A Lyman/AT antenna in Eastern Australia?

R.P.Norris

16 June 1987

Introduction

It has been suggested that the proposed Lyman spacecraft would benefit from a downlink in eastern Australia, and that since Lyman would only use the downlink antenna for half the time, the remaining half might be useful for the Long Baseline Array (LBA) of the Australia Telescope (AT). Here I examine a number of possible sites for such an antenna, and evaluate their usefulness for the AT.

Because this report had to be completed in time for the Lyman A1 meeting in the UK on June 23, there was not enough time to run full mapping simulations for each site. Instead, an estimate of the value of each site has been made on the basis of the u-v coverage obtained by including each site in turn.

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 might be available for perhaps 50% of the year. Although there are a number of useful astronomical tasks that can be done using just three antennas (e.g. astrometry, pulsar proper motion, mapping of simple structures), such an array cannot 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 one function of an additional antenna would be to turn the three-antenna LBA (available for 50% of the time) into a four-antenna array capable of very much higher quality synthesis than its three-antenna counterpart.

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.

Thus a second function of an additional antenna could be to improve the image quality of the five-station LBA.

The maximum baseline of the 5-station array is between Culgoora and Hobart, a distance of about 1400km. This yields an angular resolution at 2.3 GHz of about 0.02 arcsec. For many purposes, an even higher resolution is desirable, and this would be achieved by placing an additional antenna further away than 1400km from the other antennas. Thus a third function of an additional antenna could be to increase the resolution.

It is possible that in the next few years an additional antenna may become available in South Australia or Western Australia. In this case, the conclusions of this note will be altered. However, the tentative state of this possibility does not warrant its incorporation into the tests discussed here.

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 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. Another is the annular gap seen at extreme southern declinations when Norfolk Island is included in the array. Gaps such as these should be minimised in order to maximise the quality of the images.

The Tests

Four plausible sites (Brisbane, Coffs Harbour, Taree, and Newcastle) were chosen on the East Coast of Australia, and two additional Pacific sites (Norfolk Island and Lord Howe Island) were also included. All of these sites are potentially usable for Lyman, and are also potentially usable for the LBA in the sense that they fall within an AUSSAT footprint.

Each site was examined for its effect on (a) the three-station LBA (Culgoora, Siding Spring, and Parkes), and (b) 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.

Results

Fig 1. shows the effect of adding an antenna to the basic three-station LBA. Each column shows an array configuration, with the basic LBA (labelled LBA00, which comprises Culgoora, Siding Spring, and Parkes) in the left hand column. Each column to the right of that shows the effect of adding one antenna in the location indicated to the basic LBA. Each row shows the uv coverage obtained for one particular declination.

It is immediately apparent that the basic LBA has very poor u-v coverage, thus limiting its map-making ability to very simple structures. It is also apparent that the addition of an antenna at Lord Howe Island or Norfolk Island (the right hand pair of columns) does little to improve this, although the longest baselines (and hence the resolution) are considerably extended.

Each of the four intermediate columns shows some filling-in of the gaps in the basic u-v coverage. This filling-in is best for Newcastle and Taree, with a reduced benefit from Coffs Harbour and Brisbane. Brisbane is especially poor at low absolute declinations.

Fig 2. shows the effect of adding an antenna to the extended five-station LBA. Each column shows an array configuration, with the LBA (labelled LBA01, which comprises Culgoora, Siding Spring, Parkes, Tidbinbilla, and Hobart) in the left hand column. Each column to the right of that shows the effect of adding one antenna in the location indicated. Each row shows the uv coverage obtained for one particular declination.

In this case, 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.

The addition of Norfolk Island improves the coverage at equatorial declinations, but still leaves large gaps at other declinations. Lord Howe Island, on the other hand, provides useful filling-in at all declinations, although still leaving an inner East-West gap at all but extreme southern declinations. Coffs Harbour, Taree, and Newcastle each provide some filling-in of the inner East-West gap, but leave an outer East-West gap. Brisbane is noticeably poorer than these at all declinations.

Conclusion

Three benefits are potentially to be gained by the addition of an antenna to the LBA: (i) improvement of the u-v coverage of the basic 3-station LBA, (ii) improvement of the u-v coverage of the extended 5-station LBA, and (iii) extension of the longest baselines of the LBA.

Addition of an antenna at Newcastle or Taree (or the surrounding area) maximises benefits (i) and (ii). Benefit (iii) is maximised by the addition of an antenna on Lord Howe Island, but this leaves gaps in the inner part of the u–v plane for most source declinations. It should be noted that the addition of an antenna on Norfolk Island gives little benefit without the addition of a further antenna at an intermediate distanmce.

In conclusion, the benefit to the AT is probably maximised by the addition of an antenna between Taree and Newcastle. Such an addition will (i) make the basic LBA into a usable synthesis instrument, (ii) greatly improve the quality of maps made with the extended LBA, (iii) extend the usable range of the LBA to near-equatorial declinations.

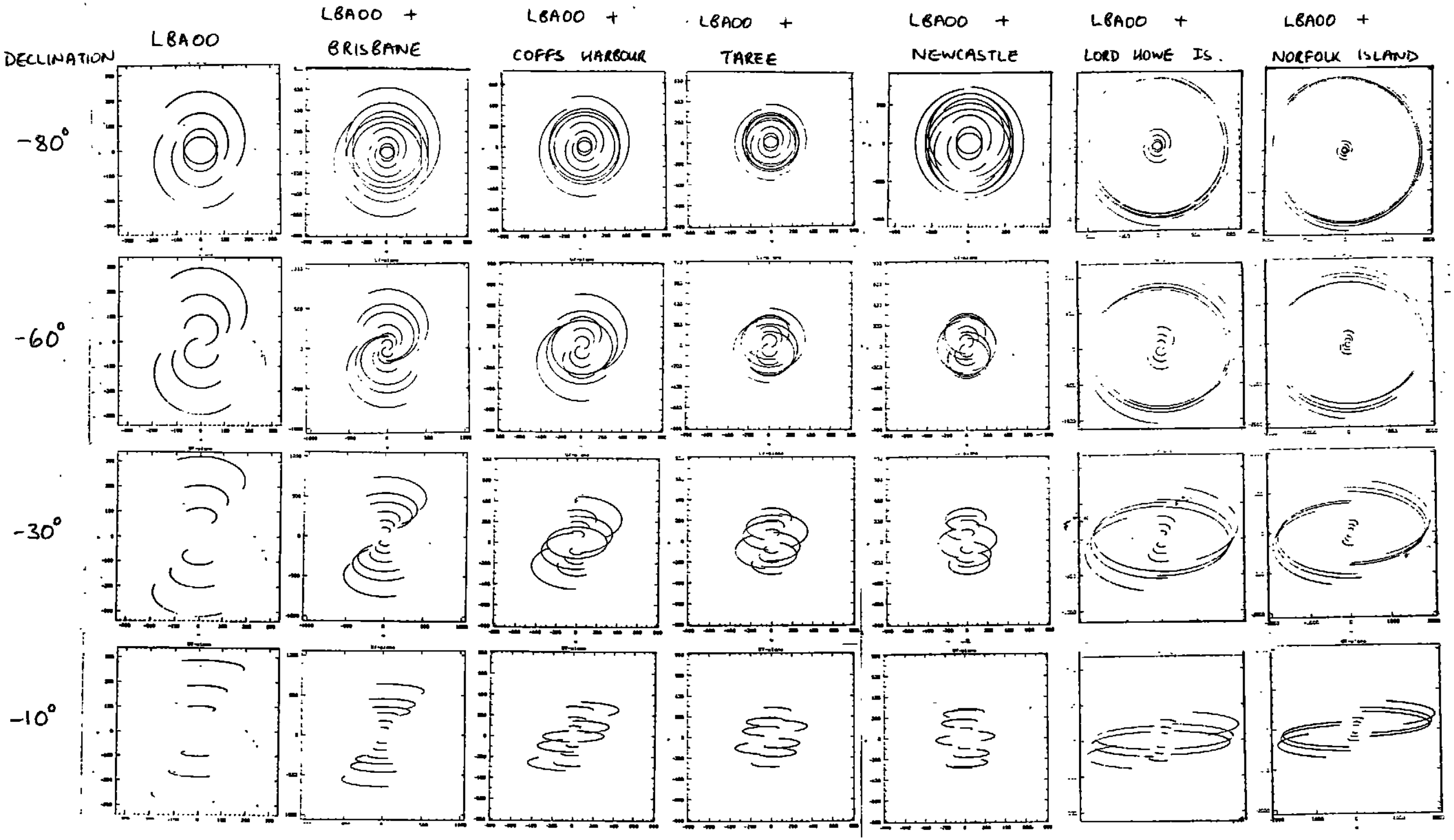
DECLINATION
LBAOO
LBAOO + BRISBANE
LBAOO + COFFS HARBOUR
LBAOO + TAREE
LBAOO + NEWCASTLE
LBAOO + LORD HOWE IS.
LBAOO + NORFOLK ISLAND
-80°
-60°
-30°
-10°

FIGURE 1

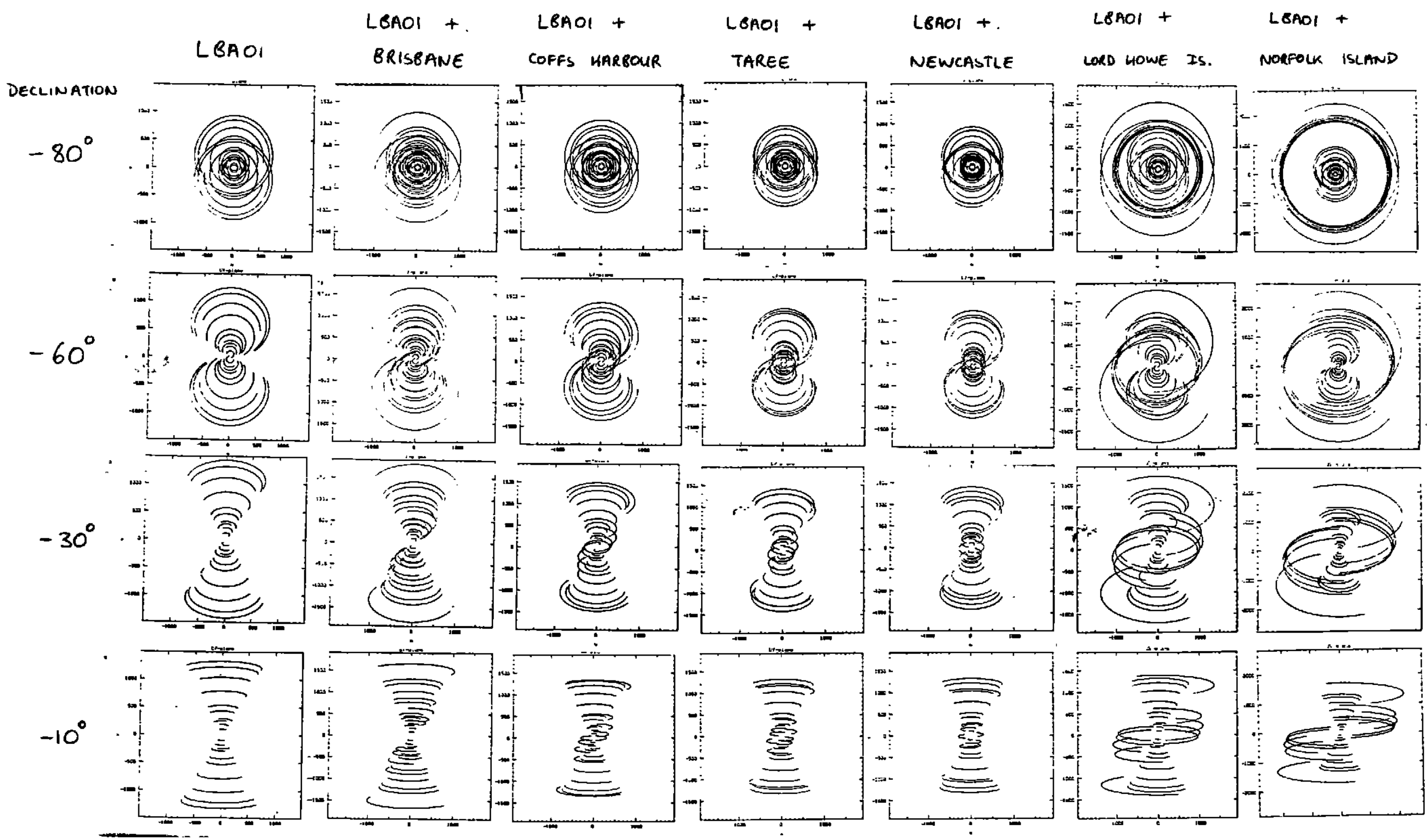
LBA01
LBA01 + BRISBANE
LBA01 + COFFS HARBOUR
LBA01 + TAREE
LBA01 + NEWCASTLE
LBA01 + LORD HOWE IS.
LBA01 + NORFOLK ISLAND
DECLINATION
-80°
-60°
-30°
-10°

FIGURE 2