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November 1, 2005

To: Deuterium Array Group

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Subject: Possible configurations for the LMC

To observe the LMC we need a smaller beam width or equivalently more collecting area per station. If we can bring the beamwidth down to $6°$ the expected deuterium signal would be

$$0.28 \times 1.5 \times 10^{-5} \times 50 \times (1/50) \times 12/6^2 \approx 2\,ppm$$

using the method of memo #65. If we assume a beam efficiency of 70% the collecting area for a 6 degree beam is $Aeff = 60m^2$ or 2.5 m^2 per element of the 24 element area.

Since $G = 4\pi\,A/\lambda^2$ this is equivalent to 16 dBi which can be achieved with a 16 element Yagi with 4λ boom length. These Yagis would be mounted about 1.8 m apart. Unfortunately we will now be limited to about a scan angle of about 10 degrees and consequently can only track the LMC for about 6 hours per day. To be able to track the LMC for 24 hours per day while pointing each Yagi at the South celestial pole requires reducing the separation of the Yagis and their gain so that I was only able to obtain a maximum effective area of about 20 m^2. This is a loss of about 4 in signal for a gain of 4 in integration time and results in an overall loss of a factor of 2 in sensitivity.

Some general approximate rules associated with station arrays:

1] The maximum achievable gain at zero scan angle is approximately equal to the geometric area of the station array no matter how much gain is in each element. For a regular $N^{\frac{1}{2}} \times N^{\frac{1}{2}}$ array with spacing s between elements the maximum collecting areas is approximately Ns^2.

2] For a given element gain the array gain at zero scan angle increases with element spacing to reach a maximum collecting area equal to the number of elements times the collecting area of each element.

3] The maximum useable scan angle, θ, is approximately given by $\theta = \sin^{-1}(0.5\lambda/s)$ from the 1 and 2 above the optimum spacing for maximum gain and scan angle is approximately $s = a^{\frac{1}{2}}$ where a is the collecting area of each element.

Combining 1 and 3 we obtain the maximum achievable collecting area, A_{max}, for an array of N elements which can be steered to a maximum scan angle of θ degrees with less than 50% extra loss at the maximum scan angle:

$$A_{max} = N \times 0.5^2 \times \lambda^2 / \sin^2 \theta$$
$$= 40m^2 \quad \left(\theta = 20°, N = 24 \right)$$

An alternate approach

An alternate approach is to phase 4 stations together to form 6 "superstations" from the 24 stations. This approach would require the following changes in the array architecture:

1] Add cables to connect the L.O. from the "master" station to 3 "slave" stations.

2] Constantly transfer data from each station software beamformer to the central array computer to form the "superstation" beams. If we assume a 250 kHz bandwidth, 2 beams and 4 bytes per complex beam the data rate to the central processor would be a sustained

$$24 \times 2 \times 4 \times \left(\tfrac{1}{4} \right) = 48 MB / s$$

If each station has a collecting area of 20 m^2, which is the maximum that can be achieved at 20 degree scan angle, the "superstation" will have a collecting area of 80 m^2. Since the superstation has a 20 degree scan angle capability it can track the LMC for 24 hours a day. The relative sensitivity of this alternate method is $(80/60) = 1.3$ or a 30 percent gain for a substantial increase in complexity.

Assuming 24 dual polarization stations of 60 m^2 the expected SNR for a resolution of 50 kHz and 1 year of observing of 6 hours per day is about 9.