Mid Frequency Aperture Array Technology Developments for the SKA

J. G. Bij de Vaate, P. Benthem, R. Witvers, R. van den Brink
ASTRON
Dwingeloo, The Netherlands
vaate@astron.nl

Y. Zhang
Manchester University
Manchester, UK
David.zhang@manchester.ac.uk

S. A. Torchinsky
Station de radioastronomie
Observatoire de Paris, France
torchinsky@obs-nancay.fr

***Abstract*—This paper describes the technology developments of antenna arrays for the mid frequency instrument of the Square Kilometre Array radio telescope.**

Keywords—radio astronommy; aperture arrays;

I. INTRODUCTION

The Square Kilometre Array, SKA [1], the next generation radio telescope, is under development now. The SKA will be 100x more sensitive and will to survey the sky a million times faster than any present radio telescope. The SKA will be realized in Australia and in South Africa.

The SKA will be built in two phases: SKA_1, which is approximately 10% of the final system, followed by SKA_2, the complete system. Besides a ramp-up in size, SKA_2 will also be deployed with more advanced technology. One of the advanced technologies which is being considered is Aperture Array (AA) technology for the frequency band of 350-1450 MHz. An AA system in this frequency band would have unprecedented performance advantages compared to a dish based array: 1) A fully sampled unblocked aperture, 2) Large field of view (~100 sq. deg @ 1GHz) and, 3) Multiple independent fields of view. This creates an extremely fast survey machine for HI at cosmological redshifts and will allow a billion galaxy survey for Dark Energy science.

Note that low frequency aperture arrays are considered to be more mature technology, extensively used in systems like LOFAR [2] and therefore ready for SKA_1.

II. SKA WORKPACKAGES

The SKA design effort is being executed by a number of international consortia, all reporting to the SKA office at Jordrell Bank (UK). The consortium for the AA-mid work consists of ASTRON (lead), Observatoire de Paris, University of Manchester, University of Cambridge, University of Bordeaux, KLAASA (Hefei, China) and associate members including African institutes. This Aperture Array MID frequency (AAMID) consortium recently started the design work which should lead to a Preliminary Design Review in 2016. Figure 1 gives an artist impression of a possible realization of the AA-mid SKA system: hundreds of ~70m diameter stations.

The work of the AAMID consortium builds on a long international cooperation which started with the SKA Design Study (SKADS), an EU FP-6 project, in 2005.

Fig. 1. Artist Impression of SKA_2 AA-mid.

III. APERTURE ARRAY DEMONSTRATORS

The SKADS project realized two large AA demonstrators, one in Westerbork, the Netherlands and one in Nançay, France: the EMBRACE (Electronic Multi Beam Radio Astronomy Concept) systems [3,4]. EMBRACE has 5000 to 10.000 Vivaldi antennas followed by a dual beam analogue

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beam former and a digital processing back-end. Figure 2 gives a photograph of one the arrays. EMBRACE demonstrated antenna array performance but also basic radio astronomy: HI Milky Way observations, nearby galaxy and pulsar detections [4].

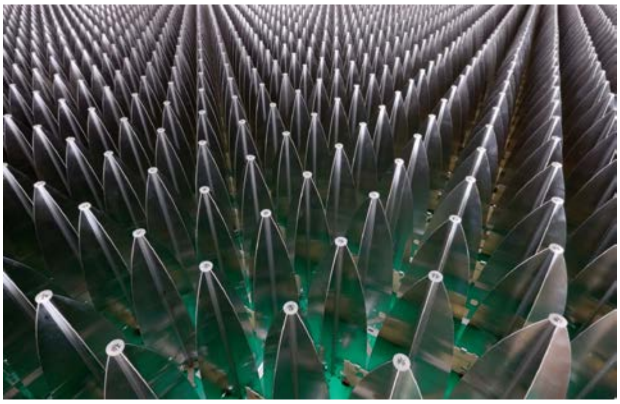

Fig. 2 Photograph of the EMBRACE antenna array

Although successful, significant further development is required in order to bring the SKADS technology to a sufficient readiness level for SKA deployment. Cost reduction, power consumption reduction and basic performance, e.g. noise temperature, have to be improved.

IV. TECHNOLOGY DEVELOPEMENT

The following gives a snap shot of the technology development work in AAMID:

A. Antenna design

Good results have been achieved with the Vivaldi antenna in EMBRACE. EMBRACE is however a single polarization instrument, therefore design effort will be required to realize a dual pol. system [5]. Besides the Vivaldi a new planar antenna concept is being considered, the Octagonal Ring Array (ORA) [6]. The ORA concept has the potential of an improved polarization performance and lower high volume production cost.

B. Noise temperature

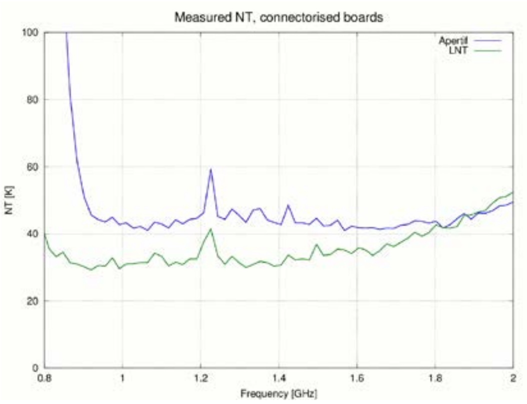

Fig. 3 Low Noise Tile (LNT) receiver noise measurements

The use of a recently released Skyworks transistor and an improved Low Noise Amplifier (LNA) design demonstrated good low noise temperatures, the Low Noise Tile (LNT) curve in Figure 3. The frequency bandwidth in this test was limited due to local RFI conditions. Besides off-the-shelf transistors also custom IC are developed for the LNA.

C. Integration

EMBRACE uses a beam former IC (NXP process) designed by the Obs. de Paris [7]. Development is required to improve the current design, integrate more components on a single chip and to reduce the complexity of the receiver by means of direct sampling (>3Gsample/sec) for which an ADC is developed.

D. Site environmental tests

The environmental conditions in the Karoo, the South African SKA site, are very different from the conditions at European sites. Therefore new tile development should combine resistance to a hot desert climate with further cost reduction. Figure 4 gives one the options which will be tested at the SKA site.

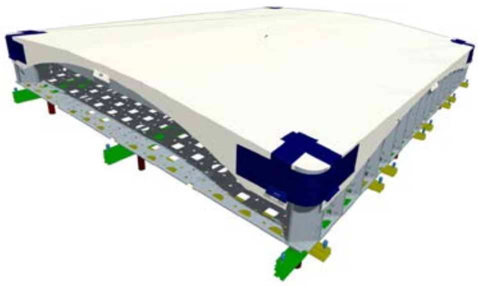

Fig. 4. Design drawing of a new AA tile concept.

V. CONCLUSIONS AND FURTHER PLANS

High frequency aperture array technology is on the verge to be mature enough for large scale deployment. After completion of the AAMID technology development this will be demonstrated with a science capable instrument (~2000m^2), to be realized in the Karoo, as pathfinder for SKA$_2$

REFERENCES

[1] The SKA telescope project, www.skatelescope.org
[2] LOFAR, www.lofar.org
[3] P. Benthem, et al., "EMBRACE: Results from an Aperture Array for Radio Astronomy", EuCAP 2012, Prague, Czech Republic.
[4] S. A. Torchinsky et al., "Characterization and Initial Results with EMBRACE", SF2A, Société Française d'Astronomie et d'Astrophysique, June 2013, Montpellier, France
[5] M. J. Arts, B. Fiorelli, "Polarization studies of Vivaldi aperture arrays for the Square Kilometre Array", ICEAA 2013, Torino, Italy
[6] Y. Zhang, A. K. Brown, "Octagonal Ring Antenna for a Compact Dual-Polarized Aperture Array", IEEE Transactions on Antennas and Propagation, Volume 59, Issue 10, 2011
[7] S. Bosse, et al., "Beamformer ASIC in UHF-L band for the Square Kilometre Array international project", EuMIC 2010, Paris, France