ngvla
Next Generation Very Large Array

ngVLA Antenna Configuration Options and Performance Estimates

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Reference Design

The ngVLA reference design is comprised of three fundamental subsets: the main array (MA) of 18 meter antennas, the long baseline array (LBA) of 18 meter antennas and the short baseline array (SBA) of 6 meter antennas. Four antennas in the MA will also be equipped to measure total power. The ngVLA antenna locations have been chosen to accommodate a wide variety of scientific observations, aiming to deliver high sensitivity over a wide range of resolutions with a non-reconfigurable array.

The ngVLA can in principle operate with combinations of different subsets and/or subarrays (see some examples in Table 1 below).

Table 1. Subsets and selected subarrays of the ngVLA reference design.

Subset/Subarray	B_{min} (km)	B_{max} (km)	# antennas
LBA	0.033	8856	30
MA	0.031	1005	214
SBA	0.011	0.06	19
MA+LBA	0.027	8856	244
Mid	7.7	1005	46
Plains	0.25	36.5	74
Plains+Core	0.027	36.5	168
Core	0.027	1.3	94

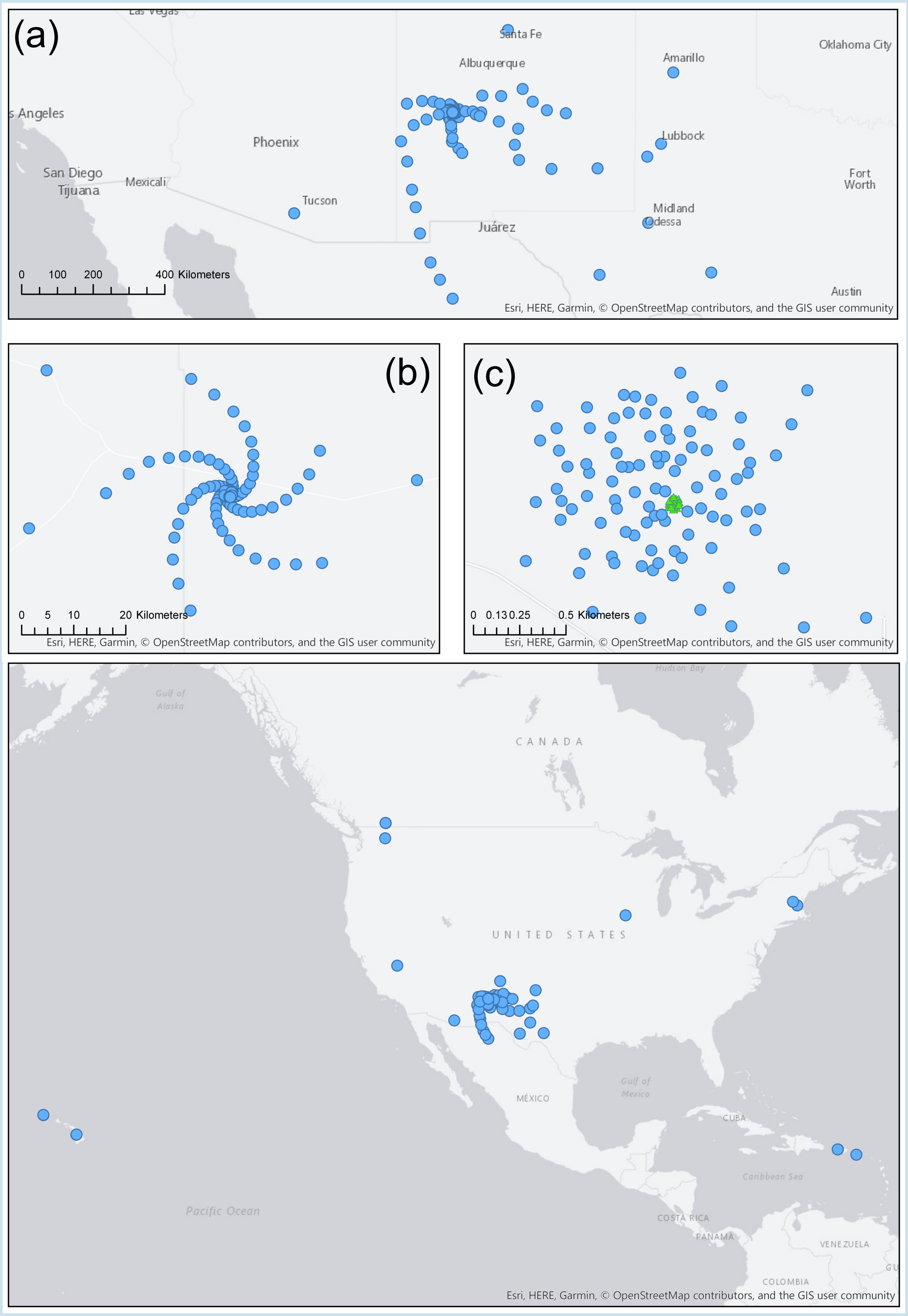

Figure 1. Top: Subarrays of the MA: a) Mid; b) Plains; c) Core (with SBA shown in green). Bottom: the MA and the LBA. Multiple antennas (typically ~3) are located at each of the 10 LBA stations.

Sensitivity

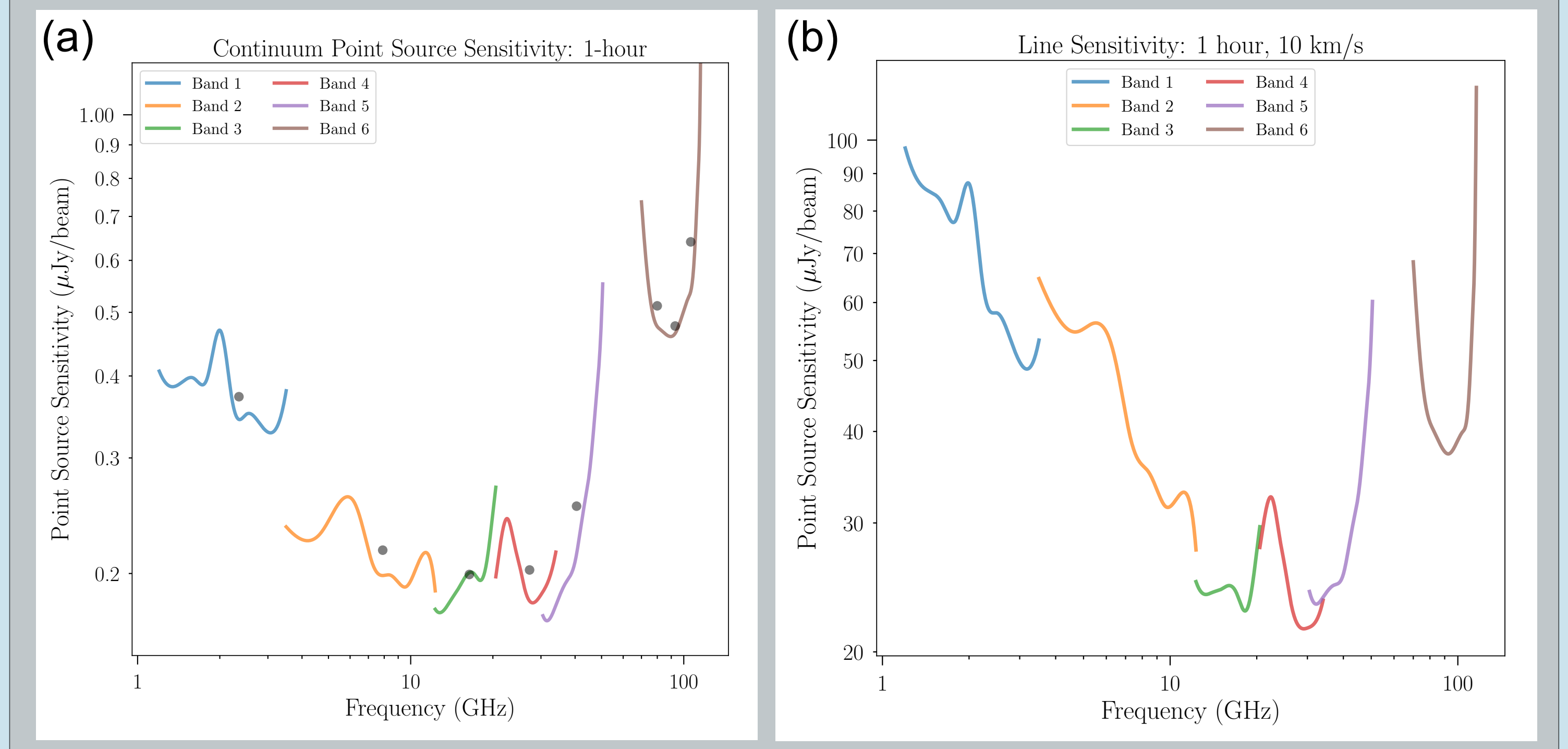

Figure 2. The ngVLA is designed to operate over a frequency range of 1.2 - 116 GHz with 6 receiver bands. The achievable image sensitivity has been carefully modeled, accounting for the receiver temperature, aperture efficiency, atmospheric conditions and spillover as a function of frequency.

The black points in Figure 2a show the 1-hour continuum sensitivity using the maximum available bandwidth and the colored lines show the relative SEFD across each band. The maximum instantaneous correlator bandwidth of 20 GHz exceeds the receiver bandwidth at all bands except at band 6. Figure 2b shows the 1-hour spectral line sensitivity assuming a 10 km/s channel width.

Taperability

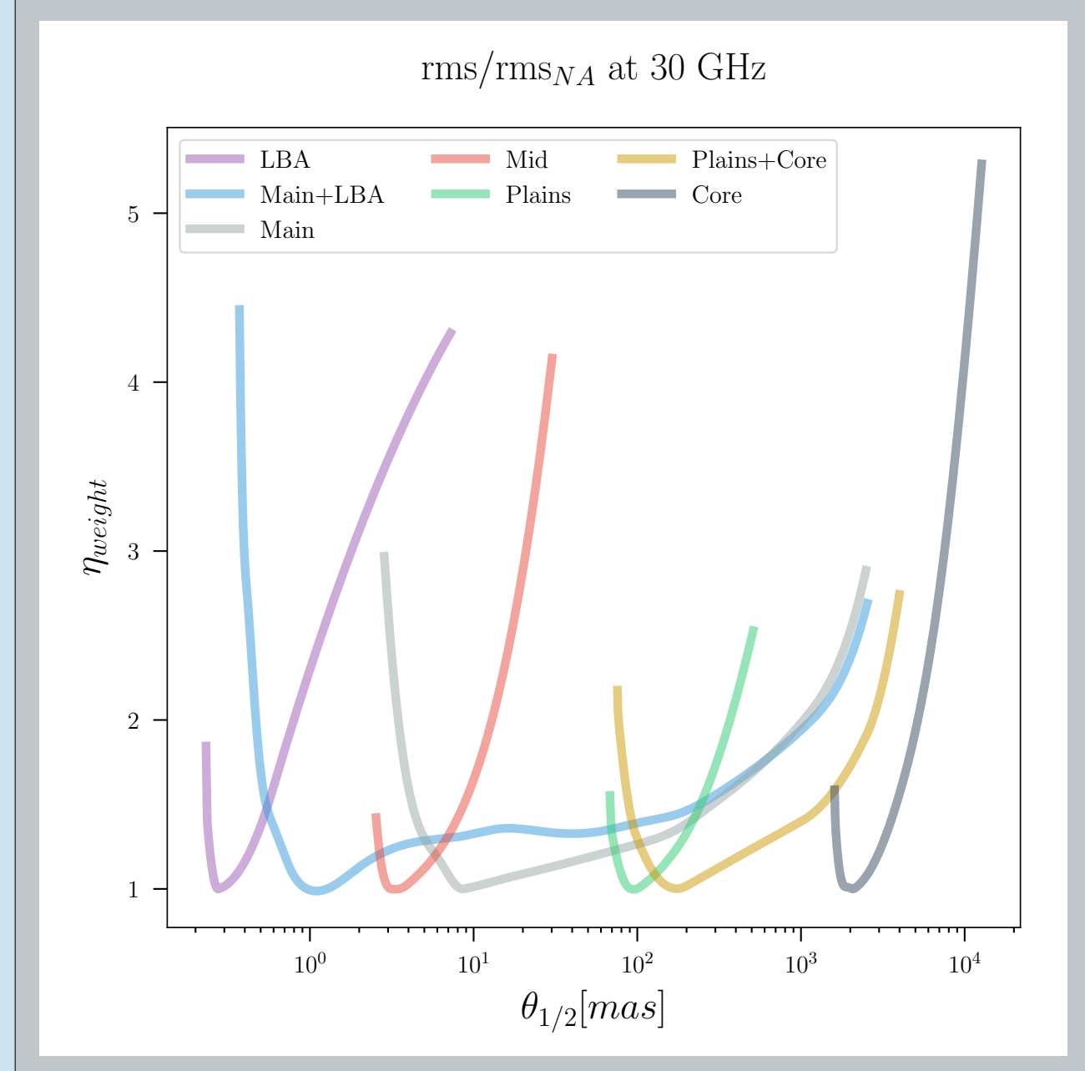

Figure 3. Relative sensitivity vs. resolution for ngVLA subarrays and selected array combinations.

Taperability (*i.e.*, the change in sensitivity versus resolution) is used as a metric to compare arrays and to understand how well an array can perform at both high and low resolutions. We tabulate the simulated image noise from 4-hour simulations at 30 GHz over a range of angular scales, $\theta_{1/2}$, achieved by varying the imaging weights (Briggs robust parameter and outer UV-taper). These results can also be applied to other frequencies by scaling $\theta_{1/2}$ (see ngVLA memo #55).

Figure 3 shows a compilation of the taperability curves for the arrays presented in Table 1 (except for the SBA). Each curve is normalized by the naturally weighted rms, σ_{NA}, and we have defined an efficiency factor, η_{weight}, such that the expected image rms after weighting is $\sigma_{rms}=\eta_{weight}\sigma_{NA}$. From this study we concluded that the full complement of ngVLA 18 meter antennas (Main+LBA) has a high degree of taperability, *i.e.*, it can accommodate a wide range of resolutions without a great loss of sensitivity ($\eta_{weight}\leq 2$). This figure also demonstrates the advantage of subarrays at extreme resolutions or to obtain greater efficiency at specific intermediate resolutions.

Simulation Tools

The results presented here are derived from simulations using the Common Astronomy Software Applications (CASA) package. CASA has two simulation tools available: the `simobserve` task and the `sm` toolkit. These methods generate measurement sets, predict model visibilities and can add different types of noise. A guide to running ngVLA simulations in CASA can be found at *casaguides.nrao.edu* under the *Simulations* section.

Array configuration files for ngVLA subarrays and selected subarray combinations can be obtained from *ngvla.nrao.edu/page/tools* for use in simulations and calculations that investigate the scientific capabilities of the ngVLA.

PSF Quality and Efficiency

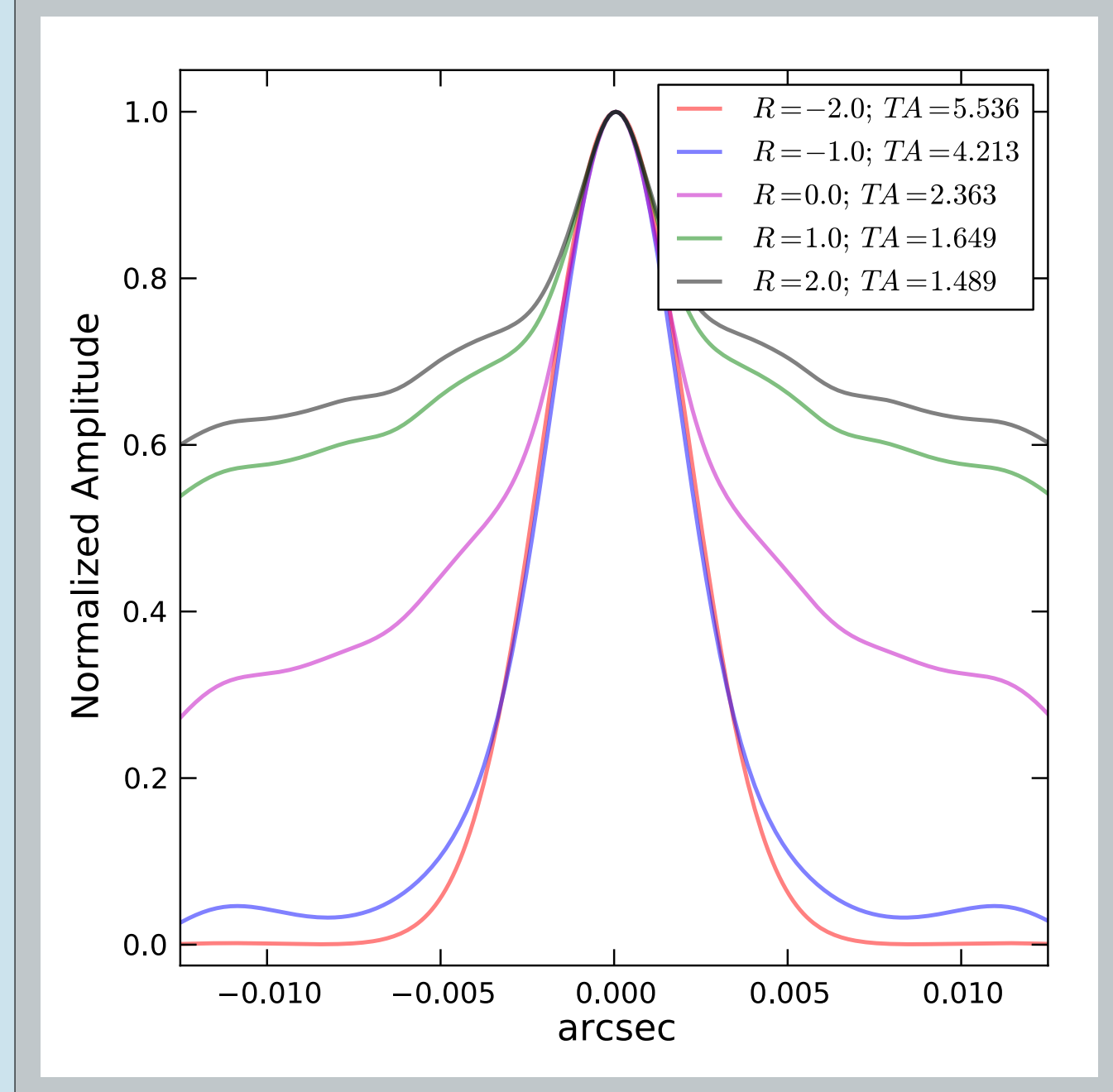

Figure 4. 1D East-West cuts through example PSFs showing the effect of different imaging weights for a constant clean beam size of 5 mas.

Subarrays that include an over-density of short baselines produce a naturally-weighted PSF that has a broad skirt. We have found that combinations of robustness and tapering allow for a higher quality beam (*i.e.*, more Gaussian; see Figure 4) at the expense of sensitivity. But it is important to select a combination of image parameters that will reduce the skirt to an acceptable level without losing too much sensitivity compared with natural weighting.

An alternative way to reduce the level of the skirt is to select a subarray where the ratio of short baselines is not as large when compared with the amount of longer baselines.

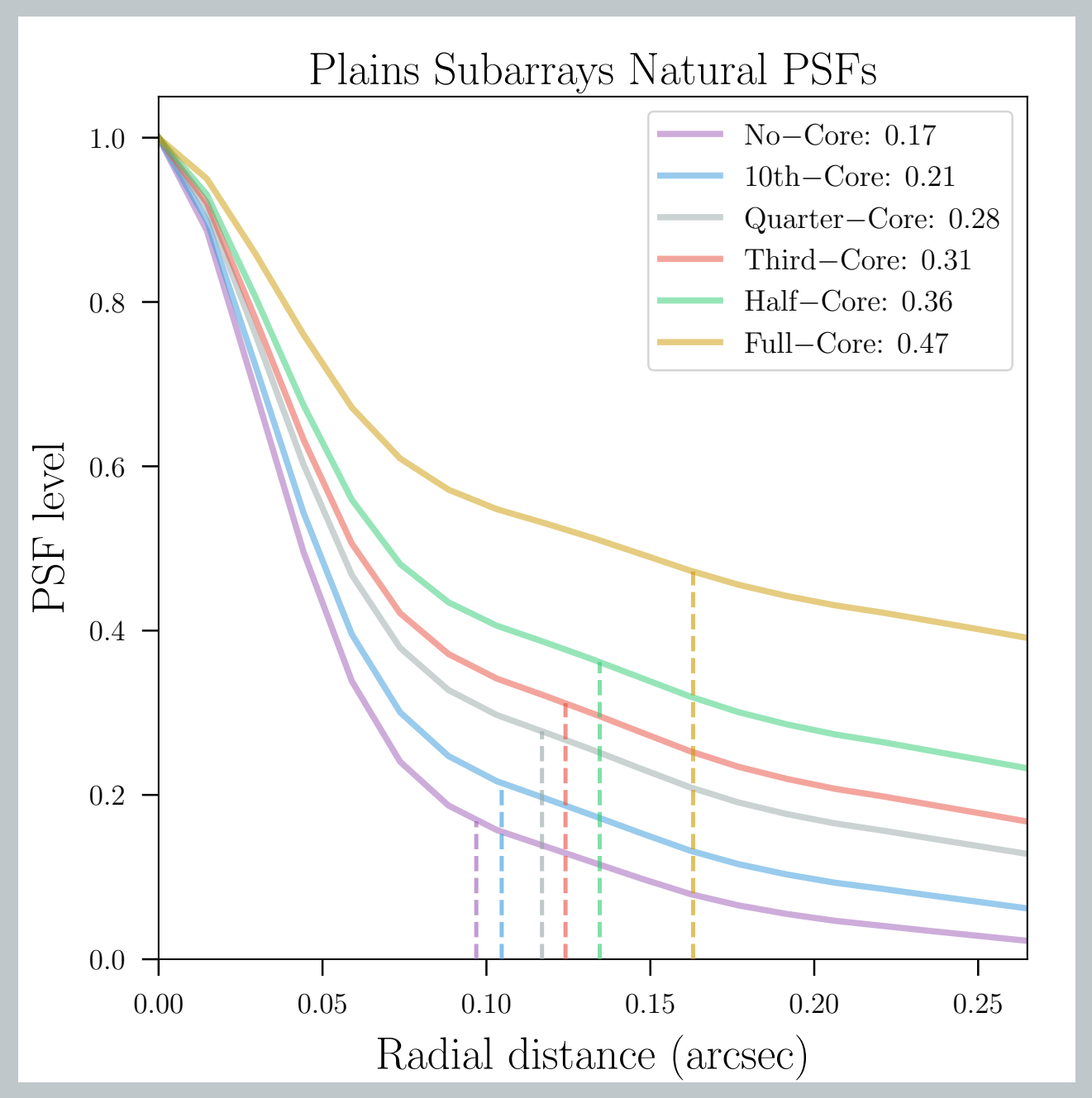

Figure 5. Naturally weighted and untapered PSF profiles for different subarrays (dashed lines show the level of the PSF at a radius of one FWHM).

As an example of choosing such a subarray, Figure 5 shows PSF profiles for subarrays that contain the Plains plus a fraction of the Core. In our study, we found that both the efficiency and quality of the beam improves by reducing the number of Core antennas used together with the Plains subarray. Figure 6 shows slices at constant resolution through the taperability curves for these subarrays, illustrating how different subarrays are more efficient at different resolutions. Furthermore, subarrays that produce a more Gaussian PSF will require less extreme imaging weights and therefore will incur a less severe sensitivity penalty.

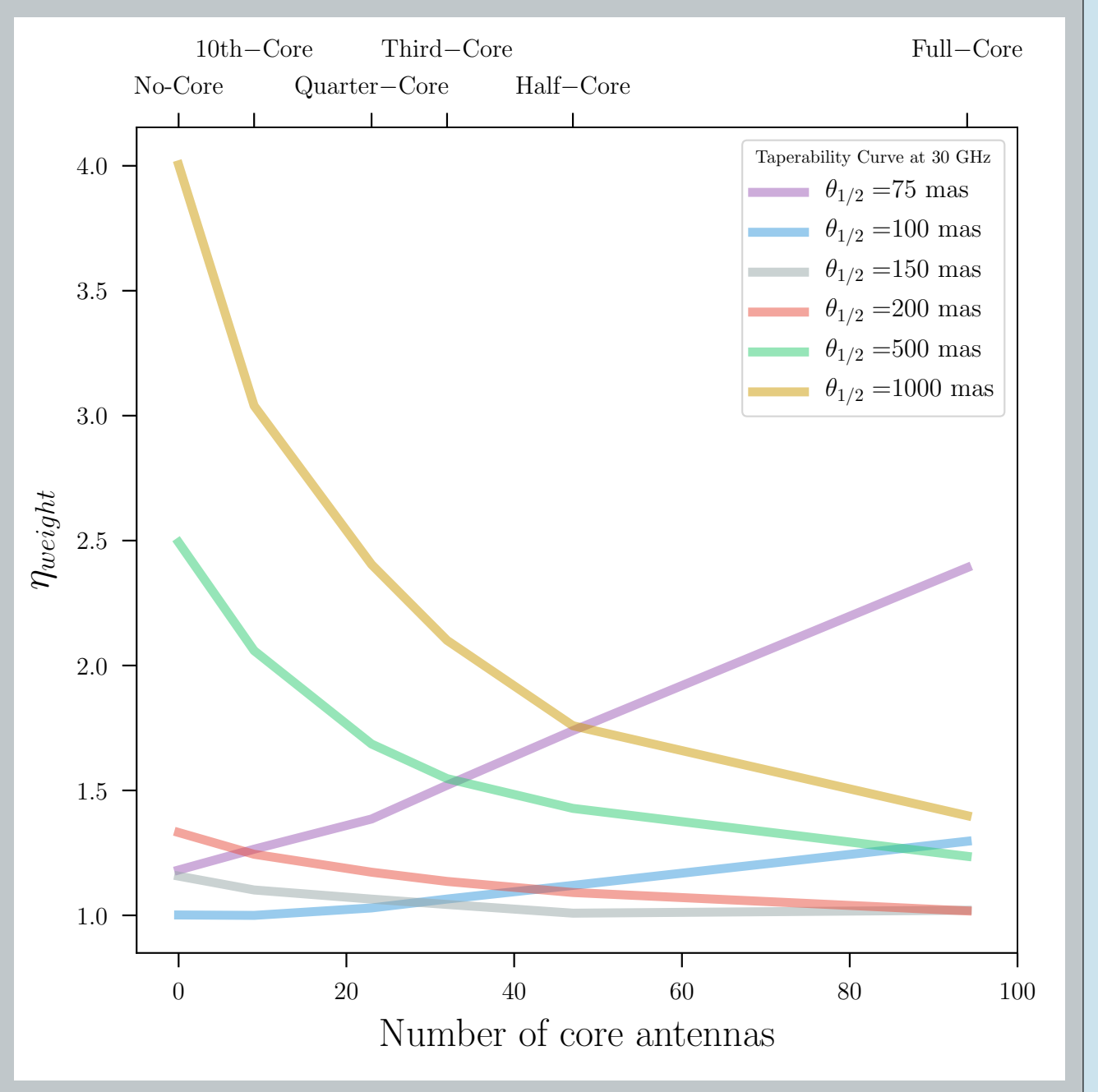

Figure 6. Efficiency curves for different selected resolutions and subarrays, relative to the naturally-weighted sensitivity.

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The Next Generation Very Large Array is a design and development project of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

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