Phased Arrays in Radio Astronomy

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Summary

With the advent of new radiotelescopes ready for observations within the next few years plus the new generations planned later, the radio window will be opened completely for new detailed and sensitive explorations. Taking these instrumental developments together, they will complete the disclosure of the full radio window covering 5 decades in frequency. Different collector concepts are necessary to optimally cover this frequency and a variety of novel concepts are proposed some of which have never been used in radioastronomy.

On the high side of the radio spectrum still observable form the ground, the Atacama Large Millimeter Array ("ALMA", see e.g.: www.eso.org/projects/alma) is in the process of being build now by a consortium of European, North American and Japanese institutions. The over 60 ALMA antennas will be located at a high altitude plateau of the Atacama desert at 5000m and will revolutionize our knowledge about the Universe in the (sub)mm range of frequencies from 100 -1000 GHz.
At the low frequency end, northern Europe and most pronouncedly the Netherlands, houses the Low Frequency Array ("LOFAR", see: www.astron.nl/ska/ and www.lofar.org) planning to become operational in a few years. The frequency is covered in two ranges from 30MHz to 250MHz and excludes the FM receiving band. Similar instruments are being build in New Mexico in the US (the "Long Wavelength Array") and the Murchison Widefield Array ("MWA" see e.g. www.hystack.mit.edu/ast/arrays/mwa) by groups in the US, Australia and India to be operated in a much more benign site in terms of RFI in Western Australia. Contrasting the commonly used arrays in Radio Astronomy and in particular as compared to ALMA, there are hardly any requirements on the mechanical accuracy of the receiving antennas as they are essentially electrically small very wide band dipoles, fixed mounted with almost all-sky coverage.
Going beyond developments for instruments for this decade, the international radio-astronomy community is engaged in major upgrades of existing arrays, pathfinder projects and detailed plans toward the development of the Square Kilometer Array ("SKA", see www.skatelescope.org). Planned for operation from 100MHz to 25GHz in the next decade, SKA will be two orders of magnitude more sensitive than telescopes currently in use and besides a high angular resolution instrument, it is planned to increase the instantaneous field of view by the same orders.

In all cases, the key observing techniques is Radio Aperture Synthesis based on interferometry (see e.g.[1]). Following major advances in a range of technologies, the technique has been extremely successful for (polarimetric) imaging and spectroscopy of cosmic radio signals achieving unique spatial and spectral resolutions. Coupled to new calibration techniques (see e.g. [2]), phased array techniques hitherto not common in radio astronomy, are now used for potential upgrade on existing telescopes as focal plane arrays (see e.g. [3])and in the new generations of m-cm wavelength instruments (see e.g. [4]) just mentioned as aperture arrays.(see e.g. [5]) These techniques add to the capability of widefield observations, limited "only" by computational power.

The importance of phased arrays as a result of this and other intrinsic characteristics has lead to the growing acceptance of its potential in the community. This tutorial will address the new capabilities and aims to provide insight in the status of enabling technologies and technical research and the potential of phased arrays for future growth in radio astronomy.
The contributions from many others although not mentioned explicitly in this tutorial, in particular those of ASTRON are greatly acknowledged.

References

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