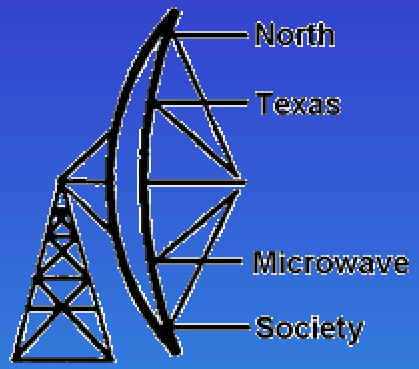


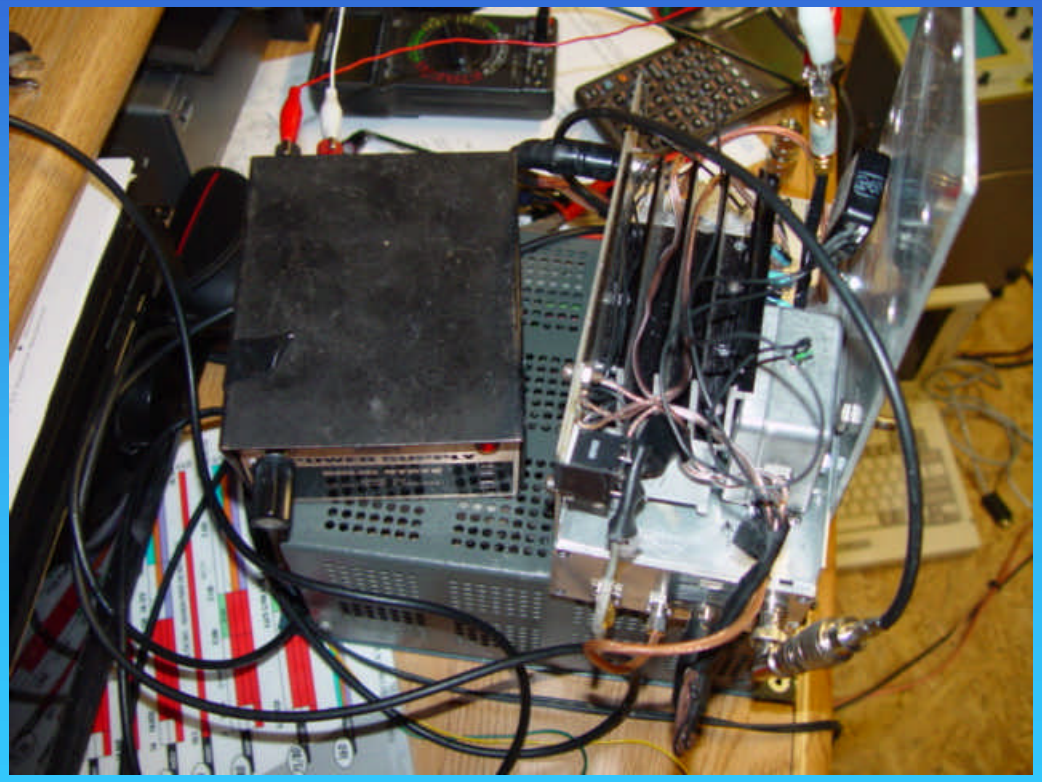
Noise figure measurements with a AT-30511 as a noise source using a PC for Y-factor measurement

Joe Jurecka – N5PYK
for
The North Texas Microwave Society

Goals

Learn how to measure noise figure without a NF meter

Develop a simple system for measuring system noise figure



Simple Noise figure calculations†

NF=((Th/To)-1) – Y((Th/To)-1) / (Y-1)

Or, in simple dB terms

NF (dB) = ENR – 10 LOG (Y-1)

So, if you know your ENR and your Y-factor, you can Compute the noise figure of your system.

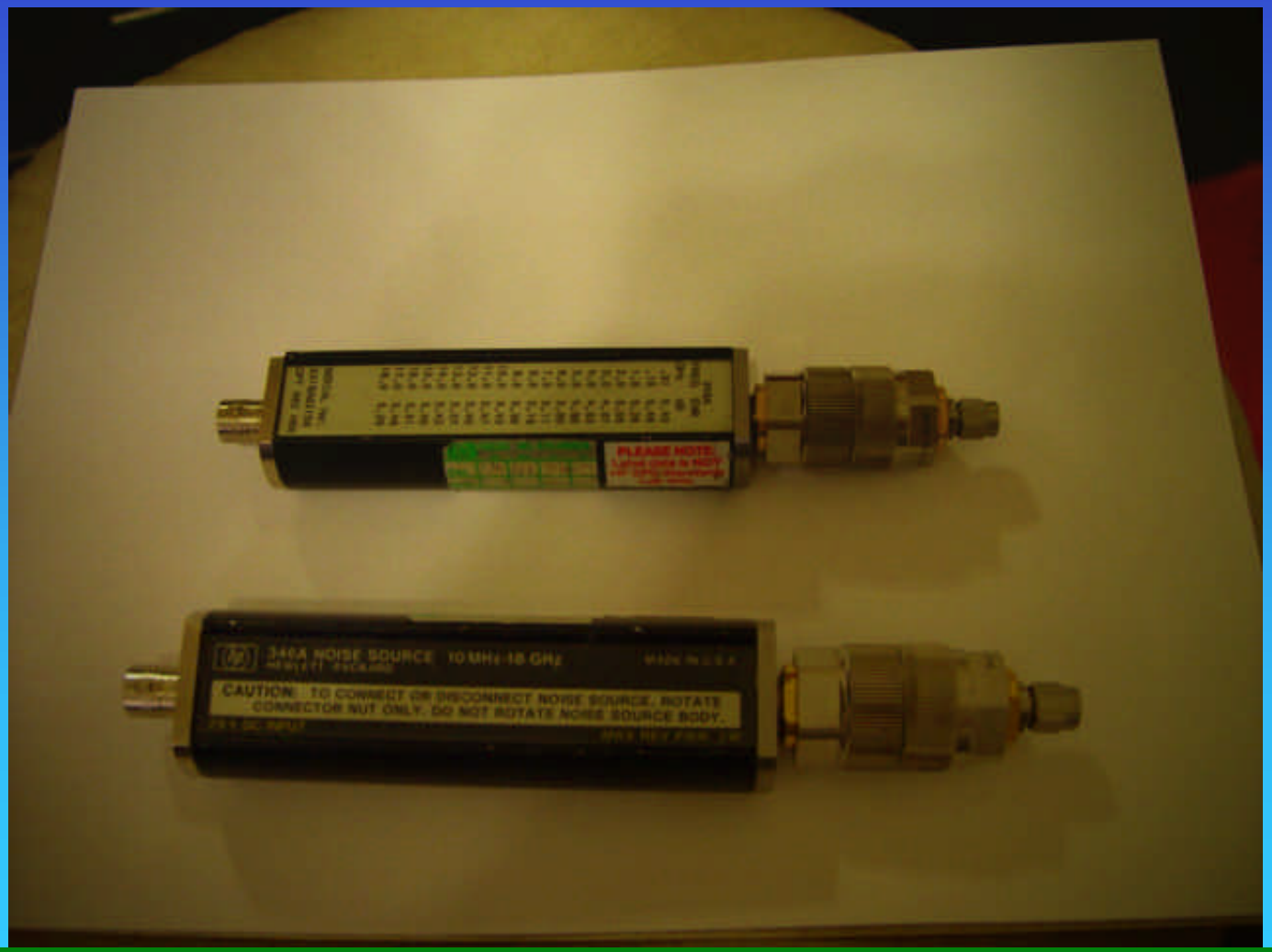
Example
ENR 5.5 dB Y-Factor 6dB or 4 expressed as radio

NF = 5.5 – 10 LOG (4-1) = 0.73dB

†"Noise figure Measurements by Al Ward WB5LUA", Microwave Update Proceedings 1997

Noise source of a commercial noise figure meter

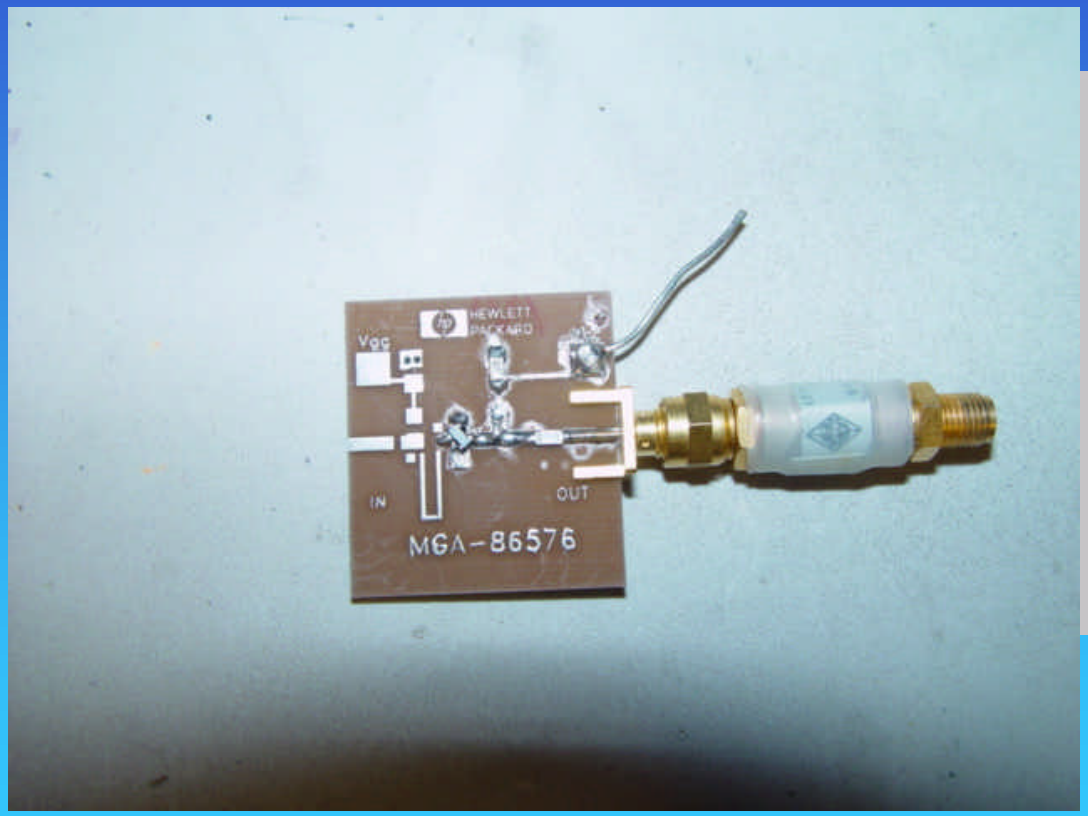
HP 346 A – ENR 5.44dB at 10.3 GHz

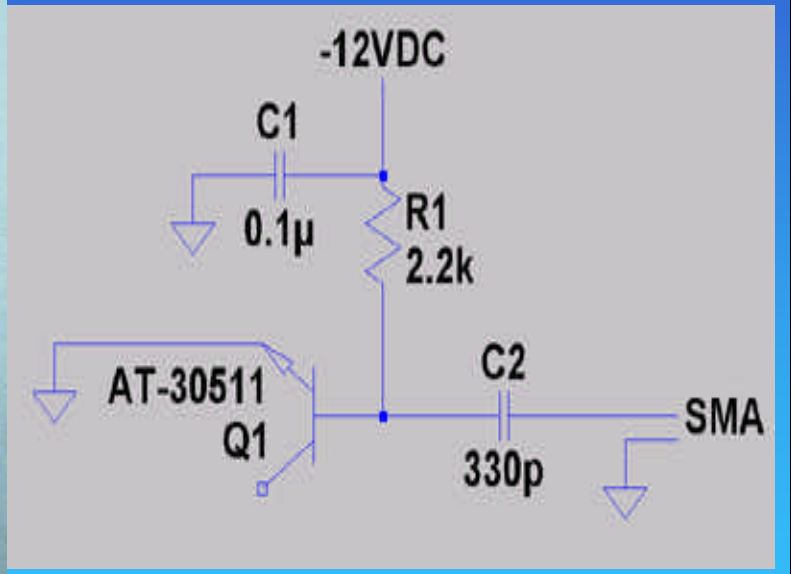


This was my reference!

Build a noise source

Based on Agilent AT-30511 and evaluation board





Note collector is open with negative bias on base

This circuit outputs around 25dB ENR through 10 GHz
Use attenuators to bring level down to ensure better 50O match.

Accurately determine attenuation at frequencies of interest

Calibrate your noise source if you can.

Attenuator	Reference	Minicircuits 20dB	Lcom 10dB	5dB	Selectrum10dB
50		-19.8	-9.65	-4.8	-9.95
144		-19.81	-9.66	-4.8	-9.96
222		-19.83	-9.68	-4.81	-9.97
432		-19.82	-9.7	-4.82	-9.97
902		-19.76	-9.7	-4.81	-9.97
1296		-19.71	-9.76	-4.87	-10
2304		-19.63	-9.81	-4.91	-10
3456		-19.52	-9.87	-4.98	-9.97
5760		-19.97	-10.51	-5.22	-9.93
10368		-16.71	-21.6	-6.25	-10.04

The Mini-circuits 20dB pad was used for my measurements

Notice the attenuator characteristics changing at 10GHz

	Relative power				Relative power				
Freq	Tcold 346A	Thot 346A	Y-dB		Tcold pyk	Thot pyk	Y-dB raw		Y (dB) Delta
50	19.16	21.67	2.51		19.22	22.02	2.80		0.29
144	17.79	20.72	2.93		17.82	20.90	3.08		0.15
222	17.00	20.00	3.00		17.02	20.17	3.15		0.15
432	15.54	18.57	3.03		15.56	18.71	3.15		0.12
902	13.08	16.17	3.09		13.23	16.43	3.20		0.11
1296	10.61	13.73	3.12		10.48	13.81	3.33		0.21
2304	13.64	16.39	2.75		13.32	16.47	3.15		0.40
3456	16.86	19.72	2.86		16.27	19.30	3.03		0.17
5760	18.98	21.72	2.74		19.94	22.82	2.88		0.14
10368	20.24	23.44	3.20		20.62	25.32	4.70		1.50

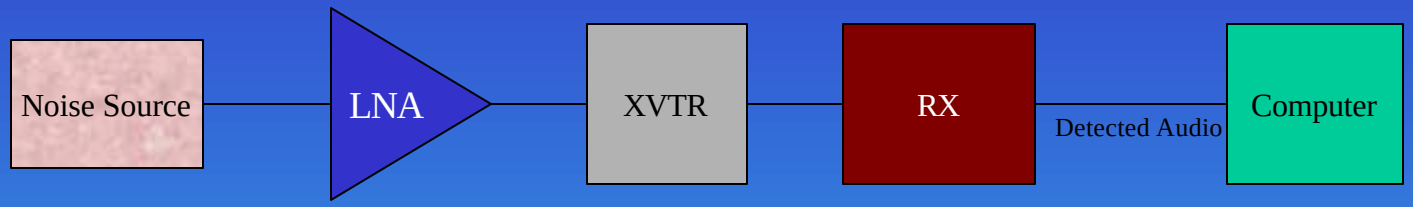
Relative power measurements made with HP 8970 NF meter in manual mode

Comparison of HP346A head and homebrew head

	HP Head	N5PYK Head	Head Delta
50	5.06	5.35	0.29
144	5.12	5.28	0.16
222	5.12	5.30	0.18
432	5.09	5.23	0.14
902	5.03	5.10	0.07
1296	4.98	5.10	0.12
2304	4.85	5.08	0.23
3456	4.83	4.72	-0.11
5760	4.67	4.98	0.31
10368	5.08	6.58	1.50

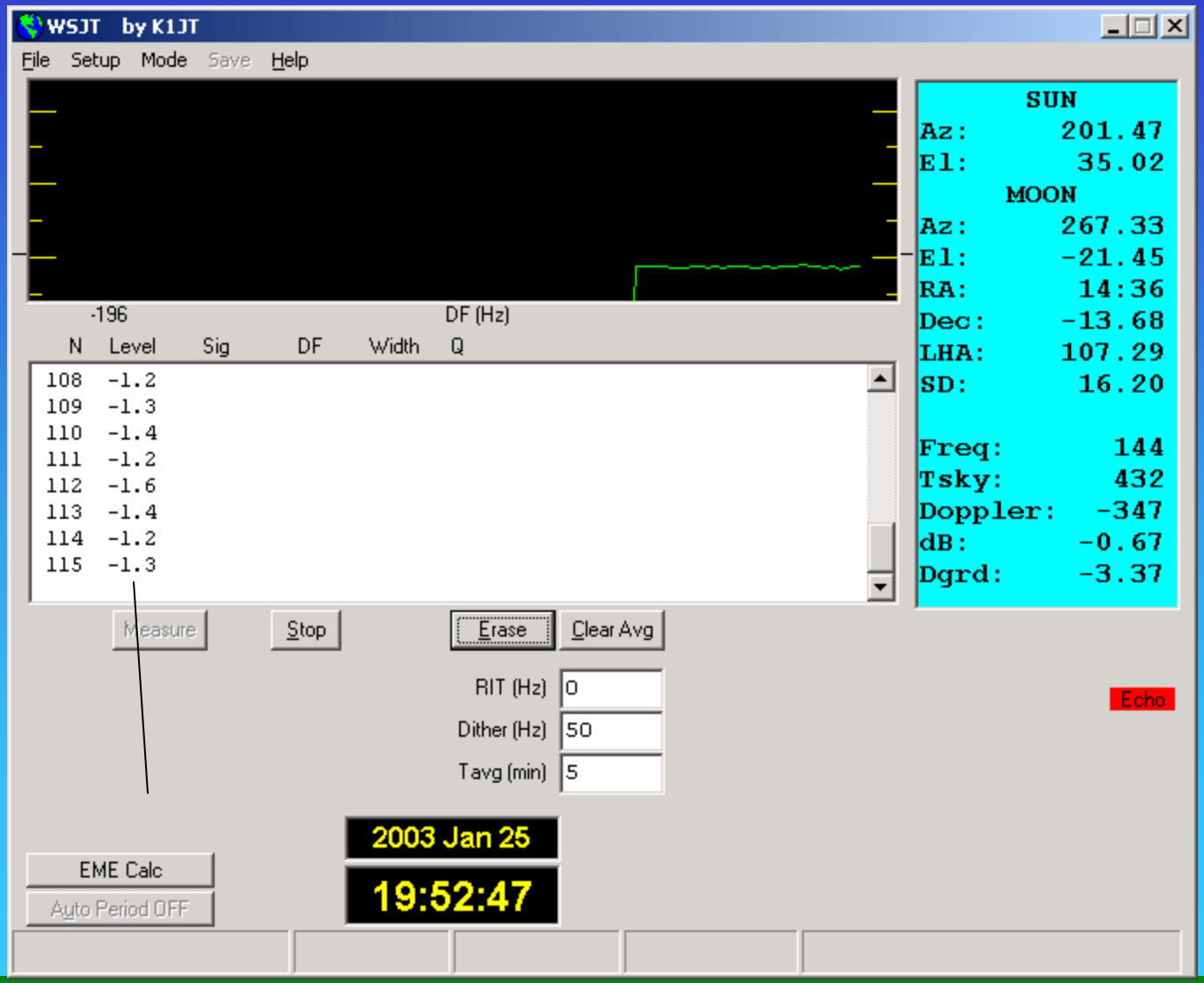
Note that things get a little divergent at 10GHZ!

Equipment hookup



This method measures total system noise figure all the way to your receiver. It does not measure only the LNA or transverter. But, then again, if you measure the NF of your receiver and determine gain on previous stages, one can derive individual element noise figures via a sequence of calculations.

Using WJST for making level measurements



With a radio to computer interface, one can use WSJT to make relative noise level measurements (e.g. Y-Factor)

Start measurements then copy the results into your favorite spreadsheet program and perform an average. The result should be a fairly good approximation of the receiver noise floor.

Joe Taylor, K1JT recommends keeping the level between –10 and +20. Adjust accordingly

How to make Y-Factor measurements

Make measurements with the noise source off then with the noise source on. The measured difference is the Y-factor. The Y-factor, combined with the actual ENR of your noise source provides you with the necessary information to calculate your noise figure of the system.

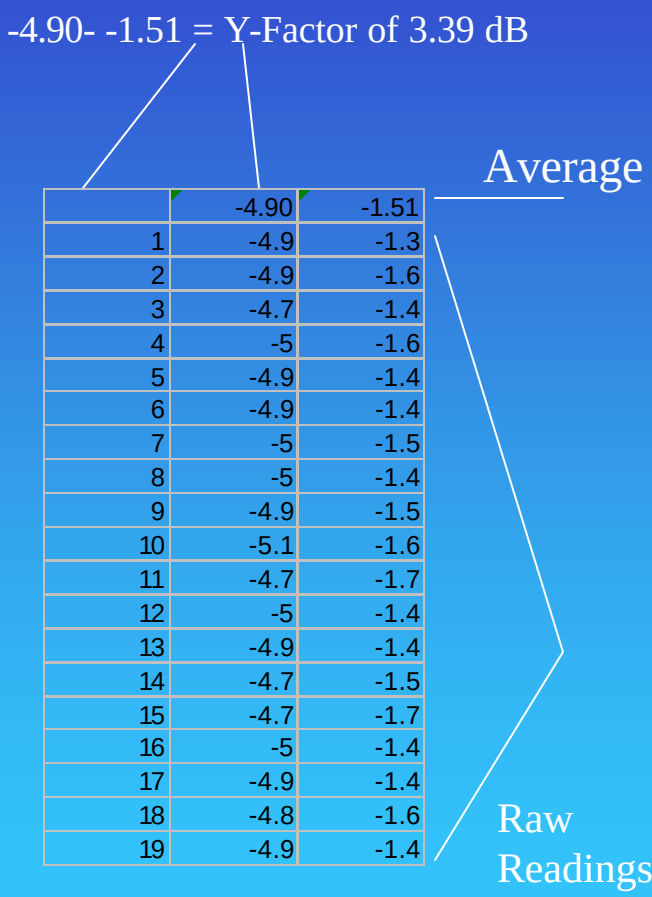
Turn AGC off or back off the RF gain so that with the noise source on and off, little AGC compression is possible.

This picture is a bit extreme but it makes a point….try for 2 S units above T-hot noise

Use Excel as a tool to average readings

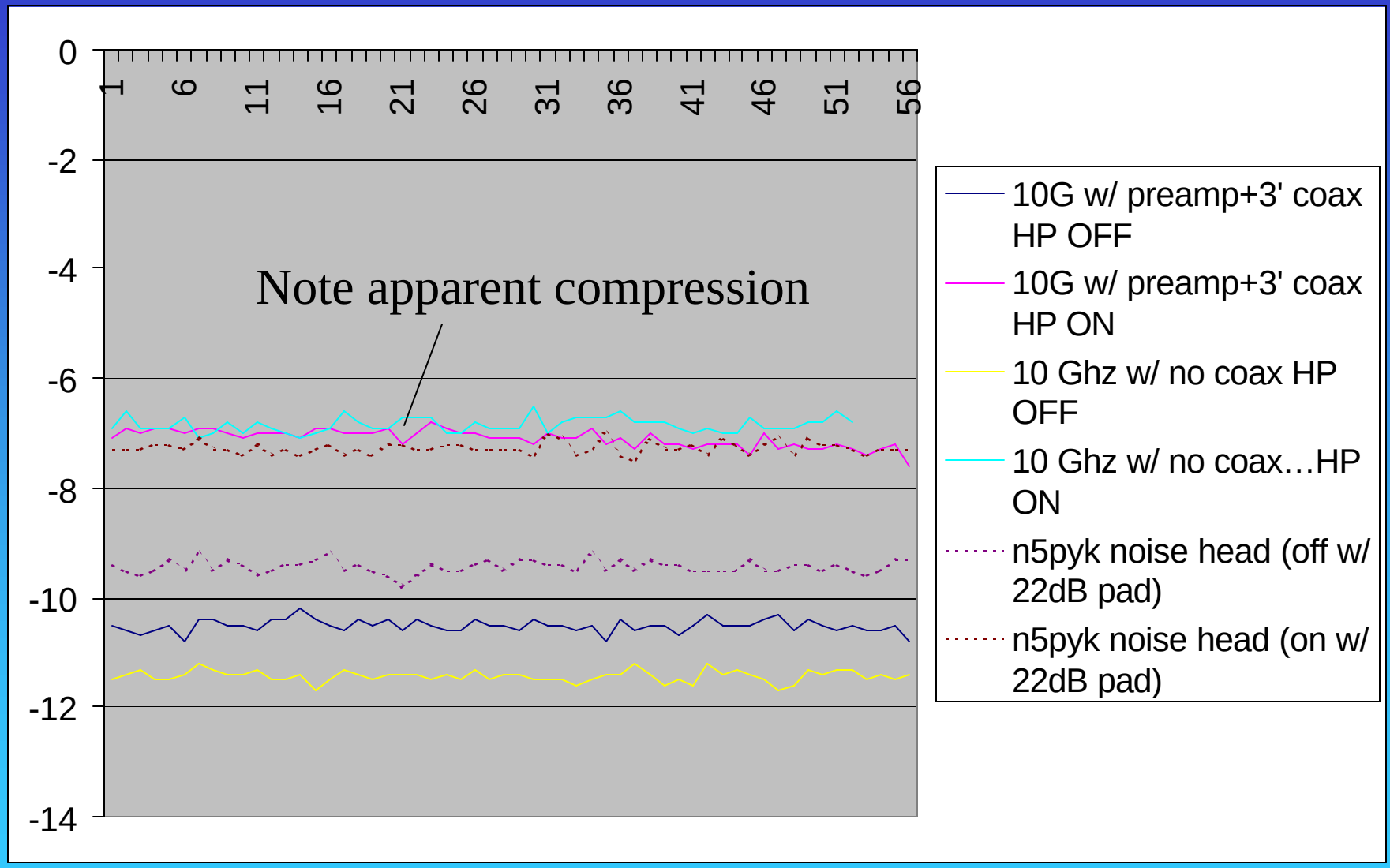
Let WSJT measure the noise levels over several measurements.

Averaging tends to smooth out the variations of noise.



	-4.90	-1.51
1	-4.9	-1.3
2	-4.9	-1.6
3	-4.7	-1.4
4	-5	-1.6
5	-4.9	-1.4
6	-4.9	-1.4
7	-5	-1.5
8	-5	-1.4
9	-4.9	-1.5
10	-5.1	-1.6
11	-4.7	-1.7
12	-5	-1.4
13	-4.9	-1.4
14	-4.7	-1.5
15	-4.7	-1.7
16	-5	-1.4
17	-4.9	-1.4
18	-4.8	-1.6
19	-4.9	-1.4

RF AGC too low



Practical Measurement Results

FT-847 432.1 Preamp on
HP Noise Source AGC S2 on FT-847
80 averages

T-hot = -1.73dB
T-cold=-4.88dB

Y(dB) factor	3.150	dB		Source ENR	5.090	dB
Y factor	2.065			Source Temp	646.263	K
				Tc=To (290K)	290.000	K
	ENR	10 LOG (Y - 1)				
NF dB	5.090	0.275	=	4.81	dB	

Noise Head 5.09 dB ENR

Total system noise figure 4.81 dB

FT-847 432.1 Preamp off
HP Noise Source AGC S2 on FT-847
80 averages

T-hot = 3.62dB
T-cold=1.65dB

Y(dB) factor	1.970	dB		Source ENR	5.090	dB
Y factor	1.574			Source Temp	646.263	K
				Tc=To (290K)	290.000	K
	ENR	10 LOG (Y - 1)				
NF dB	5.090	-2.411	=	7.50	dB	

Noise Head 5.09 dB ENR

Total system noise figure 7.50 dB

FT-847 432.1 Preamp on
N5PYK Noise Source AGC S2 on FT-847
80 averages

T-hot = -1.51dB
T-cold=-4.9dB

Y(dB) factor	3.390	dB		Source ENR	5.230	dB
Y factor	2.183			Source Temp	676.937	K
				Tc=To (290K)	290.000	K
	ENR	10 LOG (Y - 1)				
NF dB	5.230	0.729	=	**4.50**	dB	

Noise Head 5.23 dB ENR

Total system noise figure 4.50 dB

FT-847 432.1 Preamp on
N5PYK Noise Source AGC S2 on FT-847
80 averages

T-hot = 3.72dB
T-cold=1.69dB

Y(dB) factor	2.030	dB		Source ENR	5.230	dB
Y factor	1.596			Source Temp	676.937	K
				Tc=To (290K)	290.000	K
	ENR	10 LOG (Y - 1)				
NF dB	5.230	-2.248	=	**7.48**	dB	

Noise Head 5.23 dB ENR

Total system noise figure 7.48 dB

10 Ghz transverter w/ preamp
HP Noise Source AGC S3 on FT-847
10 samples

T-hot = -3.77dB
T-cold=0.79dB

Y(dB) factor	4.560	dB		Source ENR	5.080	dB
Y factor	2.858			Source Temp	644.110	K
				Tc=To (290K)	290.000	K
	ENR	10 LOG (Y - 1)				
NF dB	5.080	2.689	=	2.39	dB	

Noise Head 5.08 dB ENR

Total system noise figure 2.39 dB

Measured on HP8970, 2.0-2.1dB

10 Ghz transverter w/ preamp
N5PYK Noise Source AGC S3 on FT-847
10 samples

T-hot = -2.43dB
T-cold=3.60dB

Y(dB) factor	6.030	dB		Source ENR	6.580	dB
Y factor	4.009			Source Temp	1029.465	K
				Tc=To (290K)	290.000	K
	ENR	10 LOG (Y - 1)				
NF dB	6.580	4.784	=	1.80	dB	

Noise Head 6.58 dB ENR

Total system noise figure 1.80 dB

Measured on HP8970, 2.0-2.1dB

VSWR problems may be contributing to the lower NF at 10 GHz

10 Ghz transverter w/ preamp
Plus coax relay and 3' of LMR240

Y(dB) factor	3.359	dB		Source ENR	5.440	dB
Y factor	2.167			Source Temp	724.841	K
				Tc=To (290K)	290.000	K
	ENR	10 LOG (Y - 1)				
NF dB	5.440	0.671	=	**4.77**	dB	

Noise Head 5.44 dB ENR

Total system noise figure 4.77dB

See just how bad that coax is hurting your 10 Ghz signal!

Lessons learned

- Building a good noise source for amateur use is not as hard as it might seem
- Using your soundcard and computer, you can make noise measurements with WSJT
- Make sure you have a good, flat attenuator before going too far
- VSWR can cause some variation in measurements.
- Attempt to cross calibrate and make adjustments for abnormalities
- Strive for hundredths of a dB but be happy with tenths