Comparison of E and D configuration sensitivity when D configuration is tapered.

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1 Introduction

The latest design of the new most compact E-configuration of VLA has been finished. The array is located inside of the ellipse (250mx300m). So the array dimensions are approximately 3 times less than the existed most compact VLA configuration: D. Therefore the sensitivity of E-configuration to the brightness temperature of an expanded source might be expected to be 9 times better in comparison with D configuration. However using tapering with the D-configuration data can diminish this advantage. In this memo we estimate the actual possible advantage of E configuration when tapering is used with the D configuration data.

2 The estimation of the sensitivity when the tapering is applied.

The sensitivity (Signal to Noise Ratio-SNR) of an array to the brightness temperature of an expanded source is determined by the ratio of the beam width (in area) BW and noise $NOISE$.

Tapering of D configuration leads to the increasing of its beam width diminishing the advantage of E-configuration. But the tapering also leads to an increase in the noise. In this memo we look at both the effects of the D configuration tapering (beam width increasing and noise increasing) to estimate the final advantage of E-configuration. We consider the noises and efficiencies are identical for all antennas. So effect of the tapering is determined exclusively by the distribution of the array's baselines.

$$\frac{SNR_E}{SNR_D} = \frac{BW_E}{BW_D} \cdot \frac{NOISE_D}{NOISE_E} \tag{1}$$

The noise is inversely proportional to the square root of equivalent number of baselines: $\sqrt{N_{bl}}$. If both D and E configurations are not tapered, then $NOISE_D = NOISE_E$ (because number of baselines is the same) and sensitivity of E-configuration is $\sim$ 9 times better than sensitivity of D configuration (because $\frac{SNR_E}{SNR_D} = \frac{BW_E}{BW_D} = \frac{D^2_{sizeD}}{D^2_{sizeE}}$)

Consider the special case when the tapering of D-configuration makes its beam width the same as for the untapered E configuration. The tapering of D-configuration will increase the noise of D-configuration because the equivalent number of baselines will be decreased. The signal to noise ratio at this case will be equal:

$$\frac{SNR_E}{SNR_D} = \frac{NOISE_D tap}{NOISE_E} = \frac{\sqrt{NBE}}{\sqrt{NBD_{tap}}} \tag{2}$$

where NBE is number of the baselines at the untapered E-configuration

NBD_{tap} is equivalent number of the baselines at the taped D-configuration

As we discovered, D-configuration has the remarkable feature:
Number of baselines inside of the circle of radius R is proportional to this radius (not to the radius' square) with high accuracy!.
Therefore, the ratio $\frac{\sqrt{NBE}}{\sqrt{NBD_{tap}}} = \frac{\sqrt{NBD_{notap}}}{\sqrt{NBD_{tap}}}$ can be substituted by the SQRT of ratio of the equivalent sizes of untapered and tapered D-configuration, which is equaled to ratio of the linear sizes of the relevant beams ($\sqrt{3}$ in our case).

3 Simulation of observations on E and D configuration.

The AIPS task UVCON was used to simulate observations on E- and D-configuration. Then the AIPS task IMAGR was used to estimate both the beam widths and the noise increase caused by tapering. The result is given at the table 1.

Table 1: The result of simulations of E and D configurations with tapering. Snapshot; $\lambda = 10cm$

$UVtaper, K\lambda$	Beam, asec x asec	NoiseFact	SNR=BEAM/NoiseFact
	D-Configuration		
NoTap	26.3x24.6	1.000	647
6x6	35.6x34.5	1.102	1114
4x4	45.0x44.3	1.263	1578
3x3	55.7x55.4	1.438	2146
2x2	77.5x77.1	1.763	3389
1x1	131.9x131.1	2.599	6653
0.5x0.5	210.3x199.4	4.294	9766
0.25x0.25	298x231	6.145	11207
	E-Configuration		
NoTap	78.9x69.7	1.000	5499
4x4	82.3x73.9	1.007	6040
2x2	92.9x86.6	1.082	7435
1x1	132.1x128.3	1.484	11421
0.5x0.5	209.3x205.9	2.476	17405
0.25x0.25	313.7x246.9	4.145	18686

The table confirms the result of the previous section that tapering of D configuration to get the E-configuration (without tapering) beam makes worse the noise in $\sqrt{3}$ times (see the tapering 2x2 in the top half of the table leads to the NoiseFact=1.763).

4 Conclusions

If there is no tapering for both E and D configurations, then E configuration has advantage in surface brightness sensitivity approximately 9 times. But tapering applied to D configuration diminishes this advantage (for snapshot observation) to $\sim \sqrt{3}$ times!