IAC-02-IAA.9.1.02

THE VERY SMALL ARRAY: PROOF-OF-CONCEPT FOR ARRAY2K

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ABSTRACT

The nonprofit SETI League began conceptual design work in 1999 on Array2k, a planned phased array of satellite TV dishes, to be used as a SETI radio telescope of unique flexibility. Although the funding required to implement this design still eludes us, The SETI League has amassed, through a multitude of small contributions, the resources necessary to permit us to begin construction of a small-scale prototype. Thus, an eight-dish Very Small Array (VSA) is now taking shape in the backyard of the author's rural Pennsylvania home. This paper shows how donated dishes, student labor and volunteer design work are being combined to test a high-tech concept on a shoestring budget.

The VSA project is supported by grants from the American Astronomical Society and the ARRL Foundation, and matching funds contributed by more than fifty individual SETI League members worldwide.

INTRODUCTION

The SETI League, Inc. launched its *Project Argus* sky survey in April 1996, with the ambitious goal of real-time all-sky coverage (Shuch, 1997). Our experience in implementing a global network of small radio telescopes (Shuch, 2000) has underscored the importance of developing larger scale telescopes with improved sensitivity. Due to negative economies of scale, we early decided to explore the arraying of a quantity of the very type of antennas used in the current Project Argus network -- that is, extrapolating from our area of greatest expertise.

Array2k (Shuch, 2001, October) is an array of small, dish antennas all interconnected to accomplish specific beam patterning. As initially envisioned, the array comprises 16 individual parabolic dish antennas, each four meters in diameter. Four sub-arrays, each with four individual antennas, are established in a cross-like formation, with one sub-array each running north, south, west and east of the array's phase center. See Figure 1 for an artist's conception of Array2k, and Figure 2 for its anticipated beam patterns.

FISCAL REALITY

The SETI League, Inc. set a preliminary hardware budget of $160,000 for Array2k. Fundraising efforts were initiated in May, 2001, resulting in contributions to date totaling just over $10,000. The generosity of our 1300 members in 62 countries around the world notwithstanding, significant grant monies or major corporate sponsorship will be required to bring Array2k to fruition.

A small-scale prototype to test the technologies proposed for Array2k is within both amateur capabilities and existing budget, and can help to attract major donors. Thus, the author has begun to construct a Very Small Array (VSA) in the backyard of his rural Pennsylvania home.

The American Astronomical Society has very generously provided a NASA Small Research Grant in the amount of $2000. The ARRL Foundation then kindly contributed an additional $3000 grant to this project. Thanks to matching funds contributed by more than fifty SETI League members in a dozen countries, $10,000 has been allocated to implementing the eight-dish VSA. A quantity of donated 1.8 meter dishes and mounts (see Figure 3) should allow us to complete the prototype within budget.

INSTALLING THE MOUNTS

The VSA requires that its antennas be laid out in true North-South and true East-West baselines. Establishing these baselines requires precision surveying. Fortunately, the author is a former Professor of Electronics at the Pennsylvania College of Technology, Penn State University. That institution boasts an exemplary Civil Engineering program, whose students take courses in surveying. Through the good graces of Prof. William Sprinsky, CE students Ruth Ayn Sitler and Timothy Wentz were recruited to establish the baselines, and stake out the locations of the individual antennas. A 24-inch auger on a Bobcat (Figure 4) was rented, and eight holes of 42-inch depth were dug, centered on the individual antenna locations.

Concrete block was laid in the bottom of each of the antenna holes, to support the antenna masts. Each mast was cut from 4 inch OD, 3 ½ inch ID Schedule 40 galvanized steel pipe. A hole was drilled near the bottom of each mast section, and a length of steel reinforcing bar

placed through it, to prevent twisting of the mast under wind loading (see Figure 5).

The terrain at the VSA site is quite uneven (Figure 6). Leveling the masts was accomplished with two bubble-levels with magnetic backings, stuck to each mast 45 degrees apart (Figure 7). Temporary guys (Figure 8) held the masts in place, while 0.4 cubic yards of concrete were poured into each of the eight holes. Curing time for the concrete was two days, after which time the guy wires could be removed.

Because the VSA site is on rolling terrain, and proper phasing of the array elements requires that the antennas all be at approximately the same absolute altitude, a string level was used to mark trim lines on all eight masts, and they were all adjusted to proper height with a cutoff wheel (see Figure 9). The result is eight masts that appear to the eye not to be level (Figure 10), but in fact are.

AESTHETIC MITIGATION AND PRB-1

As is good practice in residentially zoned neighborhoods, the author received approval from his Township Board of Supervisors prior to commencing construction of the VSA. However, with eight masts planted, the neighbors immediately began protesting the project to that same Township Board.

Legalities notwithstanding, one must take the concerns of one's neighbors very seriously. We radio amateurs in the United States enjoy a degree of legal protection which our counterparts in other countries well may envy. As the holder of a US Amateur Radio license, constructing an antenna to be used under the rules of the Amateur Radio Service in the allocated ham bands, my antennas fall under the protection of PRB-1, the FCC's federal pre-emption of local zoning regulation over ham radio antennas. Since the VSA is designed to operate within the 23 cm amateur radio band, for reception tests in connection with our W2ETI moonbounce beacon (clearly a ham radio educational and scientific activity), I invoked PRB-1 to my local Township Supervisors.

In brief, PRB-1 recognizes the value to the community of the Amateur Radio Service, acknowledges the importance of antennas to achieve effective ham radio communications, and prohibits local governments from unrealistically restricting ham antennas. And, to my surprise and delight, the local township Solicitor informed my Supervisors at a local Township meeting that PRB-1 did indeed apply, protecting the VSA from zoning restrictions and local regulation.

If you think that ruling allayed my neighbors' concerns, you overestimate the power of reason. Federal regulations aside, they argued to our Township Supervisors, they moved onto our scenic hilltop to enjoy the wonders of nature, not the terrors of technology. Since membership on the Township Board is an elected position, whose voice do you suppose carries best, that of one lone ham, or a dozen of his voter/neighbors?

Without belaboring the ensuing legalities, suffice it to say that compromise carried the day. Since an amateur radio telescope points generally 'up', and since moonbounce activities can be conducted when the Moon is relatively high in the sky, it was practical to mount the dishes of the VSA relatively close to the ground, pointing up. This permitted me to plant a ring of trees (see Figure 11) around the dishes, shielding them from the view of my neighbors. The sad irony is that the cost of the shrubbery ended up exceeding the cost of the sheet metal. But I have to admit that the forty arbor vitae recently planted in my backyard are attractive -- almost as pretty to my eye as the dishes they mask!

The bottom line is that we each can choose between confrontation and conciliation. Our legal rights notwithstanding, as good neighbors it behooves us, and benefits our hobby, to choose the latter.

MOVING AHEAD

Trees planted, the first dish appeared within a day (see Figure 12). It flies the same Flag of Earth that graces SETI facilities worldwide. The Flag symbolizes the fact that SETI is carried out on behalf of humankind as a whole. The individual people, organizations, and nations involved are immaterial, since any signal received will belong to all of humanity, and represent Earth's entry into the Galactic community. I can think of no symbol more appropriate for an Amateur Radio educational and scientific project.

At press time, each of the VSA masts was topped with an azimuth-elevation mount. By the time this paper appears in print, those mounts will sport eight more dishes, with the necessary mounts and electronics to recover echoes off the Moon from the W2ETI 1296 MHz EME beacon (Shuch, 2001, November). Whether the VSA paves the way for the more ambitious Array2k project or not, it shows how donated dishes, student labor, and ham ingenuity can combine to test a high-tech concept on a shoestring budget.

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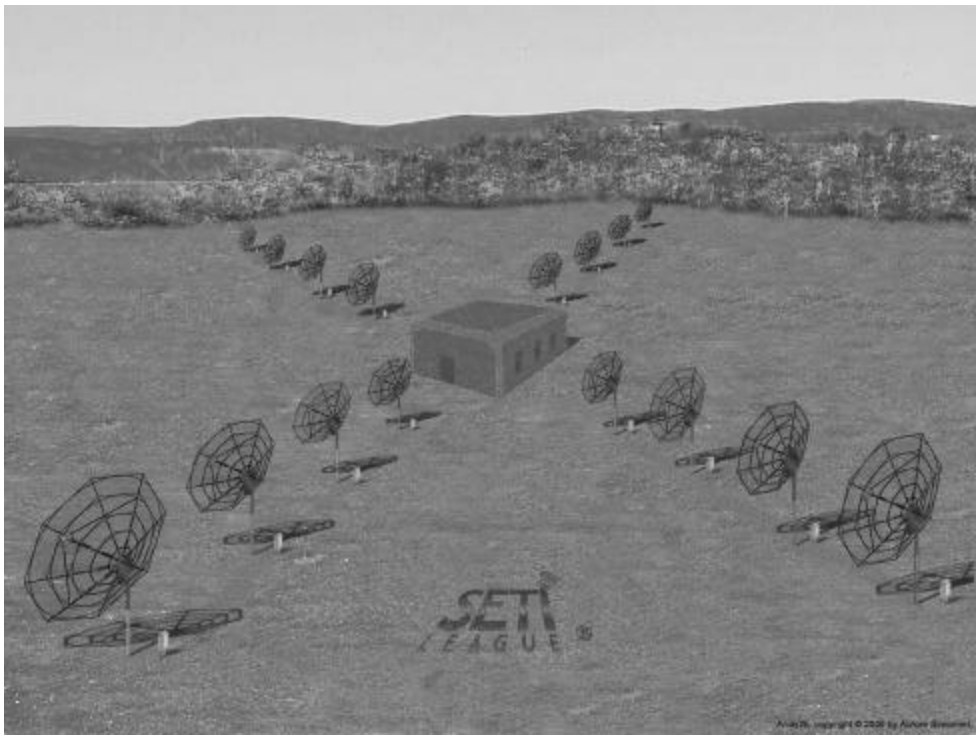

Figure 1
Array2k Artist's Rendering (© 2000 by Aurore Simonnet)

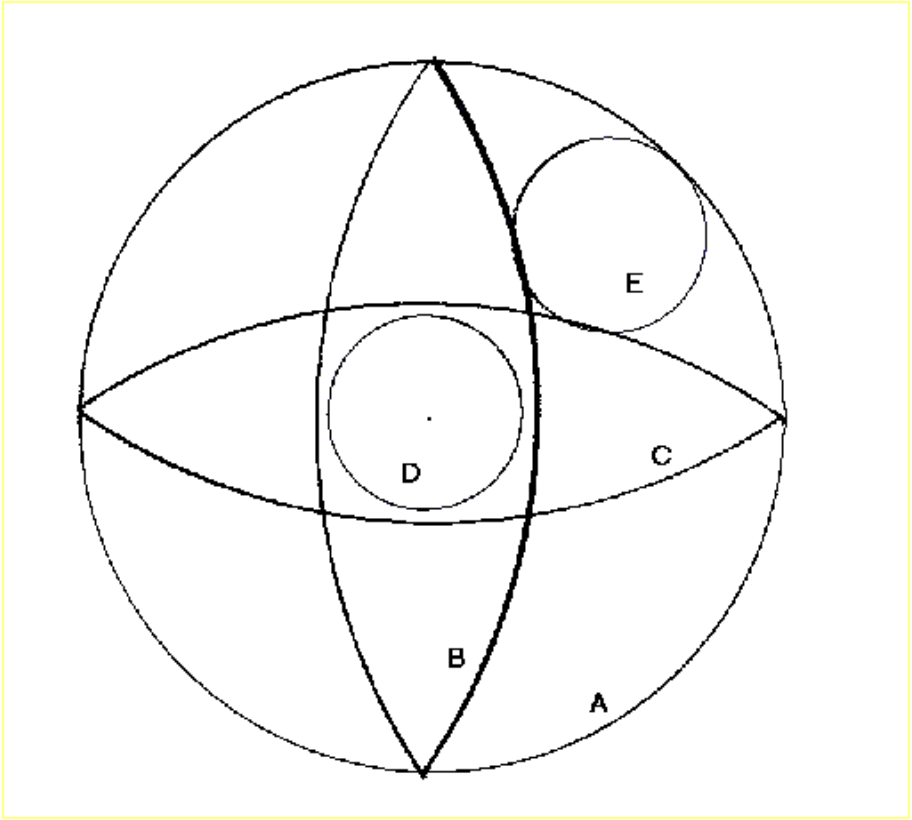

Figure 2
Beam Pattern, plotted in Elevation vs. Azimuth, of the Adaptive Microwave Array in its five operating modes.

Figure 3
The author poses with one of 47 donated 1.8 meter dishes.

Figure 4
Auger being aligned on first antenna location stake.

Figure 5
Mast are set on concrete blocks in each hole, with reinforcing bar to prevent twisting (see text).

Figure 6
The rolling terrain of the VSA site belies the fact that the mast is perfectly vertical.

Figure 7
Two magnetic bubble levels, attached at right angles, facilitate leveling the masts.

Figure 8
Temporary guys hold the masts in position during the pouring and setting of the concrete.

Figure 9
After measuring with a string level, all eight masts are cut off to the same absolute altitude.

Figure 10
Straight and level, the eight masts of the VSA are now ready to receive az-el mounts and dishes.

Figure 11
Forty *Arbor Vitae* are planted around the VSA to mitigate its visual impact.

Figure 12
The Flag of Earth flies proudly from the first dish planted in VSA Grove.

Figure 13
Azimuth-Elevation mounts installed on the remaining VSA masts, awaiting arrival of their dishes.