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AT/17.2.1/002
TECHNICAL ADVISORY GROUPS
CONFIGURATION STUDY GROUP
TECH NOTES & REPORTS

**Further thoughts on the length of the AT Spur**

*J R FORSTER - 22 October, 1984*

In AT/17.2.1/001 computer simulations were presented in an attempt to find the optimum length of the proposed north-south addition to the AT compact array. The conclusion was that a length of about 1.0 km was optimum for use with the 1.5 km section of the array, with the proviso that if compact structure were discovered to exist in high frequency maps, a larger array might be useful. In this note a case is presented for making the length of the spur at least 1.5 km in order to improve the beam ellipticity at declinations near zero.

Beam ellipticities of a factor two and higher can severely complicate the interpretation of radio images. The AT is being designed to accommodate 44, 90 and 115 GHz receivers, none of which are available on the VLA. It is therefore important to maintain good mapping ability at these frequencies for all declinations. Even at 115 GHz the resolution on a 1.5 km baseline (0.25 arcsec) is below the expected "seeing" limit imposed by the atmosphere (about 0.2 arcsec). At least for continuum observations, the full 1.5 km subarray will be useful for mapping at the highest frequencies available on the AT.

It should also be pointed out that compact structure in high frequency molecular lines has been observed. VLA maps in $NH_3$ towards nearby bipolar nebula have revealed parsec sized molecular toroids which might be the focusing agents for the outflows. Clumps smaller than 1 arcsec have been seen in absorption towards young HII regions at both 6 and 2 cm in the $H_2CO$ lines. Observations with the Hat Creek interferometer in the 89 GHz HCN line towards W3OH revealed an emission source associated with a cluster of $H_2O$ masers. This source is unresolved with a 1.4 arcsec beam. While it may be true that the low excitation CO lines at 115 GHz will not show compact structure, the AT will be capable of observing many high excitation molecules around 90 GHz. There is little doubt that with enough sensitivity these lines will provide useful probes of the compact high density gas in molecular clouds.

The primary argu ment for adding a north-south extension to the AT compact array is to decrease the dependance of the beamsize on the source declination. With a purely east-west baseline, the synthesized beam after 12 hours of observing has an ellipticity of 1/sin(dec). In order to attain the maximum value of V necessary to bring the ellipticity to this value, observations are needed at the extreme ends of the observable hour angle range. This is inefficient for two reasons: at these hour angles the source elevation is low and the effects of the atmosphere and ionosphere are greatest; secondly, the rate of change of V with respect to time has a cos(ha) dependance, so a lot of time must be spent at the extreme hour angles in order to get the most out of the projected east-west baseline.

The primary argument against using a two dimensional array is that for good UV coverage the most efficient way of disposing N antennas is along a line in a minimum reduncancy configuration. When N is only 6, as is the case for the compact array, this is indeed a good argument. However, it is only valid for declinations far from the equator, and is mainly applicable to sources with extended structure. In compact sources where uniform and closely spaced UV coverage is not critical, a two dimensional array will generally provide more information.

In order to quantify the beam ellipticity argument somewhat, Figure 1 shows the ellipticity versus declination for the case of no spur, and for various values of Bn/Be, where Bn is the length of the north-south spur and Be is the length of the east-west baseline. The ellipticity is simply the ratio Umax/Vmax, where Umax is taken to be Be, and Vmax is calculated from

$$Vmax = Bn*\cos(Latt)*\cos(dec) + Be*\sin(dec)/2$$

The curves of Figure 1 give an idea of the effect of various choices of Bn/Be on the resulting beam ellipticity. The spur has its maximum effect when the largest skewed baseline is used, ie the east-west component is Be/2, and the north-south component is Bn. For any Bn/Be < 1, the projected east-west baseline (Vmax = Be*sin(dec)) will dominate the V term at some declination. At this point Vmax for the spur crosses the curve for a pure east-west baseline and the spur no longer improves the beam ellipticity.

In order to keep the beam ellipticity below 2.0 at -10 degrees declination the ratio Bn/Be must be at least 0.50. For Bn/Be = 1.0, the ellipticity never exceeds 1.2 for any declination. Since the 1.5 km array with a 1.5 km spur gives very good beam shapes for all declinations, and the ellipticity is kept below 2.0 for declinations south of -10 degrees with the 3 km array, a 1.5 km spur seems a good choice for the AT.

In the Table below a 1.0 and a 1.5 km spur are contrasted in terms of ellipticity at various declinations, and the declination south of which the spur no longer dominates Vmax (crossover). Numbers are given for the 1.5, 3 and 6 km subarrays. It is clear that for the 1.5 km subarray a large improvement in beam shape is gained for declinations north of -59 degrees by choosing a 1.5 km spur instead of a 1.0 km spur. The improvement is also substantial with the 3 km subarray for declinations north of -40 degrees. Some improvement is gained from a 1.5 km spur with the 6 km array, but only for declinations north of -23 degrees.

**Table of Beam Ellipticities**

| Subarray<br>Spur Length | 1.5km<br>1.0 | <br>1.5 | 3.0km<br>1.0 | <br>1.5 | 6.0km<br>1.0 | <br>1.5 |
|---|---|---|---|---|---|---|
| Crossover Dec. | -48 | -59 | -30 | -40 | -16 | -23 |
| Dec = -10 | 1.57 | 1.09 | 2.76 | 2.00 | 4.45 | 3.41 |
| Dec = -20 | 1.43 | 1.04 | 2.30 | 1.77 | - | 2.71 |
| Dec = -30 | 1.36 | 1.02 | 2.03 | 1.63 | - | - |
| Dec = -40 | 1.33 | 1.04 | - | 1.55 | - | - |

CONCLUSION

In order to maintain beam ellipticities at reasonably low levels for declinations near the equator a 1.5 km spur track is preferable to a 1.0 km track. It is expected that the 1.5 km array with spur track will produce excellent maps at all declinations even at the highest frequencies available on the AT.

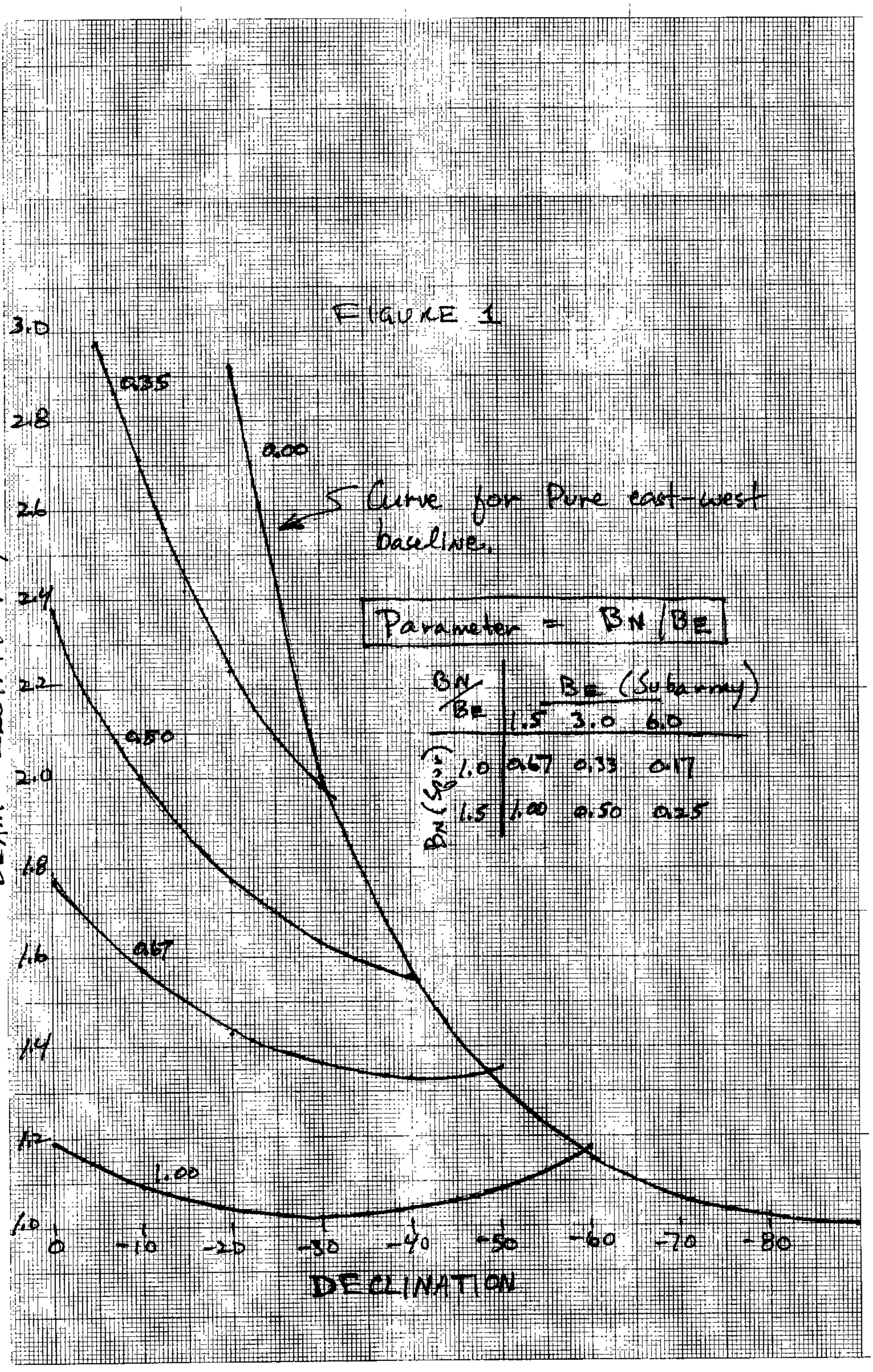
FIGURE 1
Curve for Pure east-west baseline.
Parameter = BN / BE
BN/BE
BE (Subarray)
1.5 3.0 6.0
BN (Subarray)
1.0 0.67 0.33 0.17
1.5 1.00 0.50 0.25
0.35
0.00
0.50
0.67
1.00
BEAM ELLIPTICITY
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0
-10
-20
-30
-40
-50
-60
-70
-80
DECLINATION

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The curves of Figure 1 give an idea of the effect of various choices of Bn/Be on the resulting beam ellipticity. The spur has its maximum effect when the largest skewed baseline is used, ie the east-west component is Be/2, and the north-south component is Bn. For any Bn/Be < 1, the projected east-west baseline (Vmax = Be*sin(dec)) will dominate the V term at some declination. At this point Vmax for the spur crosses the curve for a pure east-west baseline and the spur no longer improves the beam ellipticity.

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