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Development of the LOFAR2.0 Advanced HBA Frontend

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The Low-Frequency Array (LOFAR) consists of thousands of low-band antennas (LBAs) and high-band antennas (HBAs) operating in the 10-90 MHz and 110-240 MHz bands respectively [1]. LOFAR2.0 is a major upgrade of the LOFAR stations [2]. The LOFAR4SpaceWeather project investigated several ways in which the HBAs can be improved in order to comply with the LOFAR2.0 requirements [4]. Based on this knowledge, new HBA frontends, called the advanced HBA frontend (AHBFE) are being developed in the DANTE project.

The LOFAR HBAs consist of tiles, each with 4x4 dual-polarized antenna elements that are combined in an analog beamformer so that each tile can be considered as a single active antenna, pointing in a certain direction. Each of the dual-polarized antenna elements has a frontend PCB that consists of a low-noise amplifier (LNA), band-pass filter, digitally controlled true-time delays and an output amplifier for each of the two polarizations. The two output signals are transported to two central summator units in the tile, one per polarization. Here the signals from the 16 frontends are combined to form the analog beam.

New HBA frontends are needed for the following reasons:

- Various components in the LOFAR frontend are getting obsolete. The most critical obsolete component are the low-noise transistors. The new LNA therefore uses new low-noise transistors.
- The linearity of the current frontends are not sufficient for the future of LOFAR, as strong radio frequency interference (RFI) in Europe will likely be increasing. The new frontend therefore has much better linearity performance, making it possible to perform radio astronomical observations among higher RFI levels.
- The transmission line time delays are very sensitive to the PCB manufacturing process. The new frontend uses discrete time delays which can be manufactured more precisely, resulting in higher beamforming efficiency.

The most challenging aspect has been the design of the new LNA, as it needs to meet stringent requirements on gain, noise figure, linearity, power consumption, cost, output impedance and unconditional stability. The selected low-noise transistor did not have good noise parameters in the HBA frequency range so that the noise parameters needed to be extracted. This was done by measuring the output noise for five different input impedances (terminated input, open and shorted input and using an open and shorted coaxial cable). Using the new noise parameters, good agreement between the measured and simulated performance of the LNA was obtained. The linearity requirement can only be met by using a fully differential configuration. However, the transistor has never before been used in a fully differential configuration as its high gain bandwidth (up to 12GHz) and parasitic effects make it highly unstable. It is shown that unconditional stability can be achieved using feedback in combination with careful PCB layout. Several iterations of PCB electromagnetic simulation and prototype measurements, however, were needed to converge to an unconditional stable amplifier.

All the individual RF blocks of the AHBFE has been tested using prototypes and are compliant to the LOFAR2.0 DANTE requirements.

References

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