KFPA Single Beam Receiver
Noise and Total Power Stability Measurements

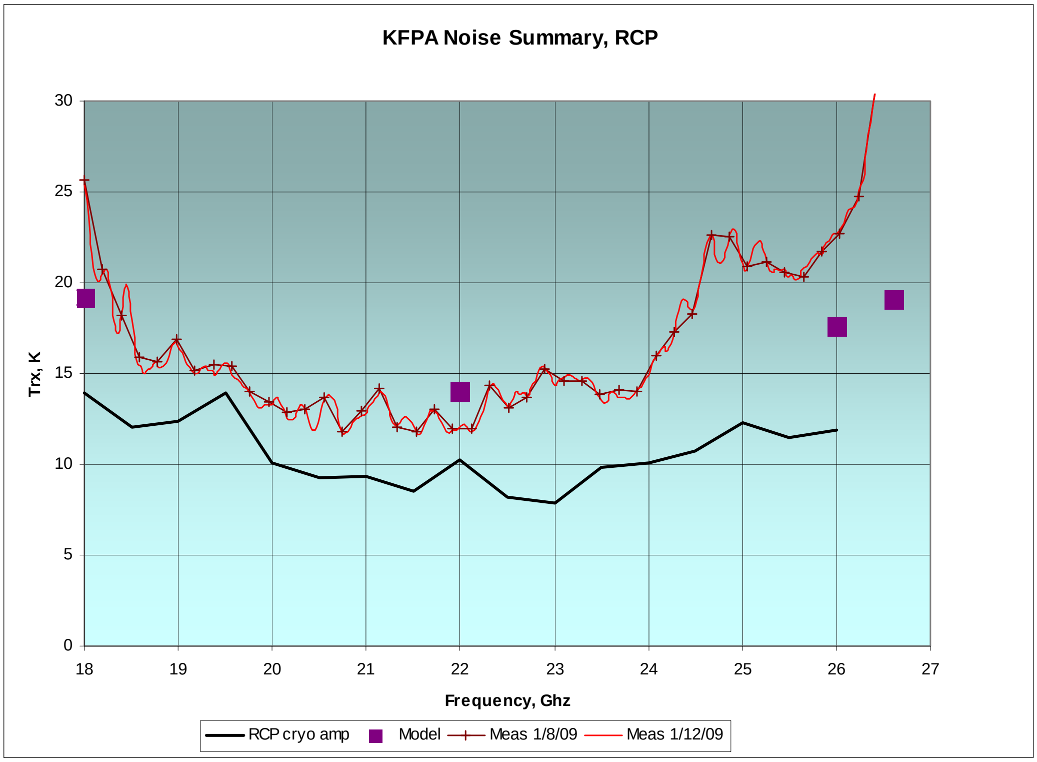
The KFPA noise temperature specification is 36 K maximum over 18-26.5 GHz and 25 K maximum over 75% of that frequency range, referenced to the feedhorn aperture. Figure 1 summarizes laboratory noise measurements taken on the single-beam prototype, and it can be seen that the receiver easily meets the noise temperature specification. Data from two dates are plotted as an indication of the measurement stability. The measurements were done with a LN2 "absorber-in-box" cold load and ambient absorber Y-factor test. In both cases the detected bandwidth was 40 MHz – the frequency step between measurements on 1/8/09 was 200 MHz and on 1/12/09 was 40 MHz. The ripple period in the data is about 250 MHz, approximately corresponding to the distance between the feed aperture and the cryogenic isolators. It is possible the ripple is due to reflections between the cold load and the isolators – if so, it would not be seen on the GBT. Also plotted on Figure 1 are the NRAO LNA noise temperatures measured at the CDL, and a few data points from a receiver noise model. The CDL test set uses a cold horn, vacuum window, and LN2 conical cold load for the Y-factor LNA tests and has 200 MHz detection bandwidth.

Figure 2 compares the measured KFPA noise with that for the older GBT K-band receiver. It can be seen that we can expect about 5 K lower noise with the KFPA over most of the band. The receiver noise calibration signals are also plotted in Figure 2. While the KFPA noise cal shows significant variation over the total frequency range, it is also significantly smoother which should improve spectral baseline calibrations, especially on continuum sources.

Figure 3 shows a total power stability measurement for one of the KFPA channels. The data was taken by sampling an Agilent power meter at about 40 samples/second for 30 minutes.

Figure 4 is an example of the spreadsheet used to model the receiver noise temperature budget. The receiver noise is of course primarily determined by the LNA noise and by input losses. The input isolators were measured at the cold operating temperature, but other input components were measured at room temperature. The room temperature losses for cooled components were scaled by 1/3, typical for copper or gold loss improvements when cooled (see for example NRAO EDIR 321, http://www.gb.nrao.edu/electronics/edir/edir321.pdf). It can be seen from Figure 1 that the budget produces a reasonable prediction of receiver noise below about 24 GHz, but the receiver noise measurements increase faster than predicted at higher frequencies. We do not currently have an explanation for this fact.

Twelve cryogenic LNAs have already been delivered for use in the KFPA 7-beam receiver, and the measured noise is shown in Figure 5.



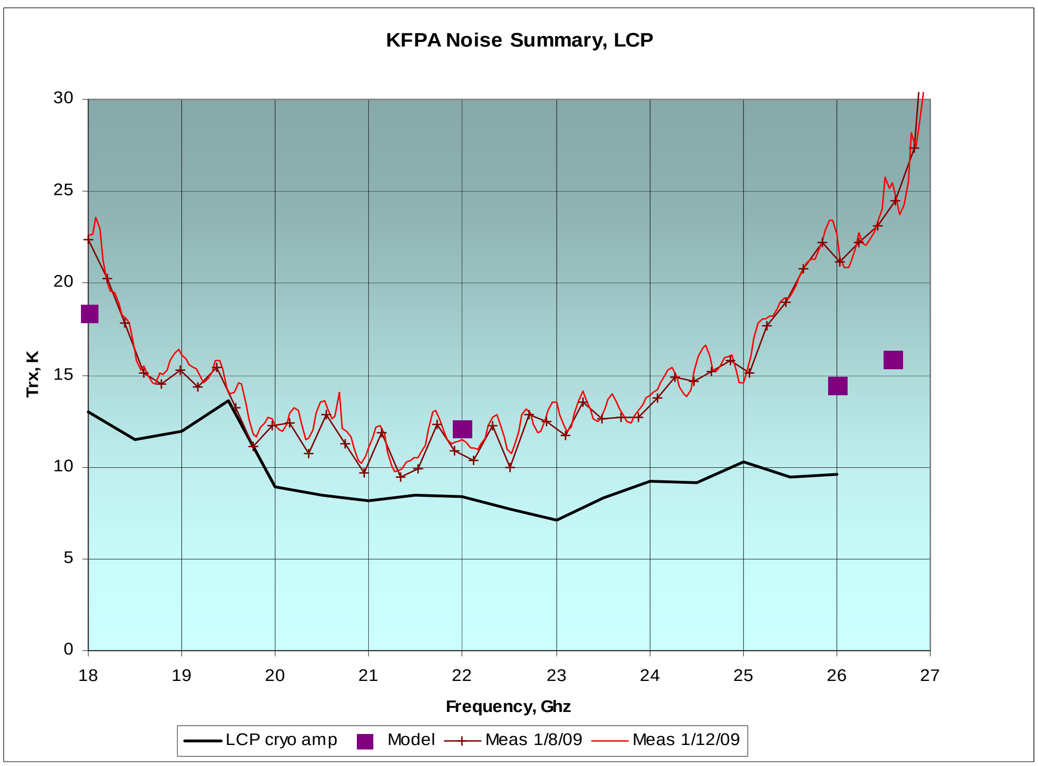
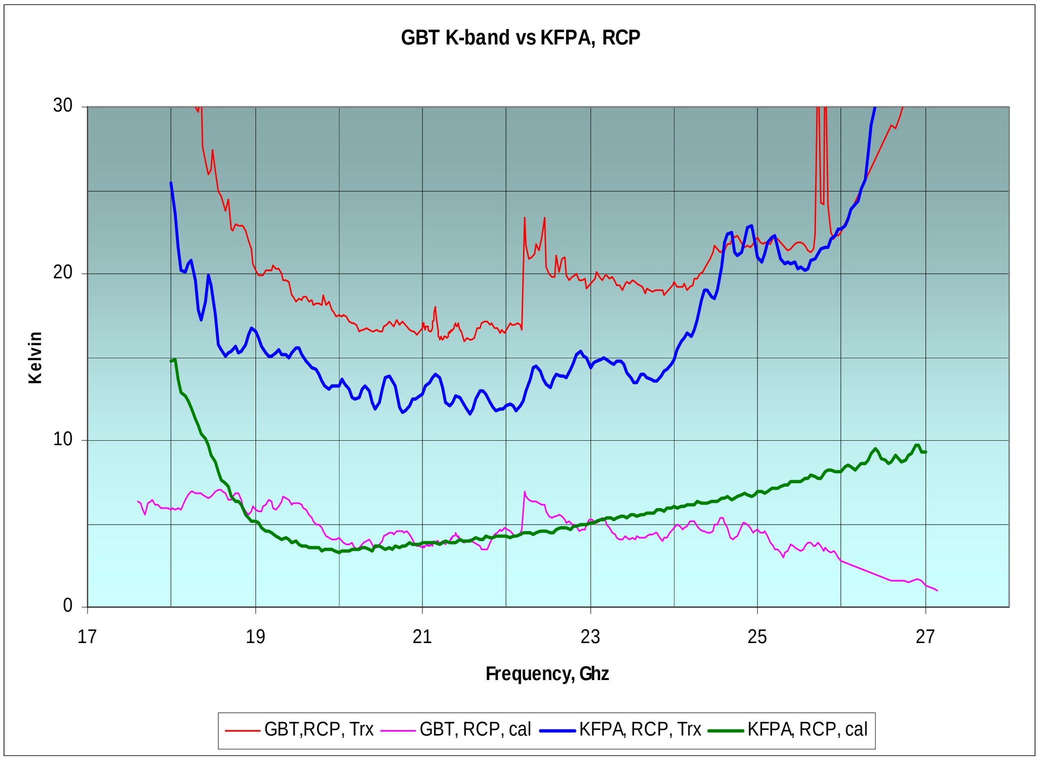


Figure 1: Receiver noise temperature measured at the feed aperture, along with the LNA noise and modeled receiver noise.



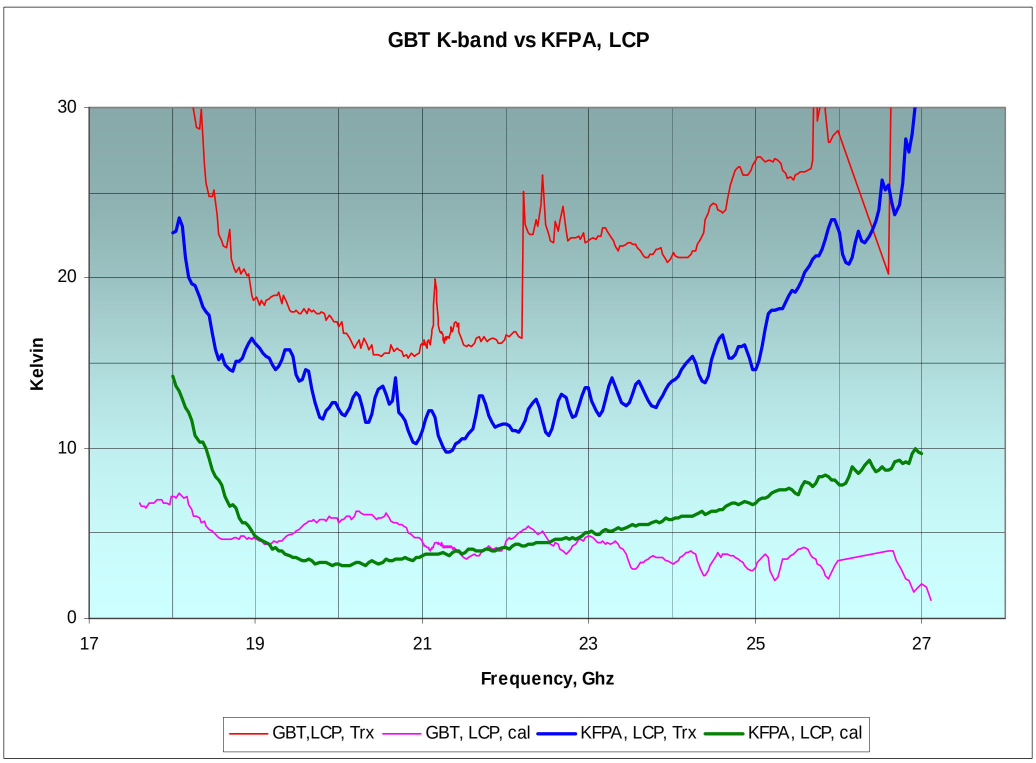


Figure 2: KFPA measured Trx and Tcal compared with equivalent data for the older GBT K-band receiver.

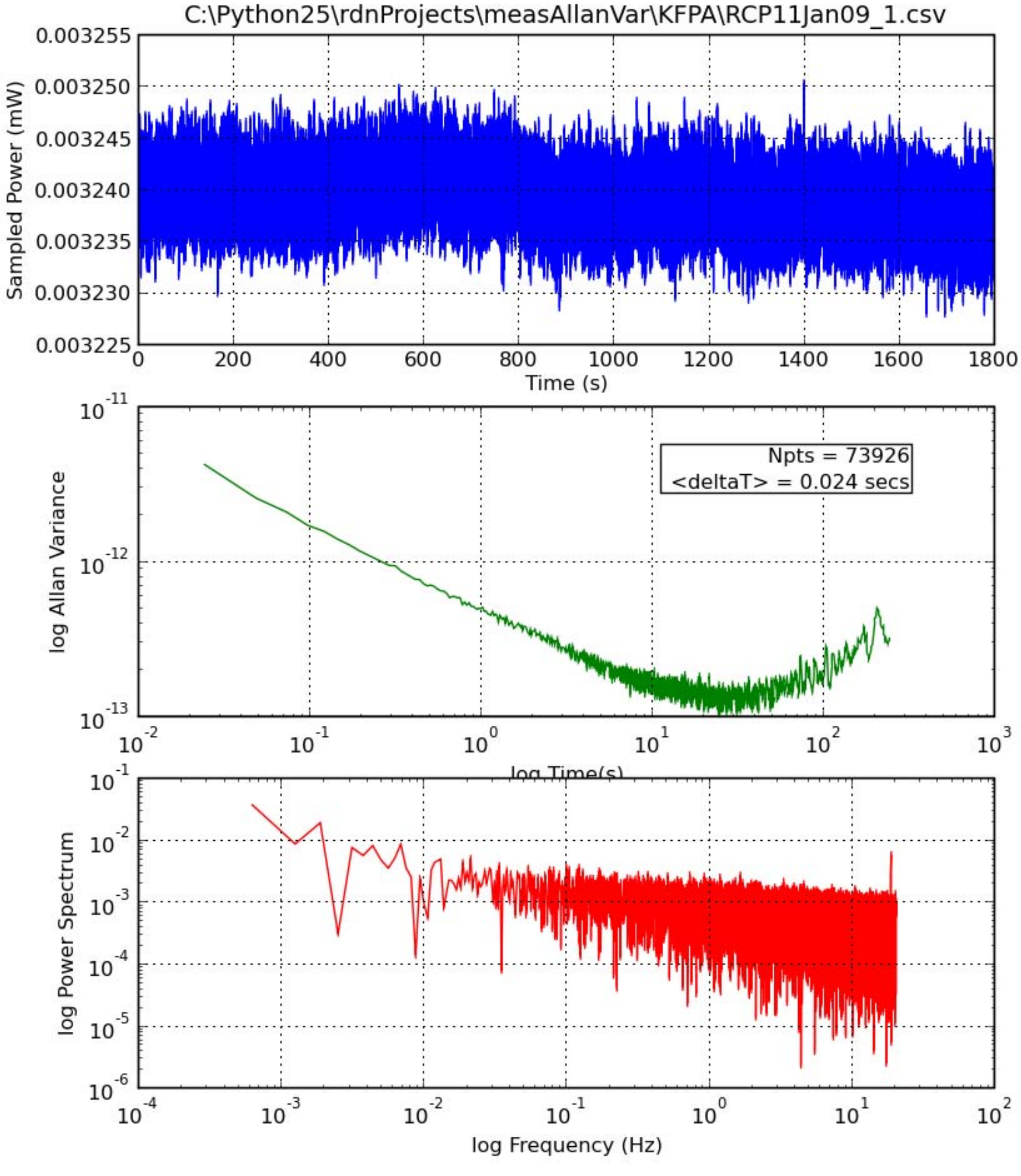


Figure 3: KFPA total power stability measurements. Detected bandwidth 1280 MHz, sampled at about 40 sps.

System Noise Analysis KFPA, IDM Type 2, RCP @ 26 GHz

1/12/2009

		1	2	3	4	5	6	7	8	9	10
	Signal	Horn & Win	Polarizer	OMT	WG	Cal Coupler	Isolator	Amplifier	WG & Win	WG	Amplifier
Input Tsource (K)	90							NRAO			ALH476
Physical Temperature (K)		300	12	12	12	12	12	12	100	300	300
Gain (dB)	0	-0.02	-0.12	-0.03	-0.03	-0.04	-0.40	31.00	-0.50	-0.01	20.00
Cum. Gain (dB)	0	-0.02	-0.14	-0.17	-0.20	-0.24	-0.64	30.36	29.86	29.85	49.85
Gain (ratio)	1	1.00	0.97	0.99	0.99	0.99	0.91	1258.93	0.89	1.00	100.00
Cum. Gain (ratio)	1	1.00	0.97	0.96	0.95	0.95	0.86	1085.68	967.61	965.38	9.65E+04
Device Noise Temp (K)		1.38	0.34	0.08	0.09	0.11	1.16	12.00	12.20	0.69	170.00
Sys Noise Temp (K)		**17.58**	**16.12**	**15.35**	**15.16**	**14.96**	**14.71**	**12.36**	**454.42**	**394.13**	**392.53**
Input Loss Contrib. (K)		**1.46**	**0.77**	**0.19**	**0.21**	**0.25**	**2.35**				
Device OND (mW/MHz)	1.24E-12	1.90E-14	4.51E-15	1.14E-15	1.25E-15	1.52E-15	1.46E-14	2.08E-10	1.50E-13	9.52E-15	2.35E-10
Sig. OND (mW/MHz)		1.24E-12	1.22E-12	1.22E-12	1.21E-12	1.20E-12	1.10E-12	1.40E-09	1.43E-09	1.43E-09	1.43E-07
Total OND (mW/MHz)	1.24E-12	1.26E-12	1.23E-12	1.22E-12	1.21E-12	1.20E-12	1.11E-12	1.61E-09	1.43E-09	1.43E-09	1.43E-07
Sig OND / Dev OND (dB)		18.13	24.32	30.28	29.84	28.98	18.76	8.26	39.79	51.76	27.84
Output Noise Pwr (mW)	1.61E-08	1.63E-08	1.59E-08	1.58E-08	1.57E-08	1.56E-08	1.44E-08	1.59E-05	1.41E-05	1.41E-05	1.41E-03
Output Noise Pwr (dBm)	-77.92	-77.87	-77.98	-78.00	-78.03	-78.07	-78.41	-47.99	-48.49	-48.50	-28.49
Bandwidth (MHz)	13000	13000	13000	13000	13000	13000	13000	10000	13000	13000	13000
P1dB (dBm)								0			14

11	12	13	14	15	16	17	18
BPF	Mixer&Pads	Amplifer	LPF&ATT	Amplifier	Attenuator	Amplifier	Attenuator
		ALH444		ALH444		ALH444	
300	300	300	300	300	300	300	300
-1.00	-16.00	17.00	-6.00	17.00	-3.00	17.00	-3.00
48.85	32.85	49.85	43.85	60.85	57.85	74.85	71.85
0.79	0.03	50.12	0.25	50.12	0.50	50.12	0.50
7.67E+04	1.93E+03	9.65E+04	2.42E+04	1.22E+06	6.09E+05	3.05E+07	1.53E+07
77.68	11643.22	120.00	894.32	120.00	298.58	120.00	300.00
22253.19	**17614.64**	**150.00**	**1503.33**	**152.98**	**1652.71**	**678.67**	**28000**
8.51E-13	4.04E-12	8.30E-11	3.10E-12	8.30E-11	2.07E-12	8.30E-11	1.94E-10
1.14E-07	2.85E-09	1.43E-07	3.60E-08	1.80E-06	9.04E-07	4.53E-05	2.27E-05
1.14E-07	2.86E-09	1.43E-07	3.60E-08	1.80E-06	9.04E-07	4.53E-05	2.27E-05
51.25	28.49	32.37	40.65	43.37	56.41	57.37	50.69
1.13E-03	2.85E-05	1.43E-03	3.60E-04	1.80E-02	9.04E-03	4.53E-01	2.27E-01
-29.45	-45.45	-28.44	-34.44	-17.44	-20.44	-3.44	-6.44
9000	13000	12000	8000	12000	12000	12000	12000
		19		19		19	

Definitions:

Input Tsource (K) System input source temperature, e.g. from the atmosphere or a test load. Value enters into noise power calculations. This and all other shaded cells to be entered by the user.

Physical Temperature Actual physical temp of the selected device. This quantity can be entered by the user.

Gain Power gain of the selected device, expressed in dB and as a ratio.

Cum. Gain Cumulative power gain through all devices prior to and including the selected device. Equals the sum (or product for ratios) of individual gains.

Device Noise Temp (K) Noise temperature of the selected device. Entered for amps by the user for, for losses calculated T = (Loss-1)Tphysical, Loss = 1/Gain(ratio).

System Noise Temp (K) Noise temperature referenced to device input. Caluclated right-to-left using Tin = Ti + (Ti+1)/Gi. Value in last column entered by user to include following receiver noise temperature.

Input Loss Contrib. (K) Increase in system noise due to the column component input loss.

Device OND (mW/MHz) Component of the Device Output Noise Density due to device noise temperature. Equal to Boltzmann's Constant * Device Noise Temp * Device Gain

Sig. OND (mW/MHz) Component of the device OND due to noise leaving the previous device. Previous device Total OND * Device Gain.

Total OND (mW/MHz) Total power at the device output. Sum of above two components.

Sig OND / Dev OND (dB) Ratio of the two components of OND. Large number indicates the device degrades system noise temperature by relatively small amount.

Output Noise Pwr Device total output noise power. Takes into account bandwidths of device and previous devices.

Bandwidth (MHz) Bandwidth of the selected device, in MHz. This quantity can be entered by the user.

Figure 4: Spreadsheet used to model the receiver noise budget.

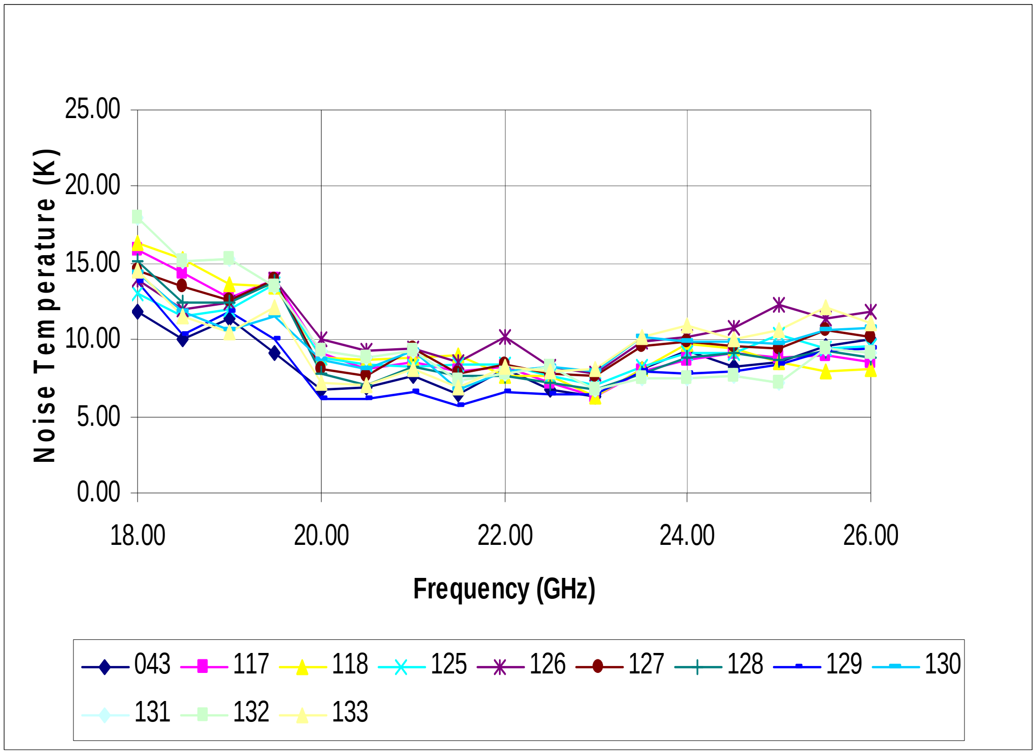


Figure 5: Measured noise for 12 of the LNAs currently built for the 7-beam KFPA. Amplifiers used in the single-beam test receiver are SN125 (LCP) and 126 (RCP).