The Large Adaptive Reflector concept

S.M. Dougherty\(^1\), P.E. Dewdney\(^1\), A. Gray\(^1\) and A.R. Taylor\(^2\)

\(^1\)National Research Council, Herzberg Institute for Astrophysics, Dominion Radio Astrophysical Observatory, Canada
\(^2\)Department of Physics & Astronomy, University of Calgary, Canada

ABSTRACT

Cost effective, new antenna technology is required to build the large collecting area being planned for the next generation of radio telescopes. The Large Adaptive Reflector (LAR) is a novel concept being developed in Canada to meet this challenge. A prototype with a 200-350m diameter reflector, operating up to 2 GHz with a bandwidth of 750 MHz is planned. With a collecting area up to ~ 10% of the planned SKA, and an array feed capable of imaging a 0.3 deg\(^2\) field-of-view, the prototype would address a number of the most compelling questions in modern astrophysics.

Key words:

1 THE LAR

The LAR is a concept for a large diameter, large f/D parabolic reflector that requires an air-borne platform to support the prime focus receiver system. The active reflector surface has a very flat profile, supported over a large area, to reduce significantly the cost per unit area compared to traditional designs. A large field-of-view across a wide bandwidth is attained through the use of a focal plane phased array (Dewdney et al. 2002; Carlson et al. 2000).

1.1 Tethered Aerostat System

As the LAR reflector has a focal length of several hundred metres, the Focal Point Apparatus (FPA) needs to be supported by a “sky-crane”, for which we have chosen a helium-filled aerostat (Fig. 1). The aerostat is attached to the FPA via a leash, isolating the FPA from balloon motions, and the position of the FPA is controlled by six computer-controlled winches. This system is being evaluated using a 1/3-scale prototype (Fig. 1) to verify a computer simulation of the system. Once verified, the computer model becomes an extremely powerful design tool for the full-scale system. Recent tests on the prototype reveal that this system can work down to a zenith angle of 60\(^\circ\), while maintaining the position of the FPA to within a few centimetres, adequate for the focus design we propose (Sec. 1.3).

1.2 Reflector

The LAR reflector is a large diameter, faceted approximation to an offset parabolic reflector with a long focal length (f/D~2.5). Each of the 20-m triangular facets is supported on actuated legs that extend up to 12m. These actuators maintain the parabolic shape of the reflector as the pointing

Figure 1. The Large Adaptive Reflector Concept. The top figure shows a cartoon of the system configuration. The lower figure shows the aerostat being used currently in the 1/3-scale prototype of the tethered aerostat system.
direction is changed. The major advantage of such a design is that the reflector is very flat, permitting its weight to be supported at many locations, rather than at the single or double mount points of more traditional designs. A single facet using this design has been built and tested (Fig 2). This has demonstrated the low cost of the actuation design, and established an initial reflector cost estimate of $400 US per square metre.

1.3 Focal-Plane Phased Array

A phased-array feed at the focus confers a larger field-of-view (FOV) than a traditional single-feed receiver system, by sampling the electromagnetic field at the focus to form multiple beams. The ability to modify the beam pattern of an array feed is essential to the LAR concept to control the illumination of the reflector as the zenith angle changes.

Until recently, array feeds in radio astronomy have been impractical because suitable array elements were either not available or were too expensive. Today, the Vivaldi antenna is recognised as having the most suitable characteristics, with wide bandwidth, packing density, and low loss performance.

A three-fold development process for attaining a phased-array feed design for the LAR is planned: 1) Build a 200-element Vivaldi array equipped with a simple, low cost, narrow band receiver system from off-the-shelf components (Fig. 3). This is an engineering demonstrator to establish a fundamental understanding of the capabilities and limitations of phased-array feeds on reflector telescopes; 2) In parallel, develop high performance uncooled, monolithic, integrated LNAs to attain good system noise without the need for cryogenically cooled amplifiers, and RF-to-Optical modules for data transmission from the receivers to the ground-based beamformer; 3) Lastly, develop an astronomically capable phased-array as a prototype for the LAR. Currently, the first two phases of this development strategy are underway.

1.4 The Focal Point Apparatus

The Focal Point Apparatus (FPA) is the mechanism at the focus of the LAR reflector that is supported by the aerostat, and controls the pointing of the phased-array feed. The tethers that control the position of the focus are attached to the FPA. Taking into account the necessary degrees of freedom, the workspace volume and a minimal mass target, a number of well-known control mechanisms are ruled out, and point to a cable-based mechanism acting within a large space frame. A prototype of this system is currently being built, to be flown on the tethered aerostat system in June 2006.

2 SCIENCE WITH A CLAR

A prototype of the LAR concept, known as the CLAR, is envisaged to be a 300-m diameter reflector, with sky coverage down to 30° elevation, an array feed with a FOV of 0.3 deg², and operating up to 2 GHz with an instantaneous bandwidth ratio of 2:1. Such a prototype represents 7 times the collecting area of the VLA, with 100 times its survey speed. With 7% of the area of the SKA and a large FOV giving high survey speed, this prototype can address many of the compelling questions facing modern astrophysics.

In particular, the CLAR will measure the redshift and distribution of millions of galaxies out to a redshift of z ~ 2 using the 21cm hyperfine transition of atomic hydrogen. This will enable the measurement of the spatial power spectrum of the distribution of galaxies at different values of z, opening up the way to determine the equation of state of the universe. A more shallow survey covering the whole sky will map the large-scale structure of the nearby universe through the detection of over 10 million galaxies, surpassing the SLOAN survey by at least a factor of 20.

With a collecting area of nine times the GBT and sky coverage down to 30° elevation, the CLAR will be a second-to-none pulsar discovery machine. This will open up a new era in precision tests of General Relativity through the binary pulsar systems that will undoubtedly be found, as well as studies of the extreme physics of neutron stars themselves.

REFERENCES

Dewdney P.E., Nahon M., Veidt B., 2002, Can. Aero. Space J., 28, 239
Carlson B., Bauwens K., Belostotski L., Cannon W., Chang Y.-Y., Deng X., Dewdney, P.E., Fitzimmons, J., Halliday D., Kurshner K., Lachapelle G., Lo D., Mousavi P., Nahon M., Shafai L., Steiner S., Taylor A.R., Veidt B., 2000, Proc. SPIE Int. Symp on Astronomical Telescopes and Instrumentation, p 4015.

© 2005 APRIM, 1–2