The Effect on the AT of an Antenna at Adelaide

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Introduction

The construction of an antenna near Adelaide to be used both for Earth-Space communications and for use as an element of the Long Baseline Array (LBA) of the Australia Telescope (AT) has been proposed. This note presents simulations to determine the value of such an antenna to the LBA. It should be noted that this document is an extension of an earlier study (AT/17.3.1/013; Lyman-SWG-005), although, in order that this note be self-contained, it incorporates some introductory material from that earlier study.

Background

The LBA at present consists of the tied array at Culgoora, the 22-m antenna to be built at Siding Spring, and the existing 64-m antenna at Parkes. In addition, it is hoped to incorporate, on a collaborative basis, the antennas at Tidbinbilla (owned by NASA) and Hobart (owned by the University of Tasmania) in the array for perhaps one or two months each year.

The three antennas at Culgoora, Siding Spring, and Parkes cannot , on their own, produce high quality synthesis images. Such images can, however, be produced by the addition of one or more antennas to the array. Because of the way the synthesis algorithms work, the effect of additional antennas is much greater than the simple increase in numbers. Thus adding a fourth antenna multiplies the amount of information by a factor between 2.0 and 4.0 (depending on the algorithm), whereas a fifth gives a further multiplication by a factor between 1.67 and 5.0, and so on. In qualitative terms, three antennas can produce a usable map only on the simplest structures, four antennas will generally produce a usable map , and five antennas can produce a high dynamic range map.

Thus, during the one or two months per year that the LBA collaborates with Tidbinbilla and Hobart to become a five-antenna array, the LBA is clearly capable of high quality synthesis imaging. However, this capability is limited by the geographical location of the antennas: they all lie approximately along a North-South line. The effect of this is that maps of sources at low absolute declinations will suffer from poor East-West resolution and imaging artefacts. This defect can best be rectified by incorporating into the array an antenna which is East or West of the other antennas. This would be the principle benefit of an antenna situated at Adelaide. There would be two additional benefits (a slight increase in overall resolution and the ability to make usable synthesis images without Tidbinbilla or Hobart) but these are of minor importance compared with the dramatic effect that an antenna at Adelaide would have on the image quality obtainable with the complete LBA.

U-V Coverage

The quality of a synthesis image depends not only on the number and separation of the antennas of an array, but also on their location. This is conveniently represented on a u-v diagram, which shows the apparent locations of the antennas as seen from the source. The Earths rotation causes these locations to appear as elliptical tracks in the u-v plane. The u-v plane is in the Fourier transform domain of the image, and so the tracks represent the sampled portions of the synthesised aperture. In general the best images are obtained from uniformly sampled u-v planes, and so a synthesis array should be designed to have as few major gaps in the u-v coverage as possible, since any gap will transform to a spatial frequency to which the array will be insensitive. The u-v coverage should also cover as large an area as possible, in order to achieve the highest resolution. Thus the goal of a designer of a VLBI array is to cover as much of the u-v plane as possible (for high resolution), whilst leaving as few gaps in that coverage as possible (for high image quality). The art of designing a good VLBI array is to balance these two factors.

The u-v diagrams to be shown here show a variety of gaps. The most pronounced is the East-West gap in the basic LBA for sources at near-equatorial declinations. Gaps such as this must be minimised in order to maximise the quality of the images.

The Effect of Adelaide

The Adelaide site was examined for its effect on the five-station LBA (Culgoora, Siding Spring, Parkes, Tidbinbilla, and Hobart) at four negative declinations (-80°, -60°, -30°, -10°). Positive declinations were not tested as the Northern sky is adequately observed by northern VLBI arrays.

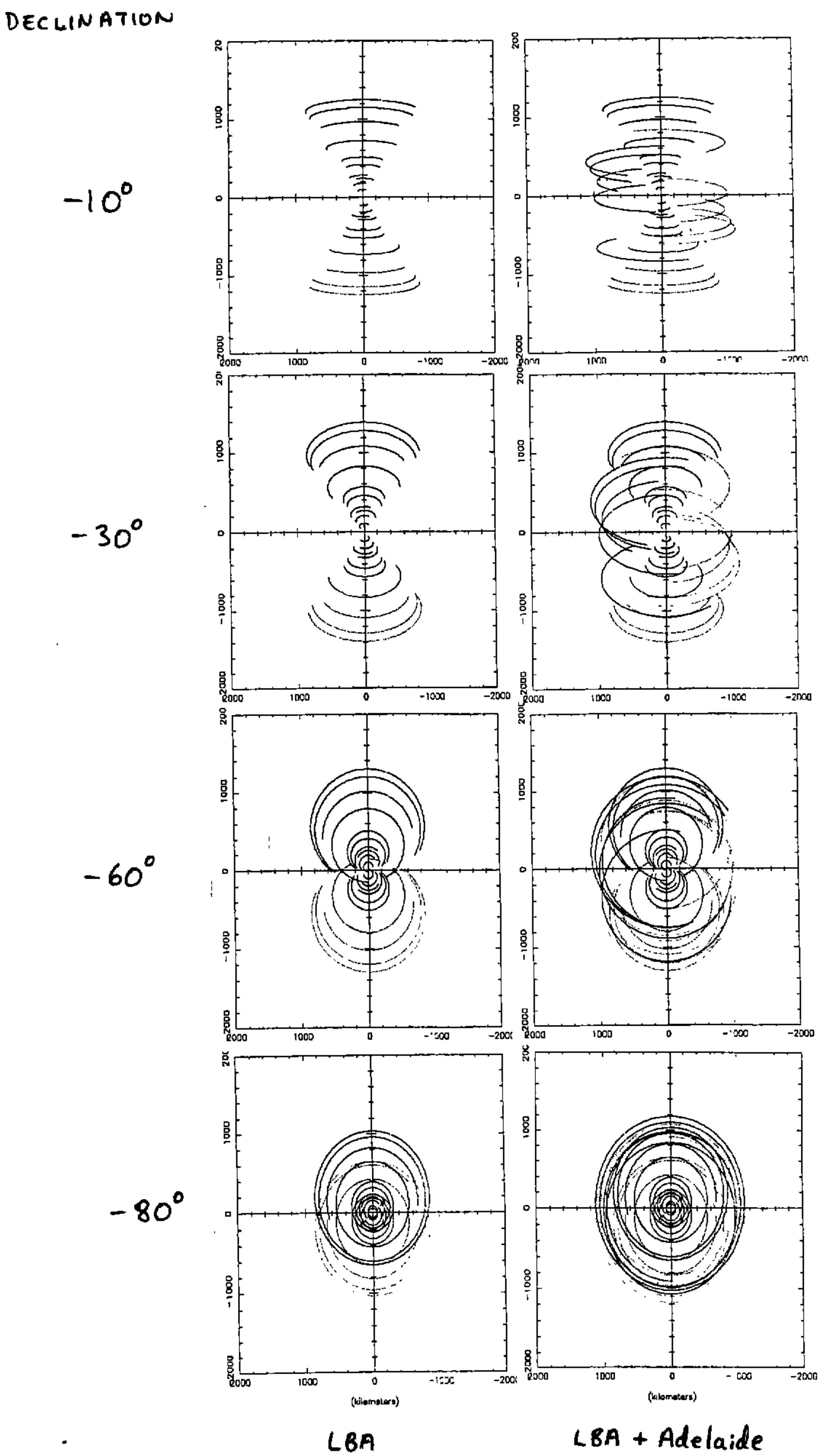
Fig 1. shows the u-v coverage of the LBA. The left hand column shows the u-v coverage of the five-station LBA, and the right-hand column shows the effect of adding Adelaide. Each row shows the u-v coverage obtained for one particular declination.

In the left-hand column, it can be seen that the LBA will perform well as an imaging instrument at extreme southern declinations, but that it suffers from an East-West gap which becomes progressively worse at more northern declinations. By declination -10°, the u-v coverage suffers from large gaps to the East and West, resulting in a poor image quality at these declinations.

In the right -hand column, it may be seen that an additional antenna at Adelaide fills in these gaps extremely effectively (more so, in fact, than any of the Eastern Australia sites considered in the earlier study), resulting in an array which will produce high-quality, high-resolution images for the entire southern sky.

Conclusion

At present, the 5-station LBA suffers from a lack of East-West baselines, which will result in a image quality which is high only for extreme southern declinations, and which deteriorates rapidly with increasing declination, until the images obtained at -10° declination will suffer from severe artefacts. The addition of an antenna at Adelaide will provide the necessary East-West baselines, and allow the LBA to be used as a high-quality synthesis imaging instrument throughout the southern sky. Such a development would have a considerable effect on the position of Australian astronomy, and on the global capability for studying the southern sky.



DECLINATION
-10°
-30°
-60°
-80°
1000
0
-1000
-2000
2000
(kilometers)
LBA
LBA + Adelaide

Fig. 1