By Dr H. Paul Shuch, N6TX

The Very Small Array

A prototype array of small dishes taking shape in rural Pennsylvania is evidence that the SETI League is thinking big on a small scale.

The nonprofit SETI League began conceptual design work in 1999 on *Array2k*, a planned phased array of satellite TV dishes, to be used as an Amateur 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 grants and 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 article shows how donated dishes, student labor and ham ingenuity are being combined to test a high-tech concept on a shoestring budget.

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Introduction

The SETI League launched its *Project Argus* sky survey in April 1996, with the ambitious goal of real-time all-sky coverage.[1] Our experience in implementing a global network of small radio telescopes has underscored the importance of developing larger scale telescopes with improved sensitivity.[2] 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 is an array of small satellite dish antennas all interconnected to accomplish specific beam patterns.[3] As presently envisioned, the array comprises 32 individual parabolic dish antennas on az-el mounts. Four sub-arrays, each comprised of eight 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.

Fiscal Reality

The SETI League set a preliminary hardware budget of $160,000 for *Array2k*. Overhead and infrastructure needs can be expected to raise the total cost to around $250,000. Though roughly 1% of the cost of professional radio telescopes, this is still a substantial sum, beyond the reach of Amateur Radio clubs like the SETI League. Nevertheless, fundraising efforts were initiated in May 2001, resulting in a handful of modest (but hopelessly inadequate) contributions. 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*, on the other hand, is within both amateur capabilities and existing budget, and may help us attract major donors. Thus, I began in the spring of 2002 to construct the Very Small Array (VSA) in the backyard of my rural Pennsylvania home.

To facilitate completion of this prototype, the American Astronomical Society very generously provided a NASA Small Research Grant in the amount of $2000, and the ARRL Foundation kindly kicked in an additional $3000. Thanks to matching funds contributed by more than 50 radio amateurs, $10,000 has now been allocated to implementing the eight-dish VSA. A quantity of donated 1.8-meter dishes and azimuth-elevation mounts should allow us to complete the VSA prototype within budget, hopefully by early next spring, about a year after the project was begun.

Mounting the Masts

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, I spent a few years as a 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 my former colleague Professor William Sprinsky, CE student Timothy Wentz was recruited to sight the Sun with a theodolite. Using solar ephemeris tables and an accurate clock, he was thus able to establish precise baselines and to stake out the locations of the individual antennas. A 24-inch auger on a Bobcat track vehicle was rented, and eight holes of 42-inch depth were dug, centered on the indi-

[1]Notes appear on page 30.

Noted space artist Jon Lomberg created this conception of *Array2k*, the next-generation radio telescope now in preliminary design phase at SETI League headquarters.

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vidual 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, 3½-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.

The terrain at the VSA site is quite uneven. Leveling the masts was accomplished with two bubble-levels with magnetic backings, stuck to each mast 90 degrees apart. Temporary guys 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 of the VSA site's rolling terrain, and the fact that 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, which were then adjusted to proper height with a cutoff wheel.

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.

To any radio amateur planning an antenna project which might impact on his or her neighbors, I can highly recommend K1VR's fine book on antenna zoning, available through the ARRL.[4] Had I bothered to consult it before I started working on the VSA, I could have spared myself considerable grief.

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 preemption 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 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 40 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 the Township solicitor sent me a letter, stating "that in the Township's view your backyard antennae and related facilities *are* within the protection of certain FCC Rulings, and *do* comply with all applicable Township regulations such as screening and setback requirements. Your continuing effort to deal openly and above-board with the Township about your property and your projects has been very much appreciated."

In summary, 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. 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 edu-

cational and scientific project.

Next, each of the VSA masts was topped with an azimuth-elevation mount, and the mounts began to receive their dishes. Offset feedhorn-support tripods were then affixed to the reflectors. As these dishes are designed for non-blocked apertures, the feed points appear significantly off-center.

Feeding an offset dish is a bit trickier than it would be to feed a standard prime-focus parabola. With offset dishes, the reflector is only a sector of a paraboloid, rather than a full parabola. Thus, the effective focal length to diameter ratio (F/D) is greater than it would be for the equivalent prime-focus dish, and the required beamwidth of the feedhorn is correspondingly narrower (in the case of the VSA antennas, 41 degrees). Design considerations for the required high-gain feedhorns have been well documented by W1GHZ.[5] But I chose a different approach.

Commercial feeds were supplied with the Prodelin dishes donated for the VSA. They were built for the 3.7 to 4.2 GHz C-band satellite TV allocation. Since we intend to use the VSA at L-band, on a frequency of 1296 MHz, one can scale the dimensions of the standard C-band feed by a factor of three. The result is shown in the accompanying photo. As is the amateur tradition, and should be evident in the photos, this feedhorn is constructed from low-cost materials!

At press time, 1296 MHz feedhorns had just been installed on the eight dishes of the VSA. The VSA has begun to look like a real antenna array. Over the coming months, those eight dishes will begin to acquire the necessary electronics to recover echoes off the Moon from the W2ETI 1296 MHz EME beacon.[6] The continuous availability of EME calibration signals will enable us to optimize the array's receive circuitry. We plan to try out new ways to phase and combine signals from multiple dishes, providing limited electronic beam steering. Then, it will be on to radio astronomy, and SETI research, and (just maybe) a shot at the ultimate DX.

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

The VSA phasing matrix. These bias Ts and power dividers/combiners will produce four different beam patterns simultaneously, in two orthogonal circular polarizations.

Conclusion

Once the Very Small Array becomes operational, I hope its success will enable the grassroots SETI League to attract major corporate funding for its much more complex *Array2k*, a massive radio telescope array first contemplated in 1999. The bargain-basement VSA will be used to test engineering concepts for the planned $250,000 *Array2k*, which is itself a hundred times cheaper than conventional radio telescope designs. Thus, we hope to help bring radio astronomy and SETI research to the masses. Already, several SETI League members in the Third World have used amateur techniques to build the first radio telescopes in their respective countries. But whether the VSA paves the way for more ambitious projects or not, it shows the world how donated dishes, student labor and ham ingenuity can combine to test a high-tech concept on a shoestring budget.

Notes

[1]H. Paul Shuch, *Project Argus and the Challenge of Real-time All-sky SETI*, in *Astronomical and Biochemical Origins and the Search for Life in the Universe*, IAA Colloquium 161, 693-700, 1997.

[2]H. Paul Shuch, Project Argus: O*ne Hundred Up, 4900 to Go!* IAA-00-IAA.9.1.04, Oct 2000.

[3]H. Paul Shuch, *Array2k: Multiple Dishes, Multiple Modes.* IAA-01-IAA.9.1.02, Oct 2001.

[4]Fred Hopengarten, *Antenna Zoning for the Radio Amateur*, ARRL, Newington, CT, 2001. ARRL publication no. 8217. Available from **www.arrl.org/shop/**.

[5]H. Paul Shuch, "2001: A Moonbounce Odyssey," *QST,* Nov 2001, pp 38-43.

[6]Paul Wade: *W1GHZ Microwave Antenna Book Online*, **www.w1ghz.org/antbook/preface.htm**.

Dr Paul Shuch, who serves as executive director of the SETI League, is a long-time engineering professor credited with designing the first commercial home-satellite TV receiver. A Fellow of the British Interplanetary Society and Fellow of the Radio Club of America, he is the author of more than 300 publications, has received numerous honors and awards and (as N6TX) has operated in all 20 ham bands between 1.8 MHz and 24 GHz. Paul served as director, technical director and chairman of the board of Project Oscar Inc, predecessors to AMSAT. He lives on a radio-quiet hilltop in northern Pennsylvania with his biologist wife, five of their seven recombinant DNA experiments, 10 networked computers, three motorcycles, two radio telescopes and an antique MG-TD. You can reach the author c/o The SETI League, Inc, PO Box 555, Little Ferry, NJ 07643; **n6tx@setileague.org**; **www.setileague.org**.