DEUTERIUM ARRAY MEMO #070

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To: Deuterium Array Group

From: Alan E.E. Rogers

Subject: SNR of dense and sparse arrays

1] Array Density

There is considerable debate over the relative merits of "dense" and "sparse" antenna arrays for Radio Astronomy. I am not sure that anyone has precisely defined the array density or the point at which an aperture array makes the transition from dense to sparse. In this memo I define the density as

$$density = NAe/Ar \ \geq 1$$

where $N$ = number of elements

$Ae$ = collecting area of each element

$Ar$ = total collecting area of the array

For an array whose individual elements are far apart there is no mutual coupling between elements and the total collecting are is equal to $NAe$ for a density of one. This is the case of a "sparse" array in which the collecting areas do not overlap. In a sky noise dominated regime the system noise is the sum of the amplifier noise and the sky noise received by each element. When the collecting areas of the elements start to overlap the density becomes greater than 1 and the total collecting area is less than the sum of all the individual elements. For half-wave dipole elements over a ground plane this point is reached for an element separation of a half-wavelength. In the SKA documents the half-wavelength spacing of elements is used to define the transition from dense to sparse.

However, if the antenna elements are high gain Yagis or log periodics than the transition occurs at much larger element spacing. If the deuterium array were to be set-up to observe the Magellanic clouds using Yagis with 16 dBi gain the optimum spacing would be about 2 wavelengths as described in D array memo #67.

2] System noise

As mentioned above the sky noise contribution to system noise in a sparse array is just that from each element independently. However as an array becomes dense the sky noise contribution is no longer from the average over the element beam pattern and can be significantly lower in the case where the array beam is directed to a colder region of the sky.

This effect is discussed in detail with D array memo #3

Figure 1 shows the noise from an active array of half-wave dipoles 0.2 wavelengths above a ground plane. Two cases are shown:

1] The array is a regular 4×4 with half-wave spacing.

2] The array is regular 4×4 with 2 wavelength spacing.

In both cases the calibrated output at 150 MHz is shown for the zenith pointing of the array at a latitude of -29˚. The sky model was taken from the 408 MHz all sky map of Haslam et al. (1982). By "calibrated" we mean that the output would be a constant equal to the sky brightness temperature for a uniform sky.

A point source at the zenith would produce the same signal output in either case, however the sky noise contribution is significantly different in each case. The dense array has lower noise when a cold region is in the zenith pointed beam while the sparse array has lower noise when large diffuse regions of the galactic plane are in the main beam.

Figure 2 shows the calculation of the density for an array of dipoles as a function of the element spacing. The effective aperture of the array is calculated using EZNEC for a beam pointed normal to the array.

3] Comments on the results

The dense array allows a larger field of view for each pointing of the beamformer and in addition results in a larger SNR for regions close to the plane but far enough away to be out of the beamwidth of the array. On the other hand the sparse array has a much narrower field of view for each pointing of a beamformer and has side lobes which can raise the noise for observations of the adjacent cold regions.

The field of a view sparse array problem can be solved by using simultaneous multiple pointings of the beamformer or by performing aperture synthesis using the individual elements for a vast increase in the number of baselines in an array of arrays.

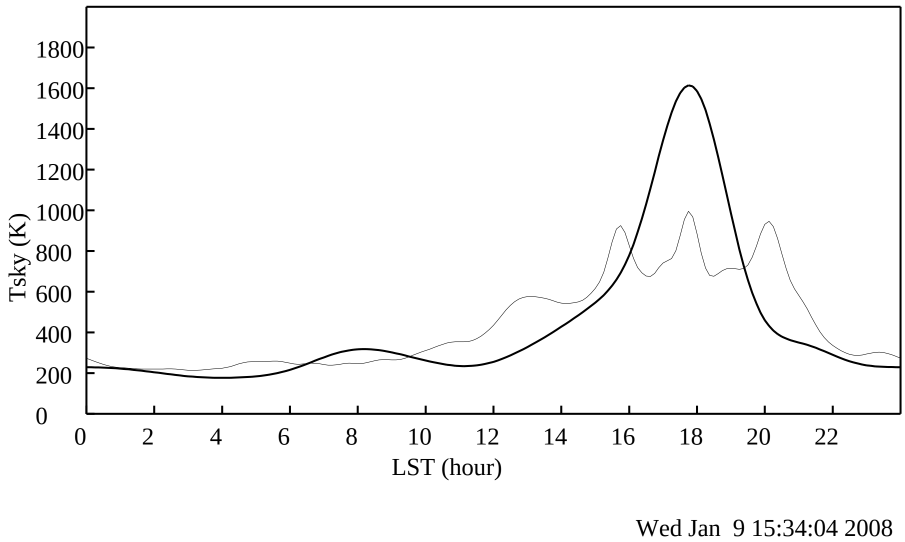


Figure 1. The curves are the antenna temperature from a beamformer pointed at the zenith for a site at -29 degrees latitude using the sky map of Haslam et al (1982) scaled to 150 MHz using a spectral index of 2.5. The thick solid curve is for a "dense" array and the thin curve is for a "sparse" array. Grating lobes of the Galactic center can be seen in the sparse array. Both arrays have the same collecting area so that a pointing source produces the same signal in each array so that the SNR for a point source is proportional to the inverse of these curves.

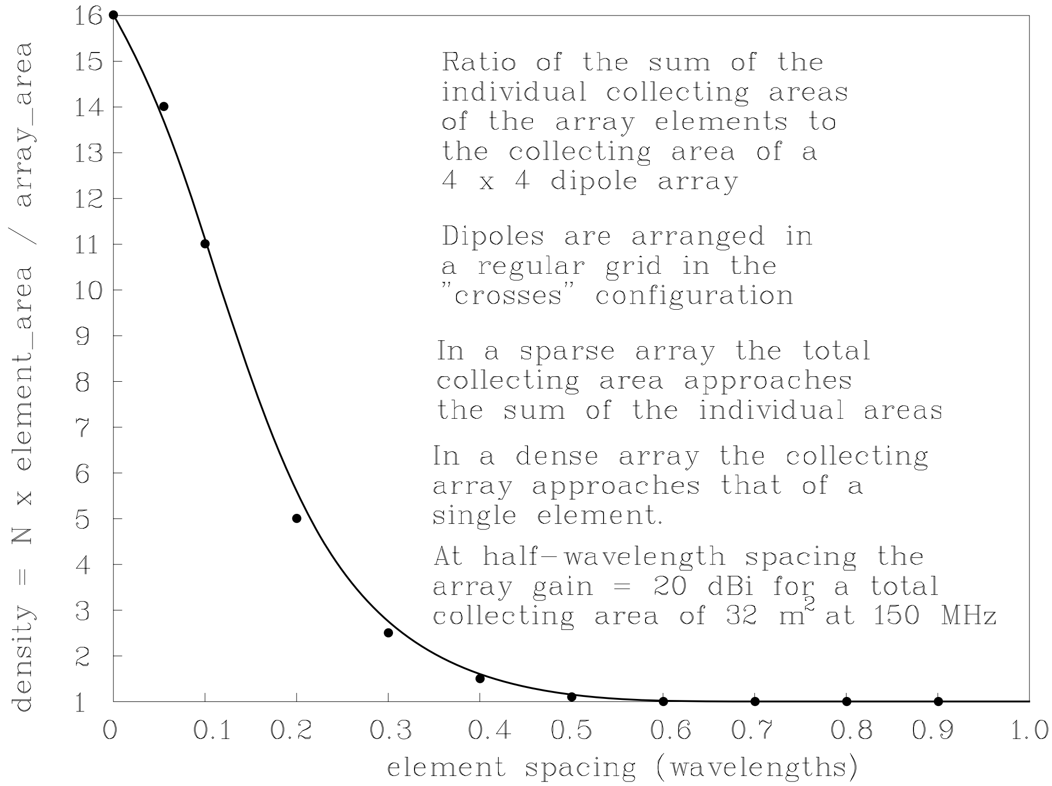


Figure 2. Effective aperture of dipole array as a function of element spacing.