EVLA Memo 65

Comparison of the Brightness Sensitivities of the EVLA Compact E - Configuration and ATA (q8a_2w)

L. Kogan, R. Perley

National Radio Astronomy Observatory, Socorro, New Mexico, USA

September 25, 2003

This report gives a comparison of the brightness sensitivities of two future arrays: the most compact E - configuration of the the Expanded Very Large Array (EVLA) and the Allen Telescope Array (ATA, version q8a_2w). The configurations of these arrays are shown in Fig 1 and Fig 2.

One of the most important applications of both of these arrays will be for mapping low surface brightness emission. Hence it is important to estimate the relative capabilities of these arrays.

The expression for the brightness temperature r.m.s. is given by the following expression:

$$\sigma T_b = 2.14 \, \alpha \, T \, \frac{1}{\eta \sqrt{\Delta f \tau}} \, \frac{1}{FILFAC} \tag{1}$$

where T is the antenna system noise temperature

Δf is the bandwidth

τ is the time of averaging

$\alpha = 1 - 2$ stands for the noise increasing because digitizing of signals

η is the antenna efficiency

The filling factor FILFAC is determined by the following expression:

$$FILFAC = \left(\frac{D_{ant}}{D_{eff}} \right)^2 \tag{2}$$

where $D_{eff} = 1.04 \frac{\lambda}{\theta_{0.5}}$ is the diameter of the equivalent circular dish with the uniform illumination which has the given beam width at the level 0.5

$\theta_{0.5}$ is the full(double) width of the array beam at the level 0.5

$D_{ant} = D \sqrt{N}$ is the diameter of the equivalent circular dish with the uniform illumination which has the geometric area equaled to the area of all antennas of the array

D is diameter of the array antenna

For a single dish with uniform illumination, $D_{ant} = D_{eff}$, and therefore FILFAC=1. For an actual array $FILFAC < 1$ and the more FILFAC is the better the surface brightness sensitivity.

The expression for FILFAC when UV data are tapered is the following:

$$FILFAC_{tap} = FILFAC \, \frac{(beamx * beamy)_{tap}}{(beamx * beamy)_{notap}} \, \frac{1}{SENS} \tag{3}$$

Table 1: Comparison of the filling factors of the two array configurations: E-EVLA and ATA version q8a_2w. The resolution is appropriate for $\lambda = 20cm$.

Array	Size, m	Nant	Dant, m	Beam, "	D_{ant}, m	D_{eff}, m	FILFAC
E-EVLA	250	27	25	165x135	130	288.4	0.203
ATA_tap	900	350	6.1	165x135	114	288.4	0.095
ATA_notap	900	350	6.1	73x63	114	631.3	0.032

Table 2: Comparison of the brightness r.m.s of the two array configurations: E-EVLA and ATA.

Array	FILFAC	brightness r.m.s	ratio of FILFAC	ratio of r.m.s
		arbitrary units		
E-EVLA	0.203	3.36E-3	1	1
ATA_tap	0.095	7.36E-3	2.14	2.19
ATA_notap	0.032	21.0E-3	6.34	6.25

where $(beamx * beamy)_{notap}$ is the no tapered beam size
$(beamx * beamy)_{tap}$ is the tapered beam size
$SENS > 1$ is the loss of sensitivity because of the tapering

We simulated (using AIPS task UVCON) a snapshot observation of a point source at the declination $\delta = 37.1°$ for the two arrays. The AIPS task IMAGR was used to estimate the synthesized beam sizes and the noise increase because of the tapering of the UV data. A wavelength of 20cm was used for the simulation.

Based on the above expressions, Table 1 gives the comparison of the E-configuration of EVLA with the ATA. When the ATA is tapered to the E-EVLA resolution, the relevant loss of the sensitivity because of the tapering is given by IMAGR as 1.639. The actual noise comparison was carried out simulating the observation of a very weak (negligible) point source by the two arrays. The image was created by the AIPS task IMAGR for the three cases shown in table 1. The r.m.s of the noise was calculated for the three cases. Table 2 shows the resulting r.m.s brightness sensitivities (arbitrary units), and their ratios, along with the computed FILFAC.

The ATA array has a lower level of side lobes (because of the much larger number of antennas). Figures 3, 4, and 5 show the histogram of the side lobe distribution inside of the relevant primary beam. The E-EVLA compact configuration was optimized minimizing the product of the PSF function and the primary beam pattern. Histograms with and without multiplication by the primary beam pattern are given for E-EVLA. The positive peaks and rms' of the side lobes are given at the table 3. The most negative side lobes are equal $\sim 4\%$ for E-EVLA and $\sim 0.3\%$ for ATA which are in agreement with the

Table 3: Comparison of the side lobe levels inside of the relevant primary beam of the two array configurations: E-EVLA and ATA version q8a_2w.

Array	Peak, in%	r.m.s, in%
ATA	2	0.27
E-EVLA_nopb	8	2.3
E-EVLA_yespb	3	1.2

theory for natural weighting ([1]).

Conclusion

The EVLA compact configuration has an advantage of about a factor of two in surface brightness sensitivity over the ATA configuration with identical antenna efficiencies, system temperatures, bandwidth, and average time. The final comparison has to take into account the difference in antenna efficiencies, system temperatures, bandwidth, and average time.

The ATA array will have an advantage in mosaicing speed (taken as proportional to $N D$), because of the smaller size of its antennas and as a result its wider field of view.

The lower side lobes of the ATA should give an advantage to that array for imaging fidelity.

References

[1] L. Kogan, Level of Negative Side Lobes in an Array beam, Publications of the Astronomical Society of the Pacific, **111**: 510-511, 1999 April
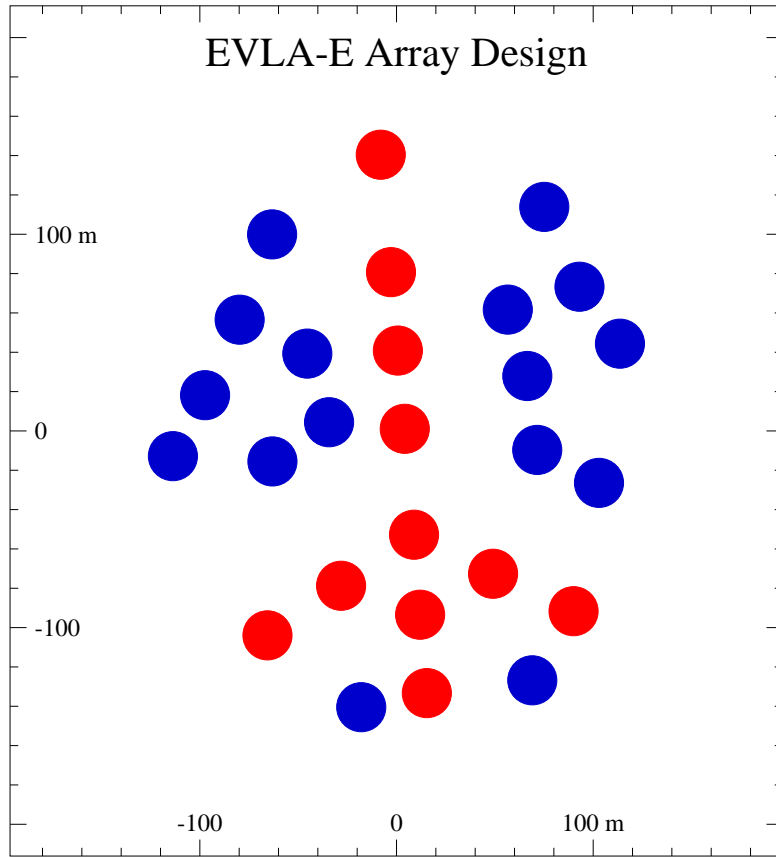
Figure 1: The EVLA E - configuration. The size of the dots shows the antenna diameter of 25 meters. The red antennas are on existing (D-configuration) pads. The blue dots mark locations of the proposed new pads.
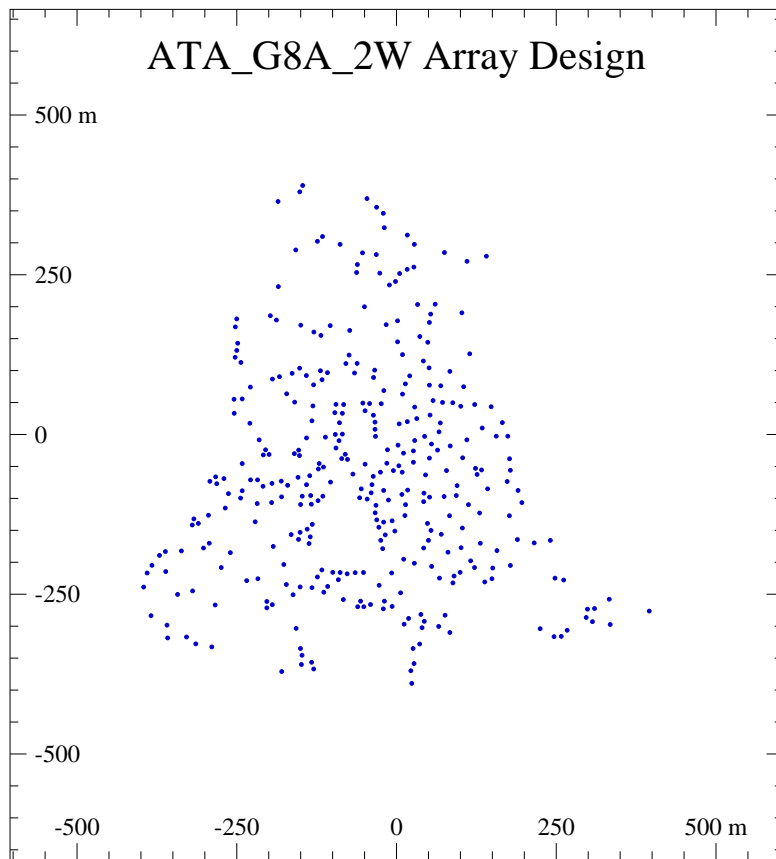
Figure 2: The ATA configuration (version Q8A_2W). The size of the dots shows the antenna diameter of 6.1 meters.
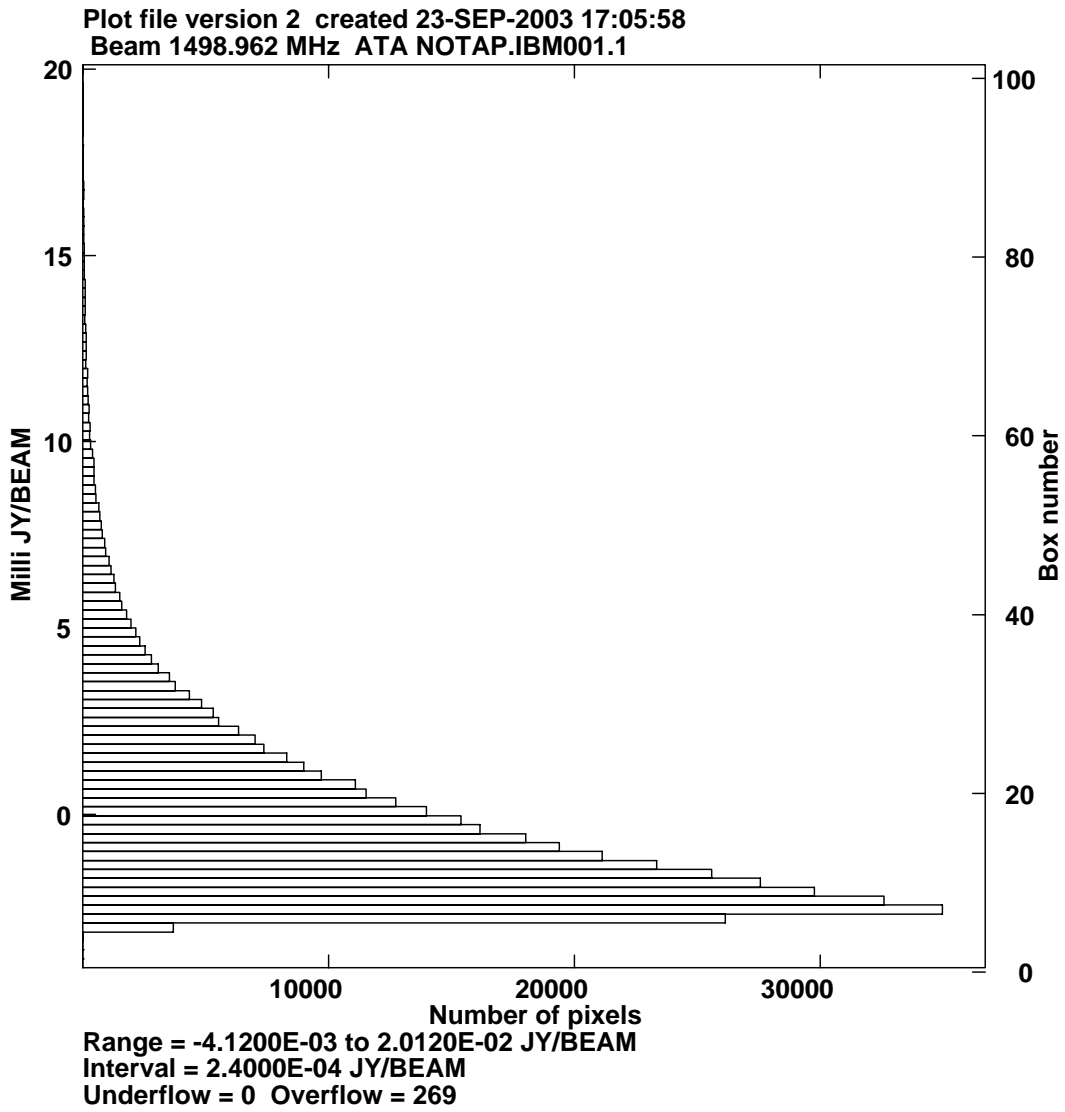
Figure 3: The histogram of the ATA configuration (version Q8A_2W) side lobes inside of the ATA antenna primary beam. Natural weighting was used to create the PSF function. The PSF function has not been multiplied by the antenna primary beam. The peak side lobe is $\sim 2\%$. RMS of side lobes is $\sim 0.27\%$.
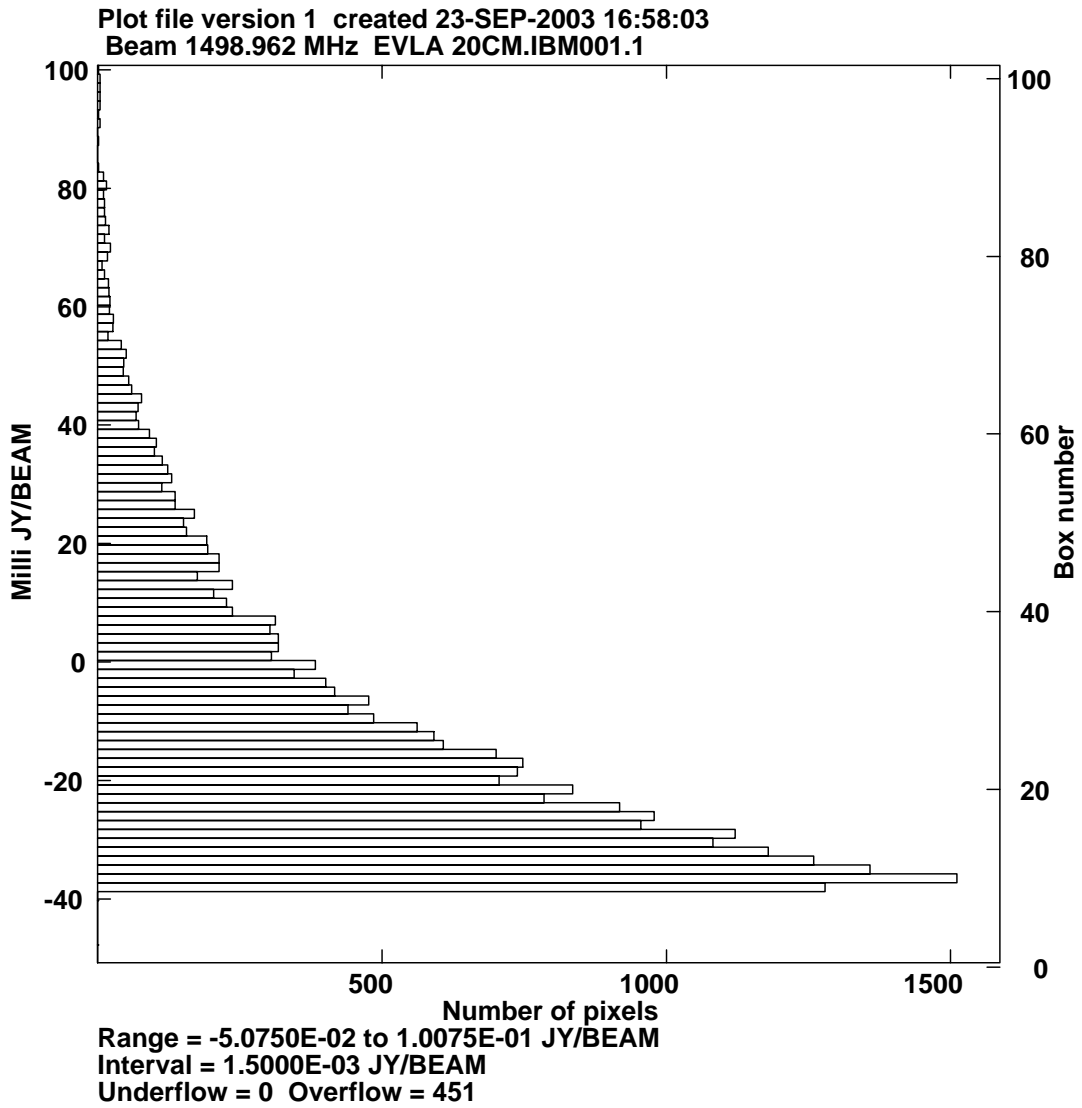
Figure 4: The histogram of the E-EVLA configuration side lobes inside of the EVLA antenna primary beam. Natural weighting was used to create the PSF function. The PSF function has not been multiplied by the antenna primary beam. The peak side lobe is $\sim 8\%$. RMS of side lobes is $\sim 2.3\%$.

Plot file version 1 created 24-SEP-2003 09:41:22
Beam 1498.962 MHz EVLA 20YESPB.IBM001.1

Range = -4.0450E-02 to 5.0450E-02 JY/BEAM
Interval = 9.0000E-04 JY/BEAM
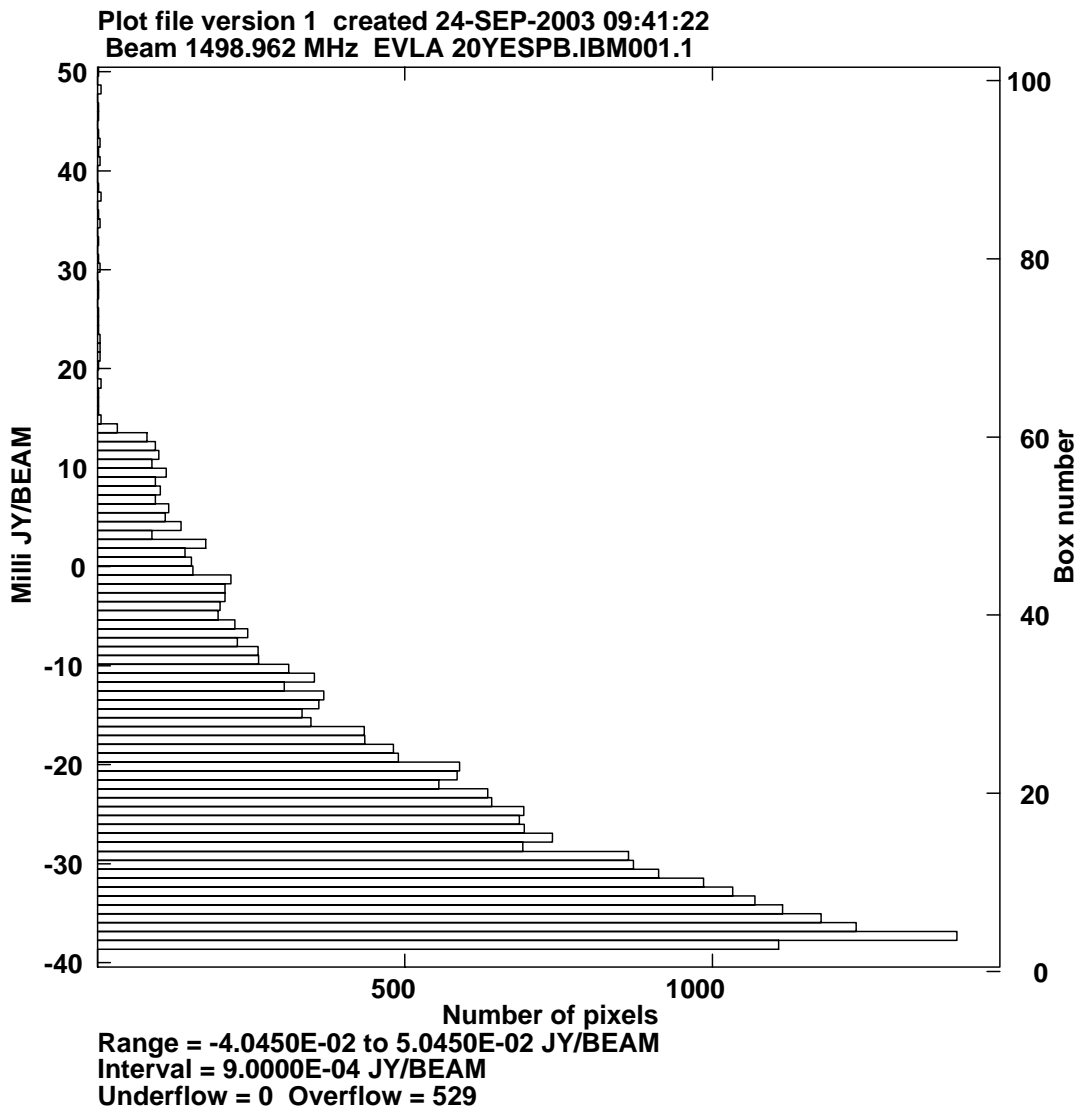**Underflow = 0 Overflow = 529**

Figure 5: The histogram of the E-EVLA configuration side lobes inside of the EVLA antenna primary beam. Natural weighting was used to create the PSF function. The E-EVLA configuration was designed minimizing the product of the PSF and primary beam functions. Here the PSF function has been multiplied by the antenna primary beam. The peak side lobe is $\sim 3\%$. RMS of side lobes is $\sim 1.2\%$.