

## Reference Design

The ngVLA is designed to operate over a frequency range of 1.2 – 116 GHz with up to 20 GHz of instantaneous sampled bandwidth.

The antenna locations have been chosen to accommodate a wide variety of scientific observations, aiming to deliver high sensitivity over a wide range of resolutions in a non-reconfigurable array.

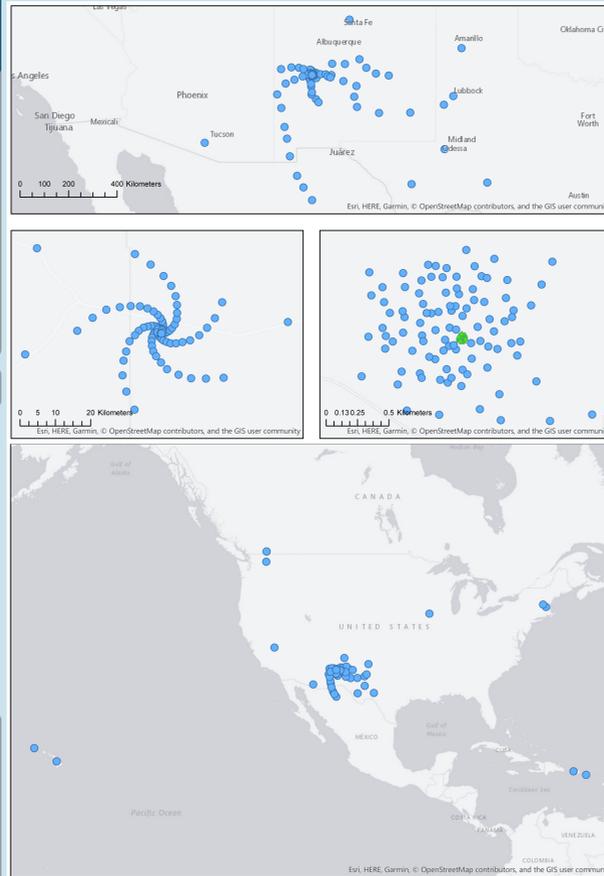
The present reference ngVLA array design (Rev. C; October 2018) includes four main components, summarized in Table 1.

**Table 1.** Summary of elements within the ngVLA array configuration.

Component Name	Aperture Diameter (m)	Quantity	$B_{min}$ (m)	$B_{max}$ (km)
Long Baseline Array	18	30	32.6	8856
Main Interferometric Array	18	214	30.6	1005
Short Baseline Array	6	19	11.0	0.06
Total Power	18	4 <sup>a</sup>	–	–

<sup>a</sup>These antennas are a subset of the 214 antennas of the main array.

**Figure 1.** Top three panels: main interferometric array (Spiral 214) composed of a compact core (middle right; short baseline array antennas are shown in green), a five arm spiral spanning the Plain of San Augustin (middle left) and a roughly 3-armed spiral that extends to TX, northern Mexico and AZ (top). Bottom panel: view of the main array and the long baseline array (244 18 m antennas total). Multiple antennas (typically ~3) are located in each of the 10 stations of the long baseline array.



## Components

**Long Baseline Array (LBA):** These 10 outlying stations will provide intercontinental-scale baselines to achieve a resolution of ~0.1 mas. Clustering of antennas at each site is a cost effective way to increase the array’s sensitivity, i.e., sharing the operational infrastructure per site. This also allows for unique capabilities, e.g., simultaneous observations of the scientific target and a calibration source, simultaneous observations at multiple bands, and small phased arrays at each site.

**Main Interferometric Array:** These antennas are distributed over a range of physical scales and with different geometries: i) a dense core which provides high surface brightness sensitivity at ~1,000 mas resolution; b) a multi-arm spiral – located within the Plains of San Augustin, NM – capable of high-fidelity imaging at ~100 mas scales; c) longer arms which provide mid-scale baselines for imaging at ~10 mas.

**Short Baseline Array (SBA) and Total Power:** The SBA is composed of a compact array of smaller antennas which will provide sensitivity on angular scales larger than those sampled by the main array. Additionally, four antennas of the main array will be equipped to measure total power in order to fill in the center of the (u,v)-plane.

## Array Performance

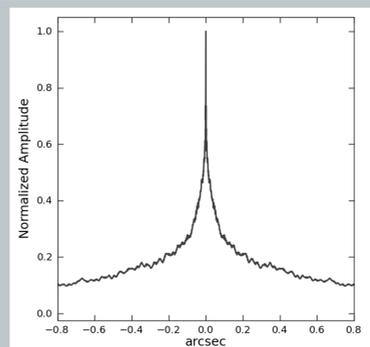
The multi-scale nature of the ngVLA array leads to a naturally weighted beam that is not well characterized by a Gaussian function (see Fig. 2). Specific science applications may need to adjust the uv-weighting and other image parameters to “sculpt” a synthesized beam that is suitable for the particular science goal while maintaining reasonable sensitivity.

In our study, *taperability* is used as a metric to understand how well an array can perform at both high and low resolutions as measured in terms of relative sensitivity.

Several selected subarrays within the reference design are considered, since these can in principle be used as stand-alone arrays depending on the science goals.

A set of simulations at 30 GHz — with integrations of 4 h at +24 Dec centered on transit — for selected subarrays from the ngVLA reference design were imaged with a range of uv-tapers and robust imaging weights to study their taperability (i.e., change in sensitivity versus resolution; see Fig. 3).

From our results, we conclude that the current ngVLA reference design has a high degree of taperability, i.e., that it can accommodate a wide range of resolutions without a great loss of sensitivity ( $\approx 2$ ).



**Figure 2.** Natural PSF of the ngVLA (main array + LBA) at 30 GHz

## Simulation Tools

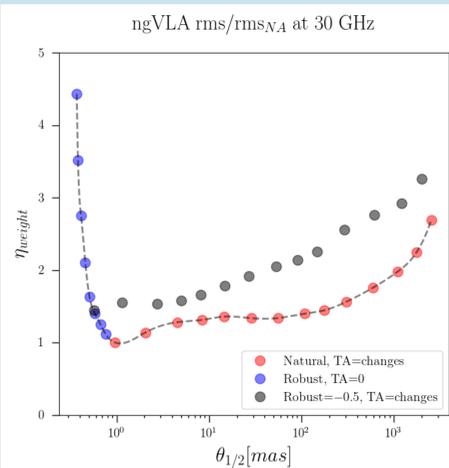
CASA has two simulation tools available: the `simobserve` task and the `sm` toolkit. These methods generate measurement sets, add thermal noise and predict model visibilities, from which we can explore the ngVLA’s imaging capabilities.

Table 2 lists the current configurations (Rev. C) from the ngVLA reference array.

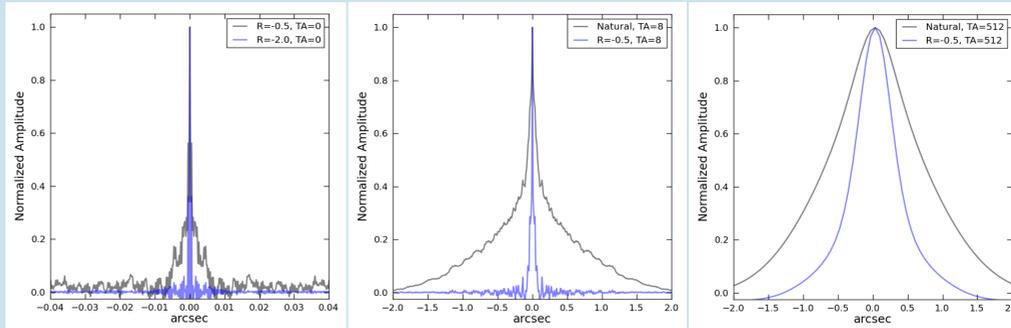
These configuration files are found in <http://ngvla.nrao.edu/page/tools> and can be used for simulations and calculations that investigate the scientific capabilities of the ngVLA.

Subarray	$B_{max}$ (km)	# antennas
Main+LBA	8856.4	244
Main	1005.4	214
Core	1.3	94
Plains+core	1005.4	168
Mid-baseline	1005.4	46
LBA	8856.4	30
SBA	0.057	19

**Table 2.** Current available configurations



**Figure 3.** Taperability curve for the present ngVLA reference array (simulated at 30 GHz) showing the image noise (rms) at different angular resolutions (FWHM) achieved by varying the imaging weights. The noise has been scaled relative to that of the naturally weighted image ( $rms_{NA}$ ). The red symbols correspond to use of a uv-taper and natural weights, and the blue symbols to Briggs robust weighting without a taper. The gray symbols are for Briggs robust  $R=0.5$  and a varying uv-taper, which has a large effect on beam quality (Fig. 4).



**Figure 4.** Simulated 30 GHz PSFs for the present ngVLA reference array over a range of resolutions, showing the effect of different imaging weights (TA: uv-taper in mas, R: Briggs robust parameter). The PSFs are a selection of the data presented in Fig. 3. These examples illustrate how combinations of robustness and tapering allow for a beam of much higher quality (but at the expense of sensitivity).

The ngVLA main+LBA, main and plains subarrays produce a PSF with a broad skirt when using natural weighting, but this is reduced substantially by using Briggs weighting with a value of robust  $R=0.5$ .

The naturally weighted beams for the mid-baseline and core subarrays are quite Gaussian due to their more uniform distribution of baseline lengths, and therefore use of Briggs weighting with these subarrays is not advisable.

