L - S Band
Low Noise Amplifiers
Designs
… is Cooling Necessary ?

Tommy Henderson – WD5AGO

What's New in Low Noise Devices?

- pHEMT Devices have lower noise figures in the 10 to 20 GHz spectrum but little has change in n/f performance from 0.5 to 5 GHz
- Low noise MMIC technology is near and with cryogenic cooling can out perform pHEMTs
- mHEMT Devices have lower noise figures but are currently in non leaded chip-die's

Stability and Advantage in 2nd Stage

- Determined both experimentally and in CAD a 2 stage LNA is some what easier to stabilize than a single stage design
- 2nd stage contribution will increase noise figure slightly but will lower overall system noise performance,

How Much Does 2nd Stage Effect LNA Noise Figure?

$$F = F_1 + \frac{F_2 - 1}{G_1} \qquad NF = 10 \log_{10} F$$

With … NF_1 = 0.4 dB, 13 dB G_1

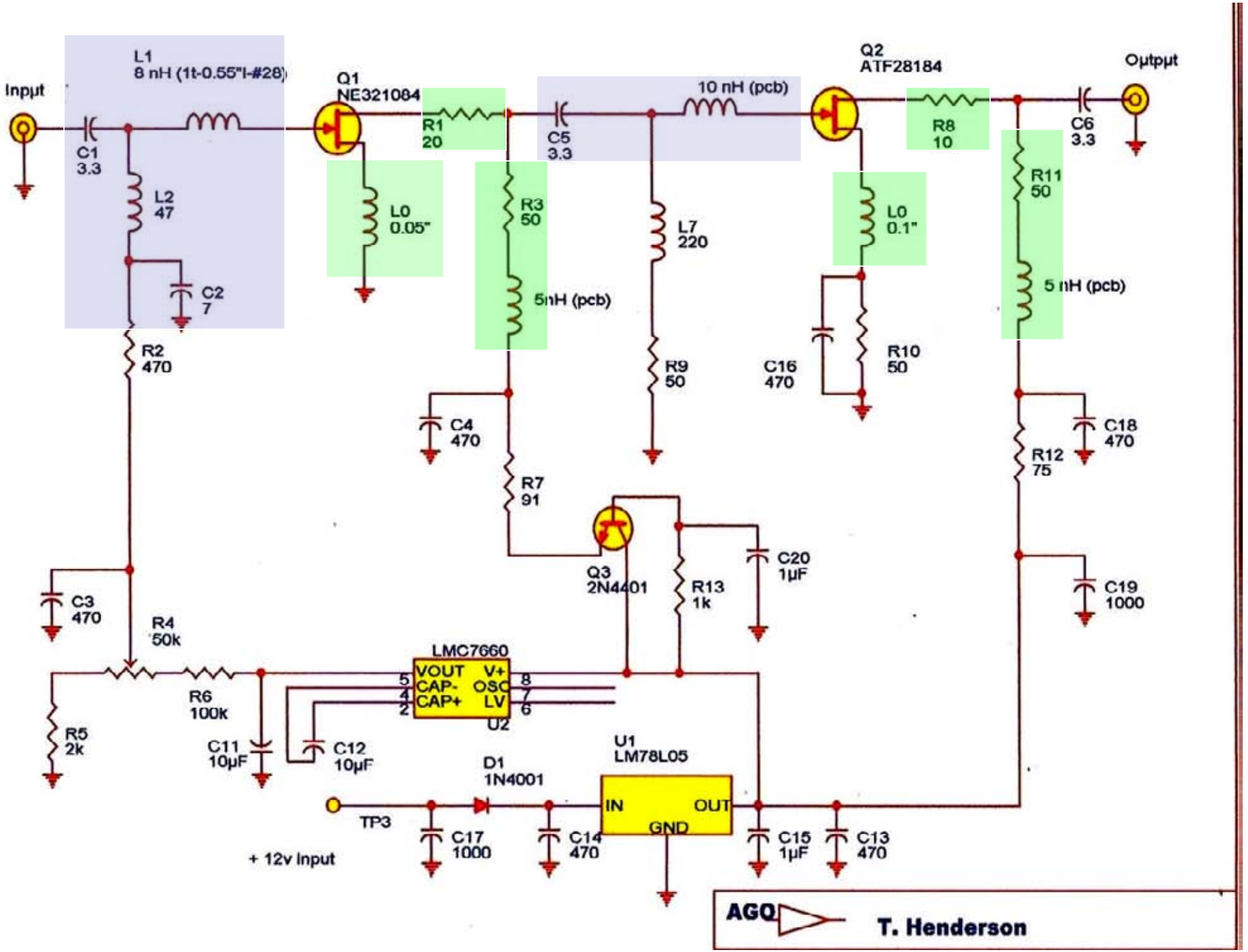
NF_2 = 1.0 dB NF = 0.45 dB

NF_2 = 0.75 dB NF = 0.44 dB

NF_2 = 0.5 dB NF = 0.42 dB

Source Inductance Effects on L-Band PCB using NE32584 Modeled in Touchstone

- 30mil k=0.6 @ 0.8 GHz
- 40mil k=0.7 @ 0.8 GHz
- **50mil k=1 @ 0.8 and k=0.9 @ 9 GHz**
- 60mil k=0.6 @ 9 GHz
- 70mil k=0.3 @ 9 GHz


Input
L1
8 nH (1t-0.55"I-#28)
C1
3.3
L2
47
C2
7
R2
470
C3
470
R4
50k
R5
2k
R6
100k
C11
10µF
C12
10µF
Q1
NE321084
L0
0.05"
R1
20
R3
50
5nH (pcb)
C4
470
R7
91
C5
3.3
10 nH (pcb)
L7
220
R9
50
Q2
ATF28184
L0
0.1"
C16
470
R10
50
R8
10
C6
3.3
Output
R11
50
5 nH (pcb)
C18
470
R12
75
C19
1000
Q3
2N4401
R13
1k
C20
1µF
LMC7660
VOUT
CAP-
CAP+
V+
OSC
LV
U2
TP3
D1
1N4001
+ 12v Input
U1
LM78L05
IN
OUT
GND
C17
1000
C14
470
C15
1µF
C13
470
AGO
T. Henderson

What are the new Challenges in LNA Designs?

- Low frequency circuit stability still difficult to achieve due to devices designed for higher frequency usage
- Device package changes by Manufactures require up-dated PCB designs – *and Glasses!*
- Higher IMD performance due to ISM and other in/out of band noise sources

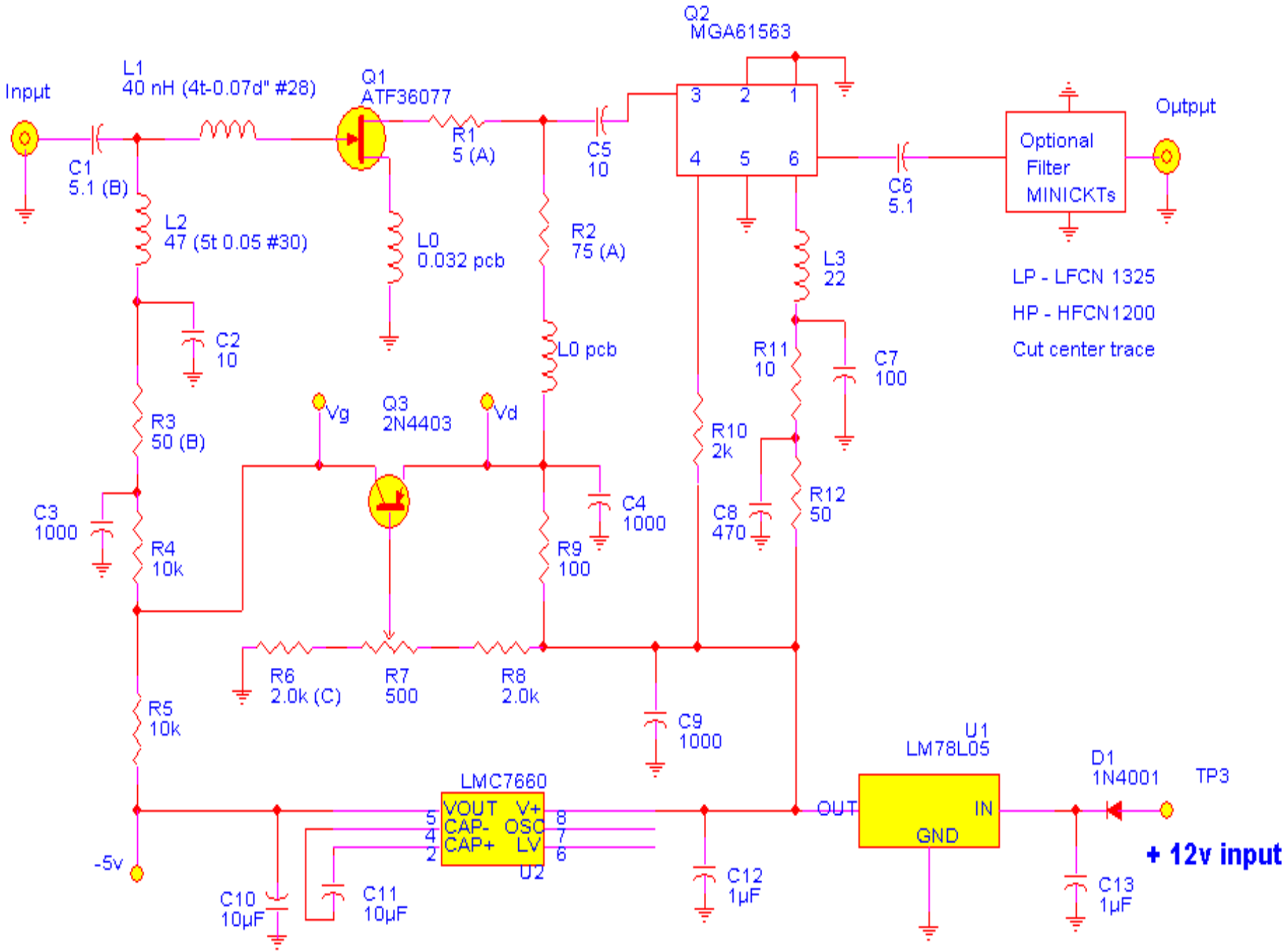
Using 62mil-FR4 above L-Band?

- Laboratory and CAD analysis has indicated too much source inductance for the 9cm band using 62 mil PCB.
- PCB losses does not effect the noise figure as the low loss input circuit is suspended in air.
- Conclusion: Stay with FR4 but use 32 or 20 mil board for f > 2GHz.

Device	Gate Width	Specified F_{MIN} @ 2GHz	Measured dB NF @ 2GHz	Specified P_{1dB}
ATF34143	800 um	0.50	0.68	+20
ATF35143	400 um	0.30	0.60	+11
ATF36077	200 um	0.30	0.42	
ATF36163	200 um	0.50	0.61	+5
FHC40LG	200 um	0.28	0.45	
MGA61563	MMIC	0.80	0.90	+15
MGF4931	160 um	0.28	0.45	
MGF4953	160 um	0.25	0.43	
NE3210S01	160 um	0.29	0.42	
NE3511S01	160 um	0.26	0.38	

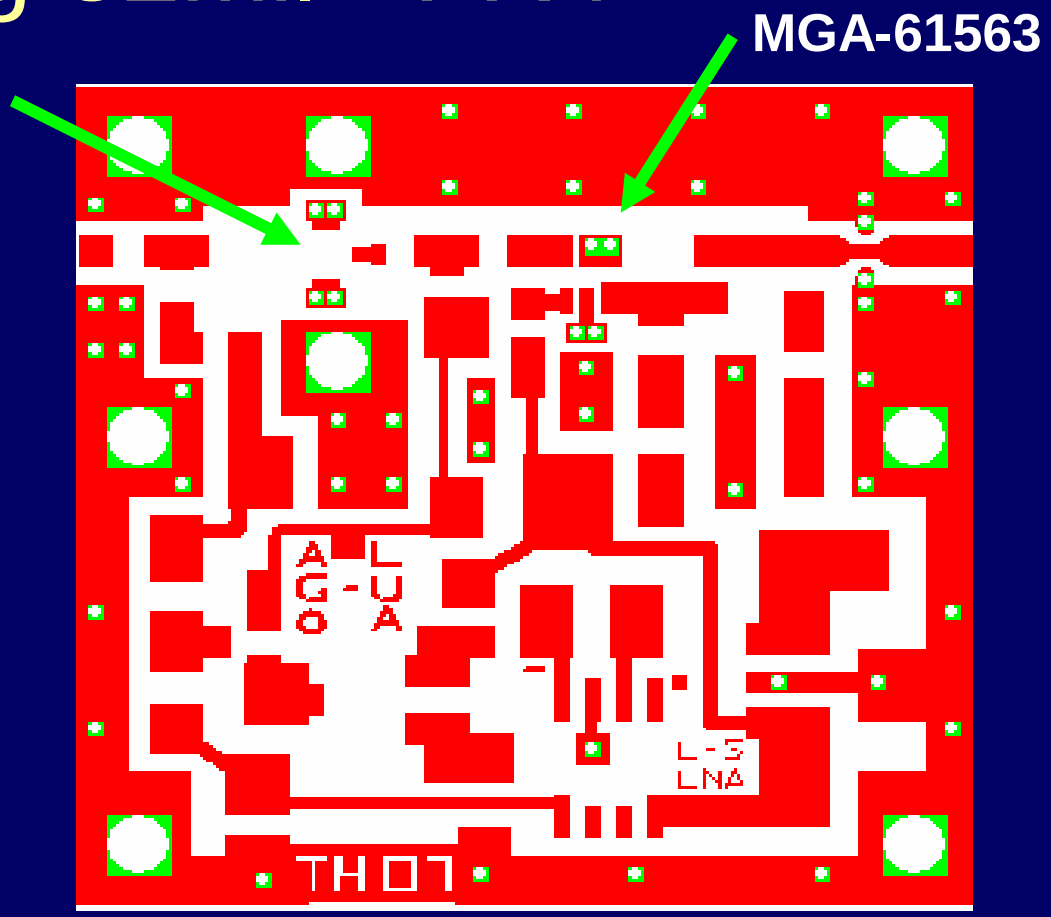
MMIC in 2nd Stage?

- Adding a low noise (~ 0.8dB) 2nd stage MMIC improved broad stability k >1
- Noise figure average 0.05 dB higher than original AGO circuit with ATF21186 in 2nd stage (0.25 to 0.30 dB n/f on 23cm)
- Lower frequency cutoff made possible by Mini –Circuits SMD HP filter


Input
L1
40 nH (4t-0.07d" #28)
Q1
ATF36077
C1
5.1 (B)
L2
47 (5t 0.05 #30)
L0
0.032 pcb
R1
5 (A)
C5
10
Q2
MGA61563
3 2 1
4 5 6
C6
5.1
Optional
Filter
MINICKTs
Output
LP - LFCN 1325
HP - HFCN1200
Cut center trace
R2
75 (A)
L0 pcb
L3
22
R11
10
C7
100
C2
10
Vg
Q3
2N4403
Vd
R3
50 (B)
R10
2k
C3
1000
R4
10k
C4
1000
R9
100
C8
470
R12
50
R6
2.0k (C)
R7
500
R8
2.0k
R5
10k
C9
1000
U1
LM78L05
OUT
IN
GND
D1
1N4001
TP3
LMC7660
VOUT V+
CAP- OSC
CAP+ LV
5 8
4 7
2 6
U2
-5v
C10
10µF
C11
10µF
C12
1µF
C13
1µF
+ 12v input

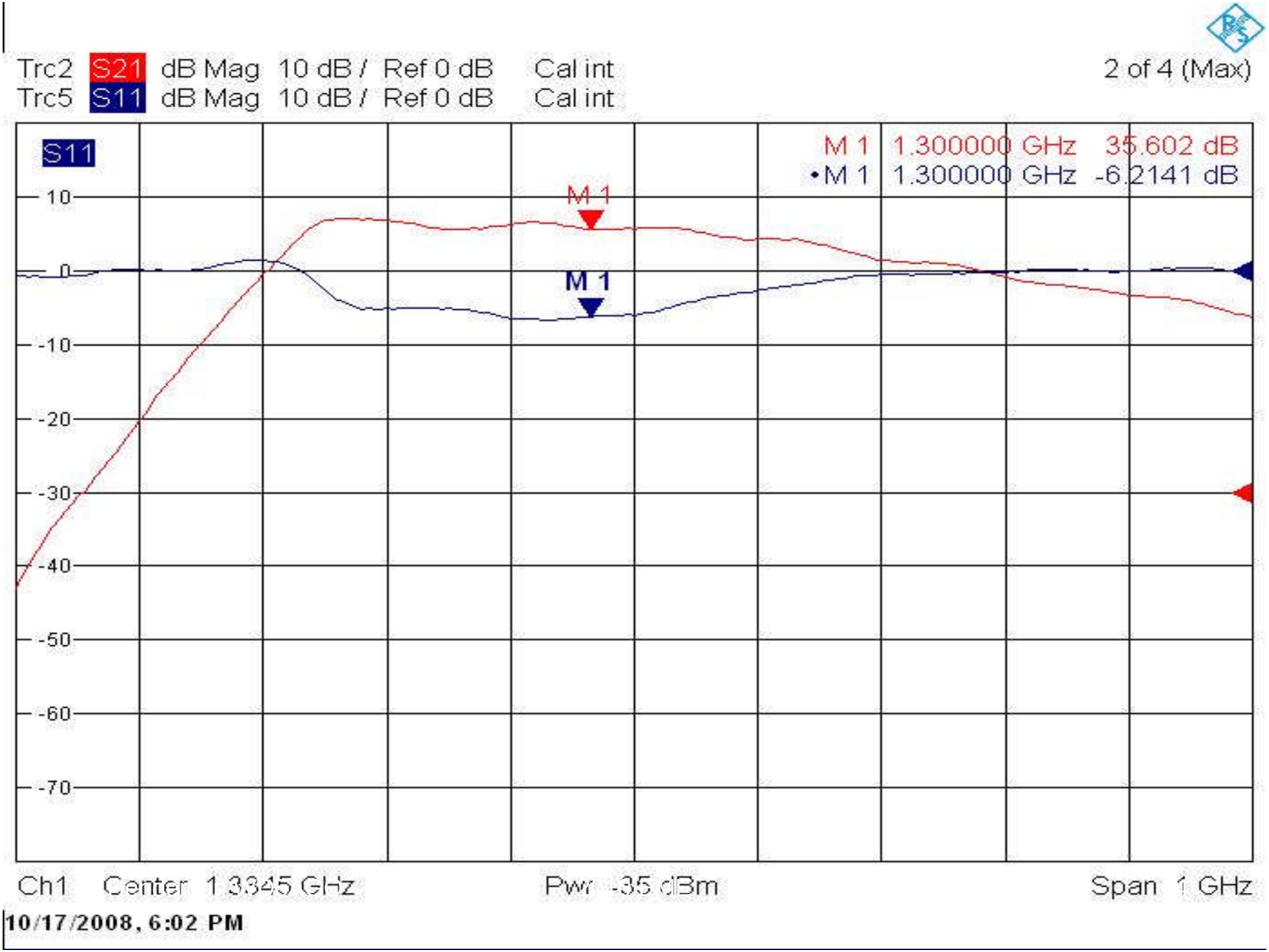
AGO – LUA L Band Higher IP LNA Using 32mil - FR4

Higher IP PCB designed for L Band with stable performance though S Band



Measured High IP L – S Band LNA Results

Band – Device (S_{11}~4dB)	**Noise Figure dB**	**Gain dB**	**P_{1in} dB** (-31)
23cm – ATF36077	0.31	38	-20
23cm – NE3511S01	0.29	40	-22
13cm – ATF36077	0.48	28	-21
13cm – NE3511S01	0.45	29	-22
9cm – NE3511S01	0.51	28	-23


Trc2 S21 dB Mag 10 dB / Ref 0 dB Cal int
Trc5 S11 dB Mag 10 dB / Ref 0 dB Cal int
2 of 4 (Max)
S11
M 1 1.300000 GHz 35.602 dB
•M 1 1.300000 GHz -6.2141 dB
M 1
M 1
10
0
-10
-20
-30
-40
-50
-60
-70
Ch1 Center 1.3345 GHz
Pwr -35 dBm
Span 1 GHz
10/17/2008, 6:02 PM

Converting LNA to 13 or 9cm

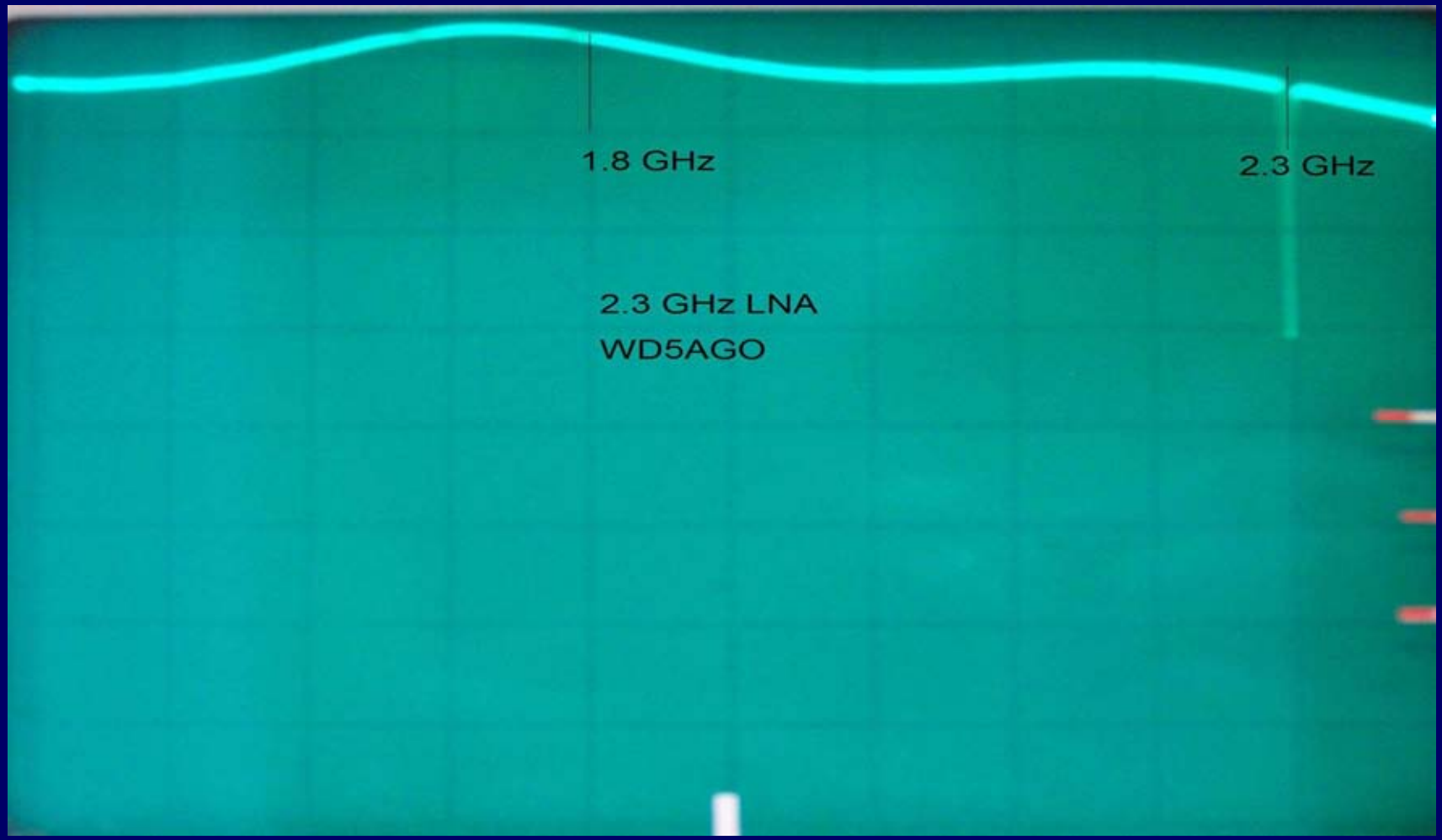
ATF36077

- 13cm : Lg straight 0.4” long
- 9cm : Lg 0.25” long
- C-input is 2.7 pF
- C-MMIC coupling is 4.7 pF

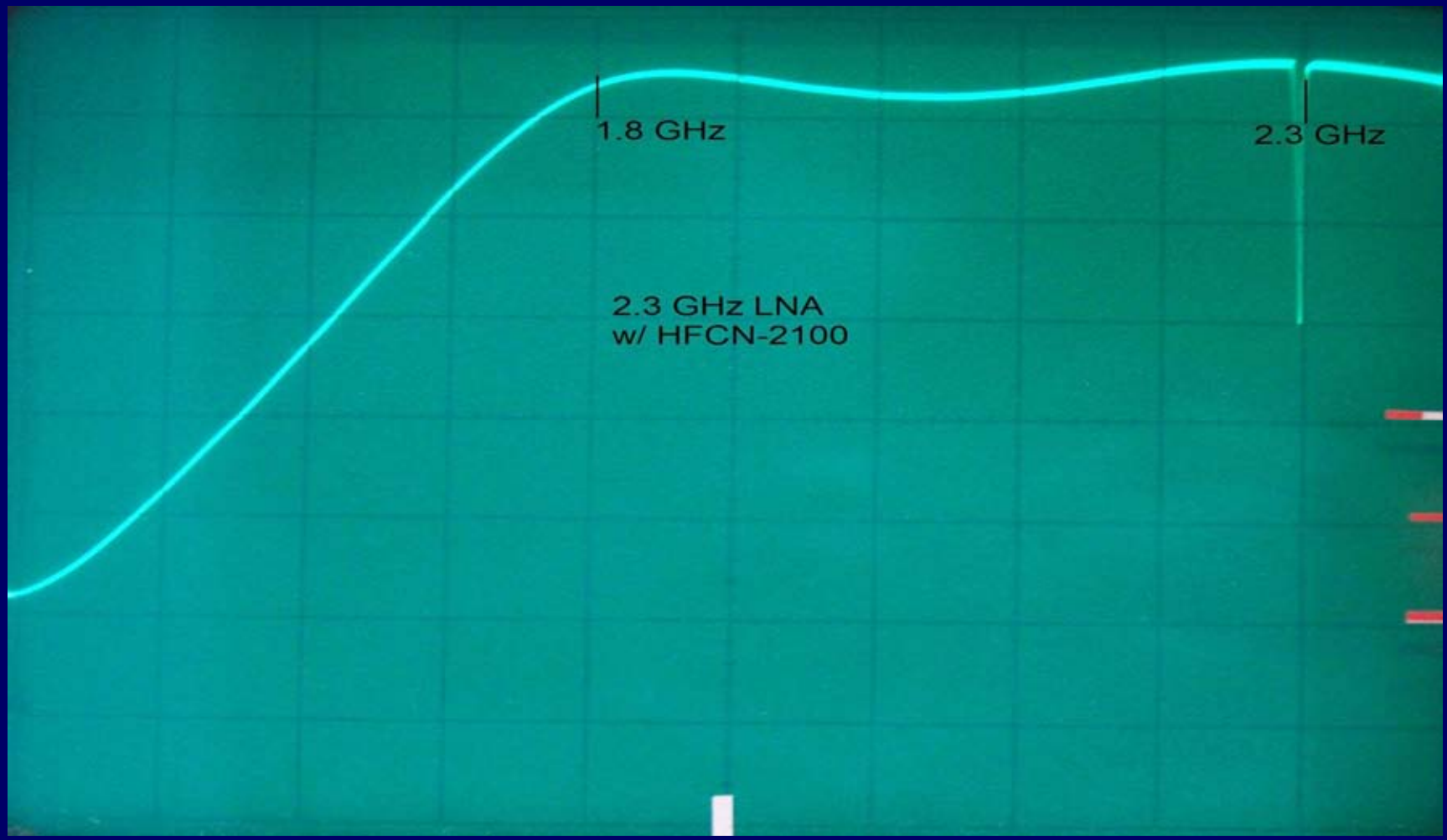
NE3210S01

- 13cm : Lg = 0.5” long
- 9cm : Lg = 0.3” long

13cm Higher IP LNA w/o Filtering

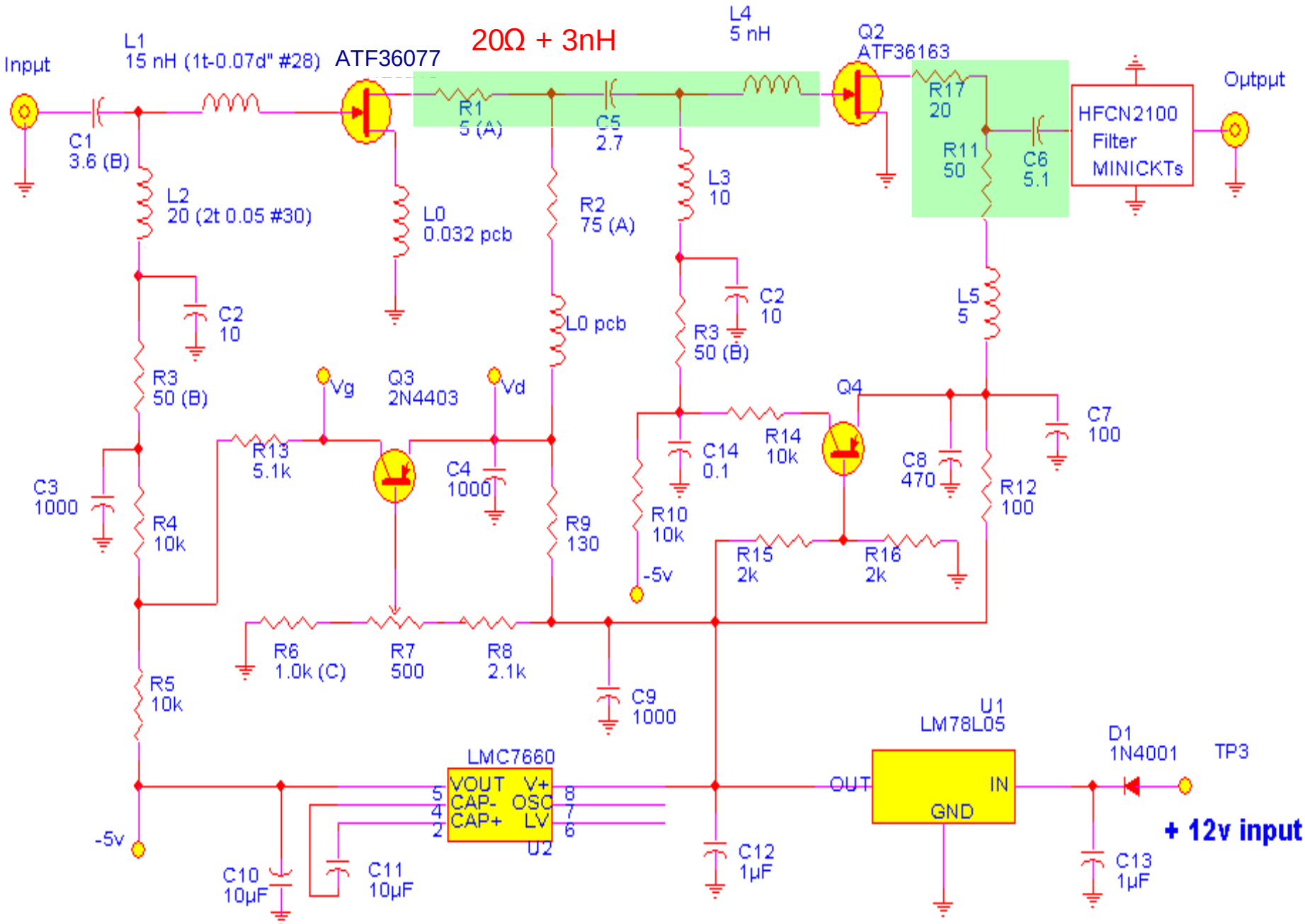


LNA w/SMD Filter



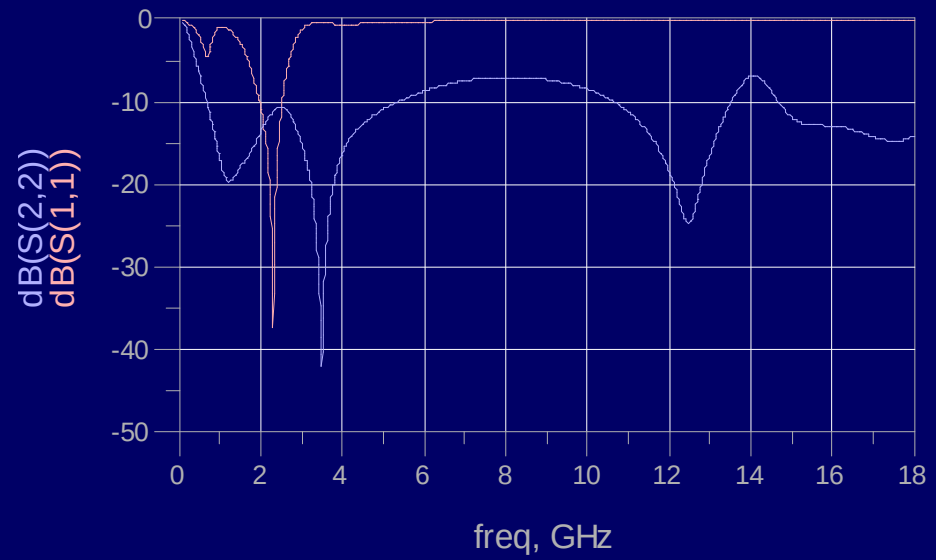
Other Changes to the VLNA

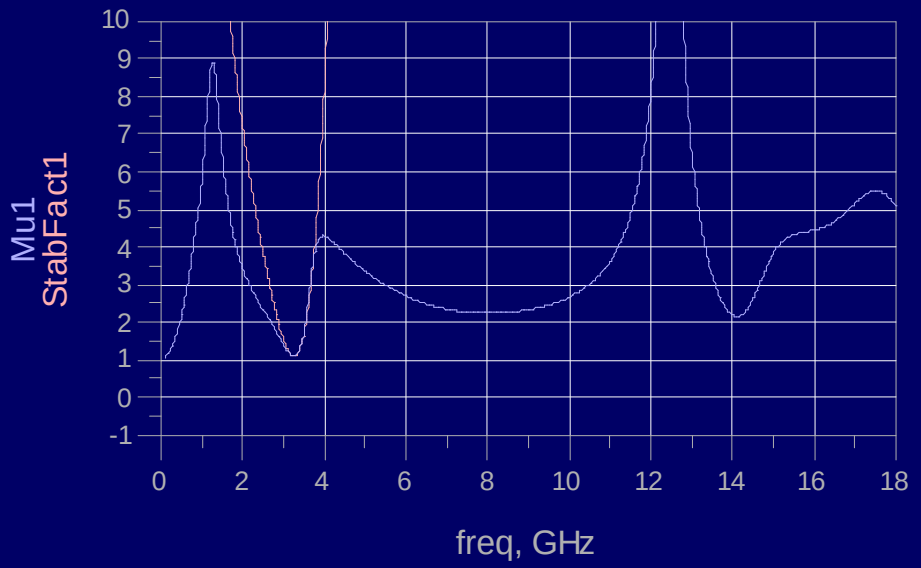
- Adding Active bias to pHEMT 2nd Stage for either the ATF36163 or ATF34143
- Must have a combination of resistive loading which increases stability
- Using lower loss 20mil Rogers 4003 board material
- Control source inductance near frequency center of 2800 MHz

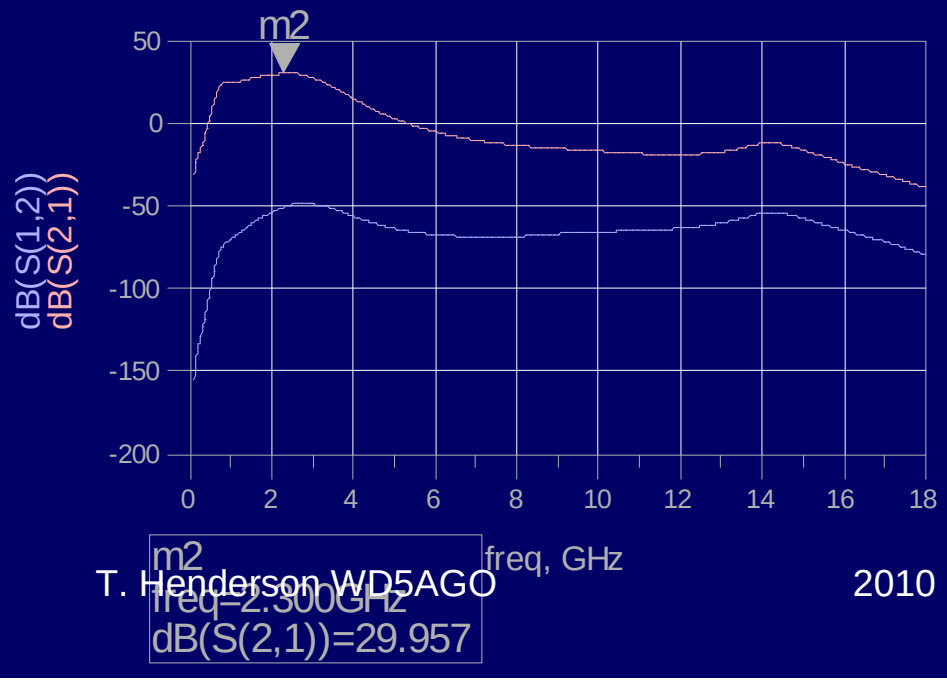

Input
L1
15 nH (1t-0.07d" #28)
ATF36077
20Ω + 3nH
L4
5 nH
Q2
ATF36163
Output
C1
3.6 (B)
L2
20 (2t 0.05 #30)
L0
0.032 pcb
R1
5 (A)
C5
2.7
R2
75 (A)
L3
10
R17
20
R11
50
C6
5.1
HFCN2100
Filter
MINICKTs
C2
10
L0 pcb
R3
50 (B)
L5
5
Vg
Q3
2N4403
Vd
Q4
R13
5.1k
C4
1000
C14
0.1
R14
10k
C8
470
C7
100
C3
1000
R4
10k
R10
10k
R12
100
-5v
R15
2k
R16
2k
R9
130
R6
1.0k (C)
R7
500
R8
2.1k
C9
1000
R5
10k
U1
LM78L05
D1
1N4001
TP3
LMC7660
VOUT
CAP-
CAP+
V+
OSC
LV
U2
OUT
IN
GND
+ 12v input
-5v
C10
10µF
C11
10µF
C12
1µF
C13
1µF

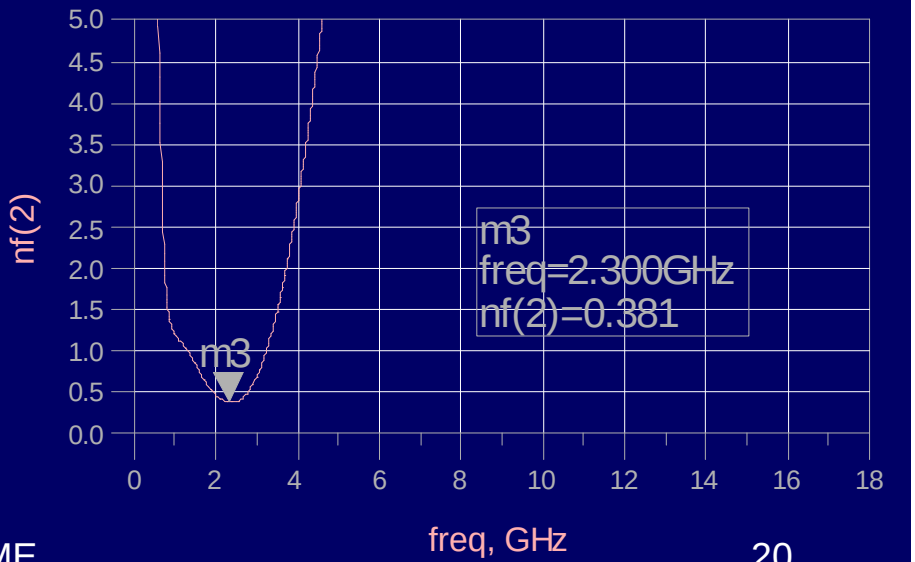
LUA/AGO 13cm ADS Model

ATF-36077 Rd=5Ω – ATF-36163 Rd=27Ω

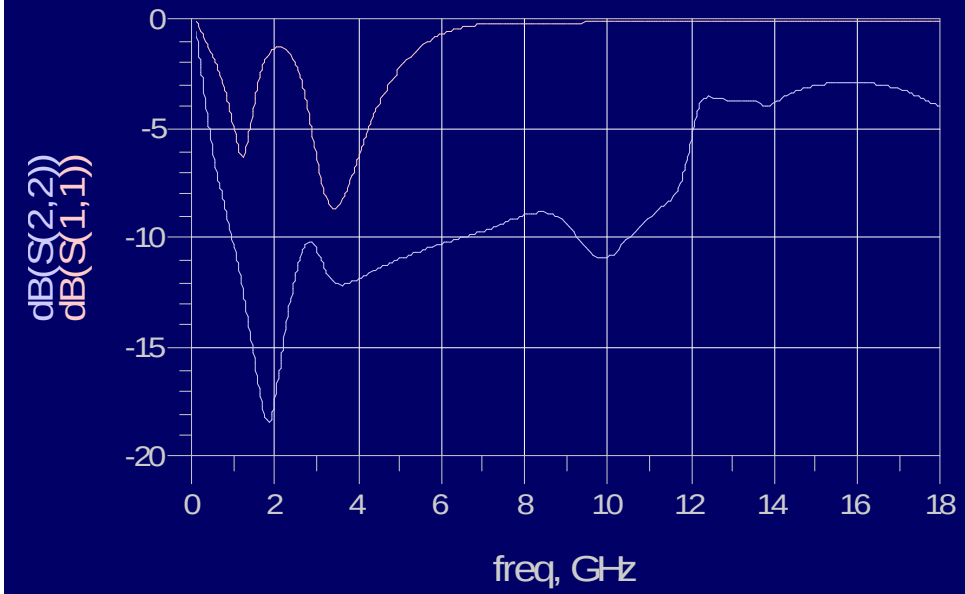


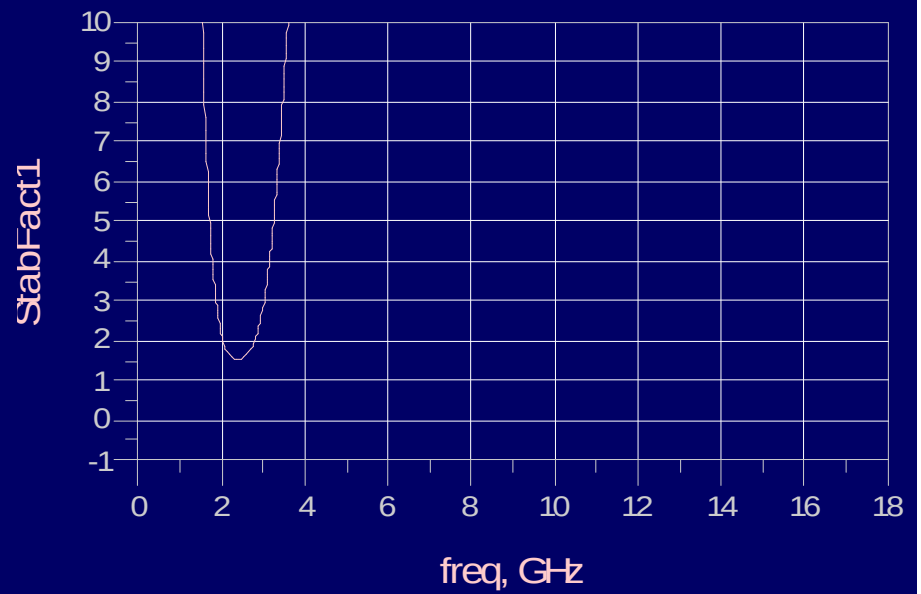


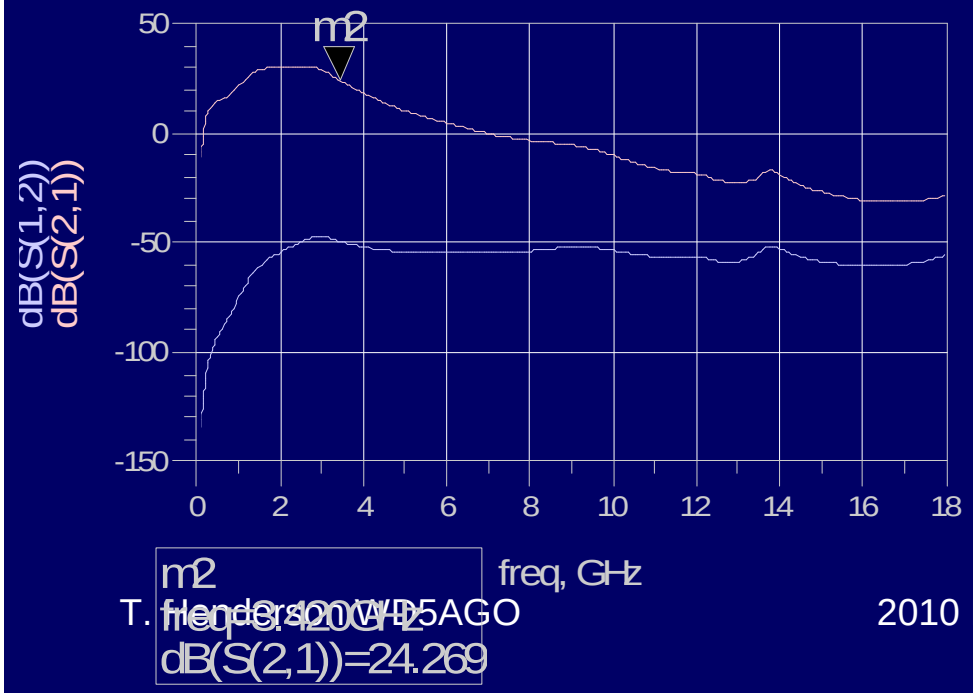


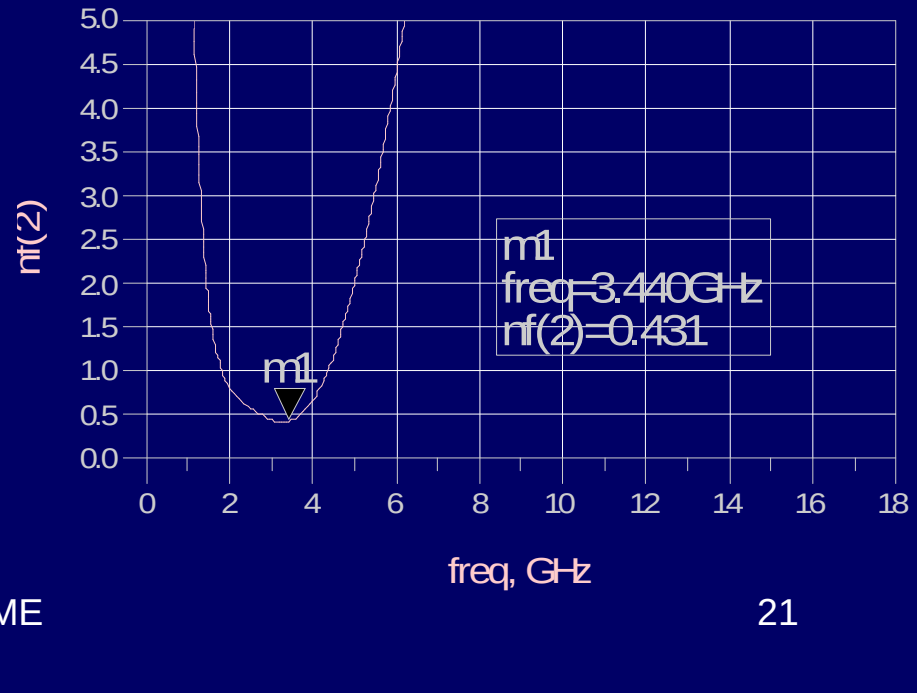


W5LUA - AGO 9cm ADS Results



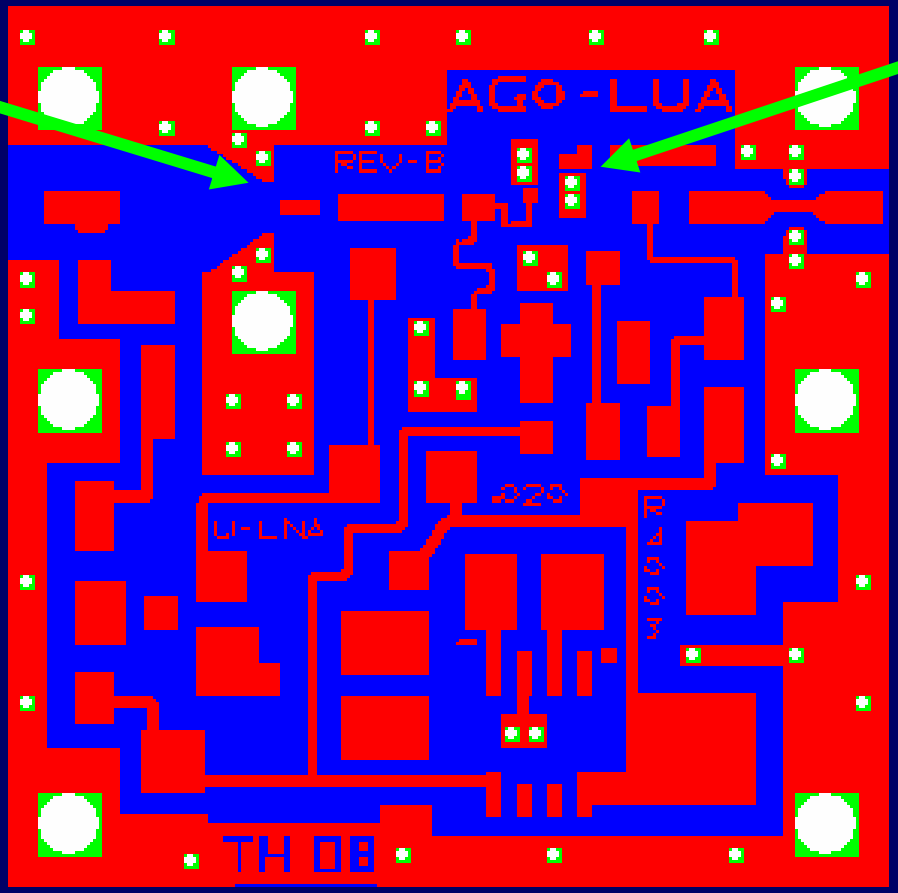






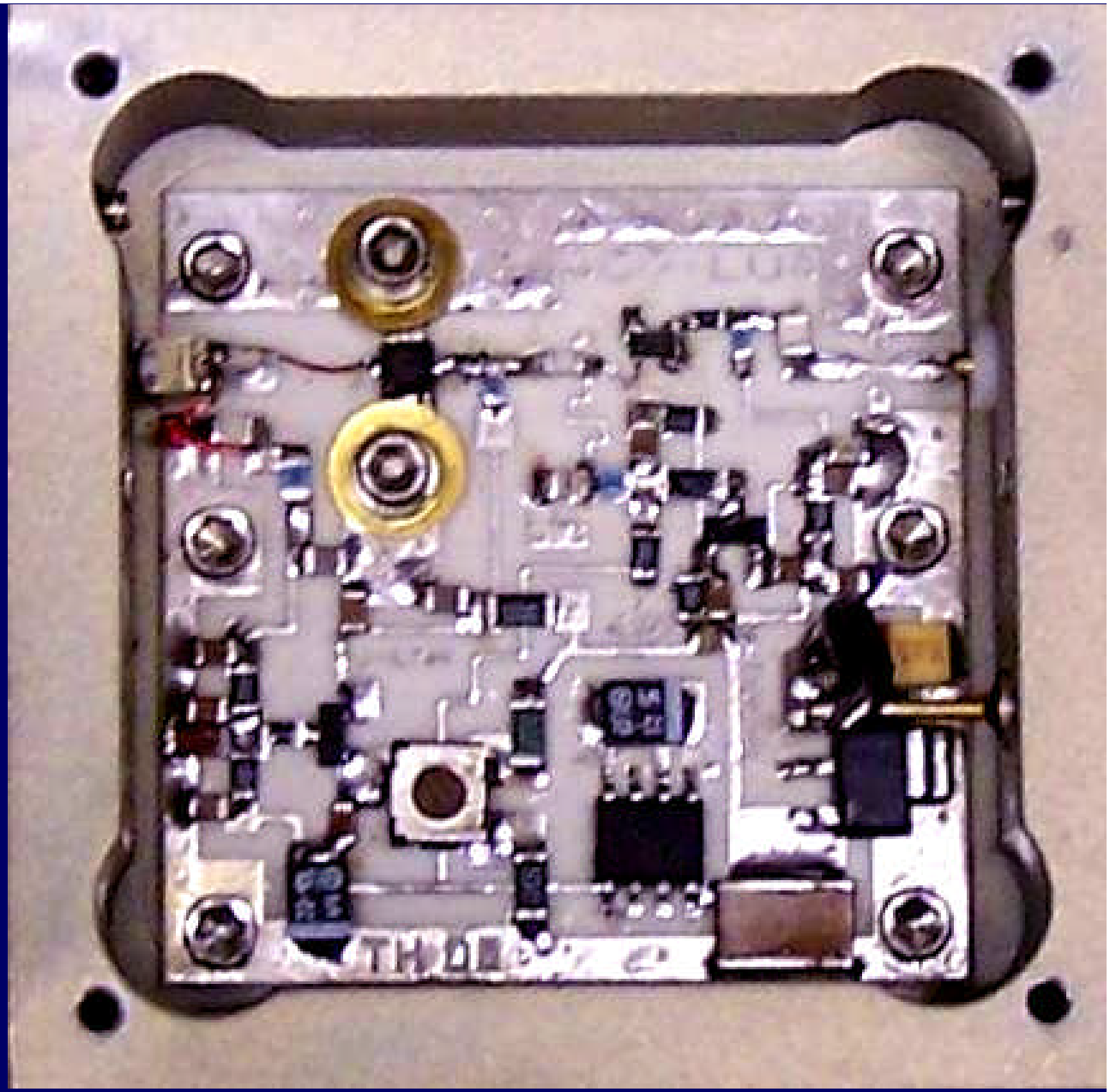
Newest S-Band Prototype using a pHEMT 2nd Stage

Control of Source Inductance for the 1st stage



ATF36163 or ATF34143

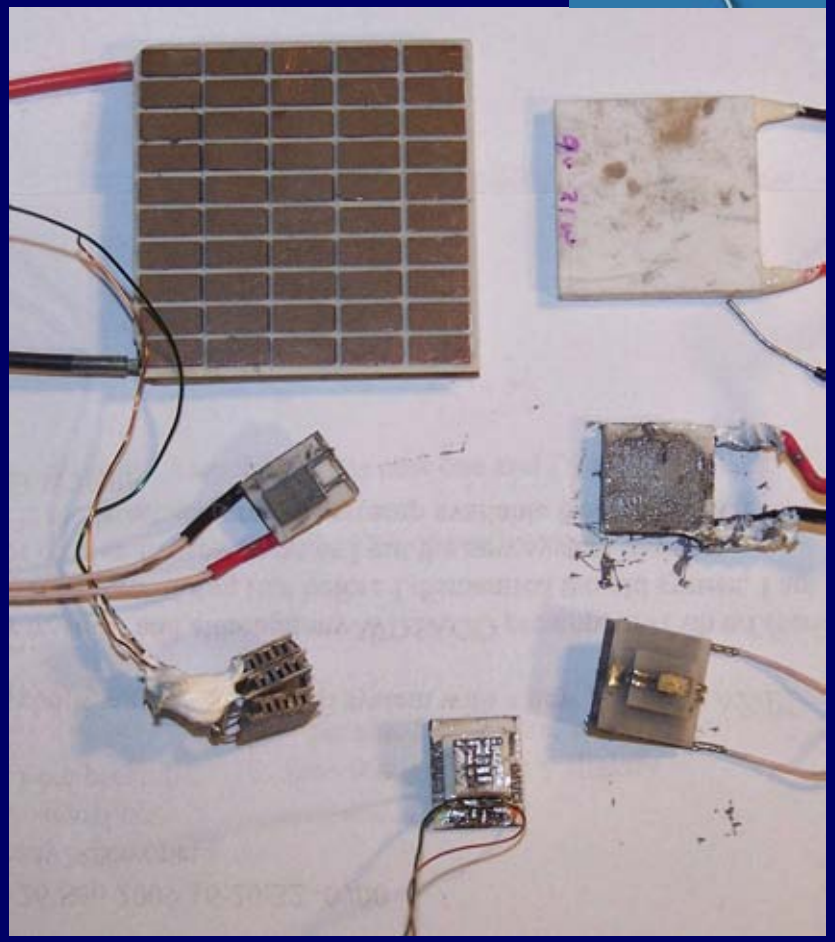
9cm VLNA on Rodgers 4003. NE3511S01 1st Stage and ATF35143 2nd Stage.



Thermal Electric Device (TED, Coolers, Peltier)

- A “Convenient” way to cool a LNA?
- Power Efficiency < 10%
- Current 4 stage unit

  6 V @ 10 Amps
- Best Tc = 200° K or about - 100° F
- 5 to 6 Stages Max



Qc W max

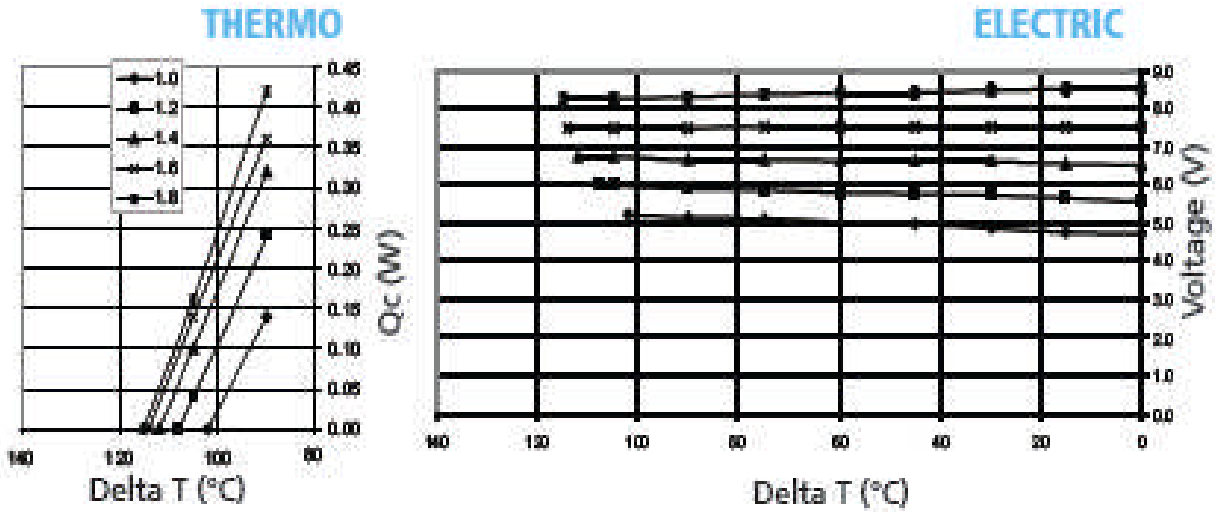
Laird TECHNOLOGIES

Innovative Technology for a Connected World

Multistage Series MS4,129,10,15

Thermoelectric Modules

Performance Curves at Th = 25°C

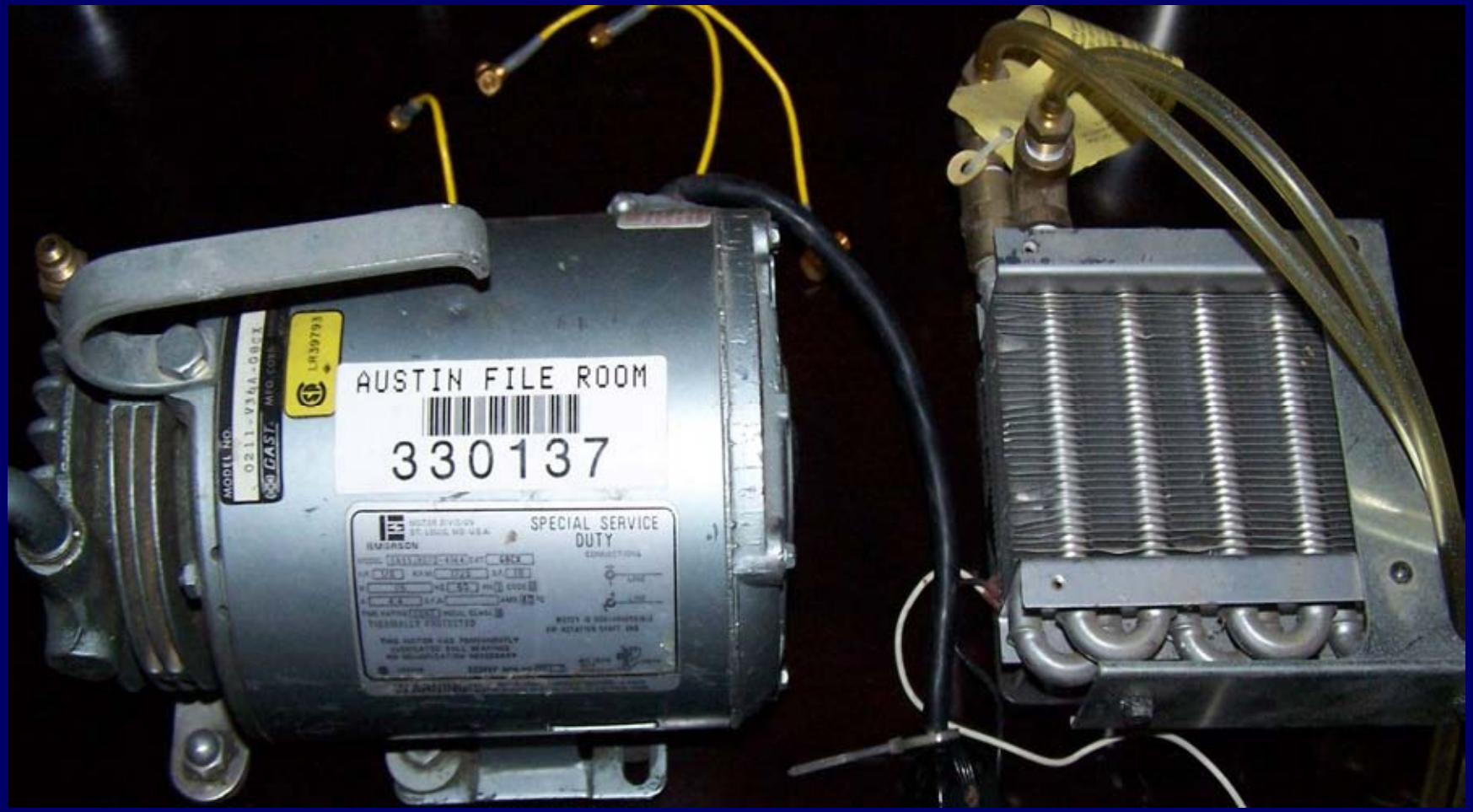


T. Henders

TED House Keeping

- COP is normally rated with no load
- Device loading ***Will*** greatly effect Tc in turn ΔT.
- Air Cooled Heat sink performs well for Th at about 325° K ~ 125° F
- Best ΔT with ACHS and ¼ W load ~ 70° C
- Water cooling reduces overall Tc
- Point of Zero COP is 100 to 125° K
- Vacuum Roughing Pump ~ 1 milliTorr

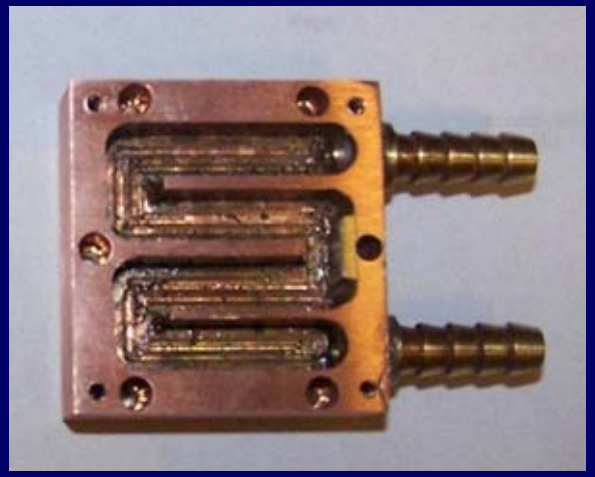
Pump and Water/Heat Radiator



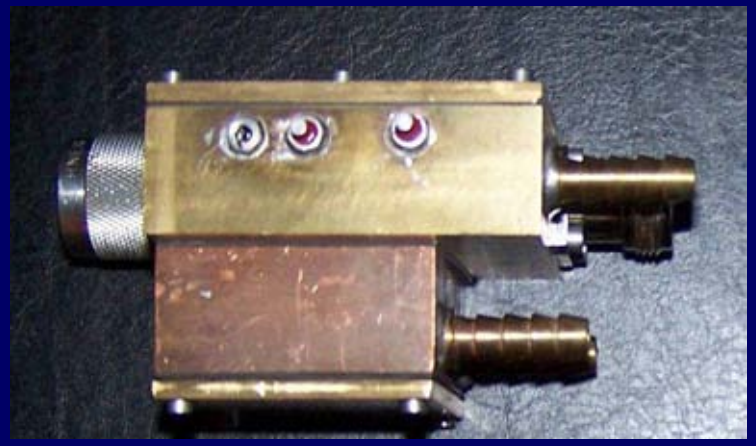
And…

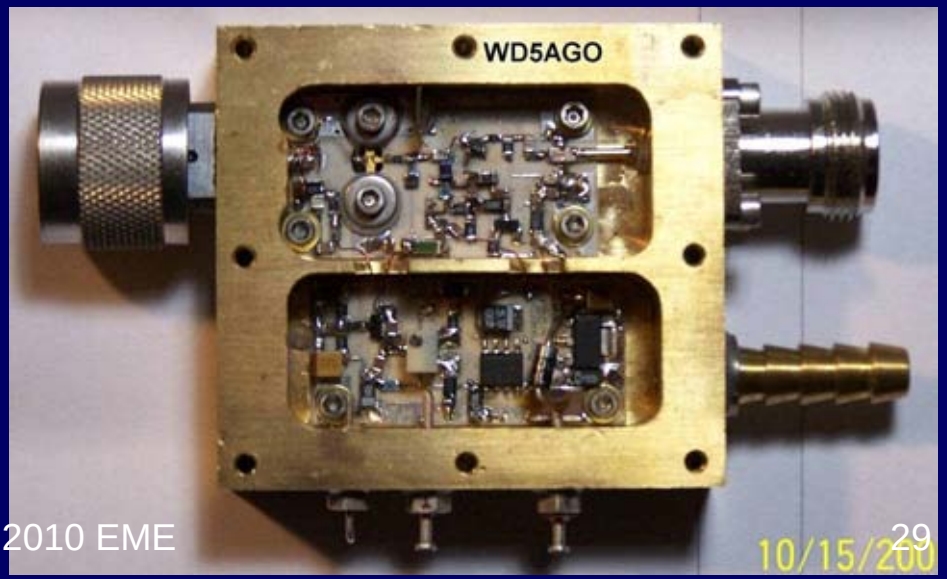
- Vacuum is needed to keep condensation off of ckt
- Sealed connector plates and Neoprene for all gaskets
- Cooling the whole unit requires more power due to heat losses
- Less effective but better control is to cool the first stage device
- Heat loses through device leads
- Ceramic Device not the best but better than plastic

1st Device Only Cooler 0.4W



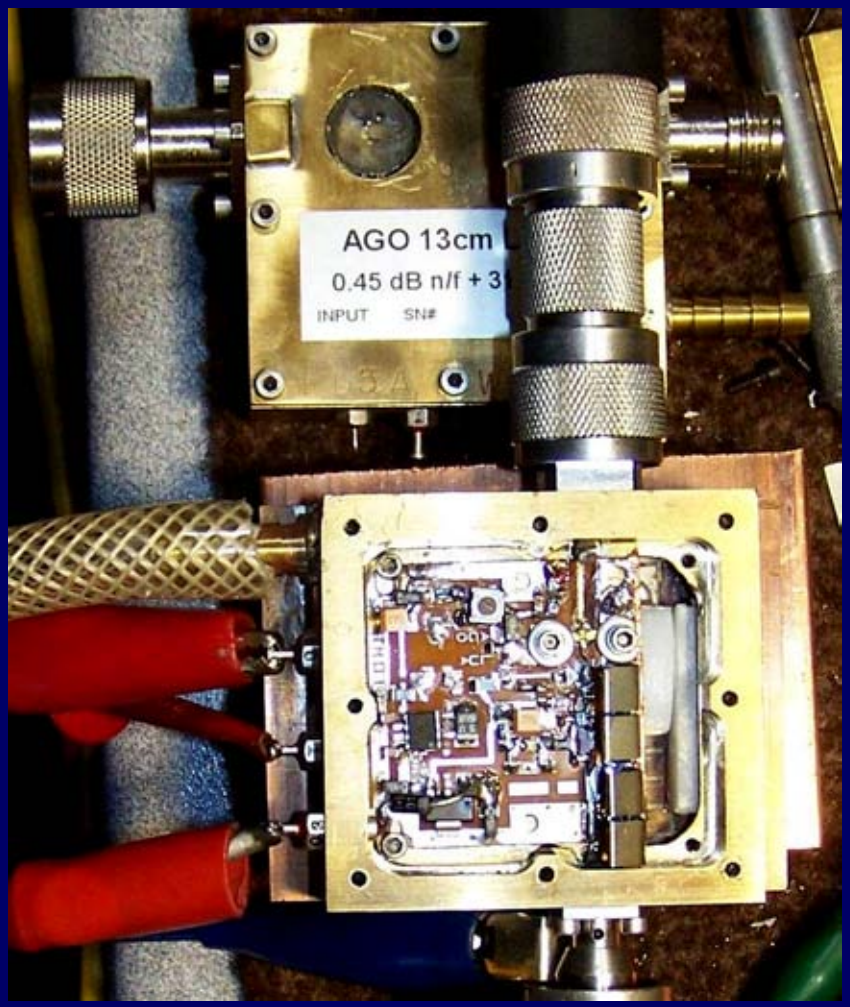
- Water Cooler Built in TED.
- Needed 3 Gaskets
- 5 Stack



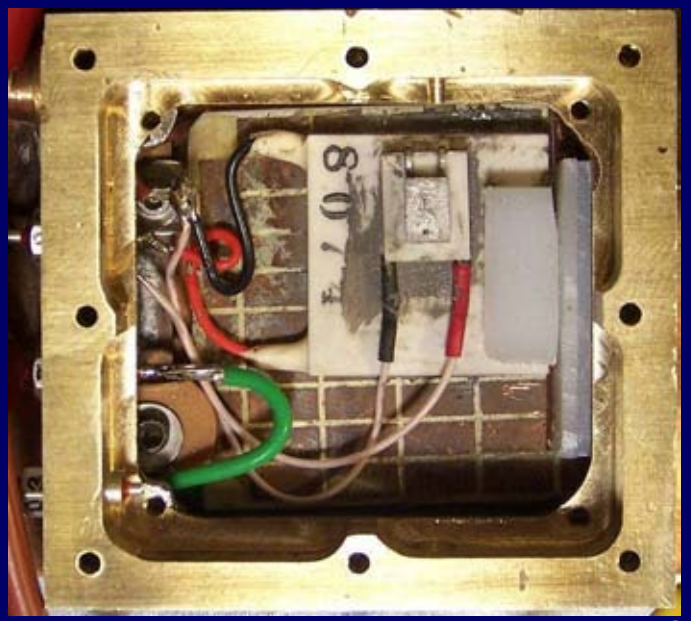


200° K w/o L, 240 ° w/L

2nd Unit 4 Stage 1.5W



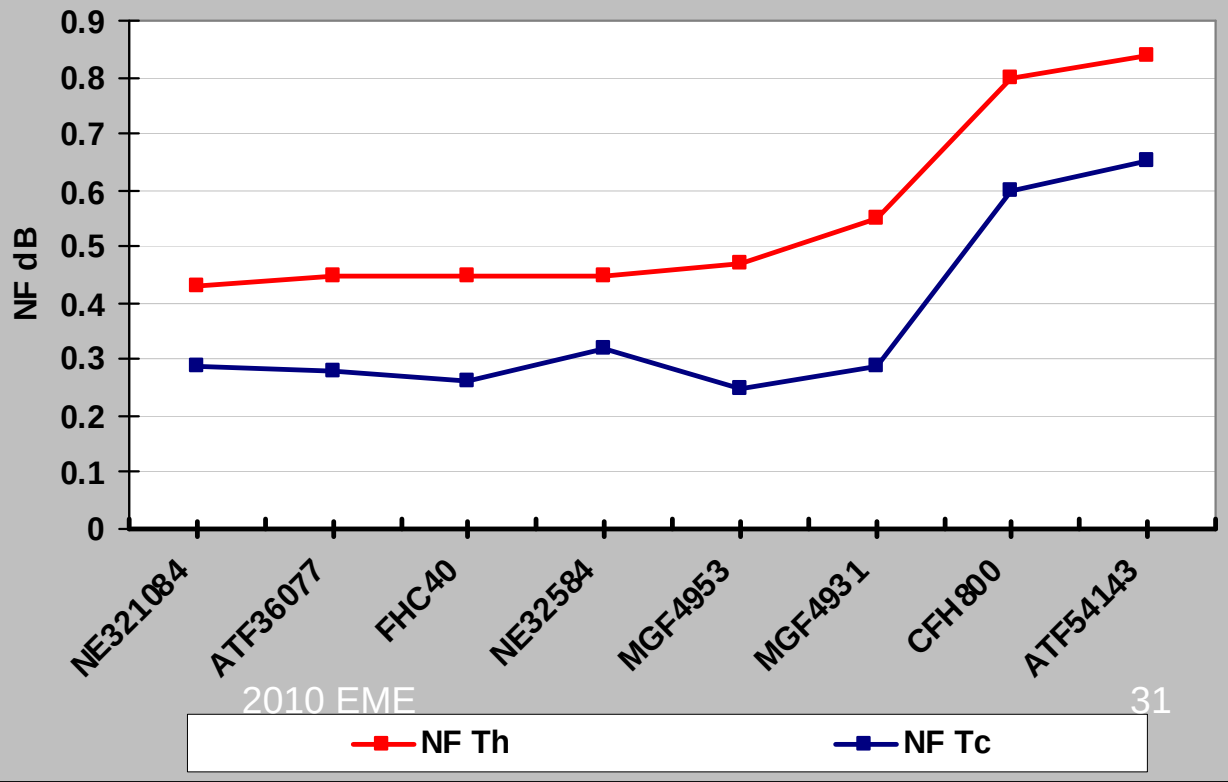
- 210° K w/o L
- 230° K w/ L
- Results - 0.05 dB
- Wire bond Source Leads



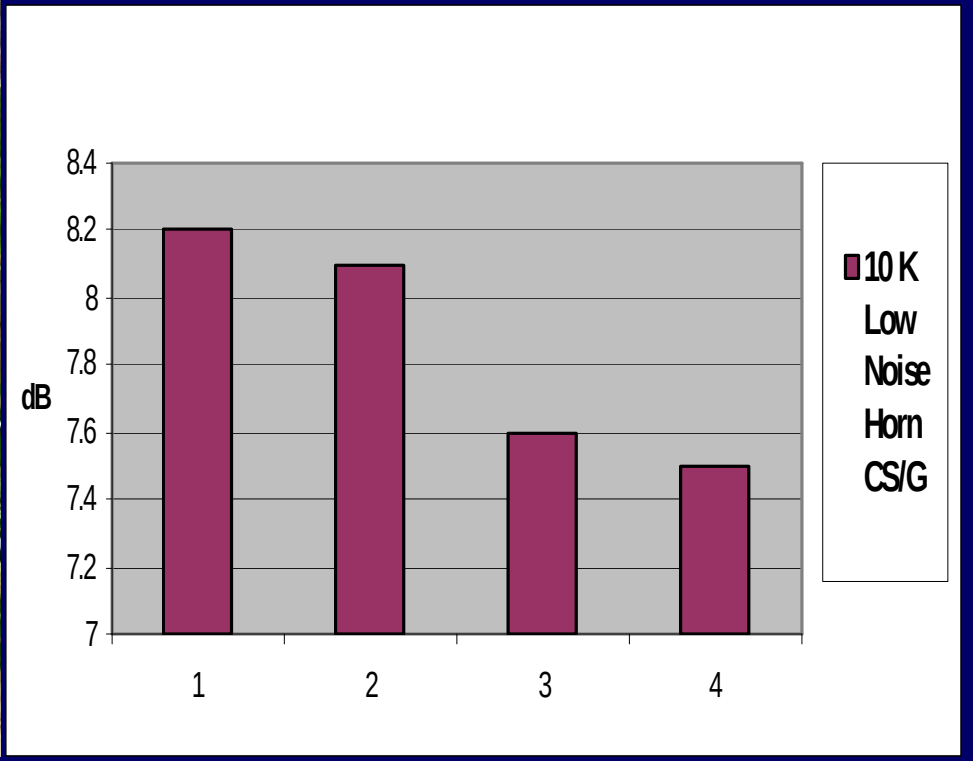
Cooled 13cm VLNA Performance of Several different Low Noise Devices. A Combination of Peltier and Dry Ice ~ 200°C

Fig 3
13cm Cooling test fixture

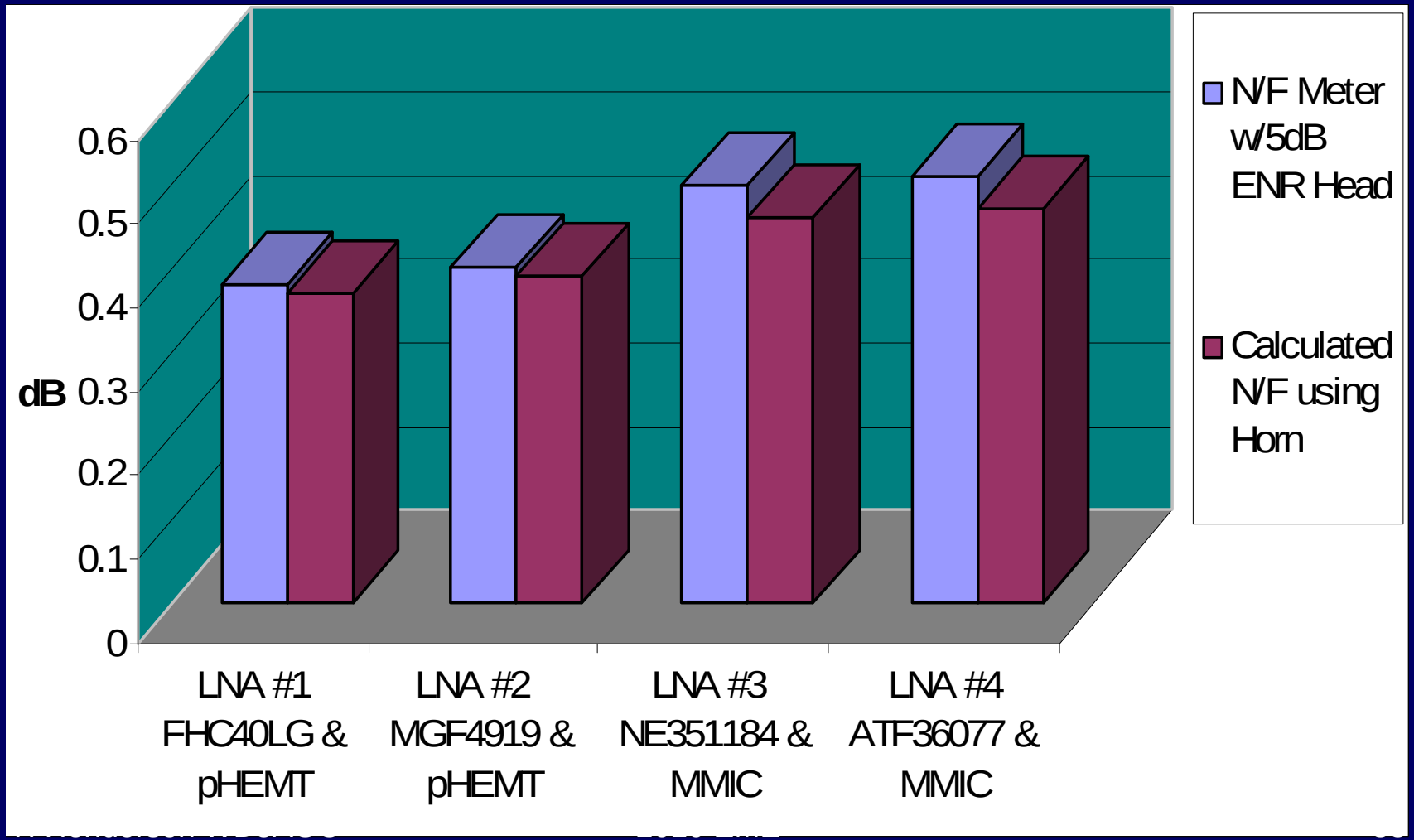
13cm Devices Th - Tc



6’ * 1.5’ Low Noise Horn used for S Band LNA CS/G Testing



Results a Little Better w/Y factor



Andrews Grid
2.4m 0.375 f/D
extended to 2.7m
0.33 f/D for

13cm – (#50 int)
9cm – (#2 int)
6cm – (#7 int)

Got Braver

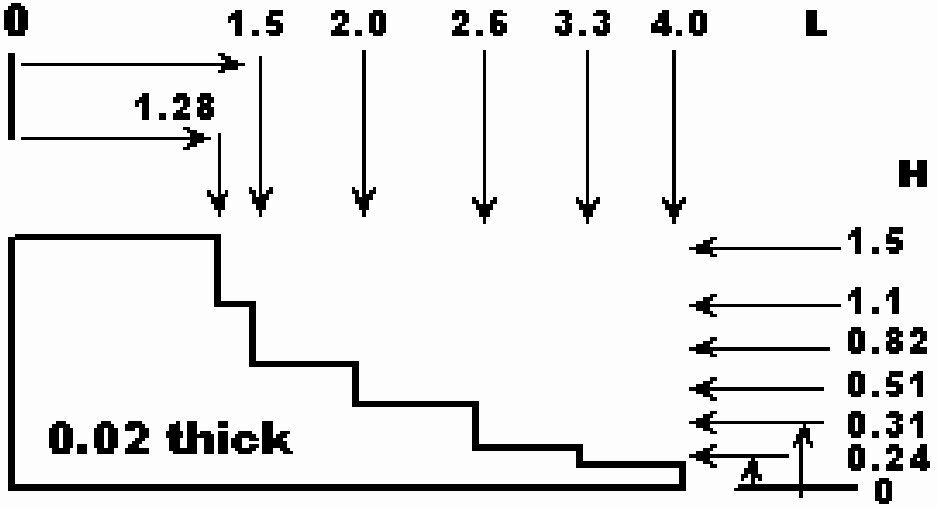
New 3.1 M
0.38 f/D
Summer 09

13cm #61
13 dB sn
9cm #15
12.7 dB sn
6cm #16
12 dB sn

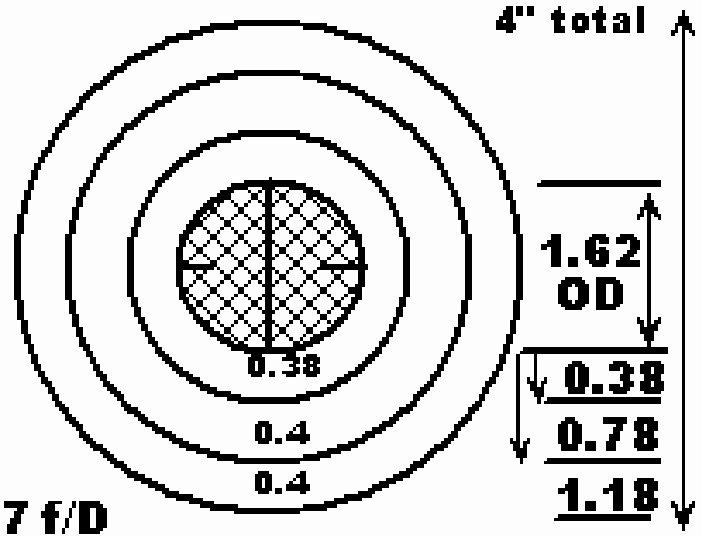
- CP Feed horns
- Square or Round
- Look in Disk for Dim.

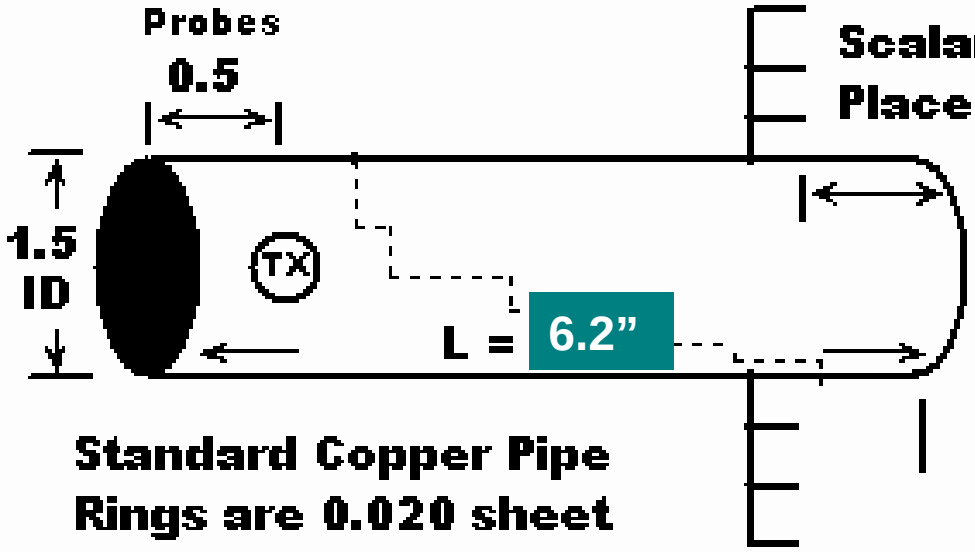
WD5AGO 5760 MHz CP Feed for f/D of 0.35 to 0.40

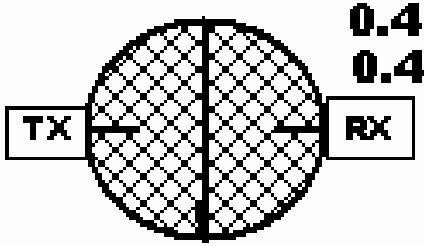
5 Step Septum



All Dim. in inches





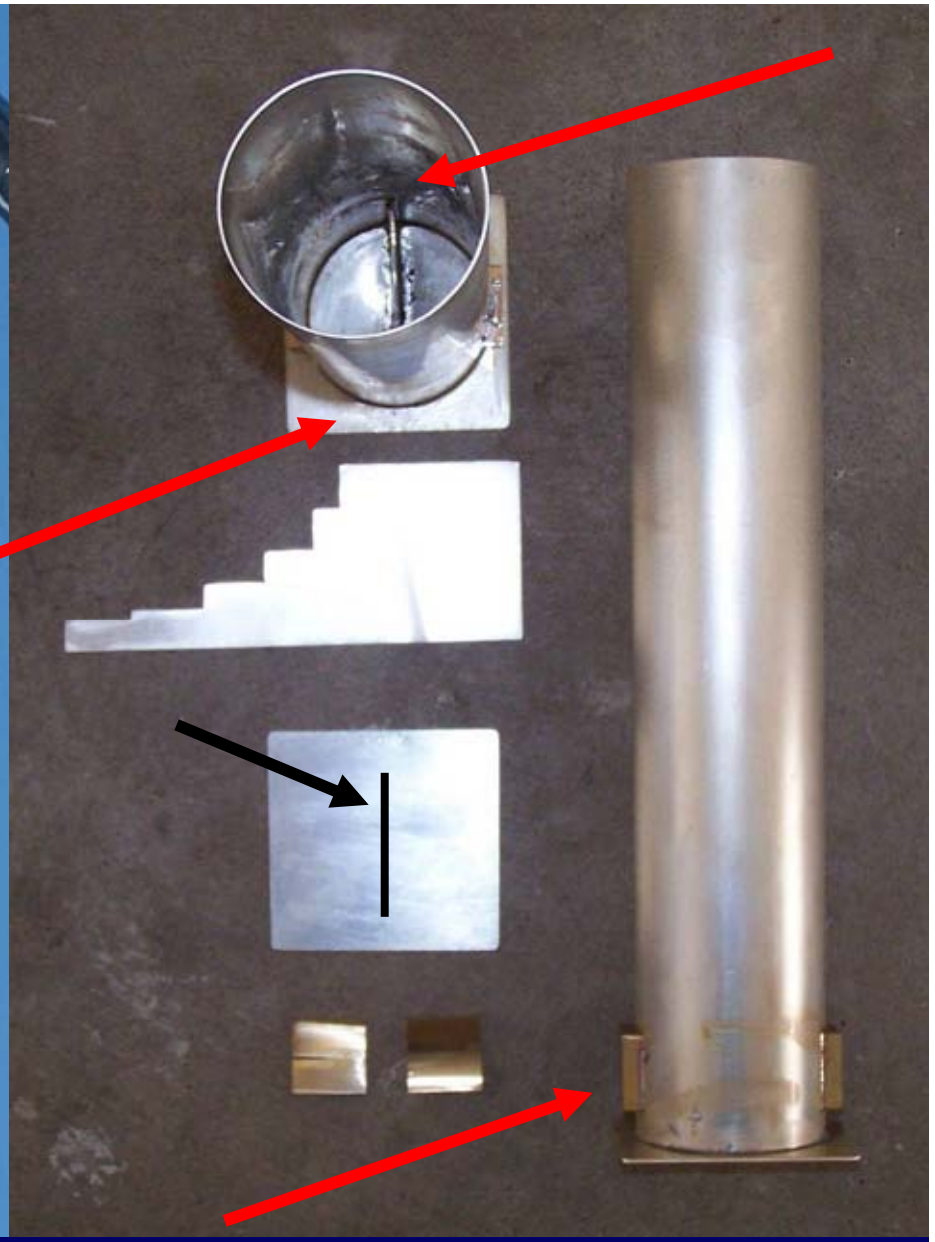


Probes: 0.05" Dia
0.41" Long, Trim to
0.40 to 0.39"

Standard Copper Pipe
Rings are 0.020 sheet

All are 0.4

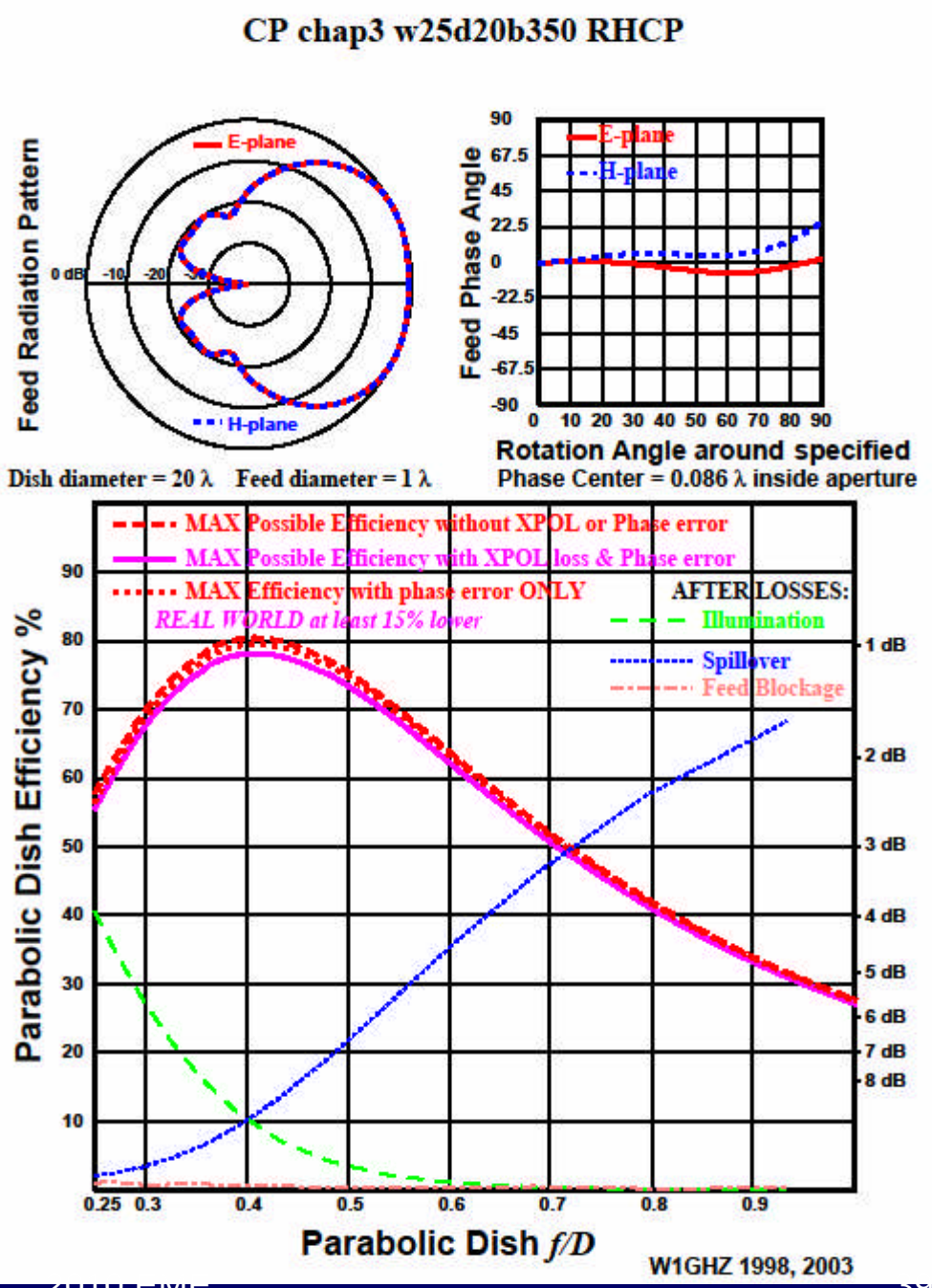
T.D. Henderson		
Title: 5760 CP 5s Feed		
Size A	Document Number	Rev A
Date: Sun, June 10, 2007		Sheet 1 of 1



13cm and 9cm

Satisfied for the past 3 years of optaining the best possible efficiency of 59% for 0.33 f/D, New Dish of 3m, 0.41 f/D, added rim to 3.15m. Larger scalar tested to bring efficiency to ~64%, W1GHZ confirms added gain.

T. Henderson WD5AGO



Conclusions

- Presented were modifications to existing 23cm LNA designs to place them on 13 or 9 cm.

- Also a stable, higher IP LNA and a VLNA, Both Designed and Optimized for L – S Band. 6cm LNA designs measured poorer results w/match

- Cooling will be of little benefit on 23cm and a increase of 0.2 to 0.5 dB in Sun noise on 13 or 9cm. Using Dry Ice maybe a better alternative until TED's break bellow 125° K