A Multibeaming SKA Prototype: Some Thoughts

Peter Hall, 31 October 2002

Background

The recently-submitted SKA concept descriptions (‘whitepapers’) underline the point that it is difficult to design an SKA which both covers high frequencies (>10 GHz) and supports widely-placeable fields-of-view. Optimization in the high-frequency and multi-beaming domains leads to different technologies and, while the Allen Telescope Array (ATA) and possible Deep Space Network (DSN) prototypes will effectively demonstrate high-frequency approaches, no similar scale prototype is currently planned for the cm-wave multi-beaming concepts.

As I mentioned at the recent Groningen international SKA meeting, there is a need for a large-area multi-beaming demonstrator for at least two reasons. First, the radio science behind many of the possible realizations is still rather new and uncertain; implementing a scaleable technology gives confidence that the new technologies can deliver the performance expected by the SKA community. Second, no multi-view radio synthesis telescope currently exists; building a multi-beaming telescope of worthwhile size allows the scientific credentials of multi-beaming to be established and the leap-of-faith to an SKA with 100 (or so) beams to be minimized.

The LOFAR instrument, to operate in the frequency range 10-250 MHz, will contribute vital information to the design and operation of a new class of multi-beaming telescope. However, LOFAR will not contribute to the advancement of dense, active, aperture phased array antennas of the type needed for SKA. The different operating frequency range also means that LOFAR cannot illustrate the scientific potential of area re-use (multi-beaming) in the cm-wave band. Still, the similarities are strong enough, and the overall data rates comparable enough, to make co-siting LOFAR and the SKA demonstrator a real possibility.

The SKA Multi-Beaming Demonstrator

With multi-view radio astronomy in its infancy, it is a challenge to specify an instrument which demonstrates everything required for progression to the SKA. At the top level, it can be reasonably argued that with the SKA 100 times as sensitive as present instruments, the demonstrator should couple an area re-use capability with a single-beam sensitivity comparable to current telescopes. This will ensure a scientifically useful exploration of new parameter space and observing modes. Given an effective collecting area of 10,000 m^2 (comparable with the VLA, similar to the ATA and three times that of the ATCA) the new instrument would be well-placed to tackle known challenges such as the search for gravitational radiation via simultaneous pulsar timing experiments or the timely observation of GRB phenomena. The real hope is of course that it would take us beyond what is known, perhaps into the realm of serendipity for a new class of telescope.

The demonstrator could be build as a single unit, similar to one SKA station. Alternatively, and probably more usefully from a technical perspective, the area could be split into five or so mini-stations to allow SKA-style data transfer and processing to be undertaken. However, this warrants careful discussion, if only because some of the major science applications might well be best tackled with the single filled aperture. It may be though that a multi-beaming 'compact array' offers a reasonable compromise.

Maximum gain in the area re-use parameter can only be achieved using phased array technology and 'full' (Fourier) beam-forming. Assuming we want adjacency with likely LOFAR band limits, and bearing in mind a likely technical limit of 5:1 in the antenna and time-delay RF beam-forming, I propose a single band of 300 MHz – 1.5 GHz. The time-delay beam-forming is significant: unlike present phased array models, beam position is independent of frequency and the whole antenna band is available simultaneously for astronomy.

What might such an instrument cost? Looking at the recent whitepapers, estimates for the SKA are currently around USD 1.5 billion. The budget for a 1% area, multi-beaming, demonstrator might therefore be naively be reckoned at USD 15 million. After allowing for a factor of three development overheads in key antenna and related technologies, a safer reckoning might be USD 30 million: similar to the ATA.

Conclusion

A sizeable, and most probably on-site, demonstrator has always been inevitable in any sensible SKA project plan. Proponents of multi-beaming now have an exciting opportunity to specify a next-generation telescope which will be a true stepping stone to one version of the SKA. By definition, technologies inherent in the demonstrator concept are highly scaleable and it is timely to align international R&D efforts with the goal of producing the new instrument. With an effective collecting area equivalent to a 150 m dish, this new telescope has enormous scientific potential and, perhaps as importantly, the potential to bring the multi-beaming operational concept to mainstream radio astronomy.