

# **Prototype Development of the S/X RF-to-IF System for the Dedicated Interferometer for Rapid Variability**

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## **Abstract**

We discuss the development of low-noise, radio-frequency receivers at S-band (2.2 GHz) and X-band (8.4 GHz) to be used for the Dedicated Interferometer for Rapid Variability, or DIRV. Components selected for the receivers were individually and collectively tested for their noise characteristics and their susceptibility to outside radio-frequency interference. The completed system had noise figures of 62K at S-band and 108K at X-band.

## **Introduction**

When completed, DIRV will be a two-element radio interferometer located at the Pisgah Astronomical Research Institute (PARI). Two hybrid S/X (2.2 and 8.4 GHz) feeds, originally built and used in NRAO's Greenbank Interferometer, will be installed at the prime focus of PARI's two 26-m radio antennas. The scientific goal of the instrument is to observe the rapid variability of extragalactic radio sources due to scintillation originating in our own galaxy. The radio flux of these sources is too weak to be measured by a single 26-m antenna, so, we are constructing an interferometer to reduce confusion and improve signal-to-noise. In addition, we must optimize the receivers to have low noise and high gain so that the system temperature is minimized.

## **S/X Receiver**

The prototype receiver system, designed by C. Osborne (PARI, 2007), begins at each frequency band with a high gain, low noise, pre-amplifier that is followed by isolators, filters and post-amplifiers prior to transmission of the signal via fiber optics from the antenna to the control room at PARI. A fiber optic receiver converts the signal back to a radio-frequency band (RF), where it is then downconverted to a low intermediate frequency (IF) band for insertion into the DIRV correlator (also under construction). The power output of each component had to be carefully set to avoid amplifier compression but provide enough signal level for input to the fiber optic transceiver and the correlator.

## **System Temperature Measurement**

To determine the system temperature of the amplifiers and the receivers as a whole, we measured the change in output power level through a component (or series of components) when an input source of known temperature/power was toggled on and off. We used a HP 346B noise source with an ENR of 15 dB (ratio of noise temperature when powered on over the room temperature), which was useful over a range of 10 MHz to 18 GHz. Slight variations of the ENR were labeled on the 346 B package and factored in our measurements. Power was measured using two devices: a Rohde and Schwarz NRP-Z21 Average Power Sensor and a Rohde and Schwarz FSU Spectrum Analyzer. Power could be directly measured across a total bandwidth of 18 GHz using the Power Sensor,

measured by eye using the Spectrum Analyzer, or by using the Spectrum Analyzer's noise figure measurement function.

Calculation of the noise figure / system temperature was achieved by solving the following equation:

$$T_{\text{sys}} = 293\text{K} (10^{\text{ENR}/10} - 10^{\Delta/10}) / (10^{\Delta/10} - 1),$$

where  $\Delta$  is the difference in power, in dB, between noise source toggled on and off.

This worked well for the individual components (see Table 1), but did not work as well for longer chains of components, especially those with multiple amplifiers. Either the Power Sensor or Spectrum Analyzer would experience input level compression effects unless appropriate filters and/or attenuators were used to limit the power input to the sensor.

Table 1: Pre- and Post-amplifier Noise and Gain

Amplifier	Noise Figure (dB NF)	Temperature (K)	Gain (dB)	Frequency (GHz)
Kuhne S-band Pre-amplifier	0.892	66	31	2.2
Mini-Circuits ZX60-3018G-S+	2.867	271	19	2.2
Kuhne X-band Pre-amp	1.135	87	28	8.4
Ciao X-band Post-amp	1.968	166	31	8.4

### RF-to-IF Results

The results that we got, after re-ordering the path of components, were encouraging. The final system temperature of the 2.2-GHz system is 62K from the pre-

amp, through the fiber, and through the downconverter. At 8.4 GHz, the system temperature was measured to be 108K after the downconverter.

One result of note was that, as we went through the 8-GHz chain, we noticed an abnormally high system temperature after the second post-amplifier from the design. As we looked at both the spectrum and the averaged power from the Power Sensor, we noticed that noise out of our bandpass was amplified in the last post amp, resulting in an abnormally high system temperature. Our solution to this problem was to move a filter originally placed after the fiber system to a location between the two post amps. This cut down on the amount of out-of-band noise from the first post amp so the second would not exhibit excess amounts of noise power.

## **Conclusion**

The system does not require any major changes from the initial setup. The only change needed is to move the above mentioned filter in the 8-GHz system.