6 Technological Developments

6.1 SKA Pathfinders and Prototypes

6.1.2 EMBRACE [S.A. Torchinsky]

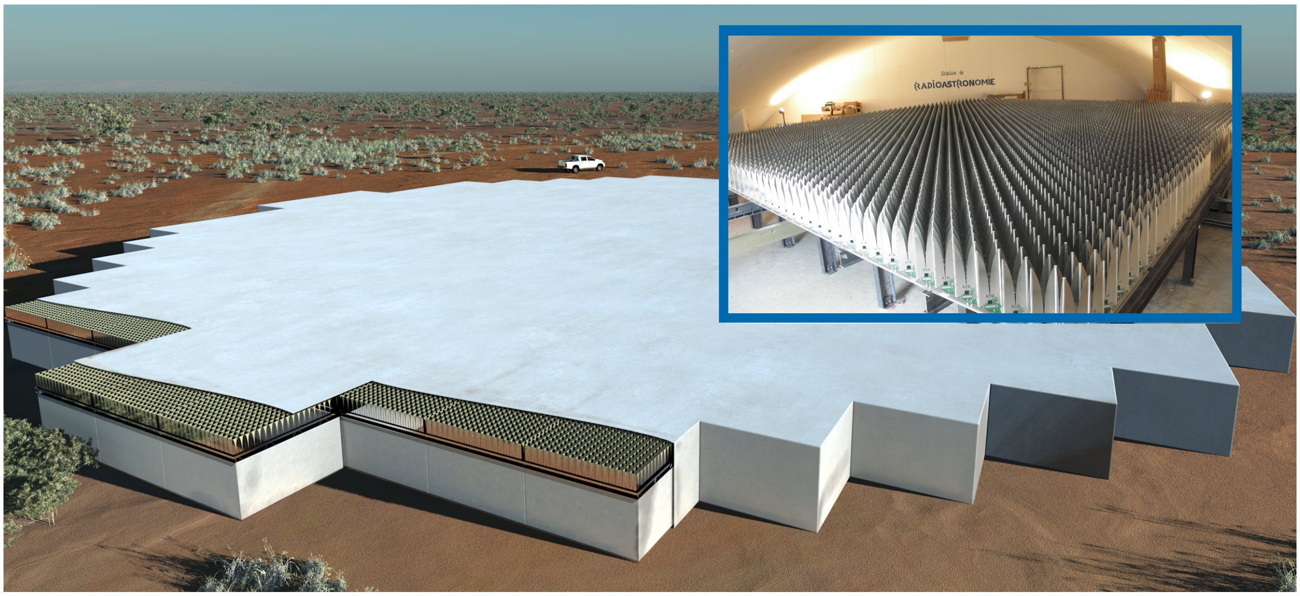

Figure 1: This artist's conception shows a single station of a mid-frequency aperture array instrument proposed for the Square Kilometre Array (SKA). Over two hundred stations will be required for the full SKA. The inset shows the currently operational EMBRACE array at the Nançay Radio Observatory in France. EMBRACE@Nançay is composed of 4608 Vivaldi antenna elements separated from each other by 12.5 cm, making it a dense array for frequencies above 1200 MHz. EMBRACE@Nançay measures 8.42 m $\times$ 8.42 m for a total area of 70.8 m^2.

Modern digital technology has sparked a revolution in radio astronomy techniques, resulting in a fundamental change in how telescopes are built and operated. Instead of large mechanical structures, aperture arrays can be built which are composed of many small antennas with signals combined together to form the equivalent of a telescope with large collecting area. The design philosophy puts the hard work on the digital electronics, while the mechanical parts, such as dishes and antennas, are made as simply as possible. The result is an instrument built from many small mechanical components and electronically combined together with the power of fast digital processors. Not only is such a system easier to build and maintain, it also provides distinct operational advantages. Perhaps most importantly, aperture arrays have an extremely large field of view for fast surveys of the sky. This is the technology which makes the billion galaxy catalogue a feasible goal for the SKA, and in turn, will make a fundamental advance in our understanding of Dark Energy (Rawlings et al. 2004).

The challenge to move this design philosophy to higher frequencies is mainly driven by the large number of components and associated electronics. At frequencies around 1 GHz, the goal is to maintain the large field of view and observational flexibility made possible by the aperture array technology while surpassing the sensitivity of large parabolic dishes. This can only be done by fully sampling the aperture with antennas that are closely spaced together. The result is an instrument that collects all the available signal, as would do a dish of the same size, but having all the advantages of an aperture array, including the possibility for full sky imaging.

Observatoire de Paris has been a major partner in the development of dense phased arrays for radio astronomy since 2005, working closely with The Netherlands Foundation for Radio Astronomy (ASTRON). The joint project is called EMBRACE (Electronic MultiBeam Radio Astronomy Concept, Kant et al. 2011). With significant funding from European Commission FP6 project SKADS, an EMBRACE prototype was built and is operational at Nançay since 2010 (see Figure **??**, Torchinsky et al, 2016). The Observatoire de Paris developed the analogue integrated circuit responsible for the first stage of beam forming (Bosse et al. 2010), and also provided the sophisticated Monitoring and Control software (Taffoureau et al. 2011) Observatoire de Paris continues to be responsible for the characterization and operation of the EMBRACE prototype with an on-going observing programme.

EMBRACE@Nançay has demonstrated its capability as a radio astronomy instrument, including astronomical observations of pulsars and spectroscopic observations of galaxies (Torchinsky et al., 2016). The multibeam capability has also been demonstrated. For several years until 2017 when the prototype was ordered to shutdown, EMBRACE operated in the manner of a facility instrument, doing regularly scheduled observations showing that dense aperture array technology is stable and reliable in the long term which is a key operational advantage for the future Square Kilometre Array.

References:

Bosse, S., et al. 2010, Proc. EuMC, pp. 106–109

Kant, G.W., et al. 2011, IEEE Trans. A&P, 59, 1990

Rawlings, S., et al. 2004, NewAR, 48, 1013

Taffoureau, C., et al. 2011, ADASS XXI, ASP Conf. Series, 461, 209

Torchinsky, S.A., et al. 2016, A&A 589, 77