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Millimeter Wave Measurements

Al Ward
W5LUA

Microwave Update 2010
October 23, 2010

Outline

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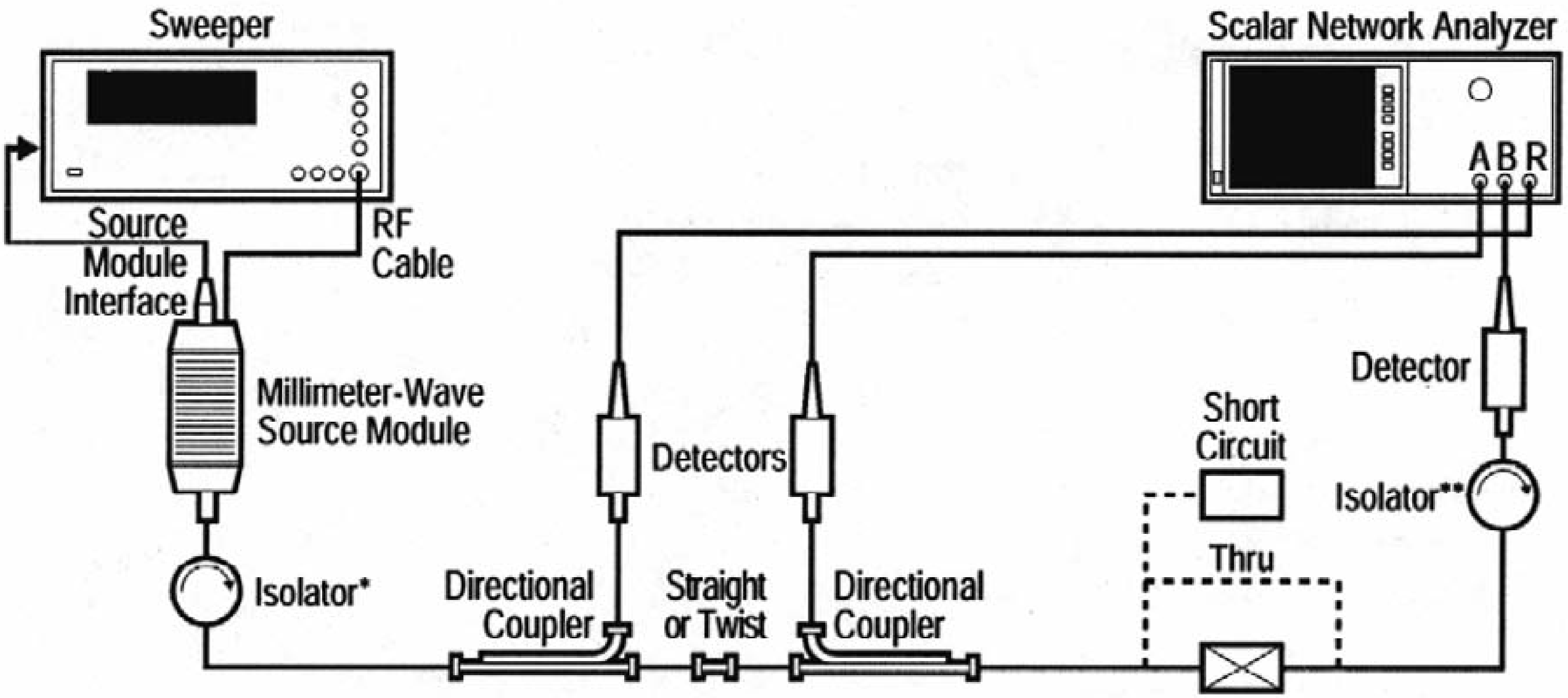
- Measurements from MUD2009
- Things learned since MUD2009
- Evaluation of the WA1MBA 78 GHz LNAs
- Sun and Moon Measurements on 78 GHz
- WA1MBA Part II – Progress on the LNAs

HP 8757 Scalar Analyzer

Swept frequency determined by sweeper – HPIB controlled or sweep input
Detect modulated RF signals with detectors connected to A, B, or C ports
Use 11664A and 85025A detectors
Responds well to modulated (27.778 kHz) RF signals that are multiplied to get onto “higher” frequencies
Plot to KE5FX 7470 emulator with Prologix GPIB to USB adapter

Scalar Analyzer Set Up

8620, 8350, 8341, etc.



* Required for R, Q, and U band measurement systems only.
** Required for V and W band measurement systems only.

40 to 60 GHz Test Setup

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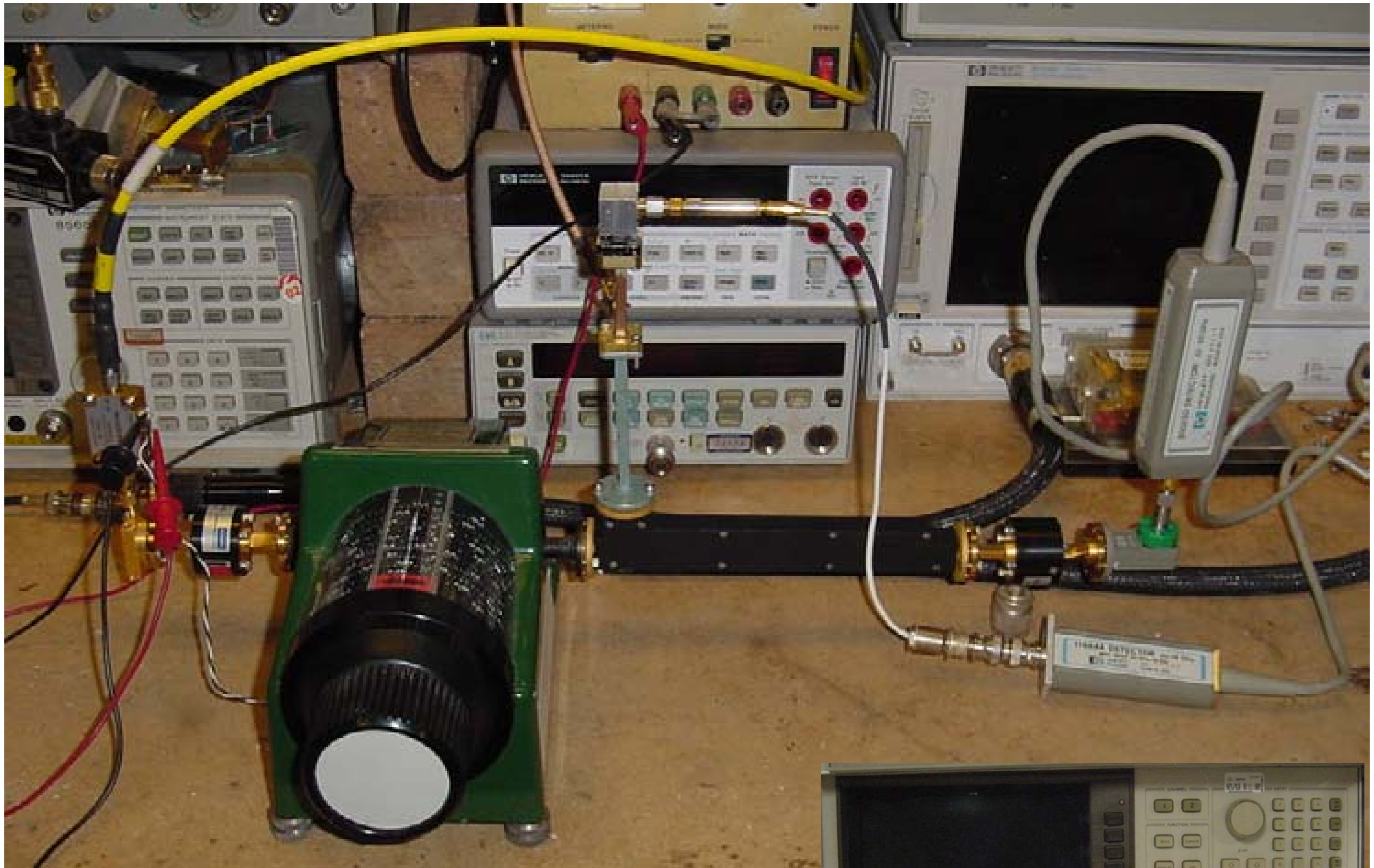

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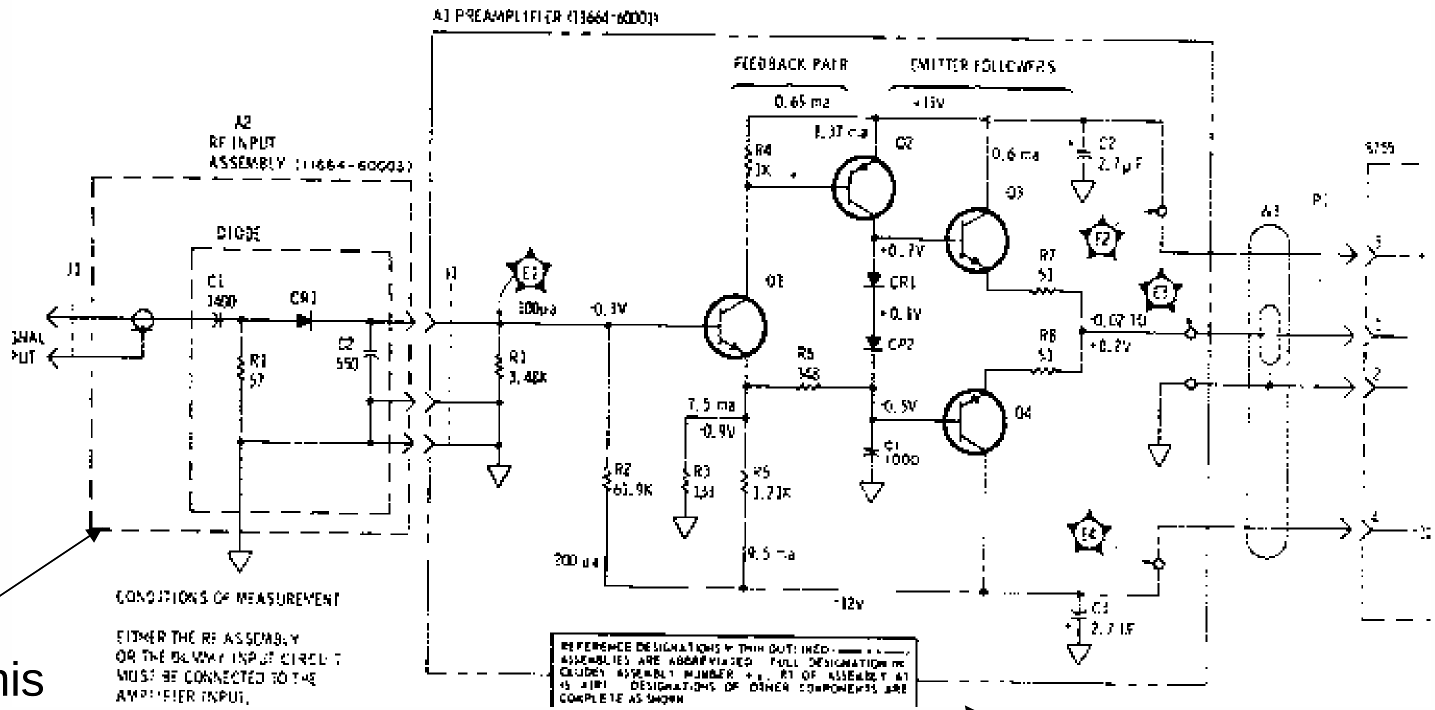
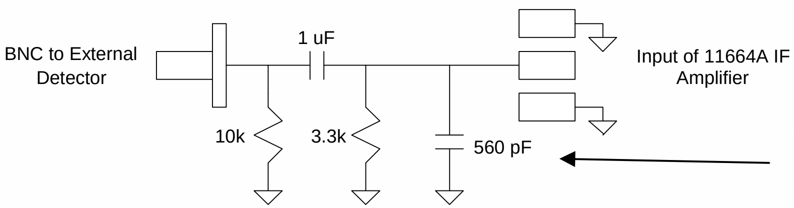
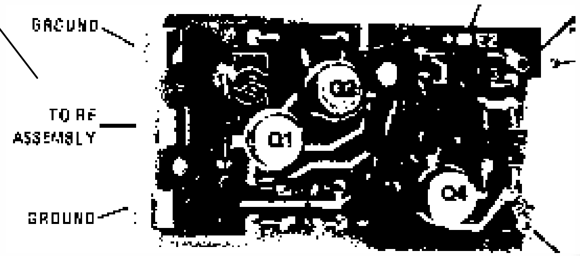
HP 11664A Detector



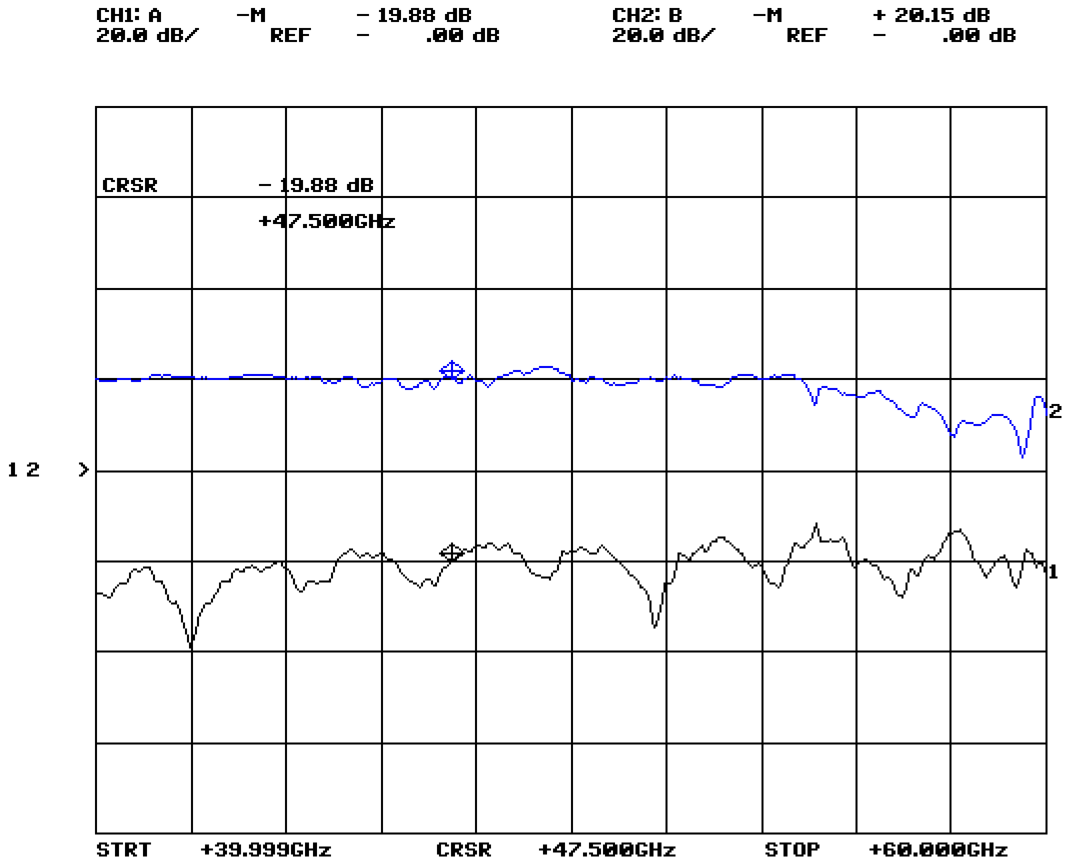
Remove this



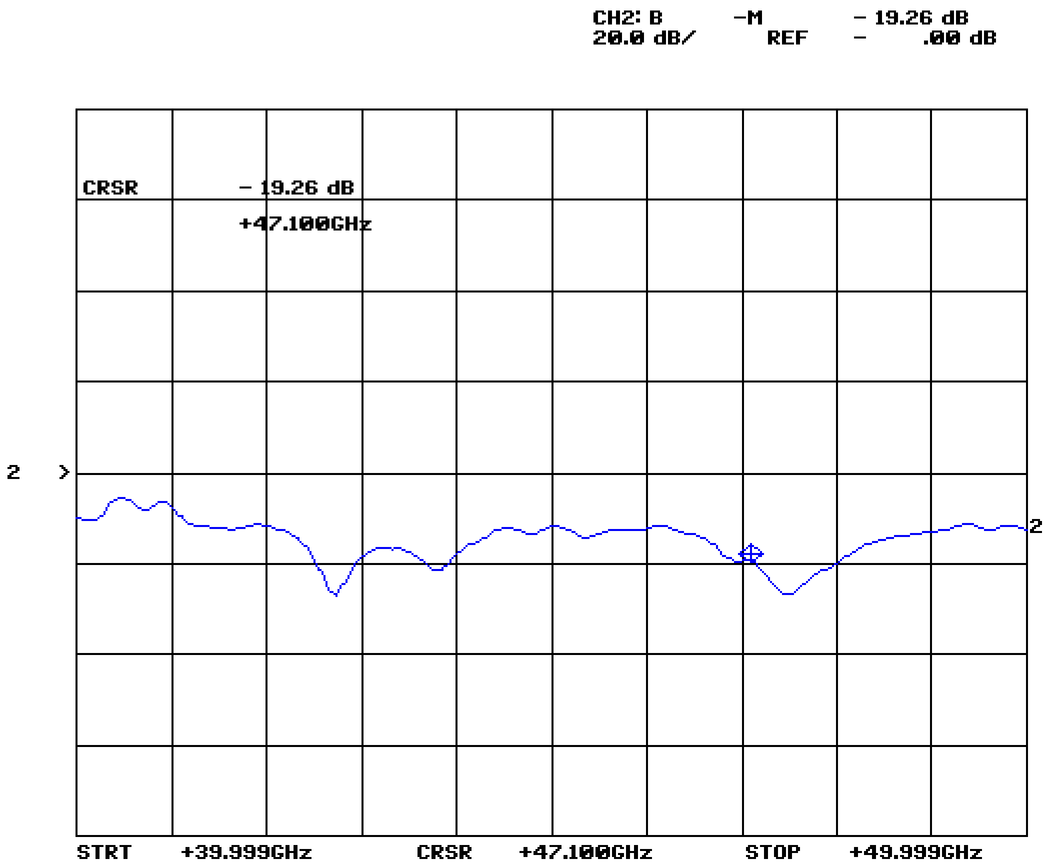


Add this to allow external detectors to be used

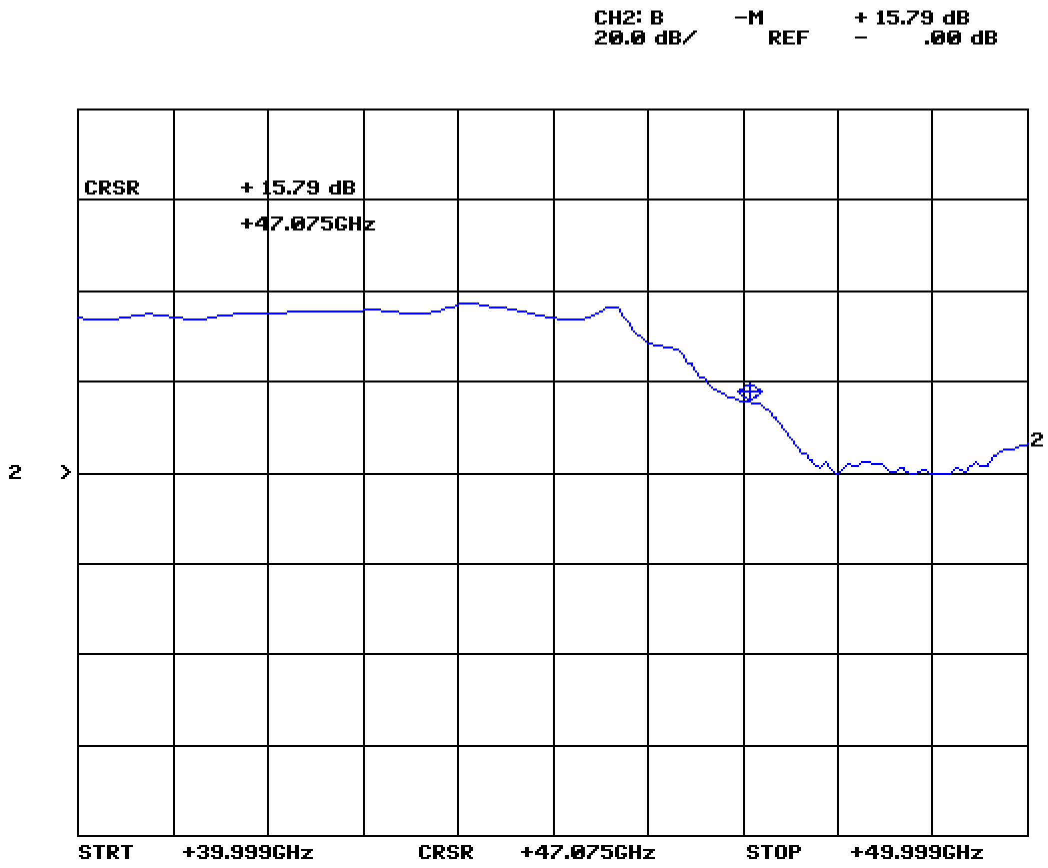
8757 40 to 60 GHz S21 & S11



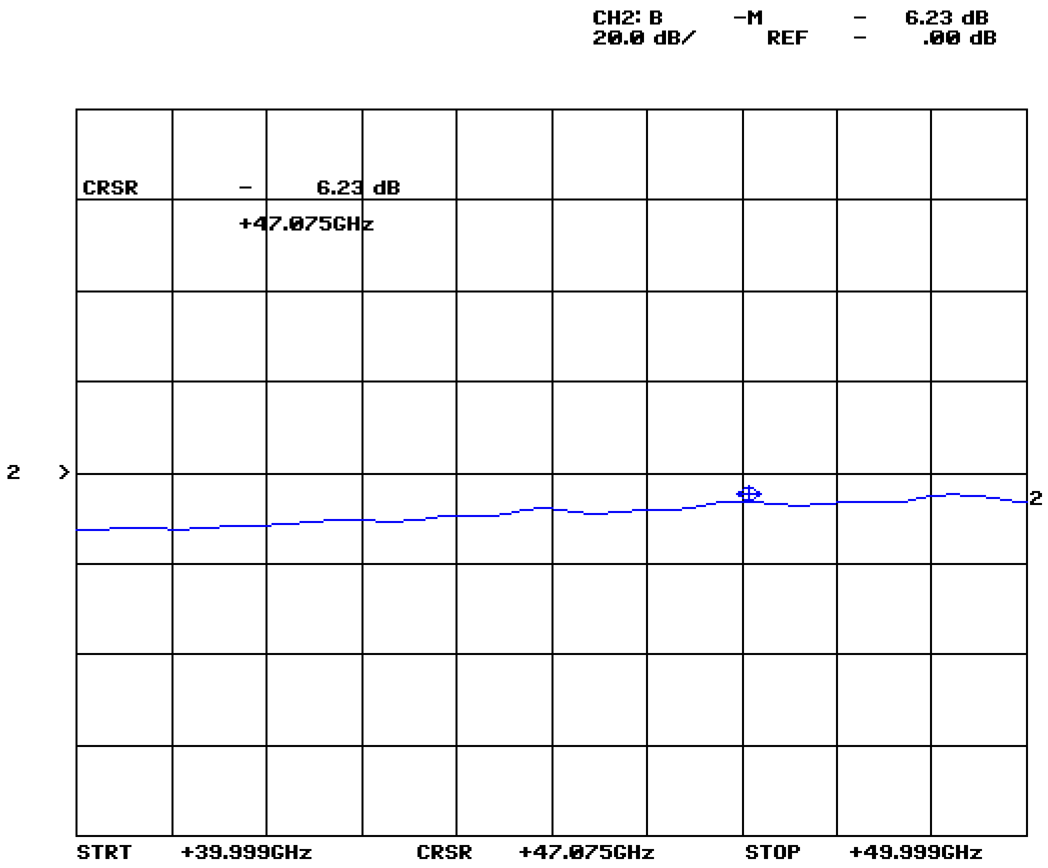
W5LUA 47 GHz W2IMU Feed for EME



W0EOM SMT S90-1240 Amplifier RF Drive level = -30 dBm



W0EOM Anritsu 52956 Shaped Attenuator 156



W5LUA Wiltron 3 dB Attenuator

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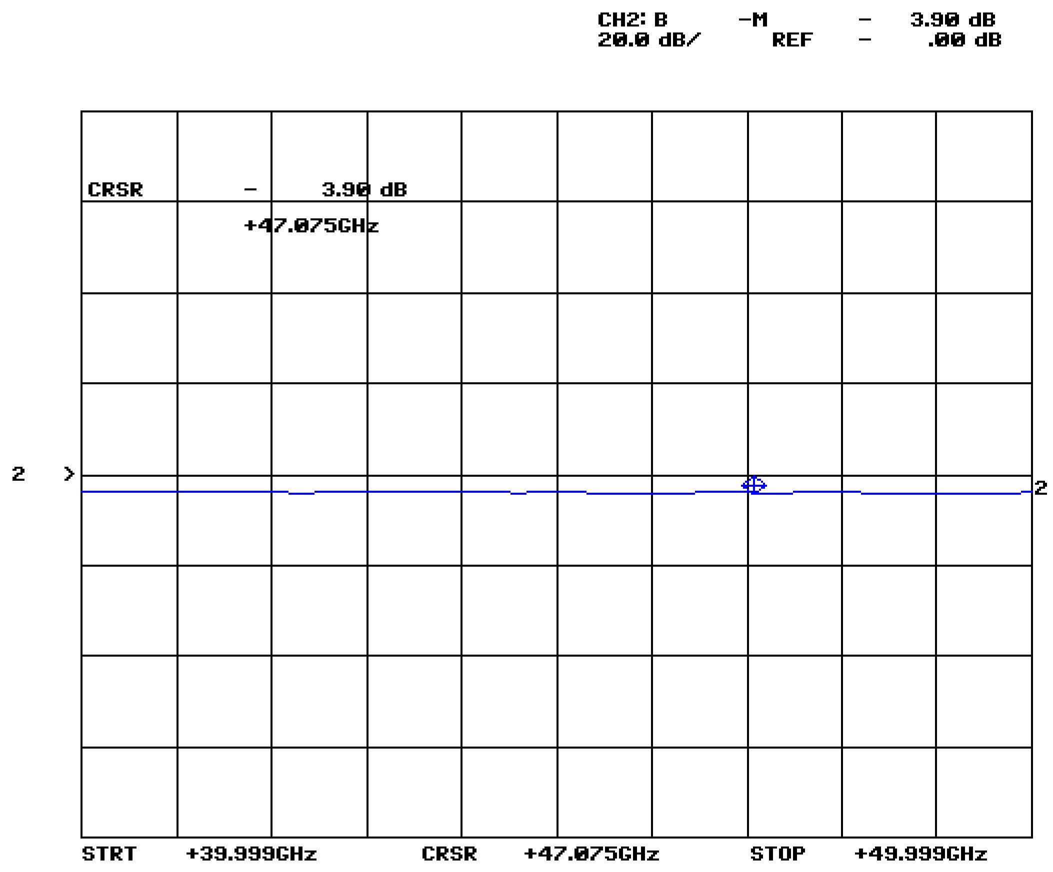
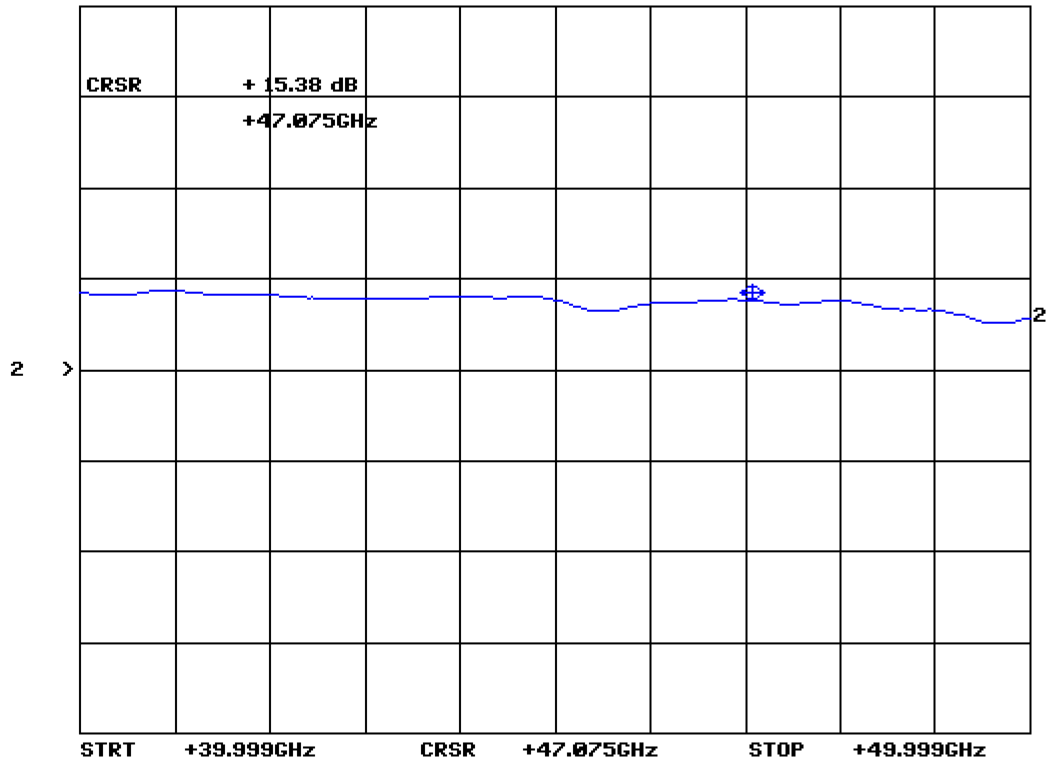


Avago AMMC-6241

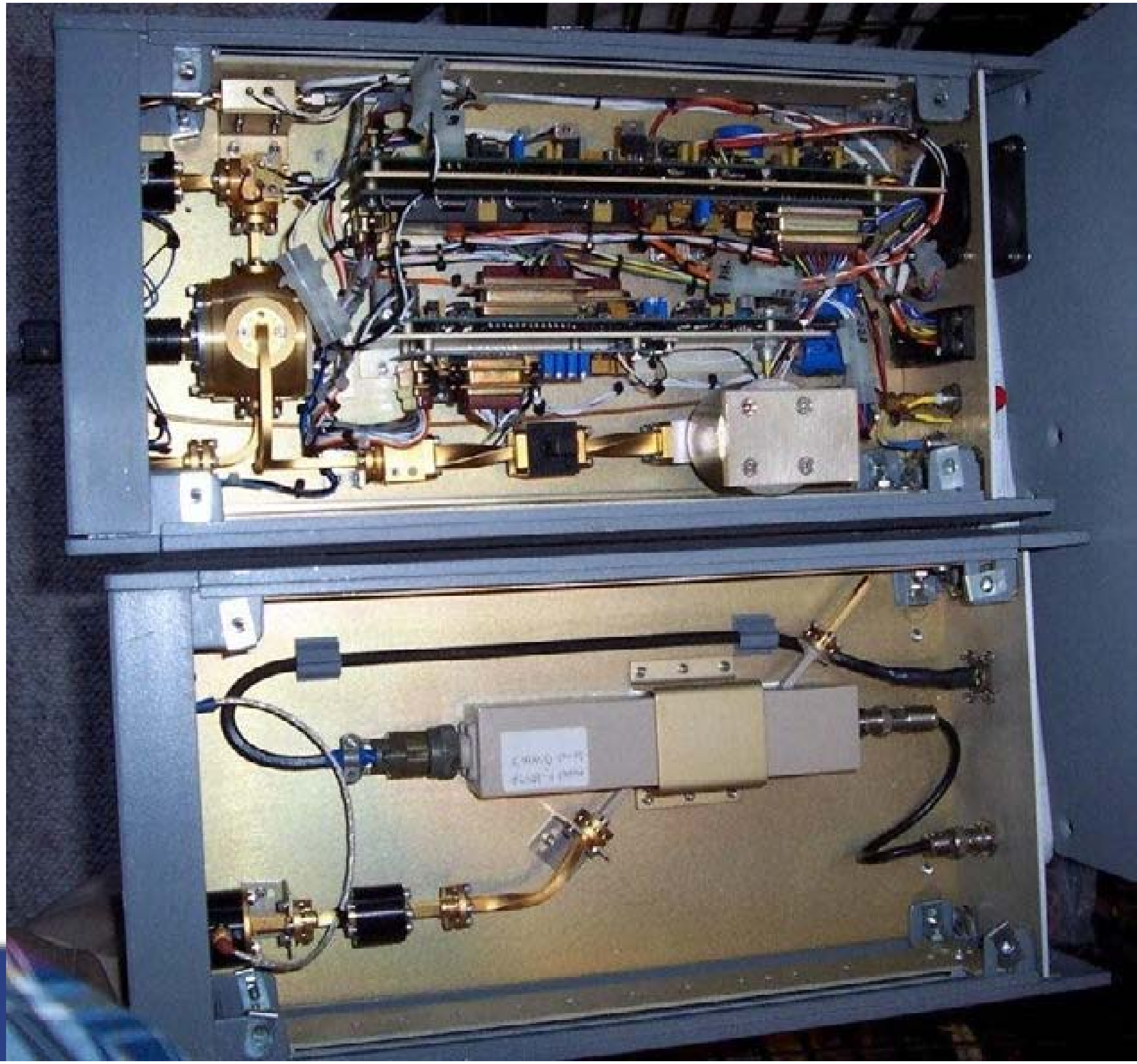


Hughes WR-15 Noise Figure Test Set

RF Input →

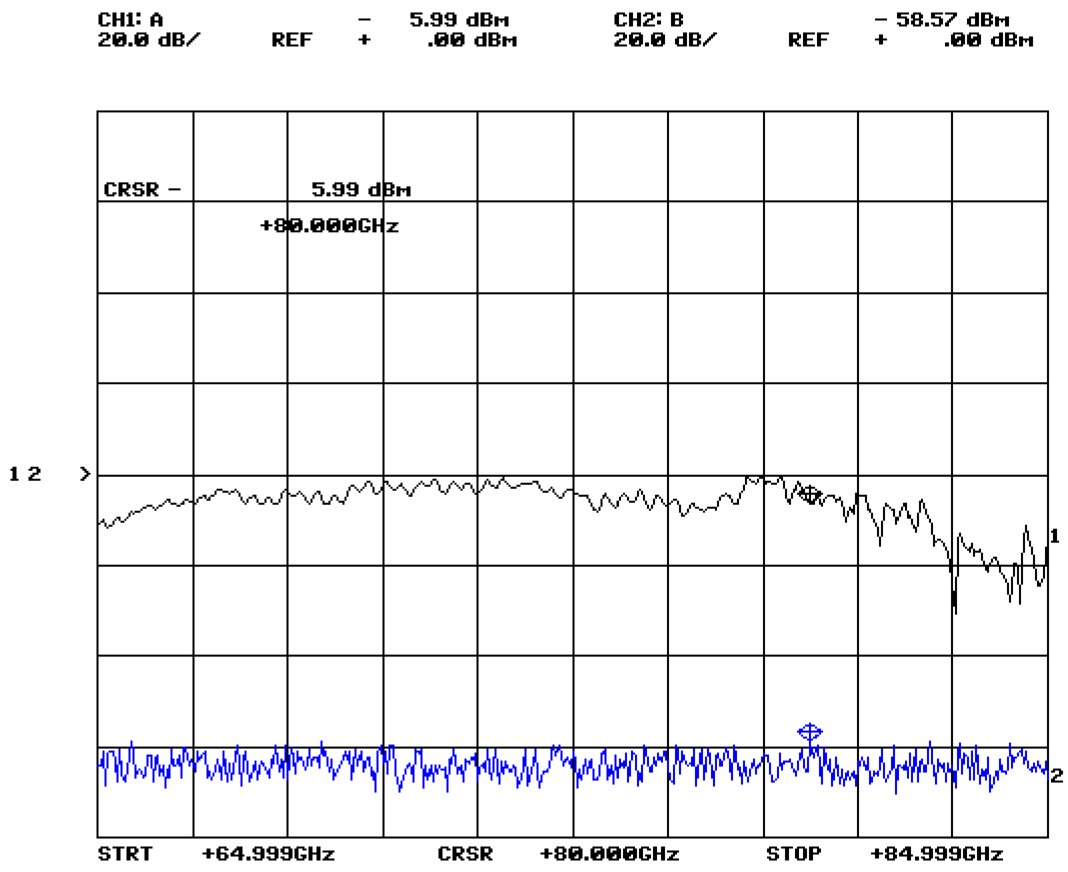
RF Output ←

Output from noise source ↖



IF Output →

WR-15 detector swept from 65 to 85 GHz



WR-15 30 dB Attenuator

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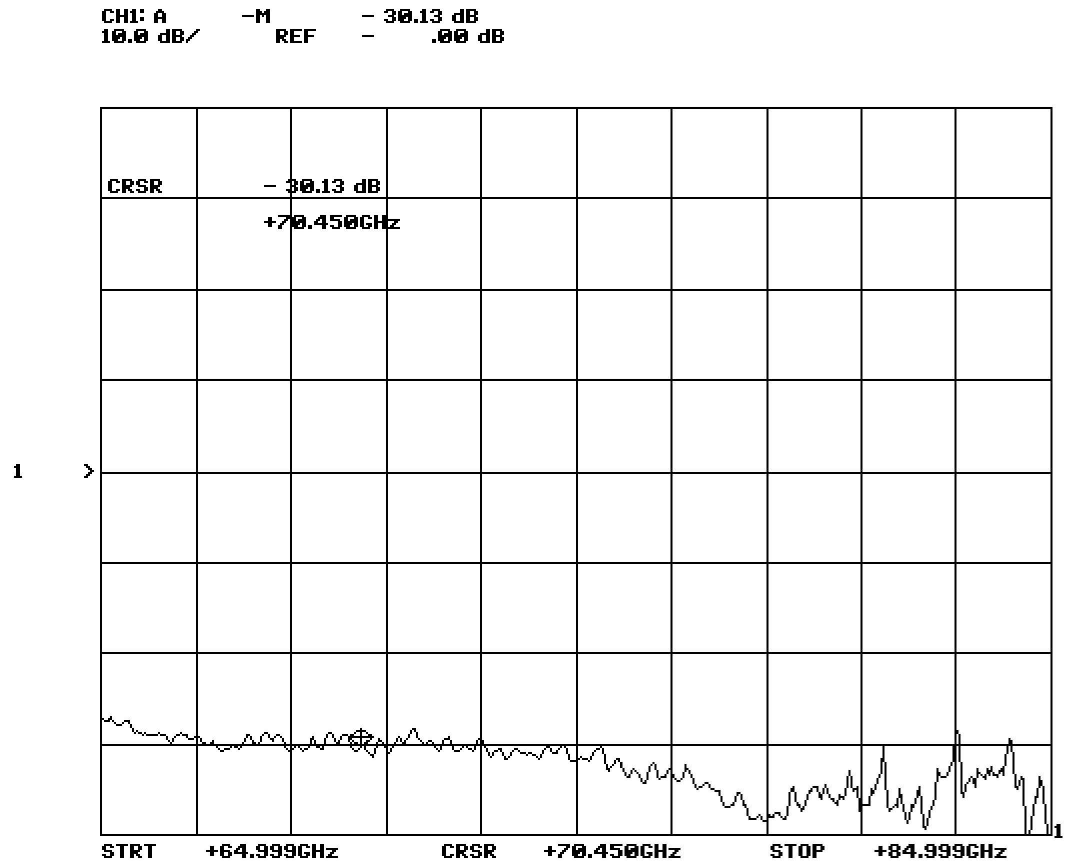
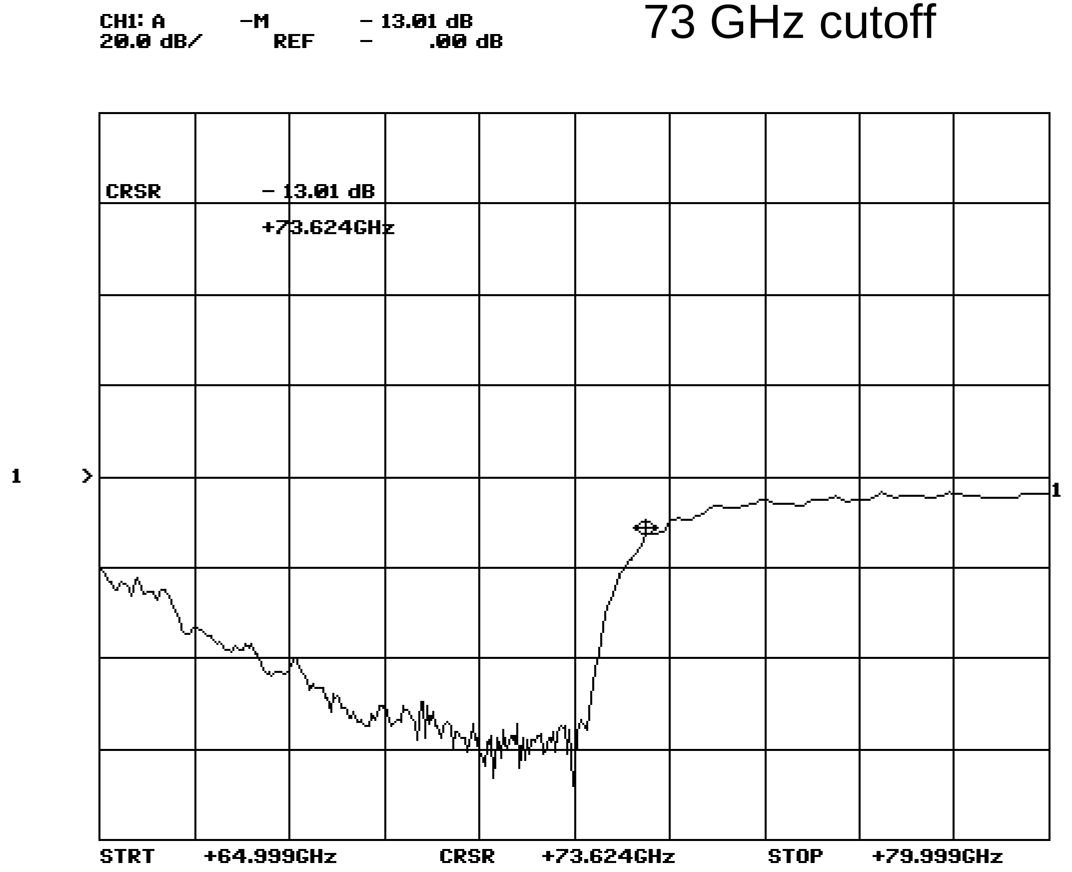


WA5VJB WR-8 (90 -140 GHz)

73 GHz cutoff



RF Input Level for LNA Tests

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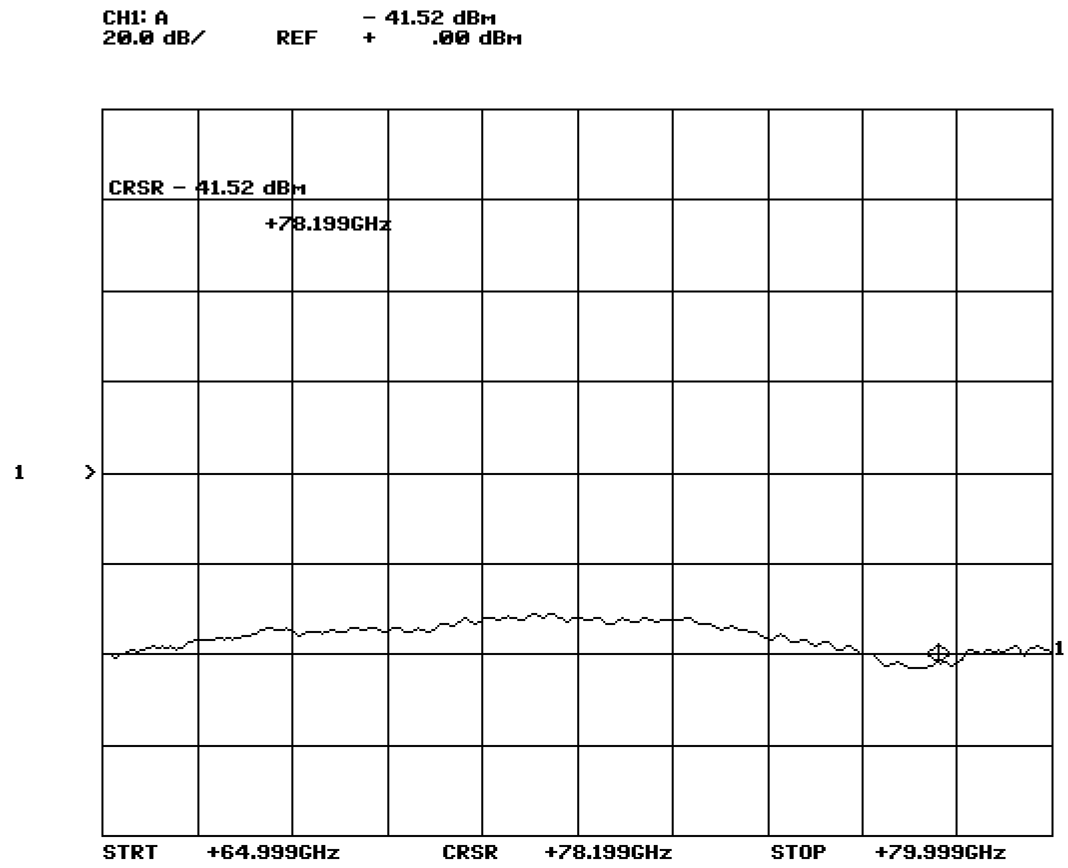

WA1MBA LNA#1

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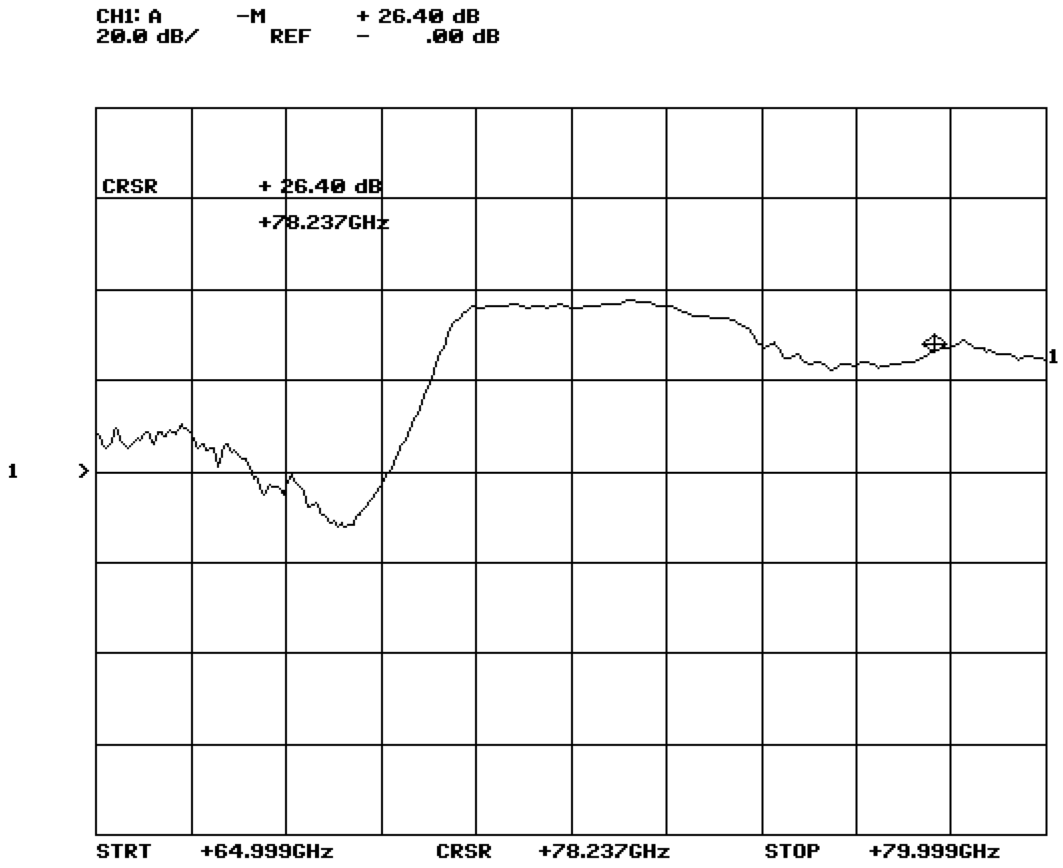

WA1MBA LNA#4

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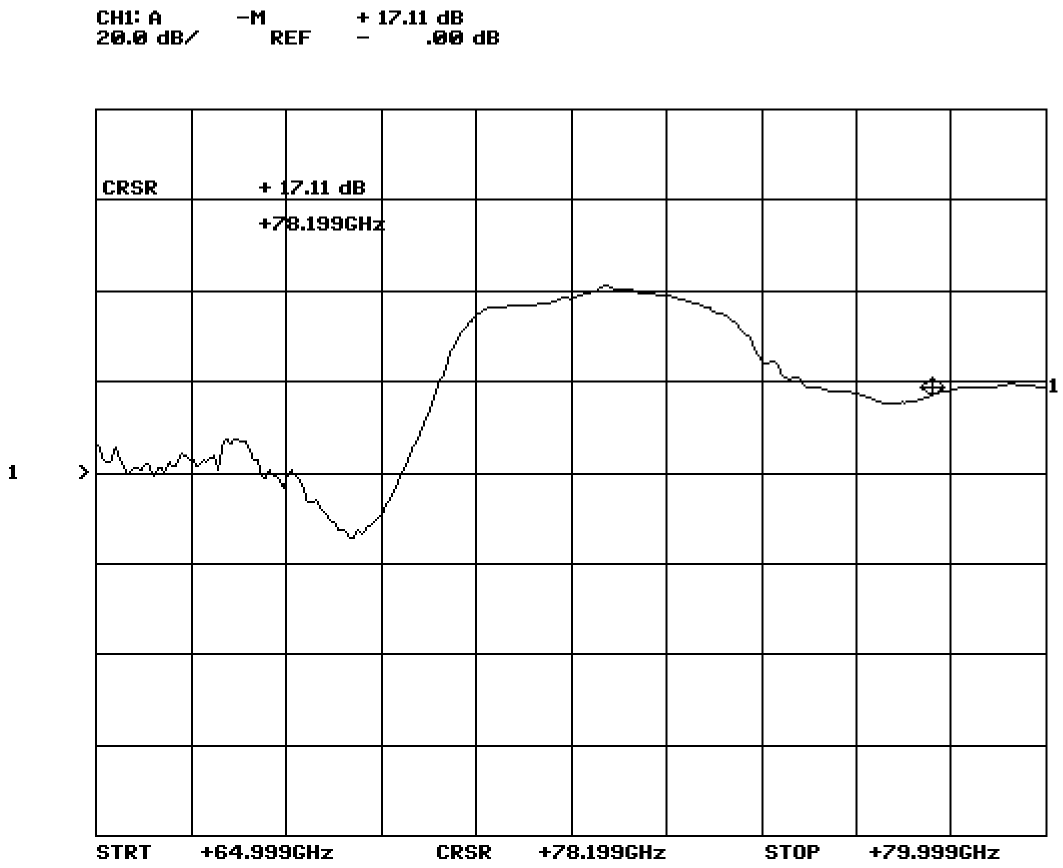

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WA1MBA LNA #5

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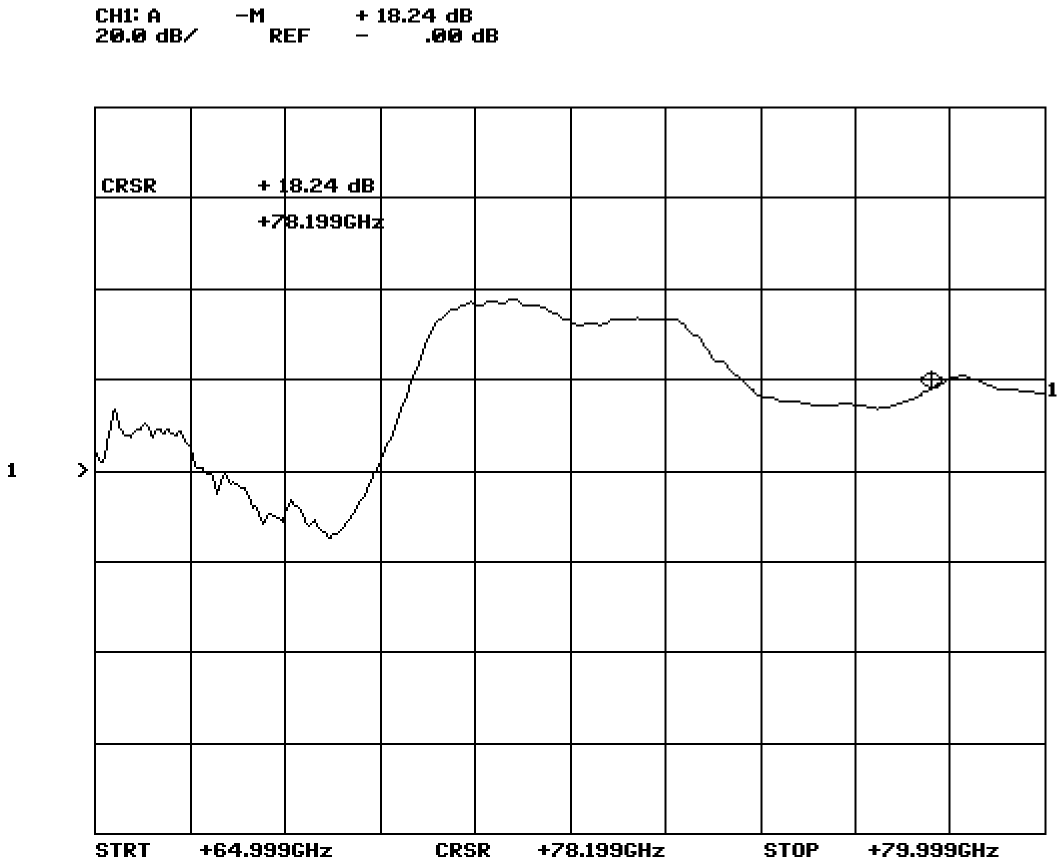

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WA1MBA LNA #6

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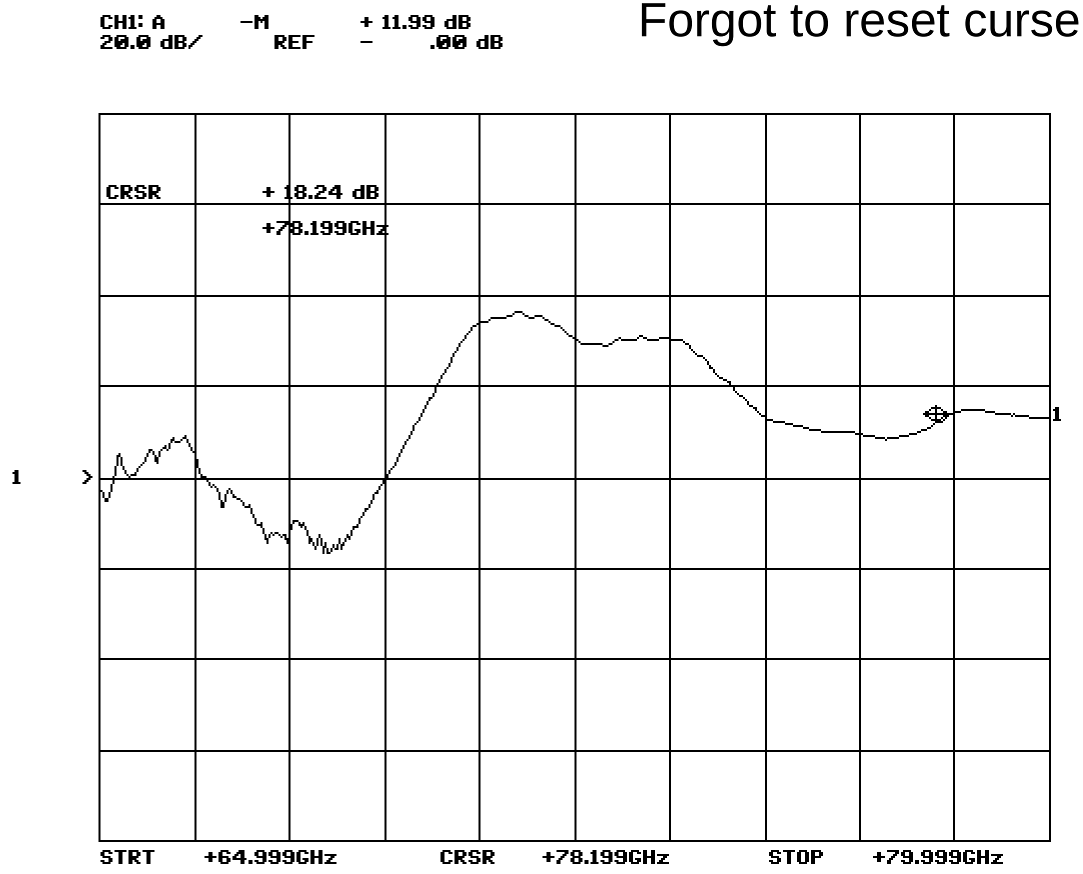
Forgot to reset curser, s/b around 16 dB



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DSB NF Measurements performed at MUD 2009

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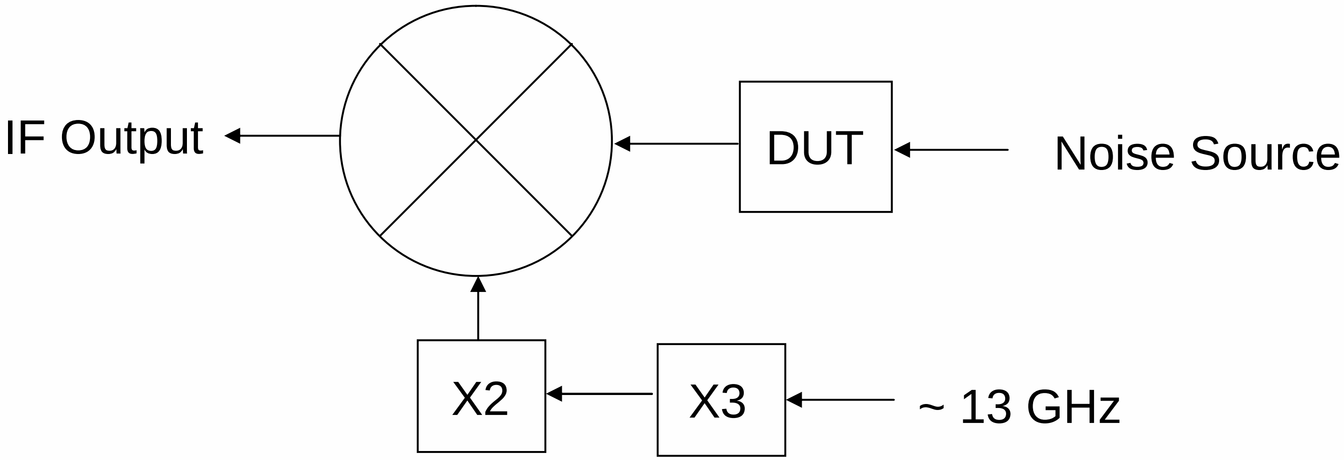
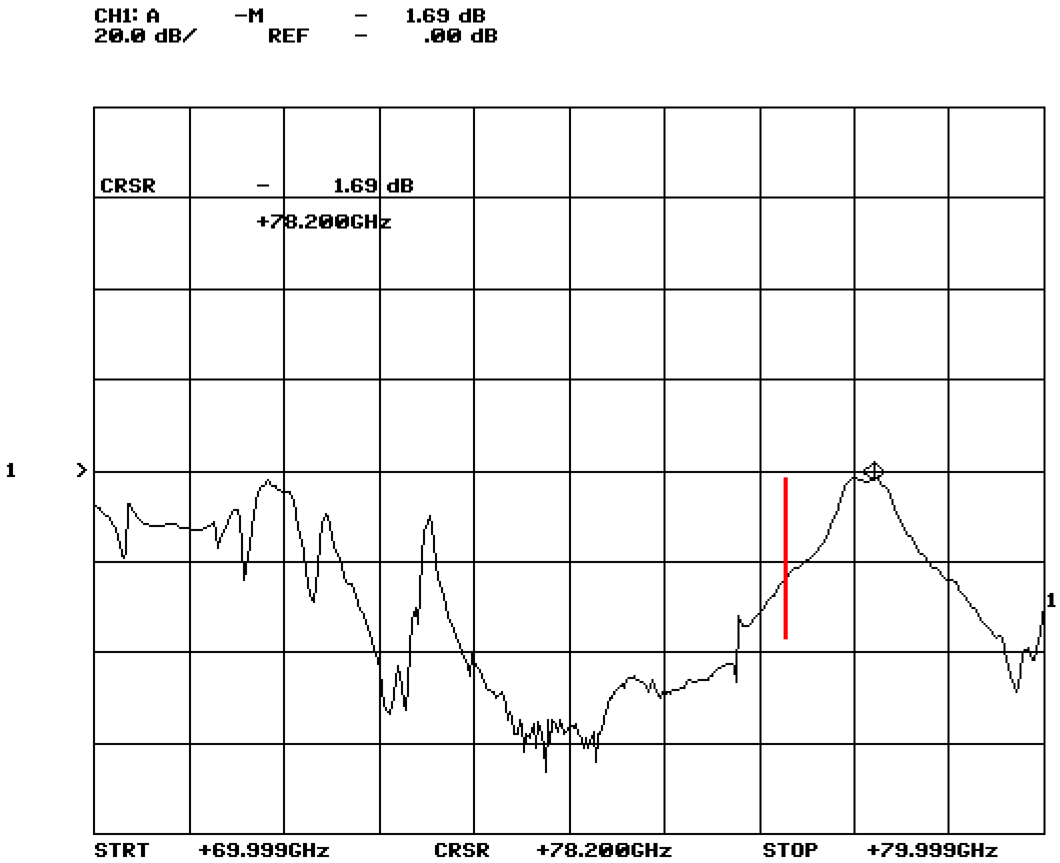
				NF (dB)	Gain (dB)
78 GHz	WA1MBA	LNA#4	2 Stage CHA1077	7.75	19.8
	VE4MA	Converter	Mixer/IF Amplifier	14.00	12.2
	W5LUA	Converter	Isolator/BPF/Mixer/IF Amplifier	20.20	15

Fundamental Mode WR-15 Mixer



Although DSB noise figure measurements provide an average noise figure at LO +/- IF, it was felt that with all the low frequency gain of the WA1MBA amplifier that some sort of filtering was required to keep from saturating the mixer. This was accidentally verified on the bench when the LO was inadvertently turned off and I was still able to make a noise figure measurement! But….. where to find a filter?

OE9PMJ 47 GHz BPF Retuned to 78 GHz



Approximately 20 dB image rejection at 77.328 GHz

OE9PMJ 47 GHz BPF Retuned to 78 GHz with WR-8 in series

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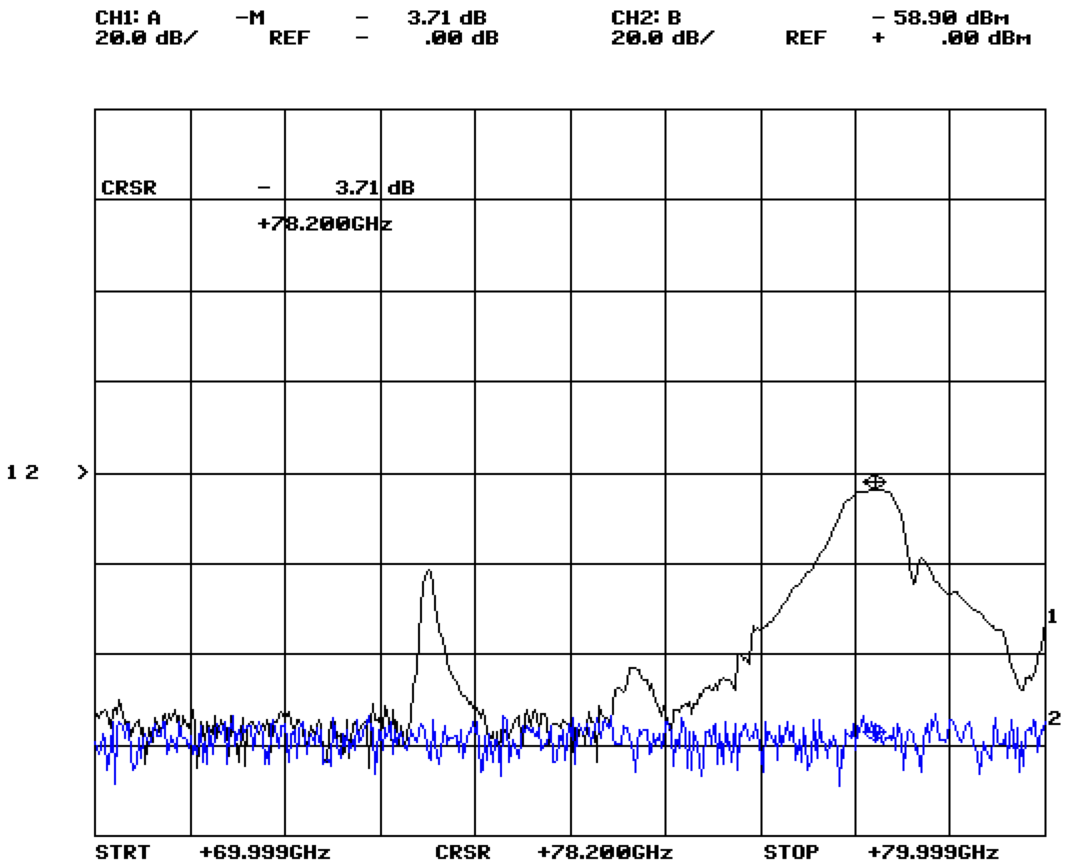

The WR-8 piece of waveguide provides additional attenuation below 73 GHz

Testing the OE9PMJ 47 GHz Filter on 78 GHz

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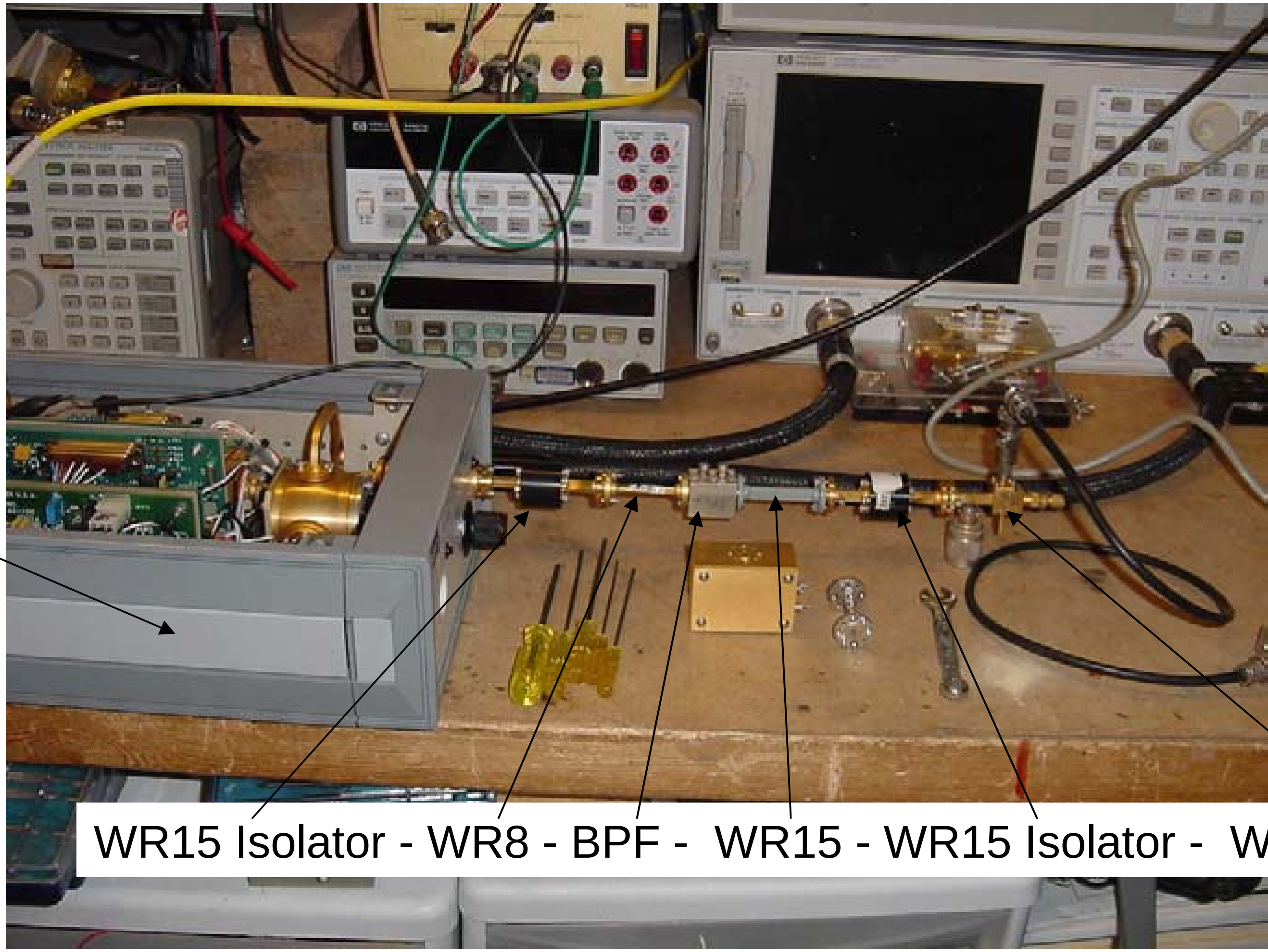
Hughes Test Box with X2 doubler to 78 GHz



WR15 Isolator - WR8 - BPF - WR15 - WR15 Isolator - WR15 Detector

Barry's New Baby – A 75 to 100 GHz Noise Source!

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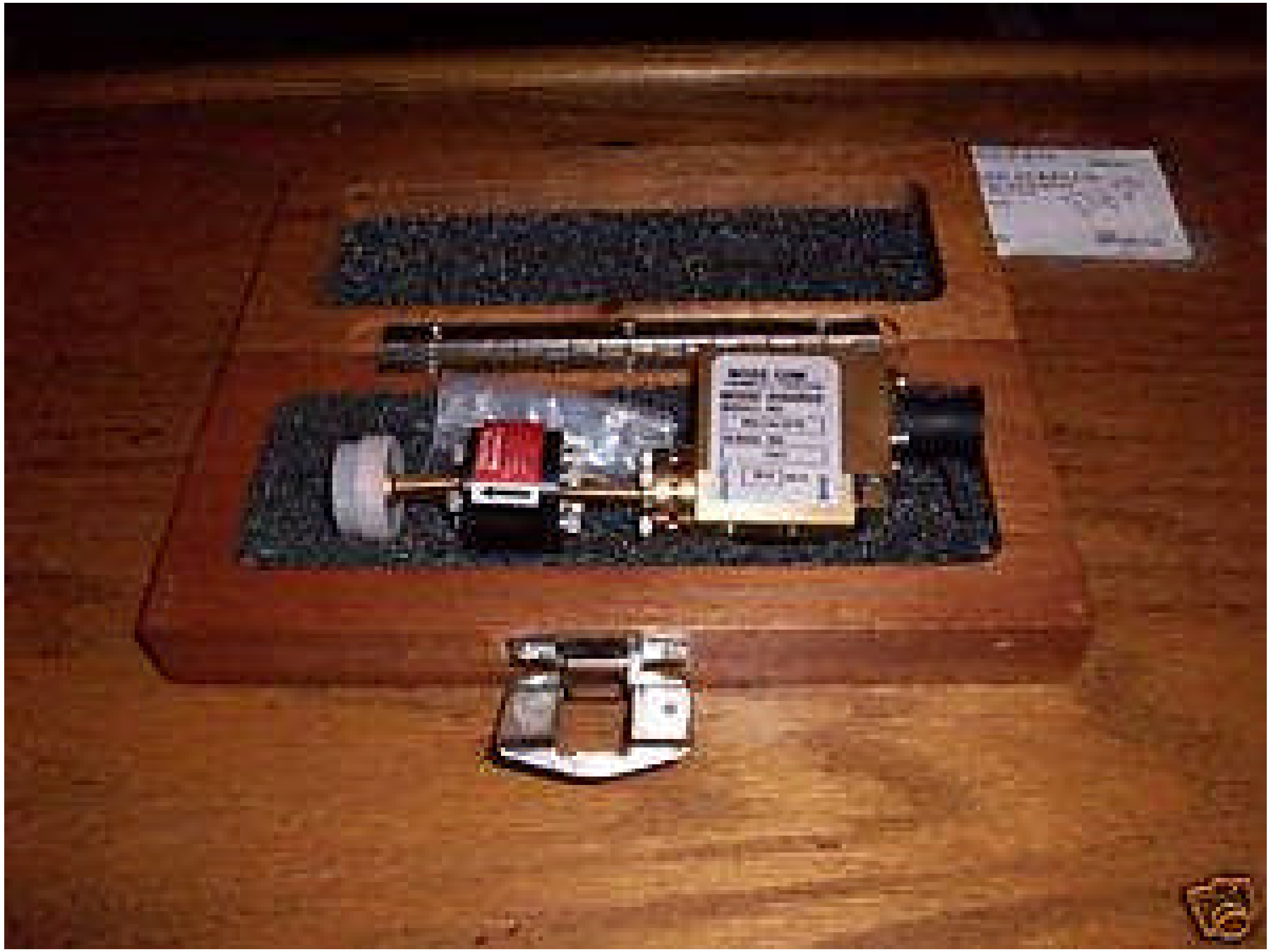

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WA1MBA 78 GHz LNAs using VE4MA WR-10 NoiseCom Noise Source

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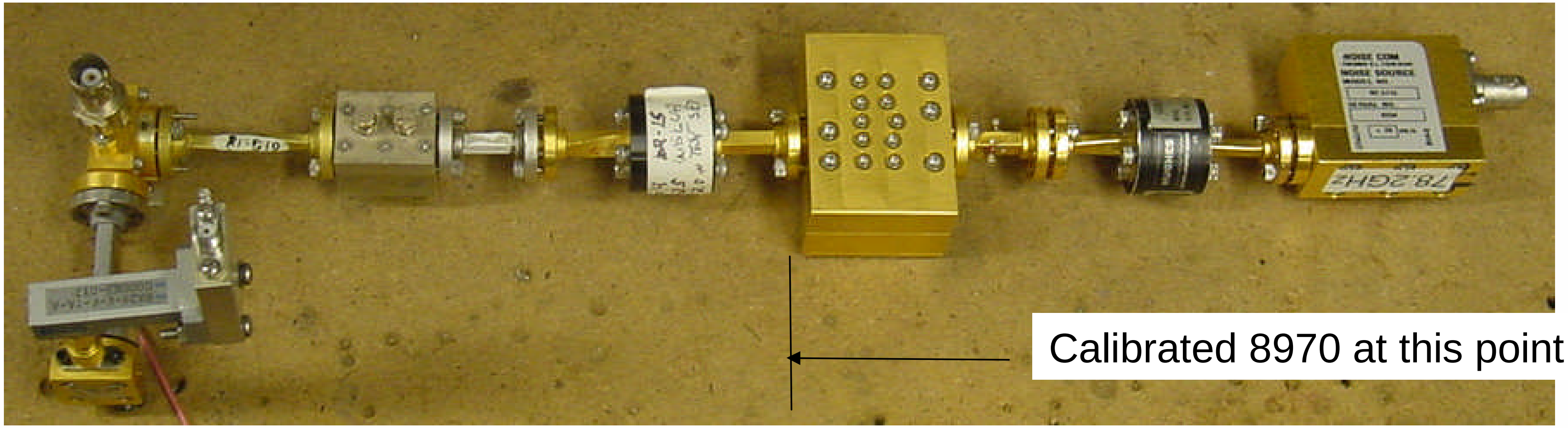
LNA #	NF w/o tuner	NF w/tuner	Gain w/o tuner	Gain w/tuner
4	10.6 dB	8.5 dB	14.6 dB	17.3 dB
5	11.8 dB	7.7 dB	14.9 dB	19.1 dB
6	11.5 dB	6.9 dB	9.7 dB	14.5 dB

It seems like we are going no where with these noise figures – something must be wrong!

WA1MBA 78 GHz LNA#6 with W/G Tuner measured at W5LUA



Calibrated 8970 at this point

The indicated NF is measured with the input waveguide tuner in place. Without the tuner the Gain is 9.7 dB and the NF is 11.5 dB. Gain can be increased above 14.5 dB with the addition of a waveguide tuner at the output of the LNA

WA1MBA 78 GHz LNA#5 with W/G Tuner

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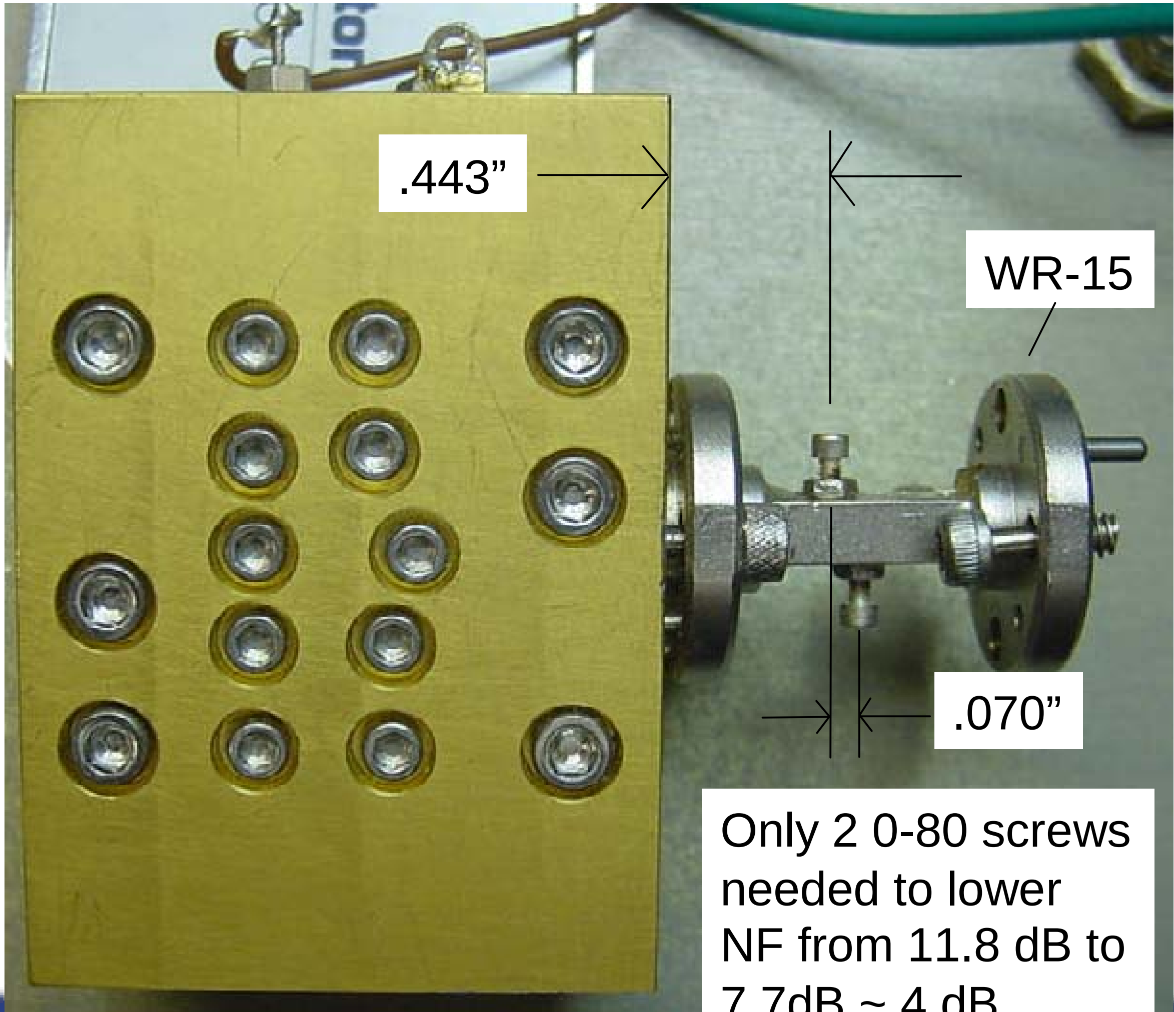
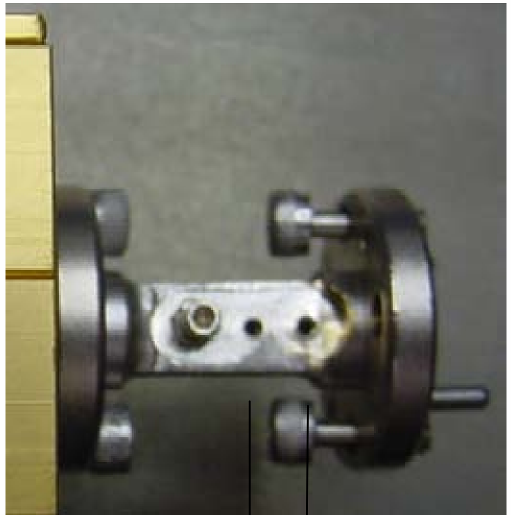


Only 2 0-80 screws needed to lower NF from 11.8 dB to 7.7dB ~ 4 dB improvement



.140”
2pl on top

3 0-80 tapped holes on top and 2 on bottom, ones on bottom are offset by .070” from top

LNA#5 with Input Tuner – 8/29/2010

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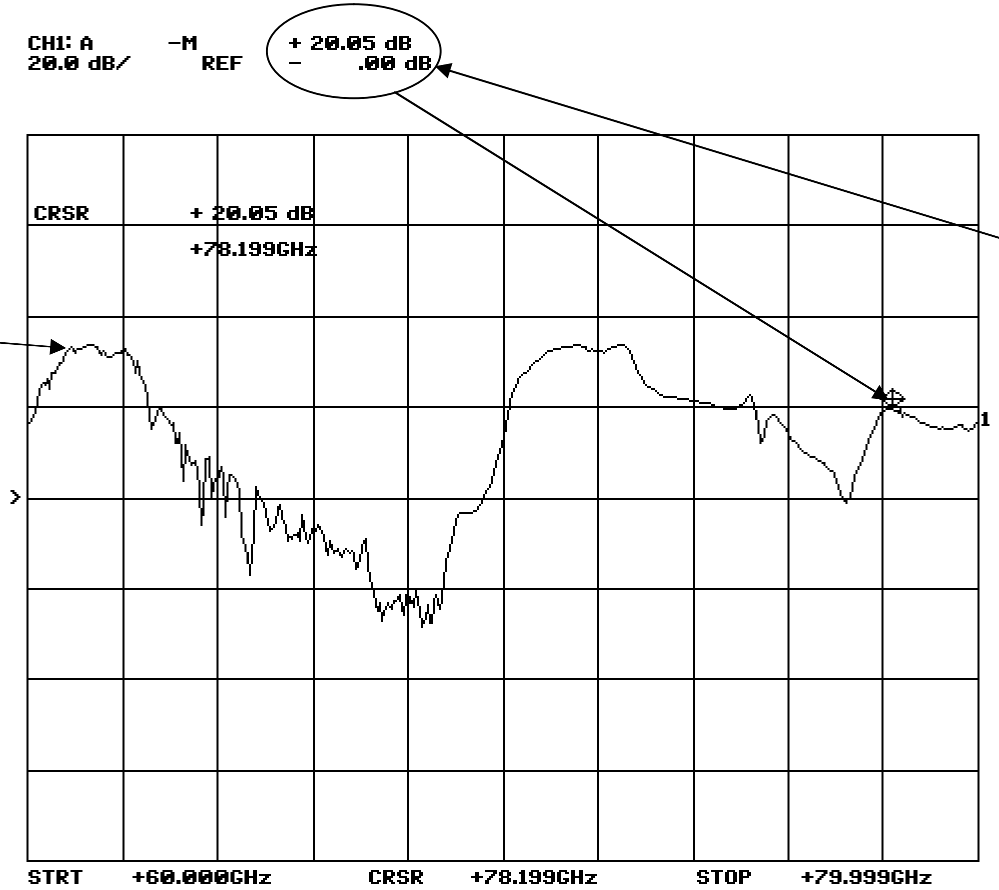
I don't believe this is real – most likely subharmonics into multiplier since multiplier is most likely responding to a 1/3 f signal as opposed to the desired ½ f.



Compares well to 19 plus dB from noise figure meter

At this point my system noise figure was pretty close to 8.5 dB but I still decided it was time to look for sun and moon noise

GR-1216 & GR-1236 IF Amplifiers

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These meters provide a 30 MHz IF amplifier with up to several MHz of bandwidth which makes it easy to measure sun and moon noise – they can be easily retuned for 28 MHz

Measurements

- Sun noise over cold sky
- Moon noise over cold sky
- Ground to cold sky or
- 50Ω to cold sky

$$\text{INV LOG ((dB)/10)} = \frac{Tr + To}{Tr + Tant}$$

Tr = 290 log (NF-1) where NF is noise factor (ratio) and NOT noise figure (dB)

Tr = Noise temperature of receiver (Kelvin)

To = temp of 50Ω load (Kelvin)

Tant in Kelvin is a measure of how quiet your antenna is on receive which takes into account feed efficiency and spillover and atmospheric absorption – lower the better

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2.4 m Fiberglass Offset Fed Dish with WR-10 Std Gain Horn

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NF = 8.5 dB (1763K)

Sun Noise / cold sky =
1.6 to 1.8 dB w / WR-10 Feedhorn
1.2 dB w / WR-15 Feedhorn
1.2 dB w / small WR-15 Feedhorn
1.0 dB w / W2IMU Feedhorn
SFI = 75

Moon Noise / cold sky = 0.15 dB
w / WR-10 Horn

50Ω / cold sky = 0.35 dB
w / WR-10 Horn, NF = 8.5 dB,
Ta = 131K

Theoretical 3 dB BW = .11 degree

1 m Winegard Offset Fed Dish with W2IMU Feedhorn built by WA5JAT

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NF = 8.5 dB (1763K)

Sun Noise / cold sky =
3.8 dB w / W2IMU Feedhorn
1 dB w / WR-10 Feedhorn
SFI = 82, 1, 1

Moon Noise / cold sky =
0.2 dB

50Ω / cold sky = 0.3 dB,
NF = 8.5 dB, Ta = 153 K

Not Optimized Yet!

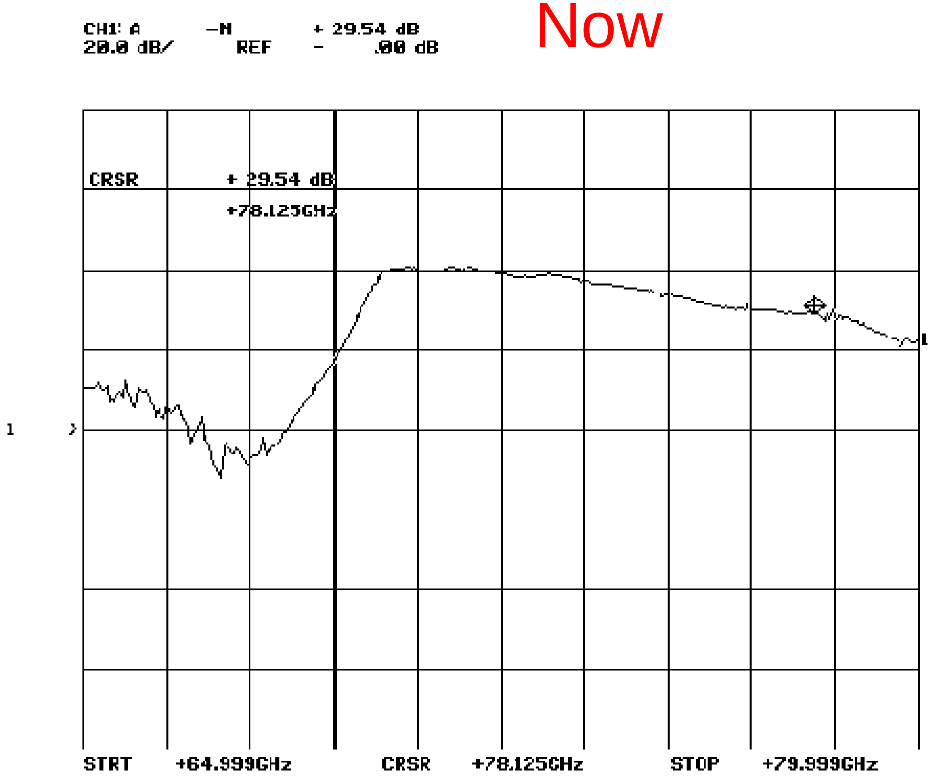
Theoretical 3 dB BW = .3 degree & G~ 56 dBi

Lessons Learned

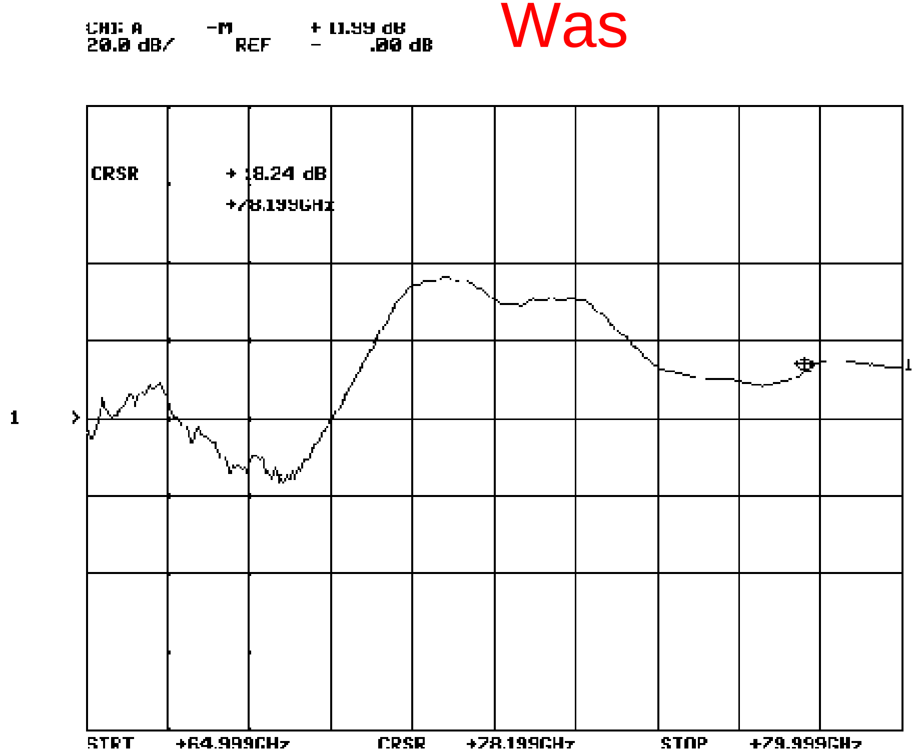
- This is not going to be easy!
- An isolator on the noise source is a must to reduce measurement error – nothing really new here…we knew that from our low frequency work over the years that an isolator or a 10 dB pad would help improve measurement accuracy
- It appears that the LNA requires an input tuner and maybe even an output tuner – not a big deal, a few screws in a piece of WR-15 and we are ready for tuning…..
- Returned a couple of units to Tom WA1MBA for verification on noise figure……standing by for a report…

New LNA#6 – Wow!

Now



Was



It appears that Tom has performed some magic on the LNA and the gain at 78.2 GHz has gone from 12 dB to 29 dB without the need for a tuner!

Testing LNA #5 8/29/2010

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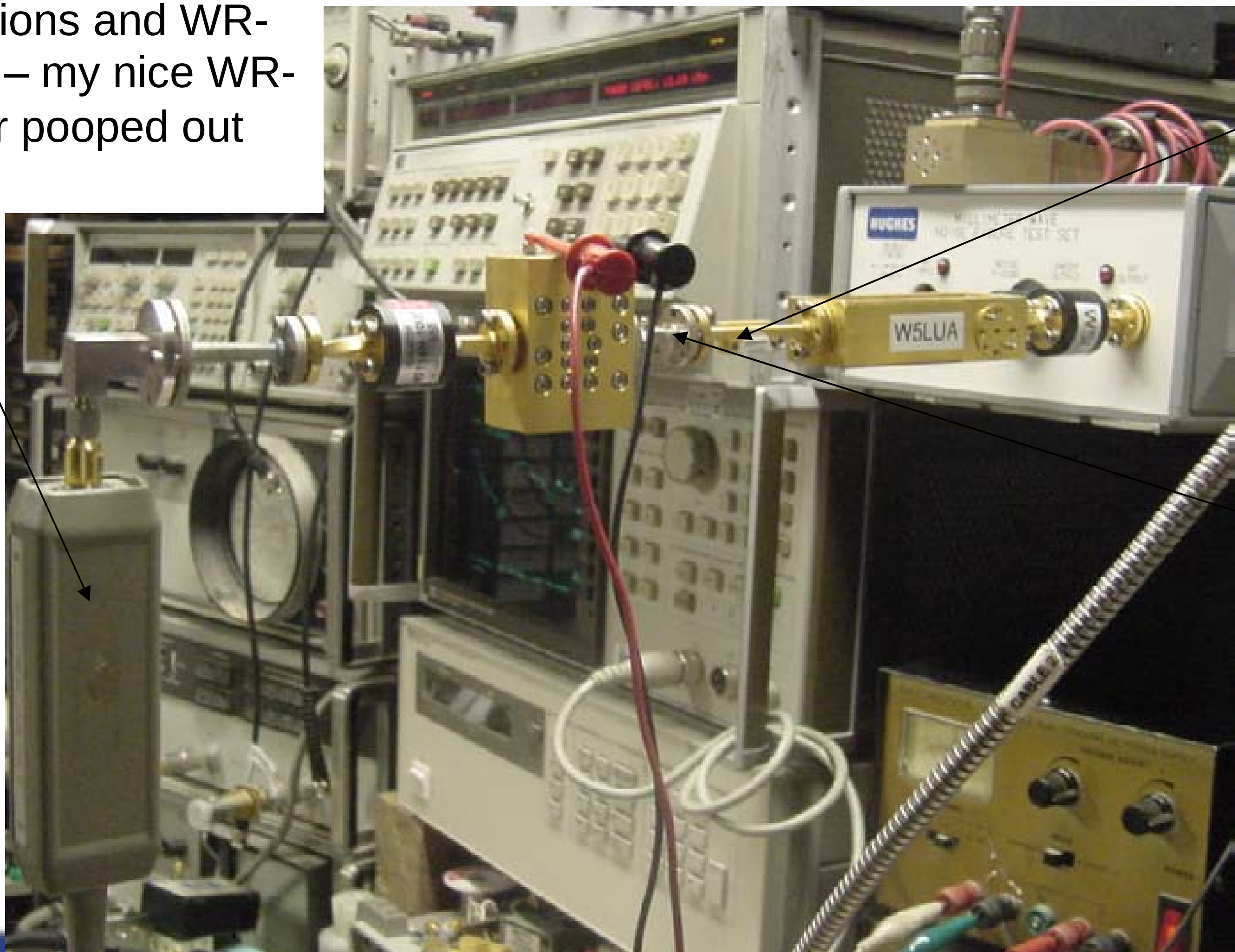
50 GHz 2.4mm detector with transitions and WR-15 isolator – my nice WR-15 detector pooped out on me



30 dB Attn

-30dBm Input power

78 GHz Converter

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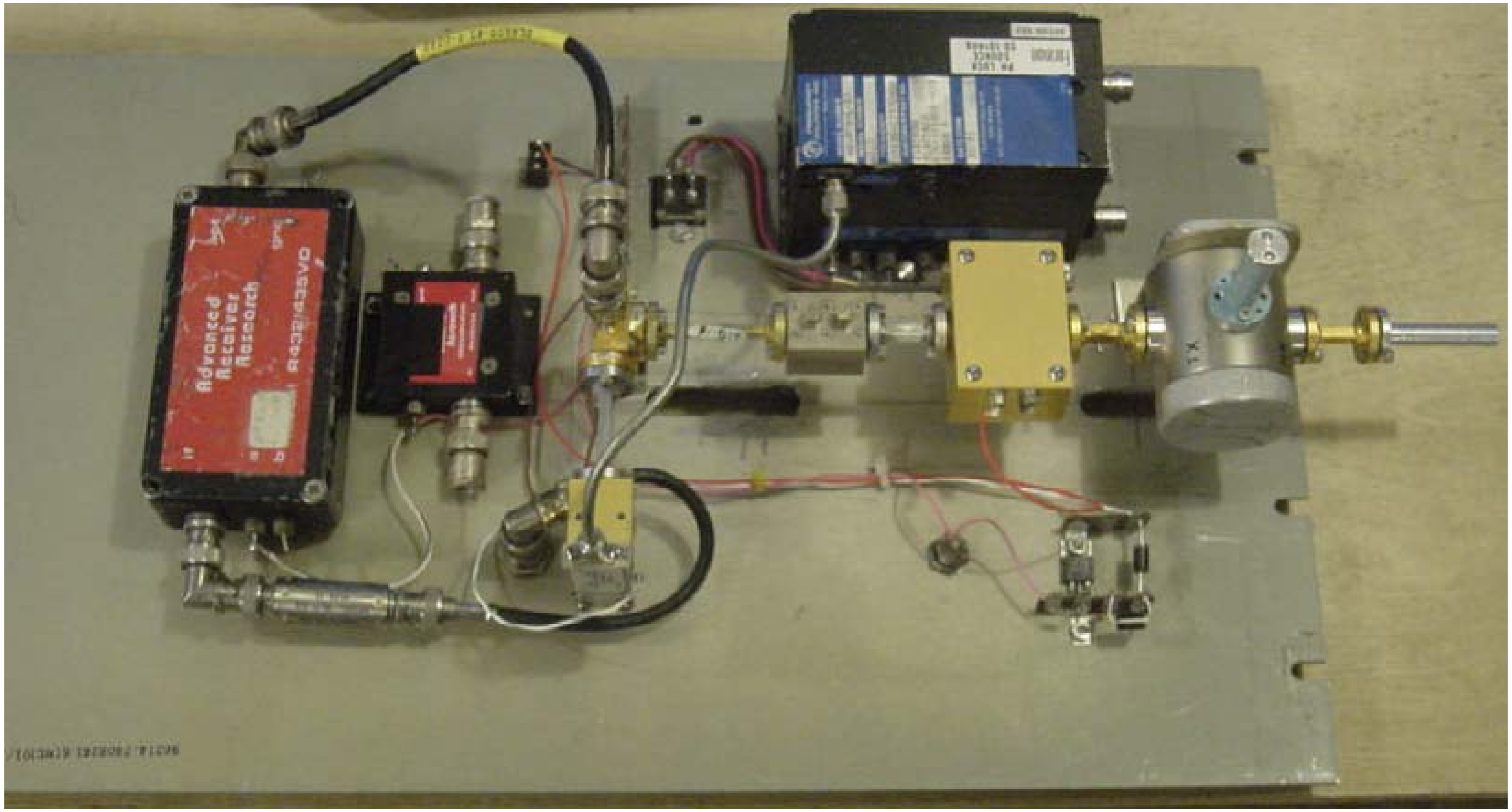

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78 GHz XVTR with new LNA !

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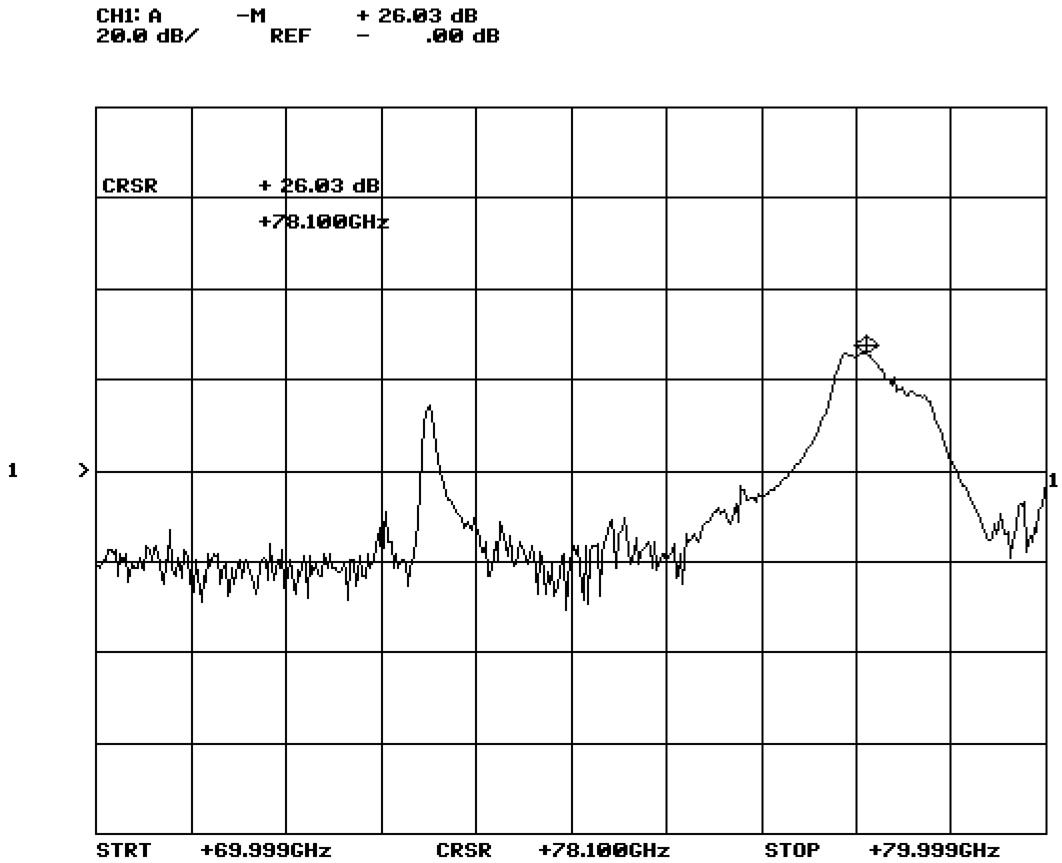
New LNA#6 w/BPF and WR-8



To the Moon, Alice!

- If these noise figure readings are real, then we must be able to verify the measurements by again using the sun and moon and noise sources

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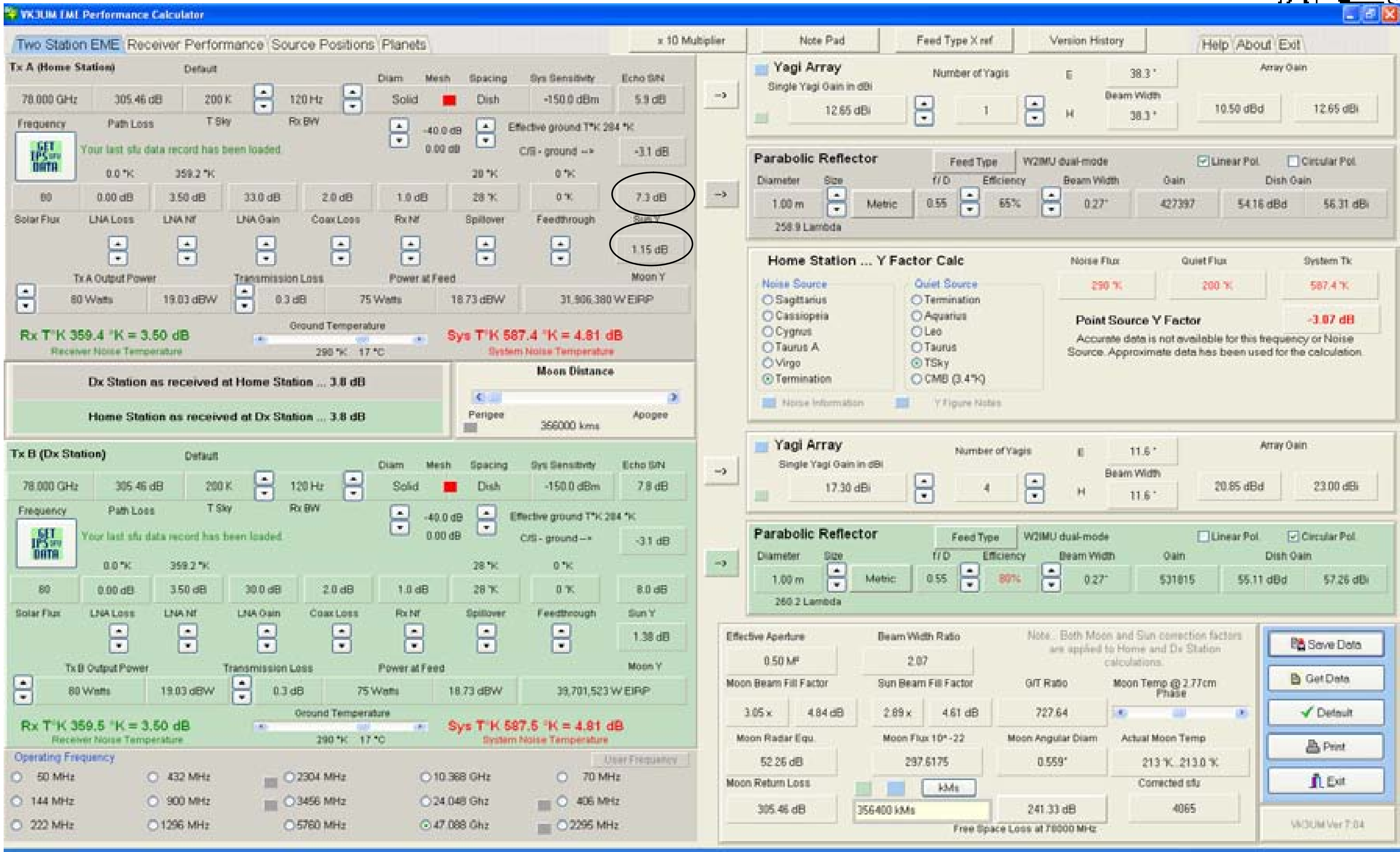
VK3UM Software



1 m Winegard Offset Fed Dish with W2IMU Feedhorn built by WA5JAT

System NF = 3.5 dB (359K)

Sun Noise / cold sky =
7.2 dB w / W2IMU Feedhorn
SFI = 87, 3, 0

Moon Noise / cold sky =
0.75 dB

50Ω / cold sky = 1.2 dB,
NF = 3.5 dB, Ta = 133 K

Feed position still not optimized!

Dew point is quite a factor in the measurements = moisture and oxygen absorption!

78 GHz W2IMU Feedhorn built by WA5JAT

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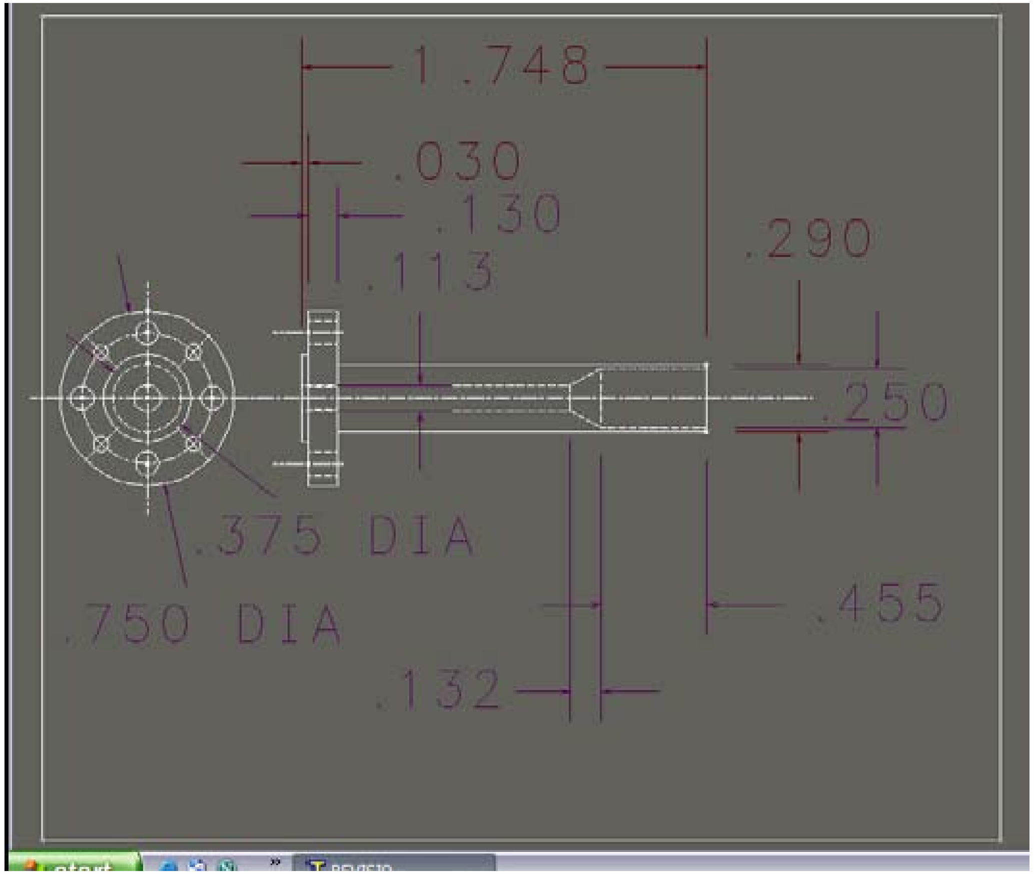
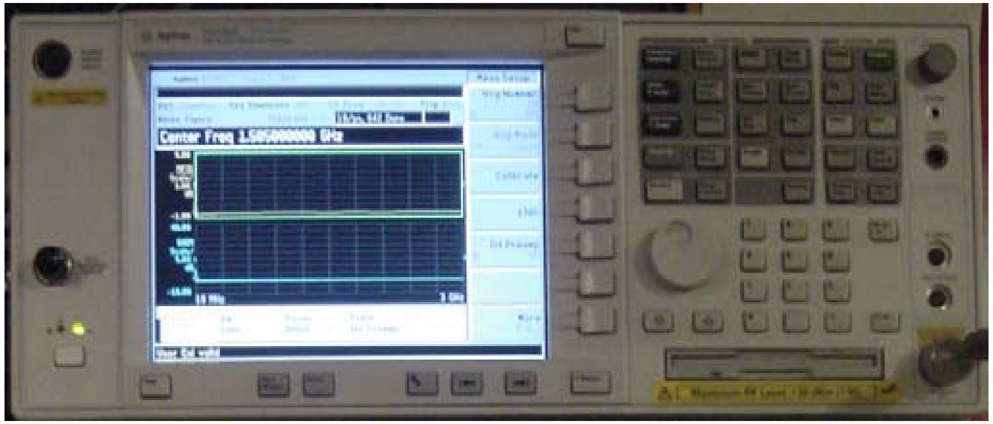


W2IMU Dual Mode “Scaled” Feed Dimensions

Noise Figure Comparison of ATF-36077 1.3 GHz LNA from Ap Note 1128 as tested on 3 different NF Test Setups

E4440



8970

8973

W5HN

Noise Figure Comparison of ATF-36077 1.3 GHz LNA from Ap Note 1128 as tested on 3 different NF Test Setups

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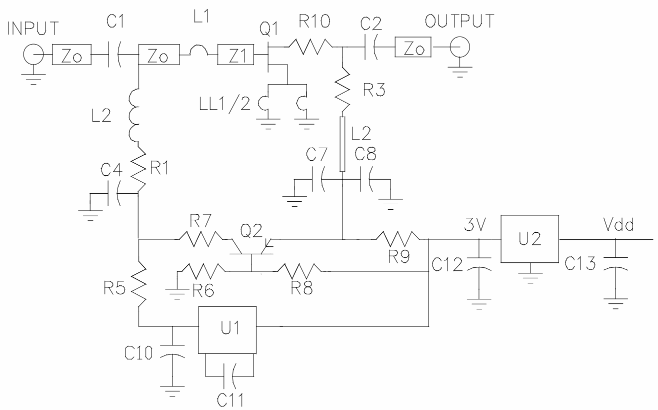
Equipment	NF of NFM – cal'ed out	BW	NF (dB)	Gain (dB)
8970B	6 dB	4 MHz	0.35	15.8
8973A	5.5 dB	4 MHz	0.43	15.9
		100 kHz	0.44	16.0
E4440*	7 to 8 dB up to 3 GHz	4 MHz	0.37	15.8
Spec Anal	With extra internal preamp	1 MHz	0.37	15.9

* With Noise Figure Personality Module

All measured with the same 346A noise source. All meters corrected for noise source Tcold. Interesting that the E4440 spectrum analyzer with noise figure personality module gives numbers closer to the old standard 8970 that the 8973 does



- Any Questions?
- My presentation will be available at www.ntms.org after the conference.
- Thank You
- See you on the moon!