Internal Technical Report

Four Channel Correlated Noise Source with Variable Correlation Coefficient

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Date: 03-01-2000

1 Introduction

The basic measurement made in a radio interferometer (like the GMRT) is the cross correlation of signals from different antennas. The hardware unit which performs the correlation is called a correlator. Since the system noise (receiver + ground spillover + “resolved” sky background) of different antennas are independent, observation on a source produce a correlation coefficient less than unity. Typically for astronomical sources the correlation coefficient varies over $3 \times 10^{-3}$ to 0.4 in the frequency band of the GMRT. To test the GMRT correlator, we designed and built a correlated noise source with correlation coefficient varying in this range. From practical considerations, the number of outputs is restricted to four. Provision to feed an external correlated signal (for example a sine wave) also exists.

2 Principle of operation

Consider two signals $v_1$ and $v_2$. Let a common signal $v_c$ be added to the two signals. The correlation coefficient of the two signal is defined as

$$\rho = \frac{\langle (v_1 + v_c) \times (v_2 + v_c) \rangle^*}{\sqrt{\langle (v_1 + v_c)^2 \rangle \langle (v_2 + v_c)^2 \rangle}},$$

(1)

where the angle brackets indicate time average. If $v_1$, $v_2$ and $v_c$ are independent Gaussian random noise then the above equation becomes

$$\rho = \frac{\langle v_c^2 \rangle}{\sqrt{(\langle v_1^2 \rangle + \langle v_c^2 \rangle)(\langle v_2^2 \rangle + \langle v_c^2 \rangle)}}$$

(2)

Let $P_1$, $P_2$ and $P_c$ are the powers of noise $v_1$, $v_2$ and $v_c$ respectively and let $P_1 = P_2 = P$, then

$$\rho = \frac{P_c}{P + P_c}$$

(3)

The above equation shows that a variable correlation coefficient between two noise sources can be obtained by adding the noise power from a third source ($P_c$) and varying its power.
3 Block diagram

The basic block diagram of the designed system is given in Fig. 1. It consists of four independent noise sources and one common noise source all realized using reverse biased zener diodes. Compared with avalanche solid state noise diode, Zener diode offers a simple and low cost method of generating the noise. Moreover, in our application the bandwidth needed is not large (< 16 MHz) and "flat" spectral density over this bandwidth is not required (~ 3dB). The output of the common noise source is fed to a four way power splitter and combined with the outputs of the four independent noise sources. The amplitude of the common noise source is controlled using a variable attenuator (0 to 15 dB and an external 10 dB fixed attenuator). In addition to this, the common noise source alone can be switched off. An external input can also be combined with all the four noise sources. Automatic level control (ALC) circuits (old GMRT ALC circuit) are introduced at the four outputs to maintain the power level to 0 dBm as required by the correlator. The output power can be further adjusted using a 0/2dB attenuator. The output bandwidth is restricted to 12 MHz using elliptic low pass filters.

4 Circuit Schematic

The schematic of the circuit is shown in Fig 2a,b. The noise generated by the zener diode is amplified using operational amplifier AD5539. The operational amplifiers are also configured to add the signal from the external input to the common noise source as well as to add the common noise to the four independent noise sources. The noise bandwidth is restricted to 12 MHz using elliptic low pass filters. A home made 4 way power splitter is used to divide the common noise source power for combining with the four independent noise sources. A 0/2 dB attenuator is implemented using reflective type GaAs FET MMIC switches (SW239).

5 System Characteristics

Fig. 3 shows the spectra at points (A) and (B) (marked in Fig. 1). For these measurements a 12 dB fixed attenuator was used. The output power spectra measured with a spectrum analyzer when the attenuator values are changed between 0 dB and 15 dB and also when the common noise source is switched off are shown in Fig. 4. Spectra of all the four outputs are shown in the same plot. The output power variation is about 3 dB.

The following measurements are made with 10 "good" multipliers of the GMRT correlator. The four channels of the noise source are connected to sampler inputs C00 to C03. The variation of correlation coefficient for different attenuator values is plotted in Fig. 5 for a narrow bandwidth of 125 KHz about 10 MHz. For these measurements a 10 dB external fixed attenuator is used along with the variable attenuator. The self spectra of all the four outputs are shown in Fig. 6. Fig. 7 and 8 are the 6 cross spectra obtained for 0 dB and 7 dB variable attenuator values. The cross coupling between the four outputs when the common noise source is switched off is shown in Fig. 9. The cross coupling measurements for channels 1, 2 and 3 are limited by the inherent coupling in the correlator. This limitation is checked
using two independent noise sources. Please note that channel 4 of the system seem to have higher cross coupling, especially with channel 3.

6 Acknowledgment

We thank T. L. Venkatasubramani and Ajith Kumar for providing tested old GMRT AL PCBs and circuits.
Fig 1: Four Channel Correlated Noise Source
Fig. 2a: 4 CHANNEL CORRELATED NOISE SOURCE.

Drawn by M. Gopinathan
4 CHANNEL CORRELATED NOISE SOURCE.
Spectrum at point B in Fig 3

All attenuators off

Spectrum at point C in Fig 3

All attenuators off

Common noise source off

Common noise source on

Spectrum at point D

Fig 3

The caption reads: "temp"

The text on the page includes technical details related to a spectrum analyzer.
Fig. 5

Correlation Coefficient

C01:C00  C02:C01  C02:C00  C03:C02  C03:C01  C03:C00

For this plot, each tick mark corresponds to 10 miles and 100 feet.

125 ft: 102
Cron power spectrum when the Common noise source is off.

- Channel 1
- Channel 2
- Channel 3
- Channel 4

Channel number (frequency range 0 to 16 kHz)

Fig 9