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Calibration of Apertif, the new Phased Array Feed System for the Westerbork Array

B. Hut* [(1)], W.A. Van Cappellen [(1)]
(1) ASTRON, P.O. Box 2, 7900 AA, Dwingeloo, http://www.astron.nl

Extended Abstract

The APERture Tile In Focus (APERTIF) project aims to increase the survey speed of the Westerbork Synthesis Radio Telescope (WSRT), by installing Phased Array Feeds (PAFs) on 12 reflector antennas. This system can form 37 compound beams simultaneously and have an instantaneous bandwidth of 300 MHz. This increases the Field-of-View (FoV) to 8 square degrees. All hardware has been installed in the antennas in 2015 and early 2016. At the same time a major upgrade of the dish mechanics was carried out. First light measurements were done in October 2015 using the first three dishes. All central systems, among other things the correlator and datawriters have been installed in mid-2016 and since then commissioning is in full swing.

In this paper, we report on the calibration of the PAF system. The system forms 37 compound beams out of the 121 receiver chains. These receiver chains need to be weighted. Between the receiver chains, electronic gains and phases can drift due to for example changing ambient or cable temperatures. These drifts affect the beamshapes of the compound beams. Given the beam stability requirements, the beamformer weights should be known to an accuracy of 0.3 dB in amplitude and 2 degree in phase. To compensate for the electronic gain variations, the beamformer weights will be updated during an astronomical observation. This online calibration is a 6-step scheme. First, the data in the regular data path is flagged as invalid to avoid calibration data to enter the astronomical data products, then an antenna on the reflector surface will radiate broadband noise to the PAF (see Figure XA). A dish-level correlator determines the complex correlation vector of all PAF elements against the noise source for both the cases that the noise source is turned on and off. These two vectors are input to an algorithm that returns corrections to the beamformer weights. The corrections are applied in the beamformer and as a final step the 'invalid data' flag is cancelled to continue the observation. The robustness of this scheme will be tested in the upcoming months.

Each of the 37 compound beams has a different set of weights, which currently are determined by single dish tests on a bright astronomical source for a given arrangement of compound beams. Such a measurement for a bandwidth of 300 MHz takes 10±1 hours. Interpolation of beamformer weights over frequency may speed up this process. Figure XB shows the beamformer weights for 7 receiver chains, for an on-axis compound beam. It shows that the weights are smooth over frequency, and that interpolation may be used. A detailed analysis of the beamformer weights is also part of the planned experiments. This also includes interferometric measurements to determine beamformer weights in a much faster alternative way. Complex radiation patterns of all individual receiver chains could be used to calculate a set of weights, given any arrangement of compound beams. This would eliminate the long single dish measurements, when a new compound beam arrangement is proposed. Consequently, the time to determine a set of weights for a new compound beam arrangement would be reduced to a few minutes.

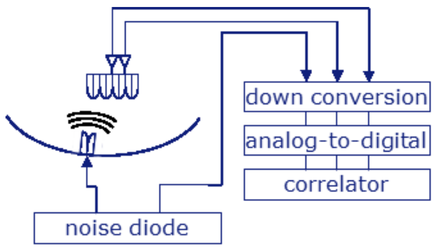

Figure 1. Block diagram of the calibration system.

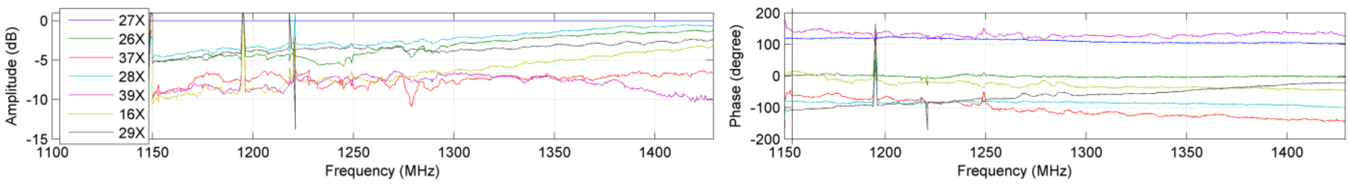

Figure 2. Beamformer weights for 7 receiver chains as function of frequency. These weights form an on-axis beam.