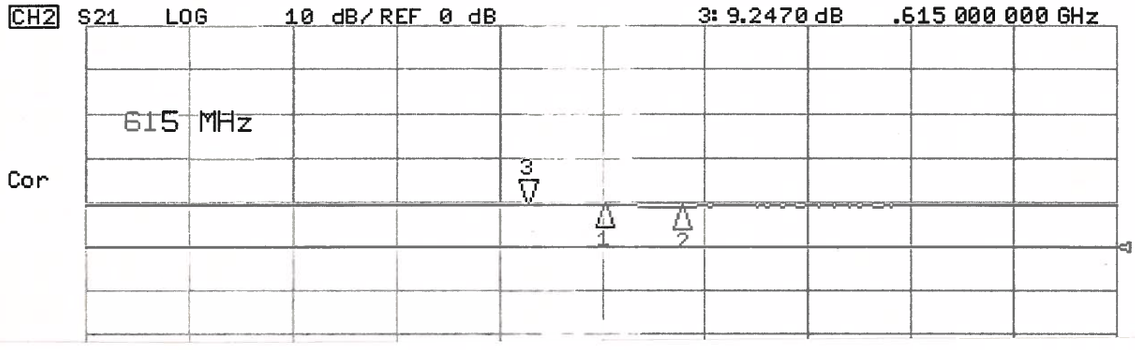


CH1 Markers

1:-33.745 dB
630.000 MHz

2:-36.018 dB
645.000 MHz

CH2 S21 LOG 10 dB/ REF 0 dB 3: 9.2470 dB .615 000 000 GHz



CH2 Markers

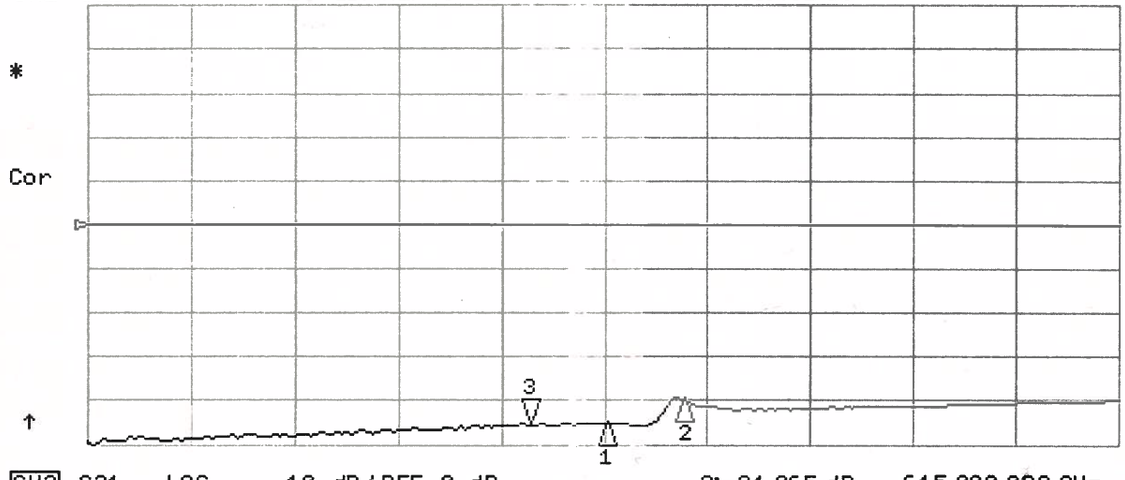
1: 9.1940 dB
630.000 MHz

2: 9.0930 dB
645.000 MHz

22 Jan 2008 10:43:16

CH1 S11 LOG 10 dB/ REF 0 dB 3:-45.462 dB .615 000 000 GHz

Filter out
31db attenuation

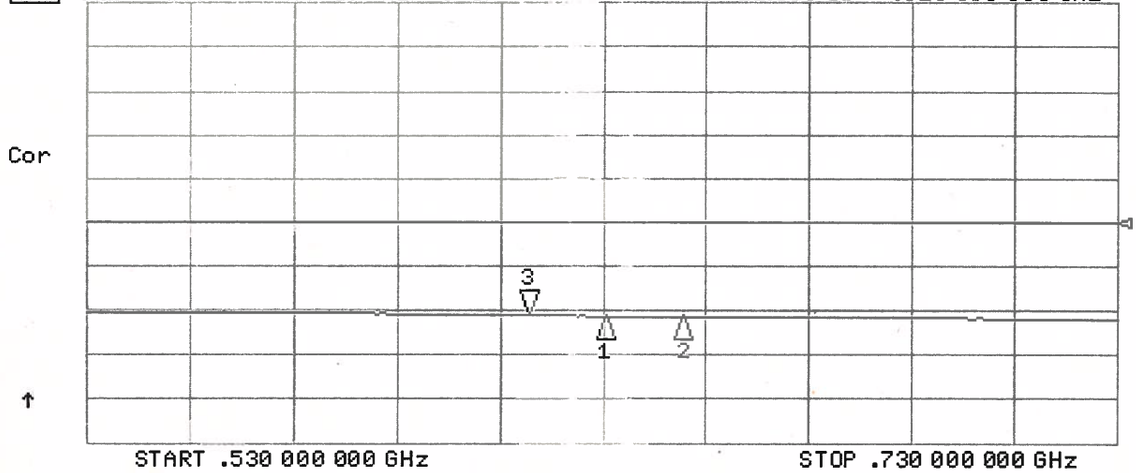


CH1 Markers

1:-45.285 dB
630.000 MHz

2:-39.738 dB
645.000 MHz

CH2 S21 LOG 10 dB/ REF 0 dB 3:-21.065 dB .615 000 000 GHz



CH2 Markers

1:-21.213 dB
630.000 MHz

2:-21.418 dB
645.000 MHz

START .530 000 000 GHz STOP .730 000 000 GHz

3/17/08 Review of the Air Cooling of the Antenna

a) The airflow from the Node has been raised from 50 CFM to ≅ 120 CFM with the new Node fan blades. The big problem with this is that there is now little smoothing or cooling through the pipes in the ground. From III p. 65-75

$$\lambda = \frac{1}{(0.87)(CFM)(.9247)}$$, with $(T_{air} - T_{gnd})(x) = (T_{air} - T_{gnd})e^{-\lambda x}$ omitting the phase term.

With CFM = 50, $\lambda = .025$

So, for example, $e^{-.025x}$ = 0.29 for x = 50 feet
= .082 for x = 100 feet

With CFM = 120, $\lambda = .0104$

$e^{-.0104x}$ = 0.59 for x = 50
= 0.36 for x = 100

It might be better to return to the slower flow: 50 CFM total and ~8 CFM to Rim Box, no, this is essential for summer. About ~20 watts must be taken out of the rim box with: 6 watts in to the supply, 35 to cryo and 10 watts to TEC

with $P(\text{watts}) = .26\,(CFM)\,\Delta T(^\circ F)$ $\quad \Delta T = \frac{(20)}{(.26)(8)} = \underline{\underline{9.6^\circ F}}$

If the input air were better coupled to the supply heat exchanger a 9.6°F rise would take out all the heat from the power supply.

Some Data from Gary

antenna	power in	cryo power
1A	65.9	35.3
1B	56.4	30.8
2G	65.9	32.3
2J	75.3	35.5

Another way to deal with hot summer afternoons would be to put a chiller into the node and turn it on only in the afternoon, leaving the air flow high. (1200 CFM)

$P(\text{watts}) = 0.26\,(\text{CFM})\,\Delta T(^\circ F)$ (III p. 73)

To lower the Node outflow temperature by 10°F would take $0.26(1200)10 = 3120$ watts! Ugly!

Cooling the cryocooler means taking 40 watts out

With an airflow of 25 CFM at the cryocooler, the temperature rise would be $\Delta T = \dfrac{40}{(.26)25} = 6^\circ F$

With 50% efficiency, that's 12°F temperature rise

Time dependence of the air temperature coming out of the end of the pipe.

From III p. 73, the total thermal impedance to the distant ground is $Z_T = .90 + i.20$ for a period of one day.

(with $Z_{earth} = +.3812 + i.2070$) (same as the number in the memo)

Along the pipe: $\Delta T(x) = \Delta T(0)e^{-\lambda x}$ Temps relative to distant average

For 50 CFM

$$\lambda = -\frac{1}{(.87)(50)(\cancel{.9270})\,Z_T} = \frac{-1}{(.87)(50)(.90+i.20)}$$

$$= -.023 + i(.005)$$

so $\Delta T(x) = \Delta T(0)\,e^{-(.023 - i.005)x}$ take $Re\{(\quad)e^{i2\pi t}\}$

$\Delta T(x) = \Delta T(0)\,e^{-.023x}\cos(2\pi t + .005x)$; $\Delta T(0)$ is the peak day's temperature of the ground

at $x = 50$ feet $\Delta T(x) = \Delta T(0)\,e^{-1.15}\cos(2\pi t + .25) = \Delta T(0)(.32)\cos(2\pi t + .25)$, hour

at $x = 100$ feet $\Delta T(x) = \Delta T(0)(.100)\cos(2\pi t + .5)$; .5 is about 30°, or ~2 hours

What's the drag? What's the exit $\mathcal{F}$(CFM) at each antenna?

3/23/08

Current Tasks

Computing
a) Rapid tracking for satellites — Gerry
b) use full GPS style ephemerides — Gerry GPS again
c) RCVR tuning at Minex — Rob (LNA bias)
d) holography software for testing all antennas { beam patterns, focus, surface

Hat Creek
a) bead blasting
b) install variable speed motors (electronic drives) (for better quiet cooling)
c) power supply fan in RimBox
d) measure air flow with 500 CFM at each ~~[illegible]~~ antenna
e) covers for mounts for temperature stability — need design

Pointing → f) base line stabilization

Minex
a) PAX case ↔ Rim Box cable (issue, parts list) RW1 (done at HC ~~or Berkeley~~)
b) PAX controller supply mod for LNA: versions software Rob
c) exchange PAX control boards (d) cycle 6 through at a time + measure Tsys.
e) design antenna mount thermal covers
(f) new teflon bearings for feed focus

front end turnaround

Pointing at Hat Creek
a) mount covers
b) understand level gauge
c) Holography maps of figures, espe. with sunlight

Berkeley
a) Build the antenna-attenuator boxes / then install
b) maybe build the PAX-RIMBox cables
c) ordering new tip circuit boards (Ed/Matt)

SRI proposal to Mike, Gerry, Rick (and Barrett)

Correlator
a) Cooling fan relocation for spectral corruptions (Matt D)
b) 64 channel single pol correlator (Dave M)
c) other bandwidths (Lynn)
d) delay and fringe correction before correlation (Lynn)
e) long delays enabled (Dave M) for satellites

How about an alarm on the Node?

SRI
a) measure i) GPS position
ii) GPS radial velocities } simultaneously
b) ephemerides from passive radar — needs long correlator delays
e) Talk to Dave Rob — Ken Dreyer and Dave Wathen re the other experiments — details

---

How about an RFI insulated, well matched room for feed pattern measurements?

3/30/08

What changes could be made in the underground cooling system parameters to make it more effective?

From III p. 68

d = diameter of pipe; v = flow vel.

$$Re \propto v d$$

$$h \propto \frac{(Re)^{0.8}}{d} \propto \frac{(vd)^{0.8}}{d}$$, convective heat transfer coefficient

$$R_{air} = \frac{1}{Ah} \propto \frac{1}{d} \frac{d}{(vd)^{0.8}} \propto \frac{1}{(v)^{0.8}(d)^{0.8}}$$

The efolding distance along the pipe $\lambda = \frac{-1}{.87\, F(CFM)\, R_T}$

for steady flow and for time periodic flow it is:

$$\lambda = \frac{-1}{(.87)\, F(CFM)\, Z_T}$$ with $T(z) = T(0)\, e^{-\lambda z}$ along the pipe

$$R_T = R_{air} + R_{pvc} + Z_e$$ Z_e for earth impedance

$$R_{pvc} = \frac{1}{2\pi k_{pvc}} \ln\left(\frac{OD}{ID}\right)$$, a weak dependence on diameter

$$R_{air} \propto \frac{1}{(v)^{0.8}(d)^{0.8}} \propto \frac{1}{d^{0.8}} \sim \frac{0.30}{(d/3)^{0.8}}$$ for 3" pipe, a small effect.

$$F(CFM) \propto v d^2$$

$Z_e \propto \ln(r)$ a weak dependence like that of R_{pvc}

For 3" diameter: $Z_T = R_{air} + R_{pvc} + Z_e = .30 + .22 + (.38 + i.21)$ for a one day period temperature (air) drive.

$$\text{so } \lambda = \frac{-1}{(.87)\, F(CFM)\, Z_T} \approx \frac{-1}{v d^2}$$

Only the air term, R_{air}, is much affected by d, whereas $F(CFM) \propto v d^2$

Increasing v or d decreases λ. 50 CFM is needed to cool and regulate the electronics. Pipe length could be increased to a few antennas.

7/8/08

Grant Proposal stuff for ATA and CARMA

I. CARMA

a) the calibration cont-ups: goal for accuracy (ref. Gibson et al, 2005): 5% is the plan, 1-2% is the goal; use $R = CO(2-1)/CO(1-0)$ for Temperature measurements, as an example.

b) Detailed maps of pre-protostellar cores, maps at CARMA ref. Swift + Welch (2008) discuss: IRDC's

II. ATA New three year proposal (end of May, also)

a) Gain measurement ref. Gibson et al (2005) some details [send to Peter Williamson]

b) do Gain in 4-8 GHz band first for the Te galactic measurement. Transfer to the moon.

c) Describe the Te measurement

d) Improve the moon flux (f) as a calibrator (check out the correlator linearity as a total power detector using the NA)

e) Spectral studies: HC_5N (in TMC1?) density measurements, look for prepmt

NB: Accurate antenna gains and patterns are also needed for CARMA and ATA.

e.g.: Tsys for ATA Discuss them all.

a) Tsys b) correlator temp scale c) antenna gains
d) antenna patterns e) brightness efficiencies
An absorber at To can be used: but the spillover pick up will need to be estimated somehow.
holography for the beam patterns

Confusion limits 4/20/08

For the ATA-350 fund on II p. 105: $11.6\,\lambda^{2.1}(m)$ mJy
A rederivation finds $12.9\,\lambda^{2.1}(m)$ mJy, about the same.
@ $\nu = 1.42$ GHz, $F = 0.49$ mJy ; @ 2.7 $F = 0.13$ mJy.
What is it for the ATA-42 (or 84, 128)?

From II p. 104

$$n(F,\lambda) = \frac{\Delta\Omega}{4\pi}\, 16{,}200\, F^{-3/2} \left(\frac{\lambda}{1.7m}\right)^{\frac{3\alpha}{2}}$$, from the 3C,

the number of sources with flux greater than F.
Assume $\alpha = .75$

ATA-42 From Geoff's Table, FWHM @ 1GHz = 348" {348 × 165} should be

$$\theta_{1/2} = \frac{348}{3600} \times \frac{\pi}{180} = .0017 \text{ rad}, \quad \text{by } .0004 \qquad \Delta\Omega = \frac{\pi}{4}\left(\theta_{1/2}\right)^2 = \frac{\pi}{4}\left\{.0017\,\frac{\lambda(m)}{.3}\right\}^2\left(\frac{1}{2}\right)$$

$$\frac{\Delta\Omega}{4\pi} = \frac{1}{4\pi}\cdot\frac{\pi}{4}\left\{.0017\,\frac{\lambda(m)}{.3}\right\}^2\left(\frac{1}{2}\right) = 1.09\times10^{-6}\,\lambda^2(m)\left(\frac{1}{2}\right)$$

$$n(F,\lambda) = \frac{1.09\times10^{-6}}{2}\,\lambda^2(m)\; 16{,}200\, F^{-3/2}\left(\frac{\lambda(m)}{1.7}\right)^{1.1}$$

$$n = .0053\,\lambda^{3.1}(m)\, F(J_y)^{-3/2}\,\frac{1}{2}$$

For $n=1$, the confusion flux level

$$1 = \frac{.0153}{2}\,\lambda^{3.1} F^{-3/2}, \text{ and } \boxed{F = \underbrace{.0616}_{2.66}\,\lambda^{2.1}(m)}\ J_y \cong .04\lambda^{2.1}$$

At $\nu = 1.412$ GHz, .21m, $F = 2.66\ 2.3$ mJy ~ 1.6 mJy
2.7 GHz, .11m, $F = 0.6$ mJy ~ 0.4 mJy

ATA-84 again from Geoff's Table FWHM @ 1GHz = 178"
A similar calculation gives

$$\boxed{F = .0281\,\lambda^{2.1}(m)\ J_y}$$

At $\nu = 1.4$ GHz, $F = 1.0$ mJy
2.7 GHz, $F = 0.37$ mJy

ATA-128 FWHM @ 1GHz = 135"
The calculation gives $\boxed{F = .0263\,\lambda^{2.1}(m)\ J_y}$

At $\nu = 1.4$GHz $F = 1.0$ mJy
2.7 2.7 mJy

4/24/08

Rick made the following observations with the solar illumination of the antennas

The sun reflected onto the radome gave (a) 119°F for shiny antenna
(b) 85°F for bead blasted ant.

The ground temperature was 85 F

Friday 5/2/08

Some air flow velocities at some of the antennas with the fan motors running at 60 Hz? From Jeff Kaufman.

	velocity				dist.	L
3J	4000 ft/minute		F in 3" pipe	284 CFM	λ (ft⁻¹)	.0044	97
3L	3100		220 CFM		.0057	214
4L	2500	$F = .01V$	178		.0070	
4H	2000		142		.0088	282
5C	2500	$F = .049V$	178		.0070	49
5G	2200		156		.0081	104

Some temperature drop measurements made near 3PM the time for the likely peak temperature difference between input and output pipe temperature (see p. 82) From Jeff

			meas.	$e^{-\lambda L}$		$9e^{-\lambda L}+8$
In node 3	temp = 17°C	3J is at	15°C	.68	L = 97	14.
		3L is at	13°C	.29	L = 214	10.7
In node 4	node temp is 17°	4H is at	9°C	.102	L = 282	8.9
In node 5	node temp is 18°C	5C is at	18°C	.78	L = 49	14.8
		5G is at	15°C	.46	L = 104	12.

The recorded average temperature was about 8°C. = $\langle T \rangle$

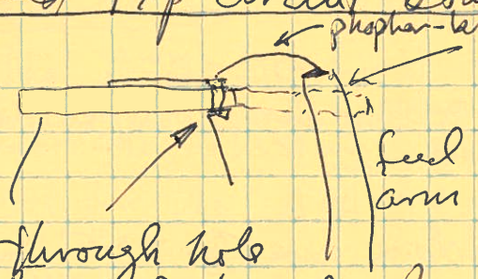
We should get $(T - \langle T \rangle)\, e^{-\lambda L} + \langle T \rangle \Rightarrow (17-8)\, e^{-\lambda L} + 8 = 9e^{-\lambda L} + 8$
or $(18-8)e^{-\lambda L} + 8 = 10e^{-\lambda L} + 8$

From p. 80: $\lambda = \dfrac{-1}{(.87)F(\text{CFM})(19 \times 0 + 120)}$

The agreement is pretty good. Probably best to lower the flow to ~ 50-60 CFM

5/15/08

New feed tip circuit board



I p. 34, 11

Losses in the length of phosphor bronze wire

$R_s = 2.52\times10^{-7}\sqrt{f(Hz)}$ for silver, $\sim 5\times10^{-7}\sqrt{f(Hz)}$ for p-bronze
$= .05$ ohm/cm @ 10 GHz

$$R/\text{unit length} = \frac{R_s}{2\pi r_0} = \frac{.05}{2\pi(.012)} = .663/\text{cm}.$$

$r_0 = 5$ mils $= .012$ cm

power exponential factor: $\frac{2R}{2Z_0} = \frac{.34}{100} = .0034$

For 0.5 cm length, get .0017 (very long)

$T = (.0017)\,300 = \underline{\underline{0.51\,K}}$ not much

---

From Rob Ackermann for LNA commands @ Mirex 5/15/08

Start → Program → Command Prompt
Then in the command prompt window:
route ADD 192.168.243.2 169.254.0.1

Then:

telnet 192.168.243.2

Inside telnet type "help" for PAX commands.

5/18/08

Tests at Minex: a) 820 had one totally dead pol.
b) one oscillating (as fake) pol.

5/19/08

Plans for cooling the feed following from III (p. 119)

a) Use just the $f > 1.0$ Hz part, half the length
b) Put the entire feed into a thin glass bottle.
c) Cool only the length of the bishop, ~ 3", and leave the rest at ambient.
d) evacuate the bottle
e) In order to cool the short lengths of feed arm, use a tip circuit board made of AlN. It's thermal conductivity is ~ 2100 watts/mK @ ~ 60K, about three times that of copper, and it's not a conductor.
f) Heat Sources to be removed at 60 K.
a) structure within the dewar: 230 mwatts (p120-122) iR
b) IR load on the feed arms and the pyramid: 110 mwatts
c) heat flow along the pyramid
Assume a gradient 230 → 70K along ~1 cm of silver plated stainless: 30 (1.5 skin depth @ 1 GHz) ~~(not about)~~
1.7 watts
d) heat flow along feed arms: 1.0 watts
e) LNA dissipation .120 watts each
f) output coax cables 2 x 12 mwatts = .024 (III pp 8-9)

Total = 3.3 watts

The cryocooler can lift 6 watts at 70°K. It should be ok.

g) Heat flow from the cooled short arms. Use AlN for the tip circuit board with its large K_{th} (ceramic)
The heat must then flow through the wires
At each wire of length .15" and thickness .03"

$$H = KA\frac{\Delta T}{\Delta L} = \frac{(830)(.0008)^2 10}{.15(2.5/100)} = 1.4 \text{ watts with } \Delta T = 10K$$

ΔT

only .25 watts needed for $\Delta T = 2K$ is needed

Feed_Upgrade.doc

h) The glass bottle may be thin: 0.5mm is a typical dimension.
The curves of p. 123 show the reflection from a plane piece of glass, with and without the double teflon ~~ear~~ strips

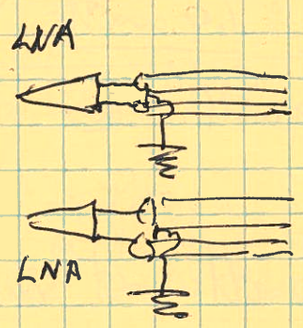
c') What's the gain? Look at the Y-factor measurement: ≲ 60K over 5-10 GHz
Take away ~10K for the LNA, leaving 50K.
That's all resistive loss. Just scale by temperature: 70/280 × 50 = 12° → 10°
for cool conductor. (copper losses also decrease)

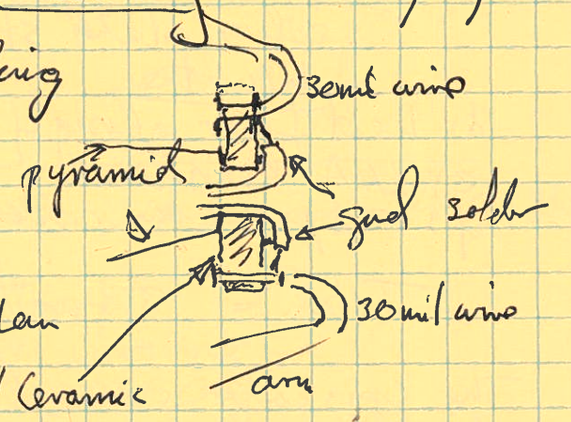
That drops the Tsys by ~200 K

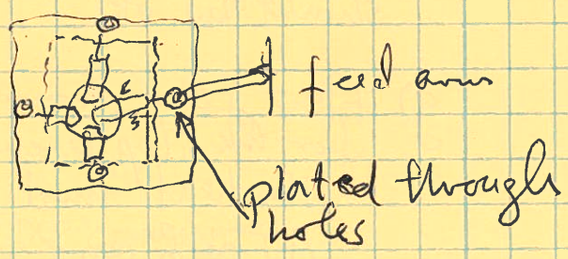
Expect an overall Tsys of ~ 25-30K for 1 GHz — 10 GHz

Further Thoughts about the cooling 5/23/08

Look at small coax coupling







Tip Board is AlN plated top and bottom. Plate the inside of the central hole for good electrical ground connection to the top surface.

Cut the edge of the central hole for easy bends to the coax

Coax losses @ 10 GHz: 0.164db/inch at room temp, .05db/inch @ 65K.
.0127, ΔT = .0127 × 65
= 0.8K/inch

STANDARD SEMI-RIGID COAXIAL CABLE*

Micro-Coax Part Number	UT 34C-10		UT 34-25		UT 34-95		UT 43C-10	
DIMENSIONS								
Outer Conductor Diameter (in) (mm)	0.034 ± 0.001 0.86 ± 0.0254		0.034 ± 0.001 0.86 ± 0.0254		0.034 ± 0.001 0.86 ± 0.0254		0.043 ± 0.001 1.09 ± 0.0254	
Dielectric Diameter (in) (mm)	0.025 ± 0.001 0.64 ± 0.0254		0.023 ± 0.001 0.58 ± 0.0254		0.027 ± 0.001 0.69 ± 0.0254		0.036 ± 0.001 0.91 ± 0.0254	
Center Conductor Diameter (in) (mm)	0.0201 ± 0.0005 0.51 ± 0.0127		0.0126 ± 0.0005 0.32 ± 0.0127		0.0028 ± 0.0005 0.07 ± 0.0127		0.0285 ± 0.0005 0.72 ± 0.0127	
Length Range (ft) (m)	1 - 15 0.31 - 4.57		1 - 15 0.31 - 4.57		1 - 15 0.31 - 4.57		1 - 15 0.31 - 4.57	
MATERIALS								
Outer Conductor	COPPER		COPPER		COPPER		COPPER	
Dielectric	PTFE		PTFE		PTFE		PTFE	
Center Conductor	SPC		SPCW		SPCW		SPC	
ELECTRICAL PROPERTIES								
Characteristic Impedance (ohms)	10 ± 3.0		25 ± 2.0		95 ± 4.0		10 ± 1.5	
Capacitance (Nominal) (pF/ft) (pF/m)	145.1 476.0		58.0 190.4		14.8 48.6		145.1 476.0	
Corona Extinction Voltage (VRMS @ 60 Hz)	200		200		1000		200	
Voltage Withstanding (VRMS @ 60 Hz)	500		500		2000		500	
Moding Frequency (GHz)	116		148		177		81	
Typical Attenuation (dB/100 ft) /Average Power (Watts CW) @ 20°C and Sea Level	ATTEN.	POWER	ATTEN.	POWER	ATTEN.	POWER	ATTEN.	POWER
0.5 GHz	100.0	15.0	49.9	30.0	42.0	28.2	65.6	27.7
1.0 GHz	141.8	10.6	70.8	21.2	60.4	19.9	93.0	19.5
5.0 GHz	319.3	4.7	160.6	9.4	137.4	8.8	210.3	8.7
10.0 GHz	454.0	3.3	229.5	6.6	196.8	6.1	299.8	6.1
20.0 GHz	646.9	2.3	329.4	4.6	283.1	4.3	428.9	4.3
MECHANICAL PROPERTIES								
Outer Conductor Integrity Temp. (°C)	175		175		150		175	
Max. Operating Temp. (°C)	150		150		125		150	
Min. Inside Bend Radius (in) (mm)	0.125 3.18		0.050 1.27		0.125 3.18		0.125 3.18	
Weight (lbs/100ft) (kg/100m)	0.30 0.45		0.26 0.39		0.19 0.28		0.45 0.67	

** Standard inventory item.*

Micro-Coax®, 206 Jones Blvd., Pottstown, PA 19464-3465 USA □ 610/495-0110 □ FAX: 610/495-6656 □ E-mail: sales@micro-coax.com

65

post reduction in velocity

~~before~~ ~~after~~

ANT/Node	Distance From Node	Temp June 16/17	Drop in Temp	Temp MARCH	Drop in Temp	Reduced Velocity Values on 6-13-08
Node 1	at node	33°C	Low Velocity	24°C	60 Hertz	32 Hz @ 1:25
Ant A	192'	23°C	10°C	17°	7°C	
Ant C	284'	22°C	11°C	15°	9°C	
Node 2		35°C		25°C		52 Hz @ 1:32
Ant E	355'	23°C	12	15°C	10	
Ant M	124'	26°C	9	19°C	6	
Node 3		35°C		17°C		55 Hz @ 1:40
Ant L	201'	22°C	13	11°C	6	
Ant J	84'	29°C	6	15°C	2	
Node 4		33°C		17°C		41 Hz @ 1:46
Ant H	252'	22°C	11	9°C	8	
Ant L	75'	28°C	5	13°C	4	
Node 5		34°C		18°C		28 Hz @ 2:28
Ant C	36'	29°C	5	15°C	3	
Ant G	91'	25°C	9	12.5°C	5.5	
	Call Jeff again March or May?					Ambient Temp: 32°C Date: 6-17-08 Time: 2:45 PM

←

Jeff Kaufman's temperature measurements:
the difference between the node temp. and the temp. of the air going into the base of the antenna.

The June measurements, after the speed reductions, show greater temperature drops at the lower speeds

The memo that discusses the basic temperature distribution along the pipe is #68 "Some Thermal Issues Regarding the ATA Noble Air System", W. J. Welch, March 23, 2005

— o —

☆ 16-18 Oct for the 50th anniversary of the RAL. Send e-mail to Don about the AKI dates conflicting. Brian Gaensler coming.

— o — Lynn suggests starting with one big length at each node

---

Expected thermal I, with the higher flow velocity and greater ground water content. 7/18/08

I. higher velocity

The original design is for $V = 5$ m/sec $= 984$ fpm
With the new fans with motors operating at ~ 3000 fpm, the air/pipe transfer Resistance drops by the factor $(3)^{-0.8} = 2.4$ i.e. from $0.30 \rightarrow 0.13$. due to the Reynolds number going up. (III p.68) Higher velocity would lower this R_{air} further.

II More moisture in the Soil

Figures 4 and 5 on III p.128 show thermal conductivity and heat capacity for dry soils
For the original calculations we used $K_e = 0.71$ w/m°K and $\rho C = C_v = 1.6$ mJ/°K m³ for heat capacity. These numbers are about right for 5% water.
At 10% water $C_v \sim 1.6$ mJ/°K m³, and $K_e \cong 1.8$ w/m°K, much higher. These give new values for $\beta = (1+i)\sqrt{\frac{\omega C_v}{2K_e}}$

$$\text{new } \beta = \frac{(1+i)}{16.7\text{cm}} = (1+i)\,1.82\ \text{ft}^{-1}$$

instead of $\beta = \frac{(1+i)}{11.27\text{cm}} = (1+i)\,2.75^{-1}$

We now have to repeat the calculation of III pp 70-72

then $\beta r_1 = 0.26(1+i)$

In the same units as before $k_e = 1.8\ W/m°K \Rightarrow 1\ BTU\,H/ft\,°F$

$K\beta\,Area = (1.0)(1+i)1.82\,(0.89\,ft) = 1.62(1+i)$

$x = r_2/r_1,\ \beta r_2 = 1.82(1+i)x$

I ignore the term multiplying T_0, let $x = 3$ (large enough)

$$H(r_1) = \frac{Q}{\Delta} K\beta Area\, T_{pvc}$$

$$= 1.62(1+i)\,T_{pvc}\left\{\frac{Y_0[1.82x(1+i)]J_1[.26(1+i)] - J_0[1.82x(1+i)]Y_1[.26(1+i)]}{J_0[.26(1+i)]Y_0[1.82x(1+i)] - J_0[1.82x(1+i)]Y_0[.26(1+i)]}\right\}$$

$$H(r_1) = (3.996 - 1.8957I)\left\{\frac{47.9135 + 29.9429I}{-6.277 + 28.5885}\right\}T_{pvc} = T_{pvc}[3.996 - 1.8957I]$$

$$Z_e = \frac{T_{pvc}}{H(r_1)} = [3.996 - 1.8957I]^{-1} = .2043 + .0961I$$

This is about half the thermal resistance as in the dryer case.

Now, let's add together both the Z_e for moist ground and the R_{air} for higher flow velocity:

$$Z_T = R_{air} + R_{pvc} + R_e = 0.13 + .22 + .2043 + i.096 = .554 + i.096$$

Now the flow velocity is up to ~ 3000 fpm

$$\lambda = \frac{1}{(.87)(150)(.554 + i.096)} = .014$$, ignoring the phase shift

New values for $e^{-\lambda x}$

50	$e^{-.014x}$	times 35°F
100	.50	→ 17.5
150	.25	→ 8.8
200	.06	→ 2.1
250	.03	→ 1.0

This isn't too bad, but it depends on the wet ground (for the shorter runs) to work well. Although even at 50' the factor is 0.5 here. Without the water, $\lambda \sim .011$

$e^{.011(50)} = 0.6$, not very different.

Since it's not very different, it may not be worth the trouble to do the watering.

Estimate of construction costs [7/19/08] beginning with the discussion on p. 12.

fully burdened salaries, first cut, was 208 K/month for everyone

Reconsideration of labor costs argued for two more elec. techs, an analog eng. and a digital engineer: 29,500 more/month.

Time requirement for construction of ~42 is one year.

Salaries are now 124 construction + 29,500 = 153,500/month. ✓

Labor, for one year, is now 12 × 153,500 = 1.82 M $ ✓

Labor Cost per antenna is now 1.82/42 = 43K for one year. ✓

Parts cost w/o the processor is now 88K/antenna ✓

Parts and labor, for a one year construction, is now ~~132K~~ per antenna: 88+43 = 132K; leave in the 10% for adall electronics, etc.

96

one FX 32 x 2 correlator is 175K parts and labor
one beam former is ~150K " " "

Divided by 42 is 4.2K for correlator and 3.6K for beamformer per antenna. 4.2 + 3.6 = 7.8K; 132 + 7.8 = 140K ✓

Total price for 42 more antennas is 5.88M $ in one year

~~There's no contingency here. 10% 5.993M $, 20% 6.6M $~~

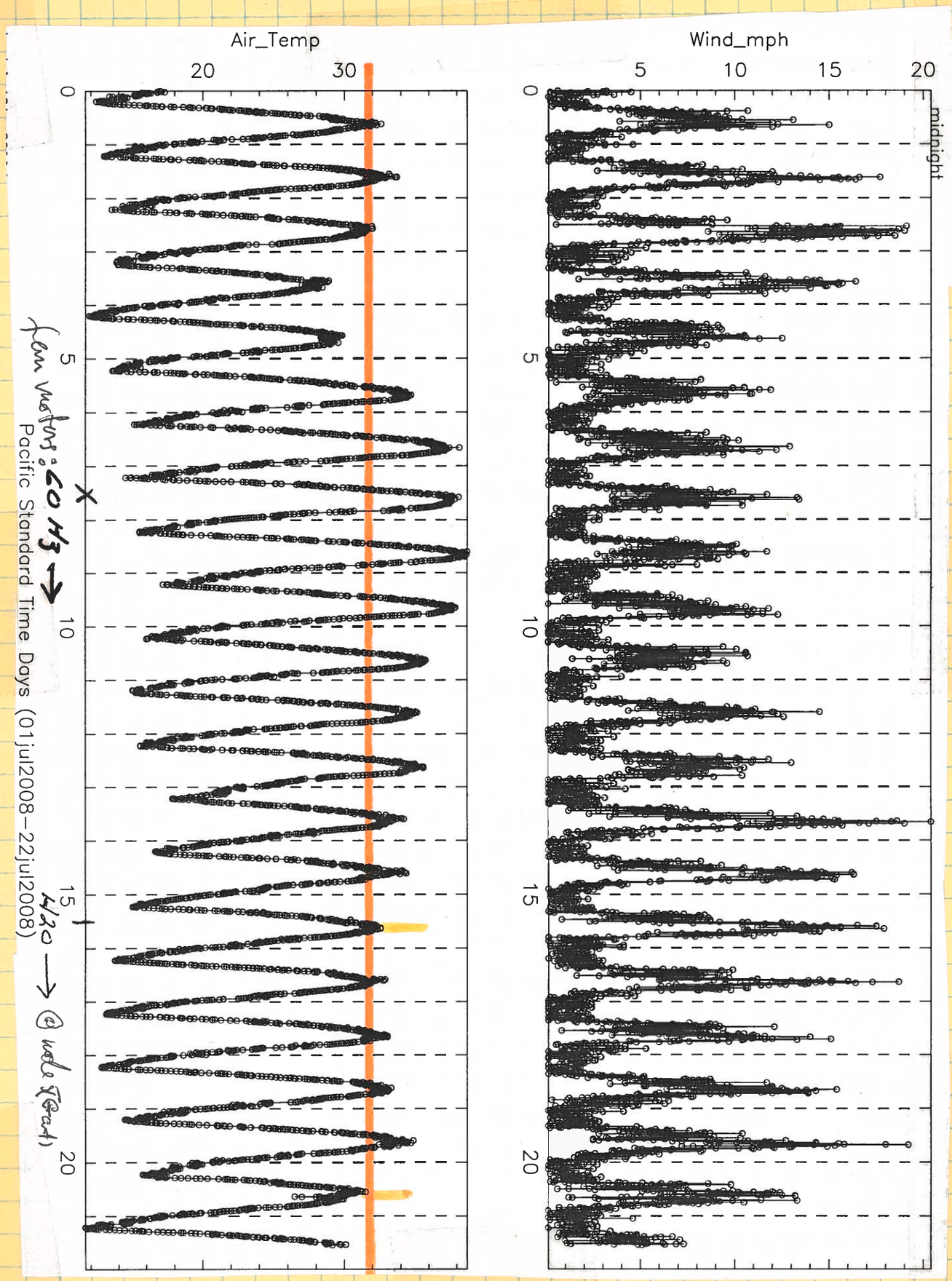
Inflation is ~2% year at present 3% in 18 months

~~That gets us to 130K per antenna w/o the processor~~
130 + 8K = 138

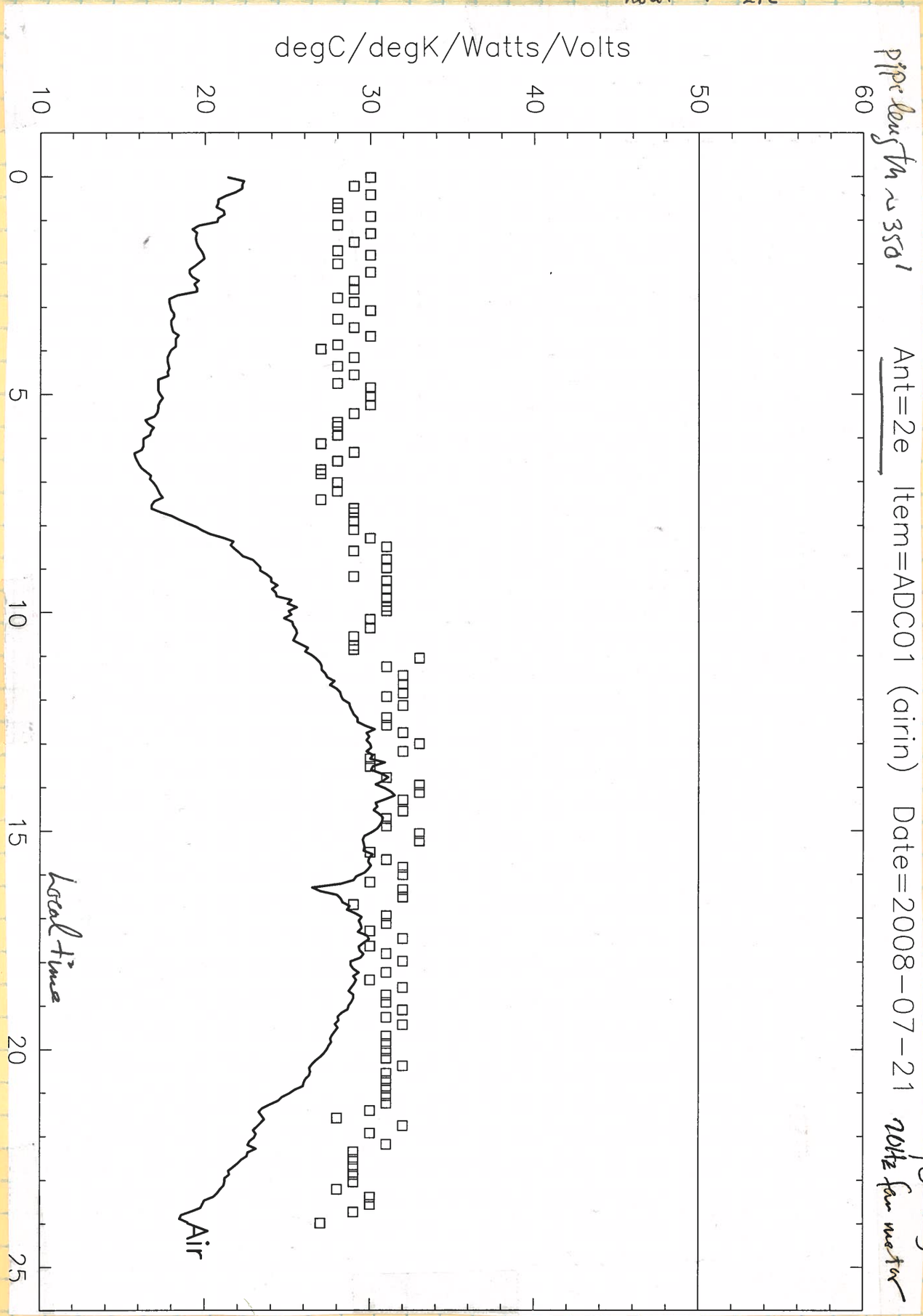
3% inflation ⇒ 1.03 × 5.88 = 6.06 M $

With 20% contingency, it's 7.3 M $

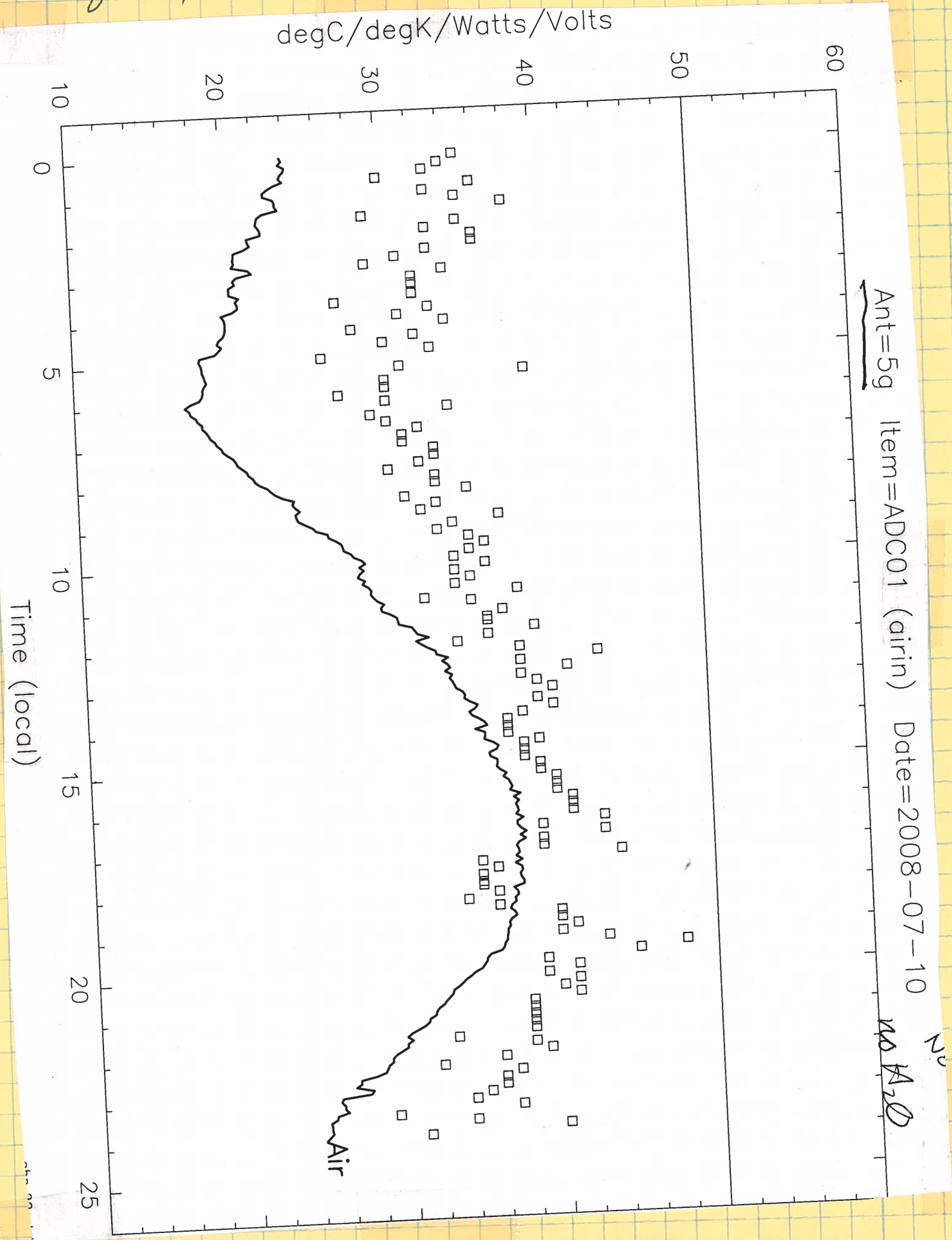
Some tests of the Underground Cooling with the greater Air Flow and Some Watering of the Ground 7/27/08
WJW, JK, RF



"airin" is the air temp. at the top of the 18' antenna pipe. This antenna run is ~350' in dry ground with air flow ≥ 150 fpm. airin is nearly constant over the day. The ground regulation works well at this distance
note: <T> ~ 29C

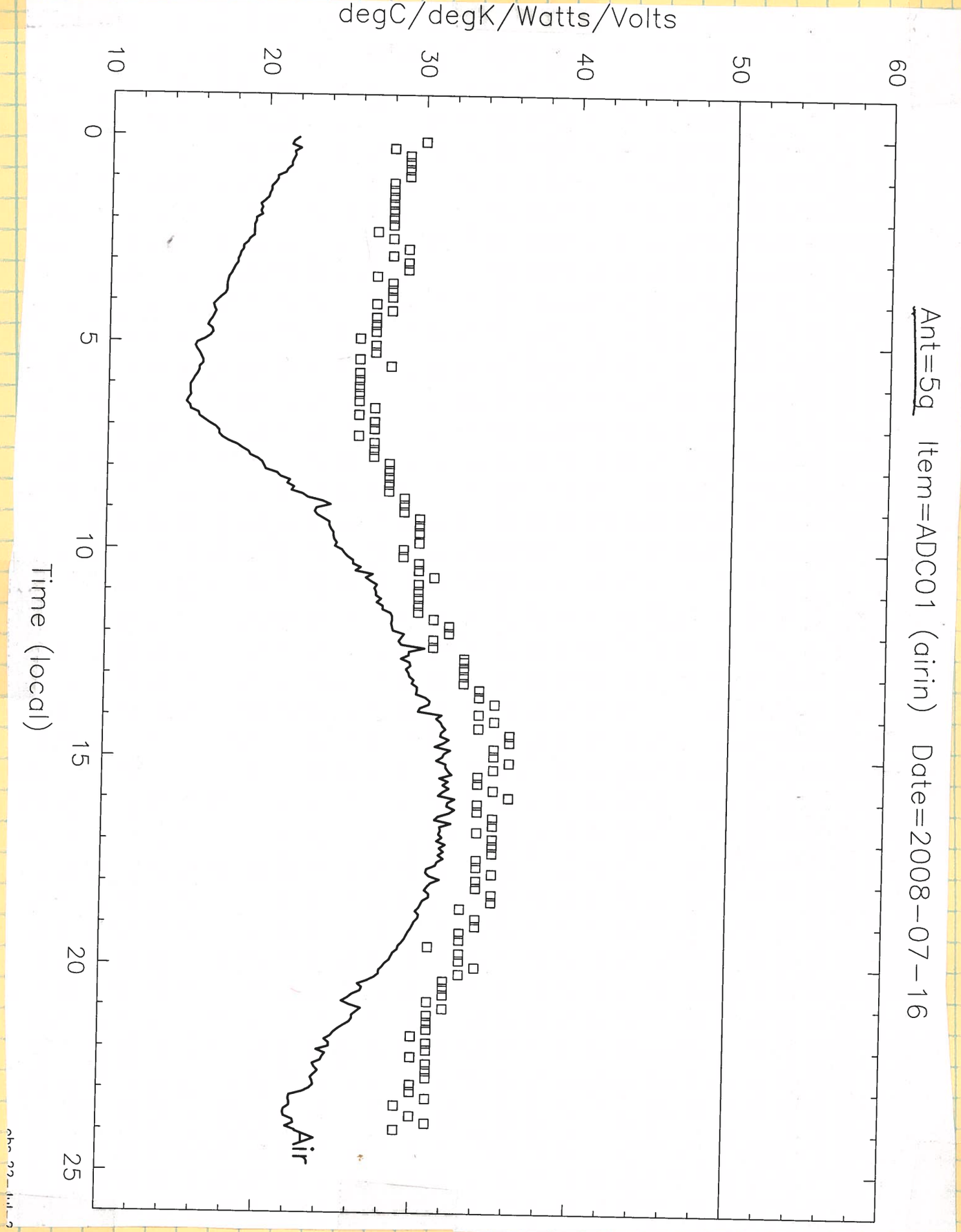


Antenna SG after a series of hot day/nights ; no water
Underground pipe run is ~100 feet "aircon"

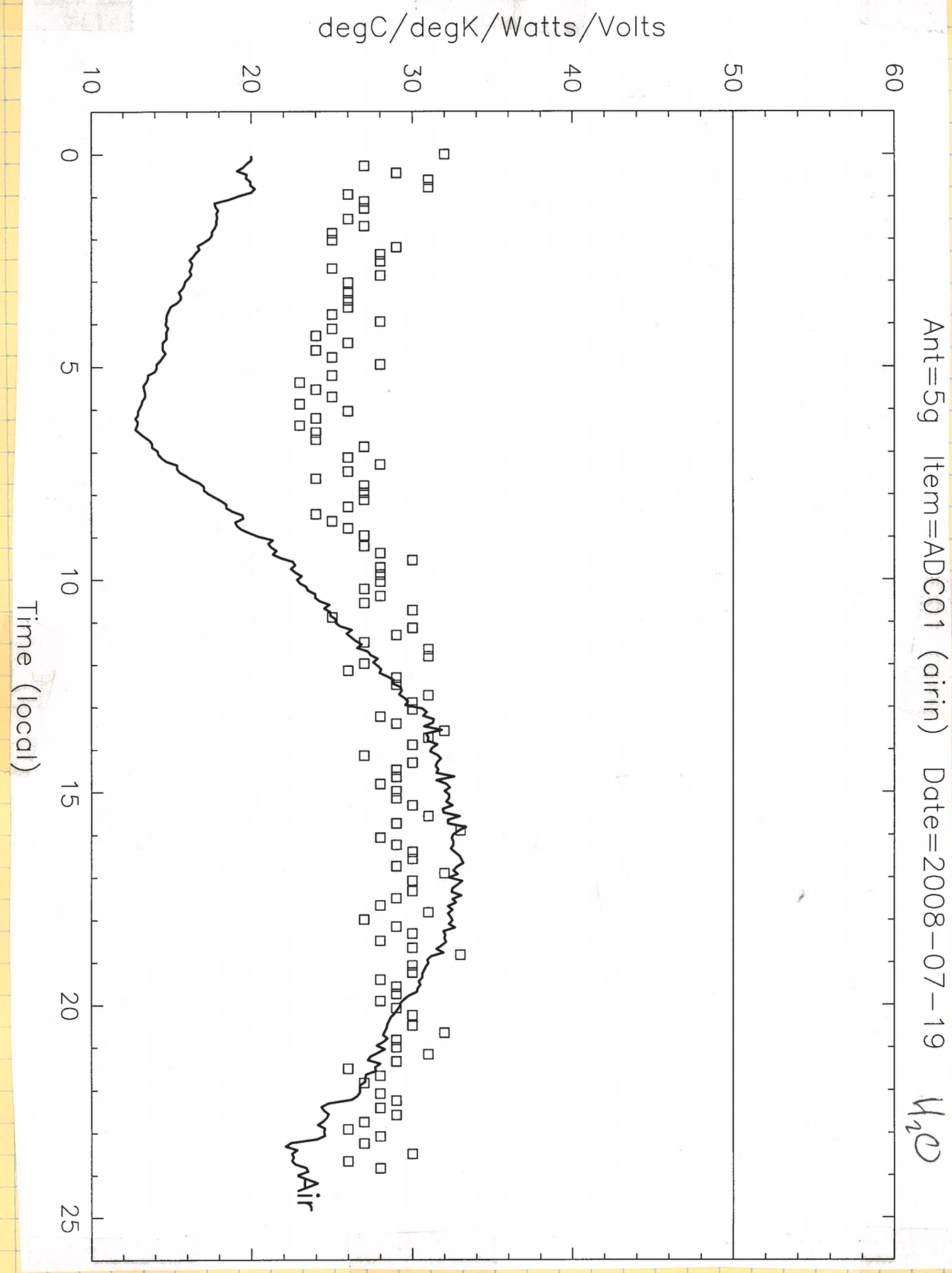


Antenna 5G after a series of cooler day/nights

Substantial diurnal variation. "airin" airin > Tair no water

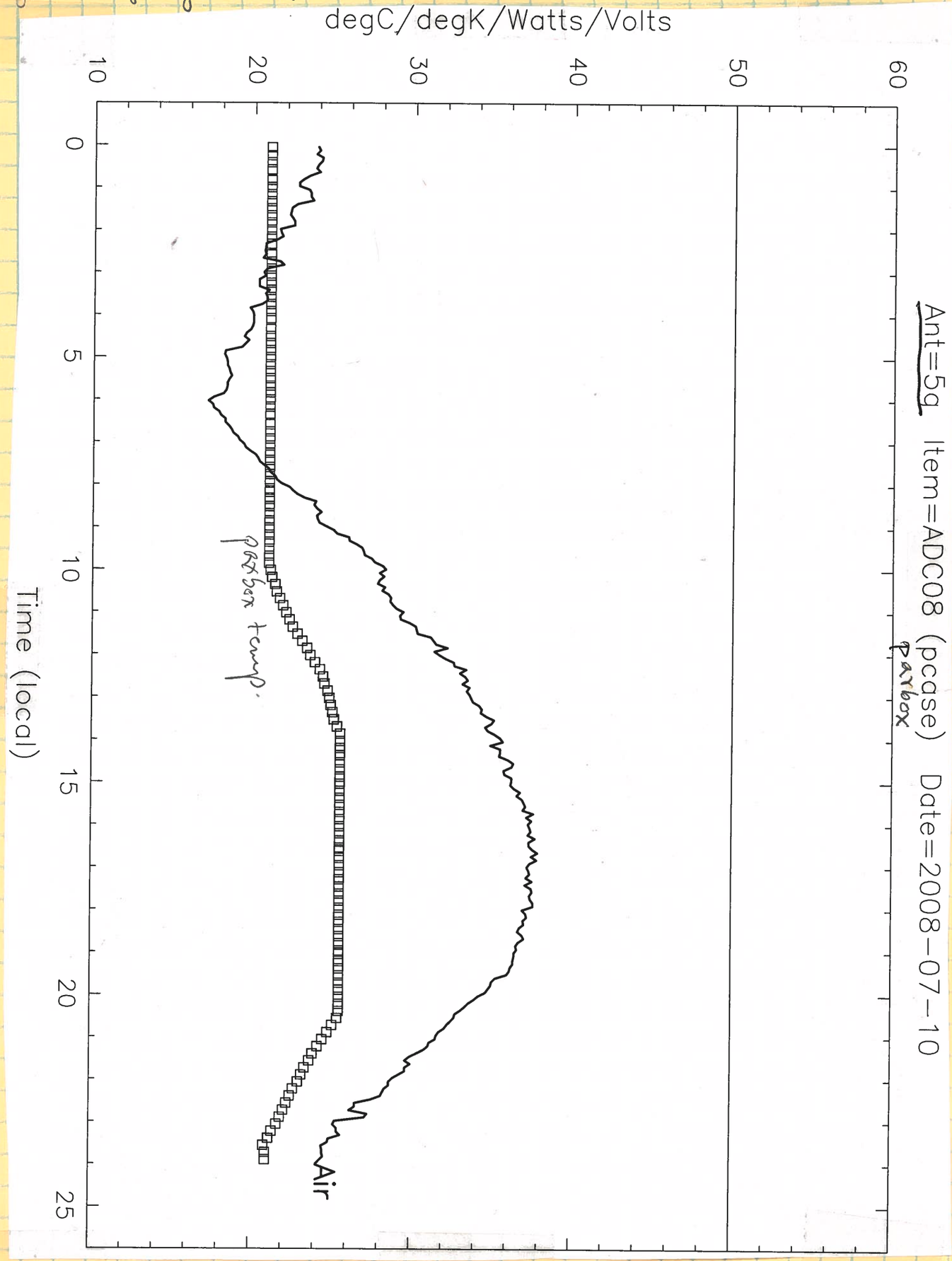


Antenna 5G "airin" after ~3 days of watering
more constant "airin" airin < Tair at midday.



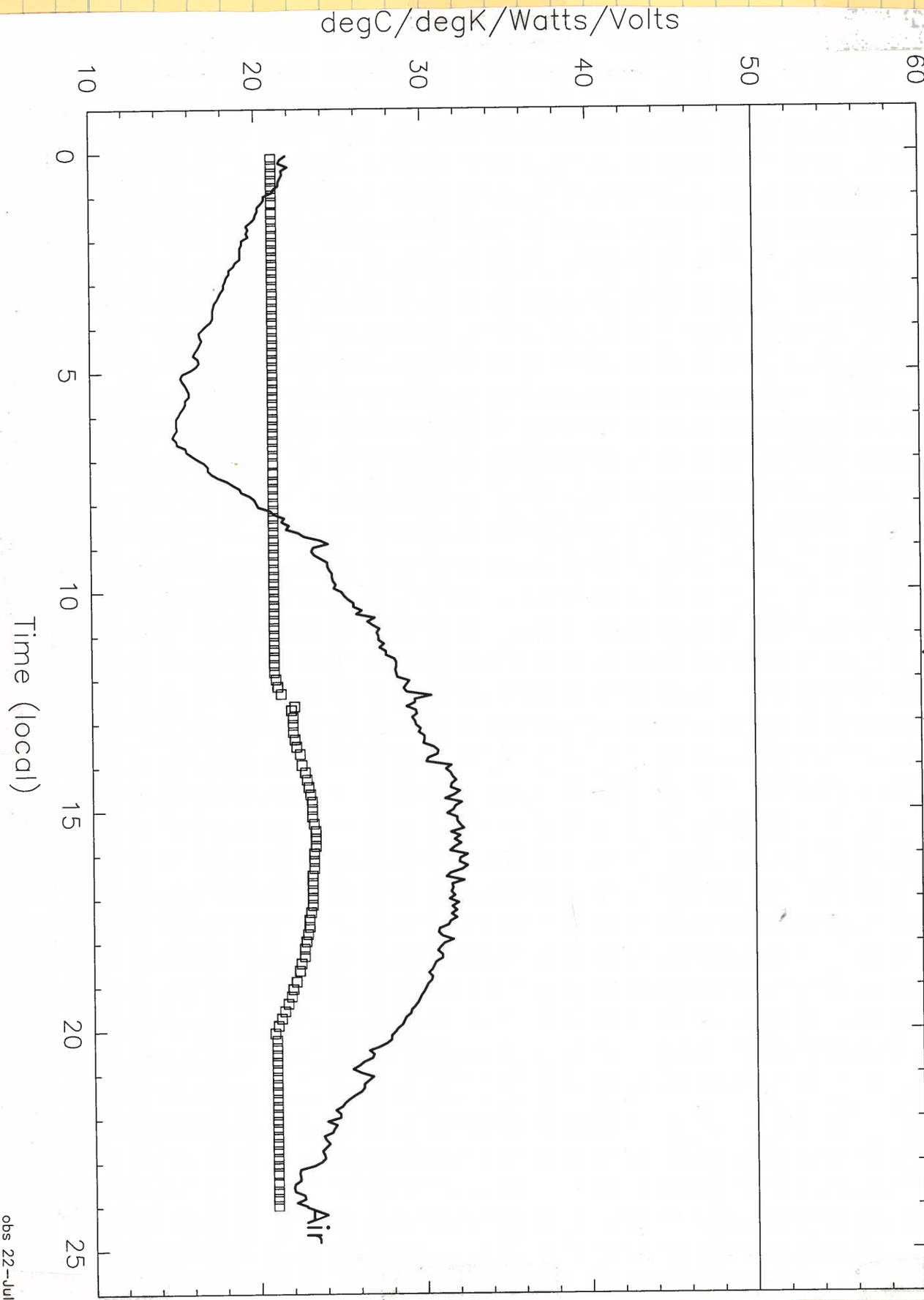
H_2O

The PaxBox temperature on a day after high temperature weather.
It goes out of regulation.
max Tair ~ 37°C

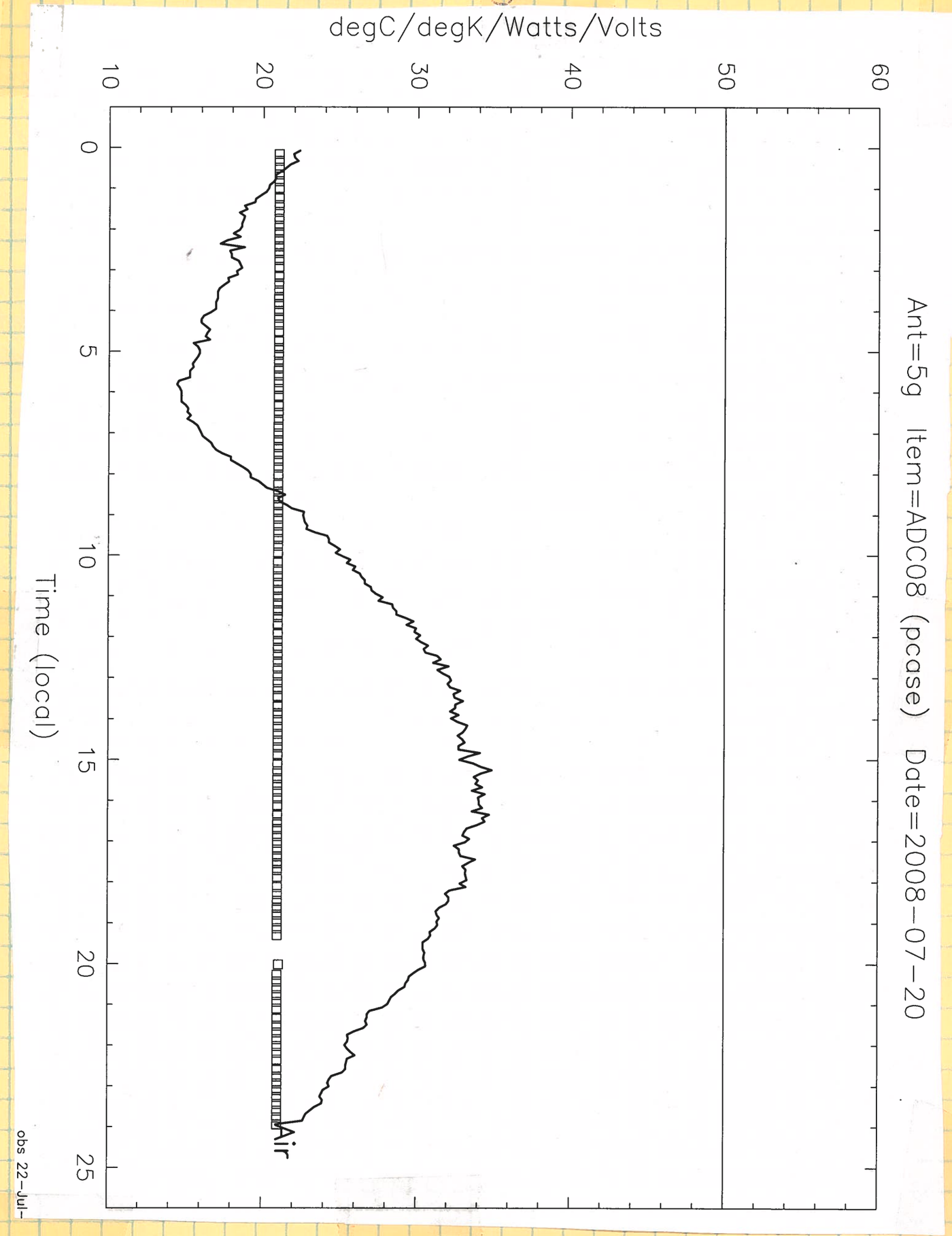


5G The PaxBox after a few days of cooler weather.
It still goes out of Regulation.

Max Tair ~31°C



5G The PaxBox after a few days of watering (~3days)
MaxTair~35°C It's regulating



The calculations on page 92, 91 suggest (a) Increasing the air flow by a factor of 3, without lowering R_e, by watering should not make a big difference in the cooling at the antenna. While the air flow in general helps cooling, the ~~air~~ temperature arriving at the antenna will be higher, especially for the short PVC pipe runs.

(b) Watering the ground to increase k_e should offset the loss of ground cooling by increasing the air flow, but not by much.

In fact the watering at node 5 (ant G) actually made a big difference, reducing the day-night "airin" temperature difference to every bringing it to a temperature below the ambient temperature during the day for the 100' run to 5G.

This suggests that the "dry" value of k_e 0.7 w/m°K used in the original calculations was probably too high. That value corresponds to ~5% ground water content. A value closer to ~1% for the unwatered ground is more likely ['see p 128 III (figure 5)] It must have been closer to 0.3 w/m°K. Going from this value up to ~2 w/m°K with the watering fits the observations better.

The measurements of the structure temperatures shown on the next page were made in early afternoon on 7/22/08. They are close to the outside air temperatures, a little warmer in the sun.

The inside air "airin" seems to hold at the day/night average pretty well ~28°C, so there seems little likelihood that "airin" is very much warmed by the direct ambient air outside of the pedestal.

ATA-Build-C Cost Estimate 7c M. Fleming; D. Backer 2009-08-08		Historical	Estimate	+100 units	Projection
Antennas in build		42	100		42
Total of listed items	$ / ant	176,433	170,100		252,791
Total cost / build	$/ proj	5,626,397	16,881,264		9,917,225
Ratio 100 price projection (some items)					1.068
Total SI+UCB: by year & total					
Total SI+UCB: by year & total w. 10% cont.					

WBS						
1.0.0	Antenna Parts Kits	$ / ant	66,923	70,175		74,957
2.0.0	Antenna Assembly	$ / ant	4,810	9,000	11.4%	9,613
3.0.0	Antenna Feed Assembly (total)	$ / ant	24,231	28,037	26.2%	29,947
4.0.0	Antenna Foundations	$ / ant	4,998	7,914	6.9%	8,453
5.0.0	Array Zone Nodes (projected 10 ant / zone	$ / ant	4,028	3,482		4,631
6.0.0	Array Utilities Delivery.	$ / ant	8,992	8,088		8,647
7.0.0	Array Analog Electronics (& digital x N)	$ / ant	19,981	10,933		10,933
8.0.0	Array Digital Electronics (x N^2)	$ / ant	10,000	0		19,048
9.0.0	Array Computing (UIUC)	$ / ant	6,784	6,784		4,762
10.0.0	Site Facilities (buildings, roads & equip)	$ / ant	12,177	12,177		19,757
11.0.0	Management & Budget	$ / ant	10,935	10,935		37,381
12.0.0	Education & Public Outreach	$ / ant	1,288	1,288		7,994
13.0.0	Array Commissioning	$ / ant	1,288	1,288		16,667

Antenna 1, 2, 4, 5,	45.8%	80,758	90,572	53.2%	97,655	38.6%
All other 3, 6 to 13.	54.2%	95,675	79,529	46.8%	155,136	61.4%
		176,433	170,100		252,791	
	1.03723					

Antenna diameter optimisation wrt to cost.

$$\text{Cost} = nA\left[\left(D/D_0\right)^{\alpha}+1\right]$$

First term is antenna cost
Second is electronics (all other)
At $D = D_0$, they are the same.

Single pointing sensitivity $S = knD^2$, $n = \frac{S}{kD^2}$

$$\text{Cost} = A\frac{S}{kD^2}\left[\left(D/D_0\right)^{\alpha}+1\right] \; ; \; \frac{\partial \text{cost}}{\partial D} = 0 \text{ gives } \left(D/D_0\right)^{\alpha} = \frac{2}{\alpha-2}$$

Then antennas relative to electronics should be $\frac{2}{\alpha-2}$

For mosaicing sensitivity $S = k'Dn$

$$\text{Cost} = A\frac{S}{k'D}\left[\left(D/D_0\right)^{\alpha}+1\right] \; ; \; \frac{\partial \text{cost}}{\partial D} = 0 \text{ gives } \left(D/D_0\right)^{\alpha} = \frac{1}{\alpha-1}$$

α	$\frac{2}{\alpha-2}$	$\frac{1}{\alpha-1}$	average	D/D_0: $\left(\frac{2}{\alpha-2}\right)^{1/\alpha}$	D/D_0: $\left(\frac{1}{\alpha-1}\right)^{1/\alpha}$
2.5	4	0.7	2.3	1.7	.87
2.7	2.9	0.6	1.8	1.48	.83
3.0	2	0.5	1.3	1.26	.79
3.3	~~0~~ 1.54	0.43		1.14	.78

$\alpha = 2.7$ is a frequent choice. This gives $\frac{\text{ant}}{\text{elec}} = 2.9$ or 0.6.
Taking into account the correlator pushes to a smaller number of antennas of larger diameter.

The average is: antenna cost ~ 1.8 electronics.

5G watered for ~3 days 2-24-08 Ground still wet Kmp

Tower Top	~~27°~~ 28° N	24.1 W	22.3 E	29.5 S
Pedestal Base	31° C			
	30.5 N	29.8 W	29.1 E	

Alidade

EL Indent 29.8

EL L upper 18.8 }?

R 18.3

Alidade Cover 22-21

Right Alidade upper 18.6

Shaded

ALL Temps @ 1:00PM Shaded

@ 2239 Light Breeze

Tower Top	35 S	31.5 W	32.3 E	33.5 S
Pedestal Base	34.7 S	33.8 W	34.6 E	34.7 S

EL Indent ~~32.7~~ upper

34.7 lower

EL L upper ~~32.8~~ 26.1

R 32.1

Alidade Cover 18.88

Right Alidade upper 31.0

34.1 L Foot down Alidade Lamp Conduit

38.9 Middle Arc

In Sun

on Tumulus: plottempmon2 2008-07-27 cart 30 please
Is air blowing back out the bottom of the antenna pipe?

Further expenses to completion

a) 20 further LNA receivers
   i) 20 Chips from Fraunhofer, @ $500 = 10,000 k$ (300 EU)
   ii) mounting and wiring up chip and associated bias circuit by Niklas Wadefalk (Low Noise Factory) in Sweden $830 each, for 20 ⇒ $16,600 [26K]

b) electronic shop (Ed) 2k$ left to spend for 100 attemplifiers
   $700 for 100 chip pads. (as part)
   6K$ for RFCBs each [2700]

c) Susie/Jeff Rim Box Fans and Connectors $ [700]

d) Matt Fleming Foam mount covers $800 each, x42 ≅ $ [22,000]

e) Matt Dexter no answer (It came later)

f) L01 band for Downconverters for f → 30 GHz Two needed, one for each 30k$ from Agilent.
   [Paul Eliot?] [60K]

System linearity measurements

1. analog power out of the attemplifier using GPS for a strong input signal and varying the attenuator setting.

2. Looking at the correlator output with a single tone @ 620 MHz added to the IF signal using a directional coupler. The power of the tone is stepped in 5db steps

3. A plot of on vs off of the tone output power with the input steps on the crb sissca.

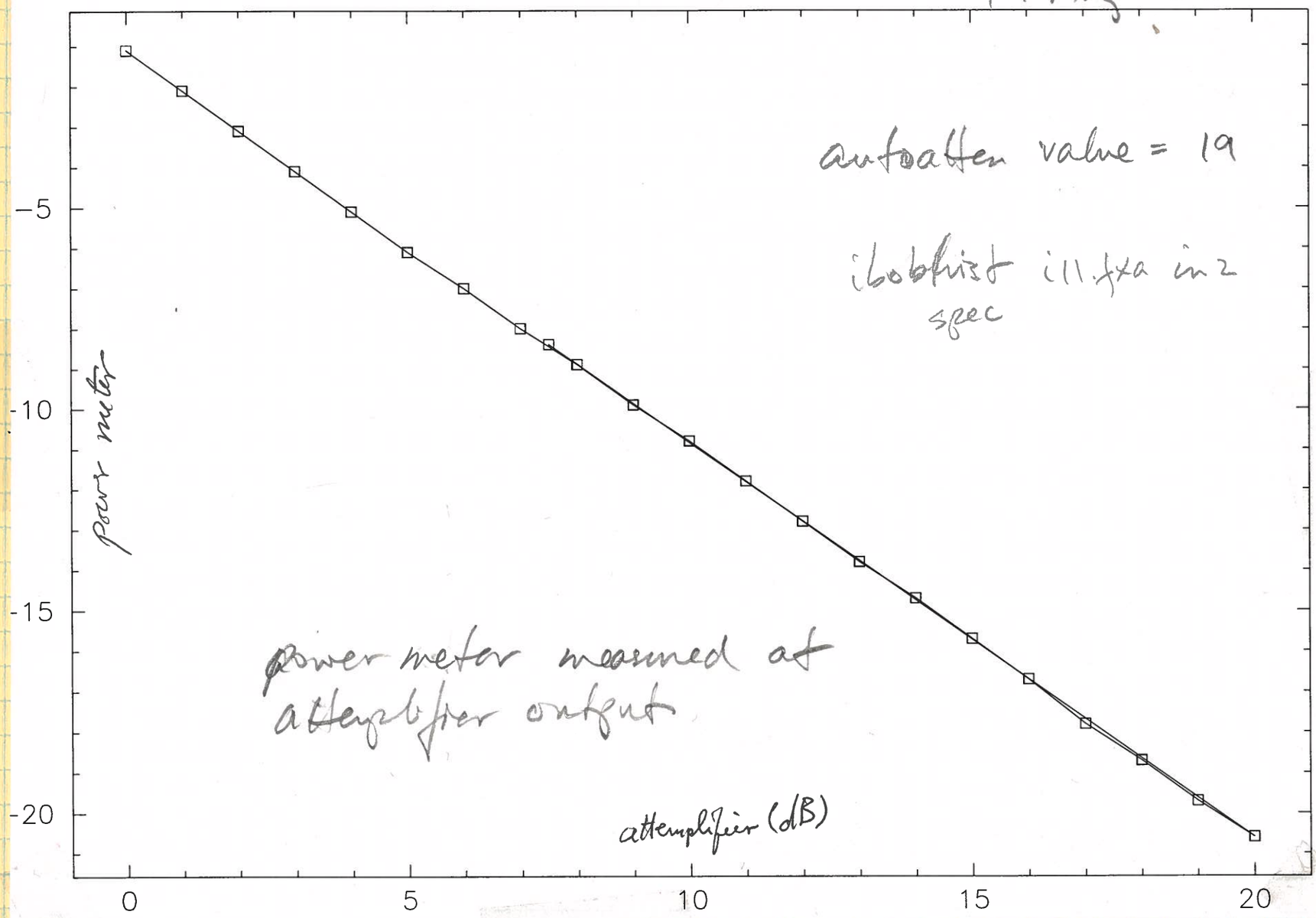
08/20/08 WJW JRF

105

1

Pam = 17 db
GPS = PRN26
19 Aug '08

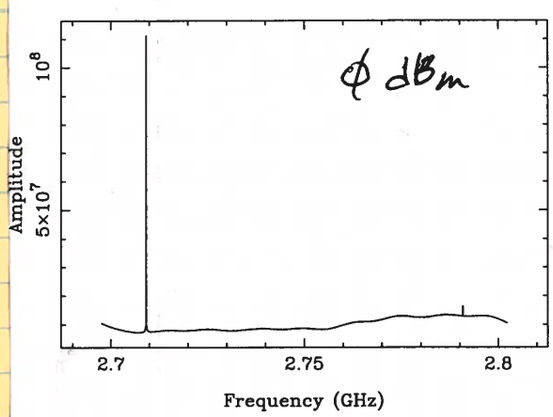
1a-x pol



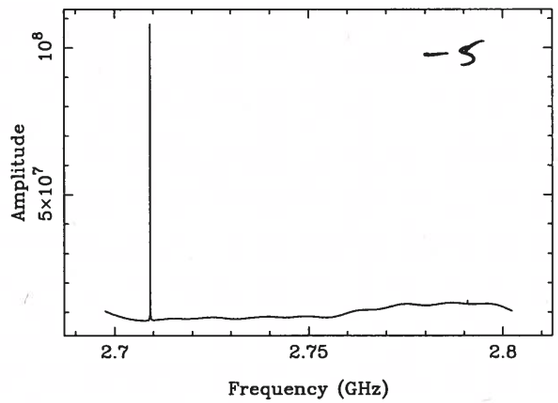
Level of PO tone in dBm

20 Aug 08/tonetest

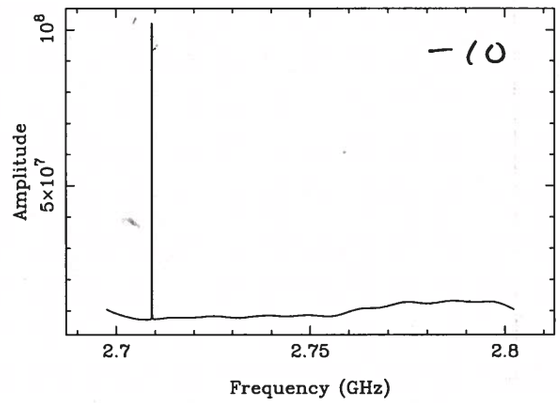
XX, τ=0.2 min, Bl=14−14, T=23:56:10



XX, τ=0.3 min, Bl=14−14, T=23:55:05

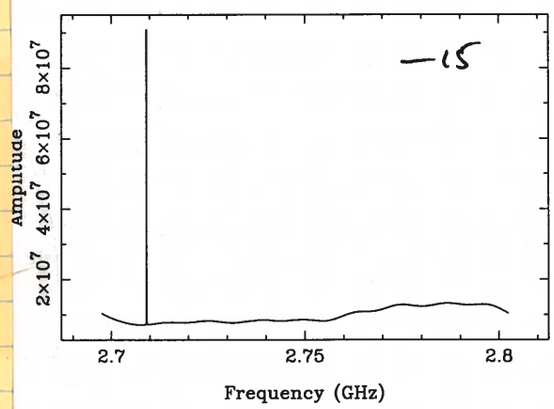


XX, τ=0.3 min, Bl=14−14, T=23:52:45

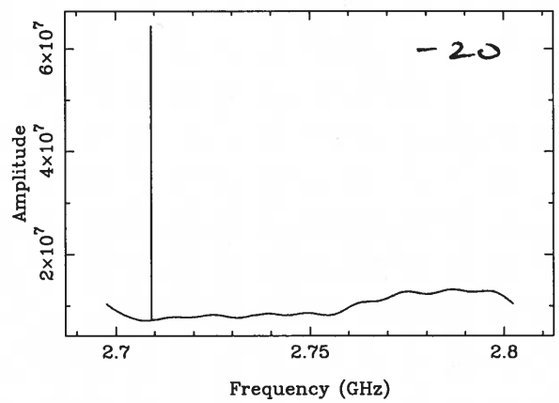


2

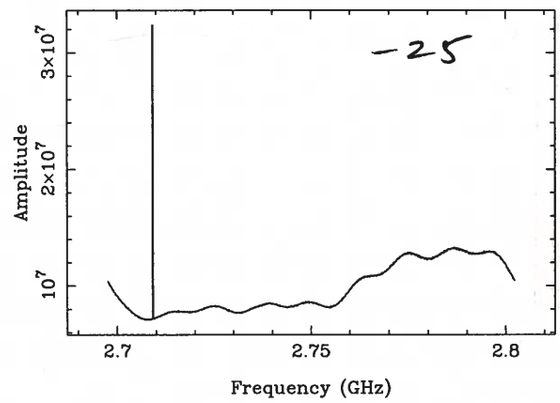
XX, τ=0.2 min, Bl=14−14, T=23:51:50



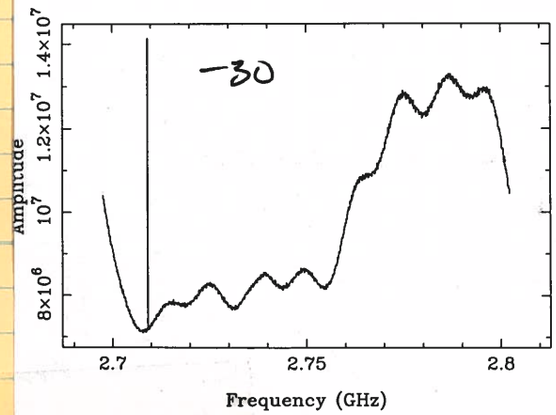
XX, τ=0.2 min, Bl=14−14, T=23:50:50



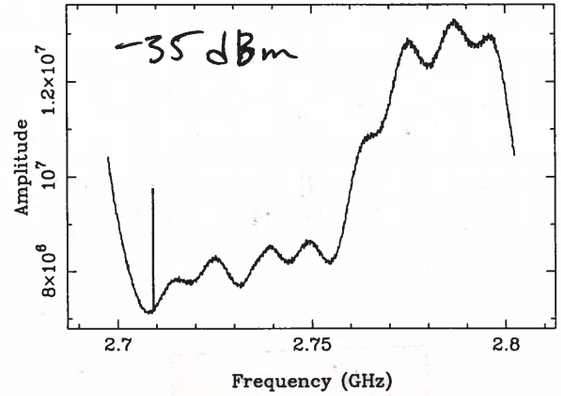
XX, τ=0.3 min, Bl=14−14, T=23:49:15



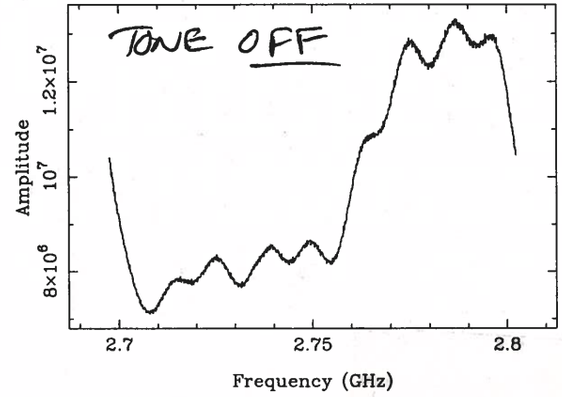
XX, τ=0.3 min, Bl=14−14, T=23:47:55



XX, τ=0.3 min, Bl=14−14, T=23:46:55



XX, τ=0.3 min, Bl=14−14, T=23:45:55

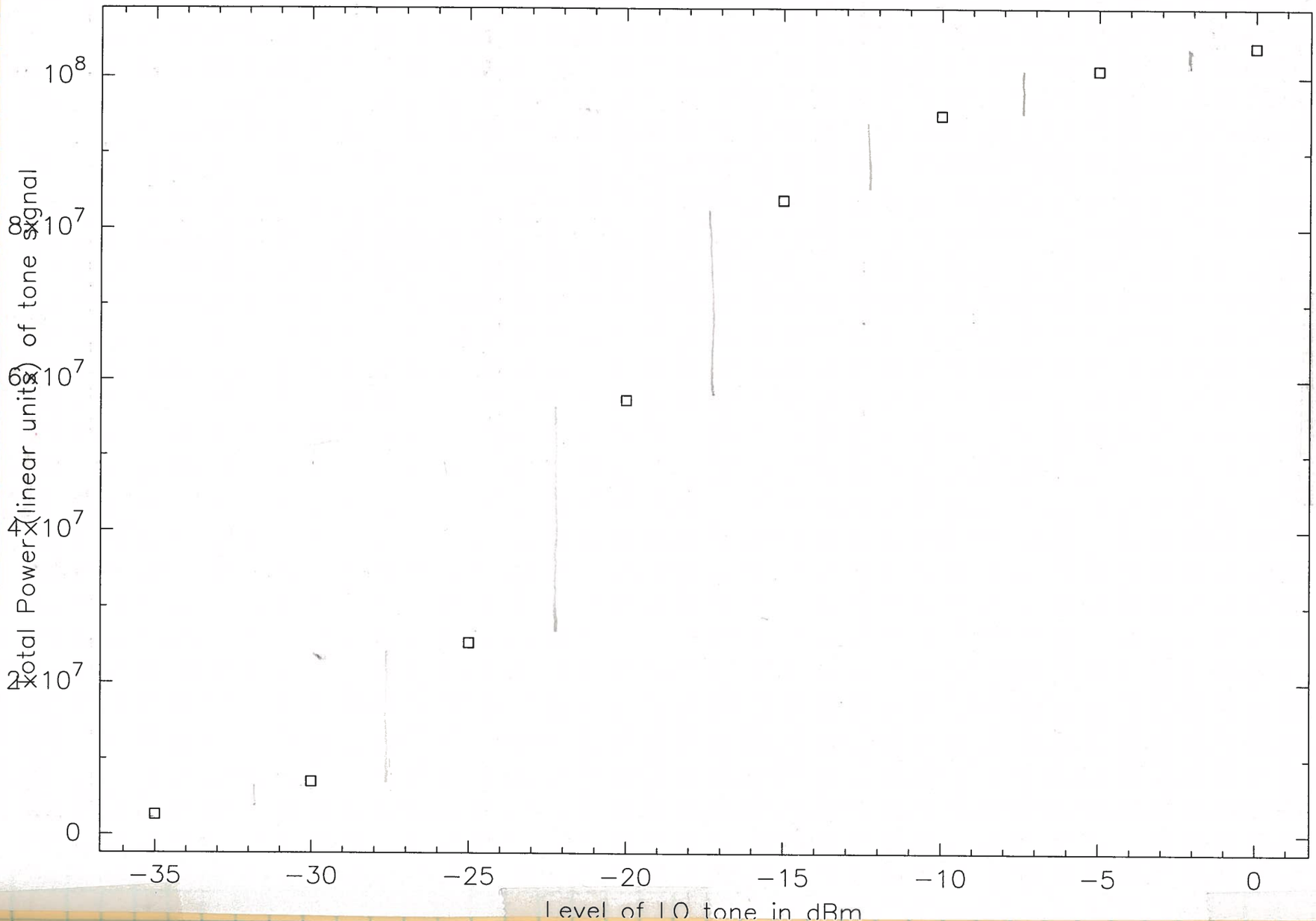


106

107

BITSEL = 8

20Aug08 – tone test using coupler
to combine 670mhz with IF into ibob forpol ant2dx



3

Looking at a single tone plus the back ground noise as a function of it's power: Use a directional coupler at the output of the RFCB (after the anti aliasing filters)

Vary the signal generator power. It's relative level is shown in the graphs. NB The channel widths are 100 kHz from the polyphase filter. The non-linearity begins at about -15 dB (9×10^7). The noise level at that frequency is about 7×10^6. This implies a dynamic range of about 10 (10 db). This seems reasonable for a 4 bit range.

This tone could be a spectral line or interference. The ADC is 8 bits and the polyphase filter uses all 8. If it is effectively ~6.5 bits, that's a factor of ~100 or 40 db. That's the headroom before the bit selection is invoked for the correlator. The next test should be to change the bit selection on that channel.

9/14/08

For building out the array a shielded processor building will be needed. The current "correlator" room is 20' x 30'. The present load is ~20 kwatts for 42 antennas. If we build out to 350 antennas, $\frac{350}{42} \sim 8$ times more array. The ~~[illegible]~~ RFCB load is up a factor of 8. The ADC and beamformer load is up by a factor of 8. The SETI detector load is up a factor of 8. The correlator load is up a factor of 8^2. What is it now?

~~Refrigerated cooling~~

Here is Matt Dexter's preliminary load estimate

Here are some preliminary power requirements for the correlator and beamformer racks.

All input power is 120VAC 60Hz single phase.

Correlator Rack (applies up to ATA-48x2)

iBob+ADC chassis	800W
F Chassis	1000W
iBob+ADC chassis	800W
X Chassis	600W
TOTAL	3300W

Correlator&Beamformer iBob Rack (applies upto ATA-48x2)

iBob+ADC chassis	800W
iBob+DAC chassis	800W
TOTAL	1800W

Beamformer Rack (applies upto ATA-48x2)

iBob+ADC chassis	800W
iBob+ADC chassis	800W
BEE2 X poln 1	500W
BEE2 X poln 2	500W
BEE2 Y poln 1	500W
BEE2 Y poln 2	500W
iBob+ADC chassis	800W
TOTAL	4600W

4000 - RFCB (no)
3300
1800
4600
13,700
3 Prelude units 6,000
19,700

Most values above are derived from measurements taken of a partially populated chassis. The calculation was basically a simple scaling with a small fudge amount added.

The Beamformer values more theoretical; I didn't want to interrupt ongoing efforts. It is conservative but not obscenely so.

Note: I haven't added in any of the other stuff that may go in these chassis. Such things would include John Dreher's FTS gizzmoes.

The X board should scale as $\frac{N^2}{2}$ i.e. $600\,W \frac{1}{2}\left(\frac{350}{42}\right)^2 = \frac{41,600}{2}$ watts

The rest scales as N $19{,}100\left(\frac{350}{42}\right) = 159{,}000$

The total is ~~$~~ 201,000 watts. [preliminary] ☆

We need to measure the actual current power because there now 2 beamformers and two correlators.

A suggestion for the new building is 30' x 100', five times bigger than the current correlator room.

The agricultural PGE cost is $1000/kw year. The cooling power will be about the same as the electrical power.

Power measurements in the current electronics room made by Gary Gimlin

9/16/08

a) Three phase power overall: 208 three phase
$\langle I \rangle = 52$ amps $52 \times 208\sqrt{3} = 18.73$ kVA ✓
This includes everything except the Liebert unit.

b) Individual components

① RFCB	5 amps,	x120 =	600 watts	14.2 watts/plate
② CHD correlator	11.6 amps,	x120 =	1392 watts	
③ new correlator	8.2 amps,	x120 =	984 watts	
④ beamformer	8.0 amps,	x120 =	960 watts	
⑤ new beamformer			960 watts	

Total power: 2 beamformers + 2 correlators + RFCB: 4896 ✓
This number will grow with the array. The other stuff including the Prelude units, LO's, computers, timing drivers, clocks, don't grow very much: 18.7 − 4.896 = 13.8 kwatts (inc. some UPS units)

Assume that the x board is (Matt F.) 600 watts and there are two: 1200 watts
This grows as $\frac{N^2}{2}$: $\frac{1}{2}\left(\frac{350}{42}\right)^2 \times 1200 = 41.6$ kwatts

The rest grows as N: $\frac{350}{42}(4896 - 1200) = 30.8$ kwatts

Total, including final power, 41.6 + 30.8 + 13.8 = 86.2 kwatts

The proposed Processor Building 9/16/08

The general idea is a Butler-type prefab steel building (but Mybrowld?)
30'x100' (that's 5 times the current space)

Cost Estimate (budgetary)
ATA Processor Building
2008-09-16

Qty		Building Total	Unit	Amount
5,037	cu-yds	Remove soil 100 x 340 x 4.0 ft	6.00	30,222
4,444	cu-yds	Sand. 100 x 300 x 4.0 ft no	10.00	44,444
15,000	ft	Alum Tubes 2 sides, 150 ft, 50 tubes, 2 ft apart, 4.5 dia	7.58	113,650
100	ea	Other tube parts.	100.00	10,000
3,000	sq-ft	Concrete slab 30 x 100 ft x 0.8 thick.	11.00	33,000
3,000	sq-ft	Metal building 30 x 100 ft	10.00	30,000
3,000	sq-ft	Insulation 30 x 100 ft	3.00	9,000
2,160	sq-ft	Screen room 24 x 90 ft	17.00	36,720
2,160	sq-ft	computer floor 24 x 90 ft	32.00	69,120
1	ea	Electrical Service	25000.00	25,000
1	ea	Special ventilation equipment.	12000.00	12,000
				413,156

Assumptions and other information

86	Kw	Power to disipate.
7.58	$ / ft	Aluminum tube 4.50 $/lb estimate Incelux 2008-09-16
95	$ / yd	Concrete base price
198	$ / yd	Concrete, base, forms, rebar, poured, finished, 2.1 x.
11	$ / ft	Concrete slab, gravel base, rebar, 8" thick, estimate Hat Creek Const. 2008-09-16
1786	$ / yd	Node slabs from $1500 for 0.84 cu-yds base, forms, rebar, slab, finishing
1.30	$ / ft	Copper screen 18 x 14 roll price 30" 100' x $329 from web.
7056	sq-ft	Surface of screen room 24 x 100 x 12 ft
9172.8	$ / sq-ft	Screen mtrl surface area cost.
4.25	$ / sq-ft	Screen material floor area. Use a multipier for frame & labor.
37.5	$ / sq-ft	Computer floor. (used material) from 2 x 2 for $150 Comx Co.

Note: Comx Co. 614-841-9000, Columbus Ohio, Todd Cogan, todd@comxusa.com, Mark Masters.

Matt, Jack, and Susie

The cooling will be done by underground airflow rather than air conditioner units like the Liebert. The Liebert system gives us a temperature that cycles up and down ±10° on a 10-20' period causing some gain and phase drifts. The underground air will be relatively steady varying by less than a degree with a period of one day. The layout will be similar to the originally planned processor building with one shielded space for the RFCBs and another for the digital stuff. It will use aluminum pipes rather than PVC to lower R_{pvc}.

p.92 shows the result of 150 CFM air through 3" PVC into a slightly moist sandy soil.

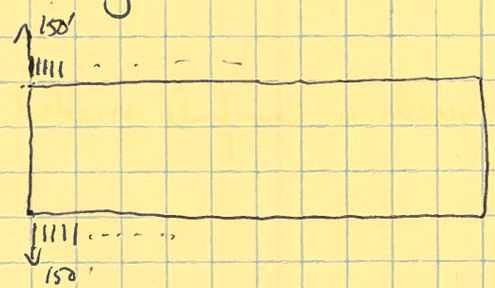
Note $Z_T = R_{air} + R_{pvc} + R_e = 0.13 + .22 + .204 + i.096$

The $R_{pvc} = .22$ is a significant contribution to Z_T. Our plan is to use Aluminum pipe for which $R \cong 0$. This leaves Z_T from $.554 + i.096$ (for 1 day period) to $.33 + i.096$.
In this case:

$$\lambda = \frac{1}{(.87)(150)(.33 + i.096)} = .021 + i.096$$

For 150 foot pipe lengths: $e^{-.021(150)} = e^{-3.24} = .039$
This multiplies the peak daily temperature of 10°C p.94).
$.039 \times 10 = .39°C$. The important point is that the period of this variation is one day. So the room temperature will be very much less in variation than the present room.

The underground pipe layout will be pipes at 2' centers, three feet deep. 100 in number on the two sides of the building.



No The present plan is to excavate on both sides of the building to 4', install the pipes, and fill with sand. Wet sand has very good thermal conductivity. [Sand is a bad idea, WJW 11/11/09] A

9/20 The heat flow from underground cooling. The air temperature after flowing underground is ~22°C or 72°F in summer, lower at other times. The cooling depends on its temperature rise in going through the electronics to the outside exhaust in the roof.

$$P(\text{watts}) = 0.34\,F(\text{CFM})\,\Delta T(°F)$$

I. With an airflow of 150 CFM (as for the antennas) and a temperature rise of 20°F (72 → 92)F:

P = 0.34 (150) 20 = 1020 watts (~1000 watts)
For 100 pipes that's 100,000 watts.

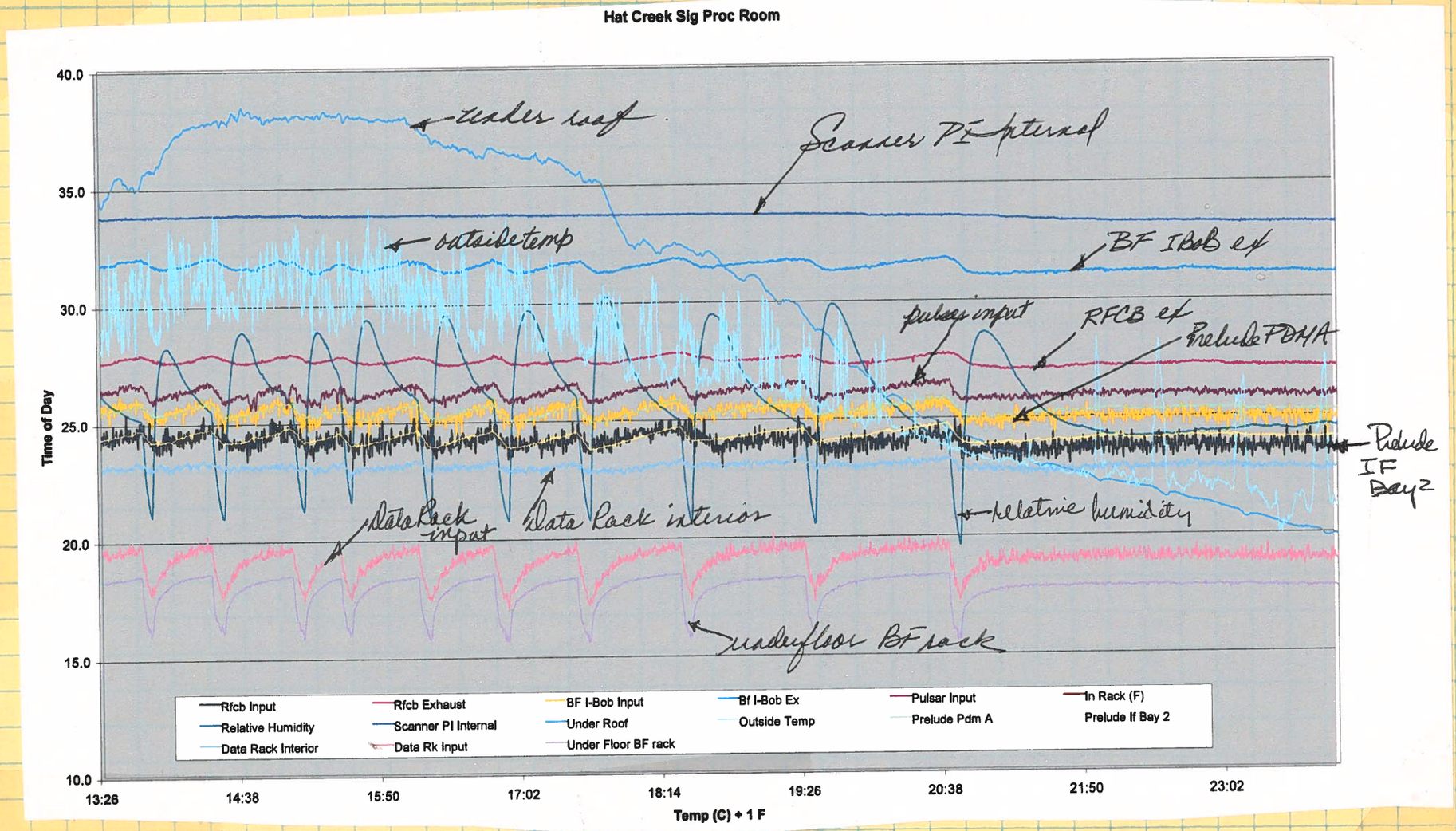
With a temperature rise of 30°, P = 150,000 watts

II. More airflow is possible
With 250 CFM / pipe and ΔT = 30° F (up to 102° F)
get 255,000 watts for 100 pipes.

The peak heat flow into or out of the ground when the air ~~ground~~ Temperature is ~ 10°C above the the ground (pipe) Temperature. Then the flow into the ground from the pipe is .34 (250)(18°F) = 1530 watts/pipe or 153,000 watts total.
For 2×100×150 = 30000 m² of surface area [No, that's 30,000]
surface heat flow density: 153,000/30000 = 5.1 watts/m²
The heat flow will be greater near the inlets because of the exponential temperature drop along the pipe.
3×5.1 watts/m² = 15.3 watts/m²
This is small compared with the solar constant of ~ 1kw/m²
But it is comparable to the daily inflow and outflow of heat through the surface. The underground will be warmed in the day by the air and cooled in the night time by the air, but the air flow temperature will be smoothed out. It will filter better @ 150 CFM. [This needs a careful model calculation]

Air temperatures are shown on the sheet on the next page.

Note also the Intel study which showed that cooling with desert air works as well as CRAC unit for processors. Dirt, heat, and humidity changes didn't really matter.


Hat Creek Sig Proc Room
Time of Day
Temp (C) + 1 F
40.0
35.0
30.0
25.0
20.0
15.0
10.0
13:26
14:38
15:50
17:02
18:14
19:26
20:38
21:50
23:02
Rfcb Input
Rfcb Exhaust
BF I-Bob Input
Bf I-Bob Ex
Pulsar Input
In Rack (F)
Relative Humidity
Scanner PI Internal
Under Roof
Outside Temp
Prelude Pdm A
Prelude If Bay 2
Data Rack Interior
Data Rk Input
Under Floor BF rack
under roof
Scanner PI pterual
outside temp
BF IBob ex
pulsar input
RFCB ex
Prelude PDM A
Prelude IF Bay 2
Data Rack input
Data Rack interior
relative humidity
underfloor BF rack

9/23 Delay observations through the RF spitter Boxes of LO1

This was done using the network analyzer set to read out phase vs. frequency with a frequency sweep over 17 – 25 GHz (8 GHz)
Then electronic delay was dialed into produce a flattened (as near as possible) trace and reading off the delay distance from the screen.

I. Measurements of 10 quiche cables

cable
① -7.195 μm (arbitrary)
② -677 μm
③ -284 μm
④ -494 μm
⑤ -494
⑥ -223
⑦ -828
⑧ -653
⑨ -300
⑩ -645 μm

The range is 670 μm.

RMS is .446 m ~ ½ mm

II. Measurements on the RF splitter boxes before the RFC Bs.
There are four channels: A, B, C, and D.
Each channel was tested separately. It's input power splitter was disconnected from it's LO and the NA was connected in on the signal port. Then then the splitter output was connected to the NA return port. The NA was set to sweep 17–25 GHz
The input power was set at -10db, the same as the signal from the LO and it's cable. (measured at 18 GHz)

Boxes: upper and lower
Banks: left to right: 1, 2, 3, and 4
terminals within banks, left to right: 1, 2, 3, 4, 5, 6.
} e.g. l(b3)6(t)

LOA

One bank: b1

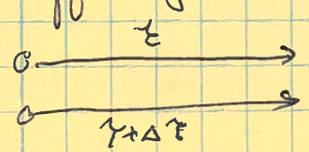
Port	delay(m)	phase slope	phase range over band	Δ[from the ave. 5.9340]
l(b1)1	5.9338	upward	90°	-.0002
l(b1)2	5.9336	"	90°	-.0004
l(b1)3	5.9340	"	90°	0
l(b1)4	5.9341	"	90°	.0001
l(b1)5	5.9340	"	90°	0
l(b1)6	5.9343	"	90°	.0003

LOA bank 3

Port	delay (μs)	phase slope	phase range over band	Δ (from 5.9340)
ℓ(b3)1	5.9410	upward	90°	.0070
ℓ(b3)6	5.9349	upward	90°	.0009
two other banks				
ℓ(b4)6	5.9345	upward ~~5.9345~~	90°	.0005
ℓ(b2)1	5.9331	upward	90°	−.0009
upper boxes				
u(b3)6	5.9526	downward	150°	.0186
u(b4)6	5.9542	"	"	.0202
u(b2)1	5.9526	"	"	.0186
u(b1)1	5.9526	"	"	.0186
LOB				
u(b3)6	5.9508	downward	150°	.0168
ℓ(b3)6	5.9500	upward	180°	.0160
LOC				
ℓ(b4)6	5.9519	upward	~180° max slope 50° over 800 MHz	.0179
u(b4)6	5.9538	downward	~150°	.0198
u(b4)1	5.9521	downward	~150°	.0181
ℓ(b1)1	5.9511	upward	~180° max slope 45° over 800 MHz	.0171
LOD				
ℓ(b4)6	5.9511	(upward)	~180° 45° over 800 MHz max	.0171
ℓ(b1)1	5.9498	(upward)	~180° 45° over 800 MHz max	.0158
u(b4)6	5.9528	(downward)	~150° 30° over 800 MHz max	.0188
u(b1)1	5.9525	downward	~150° 30° over 400 MHz max	.0185

In most cases differences are ≈ 1–2 mm.
Only in LOA is there an upper-lower difference of ~ .019 m, 19 mm.

The effect of the delay errors, $\Delta\tau$



$\phi_a = \omega_0 \tau$

$\phi_B = \omega_0(\tau+\Delta\tau)$; corrected to $\omega_0(\tau+\Delta\tau) - \phi'$, with $\phi' = \omega_0\Delta\tau$

Then $\phi_A - \phi_B = 0$

new freq: $\omega_0 + \Delta\omega_0$ $\quad \phi_a' = (\omega_0+\Delta\omega)\tau$; $\phi_B' = (\omega_0+\Delta\omega)(\tau+\Delta\tau) - \omega_0\Delta\tau$

Now $\phi_a' - \phi_b' = (\omega_0+\Delta\omega)\tau - \{(\omega_0+\Delta\omega)(\tau+\Delta\tau) - \omega_0\Delta\tau\} = \Delta\omega\Delta\tau$

For $\Delta\tau = 1\,mm$, typical, and $\Delta f = 100\,MHz$

$$\Delta f \Delta\tau = 10^8 \frac{10^{-3}}{3\times10^8\,m/sec} = \frac{10^{-3}}{3}, \text{ or } .12^\circ \text{ of phase } \underline{\text{small}}$$

For $\Delta\tau = 20\,mm$ $\quad \Delta f \Delta\tau = \frac{20\,10^{-3}}{3} = .0067$ turn, or $\underline{2.4^\circ}$

a slightly small contributor

<u>The effect of the residual phase slopes</u>

The top vs. bottom slopes have opposite sign, so that gives double the slope.

Worst case is in LOD $\quad 40^\circ$ over 800 $-$ (-30° over 800 MHz)

$= 40^\circ$ over 800 $-$ (-60° over 800 MHz) $=$ 100° over 800

10° over 80 is 12° over 100.

Getting rid of this would be a big help.

Some tests of 7 splitter boxes showed, nearly the same for all the units, a down progressing phase slope of about 150°. The LOA power is being sent back for test. These results are difficult to understand. [wrong delay setting]

Spectral Line Observing 10/29/08

Spectral Resolution

Thermal line width $\Delta V\,(\text{FWHM}) = \sqrt{\frac{2kT\ln 2}{m}}$

$\Delta V = 1.07$ km/sec @ $T = 100$K for HI.

$\Delta V \cong 1\sqrt{\frac{T/100}{m/m_H}}$ km/sec., in general.

spectral width $\Delta\nu = \frac{\nu_0}{c}\Delta V$

I. **OH** ΔV for OH @ 30K $\quad m_{OH} = 17 m_H$

$\Delta V = 1\sqrt{\frac{30/100}{17}} = 0.13$ km/sec.

for OH at 1.6 GHz: $\Delta\nu_{OH} = \frac{0.13\text{ km/sec}}{3\times10^5\text{ km/sec}} \times 1.6\times10^9\text{ Hz} = 735\text{ Hz} = .735$ kHz

Bandwidth decrease from 100 kHz resolution: 1000 channels

$\frac{100}{.735} = 136$ for channels that are one thermal width wide. This is close to $2^6 = \cancel{128}\ 64$; $2^7 = 128$

To get 5 channels over the line, one needs $2^{10} = 1024$ BW reduction. Perhaps hopelessly narrow.

II. **CH_3OH** (methanol) @ 6 GHz ($m/m_H = 32$, not 44)

$\Delta V = 1$ km/sec. $\sqrt{\frac{30/100}{44}} = .0968$; $\Delta\nu = \frac{.0968\text{ km/sec}}{3\times10^5} \times 6.6\times10^9 = 2152$ Hz

At 1800 Hz: $\frac{100}{1.8} \cong 55$; $2^6 = 64$

Masers are the best candidates here.

III **HC_3N** is an interesting line to study for star formation. The 1st detection was 0.1K in Sgr B2. That would be ~1K with the ATA. $m = 55 m_H$ $\quad \Delta V = 1\sqrt{\frac{30/100}{55}} = .07$ km/sec. (no) {7K should be 10}

For TMC1 see Avery et al (1982) Ap. J.
Hirota, Oishi, etc. (2003 Proc. conf. in Waterloo Aug. 21-23 chem. as diagnostic)

$J = 1\to0$, $F = 2-1$ $\quad \Delta T = 2.11$ on the 100m.

9097.3 F=1-1
9098.33 F=2-1
9100.27 F=0-1

P. Pratap et al is a big survey including 3 lines of HC_3N: 4-3, 10-9, 12-11. The lines are optically thick (somewhat) with widths of 0.4 km/sec. and temperatures of ~15K peak; T_{ex} ~ 10K.

Pratap et al {1997, Ap. J. ... 486 ... 862P}

line widths: 0.4 km/sec @ 4-3, 10-9, and 12-11 transitions from Pratap et al

$\Delta\nu = \frac{\Delta V}{c}\nu_0 \overset{?}{=} 0.4$ $\quad \Delta\nu = \frac{0.4\,km/sec}{3\times10^5}\, 9\times10^9 = 12\,kHz$

The three lines are ~ 1 MHz apart and won't overlap.
It will take ~ 4 MHz coverage to see all three components
3 MHz actually work. That's the spread
Down from 100 MHz it's a factor of 30 ≈ $2^5 = 32$. ← ok
That's 3 kHz resolution, which is ok for the 12 kHz ~~thermal~~ observed width.

{For HI, it would be ~ .7 km/sec resolution}

Sensitivity in one 3 kHz channel for t = 1 hour:

$$\Delta T \sim \frac{200K}{\sqrt{3000\cdot3600}} \cong .03K \text{ (in one polarization)}$$

or .021K in 6 kHz channels (one pol.) .015K 2 pols.

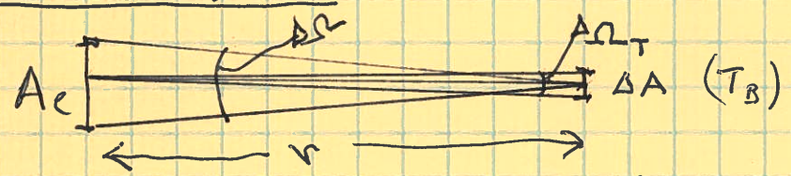
If the line strengths are ~ 2.4°K for the 4→3 transition in a big beam at the 11 m NRAO antenna. We should get a comparable brightness in the 1-0 transition with it being optically thick in the 4-3 line

ATA-42 resolution should be ~ 0.5' at 9 GHz.

new feed { ΔT = .01K (one pol) = .007K (2 pols) with 3 kHz channel

The field of view @ 9.1 GHz will be ~ 20' (23')

Signal Sensitivities



$\Delta\Omega_T$ is the telescope beam on ΔA: $r^2\Delta\Omega_T = \Delta A$

Also $r^2\Delta\Omega = A_e$

Power into $\Delta\Omega$ from ΔA $= \frac{kT_B}{\lambda^2}\Delta A\Delta\Omega$ in one polarization

Received power: $kT_A = \frac{kT_B}{\lambda^2}\Delta A\Delta\Omega = \frac{kT_B}{\lambda^2}\Delta A\frac{A_e}{r^2} = \frac{kT_B\Delta\Omega_T A_e}{\lambda^2}$

Altogether the received temperature (antenna) $\boxed{T_A = \frac{T_B}{\lambda^2}\Delta\Omega_T A_e}$

$\Delta\Omega_T$ is the antenna beam on the patch of sky ΔA.

Expected signal strength for the HC_3N 1-0 transitions at 9.1 GHz

Angular resolution for ATA-42 : $\left(\frac{300}{f}\right)'' = 33'' = \Delta\theta$

in radians $\left[\frac{33}{60}\cdot\frac{1}{60}\right]\frac{\pi}{180} = .0002$ radians ; $\Delta\Omega_T = \frac{\pi}{4}(.0002)^2 = 2\times10^{-8}$

$T_A = \frac{T_B\,[2\times10^{-8}]\,712}{(.033)^2}$; $A_e = 42\times(28)(.6) \simeq 712\,m^2$

$T_A = .013\,T_B = .065$ for $T_B = 5K$ (Protopetal) check this

.13 for $T_B = 10K$ (10K?) for 4-3 and 10-11

check these numbers

$\Delta T_A = .015K$ for the observed 12 kHz line width (in one pol)

[in one hour]

and $S/N = .065/.015 = 4.4$, 6.0 in both pols. $= \underline{\underline{10}}$ with $T_{sys} = 70K$

Degrading the angular resolution to ~1' gives S/N ~ 9

[or integrate for 4 hours] [$T_{sys} = 100K$ here] will be 30K with new feed

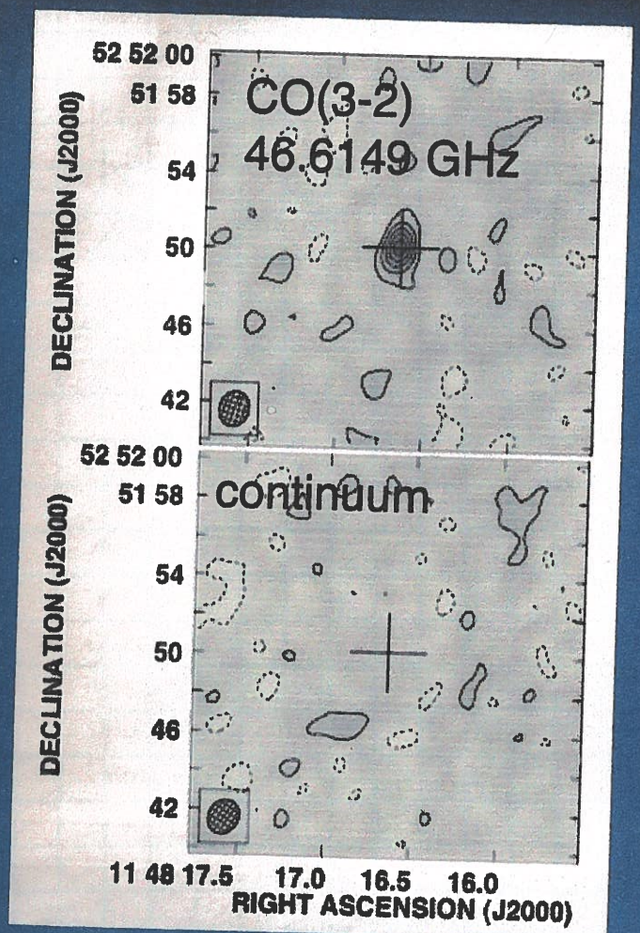
$\left(\frac{.065}{.007}\right) = 10$ with new feed, one pol, and 3 kHz = 15 with both pols averaged.

Geoff's sensitivity estimates 12/17/08

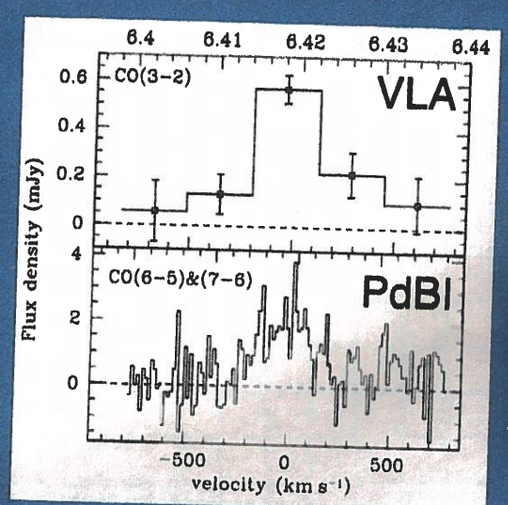
Table 1: Detailed Performance Goals for ATA-42, ATA-128, and ATA-256

Parameter	Value	Value	Value	Unit	Comment
Number of Elements, N	42	128	256		
Element Diameter	6.1	6.1	6.1	m	projected on sky
Total Geometric Area, A_{geo}	1227	3739	7478	m^2	
Aperture Efficiency, η	63%	63%	63%		
System Temperature, T_{sys}	44	44	44	K	average across 1–10 GHz
System Equivalent Flux Density	156	51	26	Jy	
Array Diameter	0.3	0.6	0.8	km	
Field of View	$3.5/f_{GHz}$	$3.5/f_{GHz}$	$3.5/f_{GHz}$	degrees	
Antenna Pointing	0.01	0.01	0.01	beam width	at 10 GHz low winds and night time
Slew time	2	2	2	minutes	to anywhere on sky
Synthesized Beam	Gaussian	Gaussian	Gaussian		
Max. Deviation from Gaussian	18%	3%	1%		"snapshot"
FWHM of Synthesized Beam	348x168	162x112	130x106	$arcsec^2$	1 GHz @ zenith
Sensitivity					
Correlator Bandwidth	2 x 100	2 x 500	2 x 500	MHz	Reducible by 2^N
Correlator Channels	2 x 1024	2 x 2048	2 x 2048	MHz	
Continuum Point Source	590	86	43	μJy	rms in 6 min (1 pol)
Brightness Temperature	34	36	24	mK	rms in 12 h @ 10 km/s in HI
Continuum Survey Speed	0.039	1.81	7.24	$deg^2\ s^{-1}$	to 1 mJy rms @ 1.4 GHz
T_B Survey Speed	0.096	0.087	0.202	$deg^2\ s^{-1}$	to 1K rms in 10 km/s @ 1.4 GHz

Molecular Gas @ z=6.4



- molecular gas mass:
  $M_{H2} = 2 \times 10^{10}\ M_{sun}$
  (assuming 'low' ULIRG α!)
- mass in C and O: ~$3\times10^{7}\ M_{sun}$
  (need ~10^{7} [100 M_{sun}] Pop III stars
  but also need to cool ejecta
  -> SF started at z~10?)



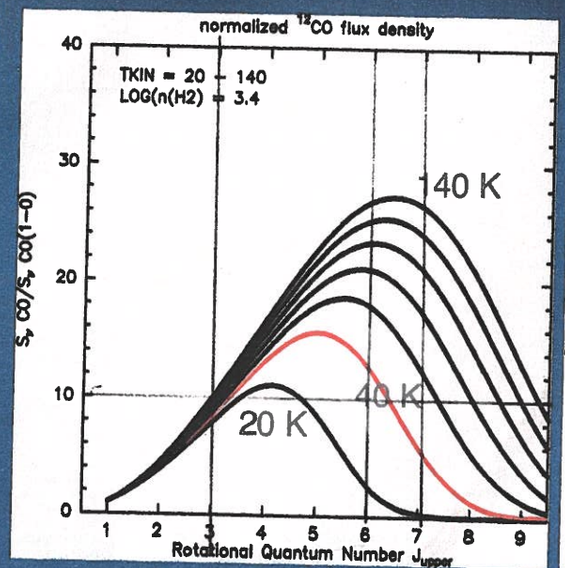
z=6.419

Walter et al. 2003
Bertoldi et al. 2003

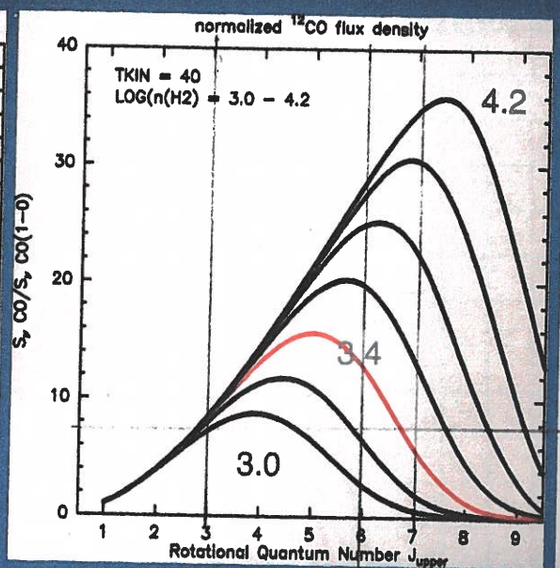
CO observations of the z=6.419 QSO

CO Line ladders: gas excitation

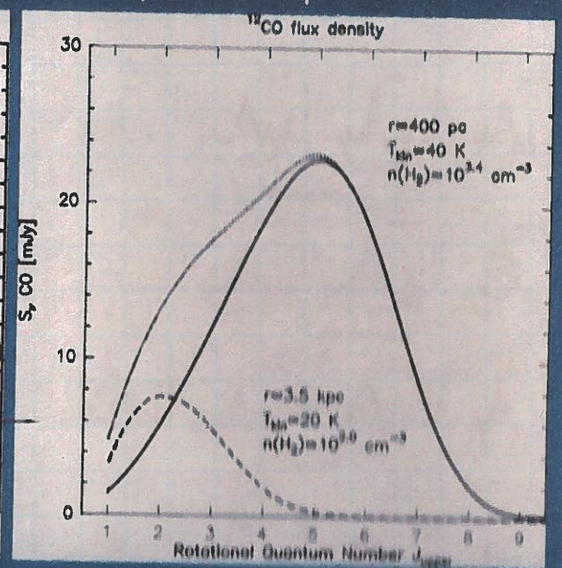
f(T)



f(ρ)



Multiple components



- turnover: measure of the CO excitation
- shape is temperature/density dependent
- shape: search for extended CO

LVG input: n(H_2), T_{kin}, [CO]/[H_2]/dv/dr (fixed to 810^{-5} pc (km/s)$^{-1}$)

Weiss 2005

LVG models for the CO line excitations

This requires the wider feed BW

12/17/08 QSO SDSS J1148+5251

Estimates of the CO(1-0) expected strength relative to the CO(3-2) and CO[(5,0), 7-6] observations.

CO lines	frequency	÷7.64 (for z = 6.4)		field (θ/2)
1-0	115.4	15.59	ATA	13.0 minutes
2-1	230.8	31.19		
3-2	346.2	46.78	VLA Q band.	1.1 minutes
4-3	461.6			
5-4	577.0			
6-5	692.4	93.57	} 3 mm band PdB	0.8 minutes
7-6	807.8	109.16		

VLA flux range ~ 0.4 mJy – 0.7 mJy chosen (0.1)

PdB ~ 1.8-2.2

calculated flux ratios: 3-2/1-0 ~7 6-5/3-2 ~3 7-6/3-2 ~3

With the CO(3-2) ≅ 0.7 mJy, expected CO(1-0) = 0.1 mJy

Line width is ~300 km/sec from the spectra.

Bandwidth @ 15.6 GHz for 300 km/sec is [for 1 MHz ↔ 20 km/sec, λ ≅ 20 mm] 15 MHz

Geoff's table lists 46 μJ for B = 1000 MHz and τ = 6 mins.

The observed BW = 15 MHz, so the noise is worse by $\sqrt{\frac{1000}{15}} = 8.2$

so .046 mJy → 8.2 × .046 = 0.38 mJy (in 6 minutes)

What do we get from a 10 hour observation? $\sqrt{\frac{600}{6}} = 10$ improvement

Including the other polarisation 14 times better

$\frac{0.38}{14} \Rightarrow .027$ mJy 0.1 is expected. S/N = 3.7

in a 10 hour integration. ok S/N = 5.2 in 20 hours, 9.3 in 60 hours

This is comparable to the reported S/N's.

☆ From Walter et al: 1" → 8.5 kpc @ z = 2 ; 1" → 5.8 kpc @ z = 6

2004, ApJ, 615, L17 VLA resolution of 0.15" → 1 kpc! · Field of 1' → 350 kpc

ATA resolution of ~~[illegible]~~ 7.7" → 45 kpc; Field of 13.5 → 4.5 Mpc

Excitation

Weiss et al, 2005, A+A, 440, L45.

SKA with 12m dish has Field of 2.3 MPc

From Sandage ARAA, 1988, 26, 561

$\Theta(z)$: For $q_0 = 1/2$ $\quad \Theta = \left(\frac{y H_0}{2c}\right) \frac{(1+z)^{3/2}}{[\sqrt{1+z} - 1]}$ $\quad \propto \frac{1}{z}$ for small z, $\propto z$ for large z!

/rai1/Welch/High-z-CO.doc is the file

ATA observations of high-z CO

Observations of the distant universe at radio wavelengths promise to provide information that is complementary to that from other parts of the spectrum in the study of the origins of the universe (e.g. Taylor and Braun, 1999). The planned study of neutral hydrogen with the Square Kilometer Array promises to elucidate the development of structure in the early universe. This large telescope may also have the high frequency capability and the sensitivity to observe the molecular hydrogen in early galaxies as traced by the emission at the shorter wavelengths from molecules such as CO. Recent simulations by Rawlings (private comm..) suggesting that the abundance of the molecular hydrogen will exceed that of the neutral species at redshifts greater than 2 underscore the importance of the CO capability. Two key features in the further development of the ATA are the expansion of the array size to at least 256 antennas and the upgrading of the feed to operation up to 24 GHz along with an improvement in its system temperature. The 24 GHz operation will allow CO(1-0) to be observed at z>4, and the improvement in the sensitivity will enable observations of the faint molecular emission to trace the evolution of galaxies in this regime. There has already been detection of higher frequency CO emission in more than 30 high-z galaxies, the largest redshift being z=6.419 in SDSS J1148+5251 (Walter et al, 2004,ApJ, 615,L17).

J1148+5251 was observed at CO(3-2) with the VLA and CO(5-6) and CO (7-6) with the Plateau de Bure interferometer. From the strengths of the signals in these three lines it is possible to predict what the sensitivity would be in the CO(1-0) transition for the ATA-256 (e. g.,Weiss et al, 2005, A&A, 440. L45). For this object at z=6.419 the CO(1-0) line frequency is 15.5 GHz where the ATA-256 Tsys is expected to be about 40K. The expected flux is about 0.1 mJy and the lne width is 15 MHz. We should see the line with a S/N of 5 in 20 hours integration. The VLA observations were made in the B array at 46 GHz achieving a resolution of 0.15", about 1 kpc, with a field of view of 350 kpc. This is a very impressive result. Though the resolution of the ATA-256 is only 8",it has a very large single pointing field of view, 13.5', about 4.7 Mpc at this redshift, somewhat larger than the Coma cluster. If this J1148+5251 were a member of a rich cluster like Coma, the single long integration might detect several such luminous galaxies.

impossible for ATA-42 (except for long integrations?

With the new feeds get S/N ~ 1 with ATA-42 in 20 hours

3/10/2012

12/24/08

Prospects for making feed pattern measurements using an interferometric pair of the ATA antennas. One antenna is an ATA antenna. On the other, the secondary is removed so that just the feed is receiving.

Observe a radio source with the 100 MHz correlator @ $\frac{3.5\,GHz}{\lambda = 8.6\,cm}$.

I sensitivity $\quad A_{e_1} = .63 \times \frac{\pi}{4}(6.1)^2 = 18.4\ m^2$

feed gain: 11.5 db $\Rightarrow 14.1 = g$

$$A_{e_2} = \frac{g\lambda^2}{4\pi} = \frac{(14.1)(.086)^2}{4\pi} = .008\ m^2$$

$$A_{eff} = \sqrt{A_{e_1} A_{e_2}} = [(18.4)(.008)]^{1/2} = 0.34\ m^2$$

$$kT = SA_e \quad , \quad T = S\left(\frac{A_e}{k}\right) = S_J\left(\frac{.34 \times 10^{-26}}{1.4 \times 10^{-23}}\right) = S_{Jy}(.00024)\ {}^{\circ}K$$

Use Cas A: Penzias + Wilson report 1086 Jy for 1965; with a 1%/year decrease, get ~ 620 Jy currently for $T = (.00024)620 = \underline{0.15k}$

S/N for the received correlated signal $\quad \Delta T_{rms} = \frac{50}{\sqrt{10^8 \cdot 1}} = .005k$ in 1 sec.

$$S/N = 0.15/.005 = 30 \quad \text{in 1 second}$$

II Observe by tracking Cas A with the regular antenna and then scanning the feed antenna

$$Out = \frac{1}{\Delta T}\int_{\Delta t} V_1 V_2(\theta,\phi)\,dt \qquad \propto \langle V_2(\theta,\phi)\rangle$$

III Expected $V_2(\theta,\phi)$ over the pattern: From I p.72, the lowest value of $E(\theta,\phi) = .05$ of the peak $\quad 1/20$, close to the S/N in one second from above.

IV The effect of using a wideband signal to avoid some of the multipath problems. The wideband signal correlates only over a limited delay.

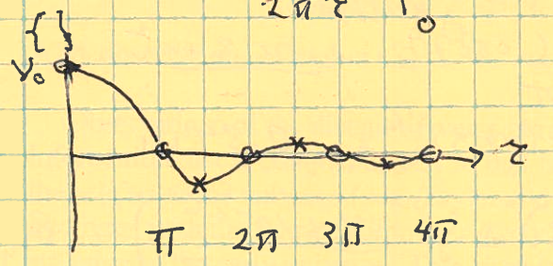
$$\int_{-\infty}^{\infty} P(\nu)\, e^{i2\pi\nu\tau}\, d\nu = \lim_{T\to\infty} \frac{1}{T}\int_{-T/2}^{T/2} V(t)\, V(t+\tau)\, dt = C(\tau)$$

ms

It's the same signal that is received by both antennas. For a multipath signal, the relative delay is differed from zero:

$$\int_{-\infty}^{\infty} P(\nu)\, e^{i2\pi\tau\nu}\, d\nu = \int_{-\nu_0}^{\nu_0} P_0\, e^{i2\pi\nu\tau}\, d\nu = 2P_0 \int_0^{\nu_0} \cos 2\pi\nu\tau\, d\nu$$

$$= 2P_0 \left.\frac{\sin 2\pi\nu\tau}{2\pi\tau}\right|_0^{\nu_0} = 2P_0 \frac{\sin 2\pi\nu_0\tau}{2\pi\tau} \Rightarrow 2P_0\left\{\frac{\sin 2\pi\nu_0\tau}{2\pi\tau}\right\}$$



$\nu_0 = 100\,\text{MHz} = 10^8\,\text{Hz}$

first null: $2\pi\nu_0\tau = \pi$, $\tau = \frac{1}{2\nu_0}$, $d = c\tau = \frac{c}{2\nu_0} = \frac{3\times10^8}{2\times10^8} = 1.5\,\text{m}$

next (negative) peak: $2\pi\nu_0\tau = 3/2\,\pi$, $\tau = \frac{3}{4\nu_0}$, $-\frac{1}{2\pi\tau} = -\frac{1}{2\pi}\cdot\frac{4\nu_0}{3} = \frac{-2\nu_0}{3\pi} = -\underline{0.21\nu_0}$

$d = c\tau = \frac{3c}{4\nu_0} = 3/2\cdot\frac{c}{2\nu_0} = \underline{2.25\,\text{m}}$

next (positive) peak: $2\pi\nu_0\tau = \frac{5}{2}\pi$, $\tau = \frac{5}{4\nu_0}$; $d = c\tau = \frac{5c}{4\nu_0} = \frac{5}{2}\cdot\frac{c}{2\nu_0} = \underline{3.75\,\text{m}}$

$\{\} = \frac{1}{2\pi\tau} = \frac{1}{2\pi}\cdot\frac{4\nu_0}{5} = \frac{4\nu_0}{10\pi} = \underline{.127\nu_0}$

next (negative) peak: $2\pi\nu_0\tau = \frac{7}{2}\pi$, $\tau = \frac{7}{4\nu_0} = \frac{7}{2}\cdot\frac{1}{2\nu_0}$; $d = c\tau = \frac{7}{2}\cdot\frac{c}{2\nu_0} = \underline{5.25\,\text{m}}$

$\{\} = \frac{1}{2\pi\tau} = \frac{1}{2\pi}\cdot\frac{4\nu_0}{7} = \underline{.09\nu_0}$

The reflected signal is not likely to be as strong as the incoming plane wave. — Except for what is reflected from the primary mirror. It is close in every case, and should be covered with absorber, at least near the feed. The two inch absorber should be ok.

V The ADC It would be best to preserve the 8 bits as much as possible for linearity. On the other hand, the voltage pattern dynamic range is only $\lesssim 20$, so that the 4 bits, $2^4 = 16$ might be enough. But it would probably be better to write a separate a separate correlation routine for the two antennas to get the output. Check with Gerry.

$c(x) = \{\ \} = \frac{\sin 2.09x}{2.09x}$ x is the spatial delay

Issues with the planned new power lines in the Hat Creek Valley 3/19

Data Source is the Thompson Memo "Radio Interference from High-Voltage Power Lines" VLA Electronics Memo #211, 1984

For a distance of 200 feet from the line and at a frequency of 75 MHz, Thompson gives a sea level value of -195.5 dB $W m^{-2} Hz^{-1}$

a) add 1 dB for each 1000 feet above sea level: 3.5 dB for Hat Creek
b) -20 dB for no rain: -20 dB [we should leave this in]
c) use a frequency slow of $1/f$: -8.2 dB for 500 MHz (figure 10)

$-195.5 + 3.5 - 20 - 8.2 = -220.0$ dB $W m^{-2} Hz^{-1}$ ~~[illegible]~~
$= -200$ dB watts $m^{-2} Hz^{-1}$, including the rainy case

What's tolerable? The noise should not exceed 1% of Tsys on one of the antennas.

One antenna sensitivity is ~ 150 Jy/K 150 Jy ≈ 1°K
Tsys is ~ 25K @ 500 MHz. It takes ~ 40 Jy to produce 0.25°K antenna temperature [But Tsys could be improved eventually]

No!!! 40 Jy is 40 watts $m^{-2} Hz^{-1} \times 10^{-26}$ = ~~[illegible]~~ -244 dB watt^2 $m^{-2} Hz^{-1}$

This is 35 dB [55] watts $m^{-2} Hz^{-1}$ lower than the expected signal at 200 ft, by a factor of about 3100.

With a spectrum of $1/f$ going to 5 GHz lowers this by 10 db to 25 dB [45] excess still too large.

d) At a distance of 10 miles ~ 50,000 feet

Figure 14 in the paper by Pakala and Chartier shows that at 50,000 feet the signal is reduced by -65 db @ 500 MHz and -48 db at 5 GHz

At this distance expect $35 - 65 = -30$ [-10] dB watts $m^{-2} Hz^{-1}$ @ 500
and $25 - 48 = -23$ [-3] dB watts $m^{-2} Hz^{-1}$ @ 5 GHz

At 200 feet we must be prepared for the antenna looking directly at the line and getting the above results. At 5 miles the antennas will always be looking above the line and we will get another 20-30 dB protection. It looks like we have a good margin @ 10 miles. [This would take out the rainy conditions even]

(see over)

A simpler summary which includes operating in the rain and allowing for excursions beyond the quasi-peak requires a better margin. Expect ~ 60db of excess noise @ 200 ft at 500 MHz.

Page 2 of Thompson has -188.5 dBwatts $m^{-2} Hz^{-1}$
For sea level it would be -195.5 dB $Wm^{-2} Hz^{-1}$
Leave in the rain and add 4db for heavy rain
We should be able to observe in the rain. Also add 3.5db for the 3500 altitude.

$-195.5 + 3.5$ db (altitude) $+ 4$ dB (heavy rain)
$= -188.0$ dB watts/m^2/Hz

What's the maximum allowed? In order that this background be equal to 1% of $T_{sys} = 28K$ .25K, it's shown that
$\doteq 40$ Jy $= 40 \times 10^{-26}$ watts/m^2/Hz {from 160 Jy/K}

That is: ~~40 x 10^-26~~ $= \cancel{-244}$ dB watts/m^2/Hz
244 ~~255~~ $- 188.0 =$ ~~[illegible]~~ 56 dBwatts/m^2/Hz

Correcting to 500 MHz, take away 8.0 dB $\Rightarrow$ ~~[illegible]~~ 48 dBwatts

~~60 dB watts/m²/Hz is approximately a factor of one million at our lowest frequency of 500 MHz (in excess of the 1% of Tsys.~~

48 dB ~~watts/m²/Hz~~

To summarize: ⓐ The acceptable power level is -244 dBwatts/m^2 Hz
ⓑ The corona power level at 500 MHz and at zero feet is $-188.0 - 8.2 = -196.2$ dBwatts/m^2 Hz

This is $244 - 196.2 = 47.8$ dB larger than is tolerable, a factor 60,000.

This was done with a peak to RMS conversion of 10. This may be optimistic.

Further issues with the power company 3/24/09

The Google picture sent to us by the TANC folks shows a distance from the "center of gravity" of the ATA to the Alternate 2 route of 3214 feet. From Google Earth that places the route directly at Bidwell road within ~100 feet. Picking the 200 foot station as a location of the array is overstated. Indeed, if we do use that station the 48dB number is correct. What is needed is ⓐ a calculation of the noise level at the present antennas and ⓑ a calculation, along with a picture, of the planned station's interference that are closer to the road.

An important issue is what is the effect of the antennas having a minimum elevation of 15° at the 3200 foot distance.

Antenna sidelobes at 500 MHz See p. 65 and use the out of focus curves as is appropriate for 500 MHz

I. For the Google Map position of the ATA-42 which seems to be about 3200 feet from Bidwell Road, which seems to be where Raven to Zeta 1 Alt would run? There are two factors. One is the distance beyond 200'. The other is the fact that the antennas do not go below 15° elevation

For 3000 feet distance from the 200 foot point, figure 14 of P and C shows -23db for lines D, E ~500 MHz, leaving 25 db of excess power
The beamwidth is: 3.5° full width at half maximum.
The power line is at 3.6° elevation, ~~with~~ 11.4° away from the antenna beam axis at 15° elevation. This is at the 20.5 db pattern level, leaving an excess of 4.4db ~ a factor 3 noise excess.

For 2000 feet distance which is actually farther than ~30 of the planned ATA antennas: the power level is -20db relative to 200 feet from figure 14: i.e. 28 dB watts/m² MHz of excess power.
For the elevation angle at 15°, the power line is at 5.7° ~~from the antenna beam axis~~ elevation 9.3° from the antenna beam axis. where the signal is down by ~6db, leaving us with 22db of excess noise, a factor of 160.

feed/LNA summary from Rick

4/8/09

Ant	miriad #	serial number 01/16/09 Feed SN	date installed HC retrofit	Jy/K * Tsys 3c147-1.4ghz SEFD X	160*45=7200 03/25/09 SEFD Y	arcmin 03/21/09 Pntoff X	arcmin 03/21/09 Pntoff Y	arcmin 03/21/09 Squint X-Y	comments
1e	5	sb31	09/03/08	6711 (41)	40139 246	4.5	5.8	2.9	x-pol good; y-pol low sensitivity
2g	17	sb27	09/03/08	6949 (43)	42404	9.4	6.2	4	x-pol good; y-pol low sensitivity
1d	4	sb28	09/03/08	9581 (59)	7747 48	2.9	2.3	5.1	y-pol good; x-pol lower sensitivity
2c	13	sb12	10/31/08	10407 (64)	7801 48	7.8	5.4	2.6	y-pol good; x-pol lower sensitivity
4f	32	sb11	01/15/09	13204 81	6825 42	24.7	6.4	22	y-pol good; x-pol lower sensitivity
4l	37	sb14	10/31/08	8547 (52)	7133 (44)	9	7	2.7	y-pol good; x-pol ok
2l	21	sb36	--	--	--	--	--	--	2 bad pols
3c	23	sb43	--	30355	45069	2.5	5.3	4.7	2 bad pols
4e	31	sb38	--	--	--	--	--	--	2 bad pols
5e	40	sb37	07/03/08 bad	--	78095	--	12.3	--	2 bad pols
2m	22	sb08	--	--	47062	--	55.2	--	2 bad pols; cryo problem
3f	26	sb35	--	--	--	6	--	--	2 bad pols; cryo problem
3h	28	sb15	--	19279	109440	0.8	10.7	10.7	2 bad pols; cryo problem
5c	39	sb6	--	--	40857	--	4.1	--	2 bad pols; cryo problem
5h	42	sb18	07/03/08 bad	72195	42524	61.9	10.5	57.9	2 bad pols; cryo problem, big squint
2d	14	sb39	--	2549802	41366	30.7	21.5	14.3	2 bad pols; pointing & cryo problem
1a	1	sb25	10/31/08	7924 49	8152 50	3.9	1.4	2.9	2 good pols
1h	8	sb21	01/15/09	7394 45	8093 50	2.5	6.3	7	2 good pols
2a	11	sb30	10/31/08	7214 44	7511 46	2.7	1.4	4	2 good pols
3e	25	sb42	01/15/09	7809 48	6582 40	2.9	4.5	2.4	2 good pols
4g	33	sb33	10/31/08	6553 40	7022 43	3.4	0.5	3.6	2 good pols
4k	36	sb23	01/15/09	7529 46	7329 45	7.7	5.9	2	2 good pols
5g	41	sb22	09/03/08	7763 49	7847 48	4.7	6.5	4.5	2 good pols
2b	12	sb20	10/31/08	6841 42	8345 51	6.9	4.8	2.6	2 good pols; dewar sensor problem
1c	3	sb29	09/03/08	7403 45	7658 47	6.4	17	11.3	2 good pols; lnas oscillate at Id>55m
3g	27	sb45	--	11783 72	8875 54	4.2	0.5	3.8	2 moderately bad pols; cryo problem
0a	0	sb26	lab	--	--	--	--	--	cryo problem
1b	2	sb34	--	31889	--	8.8	--	--	cryo problem – both pols bad
1f	6	sb9	--	13747 80	13189 80	17.1	6.2	11.4	cryo problem – both pols bad
1g	7	--	minex	--	--	--	--	--	out for retrofit
1j	9	--	minex	--	--	--	--	--	out for retrofit
1k	10	--	minex	--	--	--	--	--	out for retrofit
2j	19	--	minex	--	--	--	--	--	out for retrofit
2k	20	--	minex	--	--	--	--	--	out for retrofit
3j	29	--	minex	--	--	--	--	--	out for retrofit
3l	30	--	minex	--	--	--	--	--	out for retrofit
4h	34	--	minex	--	--	--	--	--	out for retrofit
4j	35	--	minex	--	--	--	--	--	out for retrofit
5b	38	--	minex	--	--	--	--	--	out for retrofit
2e	15	sb5	09/03/08	10698 65	22692	14.3	48	54.2	pointing probs; big squint
2h	18	sb16	--	14544	--	6.4	--	--	x-pol marginal; y-pol bad
3d	24	sb10	--	7253 44	575020	3.1	66.5	69.5	x-pol ok; y-pol big squint
2f	16	sb19	01/15/09	11148 68	9058 55	3.4	3.5	6.4	y-pol ok; x-pol low sensititivity

System noise measurements at Minex ~9/10/09

1. The ~30db dual backend amps that are connected to the cables from the LNA. Temp varies from 700K at a few GHz to 900 K at 8-10 GHz

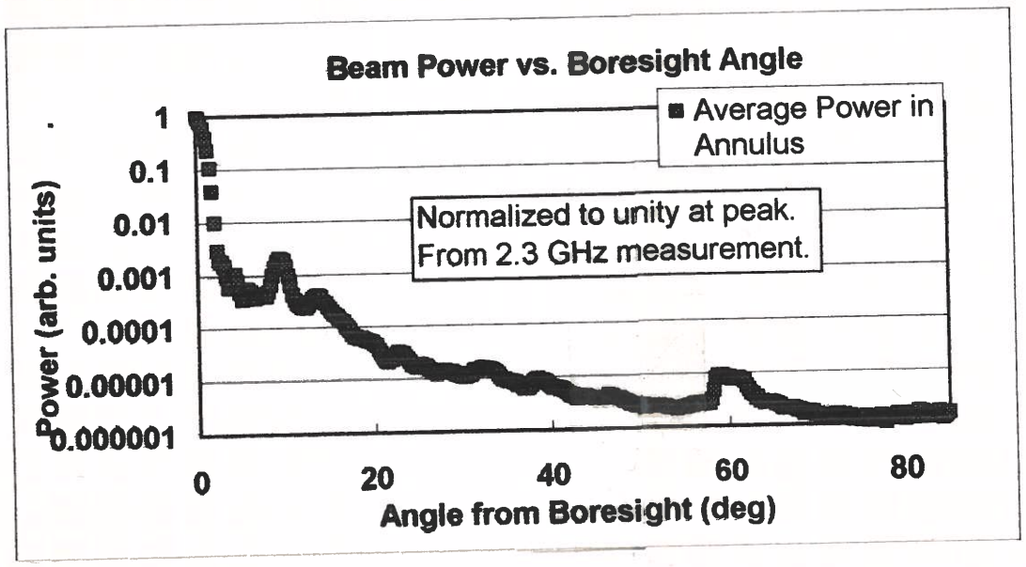
2. The Spectrum analyzer: ~ 9000K over most of the band.

NB: the noise figure measurements that show low in the 3-7 GHz range may be due to bad sampling of the Spectrum Analyzer. Yes

~~Not the measurements are real.~~

It's inaccuracy of the spectrum analyzer

From Gerry Harp's Holographic Beam Pattern measurements



5/15/89 System gain stability measurements (WJW, JRF)

Antenna 2C is set to stare north at about 45° elevation. It's fiber output into the lab is connected to a PAM amp in the "Rain Rack". It's output is passed through a high pass filter consisting of a 3-4" length of X-band waveguide with waveguide-to-SMA connectors on it's ends. It begins to pass at ~ 6.5 GHz and is full on at 7 GHz. This filter is to avoid RF interference into the antenna getting into the output. The output is connected to a total power detector. The PAM attenuator at the antenna is set at 17db for best S/noise and linearity. The attenuator in the Rain Rack unit is set to ~ -18db and the linearity is checked by inserting an extra 1 db attenuation at the antenna and observing a 1 db output change.

The TEC controller is fitted with a switch which allows it to be turned "on" or "off". We also covered the Rain Rack PAM to slow it's temperature drifts.

The DC output was recorded and the TEC turned "off", then back "on" twice. Three temperatures were recorded. a) the "air-temp" in the PAX box
b) the case temperature, 28.1C° when regulated
c) the heat sink "temperature" on the PAX case.

The first figure (top half) shows the run of output power as a function of PDT. One large tick is 0.1db. The solid curve is the case temperature, inverted to show the strong correlation between case temperature and total power. The bottom figure shows the three temperature variations with time. When the TEC regulator is turned off, the case temperature rises by 5°C and then the TEC is turned on. Two such cycles are executed, off then on. With the regulation turned off, the heat exchanger temperature drops to the air temperature. The following figure has the case temperature scaled to emphasize the correlation.

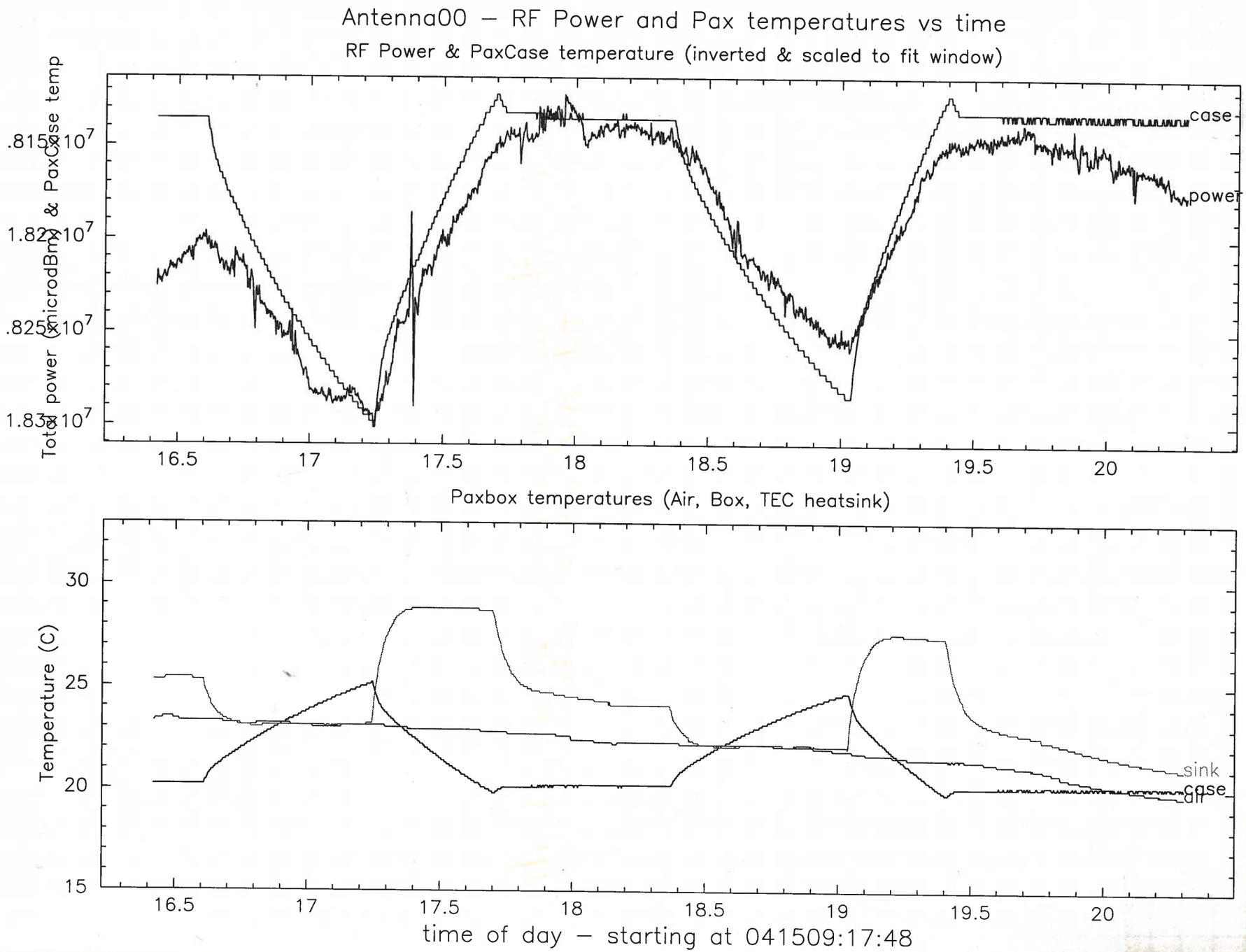
The gain changes by 0.1db with a 5°K temperature change. Earlier tests of a PAM showed a gain/temperature sensitivity of .02db/°K. This agrees well with the present test. It looks like all of the gain change can be attributed to the PAM. Nothing is left over for the OTX system.

The total power curve also shows slow drift in time. These may be temperature drifts in the output PA in the lab. These drifts are $\lesssim$ .01 db in 10 minutes or less on the time scales of minutes; $\lesssim$ .005 db (.1%) 10^{-3}

Rick's plots

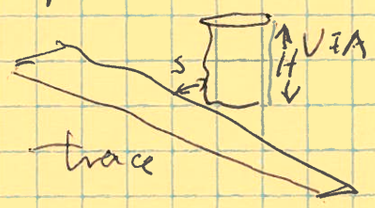
/11-12 may 09.ps
/11 jul 08 - node 1.ps
/ - node 2.ps
/ - node 3.ps
/ 11 may 09.ps
/ 11 may 09 - short.ps
/ 12 may 09.ps
/ 12 may 09 + - 1db.ps

This is all written up into a memo Sys_Gain_Stab.pdf which is now in the ATA memo series


Antenna00 – RF Power and Pax temperatures vs time
RF Power & PaxCase temperature (inverted & scaled to fit window)
Total power (microdBm) & PaxCase temp
.815x10^7
1.82x10^7
.825x10^7
1.83x10^7
case
power
16.5
17
17.5
18
18.5
19
19.5
20
Paxbox temperatures (Air, Box, TEC heatsink)
Temperature (C)
30
25
20
15
sink
case
air
time of day – starting at 041509:17:48

6/13/09 **Feed Input Circuit Calculations**

Capacitance between VIA and trace (Johnson from the WEB)



No pads on the VIA

Trace is at mid level w.r.t VIA

Experimental measurements with H = 1 inch and separations in inches : H = 1"

Spacing (s)	Cap (pF)
.233 (in)	.203
.412	0.119
.854	.031
1.667	.005

Example : H = .020" S = .033 $E_r = 4.1$
S/H = 1.667 (last row) so .005 (for H=1.)
Scale cap. to .020 and also $E_r = 1$:
Get (.020) × (.005) × 4.1 = .00041 pF

For the plated through hole on the top circuit board with H = .015 and S = .007 (from the drawing), $E_r = 2$.
Get : (with S/H ~ 0.5) use second row,
Then C = (0.119)(.015)2 = .0036 pf

This is quite small. Including the pad would increase it, maybe double it to → .007 pf.

At 10 GHz $X_c = \frac{1}{2\pi f C} = \frac{1}{2\pi(10^{10})(.007\times10^{-12})} = 2{,}273\,\Omega$

It shouldn't have much effect on the feed.

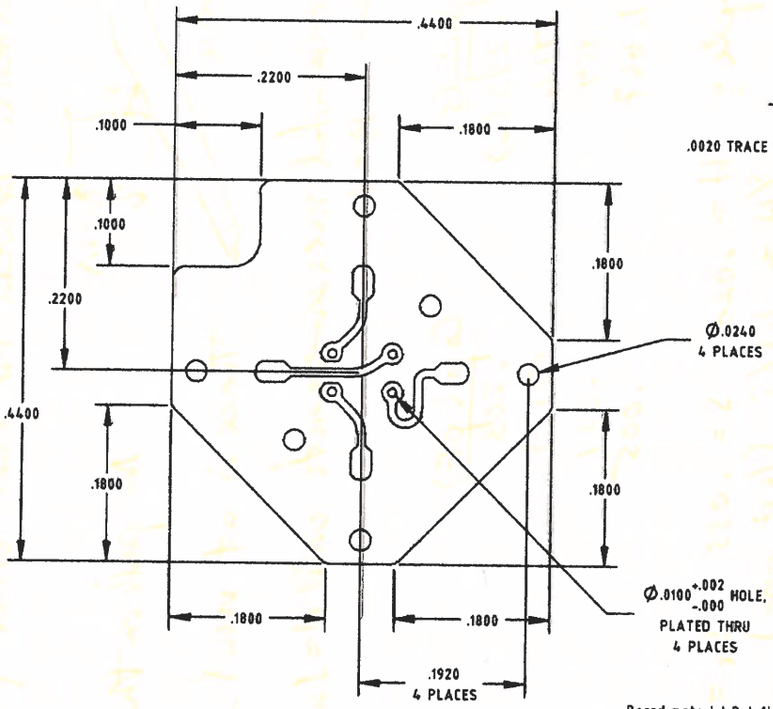
If the wire to the feed were 200 mils long and 15 mils radius, and therefore it's inductance were 2.3 nH,
$X_L = 2\pi f L = 2\pi(10^{10})\,2.3\times10^{-9} = 144\,\Omega$ (at 10 GHz)

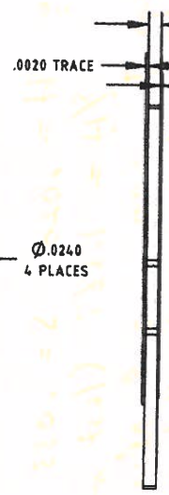
It's close to the 100 and would degrade the noise figure.

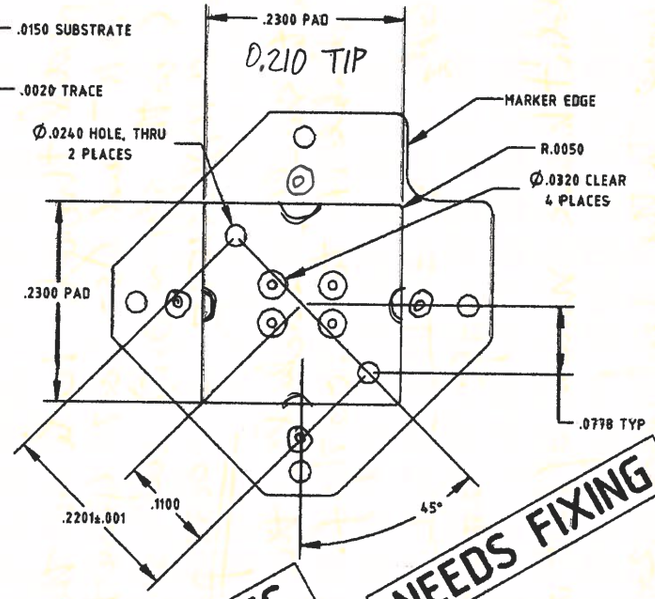
If the wire were 200 mils long and 2 in radius, L = 4.3 nH, and $X_L = 270\,\Omega$

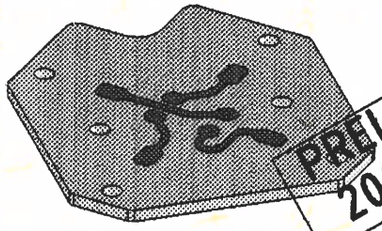
REVISIONS				
REV	DESCRIPTION	ZONE	NAME	DATE
A	RELEASED			
B	BACK PAD 0.210 SQUARE			
C	BACK PAD 0.230 SQUARE		A.V.	2006-00-00

REDRAWN M.C.F. 2007-07-18









PRELIMINARY
2008-03-06

2 SHEETS

NEEDS FIXING

Board material Polyflon CuFlon Substrate
0.015 thick with 1 oz = 0.0014 thick copper traces.
center edge slots & 4 center holes plated thru.
Gold plating over all.

Actual parts measure as follows: 2007-07-1/
Substrate 0.0150 to 0.0175
Traces 0.0015 to 0.0025 with gold plating.

Might need hydrofluric acid etch for teflon.

U. C. BERKELEY
E-SHOP NUMBER 1015 Rev C
MINEX NUMBER 20-28-203 Rev C

NAME	DATE
DRAWN A. VITOUCHKINE	2006-00-00
CHECKED	
MATERIAL	
FINISH	

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UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE INCHES & DEGREES

TOLERANCES:	LINEAR	ANGLE
WHOLE & FRACTION	± 1/32	± 1°
DECIMAL X.X	± 0.1	± 0.1°
DECIMAL X.XX	± 0.01	± 0.01°
DECIMAL X.XXX	± 0.005	± 0.001°

BREAK SHARP EDGES RAD ±
MACHINED SURF FINISH < MICROINCH

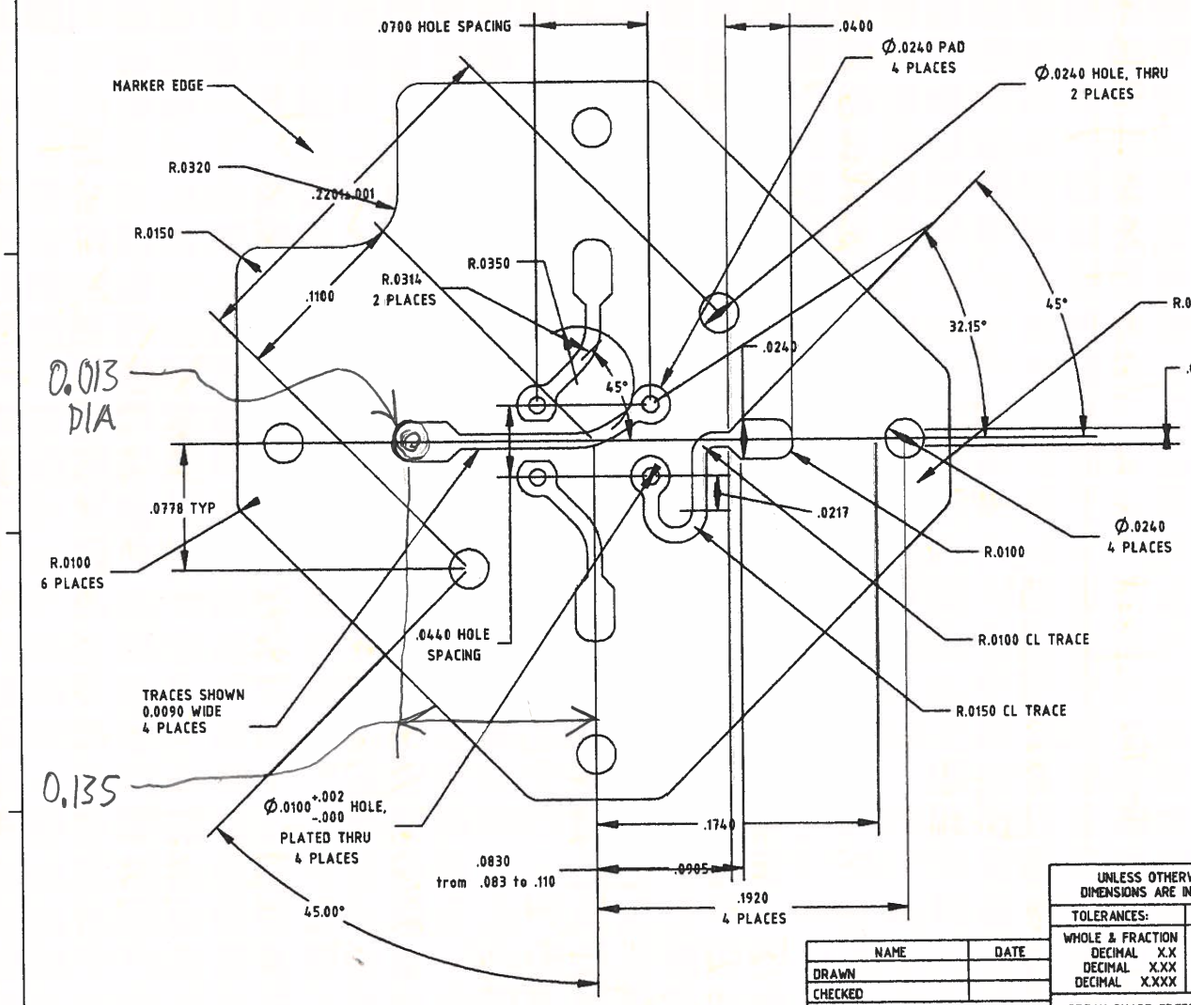
WEIGHT:
SCALE:

RADIO ASTRONOMY LAB
University of California - Berkeley
Tel: 510-642-5040 Fax: 510-642-3411

Tip Circuit Board

SIZE	DWG NUM:	SHEET	OF	REV.
B	30-28-203	1 of 2		D

REVISIONS				
REV	DESCRIPTION	ZONE	NAME	DATE
A	RELEASED			



PRELIMINARY
2008-03-06

NAME	DATE
DRAWN	
CHECKED	
MATERIAL	
FINISH	

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UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE INCHES & DEGREES		
TOLERANCES:	LINEAR	ANGLE
WHOLE & FRACTION	±	±
DECIMAL X.X	±	±
DECIMAL X.XX	±	±
DECIMAL X.XXX	±	±
BREAK SHARP EDGES	RAD ±	
MACHINED SURF FINISH =	MICROINCH	
WEIGHT:		
SCALE:		

RADIO ASTRONOMY LAB
University of California - Berkeley
Tel: 510-642-5040 Fax: 510-642-3411

Tip Circuit Board

SIZE	DWG NUM:	SHEET	OF	REV.
B	30-28-203	2 of 2		D

Wire inductances for the lead from the plated through hole to the feed

$L = 2l \times 10^{-7} \ln\left(\frac{2l}{er}\right)$; l is the length in m., r is the radius in m.
$e = 2.4$

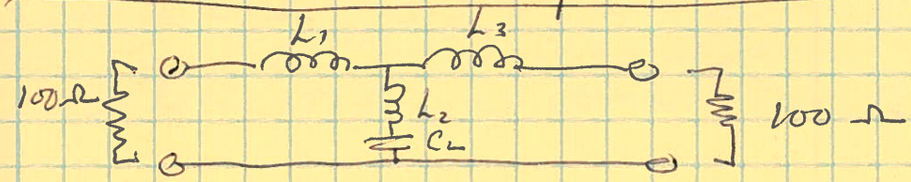
For l = 100 mils = .0025 m

r (mils)	L (nH)
5	1.4
10	1.00
15	.798

For l = 200 mils = .005 m

r (mils)	L (nH)
5	3.4 nH
10	2.7 nH
15	2.3 nH

Embed the wire to the feed in a low pass filter current feed



The 100 Ω is ½ of the antenna impedance / arm.

Zverev p. 172, $n = 3$, $\rho = 10\%$, $A_{min} = 20$ db
$L_1' = L_3' = .716$, $L_2' = .223$, $C_2' = .870$

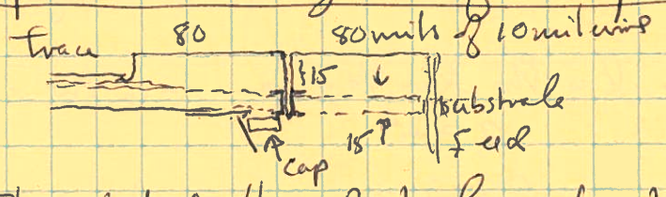
Band edge = 15 GHz, $R_r = 100\ \Omega$
$\omega_r = 2\pi f_r = 2\pi(15 \times 10^9) = 9.4 \times 10^{10}$
$L' = \left(\frac{\omega_r}{R_r}\right) L$ $\quad C' = (\omega_r R_r) C$

$\omega_r / R_r = 9.4 \times 10^{10} / 100 = 9.4 \times 10^8$ ✓ ; $\omega_r R_r = 9.4 \times 10^{10} \cdot 100 = 9.4 \times 10^{12}$ ✓
$L = L'\left(\frac{\omega_r}{R_r}\right)^{-1} = L'(9.4 \times 10^8)^{-1} = L'(1.06 \times 10^{-9})$ ✓
$C = C'(\omega_r R_r)^{-1} = C'(9.4 \times 10^{12})^{-1} = C'(1.06 \times 10^{-13})$ ✓

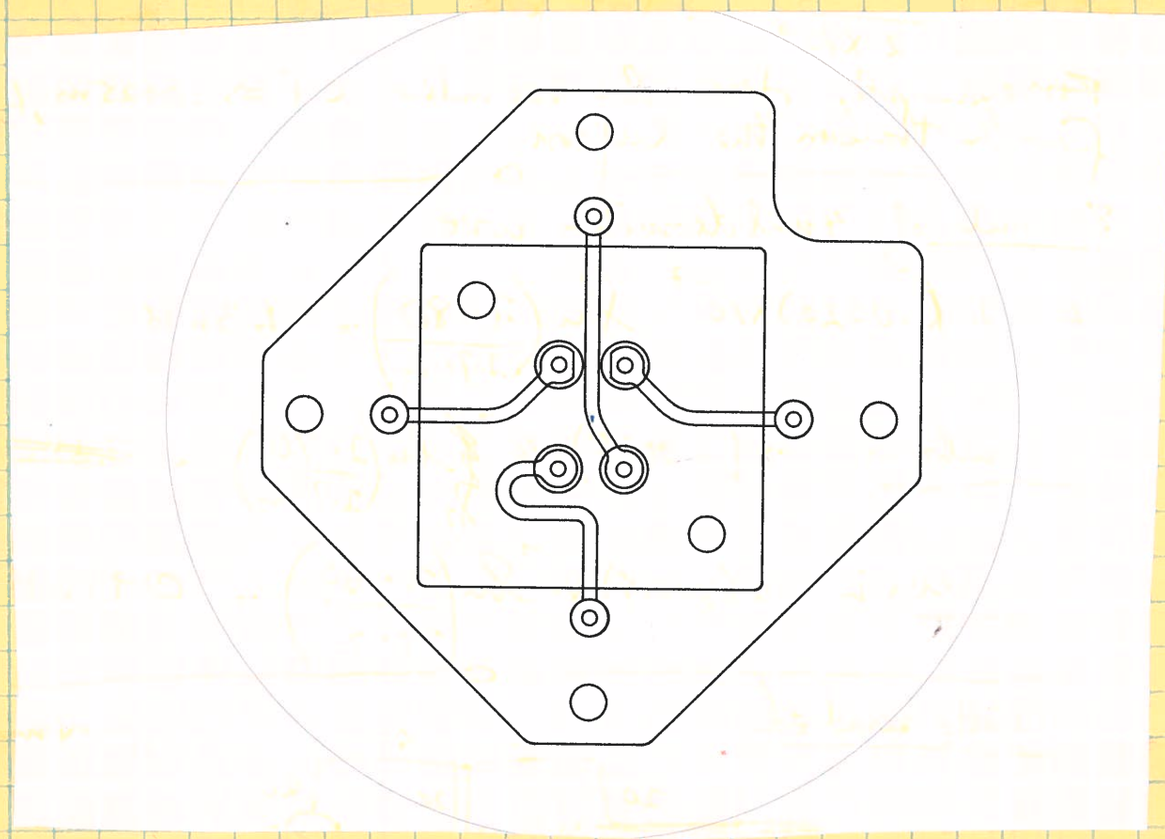
$L_1 = L_3 = .716(1.06 \times 10^{-9}) = .76$ nH ✓
$L_2 = .223(1.06 \times 10^{-9}) = .24$ nH ✓
$C_2 = (.870)(1.06 \times 10^{-13}) = .0992$ pf ✓ $\doteq 0.1$ pf ✓

Bandedge = 12 GHz
$L_1 = L_3 = (15/12) .76 \doteq$ 0.95 nH
$L_2 = (15/12) .24 =$ 0.30 nH
$C_2 = (15/12)(.099) =$ 0.124 pf

A possible realization of this filter on the present feed.



The plated through hole acts as half of the series inductor in the shunt arm. The rest of the 15 mil sticking up adds to it to provide ~0.24 nH. total. The 0.1 pf capacitor is soldered to the bottom pad and is soldered to the ground base of the substrate!. The 80 mil lengths of 10 mil wire give .99 nH inductance, a little larger than the desired .76 nH. The inner wire could be shorter. A 70 mils length, it is .84 nH, which is ok. The outer part of the inner trace should be removed.



Another view of the tip circuit board.

From Dielectric Labs a 0.1 pf capacitor

DISC FOR 1_1PX	15 x 20 x .004
20	20 x 20 x 4
25	25 x 30 x 4

For the capacitor, it looks like a GAP-CAP from Dielectrics Laboratories would work: 0.1 pf is available

G10CG0R1_2PX05
or G10CG0R1_5PX05

Inductance/m for the .009" trace on the .015 Cuflon substrate

From I. p.148 for D = 10 mils and h = 15 mils:
$Z_0 = 109\,\Omega$ (probably from EESOF program)
For cuflon, $K_\epsilon = 2$; so $v = \frac{3\times10^8}{\sqrt{2}}$ m/sec $\doteq 2\times10^8$ m/sec.

$Z_0^2 = \frac{L}{C}$, $v^2 = \frac{1}{LC}$; $L = CZ_0^2$, $LC = \frac{1}{v^2}$, $C = \frac{1}{Lv^2}$

so $L = \frac{1}{Lv^2} Z_0^2$ $\quad L^2 = \frac{Z_0^2}{v^2} \Rightarrow L = \frac{Z_0}{v}$

so $L = \frac{109\,\Omega}{2\times10^8} = 5.45\times10^{-7} = 545$ nH/m

For example, for l = 100 mils = 0.1" ⇒ .0025 m, L = 1.36 nH for the trace on the Cuflon.

---

80 mils of 4 mil diameter wire (metric)

$L = 2(.0020)\times10^{-7} \ln\left(\frac{2\cdot 80}{2.7\cdot 2}\right) = 1.3$ nH

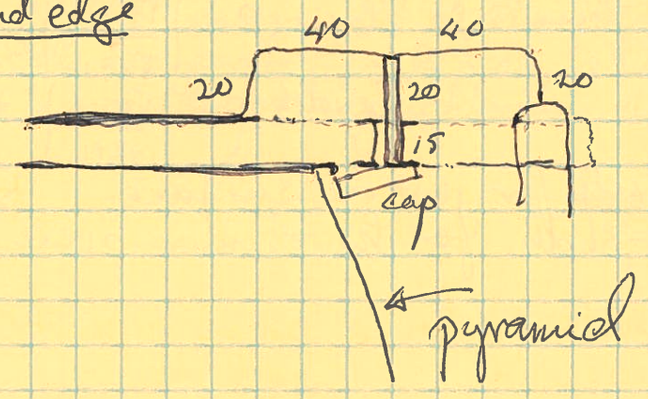
70 mils is $2(.0018)\times10^{-7} \ln\left(\frac{2\cdot 70}{2.7\cdot 2}\right) = \cancel{1.28\text{ nH}}$ 1.17 nH

60 mils is $2(.0015)\times10^{-7} \ln\left(\frac{2\cdot 60}{2.7\cdot 2}\right) = 0.93$ nH

---

12 GHz bond edge

4 mil wire

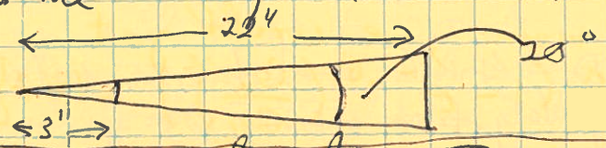


cap is 10 x 30 mils

Another possibility for cooling the feed 7/5/09

continuing from p. 87 88. Suppose we cool the entire feed down to 60K (Alternatively we might leave in an overall slow gradient from 300K to 60K). What would be the overall thermal load?

a) The load on the first 3" of feed is 110 mwatts (from p. 87). The new feed will be about 22" long.



b) from Feed_Upgrade.pdf or III p. 119: $\epsilon\sigma T^4 = 1.8$ mwatts/cm² @ 300K with $\epsilon = .04$

The area of the entire pyramid relative to the 3" part must be just 22/3 times larger. So the load must be (22/3) x .110 watts ⇒ .807 watts. We'll have to thermally insulate the back-end of the antenna. Use inflated stainless. We could do this even with the STI cooler but using the larger Sun Power unit (@ 15 watts) might be safer. First plan to use the STI cooler. It's been the most reliable item we have.

9/1/09

Matt is planning a flat rexolite plate, actually a series of such plates in place of the current rexolite stand-offs. The one closest to the tip will be at ~ 5" from the vanishing point. That corresponds to ~5.5 GHz. p. 123 (III) shows the echo from a glass plate of thickness .46 mm to be −25 db. The thinnest piece of rexolite at the 5" position will be 12 mils = .33 mm. Also Rexolite has $K_e = 2$ instead of $K_e = 4$ for glass.

The difference in the reflection from just one surface between these is: glass $\rho = \left|\frac{\sqrt{4}-1}{\sqrt{4}+1}\right|^2 = 0.11$

Rexolite $\rho = \left|\frac{\sqrt{2}-1}{\sqrt{2}+1}\right|^2 = .028$

That's 6 db for just one surface. So the reflection should be < −31 db for the thinner piece of Rexolite.

WJW

ATA Tsys for observations toward the moon - e.g. LCROSS

Oct 10, 09

$\theta_{1/2} = 2.33^\circ \left(\lambda / 0.2\,m\right)$. At 18 cm $\theta_{1/2} = 2.097^\circ \sim 4\langle\theta_m\rangle$

$\langle\theta_m\rangle = 0.5^\circ$

$\eta_B(18\,cm) \simeq .79$ for the Gaussian beam fit

also $T_m \cong 230\,K$ at all long wavelengths

pp's 46-49 and 149 (III), 40

I. Pointed directly at the moon, we would get

$$T_A = (.79)230\left(1 - e^{-.69\left(\frac{\theta_m}{\theta_{1/2}}\right)^2}\right) = 181.7\left[1 - e^{-.69\left(\frac{.5}{2.1}\right)^2}\right] = \underline{7.0\,K}$$

Pointed toward the edge of the moon at $\theta = .25^\circ$

with $G(\theta) \propto e^{-2.76(\theta/\theta_{1/2})^2} = e^{-2.76\left(\frac{.25}{2.1}\right)^2} = 0.96$

then $.96 \times 7.0 = \underline{\underline{6.7K}}$

II. At 7GHz the beam is smaller $\lambda = 4.3\,cm$

$\theta_{1/2} = 2.33^\circ\left(\frac{.043}{0.2}\right) = 0.5^\circ$, the same as the moon's diameter

Pointed directly at the moon

$$T_A = (.78)230\left[1 - e^{-.69}\right] = 87.4K$$

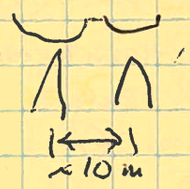
Pointed toward the edge of the moon, $\theta = .25^\circ$

$$G(\theta) \propto e^{-2.76(\theta/\theta_m)^2} = e^{-2.76\left(\frac{.25}{.5}\right)^2} = 0.5$$

So T_A is $\approx 87.4k \times 0.5 = \underline{\underline{44k}}$

For the excitation temperature of OH close to the moon.
At the surface of the moon, 1/2 of the sky will be at the moon's radio thermal temperature, ~ 1/2 230K, at cm wavelengths
So the T_{ex} for OH in ~ thermal equilibrium will be $\frac{230}{2} = \underline{115^\circ K}$

Cross Talk between two ATA antennas 10/28/09



Coupling between two antennas

$$\frac{P_o}{P_{in}} = \frac{A_1 A_2}{\lambda^2 R^2} \overset{\text{or}}{=} g_1 g_2 \left(\frac{\lambda}{4\pi R}\right)^2$$

Take $\lambda = 30$ cm, 1 GHz, .3 m

Forward gain $g_o = \frac{4\pi A}{\lambda^2} = \frac{4\pi\ 16\,m^2}{(.3)^2} = 2200 \sim \underline{34\,dB}$

From page 132, measured antenna gain is −60 dB relative to the peak at 90°. It's the same for both antennas. 34 − 60 = −26 dB is the gain at 90°, .0025

$$\frac{P_o}{P_{in}} = (.0025)^2 \left(\frac{.3}{4\pi\ 10}\right)^2 = (6.25\times10^{-6})(5.2\times10^{-6}) = 3.5\times10^{-11}$$

Since the area is frequency independent the coupling varies as λ^{-2}. At 10 GHz it would be 3.5×10^{-9}.

The idea is that the Tsys at the LNA input could be radiated out of the antenna to its neighbor. So 50K is received as $50 \times 3.5\times10^{-9} = 1.8\times10^{-8}$ K in the adjacent antenna at 10 GHz. This is too small to matter.

An actual measurement of this coupling would be important.

11/05/09

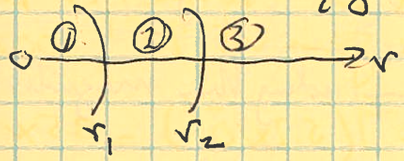
Effect of a spherical glass bulb around the tip of the feed

A source at the center will radiate a wave outward, a spherical wave. What is the the transmission through the glass sphere?

Outward wave:
$$\begin{cases} E_\theta = A\mu_0 \sin\theta\, i\omega \dfrac{e^{-i\gamma r}}{r} \\ H_\phi = A \sin\theta\, i\gamma \dfrac{e^{-i\gamma r}}{r} \end{cases} \qquad \gamma = \omega\sqrt{\mu\epsilon}$$

Reflected wave:
$$E_\theta = B \sin\theta\, i\omega \frac{e^{+i\gamma r}}{r}$$
$$H_\phi = -B \sin\theta\, i\gamma \frac{e^{+i\gamma r}}{r}$$

$$E_\theta / H_\phi = \frac{\mu_0 i\omega}{i\gamma} = \sqrt{\frac{\mu}{\epsilon}} = \eta = \eta_0 = 377\,\Omega \text{ in free space}$$



In region ①
$$E_\theta = \frac{Ae^{-i\gamma_0 r}}{r}\sin\theta + \frac{Be^{i\gamma_0 r}}{r}\sin\theta$$
$$H_\phi = \frac{Ae^{-i\gamma_0 r}}{\eta_0 r}\sin\theta - \frac{Be^{i\gamma_0 r}}{\eta_0 r}\sin\theta$$

In region ②
$$E_\theta = \frac{Ce^{-i\gamma_g r}}{r}\sin\theta + \frac{De^{i\gamma_g r}}{r}\sin\theta \qquad \gamma_g = \text{for the glass}$$
$$H_\phi = \frac{Ce^{-i\gamma_g r}}{\eta_g r}\sin\theta - \frac{De^{i\gamma_g r}}{\eta_g r}\sin\theta$$

In region ③
$$E_\theta = \frac{Ee^{-i\gamma_0 r}}{r}\sin\theta$$
$$H_\phi = \frac{Ee^{-i\gamma_0 r}}{\eta_0 r}\sin\theta$$

Tangential E and H must be continuous at the boundaries, r_1 and r_2.

At r_1: $E_{\theta_1} = E_{\theta_2}$ and $H_{\phi_1} = H_{\phi_2}$ $\qquad$ $\sin\theta$ factors out.

$$\frac{Ae^{-i\gamma_0 r_1}}{r_1} + \frac{Be^{i\gamma_0 r_1}}{r_1} = \frac{Ce^{-i\gamma_g r_1}}{r_1} + \frac{De^{i\gamma_g r_1}}{r_1}$$

$$\frac{Ae^{-i\gamma_g r_1}}{\eta_0 r_1} - \frac{Be^{i\gamma_0 r_1}}{\eta_0 r_1} = \frac{Ce^{i\gamma_g r_1}}{\eta_g r_1} - \frac{De^{i\gamma_g r_1}}{\eta_g r_1}$$

At $r = r_2$ $\quad E_{\theta_2} = E_{\theta_3}$ and $H_{\phi_2} = H_{\phi_3}$

$$\frac{C e^{-i\gamma_g r_2}}{r_2} + \frac{D e^{i\gamma_g r_2}}{r_2} = \frac{E e^{-i\gamma_0 r_2}}{r}$$

and
$$\frac{C e^{-i\gamma_g r_2}}{\eta_g r_2} - \frac{D e^{i\gamma_g r_2}}{\eta_g r_2} = \frac{E e^{-i\gamma_0 r_2}}{\eta_0 r_2}$$

The $\frac{1}{r}$ factors drop out everywhere

Set $A = 1$ and solve for E to get the transmitted signal.

After some algebra, we get:

$$A = \left\{ E\left(1+\frac{\eta_g}{\eta_0}\right)\left(1+\frac{\eta_0}{\eta_g}\right) e^{-i\gamma_g(r_1-r_2)} + E\left(1-\frac{\eta_g}{\eta_0}\right)\left(1-\frac{\eta_0}{\eta_g}\right) e^{i\gamma_g(r_1-r_2)} \right\} e^{i\gamma_0(r_1-r_2)}$$

The last phase factor can be ignored in finding the magnitude of the Transmission.

Some numerical values $\gamma = \omega\sqrt{\mu\epsilon}$, $\gamma_0 = \omega\sqrt{\mu_0\epsilon_0} = \frac{\omega}{c} = \frac{2\pi f}{c} = .2095\, f_g$

$\gamma_g = \omega\sqrt{\mu_0 4\epsilon_0} = 2\gamma_0 = .4189\, f_g$; $\gamma_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} = 377\Omega$; $\eta_g = \sqrt{\frac{\mu_0}{4\epsilon_0}} = \frac{\eta_0}{2}$

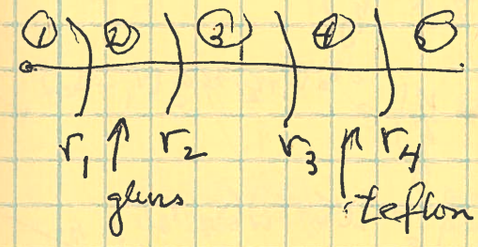
$\left(1+\frac{\eta_g}{\eta_0}\right)\left(1+\frac{\eta_0}{\eta_g}\right) = \frac{9}{2}$; $\left(1-\frac{\eta_g}{\eta_0}\right)\left(1-\frac{\eta_0}{\eta_g}\right) = -\frac{1}{2}$ $\qquad r_1 - r_2 = -.046$ cm ?! cgs?

Find $\quad E = \dfrac{1}{e^{i(.0193 f_g)} - \frac{i}{4}\sin(-.0193 f_g)}$

$|E(5)| = .9886 = 1 - .0114$ $\quad\|\quad$ $|E(5)|^2 = .9773 = 1 - .0227$

$|E(15)| = .9556 = 1 - .0444$ $\quad\|\quad$ $|E(15)|^2 = .9132 = 1 - .0868$

Add a layer of teflon with variable spacing and variable thickness: two more boundaries



In region 1: $E_\theta = \dfrac{e^{-i\gamma_0 r}}{r} + \dfrac{Be^{i\gamma_0 r}}{r}$; $H_\phi = \dfrac{e^{-i\gamma_0 r}}{\eta_0 r} - \dfrac{Be^{i\gamma_0 r}}{\eta_0 r}$

2: $E_\theta = \dfrac{Ce^{-i\gamma_g r}}{r} + \dfrac{De^{i\gamma_g r}}{r}$; $H_\phi = \dfrac{Ce^{-i\gamma_g r}}{\eta_g r} - \dfrac{De^{i\gamma_g r}}{\eta_g r}$

3: $E_\theta = \dfrac{Ee^{-i\gamma_0 r}}{r} + \dfrac{Fe^{i\gamma_0 r}}{r}$; $H_\phi = \dfrac{Ee^{-i\gamma_0 r}}{\eta_0 r} - \dfrac{Fe^{i\gamma_0 r}}{\eta_0 r}$

4: $E_\theta = \dfrac{Ge^{-i\gamma_t r}}{r} + \dfrac{He^{i\gamma_t r}}{r}$; $H_\phi = \dfrac{Ge^{-i\gamma_t r}}{\eta_t r} - \dfrac{He^{i\gamma_t r}}{\eta_t r}$

5: $E_\theta = \dfrac{Ie^{-i\gamma_0 r}}{r}$; $H_\phi = \dfrac{Ie^{-i\gamma_0 r}}{\eta_0 r}$

Match tangential E_θ and H_ϕ <u>Find I</u>
The $1/r$ factors drop out.

At $r=r_1$: $e^{-i\gamma_0 r_1} + Be^{i\gamma_0 r_1} = Ce^{-i\gamma_g r} + De^{i\gamma_g r}$; $\dfrac{e^{-i\gamma_0 r_1}}{\eta_0} - \dfrac{Be^{i\gamma_0 r_1}}{\eta_0} = \dfrac{Ce^{-i\gamma_g r_1}}{\eta_g} - \dfrac{De^{i\gamma_g r_1}}{\eta_g}$

At $r=r_2$: $Ce^{-i\gamma_g r_2} + De^{i\gamma_g r_2} = Ee^{-i\gamma_0 r_2} + Fe^{i\gamma_0 r_2}$; $\dfrac{Ce^{-i\gamma_g r_2}}{\eta_g} - \dfrac{De^{i\gamma_g r_2}}{\eta_g} = \dfrac{Ee^{-i\gamma_0 r_2}}{\eta_0} - \dfrac{Fe^{i\gamma_0}}{\eta_0}$

At $r=r_3$: $Ee^{-i\gamma_0 r_3} + Fe^{i\gamma_0 r_3} = Ge^{-i\gamma_t r_3} + He^{i\gamma_t r_3}$; $\dfrac{Ee^{-i\gamma_0 r_3}}{\eta_0} - \dfrac{Fe^{i\gamma_0 r_3}}{\eta_0} = \dfrac{Ge^{-i\gamma_t r_3}}{\eta_0} - \dfrac{He^{i\gamma_t r_3}}{\eta_t}$

At $r=r_4$: $Ge^{-i\gamma_t r_4} + He^{i\gamma_t r_4} = Ie^{-i\gamma_0 r_4}$; $\dfrac{Ge^{-i\gamma_t r_4}}{\eta_t} - \dfrac{He^{i\gamma_t r_4}}{\eta_t} = \dfrac{Ie^{-i\gamma_0 r_4}}{\eta_0}$

By adding and subtracting and successive substitution solve for I. It takes several pages of algebra

Finally (after much algebra)

$$\frac{I_t}{I} = Q_A\left(1+\frac{\eta_g}{\eta_0}\right)\left(1+\frac{\eta_0}{\eta_g}\right)e^{i\gamma_0(r_1-r_2)+i\gamma_g(r_2-r_1)} + Q_B\left(1-\frac{\eta_g}{\eta_0}\right)\left(1+\frac{\eta_0}{\eta_g}\right)e^{i\gamma_g(r_2-r_1)+i\gamma_0(r_2+r_1)}$$

$$+Q_A\left(1-\frac{\eta_g}{\eta_0}\right)\left(1-\frac{\eta_0}{\eta_g}\right)e^{i\gamma_0(r_1-r_2)+i\gamma_g(r_1-r_2)} + Q_B\left(1+\frac{\eta_g}{\eta_0}\right)\left(1-\frac{\eta_0}{\eta_g}\right)e^{i\gamma_0(r_1+r_2)+i\gamma_g(r_1-r_2)}$$

— where

$$Q_A = \left\{\left(1+\frac{\eta_t}{\eta_0}\right)\left(1+\frac{\eta_0}{\eta_t}\right)e^{i[(\gamma_t-\gamma_0)(r_4-r_3)]} + \left(1-\frac{\eta_t}{\eta_0}\right)\left(1-\frac{\eta_0}{\eta_t}\right)e^{-i[(\gamma_0+\gamma_t)(r_4-r_3)]}\right\}$$

and

$$Q_B = \left\{\left(1+\frac{\eta_t}{\eta_0}\right)\left(1-\frac{\eta_0}{\eta_t}\right)e^{i[(\gamma_t-\gamma_0)(r_4-r_3)-2\gamma_0 r_3]} + \left(1-\frac{\eta_t}{\eta_0}\right)\left(1+\frac{\eta_0}{\eta_t}\right)e^{-i[(\gamma_t-\gamma_0)(r_4-r_3)+2\gamma_0 r_4]}\right\}$$

---

substitute values: $\eta_g = \frac{\eta_0}{2}$ $\quad \left(1+\frac{\eta_g}{\eta_0}\right) = 1+\frac{1}{2} = \frac{3}{2}$

first for the glass

This assumes that $k_g = 4.0$ $\quad \left(1+\frac{\eta_g}{\eta_0}\right) = 1+\frac{\eta_0/2}{\eta_0} = \frac{3}{2}$; $\left(1+\frac{\eta_0}{\eta_g}\right) = 3$

$$\left(1-\frac{\eta_g}{\eta_0}\right) = \left(1-\frac{\eta_0/2}{\eta_0}\right) = \frac{1}{2} \; ; \left(1-\frac{\eta_0}{\eta_g}\right) = 1-\frac{\eta_0}{\eta_0/2} = 1-2 = -1$$

$$\left(1+\frac{\eta_g}{\eta_0}\right)\left(1+\frac{\eta_0}{\eta_g}\right) = \left(\frac{3}{2}\right)3 = \frac{9}{2} \; ; \left(1-\frac{\eta_g}{\eta_0}\right)\left(1+\frac{\eta_0}{\eta_g}\right) = \left(\frac{1}{2}\right)3 = \frac{3}{2}$$

$$\left(1-\frac{\eta_g}{\eta_0}\right)\left(1-\frac{\eta_0}{\eta_g}\right) = \left(\frac{1}{2}\right)(-1) = -\frac{1}{2} \; ; \left(1+\frac{\eta_g}{\eta_0}\right)\left(1-\frac{\eta_0}{\eta_g}\right) = \left(\frac{3}{2}\right)(-1) = -\frac{3}{2}$$

3/6/10

Math's Table

TDP PLP Feed Dimensions for Frequency & Wavelength

(PLP = Pyramid Log Periodic)

F =	Giga Hz	Frequency.	User input (green)
C = 29.98	Giga cm / sec	Speed of Light 2.9792558 E+10 cm / sec.	
W = C / F	cm	Wavelength λ = W	
a = W / 4 / tan(10°)	cm	Dist VP to active plane along centerline of feed.	
d = 2 a tan(10°)	cm	Pennant pt to pt dim at acitve plane. (also = W / 2)	
p = 2 a tan(5°)	cm	Pyramid dim at active plane.	
e = 0.452	in	Dist VP to beginning of tip plane of pyramid PLP 1.15	
g = 1.30	ratio	Dist VP to ground plane / dist VP to resonant plane	
h = 0.78 to 0.55	ratio	Dist VP to resonant plane / dist VP to tip of feed	

		1.4178 x λ		b = a - e	10 deg		5 deg	
F	λ	a		b	d arm dim		p pyramid dim	
GHz	cm	cm	inch	inch	cm	inch	cm	inch
		58.06	22.858	22.406			10.16	4.000
0.76158	39.36	55.81	21.973	21.521	19.68	7.749	9.77	3.845
1.0	29.98	42.51	16.734	16.282	14.99	5.901	7.44	2.928
1.313	22.84	32.38	12.750	12.298	11.42	4.496	5.67	2.231
1.4	21.41	30.36	11.953	11.501	10.71	4.215	5.31	2.092
2.0	14.99	21.25	8.367	7.915	7.49	2.951	3.72	1.464
3.0	9.99	14.17	5.578	5.126	5.00	1.967	2.48	0.976
4.0	7.49	10.63	4.184	3.731	3.75	1.475	1.86	0.732
5.0	6.00	8.50	3.347	2.895	3.00	1.180	1.49	0.586
8.0	3.75	5.31	2.092	1.640	1.87	0.738	0.93	0.366
10.0	3.00	4.25	1.673	1.221	1.50	0.590	0.74	0.293
14.0	2.14	3.04	1.195	0.743	1.07	0.422	0.53	0.209
16.80	1.78	2.53	0.996	0.544	0.89	0.351	0.44	0.174
22.0	1.36	1.93	0.761	0.308	0.68	0.268	0.34	0.133
24.800	1.21	1.71	0.675	0.222	0.60	0.238	0.30	0.118
26.0	1.15	1.63	0.644	0.191	0.58	0.227	0.29	0.113
30.0	1.00	1.42	0.558	0.106	0.50	0.197	0.25	0.098
30.0	1.00	1.42	0.558	0.106	0.50	0.197	0.25	0.098
37.000	0.81	1.15	0.452	0.000	0.41	0.159	0.20	0.079

The feed is composed of 4 feed arms and a central pyramid.
A feed arm is composed of a central spine with pennants protruding from it.
The underside of the pennants is considered the active surface on the feed arm.
Penants are active or resonate at 1/2 the wavelength of the incoming signal.
The resonant plane is the plane perpendicular to the central axis of the feed where pennants resonate.
d = Diameter or distance across pennant arms tip to tip at the resonant plane.
d = W/2
p = Diameter of the pyramid at resonant plane. Tau = 0.96 that is (dim for one tip) / (over dim next tip on the oposite side)
p = (a) tan(5°) along centerline of feed
a = Distance from vanishing point to resonant plane along feed centerline.
a = d / 2 / tan(10°) = W / 4 / tan(10°) = W x 1.417820 along centerline of feed
b = Distance from feed tip plane to renonant plane along feed centerline.
j = Distance from vanishing point to resonant point along surface of feed arm.
j = r / sin(10°) = W/4/sin(10°) = W x 1.439693 along plane of arm
k = Distance from feed tip point to renonant point long surface of feed arm.
g = Ratio of dist VP to lowest freq plane over dist VP to ground plane. (emperical ATA at 500 MHz)
g = 1.30 = 15.500 / 11.804 (500 MHz min at d = 11.804 in & ground d = 15.700 or 10.500 in ctrl extension)(dim a or p may be used)
h = 0.54 = 1.134 / 2.092 (8 GHz max at a = 2.092 in & tip end a = 1.134 in for ATA feed)(too conservative ?)

3/6/10

Estimated reflection from the planned plane rexolite standoffs. Assumed that they are full sheets

Use the one layer formula from p. 146 (IV) above.

$$4 = I\left\{\left(1+\frac{\eta_g}{\eta_0}\right)\left(1+\frac{\eta_0}{\eta_g}\right)e^{-i\gamma_g(r_1-r_2)} + \left(1-\frac{\eta_g}{\eta_0}\right)\left(1-\frac{\eta_0}{\eta_g}\right)e^{i\gamma_g(r_1-r_2)}\right\}$$

Here we use η_t for η_g and γ_t for γ_g

$$\eta_t = \sqrt{\frac{\mu_0}{2\epsilon_0}} = \frac{\eta_0}{\sqrt{2}}, \quad \gamma_t = \omega\sqrt{\mu_0 2\epsilon_0} = \sqrt{2}\,\gamma_0$$

$$\gamma_0 = \omega\sqrt{\mu_0\epsilon_0} = .2095 f_g \qquad \gamma_t = \sqrt{2}(.2095) f_g = .2962 f_g$$

$r_2 - r_1 = +\Delta X$, the thickness

$$\left(1+\frac{\eta_t}{\eta_0}\right)\left(1+\frac{\eta_0}{\eta_t}\right) = \left(1+\frac{1}{\sqrt{2}}\right)\left(1+\sqrt{2}\right) = (1.7071)(1+1.4.4) = \underline{4.1213}$$

$$\left(1-\frac{\eta_t}{\eta_0}\right)\left(1-\frac{\eta_0}{\eta_t}\right) = \left(1-\frac{1}{\sqrt{2}}\right)\left(1-\sqrt{2}\right) = \underline{-.1213}$$

$$4 = I\left\{4.1213\, e^{i.2962\,\Delta X f_g} - .1213\, e^{-i.2962\,\Delta X f_g}\right\}$$

Calculate and Plot for six different thicknesses.

.01", .02", .03", .04", .063", .093"

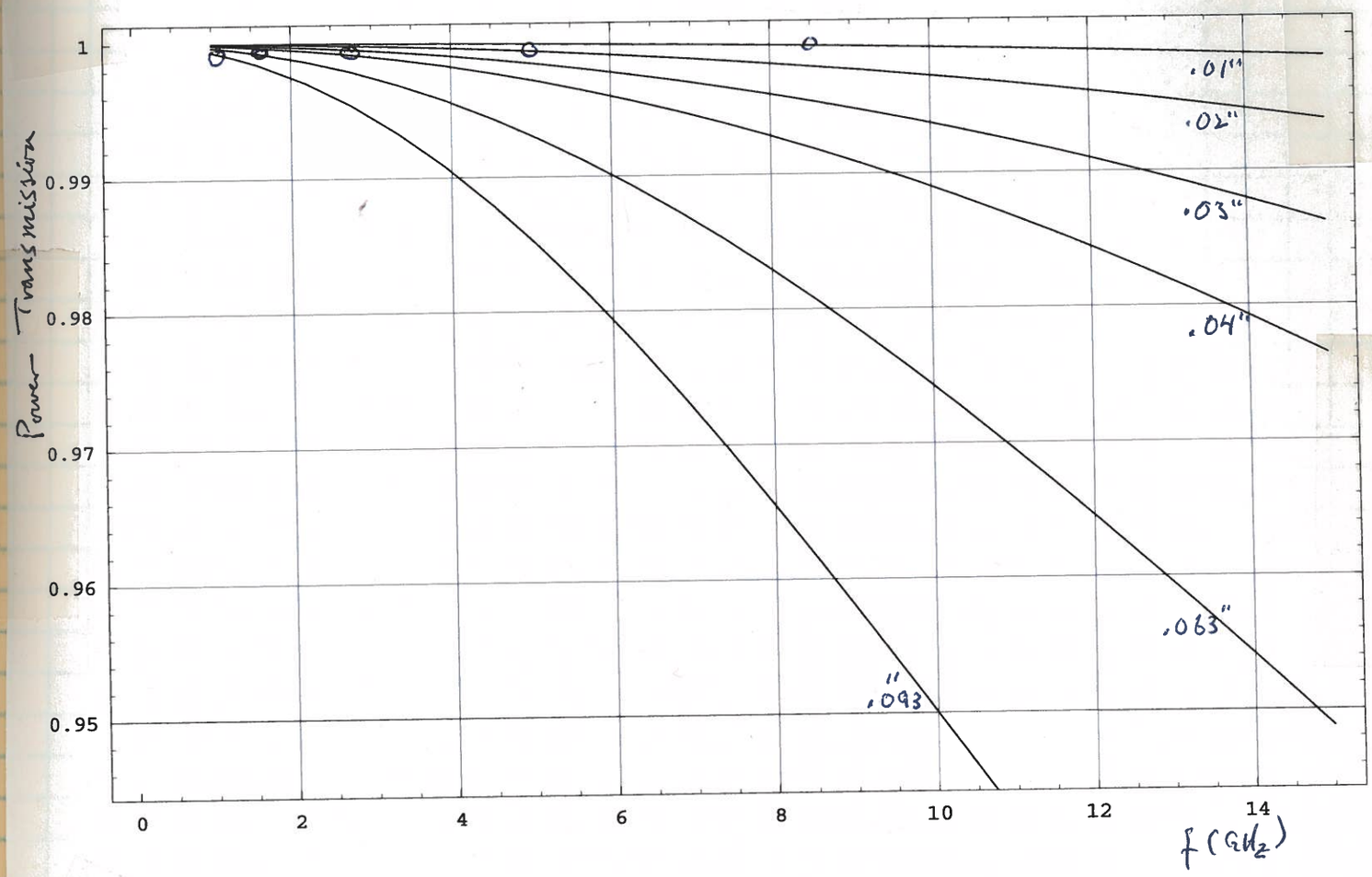
$$\Delta\Phi = .2962 f_g \Delta X \text{ (cm)}$$

$$I = \left\{\frac{4}{4.1213\, e^{i\Phi} - .1213\, e^{-i\Phi}}\right\} = \frac{4}{f_1[X]}$$

Plot [Abs[4/f1[X]]^2, {X,1,15}, Frame → True, GridLines → Automatic]

ΔX in, cm	Φ	label
	~~.0075 f_g~~	~~g41~~
.01, .0254	.0075 f_g	g41
.02, .0508	.0150 f_g	g42
.03, .0762	.0226 f_g	g43
.04, .1016	.0301 f_g	g44
.063, .1600	.0474 f_g	g45
.093, .2362	.0700 f_g	g46

G4.PDF



G4.PDF

Support thickness	(from vanishing point) location	focal point frequency (GHz)
.010"	1.0"	17.7
.010"	2.1"	8.4
.020"	3.6"	4.9
.040"	6.6"	2.7
.063"	11.2"	1.6
.093	16.2"	1.1

Reflections are < −30 dB

The Importance of Adding a Few Distant Stations to the ATA

Jack Welch

Summary: The addition of the distant stations to the ATA will allow decreasing of the error in position measurement of spacecraft by a factor of 0.3 at all operating wavelengths. Thus at the longest wavelengths, such as those of the GPS satellites, the measurement errors will be significantly under 1.0" This better accuracy should also be obtained in the mapping of radar scattering of debris fields after spacecraft collision.

Space situational awareness (SSA) is broadly defined as characterizing the space environment and its effects on activities in space. In SSA observations, two particular studies are important: one is the accurate location of the positions of radiating satellites (e.g., the GPS satellites), and the other is the mapping of the distributions of the pieces of non-emitting space debris such as those resulting from satellite collisions. In the first case, the satellite is radiating at a particular frequency that distinguishes it from other satellites, and it is a very small object in angle relative to the beam width of the observing antenna or array. So its position can be found accurately, but its small angular size cannot be measured with the array. After a collision between satellites, the distribution of the debris field is an extended source of scattering of (e.g.) a radar signal and can be mapped with the array as it evolves to understand the size distribution and velocities of the pieces.

The ATA consists of 42 6m diameter antennas distributed over a patch of ground that is approximately 300 meters in diameter. Adding together all of the different antenna signals with the correct time and phase delays will produce a point spread function (antenna pattern) similar in angular width to that of a 300m filled dish but with two important differences. The array pattern will be slightly less regular, and the peak sensitivity will be smaller for the array by the ratio of the total array collecting area to that of the complete dish. Pointing the sensitivity peak of a 300m diameter dish is accomplished by activating its large drive motors to repoint the antenna. For the array, this requires the pointing of the small antennas using their drives and adjusting the delays to phase up the combined beam. The array pattern is accurately known so that it can be fit to an array observation, yielding a precise location of the position of the radiator, which is about the same as that of the filled dish of the same diameter. The stability of the ground is a major advantage of the array over the large moveable dish antenna for angular position measurements.

Most satellites have strong transmitters, so that the modest collecting area of the array, as compared with the big filled dish is not a problem. In fact, the collecting area need consist of only a few ATA antennas to have enough sensitivity for the detection of the satellite. Finding the accurate location of any satellite depends heavily on the most widely spaced array antennas. In this case, the effective beam size of the array is determined by the largest spacing of the array antennas along two orthogonal directions. For the present array, four antennas that define the maximum separation are two north-south and two east-west that are about 300m apart for each pair.

One way to think about the improved precision that can result from adding in a few more distant antennas is to consider how a parabolic antenna can locate the position of a small radiating source, such as a satellite. In figure 1 below we show a parabolic reflector with two parallel rays from the distant source reflected toward the focal point from the mirror. The two reflected ray paths shown as solid lines are the same length and the signals add at the focus. If we tip the mirror as shown by the dashed curve, the same rays will have to travel along the dashed lines and will have different path lengths and phases at the focus. As a result of being somewhat out of phase, they will add to yield a weaker signal. Considering all the incoming rays, we expect a weaker total signal due to the tipping of the mirror. For the rays that reflect to the focus from the outer part of the

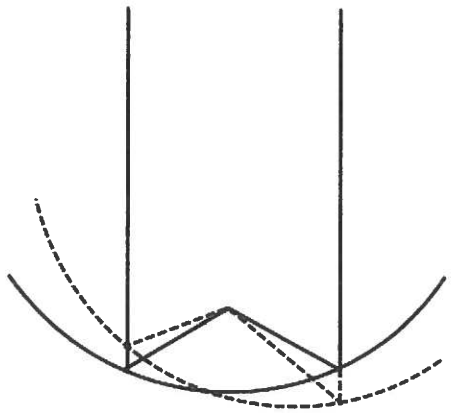


Figure 1 –

mirror the phase error will be greater due to the tilt and will depend on both the mirror diameter and the wavelength of the radiation. Averaging over all the rays, we find that the spacing of the half intensity points, the angular distance between the two angles at which the total signal has dropped to one half its maximum value is just (wavelength)÷(parabolic mirror diameter). So if we scan over the source by tipping the antenna, we can locate the source as the peak signal in the scan, and the inaccuracy of our determination will be about equal to the half intensity angle above.

To think about the array, first imagine that the above mirror is made of many contiguous panels. If we left out many of the panels, leaving the remainder in place, the phases of the remaining reflected rays would be the same, and the total signal at the focal point would just be weaker by the faction of the panels missing. Also, the result of the tipping experiment would be the same, but it's amplitude would be scaled down by the loss in area. The array can be thought of as the collection of the remaining panels. Instead of the plates of the big antenna, we have the antennas of the array, and now the signals reach the array "focal point" over cables. The tipping of the array is enabled by changing the delays in the interconnecting cables and tipping the pointing of the smaller antennas. This array is said to be a sparsely filled aperture. The array's overall pattern half angle is the same as that of the parabolic mirror. The peak in the position scan is weaker but has the same width as that of the filled aperture.

How serious is the loss of collecting area compared to what the full antenna would provide? The broadcast satellites are actually quite powerful. They must be detectable by a small antenna on a vehicle with a receiver with modest sensitivity. The "panels" of the ATA are 6m dishes, and they have excellent receivers. The gain of one of the ATA antennas is about 100,000 times greater than that of the antenna on the vehicle at a wavelength of 20cm, that of the GPS satellite transmitters. The ratio is even greater at shorter wavelengths. So the sensitivity of the "sparse" array is overwhelming good for this application.

In view of these last considerations, moving just six antennas to distant stations which generate much wider spacings will provide much better position measurements for the strongly radiating satellites than is now possible with the ATA. Figure 2 below shows a layout of the ATA site with the present group of antennas clustered around the T-shaped roadway and the locations of the more distant BIMA pad locations. The phase of the signal reaching each distant antenna will be compared with those of all the

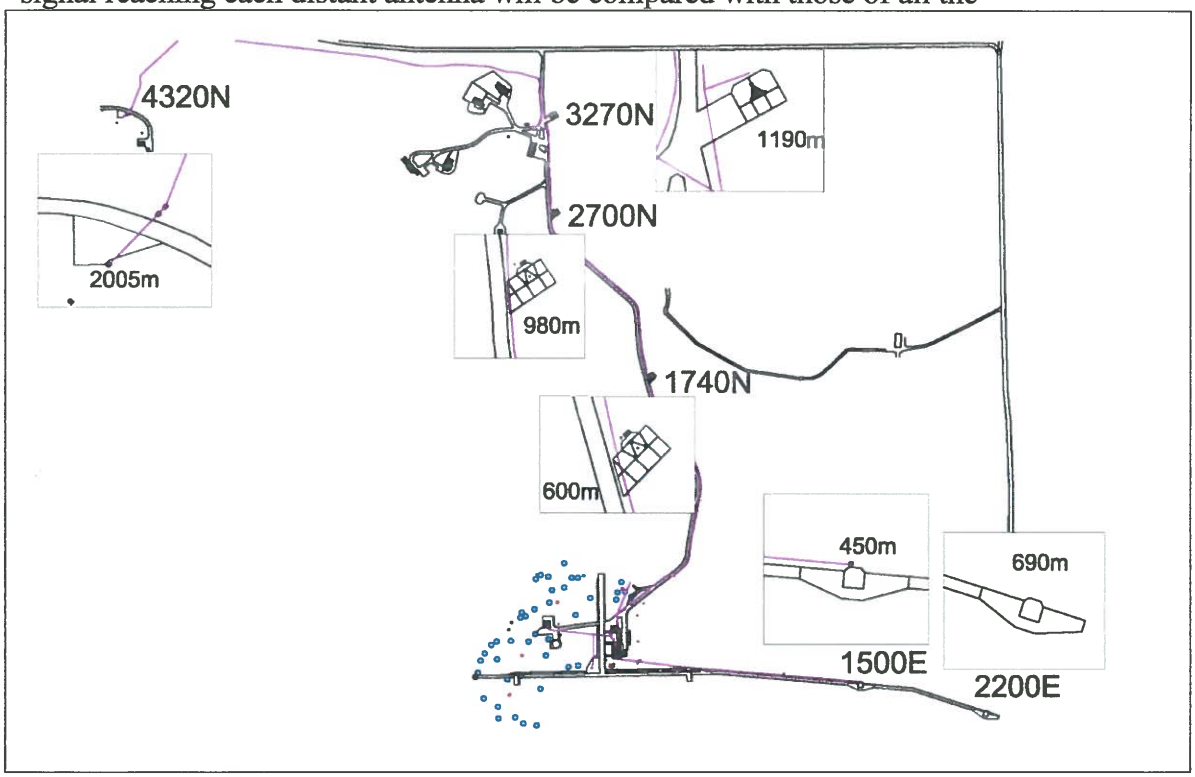


Figure 2 –

compact array antennas for measurement of the positions of the satellites. Figure 3 shows a histogram of the baseline length distributions for both with and without the distant stations. The histogram length maxima are at 400m without the outer stations and 1400m with them included. This ratio of 3.5 is the general improvement in position determinations that can be expected. This is a very important improvement in the tracking accuracy of, for example, GPS satellites in L-band, improving our current capabilities of about 2.0" accuracy to about 0.5", see Figure 4. Corresponding improvements in the shorter wavelength bands will, of course, be realized: e.g. : 0.1"