URSI - RCRS 2022, IIT (Indore), India, 1 - 4 December, 2022

Aperture Array Calibration and Beamforming for the Expanded GMRT Prototype System

Kaushal D.buch[(1)*], Bela S. Dixit [(1)], Ajithkumar B [(1)].and Jayaram N. Chengalur[(1)]
(1) Giant Metrewave Radio Telescope, NCRA-TIFR, Pune, 410504, India, e-mail:
kdbuch@gmrt.ncra.tifr.res.in; bela@gmrt.ncra.tifr.res.in; ajit@ncra.tifr.res.in; chengalur@ncra.tifr.res.in

The Expanded Giant Metrewave Radio Telescope (eGMRT) [1] prototype aperture array beamformer is implemented on an FPGA and tested in the free-space test range at the GMRT site. The beamformer is a single FPGA implementation processing 32 antenna inputs having a bandwidth of 32 MHz producing five independent beams. In the calibration mode, we configure the FPGA in raw voltage mode to acquire data from the elements, carry out an offline correlation, and compute beamformer weights. In the beamforming mode, we configure the real-time beamformer design in the FPGA and program it with different weights to produce independent beam outputs. The testing of this system is carried out in the L-band (1.1-1.7 GHz) using a 144-element Vivaldi array from ASTRON. We radiate signal in the free-space test range using a 3m diameter parabolic dish antenna with a cross-dipole at the prime focus.

We carried out conventional (coherent) beamforming for uniform linear and rectangular array mode, primarily in the 8x1 and 4x4 configurations. We present the aperture tapering and beamsteering results from this experiment. Further, we have implemented the maxSNR-based calibration technique to optimize the beamformer output's signal-to-noise ratio (SNR). This process requires off-source (radiation off) and on-source (radiation on) measurements to compute the weights. We explain the implementation of this technique in the current test setup for broadband noise radiation. We also compare the results from conventional (coherent) beamforming and maxSNR beamforming at different frequencies and show that the improvement in the SNR depends on the amount of mutual coupling. Fig. 1 shows the comparison results from an 8-element linear array. The left image shows the off-source correlation matrix, which indicates the amount of mutual coupling between the elements. The plot on the right shows the improvement in SNR, which in this case is about 1 dB for beamforming carried out using weights computed using the maxSNR method. Finally, we will describe the results from 30-element beamforming and a comparison between the two beamforming methods.

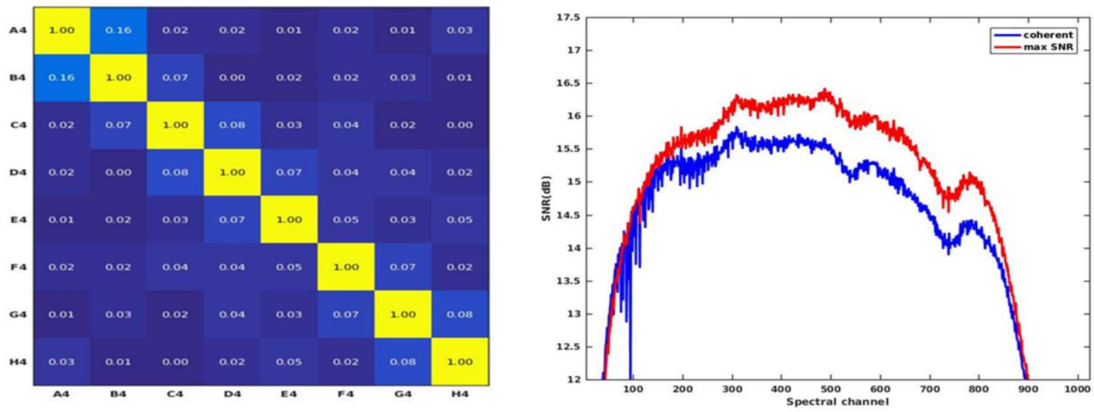

Figure 1. Left: Normalized cross-correlation for an 8-element uniform linear array (with radiation off), Right: Comparison of signal-to-noise ratio between coherent and maxSNR methods of beamforming for an 8-element uniform linear array.

1. Patra et al., "The Expanded Giant Metrewave Radio Telescope", MNRAS, 483, 3007-3021, 2019.