# 50-antenna sample configurations for the Allen Telescope Array

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## ABSTRACT

This memo presents some preliminary 50-antenna configurations prepared for the RAL review of configuration science requirements in October, 2000. Three configurations which fit on the available land at Hat Creek are examined: two with antennas uniformly distributed (with contrasting spatial resolution), and one with a doughnut shape. The *u*-*v* point density of the arrays is used for array comparison. Actual ATA array configurations will have many more antennas.

## 1. Introduction

Recent negotiations have secured additional land for the ATA from the Bidwell Ranch. It is also planned to place antennas on new land from the US Forest Service, and the existing HCRO leases from Bidwell Ranch and the USFS. These leases are shown in figure 1. Within the constraints of the available land, an array configuration must be designed that best meets the objectives of the SETI Institute and the RAL research programs. This memo presents and analyzes some sample configurations. Two alternate configurations, optimized using Keto's algorithm, have been presented by Bock et al. (2000).

## 2. Three sample configurations

For illustrative purposes, three sample configurations were chosen for analysis. Antenna positions in each configuration were set by hand, with no formal optimization of the *u*-*v* coverage. To do this, the 'Virtual Radio Interferometer'[1] was modified to accept a map of the Hat Creek site and to write out the chosen antenna configuration. This program quickly calculates and displays the snapshot *u*-*v* coverage (and earth-rotation synthesis tracks, if desired) when antennas are moved, allowing efficient 'manual' optimization. The configurations generated are presented with their snapshot *u*-*v* coverage in figure 2. In each case, only 50 antennas were used. The 'open' and 'filled'

[1]The VRI was developed by Nuria McKay et al. and is available at `http://www.jb.man.ac.uk/~nm`.

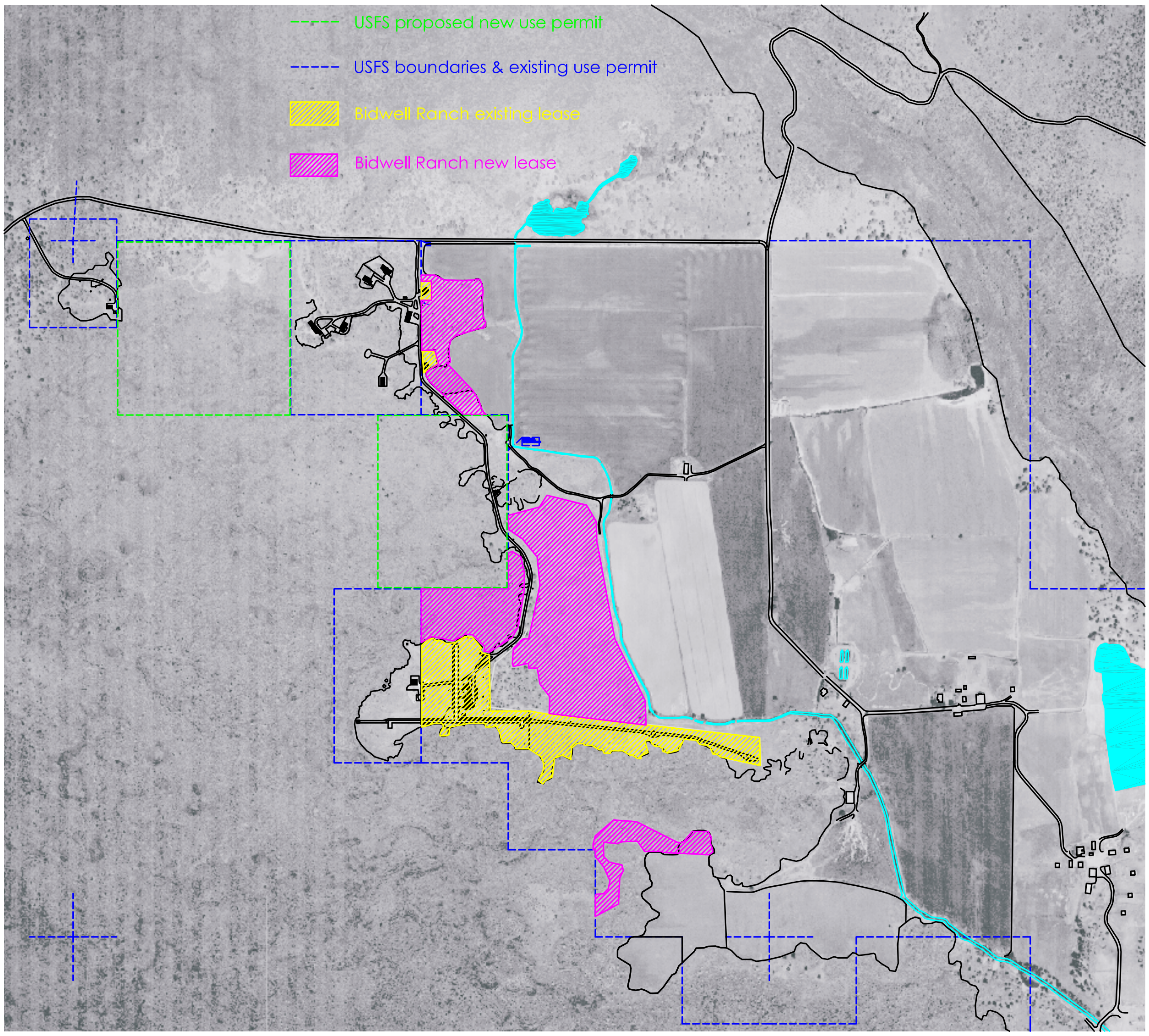



Fig. 1.— Map of available areas at HCRO

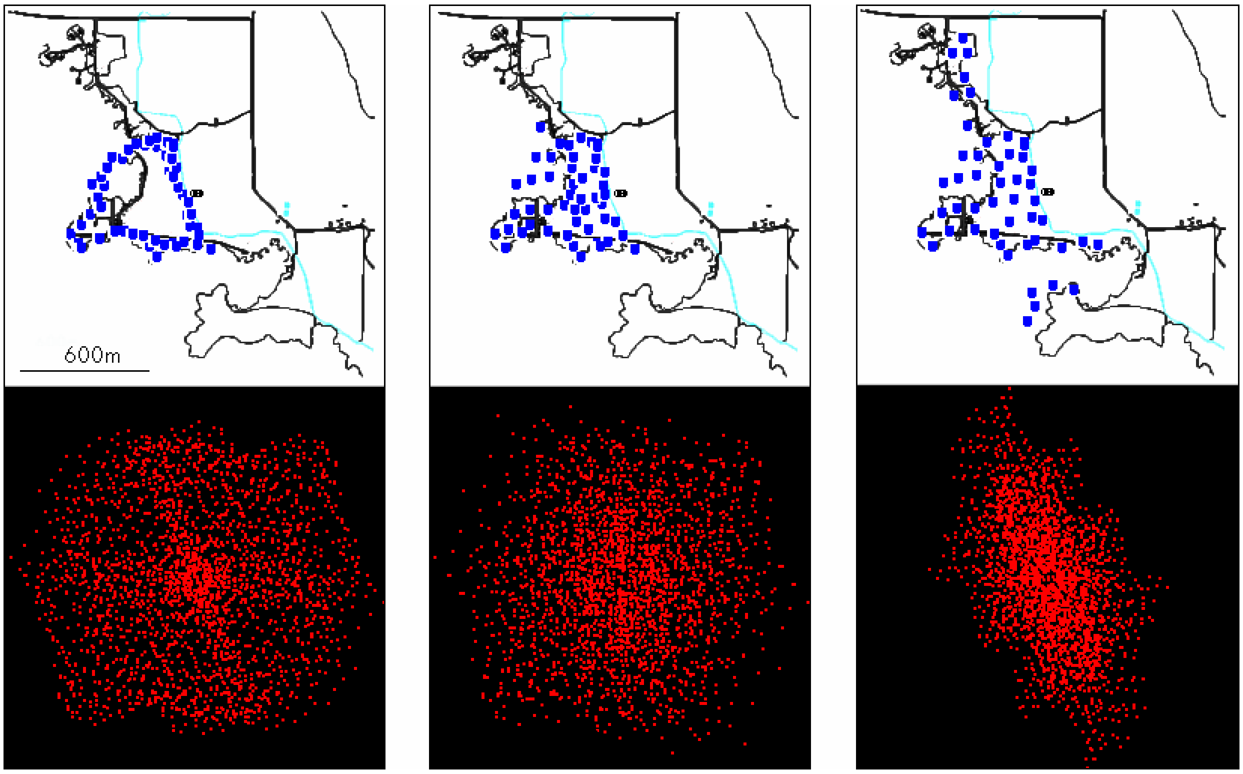



Fig. 2.— Three sample configurations, from left to right: 'compact open', 'compact filled', and 'extended'. In each case the antenna configuration is shown overlaid on a representation of the Hat Creek site, together with snapshot ($\delta = 30°$) $u$-$v$ coverage (not to scale).

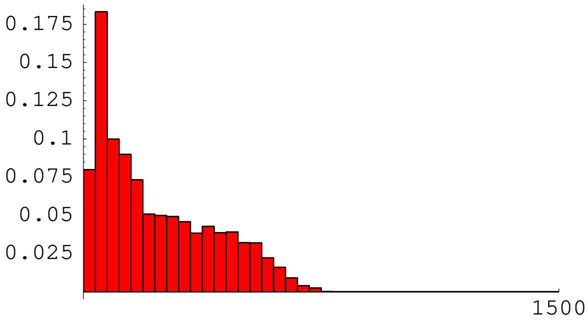
compact configurations provide very different $u$-$v$ coverages; this is seem most clearly in the $u$-$v$ density analysis which follows. However, it is already apparent that the open configuration has a $u$-$v$ point distribution which is more uniform than Gaussian. Thus it will have correspondingly better sensitivity to the smallest structures. The radial structure in the $u$-$v$ distribution of the open configuration is due to the triangular nature of the array (this shape is set by the desire to provide on the available land the maximum resolution with excellent snapshot coverage). The 'extended' configuration shows what happens when the resolution of the array is increased. In this example, 25% of the antennas have been placed outside the bounds of the previous two configurations. The $u$-$v$ coverage is significantly elongated, which will be an advantage at southern declinations. However, it has more structure, so the imaging performance will be worse. But note that the far sidelobes will be of similar magnitude, as in a well-randomized array of any shape they are set simply by the number of antennas. The $u$-$v$ coverage of this array for extended sources is set by the arrangement of the inner antennas, which could be in either an 'open' or a 'filled' configuration.

## 3. *u-v* density analysis

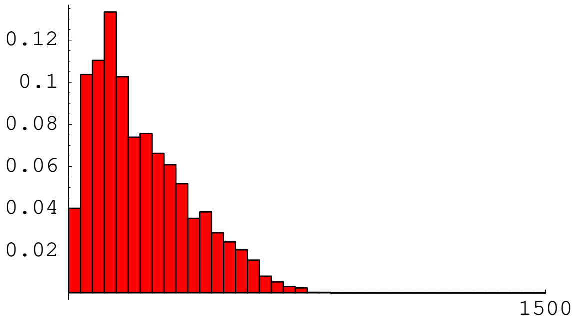
A quantitative analysis provides useful insight into the imaging performance of these arrays. We assume for this analysis that we can arrange the antennas to provide $u$-$v$ coverage that is azimuthally smooth, but wish to know the radial (i.e. resolution) effects of each distribution. Histograms of $u$-$v$ density for each of the arrays are shown in Figure 3. Several fiducial arrays have also been analyzed: the VLA D-array, an array of 50 antennas in a Gaussian distribution, and an array of 500 antennas in a Gaussian distribution. In each case, the histogram shows the proportion of $u$-$v$ points in each bin. Wright (2000) has analyzed the same configurations in a different way. Table 1 shows the proportion of collecting area in several spatial bins for each design. The two uniform arrays each have a more Gaussian distribution than the VLA D-array, as expected from their two-dimensional uniform distribution of antennas. However, they have comparable natural resolution, supplementing their longer spacings with short spacings that the VLA does not have. The near sidelobes will thus be correspondingly lower. The 'compact open' (doughnut-style) array has better sensitivity to the largest and smallest structure, at the expense of intermediate scales.

| Array | $u$-$v$ range (beam FWHM) | | | | actual beam (FWHM) | |
|---|---|---|---|---|---|---|
| | 0–1 k$\lambda$ | 1–2 k$\lambda$ | 2–4 k$\lambda$ | 4–8 k$\lambda$ | uniform | natural |
| | (140″) | (70″) | (37″) | (20″) | (″) | (″) |
| compact open | 25% | 40 | 35 | 0 | $42 \times 40$ | $60 \times 55$ |
| compact filled | 22 | 45 | 25 | 0 | $42 \times 40$ | $72 \times 60$ |
| extended | 16 | 31 | 41 | 9 | $34 \times 19$ | $60 \times 36$ |
| VLA D-array | 31 | 31 | 34 | 2 | $36 \times 35$ | $63 \times 61$ |
| Gaussian, 50 antennas | 32 | 47 | 21 | 0 | $39 \times 37$ | $70 \times 66$ |

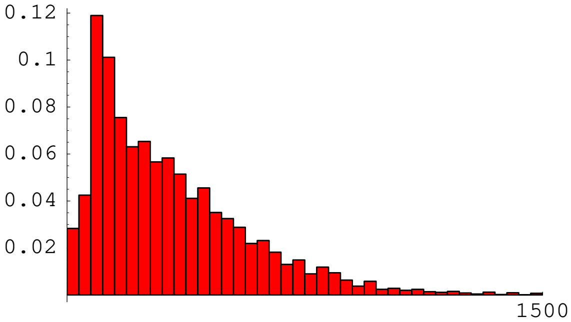
Table 1: Percentage of $u$-$v$ spacings at several scale sizes (Wright 2000)



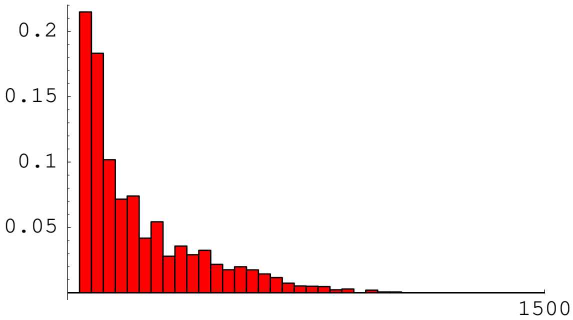

(a) compact open



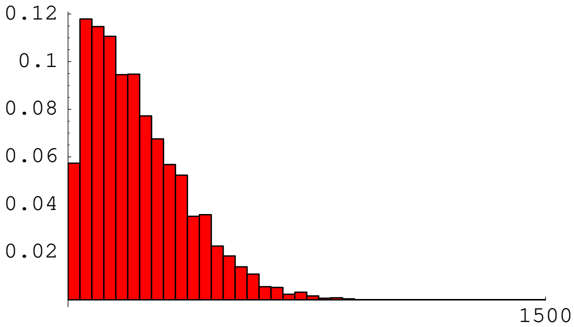

(b) compact filled



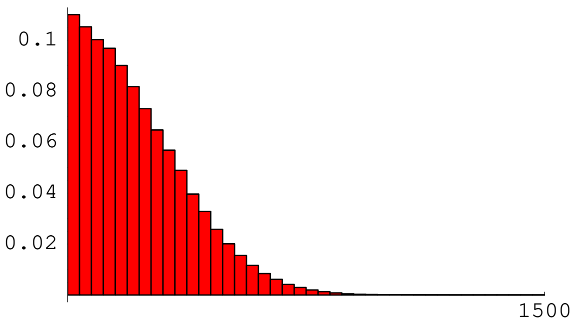

(c) extended




(d) VLA D-array




(e) Gaussian, 50 antennas




(f) Gaussian, 500 antennas

Fig. 3.— Histograms of $u$-$v$ density for the three sample configurations, and for comparison, for three additional arrays (see text). The x-axis scale is in meters, while the y-axis scale shows the proportion of visibilities in each bin.

## 4. Discussion

Of the configurations presented here, the 'compact open' configuration seems most appropriate for the science projects proposed (see ATA Configuration Science Specification). It has excellent snapshot $u$-$v$ coverage with a naturally weighted beam ($60''$) ideal for most of the projects, while maintaining some sensitivity on $30''$ scales. It is similar to the 'doughnut' configurations investigated at length for the ALMA project, with a shape modified by the boundaries of the available land. Ideally, an array for imaging southern sources would be in an north-south elongated doughnut shape. However, the available land does not admit this (although the use permit application presently before the USFS may make land available for a configuration better approximating this ideal). For observing southern sources, the best option seems to be to place a fraction of the antennas, perhaps 20%, in areas along the road to the north of the main array. Although southern areas could also be used, these add little in this circumstance, since the fraction of collecting area available on baselines from the extreme north to the extreme south would be small. It is better to use the whole central array to combine with antennas at the full north-south extent, to the north. If an array with much better resolution is desired, then a much larger (50%?) fraction of the collecting area would need to be placed away from the central array, at which time it may be profitable to place stations to the south and extreme east of the central array. Further analysis of this type of configuration is required. Among the questions to be answered are:

- How much collecting are should be placed to the north for imaging southern sources, and how will the limited availability of northern land affect the imaging properties at these declinations?
- What is width of the doughnut at appropriate array filling factors, and how does this width reduce the natural resolution of the array?
- How does the relative cost of lava-based stations (∼\$2500) and soil-based stations (∼\$5000) affect the design, given the available budget?
- How should the tradeoff between low-declination shadowing and extended structure imaging performance be made?
- What methods could be used for transport or road building on the lava, if antennas are constructed there?

This preliminary discussion has considered only configurations of 50 antennas. Tools now under development will allow the production and analysis of configurations with more antennas; these will be presented in future memoranda.

## REFERENCES

Bock, D.C.-J., Wright, M.C.H., Welch, W.J., & Tasman, J. 2000, *Configuration Choices for the Allen Telescope Array*, poster presented at the SKA Technology Workshop, Jodrell Bank, August 2000, available at `http://astro.berkeley.edu/~dbock/papers/`.

Wright, M.C.H. 2000, *Astronomical Imaging with the Allen Telescope Array - II*, ATA Memo 11.