LOFAR in Australia – A Brief Engineering Perspective

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11 October, 2002

Background

LOFAR (LOw Frequency ARray) is a proposed radio telescope designed to operate in the approximate frequency range 30 - 200 MHz. It is a low-frequency complement to the Square Kilometre Array (SKA), SKA being designed to cover the range 150 MHz to above 10 GHz. In fact, at its lowest frequencies LOFAR will also have an effective collecting area of a square kilometer (1 million square metres). LOFAR is expected to be operational by 2007, while the goal for SKA is 2015. Construction costs for LOFAR and SKA are of the order of USD 100M and USD 1000M, respectively. In both cases, the instruments would be built and operated by international consortia; Australia is a founder member of the 11-member SKA consortium and may join the USA and Europe in the LOFAR endeavour.

Despite the difference in operating frequency bands, LOFAR is a true stepping stone to SKA. It will demonstrate many key SKA technologies, and the two instruments could advantageously share sites and infrastructure. Very importantly for Australia, LOFAR technology is more accessible to R&D groups which currently lack access to the expensive design and test facilities necessary for some SKA work. While such facilities will continue to be available in organizations like CSIRO, involvement in LOFAR will enable a wider Australian contribution to leading-edge radio science and build a higher profile for Australia in SKA-related prototyping. Apart from its intrinsic synergies with SKA, LOFAR is also a logical host platform for a newly-mooted international SKA demonstrator: a large, multibeaming, radio telescope operating in the SKA frequency band.

LOFAR – SKA Similarities

Both LOFAR and SKA are geographically distributed instruments having most of their several-thousand antennas grouped into hundreds of patches, or stations. Most of the stations are located within a region a few hundreds of kilometers in extent; over half the collecting area is even more condensed, occupying only a few kilometers at the center of the array. LOFAR and SKA will:

- Be multi-beaming radio telescopes, allowing the whole collecting area to be used for tens or hundreds of simultaneous observations (c.f. existing single-beam instruments);
- Attain unparalleled sensitivity and flexibility by invoking “software radio” principles in which much signal processing is done using computers or programmable processing engines;
- Require a network of high-capacity optical fibre data links (most likely a mix of custom-installed and third-party fibre);

- Observe outside allocated radio astronomy bands and rely on radio frequency interference mitigation techniques now being developed in Australia and elsewhere;
- Demand calibration and data processing techniques of unprecedented sophistication; and
- Be built in remote, relatively radio-quiet, locations.

Many SKA concepts will be effectively demonstrated by LOFAR and, with adequate planning of e.g. optical fibre and power installation, key infrastructure could be shared by the two instruments.

LOFAR – SKA Differences

Despite the similarities, LOFAR and SKA are different instruments, largely because of science goals which have dictated operation in different frequency regimes. Some of the main differences are:

- LOFAR and SKA antennas are quite distinct and, while the LOFAR development demands are far from trivial, the SKA challenge (particularly in terms of efficiency and frequency range) is much greater;
- LOFAR observing bandwidths, and hence network data rates, are 100 times smaller than SKA, meaning that LOFAR information transfer needs are more compatible with existing fibre-optic technology;
- LOFAR receiving systems can be much simpler than SKA, with variations on leading-edge radio-on-chip technology being feasible; and
- Smaller LOFAR bandwidths mean that almost all signal processing can be done digitally, using extensions of existing computing and digital signal processing (DSP) technology.

From an engineering perspective, LOFAR is an instrument which can be built using refinements of existing technology. The application of this technology will, however, provide a platform on which to base SKA system design.

Opportunities for Australia

Advantages such as low population density, political stability, large land area, technological sophistication and Southern Hemisphere location combine to make Australia a suitable host for the SKA. Indeed, these factors, together with technical and site characterization work by CSIRO and a few other players, have resulted in Australia being thought of by many as the favoured SKA host. However, very recent international developments, based on a polarization in the world radio astronomy community, could lead to Australia being marginalized in a contest between the USA and Europe. It can be reasonably argued that hosting LOFAR, and an associated higher-frequency SKA demonstrator, would significantly increase Australia's chances of attracting SKA. While major players (such as CSIRO) could continue to contribute to frontier SKA R&D, many more university and industry partners could contribute both to a world-class instrument

(LOFAR) and, indirectly, to emergent technologies applicable to SKA. In a number of areas these technologies have the potential to build national capability, wealth and infrastructure.

In addition to astronomy and radio science community input to LOFAR, contributions by Australian commercial enterprises might include:

- Antenna and radio receiver development and manufacture;
- Photonic data transport systems, including remote area networks with capacity to support local community needs;
- Software for array control, signal processing and scientific data reduction;
- Infrastructure development, including
    - Project planning and management
    - Site preparation
    - Fibre installation
    - Provision of renewable energy sources
- Facility operation.

Examples of the many Australian companies having capability in relevant areas include CEA Technologies P/L and Codan Ltd (antenna and RF systems); Connell Wagner P/L and Sinclair Knight Merz P/L (consulting engineers and project managers); and Pacific Solar P/L and Solar Sales P/L (renewable energy systems).