Version 1: 3/2/97

CSIRO - Australia Telescope National Facility

A Discussion Paper

The 1kT Array:

A. Some Thoughts on the Overall Antenna Specifications, and

B. Concepts for and Performance of a (100m) Phased-Array Element

Introduction

The following thoughts arose from the Australian 1kT Workshop held at the Radiophysics Laboratory on 20 and 21 January 1997. In Part A of this paper, some of the key requirements and specifications for the antenna are considered and questions raised. It is assumed here that cost constraints will limit what can be achieved, ie, real compromises will have to be made in overall performance. Hopefully, this approach will tend to concentrate our thoughts on producing reasonable specifications.

In Part B, two possible solutions for the basic "tile" of an array element are proposed. These proposed concepts flow from an extension of existing technologies. However, at the same time, the opportunity should be grasped during the consideration of such a challenging facility, to contemplate entirely new concepts. In this part, the overall pattern of the (100m) array-element will also be considered.

Part A: The Overall Antenna Specifications

1. Definitions

The following definitions are proposed:

- (100m) Array-element: An antenna element of the 1kT array, approx. 100m in size, and which can operate as a single antenna if necessary.
- Tile: the basic antenna unit of an array-element, approx. 1m in size. A tile may have a number of sub-elements (individual antennas) to cover the frequency range.
- Tile Group: A basic group of tiles which are interconnected for sub-arraying (or simplification of overall phasing). A tile-group may be approx. 10m in size.

2. Some Essential Requirements:

2.1 General Specifications:

Let us assume a minimum set of requirements as follows:

- Frequency coverage: 300-1000 MHz

- Polarisation: dual circular or dual linear
- Element diameter: 100 m
- The resultant beamwidth of the element is: 0.75° - 0.22°.
- Element sidelobe level: < -20dB, with 90 percent, < -25 dB.

2.2 Interference Excision (IE):

Let us assume that IE has to be carried out at the (100m) element level.

What must IE do? It must eliminate all interfering signals to a level where the desired signal in the main beam is received at an adequate level.

It would appear that because IE is such a critical factor to the success of the 1kT project, that it is essential to determine at an early stage:

a) the specification for interference attenuation
b) whether IE is achievable to the degree required with all element configurations being proposed by the various countries. (For example, a reflector antenna may have lower sidelobes than a phased-array, but it may not be possible to implement effective IE).

In general, the approximate direction of interfering signals will be known, except for the azimuth of many land-based signals, especially those affected by anomalous propagation effects. The direction of space-based signals (eg satellite or unwanted astronomical radio sources) will be known, even if the satellites are moving in non-geostationary orbit (eg Low-Earth-Orbit (LEO) satellites). It is interesting to note that all satellite bands below 1215 MHz are relatively narrow, and there are no currently assigned bands between 470 and 1215 MHz.

Because most of the interfering sources will be coming through the sidelobes near elevation 0°, the method of IE adopted must be capable of dealing with signals in this sector, since it is doubtful if any type of antenna being proposed will be able to point in this direction.

3. *Budget Cap v Performance*

3.1 General Strategy

The 1kT project is seen as requiring many innovative solutions to meet an approximate budget of $300m. It may not be possible to reach a realistic solution which will meet the present extensive list of requirements given such a relatively short time-scale. Consequently, there may have to be trade-offs in performance, and the trade-offs may be different for the different (100m) array-element technologies being considered.

In Sec 2.1 some of the critical specifications for the element have been defined or redefined for sake of example, particularly the frequency range, sidelobe level, and the assumed requirement for dual polarisation (this represents a tightening of the current specification).

However, other critical factors which need to be determined as a result of further studies for the (100m) array-element technologies currently being considered are:

a) reasonable elevation angle limits
b) variation in effective area with frequency for the optimum elevation angle (assumed to be normal to the physical aperture, and pointing to the zenith)

c) relative gain degradation with angle from the "zenith" (zenith angle), over the frequency range.

Note that a) could be determined by a practical value of c), particularly if it is not determined by a mechanical or structural limit.

There will be other restraints as well (in addition to IE considered in Sec 2.2), and it would be most useful if experts in the relative areas could list these. This would then enable us to obtain a greater appreciation of the advantages and disadvantages of each type of general technology for the (100m) array-element.

3.2 A specific example of trade-offs in design and performance with fixed cost.

If we take the example of a phased planar array considered at the 1kT Australian Technical Workshop (see Paper by Bruce Thomas). The gain (as a function of scan angle from the normal) is proportional to

Cosθ x pattern of the (1m) tile (θ),
which for a tile pattern $\propto$ cos (θ), gives:
-3.0 dB loss at $\theta = 45°$, assuming no mutual coupling losses.

Any scan-angle use beyond $\theta = 45°$ may be considered a "bonus".

In addition, beam ellipticity increases with θ, and any grating lobes would need to be considered.

By superimposing the array on a mount, and restricting the electronic scan to $\pm$ 10°, considerable simplifications in array design result, and near-all-sky coverage with constant gain is achieved. However, this is done with additional cost (and perhaps with a reliability penalty) because of the mechanical structure. Hence if we are restricted to the same budget cap, the number of (100m) array-elements is reduced, as is the maximum effective area. We could then end up with a set of curves like Fig.A1. Given other things being equal, what is the most effective characteristic for scientific observations?

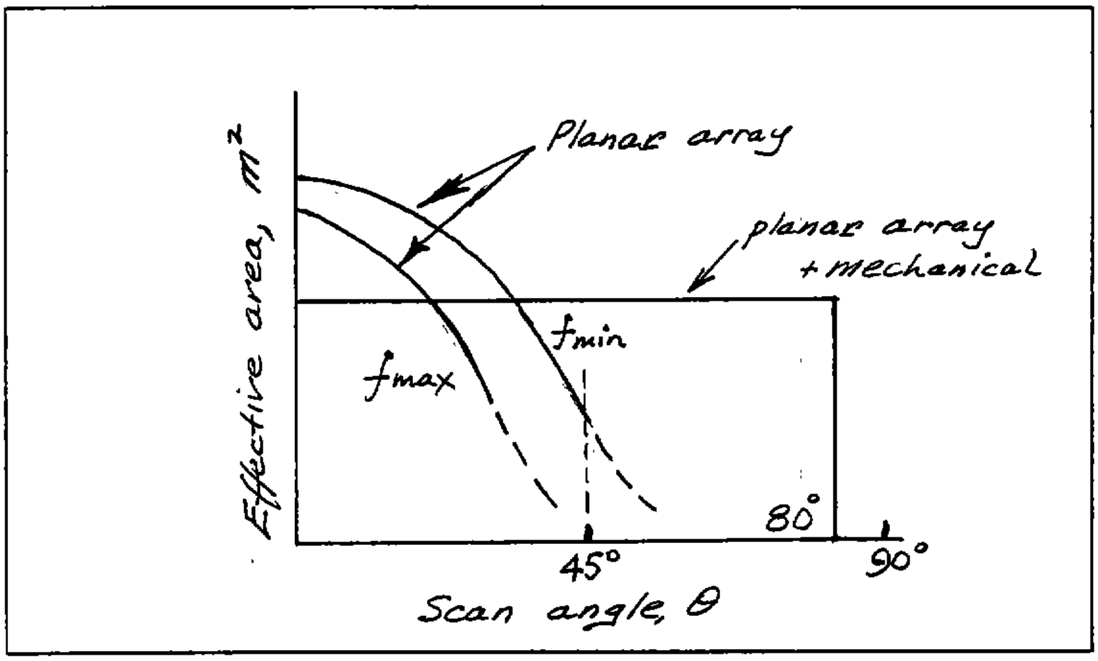


Fig. A1: ***An illustrative example comparing different (100m) array-element technologies. Characteristic: effective area versus elevation angle for a fixed cost.***

Part B: Concepts for and Performance of a (100m) Phased Array-Element

1. Introduction

In this part, a linear array of elements is assumed. The aim is to indicate two alternative concepts for the tile, and to show the effect on gain and sidelobe level of both frequency and scan-angle for the idealised "tile" which covers the two frequency bands:

Band-A: 300-555 MHz, and
Band-B: 540-1000 MHz,

the frequency ratio being 1.85:1 in both cases.

Two types of "tile" are considered, both having the common property of having four Band-B elements effectively "coincident" with one Band-A element. The two types of tile are shown diagrammatically in Fig. B1 (a) and (b):

- Type 1: "stacked" microstrip patches or equivalent vertical elements, see Fig. B1(a); and
- Type 2: waveguide arrayed elements, using metal fabrication techniques, see Fig.B1(b).

An indicative set of parameters for each band may be:

a) the element spacing is ~ 0.54 λ at the minimum frequency and 1 λ at the maximum frequency; and
b) for each elemental antenna, the radiation pattern is given by $\cos^n \theta$, where n is assumed to be a function of frequency, ie, the antenna element is assumed to have increased directivity with frequency so as to minimise the level of the grating lobes. Mutual coupling is ignored in this initial exercise. The $\cos^n \theta$ curves are given in Fig.B2.

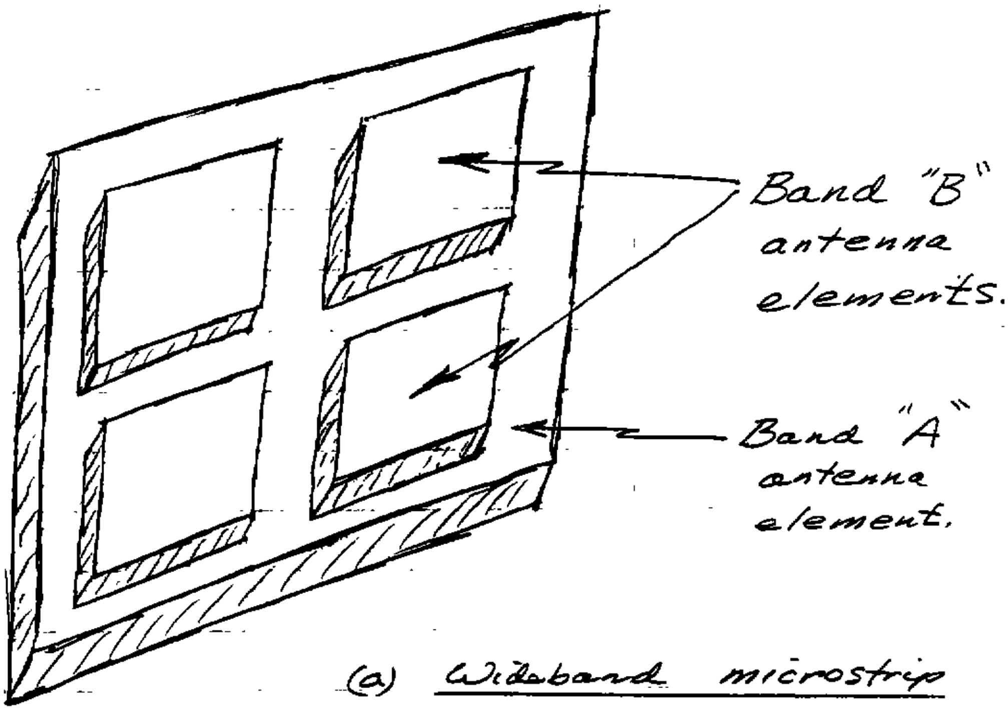
It is intended that this study should stimulate discussion and research relating to the two general Types of tiles proposed above, and secondly, to take a set of idealised tile patterns approximated by Fig.B2, and determine indicative (100m) array-element scanning characteristics as a function of frequency (neglecting mutual coupling).

TO BE CONTINUED

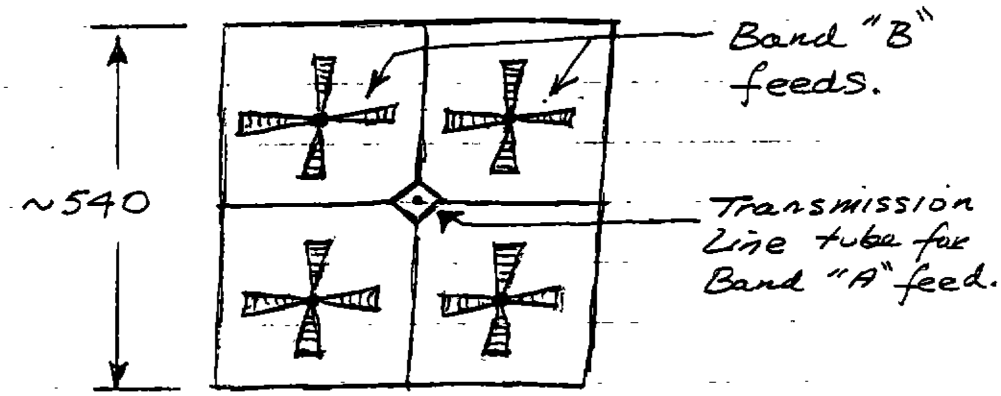
Bruce MacA Thomas
CSIRO, ATNF
3 February 1997

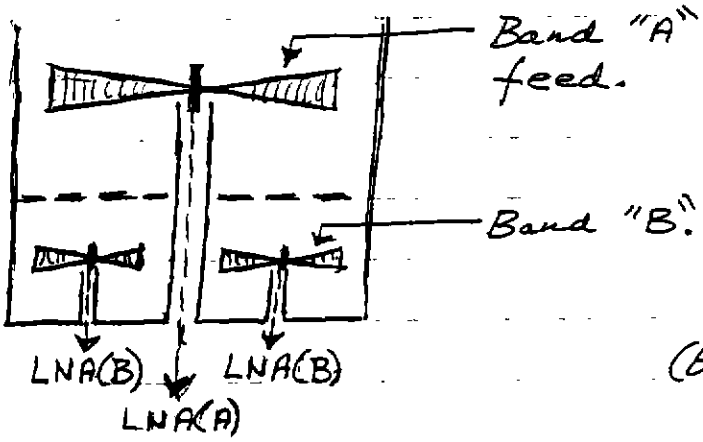
FIG. B1 : CONCEPTS FOR THE "TILE"

(Diagrammatic Only)



(a) Wideband microstrip technology (horizontal and/or vert^{l}).





(b) Square-waveguide Technology.

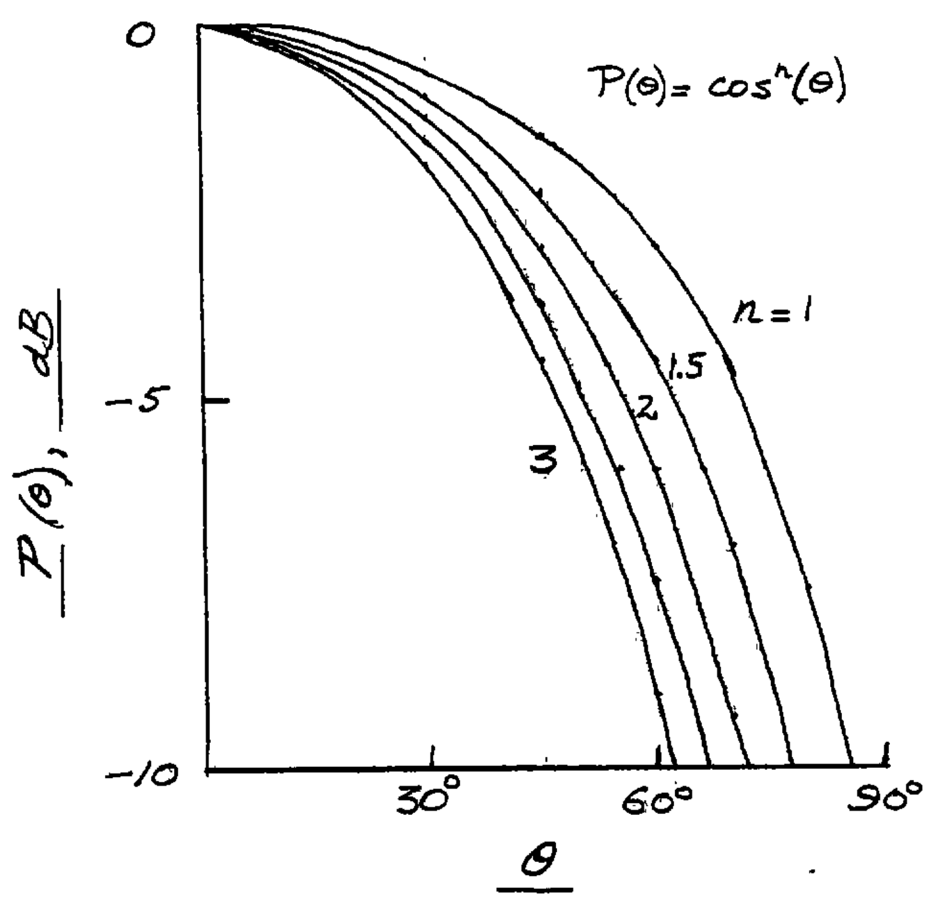


FIG. B2: Idealised tile elemental patterns for preliminary analysis.