

Optimization of SKA Configuration Minimizing the Side Lobes.

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Abstract

The result of optimization of the SKA configuration for the number of antennas 200, 500 has been given. The minimization of the worst side lobe at the given circle at the sky is chosen as a criterion of the optimization. The optimization is based on the algorithm published by L.Kogan at IEEE Transaction on AP vol48, No 7, July 2000. The algorithm is coded at AIPS as task CONF1. The found configurations gives the worst side lobes ~ 0.0008 , and ~ 0.0003 for the number of antennas 200 and 500 at the diameter of the circle at the sky equaled 20 of synthesized beam. The relevant side lobes at the diameter of the circle at the sky equaled 100 of synthesized beam are 0.019 and 0.012 for the number of antennas 200 and 500. An example of simulation is given using M51 as a model at $\lambda = 21cm$ and size of the array 400km with 200 antennas at the array.

The optimization of the array configuration is very important for any array including SKA. The statement of the task is very simple.

Having given the number of identical antennas, find their best configuration taking into account the given constraints.

The solving of this task stumbles since the beginning on the definition of the “best”. There are many criteria of definition of the best configuration. In particular they can be splited (Bryan?) on two classes making comparison at UV plane and at image plane. In UV plane it can be for example minimum of ratio of max and minimum spacing at the UV coverage, Gaussian distribution of the UV coverage density and so on. At image plane it can be shape/width of the synthesized beam, rms of the side lobes, minimum of the maximum side lobes and so on.

But everyone knows that there is no the best configuration which will be the best for any image. We can say which configuration is better only carrying out summulation of observation of the model source and estimating fidelity and dynamical range of the restored image.

If the image has a discrete Fourier transform then it is the best configuration for this image. In the reality one conclusion is obvious:

The more antennas the better.

The SKA array satisfies this criterion better than any other array because the huge number of antennas planned to use. But still it is important to try to find the best configuration.

I like criteria determined at the image plane better because they are more close to the final product of the observation: the image of the object. Just for example consider the even distribution at UV plane which looks

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rather attractive. But even distribution at the UV plane creates 100% grating side lobes. And this feature does not look so attractive.

The question:

Why do we need to optimize side lobes if CLEAN takes care of it in any case?

The answer:

The lower side lobes the better dynamic range and fidelity of the restored image especially at the presence of noise.

Recent simulation carried out for ALMA definitely showed that the lower side lobes the better fidelity and dynamical range of the restored image.

Fig 1. Compare different configuration imaging

Using the criterion of the lowest side lobes we can paraphrase the problem of optimization of the configuration:

Having given the number of identical antennas, find the configuration with lowest side lobes at the given area at the sky taking into account the given constraints.

I have developed the algorithm which solves this problem. The algorithm is coded at AIPS as task 'CONF1'. I have modified CONF1 for SKA increasing the number of possible antennas to 1000. The algorithm optimizes the positive side lobes of the snapshot observation interactively starting with an initial configuration.

Negative side lobes do not depend on the configuration. For any configuration the negative side lobes are equal $\frac{1}{N-1}$. I am speaking about snapshot observation. For example for VLBA the negative side lobes are 11% and for VLA they are 4%. We need to carry out the side lobes optimization only at zenith direction, because the side lobes at any other direction differ only in location but not in the size. So if we optimize side lobes at zenith inside of the circle of the sky of radius R, they will be the same inside of the ellipse with the minor semi axis equal R and therefore the area of optimization will be larger for the non zenith direction.

It is clear that the less area of optimization the deeper can side lobes be suppressed. By the nature the side lobes can be separated at the two classes: near side lobes and grating side lobes. Grating side lobes can be very large reaching at the extreme case of even UV distribution 100%. The near side lobes spread from the main synthesize lobe to $\sim \sqrt{N}$ of $\frac{\lambda}{D}$, where N is number of antennas at the array; D is its size. For example for VLA grating (bigger) sidelobes start at 5-6 $\frac{\lambda}{D}$. Including Earth rotation tracks usually make grating side lobes less and does not change the near side lobes.

Fig 2,3,4,5 Beam with near and grating side lobes optimized.

Fig 6. Simulation of observation of M51.

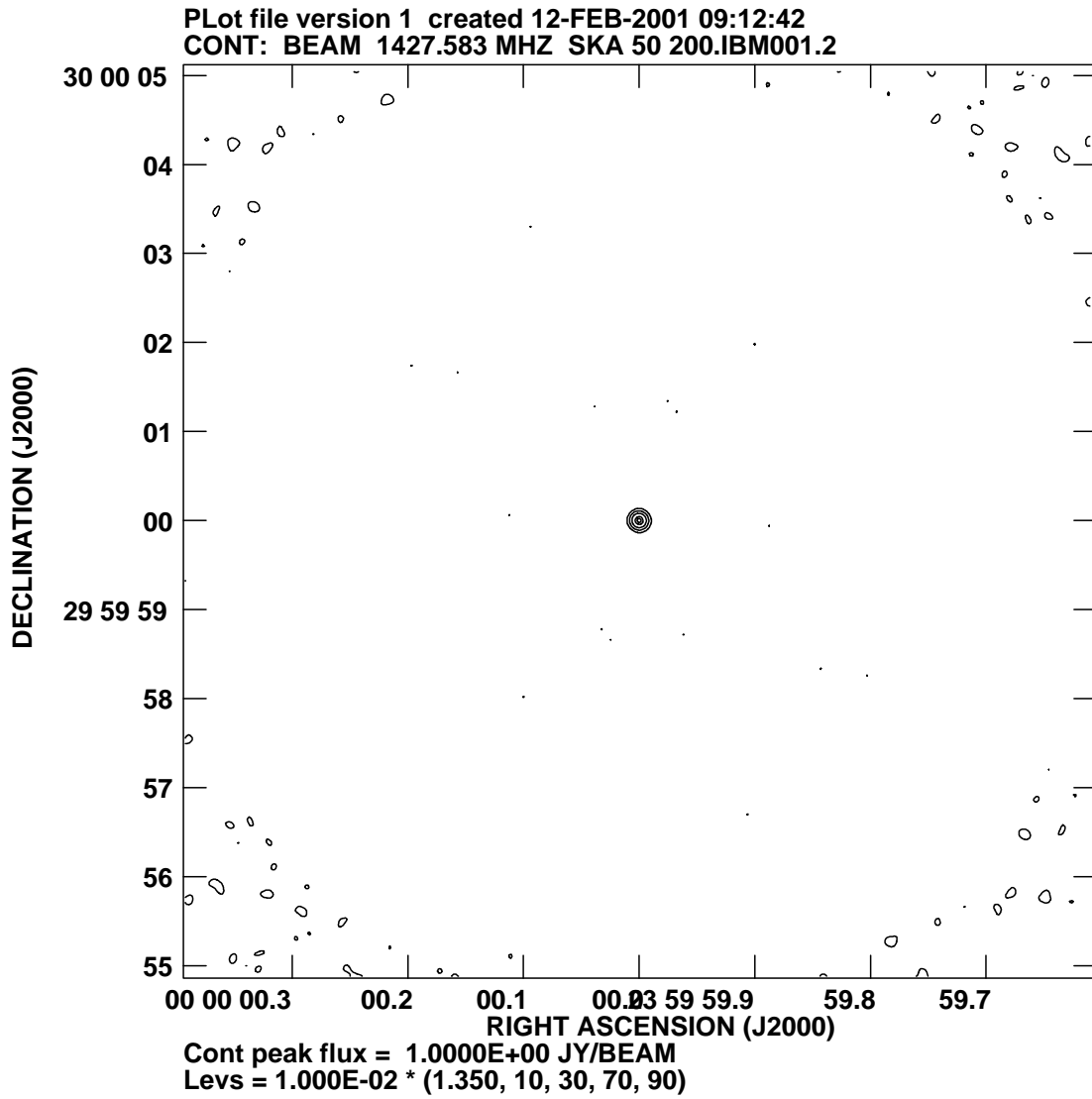


Figure 1: The two dimensional beam of the optimized array with 200 antennas. The diameter of the circle of optimization at the sky is $100 \frac{\lambda}{D}$, where $\lambda = 21cm$, $D = 400km$. The side lobes are less than 0.019.

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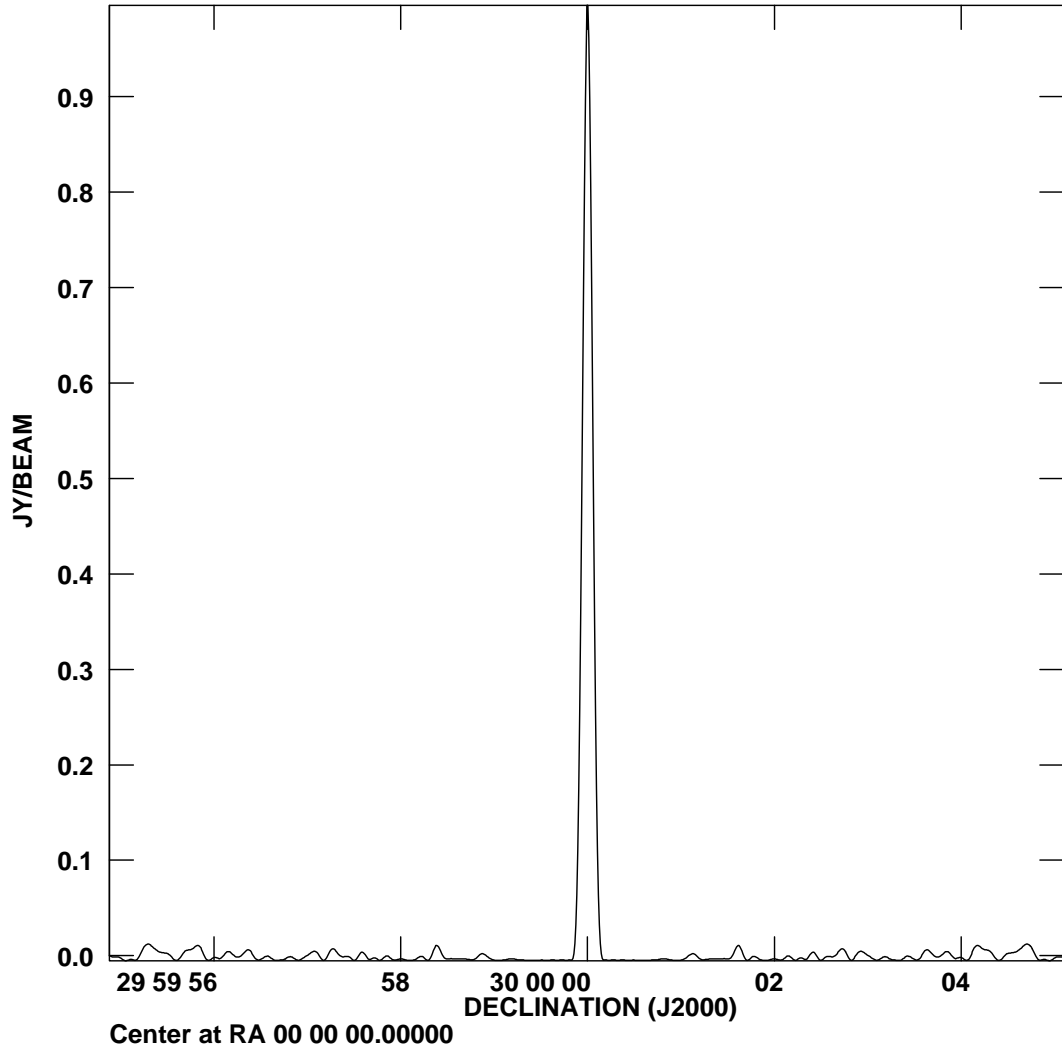


Figure 2: The beam slice of the optimized array with 200 antennas. The diameter of the circle of optimization at the sky is $100\frac{\lambda}{D}$, where $\lambda = 21cm$, $D = 400km$. The side lobes are less than 0.019.

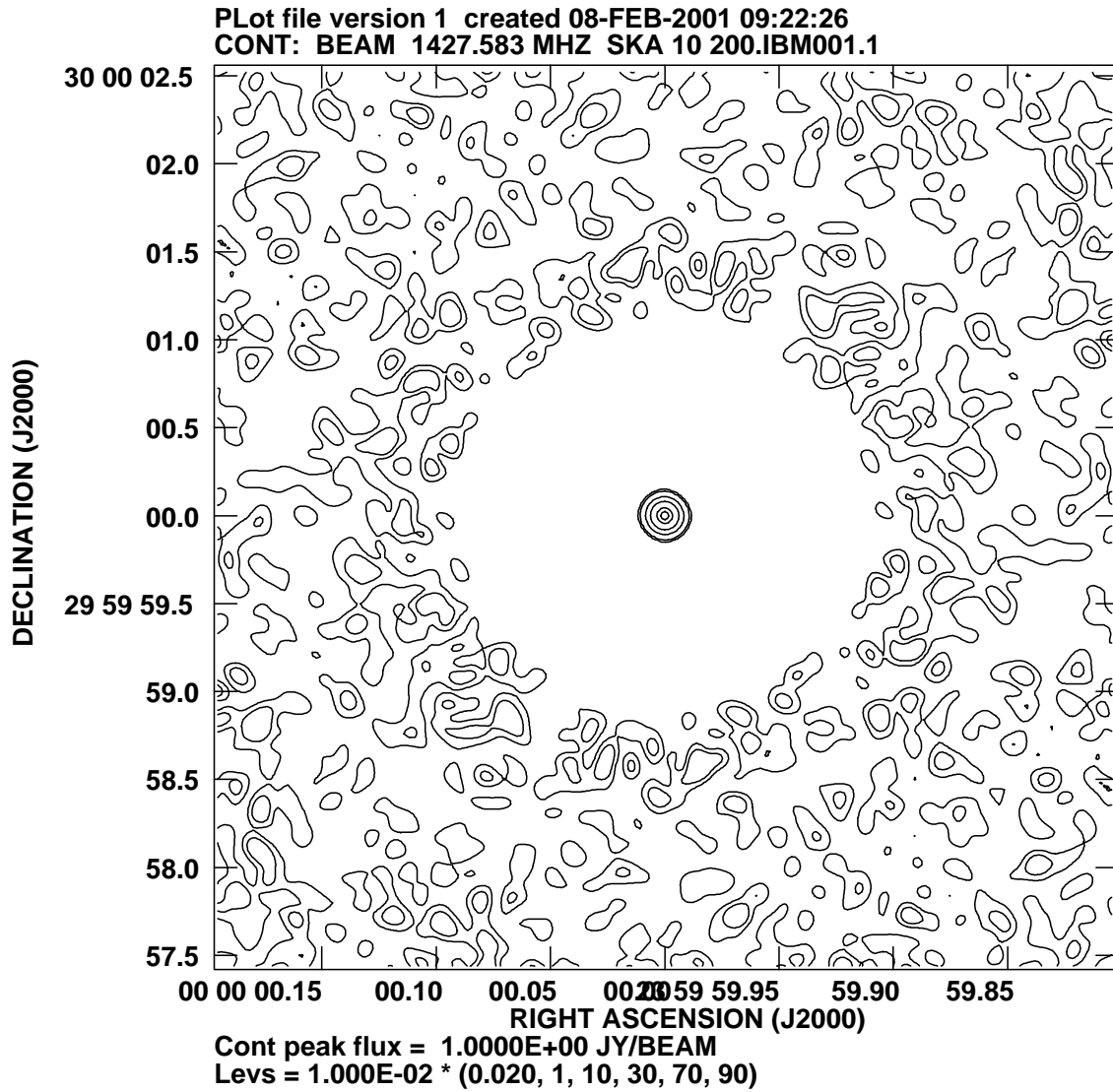


Figure 3: The two dimensional beam of the optimized array with 200 antennas. The diameter of the circle of optimization at the sky is $20 \frac{\lambda}{D}$, where $\lambda = 21\text{cm}$, $D = 400\text{km}$. The side lobes are less than 0.0008.

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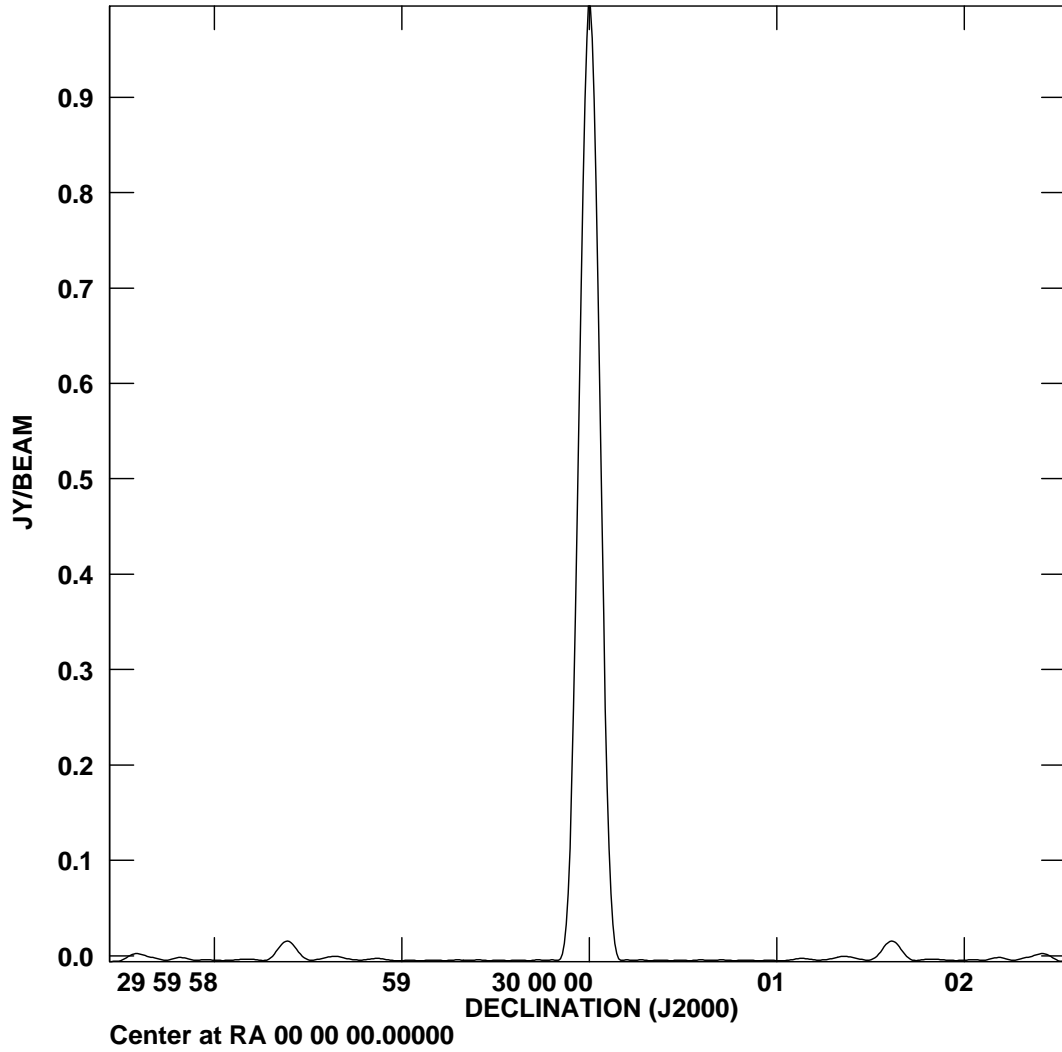


Figure 4: The beam slice of the optimized array with 200 antennas. The diameter of the circle of optimization at the sky is $20 \frac{\lambda}{D}$, where $\lambda = 21 \text{ cm}$, $D = 400 \text{ km}$. The side lobes are less than 0.0008.

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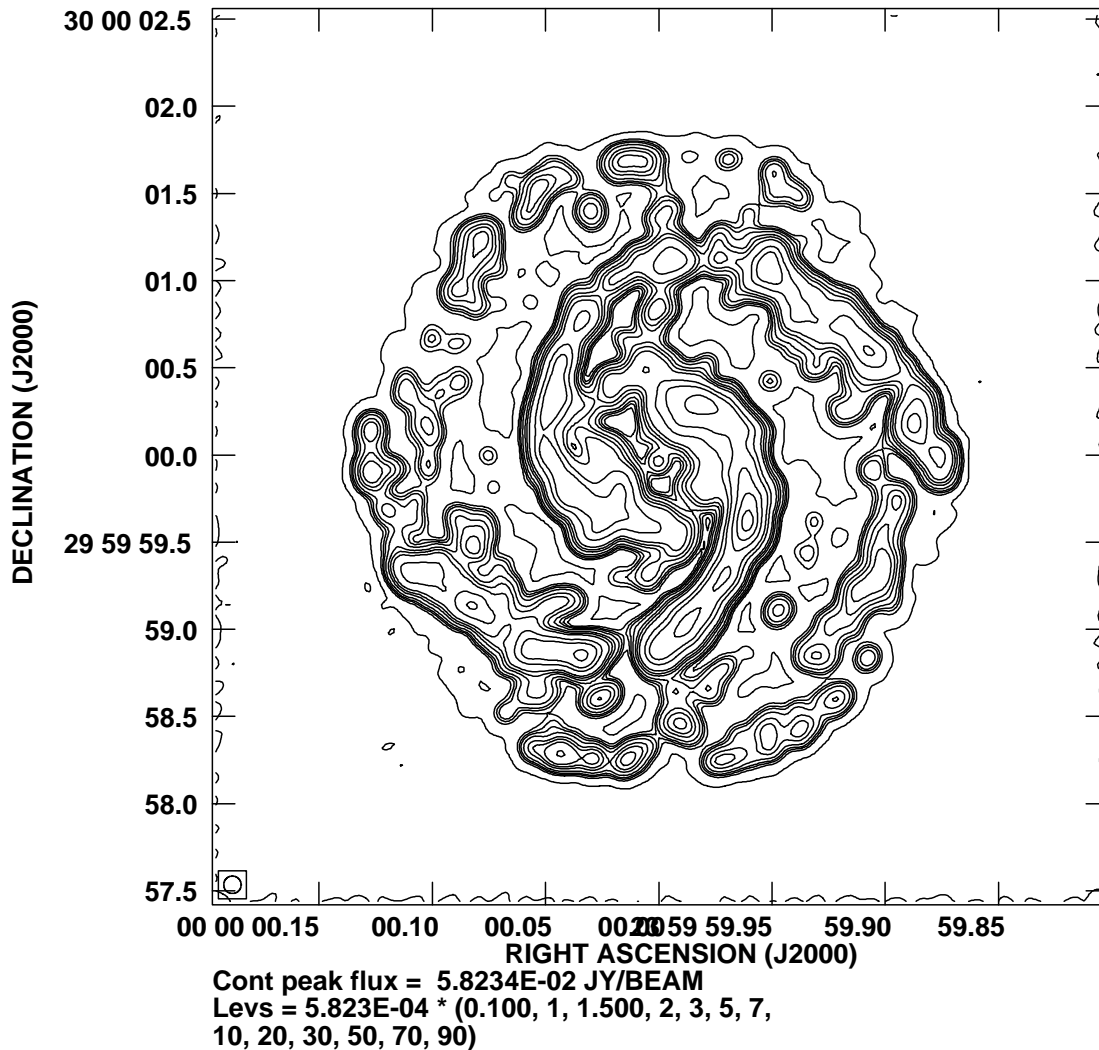


Figure 5: The image obtained from the simulated observation of M51 by the array with 200 antennas. $\lambda = 21\text{cm}$, $D = 400\text{km}$. The dynamic range of the image $1.0 * 10^4$