CQ VHF Ham Radio Above 50 MHz

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Wild Six-Meter Propagation!

- Predicting Rain-Scatter Paths
- Kenwood Teams Up with AvMap
- Grid DXpedition to EN20

■ VHF/UHF Weak Signal ■ Microwaves ■ Amateur Satellites ■ Repeaters ■ Packet Radio ■ Projects ■ Interviews ■ Plus...Reviews, Product News, and much more!

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On The Cover: ARRL Field Day 2006 and the accompanying AMSAT Field Day were held on 24–25 June. This year activity was limited to ISS, AO-51, SO-50, AO-27, FO-29, VO-52, and AO-7. For details, see the "Satellites" column on p. 44. (Photo by Keith Pugh, W5IU)

CQ VHF Ham Radio Above 50 MHz

LINE OF SIGHT

A Message from the Editor

The APRS Thread

We are now midway through the fifth year of the reintroduced version of *CQ VHF* magazine, and my mind can hardly keep up with the ever-expanding use of the VHF-plus frequency spectrum. As many of you know from reading my VHF column in *CQ* magazine, my background is in weak-signal communications. Those of you who are long-time readers of the column will have noticed that since taking on the responsibilities of editing this magazine, my coverage of VHF activities has greatly expanded beyond weak-signal communications. In fact, occasionally there are columns in which I have very little weak-signal coverage. This is because the increased interest in the VHF-plus ham bands has fractionalized into many different uses for the spectrum.

Ironically, we who are active on these bands are finding some commonality in one particular form of communications—APRS (Automatic Position Reporting System). APRS is increasingly being used for a number of VHF-plus activities, in some respects becoming the thread that weaves itself throughout our use of the VHF-plus spectrum. APRS has become a method used by bicycling-event organizers for tracking locations of lead cyclists and emergency vehicles, such as ambulances. APRS is used by balloonists to track their balloons as well as track various chase vehicles as these teams triangulate the balloon's location for recovery of its payload. APRS is being used by microwave enthusiasts for more precise aiming of their antennas for making record-setting mountaintop QSOs. In short, APRS continues to weave its way into more and more of our use of the VHF-plus spectrum.

Two articles in this issue feature APRS applications. Carlton Doe, W3DOE, describes how to build a simple APRS tracker, beginning on page 15. Gordon West, WB6NOA, reviews the marriage between Kenwood's D-7 and D-700 and AvMap's Geosat 4 beginning on page 20.

CubeSats and AMSAT

On July 26 or 27, more than a dozen miniature satellites from ten universities and one company were scheduled to be launched into orbit via a Dnepr-1LV rocket that was to carry the CubeSats into space from the Baikonur Cosmodrome in Kazakhstan. The following is from the *ARRL Letter* (June 8, 2006) and describes the CubeSat program:

> The CubeSat project is a collaboration between California Polytechnic State University-San Luis Obispo and Stanford University's Space Systems Development Laboratory. All of the CubeSats set to launch this month were designed and built by students at various universities in the US and elsewhere in the world.
>
> Cornell University, Cal Poly, and the University of Arizona each will send two CubeSats into space. Other US schools participating in the mass CubeSat launch are the University of Illinois, the University of Kansas, Montana State University, and the University of Hawaii. In addition, schools in Norway, South Korea, and Japan have built CubeSats for this month's launch.
>
> One of the CubeSats, known as SEEDS, was built by students at the Nihon University in Japan. It contains a CW beacon, Digi-Talker, and other experiments. The CW beacon will be on 437.485 MHz and use the callsign JQ1YGU. The Digi-Talker experiment will be activated later. All 13 CubeSats will identify using amateur radio callsigns.
>
> According to AMSAT-NA, the satellites will be put into a 500-by-566 km (310 by 351 miles) orbit with a 97-degree inclination. Each tiny satellite is a 10 cm (4 inch) cube weighing just 1 kg (2.2 lbs) into which the battery, transmitter, and various experiments are packed.
>
> Twelve of the satellites have downlinks in the amateur radio satellite allocation between 435 and 438 MHz, and one will operate on 145.980 MHz, so there will be lots of signals to listen out for after launch. None of the spacecraft will carry a transponder. Transmitter power outputs range from 10 mW to 2 W.

A complete list of the satellites can be found in the Satellite column, which begins on page 44. Ralph Wallo, WØRPK, maintains a website with up-to-date information on the CubeSats. The URL is: <http://showcase.netins.net/web/wallio/CubeSat.htm>. Paul Shuch, N6TX, gives some insight into the CubeSat program in his Orbital Classroom column, which begins on page 42. Perennial antenna designer Kent Britain, WA5VJB, has some "Cheap Yagis" that can be used for communicating via these satellites. You can find these designs beginning on page 28.

Speaking of AMSAT, in this issue's Satellites column Keith Pugh, W5IU, discusses the plans AMSAT has for future launches. In the near term the P3-E satellite is gearing up to be launched in 2007 or 2008, depending upon availability of a launch vehicle. Unique to this satellite will be the use of a software-defined transponder (SDX). Among the benefits from using the SDX are mode versatility, low power consumption, and a major improvement in interference and "Alligator" immunity. The latter is accomplished by way of the inclusion of auto-notching software known as STELLA (Satellite Transponder Equalizing Level Limiting Adaptor). This software is designed to reduce multiple high-level "spikes" without affecting the transponder noise floor and low-level signals.

In the long term, AMSAT is designing the Eagle satellite. Thanks to *EaglePedia*, an open forum available on the AMSAT website (http://www.amsat.org), any AMSAT member can view most design details of the satellite while it is being developed.

Remembering Two of Our Comrades

Tragically, Mike Obermeier K6SNE, and David Gordon-Ross, N6IDF, lost their lives when Mike's Jeep went off a mountain road near Lake Isabella in Kern County, California on May 27. The two of them were on a hidden transmitter hunt over the Memorial Day weekend. Homing In columnist Joe Moell, KØOV, gives a moving and sensitive tribute to these two members of our amateur radio community. His column begins on page 24.

Every time we in our ham radio community learn of the loss of life of one of our members, no matter what the cause, we need to pause and reflect on the fact that we do participate in a hobby that has some inherent dangers. In reflecting on this fact, we also need to give some thought to how we can play it safe while participating in our wonderful hobby. Until the next issue...

73 de Joe, N6CL

New DJ-V17 makes a SPLASH

with great audio and high grade waterproof design!

Actual Size

Alinco is proud to introduce a new 5-watt full power 2M HT that makes a perfect companion for outdoor activities like fishing, camping or snow-sports.

The rugged polycarbonate materials are compatible to IPX7* so it's submersible 1m/3ft. for 30 minutes! And unlike water-resistant radios you may have looked at before, the DJ-V17 has a large 40mm internal speaker so its audio is clean and crisp, not muffled. You can enjoy 500mW max audio-output, new two-touch repeater access, and over 200 memories. A special battery-drain function helps avoid battery memory-effect. Other features include an ergonomic design, ultra-flexible antenna with SMA connector, 39 CTCSS settings, split function, two-level attenuator and more. Whatever your idea of outdoor fun, Alinco's DJ-V17 is ready to take on the challenges of rain, dirt and dust and come back for more.

- New, two-touch repeater access
- High grade waterproof materials compatible to IPX7* (submersible 1m/3ft. for 30 min.)
- Rugged polycarbonate body resists dirt, dust and moisture
- Large 40mm internal speaker for great audio!
- Highly visible backlit alphanumeric display
- Direct frequency input through illuminated keypad
- 200 Memories, plus one call channel and one repeater access parameter memory
- VFO, Memory and Scan modes
- Ultra-flexible antenna with SMA connector avoids breakage
- 39 CTCSS tone squelch (encode+decode) settings
- Tone burst function (1,000, 1450, 1750 and 2100Hz)
- Battery-drain function avoids memory-effect
- Cloning feature
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- SMA antenna port
- 2-level attenuator
- Waterproof single mic/speaker jack

**Alinco guarantees this feature for 1 year provided all jack covers are properly and securely closed.*

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Six Meters Goes Wild!

Regular operators on the magic band were treated to extraordinary propagation this past June. Here Contributing Editor WB2AMU summarizes some of the numerous openings experienced by North American 6-meter operators.

By Ken Neubeck,* WB2AMU

During the summers of 2004 and 2005, sporadic-*E* conditions were modest at best for the months of June and July for much of North America. Some stations in the northern part of New England and in eastern Canada saw very little transatlantic sporadic-*E* conditions into Europe. There were long droughts of sporadic-*E* activity in general.

Part of the reason for the reduction of sporadic-*E* during the past two summers may have been the presence of moderate-to-high geomagnetic activity that resulted in aurora activity during those months. Typically, unless an intense aurora occurs, high geomagnetic activity seems to be a deterrent for sporadic-*E* activity. (This will be the subject of an upcoming article for *CQ VHF* written by Jon Jones, NØJK, and me.)

With virtually a handful of sunspots occurring during the first half of 2006, along with limited geomagnetic activity, there seemed to be the potential for a decent sporadic-*E* season beginning in May. During the winter sporadic-*E* season, activity was good for the southern tier of the United States, but for the higher latitudes there was minimal activity on 6 meters. Thus, there was a hopeful expectation that things would be better for the summer.

During May there were a number of decent openings between the U.S. and the Caribbean, as well as between the U.S. and Europe. One station that was worked quite a bit during May by stations in parts of the U.S. was EH8BPX, Avelino, in the Canary Islands. Also, a few expeditions to the Caribbean took place, such as one conducted by Howard Sine, WB4WXE, to Antigua, V26 during the first week of June, and the one conducted by Chris, W3CMP, to Haiti during the third week of June.

Howard reported that June 4th was his best day, with 29 states and 11 countries worked. He gave several VE's, as well as W3EP, a new country using a three-element Yagi and 100 watts (photo A). Some of the VE stations that Howard worked via two-hop were VE1YX, VE2CTU, VE2XK, VE2DFO, VE3GIB, VA3DX, VE3XN, and VE3IC. As you can see in photo A, Howard's three-element Yagi was hooked up to an ICOM IC-706 running barefoot.

Japan to the U.S. on 6 meters!

During the first week of June, however, a really incredible occurrence took place on 6 meters. On the evening of June 4th, a number of stations in Texas hooked up with Japan! One was Alan Benoit, WQ5W, and here is what he had to say:

Photo A. Here is the three-element Yagi antenna setup of Howard Sine, WB4WXE, during his trip to Antigua as V26HS. Howard had one really good day of propagation (June 4th) and two decent days during his one-week stay. The longest distances he worked were to VE7SL (CN 88), W7CE (CN 87), and W7MEM (DN 17). (Photo courtesy of WB4WXE)

> The prelude to the opening was pretty normal. Sunday morning we had a nice stateside opening, and EH8BPX was readable for a few hours straight. We had QSOs at 1446Z and 1729Z. Several 5's also reported working into CT3 and CT, but I couldn't hear them. In the afternoon the band opened to the Caribbean, and I worked FY1FL for a new one at 21:51Z.
>
> What happened next was the most incredible thing I have ever experienced on 6 meters. I was about to shut down the rig and go out for the evening when I checked the DX cluster one final time at around 5:15 PM local (2200Z). I noticed with interest that NL7Z in Alaska was being worked in west Texas on SSB. I had only worked one KL7 on 6 meters ever before, and that QSO was after midnight local time, so I had to

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Photo B. Jon Jones, NØJK, with the portable two-element, 6-meter Yagi he used to work JA7QVI from the roof of a parking garage where he works. Plans for this Yagi are in the book "Six Meters, A Guide to the Magic Band" by WB2AMU (Worldradio books). (Photo courtesy of NØJK)

give a listen to see if I could hear him. Sure enough he was a solid 5-7 and he responded to my call immediately.

I then saw on the chat.dxers.info 6-meter chat room page that JH2COZ was going to call CQ on 50.096 CW. I had never worked or even heard a JA on 6 meters, so I didn't think much of it. But I figured what the heck, I'd listen for a couple of minutes before heading out the door. So I tuned to 50.096, and to my amazement there was JH2COZ calling CQ a solid 559. I gave him a call and he came back immediately. I had worked my first JA ever! I then went up the band and started calling CQ and had many JA's come back to me! Over the next 3 hours, 24 minutes I worked 42 JA stations in 10 different grids! The signals were on the weak side in many cases, but all were solid Q5 copy. They were much stronger and more readable than the often ESP copy we get on EU stations from here. It felt and sounded very much like the 10-meter JA runs we get in contests at the top of the sunspot cycle.

A couple of times during the run I thought it was over, only to have more JA's come back to my CQ's a few minutes later. In between the JA's, I also worked KL8DX and several VE7's. I worked my last JA at 0151Z. It was a great experience, sharing the thrill of this opening with the guys in the chat.dxers.info 6-meter chat room. They seemed to be as thrilled and amazed as I was about this, and their encouragement and kind words made the experience even better!

I use two M[2] 6M7JHV seven-element (30-foot boom) Yagis at my QTH on different tow-

(Continued on page 73)

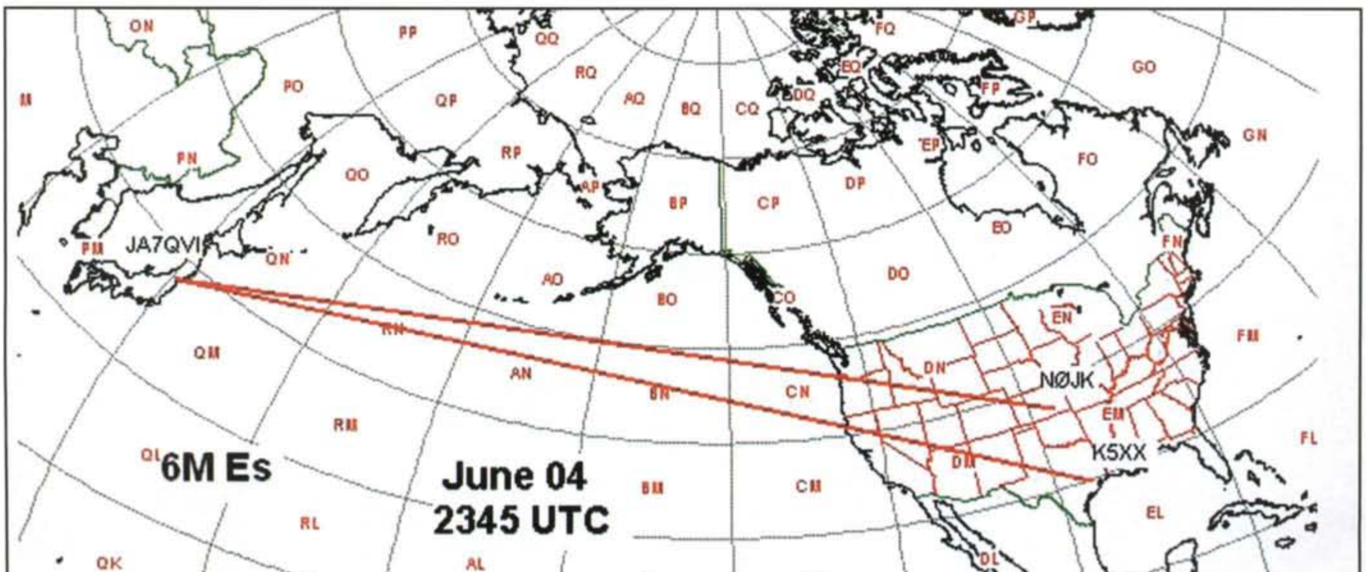


Figure 1. Jon Jones, NØJK, created this figure, which it shows the path between stations in Japan and stations in Texas and Kansas during the June 4th opening.

Grid DXpedition to EN20

KX9X and NM9H activated rare grid EN20 for the duration of this year's ARRL June VHF QSO Party. They hope their grid DXpedition experiences, presented here, will encourage others to do the same.

By Sean Kutzko,* KX9X

The following is a recap of the KS9Z/Ø grid DXpedition to EN20, which took place from June 9–12, 2006. This DXpedition was timed to coincide with the ARRL June VHF QSO Party. Matt Kolb, NM9H, and I were the operators. In contrast to a rover operation, Matt and I activated a specific, rare grid for the entire contest period, and then some. We hope that our experiences will encourage others also to go on grid DXpeditions for the purpose of activating rare grids for extended periods of time.

This was to be our first grid DXpedition in four years. We made a conscious decision to get back into things slowly, so we chose to use smaller beams on the high bands, reducing the amount of packing we had to do, and left the kilowatts at home in favor of simple bricks. We also only went out for essentially three days of operating.

**e-mail: <kx9x@yahoo.com>*

Friday, June 9

We hit the road at 4:30 AM from EM59. We arrived at the KOA campground in Rock Port, Missouri in EN20 at around 11 or so that morning. Our hosts, Annette and Dave, were delighted to see us and couldn't have been nicer. They made us feel very welcome and showed us to the small cabin we've grown accustomed to renting for these trips. It is 12' × 12', has one double bed (which served as the operating surface), and two sub-twin-size bunk beds. It is out of the elements and has air conditioning and electricity. It is all we could have asked for.

We started setting up upon arrival. It was hot (91 degrees), with bright sunshine and no shade. We took several breaks while getting the antennas up. By late afternoon, we had 6 meters and 2 meters up and running. Matt fired up some bratwursts on the grill while I started working 6 meters. Our first QSO was with WA7FPO in DM54 at around 2200 UTC.

Our first disappointment occurred when Matt took out his laptop to check his e-mail. We found no nodes to hit. We were told the site had wireless internet, so Matt asked if there was a problem. Indeed there was; it hadn't been working for a couple days and there wouldn't be a tech out to look at it until Monday! This put a *major* crimp in our plans. We were hoping to be able to check the prop loggers for info on band openings, and I had made a sked with one ham who badly needed EN20 on 6 meters. I didn't write down any of his information, since I figured I'd just get it from his e-mail. That was a big mistake, one that cost a ham a grid, and I'll never do that again.

During the early evening we worked a handful of stations to the southeast around EM73. After that run of stations we decided that even though it was early, we were tired and dehydrated, so we ended up going to bed at around 10 PM.

Saturday, June 10

We got up at around 8 AM, had breakfast, and set to work getting up the mast for the 222- and 432-MHz antennas. I worked a few folks on 6 meters in between measurements. The antennas assembled easily; 222 sounded great, but 432 didn't. Here was our second disappointment: We realized that we had forgotten the SWR analyzer *and* the SWR meter in our early morning rush out the door. Big bummer!

Matt set out to figure out what was up with the UHF bands while I worked 6 meters. We had a great opening Saturday morning to the east and southeast (FM29, EM84, FN10, etc.).

By contest time, we had taken the 432-MHz beam apart and re-adjusted it. It sure sounded better, but we had no way of checking SWR. By the time the contest started, I'd put in about 75 QSOs on 6 meters.

The cabin at the Rock Port, Missouri KOA, our site for the ARRL June VHF QSO Party EN20 grid DXpedition.

CQ Contest!

Six meters started off with a *bang*, working huge openings and big pile-ups into a single-hop radius to Maryland, Delaware, Pennsylvania, Michigan, and Ohio. We logged 88 QSOs in the first hour. The band was cooking and cooking hard!

Matt made a Q with NØWL in EN21 on 2 meters. He said we were weak. Uh oh. We tried 432 MHz with him, but he never heard us and we never heard him. Uh oh again!

I kept working guys up and down the East Coast, and every now and then I'd work somebody out west off the back of the beam. Propagation stretched up into New England at around 2200 UTC, and then got short again at around 2315 UTC. At around 0200 UTC I worked several stations out west, in Colorado and New Mexico. Matt tried to work guys on 2 meters, but was not successful. We heard NØWL talk about the sporadic-*E* he was working out to the east, but we never heard it at all. At around 0300 UTC 6 meters folded for us. By then I had 273 Qs on 6 meters in the log, which was one of my best 6-meter days ever. On the other hand, 2 meters through 432 MHz were toast, and Matt couldn't determine why.

Sunday, June 11

We woke up at around 7:30 AM on Sunday. Our first Q on 6 meters was FN03 at 1406 UTC. About 30 minutes later, I worked KØDI in DM04, so I swung the 6-meter beam west; it stayed in that direction almost all day. The desert Southwest was the source of the vast majority of QSOs I worked on Sunday, with an occasional Q into EL29 and DN71. Matt was without an operational station on 2 meters through 432 MHz, and had no internet, so he tried in vain to get the bugs worked out. He did work some 6-meter stuff on Sunday, but for the most part, Matt unsuccessfully spent most of his time trying to get the UHF stuff going.

We worked some real close-in stations at around 1700 UTC, including EN52, EN50, and EN61 (home ground of our beloved Society of Midwest Contesters). We swung the beam back west at around 1930 UTC, and it stayed there the rest of the afternoon.

Trouble with TVI

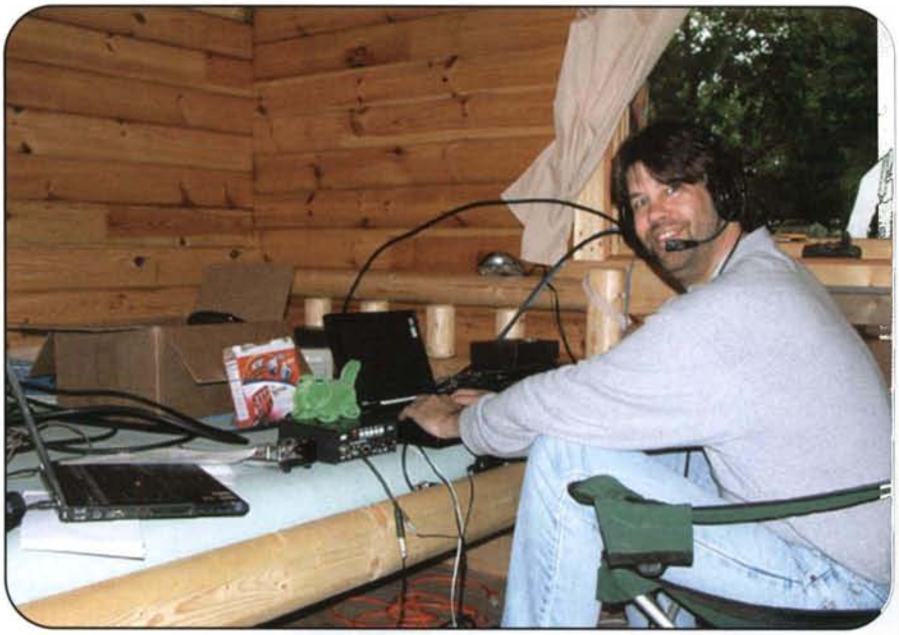
By 6:45 PM the KOA was getting full. As I was working K2DRH on 6 meters CW, I looked out the window of our cabin, directly into the front window of an RV parked right across from us. I could see the elderly lady fiddling with the TV, watching the picture get completely distorted in perfect unison with my CW. When I transferred K2DRH over to Matt (who did work him on 2 meters), Matt's SSB signal on that band was doing more damage to our new neighbor's TV than 6 meters was. I looked out the front door of the cabin and saw the place was full to capacity; it hadn't been that full all weekend!

We didn't want to cause any problems for our host, so we shut down the station. Our last QSO was with K2DRH on 2 meters at 0048 UTC (Monday AM GMT).

We were still pretty wiped out and a bit frustrated at the lack of success on 2 meters and up, so we ate dinner and went to sleep early. We woke up at about 7:30 AM on Monday, took everything down, and were on the road by 11 AM.

The folks at the KOA were *very* supportive and apologized for the lack of internet access. A lot of folks had complained about it. We did our best to keep them up to speed on what we were doing, and how things were going. They were genuinely interested. As we were leaving, Annette asked, "When will you be back?" We said maybe in September. I asked if they'd mind other hams operating from there, and they said they'd be delighted. So if anybody wants to activate EN20 any time soon, the KOA in Rock Port, Missouri would be glad to have you. E-mail me for details if you're interested.

While the incredible conditions on 6 meters salvaged the operation, the lack of QSOs on 2 meters and up has left a sour taste in our mouths. Learn from us: More careful planning is required before operating from rare grids. We felt we should have been able to provide EN20 on the higher bands as well, and we didn't do that. Still, for our first venture in several years, we did okay. We will learn from our mistakes and plan accordingly for the next grid DXpedition.



Sean, KX9X, working the 6-meter pile-ups on Saturday, June 10.

For more information on future grid DXpeditions by the Society of Midwest Contesters, please see the following URL: <http://www.ks9z.com/>. Thanks for the QSOs, everybody!

Summary

6 meters: 412 QSOs, 121 grids
2 meters: 3 QSOs, 3 Grids
222 MHz: 0 QSOs
432 MHz: 0 QSOs
Total: 415 QSOs, 124 grids

Rigs

6 meters: IC-706mk2, 100 watts, Cushcraft 3-el Yagi up 20 feet.

2 meters: Yaesu FT-736R, 2-meter brick (100 watts), 5-el homebrew Yagi up 20 feet.

222 MHz: Yaesu FT-736R, 222-MHz brick (100 watts), Cushcraft 4-el Yagi up 17 feet.

432 MHz: Yaesu FT-736R, 432-MHz brick (100 w), M^2 11-el Yagi up 20 feet.

Packing up to go back home, Matt, NM9H, stands next to our gear.

Using Radar Data to Predict Rain-Scatter Paths

Rain-scatter propagation has been around for a long time. Radar data is a way of predicting where rain-scatter propagation can happen and/or is happening in real time. Here KØSM discusses how to use radar data to predict rain-scatter propagation. He also discussess his software program, which is designed to be used for making such predictions.

By Andy Flowers,* KØSM

We say that an electromagnetic wave is "scattered" when it encounters some substance in its path that deflects some of its energy in a new direction. When one stops to think about it, most routine propagation at VHF and higher frequencies is a result of some sort of scattering. At VHF we often observe scattering effects from large objects close to Earth, such as buildings and aircraft. We also know that we can make use of small changes in air density in the lower atmosphere that allow for routine communication of a few hundred miles with amateur power levels. As we go higher in frequency, we find that smaller and smaller objects have a significant effect on propagation. Raindrops become an effective scattering medium in the microwave range. This article will focus on the mechanics of rain-scatter propagation and how freely available radar data can be used to predict possible propagation paths.

Scattering Principles I: Rayleigh Scattering

There are two sets of scattering equations that are used to calculate the amount of scattering from a medium: *Rayleigh* and *Mie* scattering. The type of scattering is a function of the size of the scattering particle relative to the wavelength of the radiation. Rayleigh scattering is simpler, so we will consider it first.

Rayleigh scattering applies when the diameter of the scattering particle (d) is much smaller than the wavelength of the radiation (λ). Rayleigh scattering is the dominant scattering mode when $d < \lambda/10$. Figure 1 shows the incoming electric field from an electromagnetic wave as it passes through a particle. When this happens, an electric dipole (p) is induced in the particle.

The magnitude of p is given by equation 1:

$$p = \frac{\pi \varepsilon_0 K d^3 E_{inc}}{2} \qquad \varepsilon_0 = 8.85 \times 10^{-12} \text{ Farads/m} \quad \text{(eq. 1)}$$

K is known as *Beer's Law absorption coefficient* and is a complex number representing the scattering and absorption properties of the dielectric. It is both wavelength and temperature dependent. Typical values of $|K|^2$ at 10 GHz/0°C are ~0.92 for liquid water and ~0.19 for ice. Therefore, this confirms that ice and snow are poorer scattering media than liquid water droplets of the same size and shape.

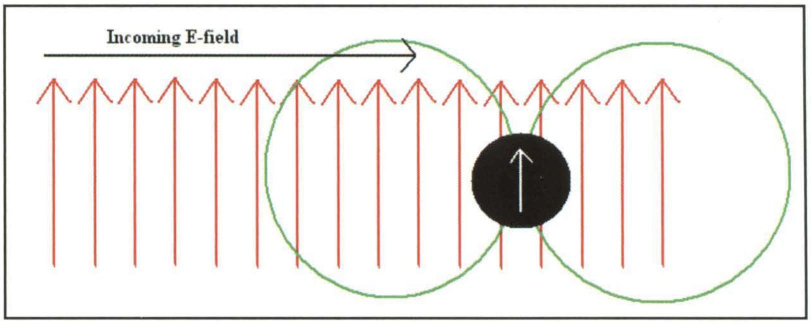


Figure 1. Induction of electric dipole in Rayleigh scattering. Arrows indicate E-field of the incoming EM wave. The two circles show the (re-)radiation pattern (H-plane) of the dipole.

The particle then *re-radiates* the energy as an omni-directional dipole, creating what we observe as "scattered" radiation. Because the dipole is induced in the same plane as the incoming electric field, the scattered radiation maintains the polarity of the incoming wave. From this information it becomes possible to derive the *radar equation,* which specifies how much reflected power (P_r) can be expected from an object. It relates transmitted power, antenna gain, distance, and scattering properties of the object as follows[ref. 1]:

$$P_r = \frac{P_t G_t A_r \sigma}{(4\pi)^2 R_t^2 R_r^2} \quad \text{(eq. 2)}$$

P_t = transmitter power
G_t = gain of TX antenna
A_r = area of RX antenna
σ = scattering coef. of target
R_t = distance from TX to target
R_r = distance from target to RX

$$\sigma = \frac{\pi^5 |K|^2 d^6}{\lambda^4} \cos\theta \quad \text{(eq. 3) [ref. 2]}$$

One of the most common uses of this formula is in weather-radar applications. If we want to know how much signal is going to be backscattered by the target (as is the case with weather radar), $\theta = \pi$ and σ becomes known as the radar *cross-section* of the target. One should also notice that the re-radiated ener-

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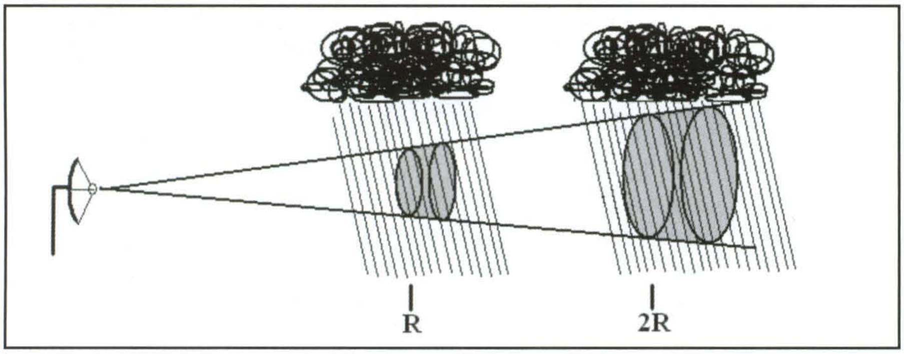

Figure 2. Reflected power is inversely proportional to R^2, not R^4, in distributed targets because the number of particles in the beam also increases with distance.

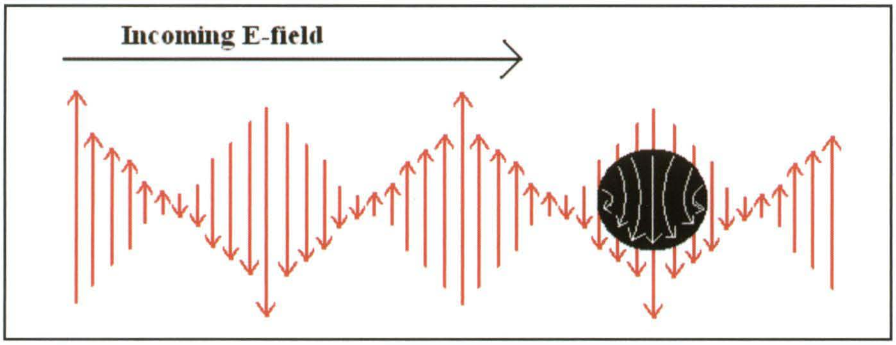

Figure 3. Distribution of electrical charge in Mie scattering.

gy is inversely proportional to λ^4. This, in combination with the power and antenna gain readily available to amateur operators, explains why 10 GHz is an ideal frequency for rain-scatter communication.

In radar applications $R_t = R_r$ so the reflected power varies with R_t^4. Scattered power that is inversely proportional to R^4 seems like a bad situation for long scatter paths. Fortunately, it is not *quite* as bad as that. Equation 2 is for *single* Rayleigh-scattering particle in the volume of the transmitted beam. In the case of a rainstorm, the radar beam is filled with many such particles, so the scattered radiation can be thought of as the sum of all their radiated powers. As the storm moves farther away from the transmitter, the number of particles in the transmitter's path increases proportionally to the square root of the distance (figure 2). Assuming that the transmitter does not under-illuminate the scattering medium, the scattered radiation becomes inversely proportional to R^2, not R^4.

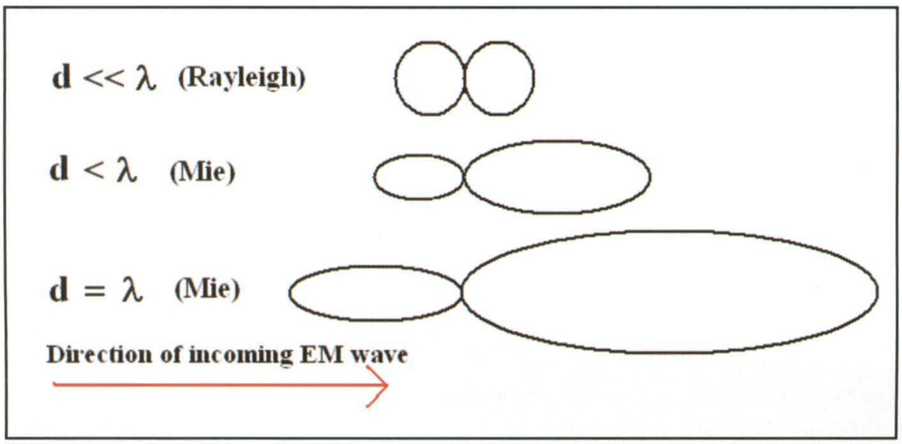

Figure 4. Approximation of radiation pattern as a particle progresses from Rayleigh to Mie scattering (H-plane).

Given the symmetry of Rayleigh scattering, this is true for both the forward-scatter and backscatter paths.

Scattering Principles II: Mie Scattering

Mie scattering occurs when the particle is of significant size that we can no longer assume that the E-field is constant across it (figure 3).

Given the complex interaction of the electric field inside the particle, the mathematics of Mie theory are quite rigorous and will not be covered here. The resulting radiation pattern can become equally complex, particularly when $d > \lambda$, but for a (roughly) spherical particle we can make some generalizations. Under most conditions there is a major lobe in the forward direction, and a lesser backscatter lobe—very much like the radiation pattern from a Yagi or log-periodic antenna. Because Mie scatterers have a larger volume than Rayleigh scatterers, the overall strength of the scattered signal tends to be larger. Mie scattering suggests the possibility for very strong *forward-scatter* propagation. Figure 4 illustrates these rough generalizations.

Both Rayleigh and Mie scattering have effects at amateur radio frequencies. The diameter of raindrops can vary between 0.5 mm in a light sprinkle to up to 5 mm in an extreme downpour. This means that the Rayleigh equations will apply to most propagation below 10 GHz (3 cm). Mie scattering will play a significant role mostly at 10 and 24 GHz, where thunderstorms can produce large raindrops and hail that are more accurately modeled by Mie scattering.[ref. 3]

Figure 5 shows the relationship between radiation pattern and drop size at 10 GHz. As one can see, larger drop sizes result in stronger signals in all directions. Mie effects begin to warp the dipole pattern when the drop size approaches 3 mm.

Since terrestrial amateur communication uses almost exclusively horizontal polarization, the scattered radiation pattern from a raindrop will look very much like that of a horizontal dipole (lefthand side of figure 5). We can treat a rainstorm as the sum of all of these particles such that the radiation pattern of an entire thunderstorm looks like that of figure 5. Using horizontal polarization will result in the strongest signals when the angle between the two stations (with the storm at the vertex) is closest to 0° (backscatter) or 180° (forward scatter). If one wishes to work

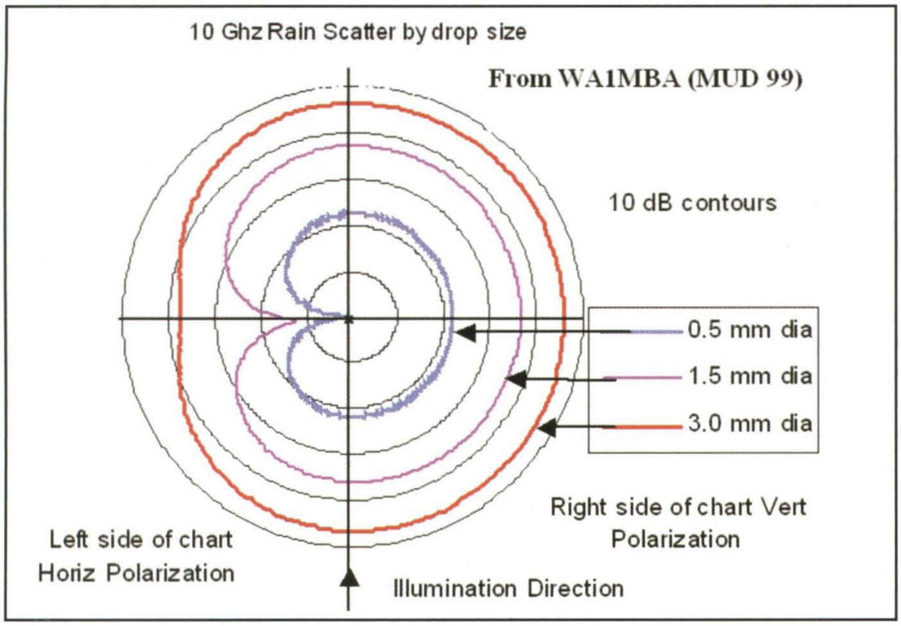

Figure 5. Scattering from spherical water droplets of different diameters at 10 GHz (from WA1MBA's presentation, MUD 99). Notice the large null at 90° with horizontal polarization.

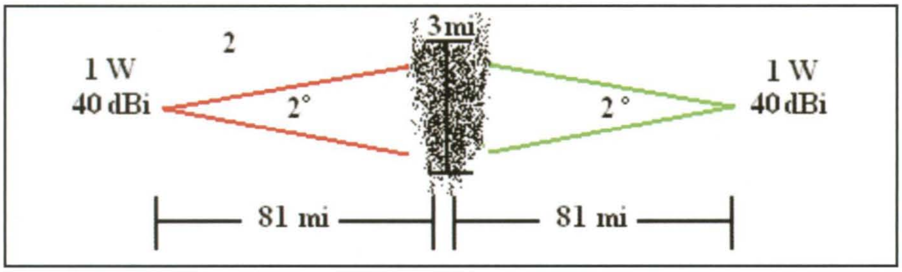

Figure 6. Two stations maximize signals when the same amount of scattering volume is illuminated.

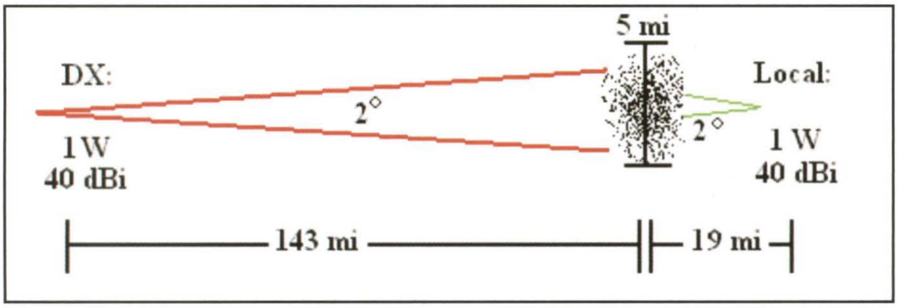

Figure 7. The storm in figure 6 has drifted to the right. The local station now under-illuminates the scattering volume of the DX station.

someone at a 90° angle, vertical polarization would probably work better.

Rain Scatter and Antennas: Bigger May Not Be Better!

Rain scatter has some propagation characteristics that may be counterintuitive to even experienced VHF operators. When making traditional link-budget calculations, we assume that the amount of power at the target is inversely proportional to the square of the distance between the source and the target. However, when we have a large distributed target such as a thunderstorm, it is possible to fully illuminate the target with the transmitter's beam. Because the target is sufficiently large, there is a point at which further narrowing of the transmitted beam (e.g., using a bigger dish) will only serve to under-illuminate the target, causing no increase in the scattered signal to the other station. This is a situation all too familiar to microwave EMEers.

To illustrate this point, figure 6 shows a situation in which the storm is equidistant from both stations. Both stations illuminate the storm equally with the same amount of power. This means that the average power density at the storm is equal from both stations. The E-field striking the water droplets is also the same and therefore their re-radiated (scattered) signals will be equal. If we assume Rayleigh scattering, we end up with equal signals at both stations.

Something interesting happens if the storm drifts to the right over time: The stations no longer illuminate an equal share of the scattering volume (figure 7). The DX station illuminates about 5 miles of the storm, while the local station only illuminates a little more than 0.5 miles. Both stations are still illuminating the storm with the same amount of power. The DX station still sees the same power density radiating from the storm, although it is unevenly distributed in his antenna's beamwidth. The local station is only able to see a fraction of the scattered signal from the DX station, but this loss in signal is made up by the local station's effective antenna area and proximity to the storm.

It turns out that to illuminate the same scattering volume using the distances in figure 7, the local station could use an antenna with a 15° beamwidth. This would result in no noticeable change in signal strength at the DX station, because the average power scattered by the storm within the DX station's beamwidth remains the same (figure 8). This means that a station using an 18-dBi horn held out of a window could be just as effective as a tower-mounted 1-meter dish for the local station, provided that each has an unobstructed view of the storm. This is almost certainly the case at the distances involved, as the common scattering volume is likely thousands of feet in the air and well above the horizon for the local station.

The point of this discussion is that more gain is not always better. The ability to switch to a medium-gain horn may actually help one make more contacts, as it is much easier to point, particularly in elevation, which will be necessary when the scattering volume is nearby. This should be encouraging news to people who live in areas with poor horizons. It also suggests that a big dish and a low noise fig-

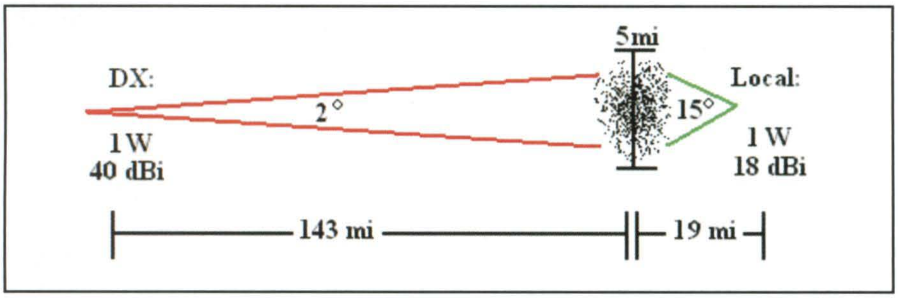

Figure 8. Local station switches to a medium-size horn antenna with no loss in signal at either end of the path.

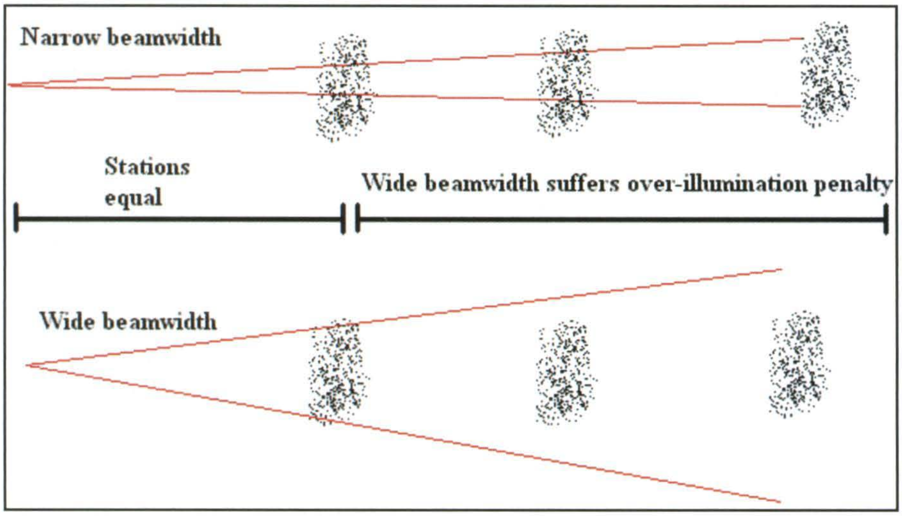

Figure 9. Over-illumination will cause extra path loss in the amount of power striking the scattering volume for increasing distance. A large dish with a narrow beamwidth will not incur these penalties as long as the storm remains under-illuminated.

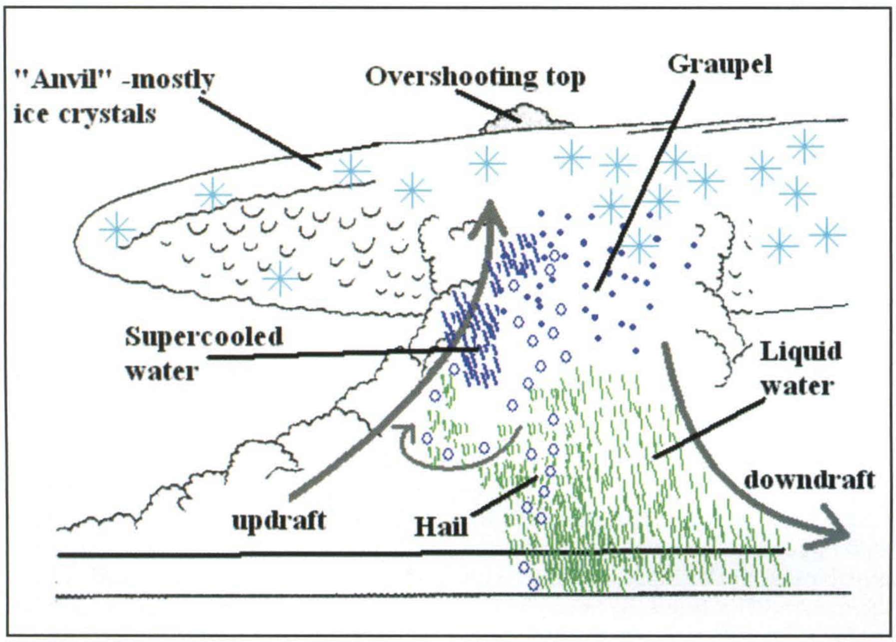

Figure 10. The anatomy of a supercell thunderstorm (view from south). (Adapted from NWS image)

ure are likely to be more helpful than a big amplifier for the stations who are located far from microwave population centers. Large dishes will not suffer over-illumination penalties except for storms at the fringes of its range (figure 9).

Anatomy of a Thunderstorm

Thunderstorms come in many shapes and sizes across the country. When it comes to rain-scatter communication, we would like to identify those storms that are likely to provide the strongest signals over the longest paths. Supercell thunderstorms are likely candidates to satisfy these criteria, as they tend to be quite tall and provide a large amount of moisture at high altitudes, thus increasing the potential scattering range. In addition, they tend to persist much longer than other single-cell thunderstorms, allowing them to be tracked by radar for long periods of time.

Figure 10 shows a supercell thunderstorm viewed from the south. This diagram also shows the primary forms of precipitation and where they can be found. The most effective scattering particles—large raindrops and hail—can be found in what is known as the *storm core*. The updraft can bring this reflective material very high into the storm, resulting in an "overshooting top" that penetrates the tropopause.

The storm core can extend tens of thousands of feet in altitude, especially if the updraft is strong. Hail forms in the storm core when supercooled water collides with (and instantly freezes to) either ice crystals or graupel (snow pellets) from above. The hailstone gains mass and starts to fall as more and more water droplets collide with it. Storms with very strong updrafts are able to circulate some of the hail back to the top of the storm many times, each time adding a new layer of water. This process results in very large hail sizes and the potential for strong scattering at lower microwave frequencies.

Figure 11 is an RHI (*range height indicator*) scan of an actual supercell thunderstorm. This is a 0.5° vertical slice of the storm showing the location of the most intense scattering material in the storm. This correlates well with the schematic drawing in figure 10. Hail shows up as the highest reflectivity because it is the most effective scattering medium. One can see that there is a large amount of water and hail held aloft

(Continued on page 78)

Building an APRS Tracker

Part 1 – The "Nimble" Tracker

APRS and GPS are initials that are enjoying increasing popularity among hams who operate on the VHF-plus bands. Here in part one of a two-part article on building APRS trackers, W2DOE describes how he built a simple APRS tracker using a Garmin eTrex GPS receiver, an ICOM IC-T2H handheld, and a TinyTrac3 TNC.

By Carlton Doe,* W3DOE

In an effort to build radio skills as a new ham in 2004, I volunteered for several road races and marathon events. I was told by the communication directors that while they appreciated my efforts, I could be more valuable to them if I had an APRS (Automatic Position Reporting System) tracker. This resulted in my first ham-oriented research and construction project: What was APRS and how would I build what everyone called an "APRS tracker"?

This article will briefly introduce APRS and tell how you can build a simple, low-cost portable tracker. Part 2 will cover construction of a more advanced and powerful tracker. I should explain that as a "bear of very little brain," I built the harder tracker first before building the one featured in part 1. I did learn a lot in the process, though, resulting in what I think is the simple and elegant "nimble" tracker covered here.

APRS & APRS Trackers

The Automatic Position Reporting System was developed by Bob Bruninga, WB4APR, as an enhancement to regular packet-mode transmission oriented specifically for publishing location-based information via RF. There are two parts to an APRS system: One part transmits where the tracking object is (the job of a tracker); the second part is the display software which receives APRS transmissions and plots the position information on maps. There are a number of software packages, such as UI-View (www.ui-view.org), that can be used to display APRS data. Some of the packages will only work if connected to a radio through either a software or hardware interface. Other packages are internet-aware and can display APRS information gated by digipeaters to APRS internet-based servers. Digipeaters function like the voice repeaters most of you are familiar with, although they handle packet-mode traffic. As a result, you can have a lower power radio yet still achieve broad distribution of your APRS information.[1] Many APRS digipeaters are linked to internet-based servers which provide a rolling and filterable archive of position reports the software uses to plot on its maps. APRS software will not be covered in either part of this article.

As I researched APRS trackers on the internet, I didn't find a lot of useful information other than some pictures. What those pictures showed, though, was that a tracker could be built into almost anything! I saw trackers in which their owners threw the components on the seat of their cars. This violated my sense of aesthetics as well as "professionalism" as an operator. I saw others built in small mint tins, discarded ammo cans, coolers, waterproof cases, and various other containers. Some appeared to have additional "bells and whistles," while others were very basic.

*e-mail: <w3doe@arrl.net>

Photo 1. The Garmin eTrex GPS receiver and its cabling.

Regardless of how the tracker was built, each had four basic components:

- A Global Positioning Satellite (GPS) receiver to generate the location-based information.
- A TNC (Terminal Node Controller) to interface with a GPS receiver and translate its data stream into a signal that can be transmitted by a radio. The TNC also connects to and controls the radio, determining how often or under what conditions the tracker will "beacon," or send out, its location information.
- A 2-meter radio able to transmit at 144.390 MHz, the APRS frequency for almost all of the United States.
- An enclosure.

It became apparent to me that building a tracker would involve balancing a number of factors, and how I weighted each would determine the size, capability, power, and portability of the tracker. For example, a high-RF-power tracker would require a larger radio. If I wanted the tracker to beacon for a long period, I'd need a larger and heavier battery. For a tracker to be easily transportable, it would have to have a small form factor, requiring a lower power radio. There isn't one set of "correct" answers to any of these issues. You as the builder have to decide what you want to do with the tracker, and that will guide the rest of your decisions.

Having built one rather large tracker (covered in part 2), I wanted to build something completely different—what I called a "nimble" tracker, which could be used if I was assigned to shadow a race official or to take with me on a Scout hike through some of the large parks and nature reserves close to where I live. The requirements for this tracker were:

- Simple construction
- Small form factor
- Light, able to be carried around for an entire day
- As inexpensive as possible
- Low(er) transmit power, would rely on digipeaters
- Modular so I could change out a piece if I didn't like it or re-use components should I decide to junk the whole thing

With this in mind, I proceeded to get a radio, TNC, and GPS receiver and hook them together.

The GPS Receiver

This was the area I knew best. I had been using GPS devices for automotive navigation for some time and was very familiar with GPS technology and the various types of receivers available. For this tracker, I wanted a receiver that was small, could be worn on a belt or elsewhere and yet still maintain an excellent lock on satellites, and was somewhat waterproof should the elements change. In my opinion, the only choice was a unit from the Garmin eTrex family of products (http://www.garmin.com/outdoor/products.html). In my opinion, Garmin builds the highest quality, most reliable GPS receivers, and their customer service is second to none.

The eTrex line is quite broad, and any one of the units, including the lowest model, would be perfect for this application. Another advantage is there are plenty of used units readily available on the larger auction and resale websites, so they can be purchased well below what new units cost. Another important consideration is that the eTrex's data port will output a constant stream of position information, as opposed to other highly portable units such as the Foretrex or Forerunner. While these could be used, a specially modified data cable needs to be built to trick the Foretrex/Forerunner into thinking it is attached to a computer requesting a data download. As the first criterion of this project was simplicity, I opted not to build that kind of cable.

As shown in photo 1, I opted to buy an eTrex Vista, even though it wasn't the least expensive model available. The Vista, though, enables the loading and use of highly detailed street-level maps used by my automotive GPS. With this, I can operate in urban events without the need to refer to paper maps; I just glance at the screen of the eTrex. This is definitely an add-on option not required to build a successful tracker. Had I not been able to load my automotive maps without an additional license fee, I wouldn't have purchased the Vista.

Photo 2. The ICOM IC-T2H handheld and the homebrew cable that connects to the TNC.

The Radio

The size, weight, and cost criteria for this tracker required an inexpensive 2-meter handheld. At the same time, it had to be rugged enough to handle the abuse of being bounced around in a fanny or day pack for the day. The ICOM IC-T2H

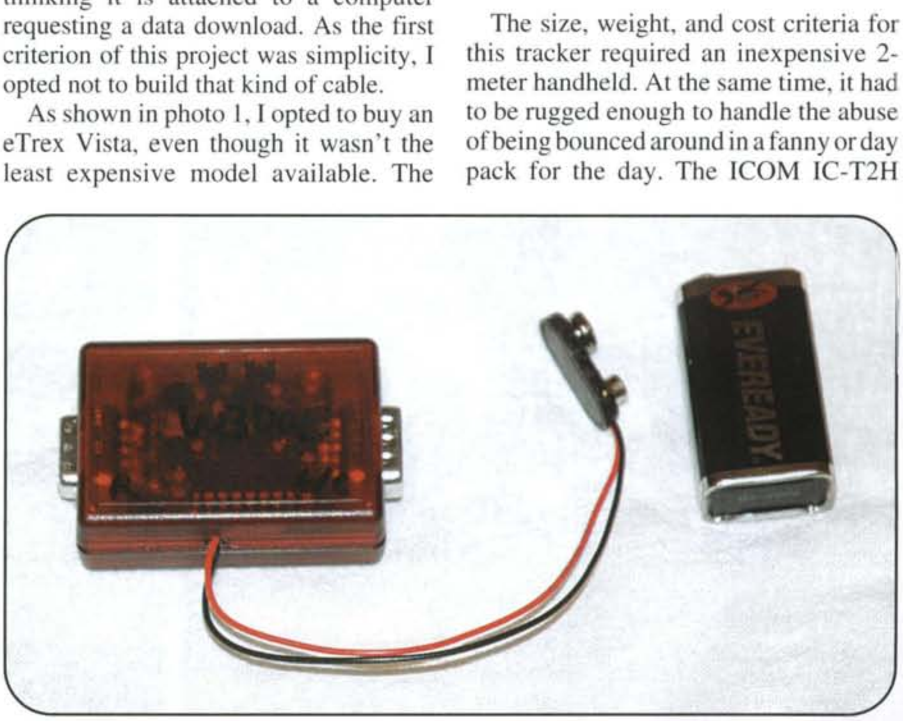

Photo 3. The modified Serpac C6 case housing the TNC board, along with the 9-volt battery.

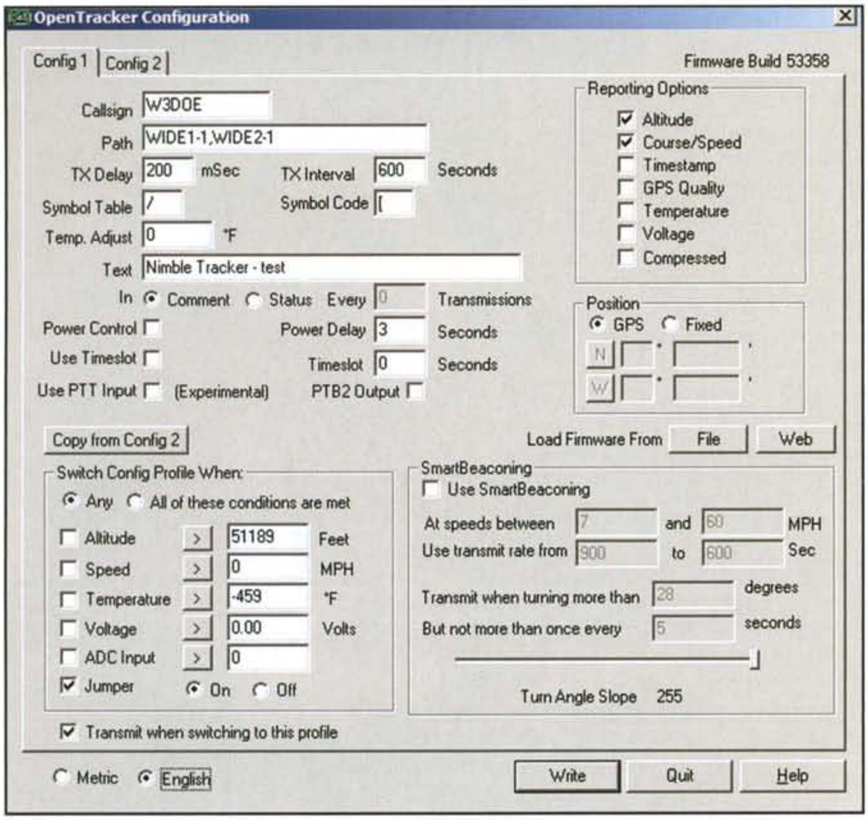

Photo 4. Screen shot of the OpenTracker configuration software.

Sport (http://www.icomamerica.com /products/amateur/t2h) shown in photo 2 fit the bill perfectly. Like the eTrex, used units in great condition can be picked up relatively inexpensively on auction or used-equipment sites. New units are not terribly expensive either, for that matter.

I did make one after-market change to the radio, though. Rather than use AA batteries, I purchased a 1700-mAh NiMH battery that was the same form factor as the included battery pack. Again, this is an elective option not required to build a successful tracker.

I built the cable shown in photo 2 to connect the radio to the output port of the TNC. While it works, I found during testing that it could be the source of a large problem: It picked up RF energy and directed it into the TNC, interfering with the TNC's ability to function. More about this later.

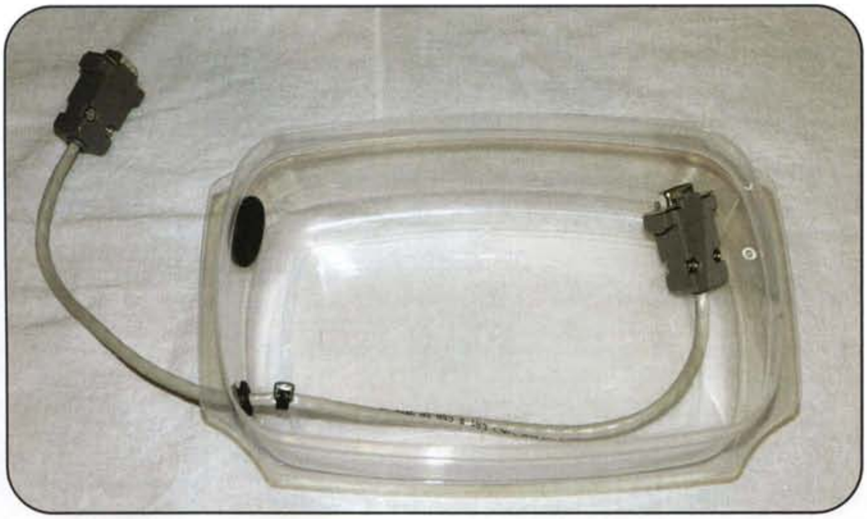

Photo 5. Modified container showing the installed homebrew serial cable.

The TNC

The TNC is the heart and soul of the tracker. It receives the position information from the GPS receiver and converts it into packet data the radio can transmit. In addition, the programming of the TNC determines how often the tracker will attempt to beacon, as well as what information is sent.

While there are a number of TNCs available to handle the various packet modes, I found two TNCs specifically designed for APRS use—the TinyTrak3 by Byonics (www.byonics.com/tinytrak) and the OpenTracker from N1VG (n1vg.net/opentracker). Both are extremely compact, have low power requirements, and are pin compatible so they can be interchanged if needed. Having used the TinyTrak3 in my first project, I chose the OpenTracker for this tracker. One consequence of this choice was having to find and modify a Serpac C6 case to hold the TNC board. The final result is shown in photo 3.

The next step was to program the TNC. This requires a Null Modem cable attached to a computer serial port. You probably will also need a female-to-female gender changer, since standard

Null Modem cables have a male connector on the end you need to connect to the TNC. Photo 4 shows a screen shot of the OpenTracker configuration software. It is here that you set your callsign, the digipath, what icon you want displayed on APRS software with the symbol table and code options, any secondary text transmitted as part of the beacon, and the time interval of the beacon or under what conditions it should beacon. For example, while this was set to beacon every 5 minutes, I could have enabled beaconing if my speed fell into a certain range or I turned greater than X degrees.

Of particular concern in programming the TNC is how a digipeater handles the tracker's traffic. While you want to ensure adequate repeating in your immediate area, you don't want to waste bandwidth and block others by requesting a large number of repeats. This is set by the PATH parameter in the software. Recommendations for this parameter have changed as APRS has grown and expanded over the years. Bob Bruninga's current recommendations are as follows:

• RELAY, WIDE, TRACE, TRACEn-N and SS are obsolete and are being phased out. Use at your own risk.

• Use WIDE2-2 for fixed stations. Use WIDE3-3 for fixed stations two hops or more from big cities. Use WIDE1-1,WIDE2-1 for two-hop mobiles in dense areas. Use WIDE1-1,WIDE2-2 for three-hop mobiles in remote rural areas. Use SS1-1,SSn-N for selected non-routine State or Section nets or when human operators are present for large area emergency needs.

This is only half of the TNC configuration. The TNC input and output levels must be set so it reads the radio correctly to (a) determine when someone else is beaconing at any given moment and (b) so it doesn't overmodulate the radio when beaconing. Accomplished by turning some set screws on the TNC board itself, I found the TinyTrak3 was significantly easier to tune through its software. It didn't take long to get the OpenTracker set up properly, though. It simply required changing to a non-APRS frequency, beaconing repeatedly, and listening on another radio to make sure the signal was clear. I followed this by connecting a radio to a computer with UI-View and "listening" to my beacon on this other frequency to make sure the packets were decipherable.

While I used the OpenTracker for a while, I must admit I eventually switched it out for a TinyTrak3 because of its enhanced programming capabilities and ease of tuning. This switch was driven purely by personal preference; the OpenTracker functioned well once it was set up.

The Enclosure

Believe it or not, this was the hardest part to find. I wanted to put the components in a basic plastic container that was just big enough to hold everything. I went to a number of large mass-market retailers, but they all carried the same type of merchandise. While it may have been great for storing food, the containers were all the wrong size for a tracker. Eventually I went to a local Container Store (www.containerstore.com), which carries a significantly broader range of shapes and sizes, to find what I was looking for.

Photo 5 shows the modified enclosure with a short, custom-made serial cable which connects to the GPS cable on one side and the TNC on the other. The other hole is large enough to permit either a rubber-duck antenna or an antenna extension

Photo 6. Radio, TNC, and cables neatly packed into the container, cushioned by a custom-cut piece of upholstery foam.

cable to pass through. Both holes are covered by a rubber grommet so the plastic doesn't cut the cables. The serial cable has a wire tie on the inside to protect against disconnecting from the TNC if any tension is applied to the cable. Using an electric carving knife, I crafted a piece of 1-inch upholstery foam to fit into the container as well as cradle the radio and other components as shown in photo 6.

The Antenna

In my early field trials with this tracker I had problems which I quickly traced to the antenna I was using. In my original design I had envisioned using the tracker either with a better grade rubber duck directly attached to the radio for relatively compact deployment or using a BNC extension cable tethered to a 3-foot dowel rod out of my daypack so the antenna would be just above my head. I found one configuration worked while the other resulted in harmful interference within the TNC such that it

About the Author

Carlton Doe, W3DOE, is fairly new to amateur radio, having received his Technician license in 2004 and his Extra class license a year later. He is particularly interested in emergency communications and APRS technologies and has passed all three ARRL EmComm classes. His wife and kids, though, are still slowly adjusting to his new hobby.

Carlton lives in Flower Mound, TX, but may be evicted if the neighborhood association, or his wife, decides to throw a fit over the HF vertical he's mounted above his chimney. Regardless, he can be reached at <w3doe @arrl.net>. Oh, and for the record, he's not related to John Doe, so don't ask.—*N6CL*

didn't function properly. What puzzled me was it didn't matter where the antenna was. If connected to an extension cable I could lay the antenna right on top of the TNC and everything was fine. If, however, the antenna was directly attached to the radio and several inches from the TNC, there were problems.

Stephen Smith, WA8LMF, finally helped me understand that HTs with rubber ducks don't have a sufficient ground plane to function properly. When we use them for voice operation, our arms and bodys provide a type of ground plane, enabling the signal to radiate out. Within my tracker system that ground plane was missing, and the RF energy was following the interface cable from the radio into the TNC. With the extension cable attached, the shield of the cable, while not the greatest ground plane, was enough to divert the RF energy from passing into the TNC. To fix this, I could put RF chokes on each conductor of my cables, wrap the connector cables several times through a toroid or ferrite core, attach a proper ground plane to the antenna connector (such as a 19-inch piece of wire with an alligator clip), and continue to use my extension cable to connect the antenna or any combination of the aforementioned. Because I didn't want to remanufacture the radio-to-TNC cable and I didn't have the room inside the container for several cores, I opted for the extension and the additional ground wire. With those in place, I never had any more problems.

Summary and Parting Thoughts

This tracker has been a pleasure to use. It's small and light with just enough power to hit the closest digipeater. I can use the GPS receiver for general hiking and other activities, as opposed to just with the tracker, improving its value for the price I paid. All in all, I'm very pleased with the whole tracker.

So there you have it. To build an APRS tracker just get a radio, TNC, and GPS receiver and throw them in the same container in which you stored last week's leftover lasagna! Seriously, though, it's not too difficult to build a tracker if you do your homework up front. Determine what kind of tracker you want to build and how it will be used; evaluate and play off all the equipment options such as size, cost, power, weight, and so on; and then build to the plan. Start with something simple like this "nimble" model to learn the basics; you can re-use almost all the components should you later decide to build a bigger, more powerful tracker.

Above all, remember to have fun. The process of learning how is, in my opinion, more important than the final result. You'll miss-drill holes or cut wires too short. It's okay. Depending on what goes wrong, you may have to make drastic changes, but that's part of the adventure of this hobby. Enjoy it.

In part 2 I will cover the construction of a seriously over-engineered and over-geeked high-power tracker. In some respects it's how *not* to build a tracker, since I had no real design when I started and made things up as I went along. The final result represents four iterations of design and thinking changes after I'd begun construction—the ultimate in "scope creep" when building an APRS tracker.

Note

1. There are specific rules for how this should be done and they are covered later in the article.

A Hot Spot GPS Finder

Kenwood teams up with AvMap to give weak-signal operators precise driving instructions to that high, dirt-road site . . .

By Gordon West,* WB6NOA

On your upcoming hilltop VHF/UHF expedition, you won't necessarily need to bring a laptop along to see detailed color maps, along with APRS position-hit-callsigns all around you. A completely portable GPS bi-directional navigating receiver can do it all, with one simple cable between the receiver and a Kenwood D-7 handheld or D-700 mobile rig.

"I slip my D-7 into my vest pocket and run the cable to my portable GPS chart display, and I can walk anywhere and everywhere squawking my GPS position on APRS while also receiving and displaying APRS stations and their callsigns right on the GPS color-map display," comments Don Arnold, W6GPS, working with Kenwood Corporation and C-Map Group, which brings in the portable GPS charting receiver from its parent company in Italy.

Don Arnold, W6GPS, works AvMap on the test bench with a Kenwood D-7 handheld rig.

"For weak-signal operators, a combined GPS that also reads grid squares and sub grids, with bi-directional capability for receiving APRS positions of other weak-signal operators, has allowed many microwave groups to speed up dish pointing," adds Don, who is a recent convert to the exciting world of 10 GHz and above.

A few years ago, a handful of Garmin GPS receivers could also show APRS received callsigns, but the display was relatively small, plus it required additional keystrokes within submenus to display driving instructions to the distant callsign on the screen. With the new AvMap, a minimum number of keystrokes let you easily "ITT"—Intercept To Target.

It has been just one short year since AvMap introduced its first GPS color-map receiver specifically designed for the amateur radio market. A provided Y cable split out NMEA GPS 1200-baud position sentences and sent them to GPS TNC-enabled equipment such as Kenwood, plus ICOM and Alinco, radios with built-in (optional) TNCs. The first unit was called Geosat 2, and the hot GPS receiver actually was built right into the antenna unit. The split out of the data occurred before the GPS NMEA sentence reached the 12-volt $5^1/2$-inch display head.

Then came Geosat 2.5, putting the driving-instruction speaker in the back of the display unit, and switching the power plug over to a simple cigarette-lighter-plug assembly. Both the 2 and the 2.5 included a CD of the entire country, with 256 MB preloaded in a proprietary compact flash card with approximately six states loaded with TeleAtlas street-level mapping, plus over 4 million Point of Interest details, including hotels, restaurants, gas stations, schools, and campgrounds.

However, the Geosat 2 and 2.5 car navigators were *not* bi-directional, so you constantly needed to look at your radio to see where other APRS operators around you were. Also, ham operators regularly driving coast-to-coast routes did not like the hassle of having to upload new sections of the country on the proprietary 256-MB flash card.

In January of this year the 2.0s and 2.5s dried up in inventory at Ham Radio Outlet, the first ham radio dealer to bring in this unique amateur radio APRS device. They began taking on stock of the new Geosat 4, the platinum version fully loaded with all the United States on a 2-gigabyte secure digital memory card, and now including the bi-direction capability to send GPS data to your radio's TNC and also decode and display APRS position hits and callsigns on the 5-inch color thin-film transistor daylight viewable screen. It's portable, too, with lithium-ion rechargeable batteries on the inside. Great for geocaching!

However, before you let the kids have it to find that geocache out at the camp-

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Portable Mapping GPS for Geocaching

By Gordon West, WB6NOA

GPS receivers with built-in WAAS (Wide Area Augmentation System) capability can target an accurate position fix to the radius of a 10-foot circle 95 % of the time. The WAAS correction signal compensates your position fix based on area ground station differentials that are uploaded to a geosynchronous satellite and downloaded by a tiny WAAS-enabled GPS receiver.

Reference ground stations have been absolutely positioned down to centimeters and are constantly analyzed for where the GPS satellite fix "within their own high accuracy receiver" indicates they are. Variations in the ionosphere may show the ground station 15 feet in error due north. If this error settles in for a few hours, the ground station uplinks the information to let area WAAS-enabled GPS receivers self-compensate for this error, forcing the equipment to correct 15 feet to the south. This differential correction will undo the ionospheric error until the reference station detects its own position getting back to spot on. Conditions change relatively slowly in the ionosphere, affecting these errors and corrections, so the WAAS reception is applied every few minutes.

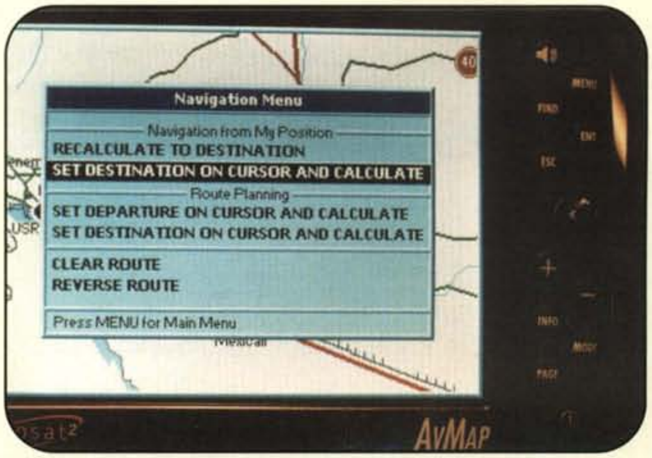
An older GPS without WAAS corrections typically is accurate to a 30-foot radius, and this is generally close enough to provide great highway navigation. Most highway GPS equipment will realize you're slightly off the straight road and automatically adjust for this error.

With spot-on accuracy with a common GPS with WAAS capability, an electronic game called Geocaching has swept the country. "More than 90,000 people have become interested in the sport since it was invented just a couple of years ago," says computer technician Jeff Atwood at the website <stubristol.com/geocaching.html>. "It's a game of high-tech hide and seek." Atwood is with MapTech, Inc., the developer of the popular topographic software for a laptop tied into GPS.

A Geocache enthusiast with a top-quality WAAS GPS handheld receiver will assemble a small watertight container of trinkets and a sign-in log book and hide it at a specific coordinate listed in degrees, minutes, *and fractions of a minute to 2 or 3 places*—not seconds, but fractions of a minute. Three digits after the decimal point will resolve accuracy down to 6 feet. Two digits after the final decimal point will resolve accuracy down to about 30 feet. One digit after the decimal point of a fraction of a minute will resolve a position fix to about 300 feet.

The cache of goodies might be in a small plastic kitchen container or maybe a cigar box, or maybe a tin from some kind of breath mints. The container needs to be large enough to hold a tiny pencil and sign-in log. Trinkets are included for trading.

This geocache (white tine) in the harbor was hidden on the channel marker "No Wake" sign. We needed a boat to get to it.



A new geocache coordinate is ready to follow!

The cache is hidden in a public place, and the GPS coordinates are checked and double checked to make sure they are as close as the equipment can provide. The coordinates are posted on numerous geocaching computer sites, and the fun begins. Sometimes hints are included to help zero in on the hidden target.

Now for *you* to find some secret caches hidden nearby, get started by bringing up the website <www.geocaching.com>. Move around the site to get as much information about this fun sport as you can, and then bring in some of the latitude and longitudes of hidden "treasures" near you.

While each portable GPS receiver has its own set of button pushes to input latitude and longitude, the most exciting portable GPS equipment is the unit that also has local maps. We used the Geosat 4 with its color screen and built-in battery supply and GPS antenna system. To use this unit, first press the FIND button, then select LAT/LON, next insert the latitude and longitude coordinates, press MENU, and set the final destination to find.

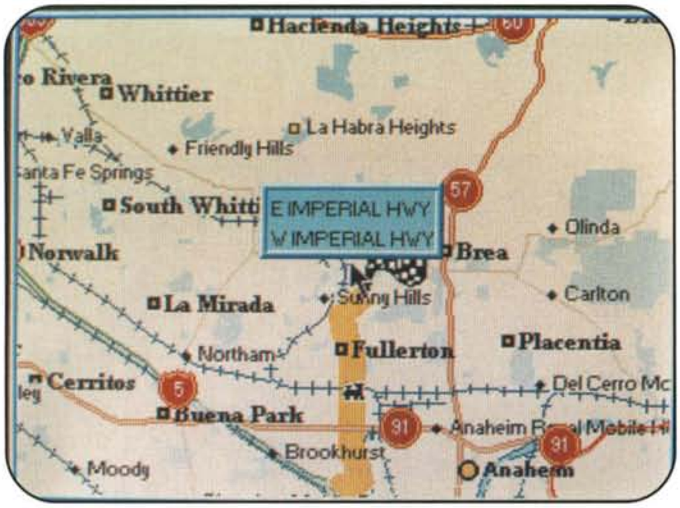
You can either beeline it directly to the hidden cache, or look over the map and decide which way will get you there without dropping off a cliff or fording a raging river. All this time your GPS mapping equipment is also showing the path that you traveled to get to the hidden location. Some will even calculate how long it's going to take to get there, too!

When you zero in on the GPS created mark, double check that the GPS readout agrees with the hidden cache readout, and then double check again that both readouts agree in either fractions of a minute (preferred) or seconds. Keep in mind that .5 of a minute equals 30 seconds.

Now start looking around and over and under. The geocache is not going to be left sitting out in the open, but rather will be protected from someone not in the know accidentally discovering it and taking it home. The local geocache that we found here in southern California was right in the middle of a pedestrian foot bridge over a river. It wasn't until we got down on our hands and knees and looked under the planks that we discovered the tin box.

Geocaching helps refine your GPS skills. For the emergency search-and-rescue teams, latitude and longitude distress calls are uplinked via PLBs (Personal Locator Beacons) on a 406-MHz data burst. Maybe your emergency search-and-rescue group is dispatched to a specific latitude/longitude. If you are active with geocaching, you will have the latitude and longitude programmed within seconds, a mark created, and a clear readout on how to get to the distant target.

Geocaching is more than just a game. As more PLBs are turned on in an emergency, the skill of locating latitude/longitude will become a lifesaving technique for everyone with a tiny GPS receiver.



The AvMap daylight-viewable screen features bright, bold graphics.

Callsigns pop up on the screen of the new AvMap G4T hooked up to the Kenwood D-7.

ground, consider all you can see on the color daylight-visible screen during the next weak-signal weekend:

- Mapping down to many dirt-road levels
- Fix (your position) latitude/longitude
- Cursor lat/lon anywhere you choose
- Maidenhead grid square to sub-grid readouts
- Distance to cursor target
- Driving instructions to chosen distant APRS station

All this is just on the first mapping screen, with little boxes off to the right. A few button pushes get you into multiple windows to calculate magnetic or true bearings to other microwave stations, either choosing the APRS ID or using the cursor to match the stated latitude and longitude.

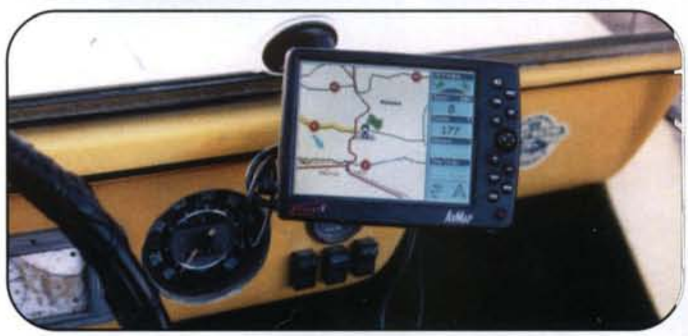
If someone indicates he or she is on the tip top of Signal Peak, you might even look up that information out of the millions of TeleAtlas POI information systems and tell your AvMap to calculate the magnetic path bearing.

Also, if it looks as if you may need to hike in to that secret high spot, the AvMap can unplug from 12 volts DC and work completely portable for up to an hour, hooked into your Kenwood D-7, offering GPS data for Kenwood APRS transmit and on-screen APRS fixes of those stations all around you.

More Technical Info . . .

The Geosat 4 incorporates the 12-channel receiver *within* the display body, along with a display body patch antenna. The GPS receiver also incorporates a wide-area augmentation system (WAAS) for spot-on position accuracy, even showing on which side of the street you are parked. Although there is a jack for an outside-vehicle GPS antenna, I have yet to find a car, RV, or motorhome with which I can't get enough signal on the inside!

DC power input may be anything from 10 volts DC to 36 volts DC. External power input automatically safe-charges the built-in lithium-ion battery pack. The battery pack will continuously run the equipment anywhere from 30 minutes to 2 hours, depending on how you have set the TFT display backlight. The LCD TFT ultra-bright 5-inch color screen has the resolution of 320 × 240 pixels, and has an automatic brightness control as well. It will go into an amazing "blackout" lighting in the dead of night, still highly visible, but easy on the eyes.

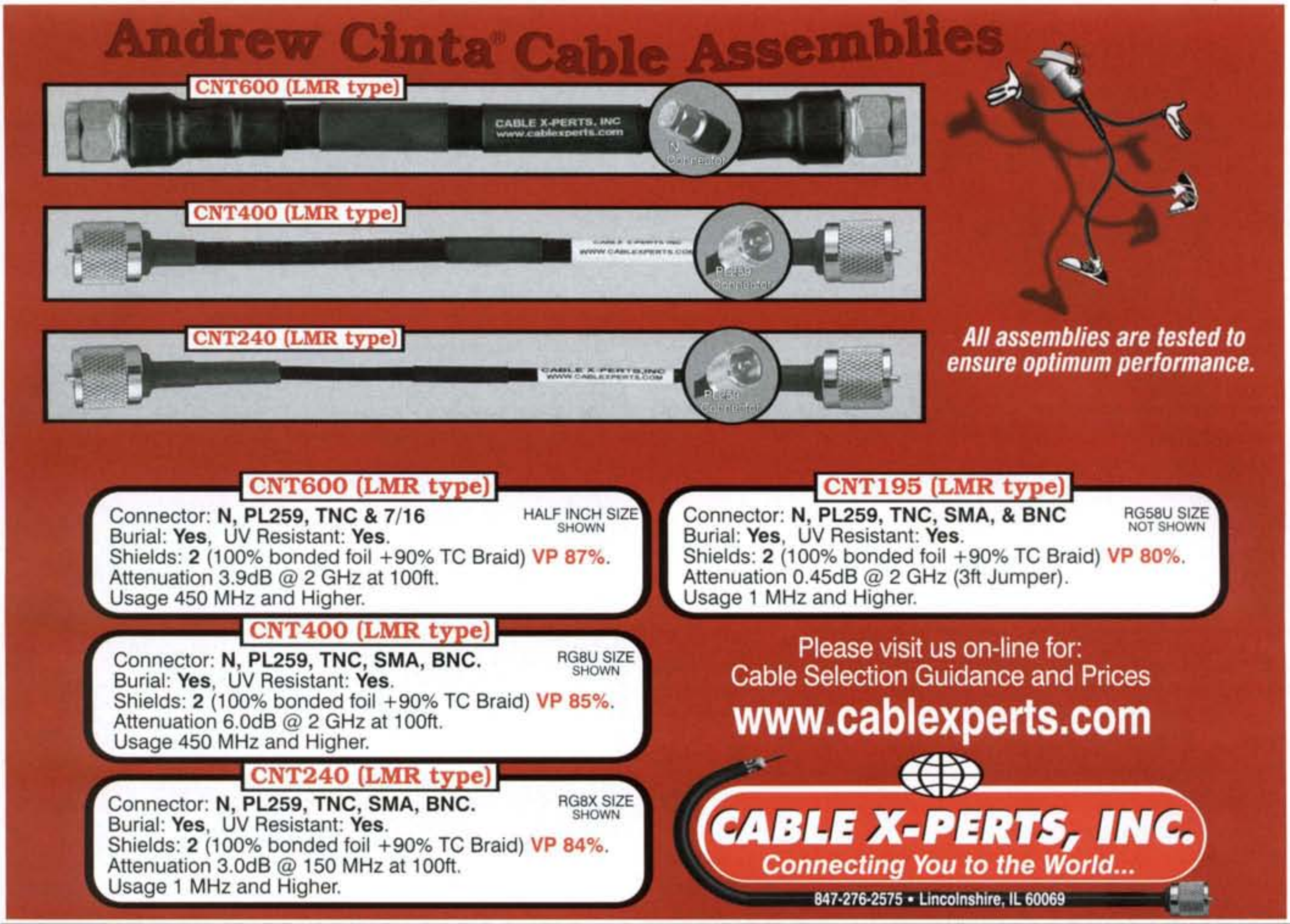


Author Gordo, WB6NOA, gets dish-aiming information from the AvMap G4T.

The Geosat 4 also includes a PC interface for software updates, as well as the capability to upload alternate mapping areas such as Alaska or over 20 countries covered by TeleAtlas in Europe. Included with each Geosat 4 receiver is a USB cable along with a DVD with Canadian cartography.

You can also receive free software updates from <www.AvMap.it>.

Each time you wish to home in on an APRS hit, it becomes a "mark," with 1000 mark points capability. With a couple of key strokes you can then calculate the best route to actually drive



to that other station, choosing either the shortest route or the calculated fastest route. Also, when you finally finish up with your mountain topping, a single push of the drive-me-home button automatically calculates the voice and visual instructions to your home QTH.

Included with the Geosat 4 is an interconnect cable for the popular Kenwood D-7 or D-700 transceiver with built-in TNC. The silver three-pole plug goes into the Kenwood radio GPS input/output socket. On the Kenwood D-700, make absolutely sure you spot the right hole before plugging in the cable. If you're not careful, you could accidentally push the small plug into the hole for RESET, and just one push will completely undo anything and everything in your Kenwood D-700 memory. Get the right hole!

The other end of the cable features a gold four-pole plug, and it goes into the "TMC" (Traffic Management Channel) port on the back of the Geosat 4. This is the same jack that will accept a "Y" cable adapter if you decide to sign up for monthly traffic-management reception—an over-the-air subscription service that turns your little GPS receiver into a smart freeway or expressway monitor, showing you up-to-date traffic conditions all around you.

On your Kenwood D-7 or D-700 radio, you will need to get into the APRS menus and add your callsign, select NMEA 96 data rate 9-digit NMEA information, and select your packet path, such as wide 1-1, wide 2-2. If your Kenwood radio has any packet path "relay," "relay, wide" is no longer used.

Many duplicate packets are generated by relay wide by these paths and cause collisions and lost packets. Go for wide 1-1, wide 2-1 recommended for mobiles for two hops; or wide 1-1, wide 2-2 for mobiles for three hops. *Avoid* relay! On some very early Kenwood D-7 handhelds, you may notice that your radio goes "beep" every few seconds, indicating the proper flow of NMEA data between both units. You can turn the volume down to minimize the "beep" driving you crazy, or you can send your very early Kenwood D-7 back to a Kenwood service center for an upgrade. Newer Kenwood D-7A handhelds all have the new upgrade program and won't "beep" at you every few seconds, except when you have selected "Beep" from a menu.

During recent testing, I found the AvMAp Geosat 4 quiet as a mouse with regard to EMI leaks. There was not a sign of the display or receiver heard on 6 and 2 meters SSB, 432 and 1296 MHz SSB, and higher. At 10 and 24 GHz, there was no RFI coming from the equipment.

The Geosat 4 can also take video input from gear, such as DVD, backup camera, and SSTV output from an ICOM R-3. There is even an optional TV tuner that lets you tune channel 3 and channel 8 in case you wish to decode ATV signals from any PC Electronics downconverter.

Best of all, for the weak-signal operator, the Geosat 4 is uncomplicated. Stick it on your front windshield with the supplied suction-cup bracket, add 12 volts to recharge the internal batteries and to power it up as you head for the high site, and let the canned voice in your choice of multiple languages steer you to your secret spot. Even in the bright sunlight the color screen stays visible!

If you have technical questions about the Geosat, send an e-mail to: <info@ Geosat.US>. If you want to look at some of the sample screen images, go to <www.Geosat.US>. To receive reviews from a Yahoo group, go <http://groups. yahoo.com/ AvMapg4t/>. And if you already own a Kenwood D-7 or D-700, it is truly plug and play! ■

By Joe Moell,* KØOV

HOMING IN

Radio Direction Finding for Fun and Public Service

Remembering Two T-Hunting Comrades

Carl Jung, the famous Swiss psychologist, wrote: "The meeting of two personalities is like the contact of two chemical substances. If there is any reaction, both are transformed."

Ham radio brings personalities together. On the air, at meetings, flea markets, Field Day, and many other events, we become acquainted with people with whom we share an interest in radio communications. Lasting friendships are created and lives are changed.

Nowhere is this more evident than among aficionados of radio direction-finding contests, both mobile and on foot. I often have written about the camaraderie that builds among hams as they engage in friendly competition to see who can assemble the most effective radio direction-finding (RDF) systems, who has the best "foxhunting" skills, and who can find the cleverest transmitter hiding sites to keep the "hounds" at bay.

Although they always welcome newcomers, the mobile T-hunters of southern California are an unorganized but close-knit community of strong personalities who play hard at their weekend sport. They also work hard when called upon to solve RF interference problems. On Memorial Day weekend, they were hit by the loss of two of their finest. As reported in the amateur radio press,[1] Mike Obermeier, K6SNE, and David Gordon-Ross, N6IDF, lost their lives when Mike's Jeep went off a mountain road near Lake Isabella in Kern County, California on May 27. It was the first serious accident in over three decades of mobile transmitter hunts in the Los Angeles area.

Southern California T-hunters were stunned. For weeks they had seen photos that Mike had e-mailed about the reworking of his Jeep to make it perfect for on-road and off-road use. He could hardly wait to take it out on one of our "All-Day" 2-meter hunts, which usually last for a full weekend and involve hundreds of miles of travel to find several well-hidden transmitters in the mountains and deserts. Even though he was a paraplegic, Mike had done his own shop work, mostly by himself.

K6SNE was one of the most active ARRL Official Observers in southern California. Thanks to the efforts of Mike and other T-hunters, there is now an unprecedented level of cooperation between ARRL OOs and the Los Angeles area FCC office in Cerritos. Mike put the finger on numerous repeater jammers and non-identifying troublemakers, including the infamous Jack Gerritsen.

David and Mike were always eager to use their RDF skills to find the sources of spurious signals and malicious interference. The problems did not have to be on a ham band; I told you about K6SNE's adventure on a banana boat in the Los Angeles harbor in my "Homing In" column for the Fall 2004 issue. He didn't hesitate to become aggressive when the ship's Russian crew members were indifferent to the likelihood that their radio gear might be making the mariners' international distress and safety channel unusable for many miles.

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At a recent club meeting, Catherine Deaton, the District Director of FCC's Los Angeles area office, was very animated when talking about the excellent cooperation between her agency and ARRL Official Observers in solving interference problems, both inadvertent and malicious. Ms. Deaton was in the large crowd that paid respects to K6SNE at his graveside service. (Photo by Joe Moell, KØOV)

It takes that sort of perseverance and self-confidence to find well-hidden transmitters in the mountains and deserts of California and western states. N6IDF and K6SNE were fearless, but they weren't foolhardy. Contrary to some uninformed posts on internet ham radio message boards, they were doing nothing more dangerous than traveling a narrow dirt road. Mike had two decades of experience driving with hand controls, but something went wrong this time.

There are two opportunities to honor Mike and Dave. The Michael Obermeier Memorial TV/Video Scholarship has been established by Santa Ana College, where Mike was an instructor. A savings account has been set up for the benefit of David's one-year-old son. The latest information on these memorials[2] is on my website.

Rolling Toward the Fox

K6SNE had been active in outdoor sports until an accident put him into a wheelchair on his nineteenth birthday. Thus, it's not surprising that on-foot transmitter hunting appealed to him almost as much as mobile RDF. When international-rules

In 1995, Mike Obermeier, then KD6SNE, was the first ham in the USA, and perhaps in the world, to participate in an ARDF event from a wheelchair. At right is Christie Edinger, KØIU, his extender. (Photo by KØOV)

radio-orienteering first came to southern California during the mid 1990s, Mike wanted to join in. That led to a pioneering experiment with the concept of "extenders" for competitors with disabilities.[3]

For the 1995 ARRL Southwestern Division Convention's on-foot hunt, the site wasn't suitable for special courses to accommodate solo blind or wheelchair hunters. Instead, K6SNE (then KD6SNE), and Dennis Schwendtner, WB6OBB, a sightless ham from Santa Barbara, were each accompanied on the regular course by a physically fit person who went into inaccessible places at the command of Mike and acted as eyes for Dennis.

The extenders weren't permitted to do any RDF; that was to be done only by K6SNE and WB6OBB. The extenders could only be used to overcome the limitations of their disabilities. Mike's helper went into the brush or dirt to search, without RDF equipment, at his direction. Dennis' extender described to him the terrain features and the presence of other hunters in the area in which he was searching.

Nobody had more fun at this convention foxhunt than Mike, Dennis, and their extenders. Neither won a prize, but they successfully found transmitters and received certificates of merit. It was a great example of inclusion and mainstreaming, two buzzwords that are popular with educators nowadays.

The concept of extenders for full-size ARDF courses has not yet caught on nationwide, but wheelchair-friendly on-foot transmitter hunts are becoming more common. In "Homing In" for the Spring 2005 issue of *CQ-VHF*, I wrote about special RDF events for students at Courage Handi-Ham Radio Camp in Malibu, California last year.

Another example is the Sequim and Port Angeles event that will take place on August 26, 2006 on the North Olympic Peninsula of Washington state.[4] According to Neil Robin, WA7NBF, there will be at least two transmitters to find in a seacoast park. One of them will run 100 milliwatts on 146.565 MHz and will be wheelchair accessible. Maps will be provided, as well as a picnic lunch.

Stray Video in Colorado

Nobody liked to tell or listen to a good transmitter hunting tale more than N6IDF and K6SNE, especially if the story was about the solution of a real interference problem. They would have enjoyed this story, which took place in March. Dan Meyer, NØPUF, of Englewood, Colorado wrote that it started when people were having problems connecting to the packet cluster on 145.05 MHz at his house.

"Our network in the Denver metro area is used almost exclusively for emergency communications and related training," he wrote, "so we needed to get it fixed promptly. I noticed that there was an S5 to S9 signal on the frequency that was locking out people's packet TNCs at certain times of the day. The modulation sounded somewhat like a 60-Hz hum. After a few days, I found a pattern to the noise; it seemed to be more prevalent during the early morning and late evening."

Dan continued, "To eliminate the possibility of the source being in my own house, I disconnected everything from the mains and ran several radios on batteries. The noise continued. I drove around my neighborhood and heard very little if anything. Next I called Bob Schellhorn, NØTI, to see if he heard it at his location, 20 miles north of mine. Sure enough, it was stronger there. Bob said it sounded to him like TV sync.

"I sent out packet, voice, and e-mail messages asking people to send reports of their location, signal strength, and bearing to the source. By plotting the many responses, it appeared to be in the north, probably around the Broomfield or Boulder area. As it turns out, some of the bearings were inaccurate, but at least we had some idea as to where to look.

"All of this took about a week's time. The following Saturday after our regular club breakfast, I set out to find the noise along with Chris Krengel, KBØYRZ, Ben Baker, KBØUBZ, and Ann Trudeau, KAØZFI. As I traveled along US 36, the signal became very strong. Chris stopped at 23rd Street and I-25 to provide a cross bearing, which narrowed the search area quite a bit. Then the signal went off, or so it seemed. Bob did some tuning and found it at 145.120 MHz. Hmmm, that might also explain the interference that some voice repeaters were having.

"Our three vehicles converged on the hot area, but due to numerous metal buildings, towers, fences, and storage tanks, we chased our tails for about an hour. Every time I moved ten yards, the bearing seemed to change 180 degrees.

"After some discussion, the four of us concluded that the source had to be near the Union Pacific rail yard. There were several towers on the property with lots of antennas on each. As we were looking around, a UPRR employee stopped us and asked us what we were doing. Although we were not on the property, he told us not to proceed any closer. Not wanting to face federal trespassing charges, we did as we were asked."

By driving carefully along the edges of the rail yard, the group finally identified the offending tower. Ben took pictures of the area and made a map of the location. They obtained a phone number of the railroad communications liaison from the employee on site.

Benjie Campbell, WØCBH, picks up the story from there: "On Monday morning, I contacted the supervisor of the

Is it in there? Scouts are learning to search for hidden transmitters at JOTA 2005 with instructor Marvin Johnston, KE6HTS. (Photo by KØOV)

Several of the practice transmitters at SBARC JOTA were wheelchair-friendly. (Photo by April Moell, WA6OPS)

Union Pacific Signal Department in the Denver area and explained what we had found. He asked for a time that we could come out and show him what we had discovered. Next day, I received an email from Dennis Leesley, KKØQ, a UPRR employee who had been assigned to the job. He had taken some equipment out and found a buzzing signal coming from the tower. It did have a camera on it, but it belonged to the Burlington Northern and Santa Fe railroad, not UPRR.

Dennis Schwendtner, WB6OBB, and his extender, Linda Reagan, now KF6MOB, found several transmitters at Hamcon/ Foxhunt 1995. (Photo by KØOV)

"Dennis knew some people at BNSF," WØCBH continued. "He called them and together they went to the site and discovered that a wideband amplifier had been inserted in the circuit for the BNSF video camera. They replaced the amplifier and the noise disappeared."

Congratulations! This was another successful find for these Denver area transmitter hunters, who get lots of RDF practice on high-altitude balloon flights by the Edge Of Space Science organization. Unlike southern California mobile T-hunters, whose motto is usually "every team for itself," the EOSS recovery group has refined the art of cooperation among hunt teams to quickly coordinate the return of valuable payloads, which often land over 100 miles from the launch site. A visit to the EOSS website[5] will give you volumes of information on RDF for balloon recovery, including map overlays and a spreadsheet for automatic triangulation by Paul Ternlund, WB3JZV.[6]

Get Ready for JOTA

As this issue arrives in readers' hands, hams and Scout leaders are planning the 49th annual Jamboree On The Air (JOTA), to take place October 21–22, 2006. All over the country, Scouts will experience the thrill of talking with other Scouts via amateur radio. They will participate in other ham activities such as building electronics, using specialty modes, and in some places, they will hunt hidden transmitters.

Last year I had the privilege of helping members of the Santa Barbara Amateur Radio Club (SBARC) put on an ambitious JOTA campout weekend for seven Scout troops at the Sedgwick Reserve. This 6000-acre wilderness area in the Santa Ynez Valley of California is owned by the University of California at Santa Barbara and is the site of frequent "digs" by UCSB archeologists such as Michael Glassow, KK6NP, and Anabel Ford, KC6GWA.

In charge of the 2005 SBARC JOTA was Darryl Widman, KF6DI, a former Scoutmaster and Scout Commissioner who

Volunteers Needed for Migratory Bird Research

Attention hams in eastern states! Here is an opportunity to assist in a wildlife radio-tracking project and help scientists learn the movements of endangered birds. With just your scanner or extended-range transceiver plus an outside antenna, you could join in and perhaps make valuable contributions.

Since 1998, hams and SWLs have volunteered to aid researchers studying various critters. Sometimes hams have gone into the field with radio direction-finding equipment, as they did during a 2005 study of Indiana Bats in New York (see "Homing In" for Summer 2005 *CQ VHF*). In other studies, they have contributed simply by monitoring from their homes and vehicles.

According to researcher Scott Tarof of the Department of Biology at York University in Toronto, his school is collaborating with the University of Guelph and the Purple Martin Conservation Association on a pioneering project to study the dispersal and migration patterns of this interesting bird species.

In mid-July 2006, Dr. Tarof and his associates will radiotag 20 juvenile Martins from wild breeding colonies in Edinboro, PA. They will then attempt to radiotrack their movements to study dispersal, migration, roosting behavior, and survival. It is thought that many will go to the Presque Isle roost site near Erie, PA in August prior to migrating south. It is hoped that some birds may be tracked all the way to their wintering grounds in southeastern states of the USA.

The tiny transmitters will be on frequencies between 172 and 173 MHz. Each will send a very short pulse every second or so, to maximize battery life. Researchers expect the batteries to last about three months.

It was originally announced that York University's bird study project for this summer and fall would be Loggerhead Shrikes in the province of Ontario, but that effort had to be postponed for at least one year. The Purple Martin study replaces that project for 2006.

Although scanner receivers in the FM mode can pick up tag signals when very close, a sensitive receiver with SSB/CW capability will give optimum range. Volunteers with high fixed antennas and computer logging equipment in their homes may be able to detect flyover and roosting. A simple Yagi made from measuring tape and a sensitive portable receiver will suffice to go into the field for direction-finding.

For up-to-date information on this project, including frequencies when available, go to <www.homingin.com>. The wildlife tracking pages of this site also describe the special characteristics of biological radio tags as well as provide information on the best equipment for monitoring and field tracking. You will also find reports of previous volunteer wildlife tracking efforts and instructions for joining an e-mail list for the latest updates.

Thanks in advance for your help! —*KØOV*

promised to give the youngsters a comprehensive amateur radio experience. For two days, Scouts built their own code oscillators from kits and discovered CW with them. They made contacts on the air, sent television pictures, and learned all about RDF. After completing each activity, they earned stars to put on their individual JOTA cards, marking progress toward their radio merit badges.

SBARC President Marvin Johnston, KE6HTS, a medal winner and organizer of the 2004 USA ARDF Championships,[7] was in charge of the RDF aspects of JOTA 2005. He was assisted by SBARC member Scott Moore, KF6IKO, and your columnist. Our goal was to help the Scouts successfully complete a 1-kilometer round-trip ARDF course on the 2-meter ham band. Following International Amateur Radio Union rules, these foxes transmitted for one minute each in rotating sequence, but there were only three of them. Scouts would take the course in teams of two or three, for safety and to help build teamwork skills.

KE6HTS set that three-fox ARDF course, but before the Scouts were ready for it, they had to become proficient at RDF by going after some practice foxes that I put out around the camp site. There were lots of them, on different frequencies, so that multiple teams could be learning without following each other around. Marvin, Scott, and I led the self-appointed teams of Scouts in their personalized training.

The first fox was always very close and easy to locate. The next was more difficult, and so on. Each member of the team took a turn at taking bearings with one of the RDF sets, which consisted of a steel-tape Yagi and a synthesized Sniffer 4 from Bryan Ackerly, VK3YNG, in Australia.[8] The audible signal-strength indicator and automatic attenuation system of the VK3YNG unit make it ideal for beginners. One of the Scouts was in a motorized wheelchair, and there were some foxes that he could find by himself.

By the time the team members had tracked down three or four transmitters, they were ready to go out on the ARDF course. Working together, they determined which of the three foxes to find first. Usually one Scout did the RDF while the other team members beat the bushes and marked the punch cards at the foxes. Then the fastest one raced back to the finish line with the card.

Stars for their JOTA cards were presented to all who completed the course. The fastest team on the ARDF course received special recognition around the campfire Saturday night.

In his wrap-up report after JOTA 2005, KF6DI wrote, "Some of the Scouts said that the transmitter hunt was the best part of all and that it was the most fun. You should have seen them running back to the starting point so as to beat the times of the other teams. They were really into this!"

Wouldn't it be great if RDF became a part of JOTA activities all across the country? Now is the time to talk to the clubs that will be putting on JOTA events in your area about selecting locations that are ARDF-friendly. I look forward to getting photos and stories of JOTA transmitter hunts in your area this year.

73, Joe, KØOV

Notes

1. <http://www.arrl.org/news/stories/2006/05/30/100/>
2 <http://members.aol.com/homingin/davemike.html>
3. <http://members.aol.com/joek0ov/extender.html>
4. <http://robin-wood.com/Ham/Fox/aug2006.htm>
5. <http://www.eoss.org>
6. Moell, "Homing In: Denver Hams 'Excel' at T-hunting," *73 Magazine*, March and April 1993
7. <http://members.aol.com/homingin/gorman04.html>
8 <http://members.aol.com/homingin/equipment.html>

By Kent Britain,* WA5VJB

Cheap Antennas for LEO Satellites

Handheld dual-band antennas are popular for QSOs through many of the LEO (Low Earth Orbit) satellites. This month we have several 145-MHz antennas and a larger number of 435-MHz antennas. We'll show how to combine them into one antenna.

If you have a strong arm or plan to use the antenna with a tripod, then by all means the 4-element 145-MHz and 8-element 435-MHz antennas can be used together. Another choice is the 2-element 145-MHz and 5-element 435-MHz combination used in AMSAT demonstrations. It's is only 32 inches long.

Would you like something much lighter for backpacking? How about a 20-inch long 2-element antenna on 145 MHz and a 3-element one on 435 MHz. For the Arrow antenna enthusiasts, this smaller 2 elements on 145 MHz and 3 elements on 435 MHz version will actually outperform the standard Arrow. More on that in a bit.

One popular commercial antenna mounts the elements 90 degrees to one another. This is a mechanical, and not really electrical, decision. On this antenna the elements can be mounted crossways, but mounting them flat makes the antenna much easier to lay down in the back of a truck or store in a garage.

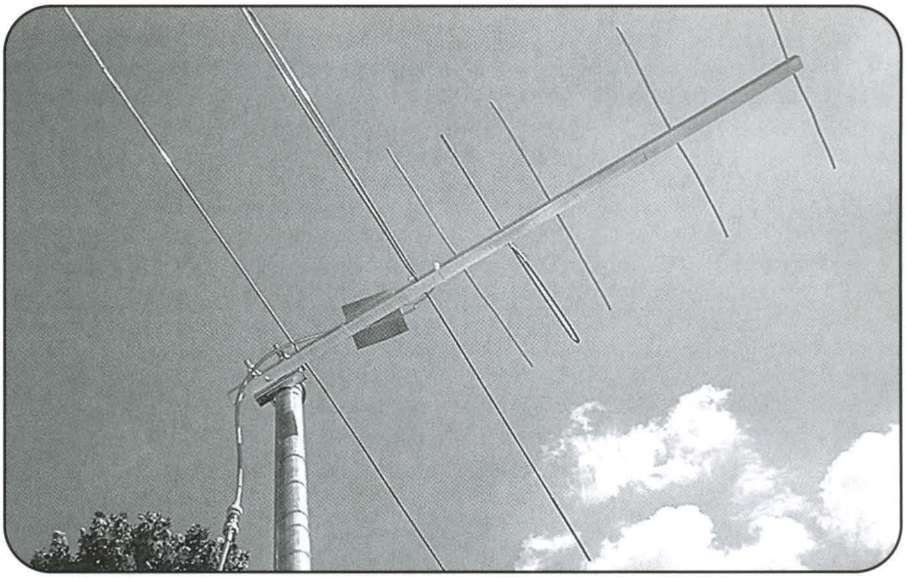

Photo A. "Cheap LEO" antenna.

Construction

For the boom, 5/8" × 5/8" or 3/4" × 3/4" wood works well. If you plan to mount the antenna outside for the long term, a coat of spar varnish, spray enamel, or some of the waterproofing stuff used on wood decks will add years to the life of the antenna.

For the elements I used 1/8-inch material. The 435-MHz reflector and directors were made from a roll of RadioShack aluminum ground rod wire. Forty feet will run you about $5.00 and will make a lot of antenna elements. However, #10 bare copper wire, bronze welding rod, and hobby tubing all have been used. If you want to use 3/16-inch diameter elements, cut them .2 inches shorter than the dimensions to compensate for the thicker material. The 2-meter elements were all made from bronze welding rod. I like to use something to which I can solder the coax, and the welding rod solders well.

The welding rod is only 36 inches long. A section of 1/8 ID copper or brass hobby tubing makes a good splice. Just slip it on and solder them together—and save some of that hobby tubing. If you have a habit of trimming an antenna twice and finding it's still too short, then you can solder a piece on the end of the driven element and start over.

I usually hold the elements in place on the boom with a drop of super glue, but

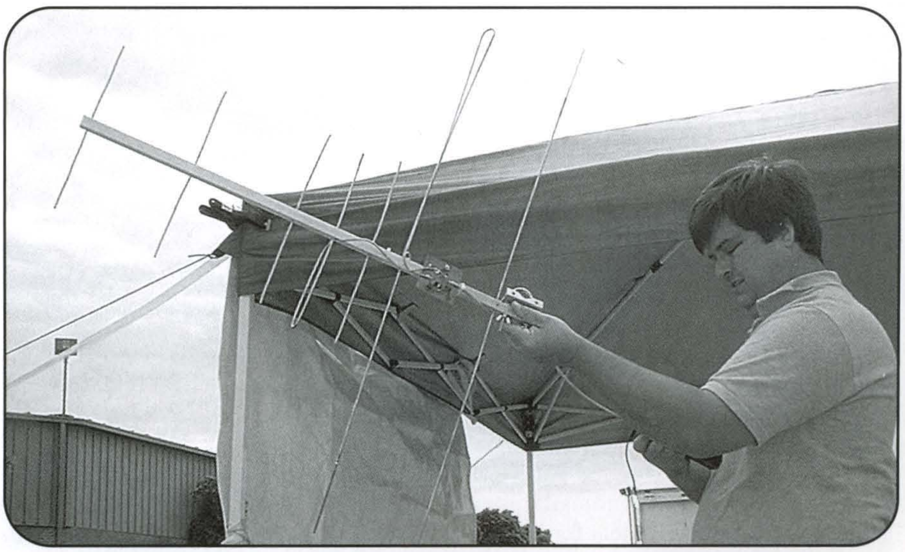

Photo B. Drew, KO4MA, using the Cheap LEO during a Dayton Hamvention® AMSAT LEO demonstration.

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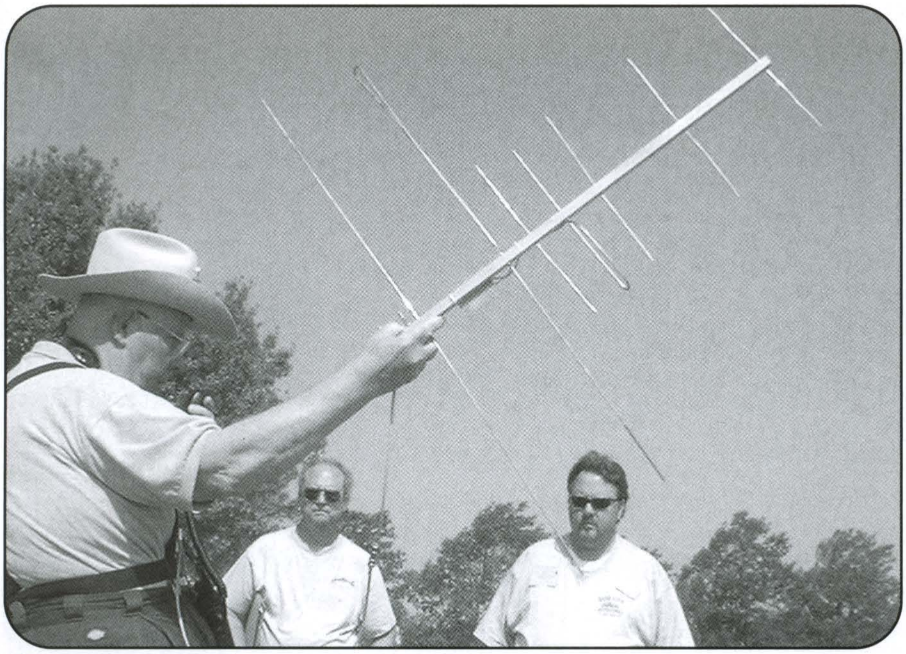

Photo C. CQ VHF *Satellites Editor Keith Pugh, W5IU, and his FT-817 using a Cheap LEO at Dallas Ham-Com for AO51 QSOs.*

silicon glue and even paint have been used.

Splitter

The band splitter is just a 250-MHz high-pass filter and a 250-MHz low-pass filter connected together.

This doesn't have to be very complex, or even very accurate. As long as the filters cut off somewhere between 200 and 400 MHz, they will work fine. Thus, if the coils get squashed, just bend them kind of back in shape and go for it. This one is cheap to build, as it's just out in the air on a piece of PC board. You can build the splitter into a box if you like, with connectors and all, but it's not going to change the performance. This band splitter even makes a good project if you want to use two other 145/435-MHz antennas.

Remember, we are not trying to filter off harmonics. We are just making the 2-meter signals go to the 2-meter antenna, and the 435-MHz signals go to the 435-MHz antenna.

Here are the parts lists:

435 high pass—two 4.7-pF capacitors; one coil, $1^1/2$ turns #18 or #20 wire on a pencil.

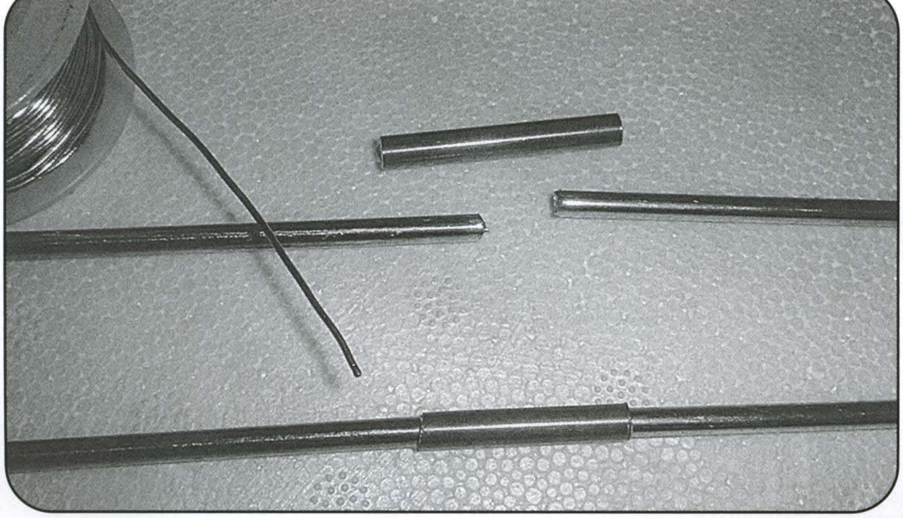

Photo D. Element splice.

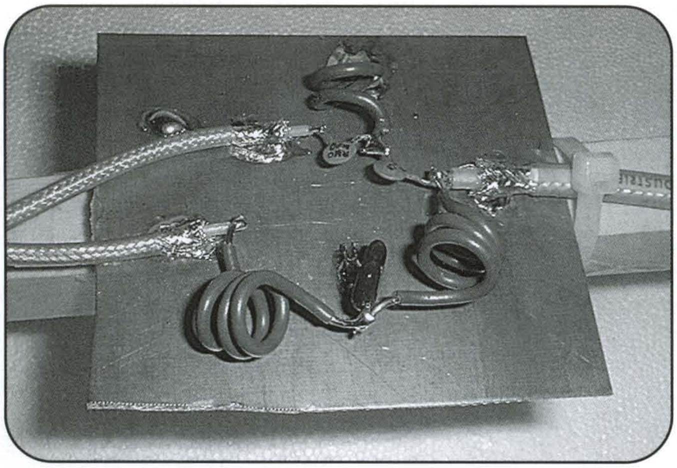

Photo E. A 145/435-MHz band splitter.

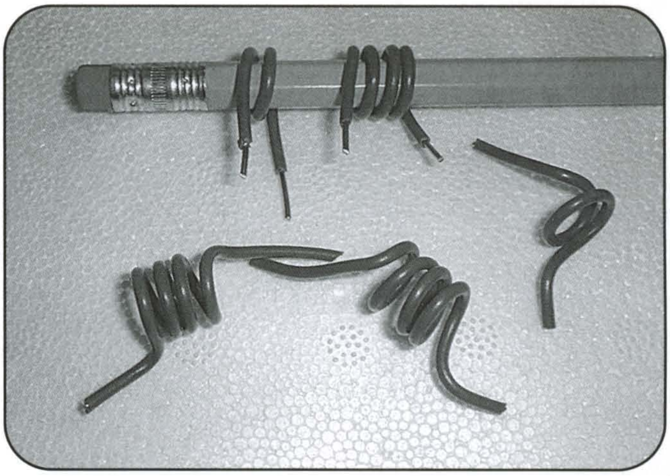

Photo F. Winding the band-splitter coils.

145 MHz low pass—one 10 pF capacitor; two coils 3 turns #18 or #20 wire on a pencil.

By the way, you're too late . . . I have already been asked if it needs to be a #2 pencil or a #3 pencil.

For the record, I wound my coils on a red grading pencil. For those of you with a more mature sense of humor, just about all wood pencils make a .3-inch coil form.

We are frequency splitting the signals, not power-dividing, so the length of the coax between the splitter and the antenna is not critical. You want to keep the coax as short as practical, but its exact length is not important. If you have a box of 4.7-

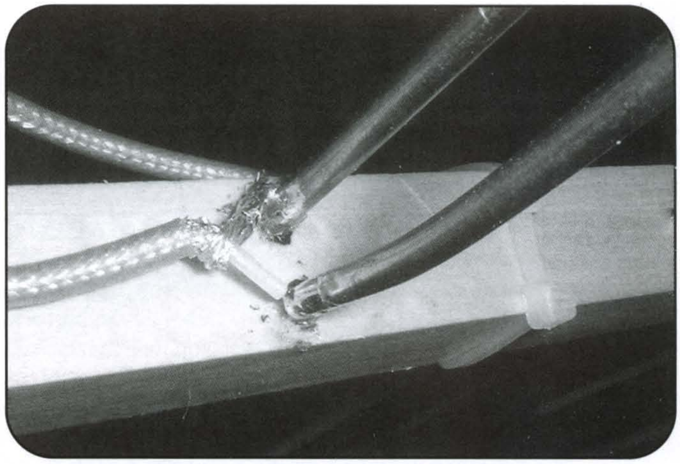

Photo G. Close-up of the driven element.

pF capacitors, you can use two of them instead of the 10 pF capacitor. Be sure to keep those leads very short. I used Teflon® coax on my splitter, as it solders so much more easily than foam RG-58. You're free to build it in a box and use connectors if you like, but it's not really necessary.

Power Handling

Power handling of this band splitter depends almost entirely on your capacitors. With 50-volt caps, 20 watts is about your limit. Dig up some 1-kV caps, and the coax will probably melt first as you warm up that 4CX250.

For one of my first prototypes, I tried to use the last 2-meter director as the 435-MHz reflector. It's an interesting idea to save weight and make the antenna shorter, but performance suffered too much. Therefore, all versions now have a reflector on the 435-MHz portion. The last 145-MHz director and the 435-MHz reflector will interact. If you plan to mount them in the same plane, space them 3 inches apart.

These J driven elements usually bring several comments from people new to "Cheap Yagis." The shield of the coax goes near the center of the top of the element. This is a voltage null and directly soldering the coax to the driven element has a lot of advantages. The tip of the coax goes to the tip of the J. Thus, you can think of this driven element as three-quarters of a fold-

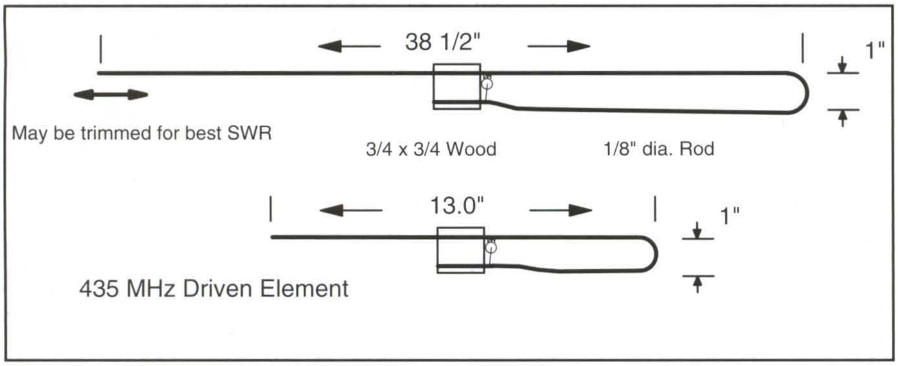

Figure 1. Dimensions of the driven elements.

ed dipole or a gamma-match with no capacitor. In free space, the J driven element has about a 150-ohm impedance. As other elements are added, they load down the impedance of the driven element. If the antenna has relatively wide element spacing, then a direct match to 75 ohms is possible. Bring in the reflector and directors a little closer, and then you have a direct match to 50 ohms. Therefore, the impedance matching is the length and spacing of the other elements. Just build the antenna to the dimensions, solder on the coax, and start talking. No tuning is required.

Tuning It Up

For the ultimate in performance, connect coax to just the 2-meter portion of the antenna and trim the free end of the J for best SWR for your favorite LEO uplink frequency. Then connect the coax to just the 435-MHz portion and again trim the free end of the element for best SWR. Now install the band splitter and this time tweak the coil spacing for best SWR at your spot frequencies.

You have now gotten the last .1 dB out of the antenna. For everyone else, just build the antenna to the dimensions (Table 1) and the SWR will be under 2 to 1 on both frequencies. Just build it and talk. The design is pretty foolproof.

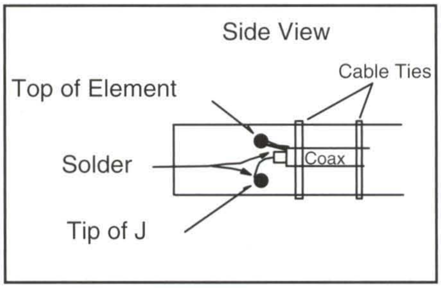

Figure 2. Attaching the coax to the driven elements.

This antenna can be built in 30 combinations of elements and polarizations. One of them should fit your need. The 2 elements on 145 MHz and 5 elements on 435 MHz version has done great in the field tests. Now you can have fun with the LEOs for less than $10.

Arrow Antennas

My first question was why the Arrow antenna has performed so poorly in the

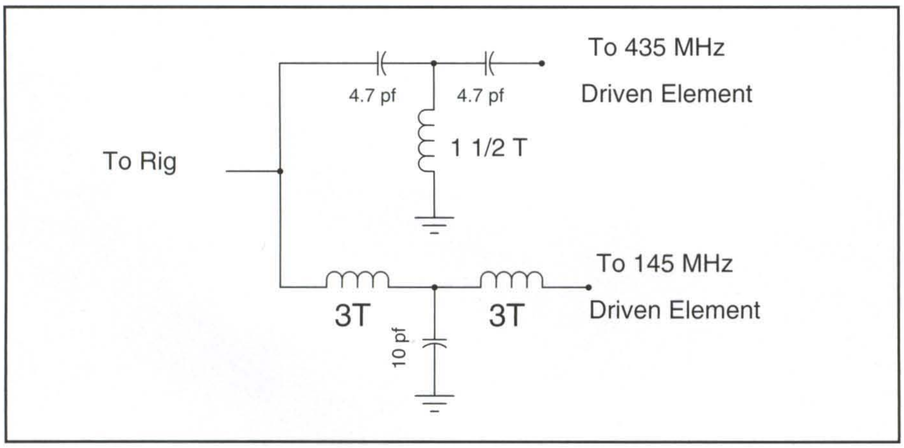

Figure 3. Schematic of the band splitter.

AMSAT demos. Arrows have been on the antenna range at several conferences showing 435-MHz gain as low as 4 dBi. I would like to thank SAM, G4DDK, for sending me the detailed dimensions of his Arrow antenna. I built an NEC model of the 435-MHz portion, and the model showed the forward gain peak to be near 457 MHz, not 435 MHz.

When you change the diameter of an element, you also have to change the length of that element to compensate for the new diameter. Two common ways to mount elements are to make the antenna element part of the boom, or using insulators, electrically isolate the element from the boom. When you make the element part of the boom, you radically change the diameter of the element in that area. Now the length of the element must be changed to allow for this new diameter. This is called the "boom correction factor." I try to avoid correction factors as best I can by using thin wood booms with my Cheap Yagis.

I don't know the history of the development of the Arrow antenna, but the model suggests that the dimensions for a 435-MHz Yagi using insulated elements were used for the Arrow, but mechanically the elements were made electrically part of boom. It appears no boom correction factor was used.

I would love to play with one on the antenna range, but it looks like a new set of 435-MHz elements, each about 1/2 inch longer, would correct the problem and give the Arrow several dB more gain.

Keep those e-mails coming. I'm always looking for antenna topics. For even longer versions of AMSAT Cheap Yagis, visit <www.wa5vjb.com/Reference>.

73, Kent, WA5VJB

Antenna Dimensions

145 MHz Version	**Ref**	**DE**	**D1**	**D2**
2 element				
Length	40.5	**	—	—
Spacing	0	7.0	—	—
3 element				
Length	40.5	**	36.5	—
Spacing	0	8.5	19.75	—
4 element				
Length	40.5	**	37.0	32.5
Spacing	0	8.5	19.0	40.0

435 MHz Version	**Ref**	**DE**	**D1**	**D2**	**D2**	**D3**	**D4**	**D5**
3 element								
Length	13.5	**	12.2	—	—	—	—	—
Spacing	0	2.5	5.5	—	—	—	—	—
4 element								
Length	13.5	**	12.4	11.5	—	—	—	—
Spacing	0	2.5	5.5	11.5	—	—	—	—
5 element								
Length	13.5	**	12.5	12.25	11.75	—	—	—
Spacing	0	2.5	5.25	12.0	18.5	—	—	—
6 element								
Length	13.4	**	12.4	12.0	12.0	11.0	—	—
Spacing	0	2.5	5.5	11.25	17.5	24.0	—	—
8 element								
Length	13.4	**	12.4	12.0	12.0	12.0	12.0	11.1
Spacing	0	2.5	5.5	11.25	17.5	24.0	30.5	37.75

***Driven element dimensions from figure 1*
Ref is the reflector; DE is the driven element; D1, D2, etc., are directors; and all spacings are measured from the reflector element.

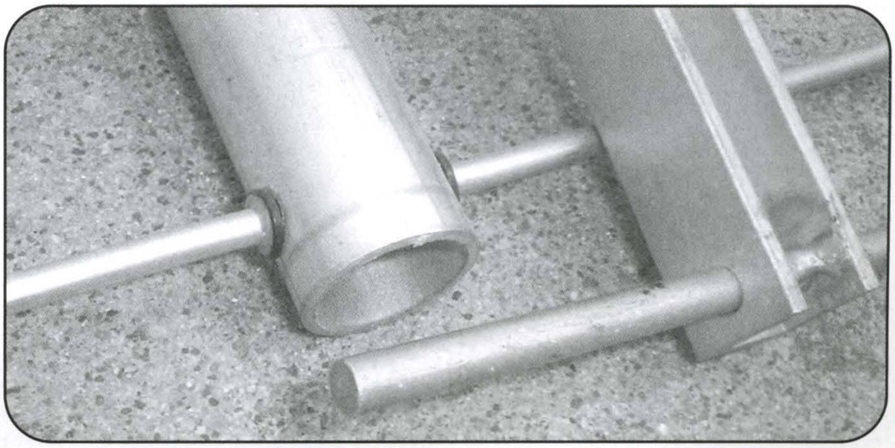

Photo H. Direct and insulated element mounting.

CQ's 6 Meter and Satellite WAZ Awards

(As of July 1, 2006)

By Floyd Gerald,* N5FG, CQ WAZ Award Manager

6 Meter Worked All Zones

No.	Callsign	Zones needed to have all 40 confirmed
1	N4CH	16,17,18,19,20,21,22,23,24,25,26,28,29,34,39
2	N4MM	17,18,19,21,22,23,24,26.28.29,34
3	JI1CQA	2,18,34,40
4	K5UR	2,16,17,18,19,21,22,23,24,26,27,28,29,34,39
5	EH7KW	1,2,6,18,19,23
6	K6EID	17,18,19,21,22,23,24,26,28,29,34,39
7	KØFF	16,17,18,19,20,21,22,23,24,26,27,28,29,34
8	JF1IRW	2,40
9	K2ZD	2,16,17,18,19,21,22,23,24,26, 28,29,34
10	W4VHF	2,16,17,18,19,21,22,23,24,25,26,28,29,34,39
11	GØLCS	1,2,3,6,7,12,18,19,22,23,25,28,30,31,32
12	JR2AUE	2,18,34,40
13	K2MUB	16,17,18,19,21,22,23,24,26,28,29,34
14	AE4RO	16,17,18,19,21,22,23,24,26,28,29,34,37
15	DL3DXX	1,10,18,19,23,31,32
16	W5OZI	2,16,17,18,19,20,21,22,23,24,26,28,34,39,40
17	WA6PEV	3,4,16,17,18,19,20,21,22,23,24,26,29,34,39
18	9A8A	1,2,3,6,7,10,12,18,19,23,31
19	9A3JI	1,2,3,4,6,7,10,12,18,19,23,26,29,31,32
20	SP5EWY	1,2,3,4,6,9,10,12,18,19,23,26,31,32
21	W8PAT	16,17,18,19,20,21,22,23,24,26,28,29,30,34,39
22	K4CKS	16,17,18,19,21,22,23,24,26,28,29,34,36,39
23	HB9RUZ	1,2,3,6,7,9,10,18,19,23,31,32
24	JA3IW	2,5,18,34,40
25	IK1GPG	1,2,3,6,10,12,18,19,23,32
26	W1AIM	16,17,18,19,20,21,22,23,24,26,28,29,30,34
27	K1LPS	16,17,18,19,21,22,23,24,26,27,28,29,30,34,37
28	W3NZL	17,18,19,21,22,23,24,26,27,28,29,34
29	K1AE	2,16,17,18,19,21,22,23,24,25,26,28,29,30,34,36
30	IW9CER	1,2,6,18,19,23,26,29,32
31	IT9IPQ	1,2,3,6,18,19,23,26,29,32
32	G4BWP	1,2,3,6,12,18,19,22,23,24,30,31,32
33	LZ2CC	1
34	K6MIO/KH6	16,17,18,19,23,26,34,35,37,40
35	K3KYR	17,18,19,21,22,23,24,25,26,28,29,30,34
36	YV1DIG	1,2,17,18,19,21,23,24,26,27,29,34,40
37	KØAZ	16,17,18,19,21,22,23,24,26,28,29,34,39
38	WB8XX	17,18,19,21,22,23,24,26,28,29,34,37,39
39	K1MS	2,17,18,19,21,22,23,24,25,26,28,29,30,34
40	ES2RJ	1,2,3,10,12,13,19,23,32,39
41	NW5E	17,18,19,21,22,23,24,26,27,28,29,30,34,37,39
42	ON4AOI	1,18,19,23,32
43	N3DB	17,18,19,21,22,23,24,25,26,27,28,29,30,34,36
44	K4ZOO	2,16,17,18,19,21,22,23,24,25,26,27,28,29,34
45	G3VOF	1,3,12,18,19,23,28,29,31,32
46	ES2WX	1,2,3,10,12,13,19,31,32,39
47	IW2CAM	1,2,3,6,9,10,12,18,19,22,23,27,28,29,32
48	OE4WHG	1,2,3,6,7,10,12,13,18,19,23,28,32,40
49	TI5KD	2,17,18,19,21,22,23,26,27,34,35,37,38,39
50	W9RPM	2,17,18,19,21,22,23,24,26,29,34,37
51	N8KOL	17,18,19,21,22,23,24,26,28,29,30,34,35,39
52	K2YOF	17,18,19,21,22,23,24,25,26,28,29,30,32,34
53	WA1ECF	17,18,19,21,23,24,25,26,27,28,29,30,34,36
54	W4TJ	17,18,19,21,22,23,24,25,26,27,28,29,34,39
55	JM1SZY	2,18,34,40
56	SM6FHZ	1,2,3,6,12,18,19,23,31,32
57	N6KK	15,16,17,18,19,20,21,22,23,24,34,35,37,38,40
58	NH7RO	1,2,17,18,19,21,22,23,28,34,35,37,38,39,40
59	OK1MP	1,2,3,10,13,18,19,23,28,32
60	W9JUV	2,17,18,19,21,22,23,24,26,28,29,30,34
61	K9AB	2,16,17,18,19,21,22,23,24,26,28,29,30,34
62	W2MPK	2,12,17,18,19,21,22,23,24,26,28,29,30,34,36
63	K3XA	17,18,19,21,22,23,24,25,26,27,28,29,30,34,36
64	KB4CRT	2,17,18,19,21,22,23,24,26,28,29,34,36,37,39
65	JH7IFR	2,5,9,10,18,23,34,36,38,40
66	KØSQ	16,17,18,19,20,21,22,23,24,26,28,29,34
67	W3TC	17,18,19,21,22,23,24,26,28,29,30,34
68	IKØPEA	1,2,3,6,7,10,18,19,22,23,26,28,29,31,32
69	W4UDH	16,17,18,19,21,22,23,24,26,27,28,29,30,34,39
70	VR2XMT	2,5,6,9,18,23,40
71	EH9IB	1,2,3,6,10,17,18,19,23,27,28
72	K4MQG	17,18,19,21,22,23,24,25,26,28,29,30,34,39
73	JF6EZY	2,4,5,6,9,19,34,35,36,40
74	VE1YX	17,18,19,23,24,26,28,29,30,34
75	OK1VBN	1,2,3,6,7,10,12,18,19,22,23,24,32,34
76	UT7QF	1,2,3,6,10,12,13,19,24,26,30,31
77	K5NA	16,17,18,19,21,22,23,24,26,28,29,33,37,39
78	I4EAT	1,2,6,10,18,19,23,32
79	W3BTX	17,18,19,22,23,26,34,37,38

Satellite Worked All Zones

No.	Callsign	Issue date	Zones Needed to have all 40 confirmed
1	KL7GRF	8 Mar. 93	None
2	VE6LQ	31 Mar. 93	None
3	KD6PY	1 June 93	None
4	OH5LK	23 June 93	None
5	AA6PJ	21 July 93	None
6	K7HDK	9 Sept. 93	None
7	W1NU	13 Oct. 93	None
8	DC8TS	29 Oct. 93	None
9	DG2SBW	12 Jan. 94	None
10	N4SU	20 Jan. 94	None
11	PAØAND	17 Feb. 94	None
12	VE3NPC	16 Mar. 94	None
13	WB4MLE	31 Mar. 94	None
14	OE3JIS	28 Feb. 95	None
15	JA1BLC	10 Apr. 97	None
16	F5ETM	30 Oct. 97	None
17	KE4SCY	15 Apr. 01	10,18,19,22,23, 24,26,27,28, 29,34,35,37,39
18	N6KK	15 Dec. 02	None
19	DL2AYK	7 May 03	2,10,19,29,34
20	N1HOQ	31 Jan. 04	10,13,18,19,23, 24,26,27,28,29, 33,34,36,37,39
21	AA6NP	12 Feb. 04	None
22	9V1XE	14 Aug. 04	2,5,7,8,9,10,12,13, 23,34,35,36,37,40
23	VR2XMT	01 May 06	2,5,8,9,10,11,12,13,23,34,40

CQ offers the Satellite Work All Zones award for stations who confirm a minimum of 25 zones worked via amateur radio satellite. In 2001 we "lowered the bar" from the original 40 zone requirement to encourage participation in this very difficult award. A Satellite WAZ certificate will indicate the number of zones that are confirmed when the applicant first applies for the award.

Endorsement stickers are not offered for this award. However, an embossed, gold seal will be issued to you when you finally confirm that last zone.

Rules and applications for the WAZ program may be obtained by sending a large SAE with two units of postage or an address label and $1.00 to the WAZ Award Manager: Floyd Gerald, N5FG, 17 Green Hollow Rd., Wiggins, MS 39577. The processing fee for all CQ awards is $6.00 for subscribers (please include your most recent *CQ* or *CQ VHF* mailing label or a copy) and $12.00 for nonsubscribers. Please make all checks payable to Floyd Gerald. Applicants sending QSL cards to a CQ Checkpoint or the Award Manager must include return postage. N5FG may also be reached via e-mail: <n5fg@cq-amateur-radio.com>.

**17 Green Hollow Rd., Wiggins, MS 39577; e-mail: <n5fg@cq-amateur-radio.com>*

By Rich Arland,* K7SZ

BEGINNER'S GUIDE

All you need to know but were afraid to ask . . .

Fun with VHF—MilCom Equipment

Sometimes we tend to forget that amateur radio is a hobby, something to have fun with. All too often we collectively take ourselves way too seriously. With this in mind, this column is dedicated to having some fun with VHF. Along with the fun we will hopefully entice some of you to try something a little different in the radio hobby—a road less traveled, if you will, but filled with rewards nonetheless.

If you have been reading this column since the beginning, you will remember that your author (that would be me) has an extensive military background. Having spent 20 years in the U.S. Air Force in (what else) Comm Command, I have had a lot of experience with military communications (MilCom) equipment. Only within the last several years, though, has the bug bitten to start obtaining some of this classic military radio gear and use it on the air.

Now I know what you're thinking: Military gear smells funny, is a nasty shade of green, is big and heavy, takes funny voltages and weird connectors, and isn't very easy to work on when things go wrong. Well, the vacuum-tube and solid-state military equipment is basically no different than any other commercial vacuum-tube and solid-state gear as far as voltages are concerned. Of course, how the military power supplies develop those voltages can be somewhat convoluted, depending upon dynamotors (huh?) and vibrator power supplies (say *what*!)

Well, the good news is that these power supplies are readily available on the used market, and since they are extremely rugged and relatively easy to repair, seldom will you have to do any troubleshooting in order to make things work. As far as connectors are concerned, they are also available from various sources at reasonable cost. Concerning maintenance, a little known fact among non-military folks is that the Technical Manuals (TMs) and Technical Orders (TOs) are written on about a sixth-grade level and are very detailed, including extensive troubleshooting information. OK, the smell: That is an anti-fungal shellac that is sprayed on the older military gear (WW II through Viet Nam era equipment) and many of us "Green Radio Guys" actually love the smell of the gear! Hey, one snort of that stuff and you know you have your hands on a piece of "real" radio equipment! As for big and heavy, yes, some of it is, but that is due to the stringent engineering that is needed to meet military specifications (mil spec) and survive in combat. In short, you can't really go wrong buying and using MilCom gear if you have the TM/TO for each particular piece of gear you own. There are many sources of TMs and TOs, so finding the right tech info is a no-brainer.

For the last 41 years I have been a proponent of QRP, low-power (5 watts and under), ham radio. Believe it or not, the U.S. military is also a big proponent of QRP and has been using it since WW II. The most familiar squad radio from the WW II era is the BC-611 handheld radio designed by Galvin Manufacturing in 1940. Galvin Mfg. later became Motorola, so the lineage of the BC-611 is pure thoroughbred all the way!

Often misidentified as a "walkie-talkie," the BC-611 was about the same size as a quart milk carton with a 39-inch pull-up whip antenna (that turned on the radio when it was extend-

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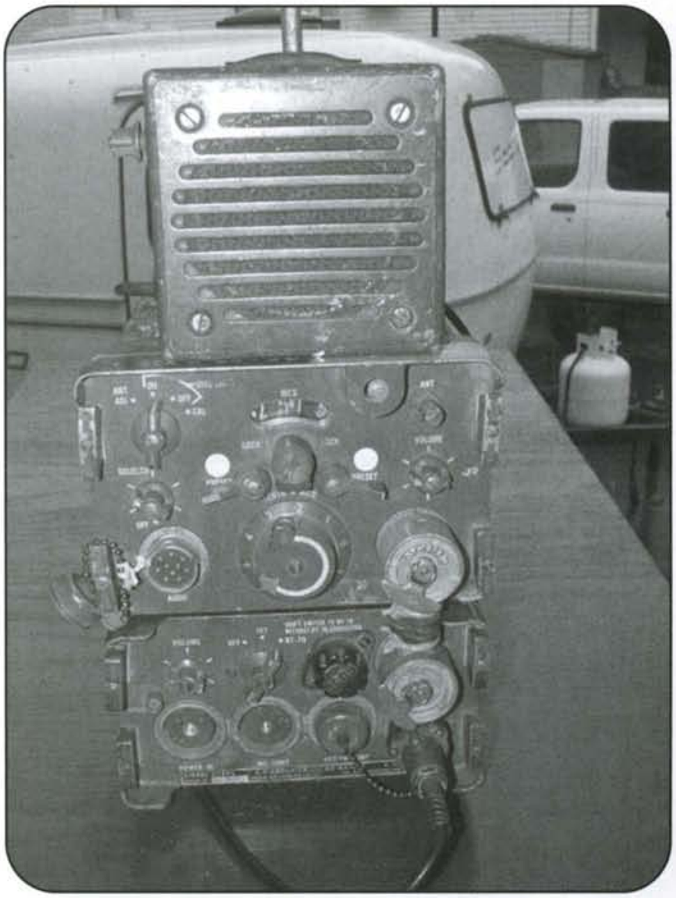
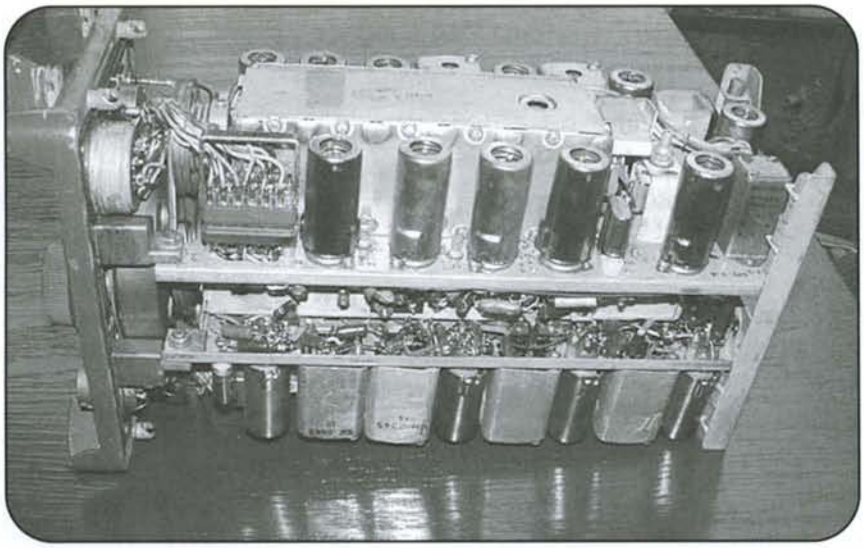
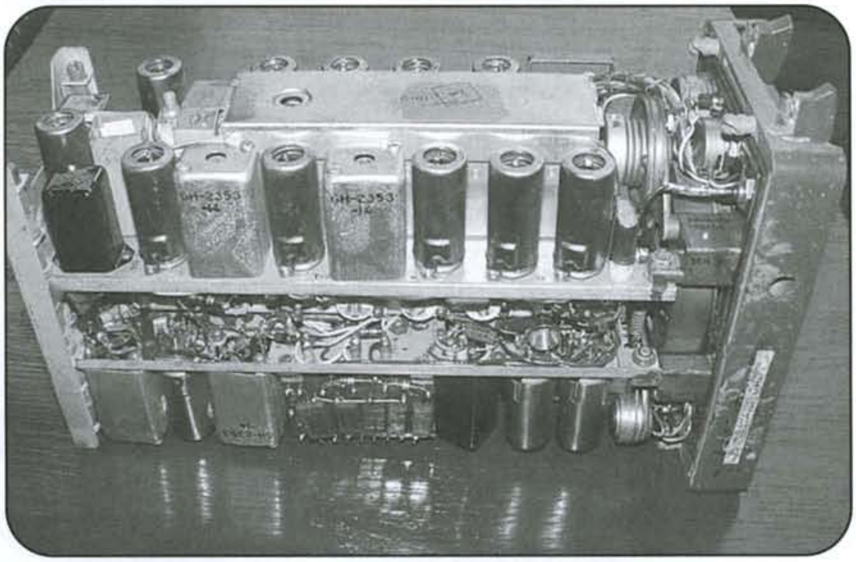


This is the venerable RT-70 transmitter/receiver (middle) coupled to its 24-volt power supply/audio amplifier, the AM-65. The loudspeaker atop the RT-70 is an LS-166, which is common among most MilCom units of this vintage. This set was used from the Korean War well past the Viet Nam era by the U.S. military in jeeps, trucks, command posts, and about anywhere tactical VHF FM voice communications was required. The RT-70 is connected to the AM-65 by spring clips on the sides of the case. Power to the AM-65 is accomplished by a cable in the lower left socket. The voltages necessary to run the RT-70 along with audio transmit and receive are coupled between the two units via a "dog-bone" connector on the right side of the radio/PSU. This unit weighs in at arond 35 pounds.





Here are shots of the top and bottom of the inside of the RT-70. As you can see, this radio set was built to last. Rugged? You have no idea!

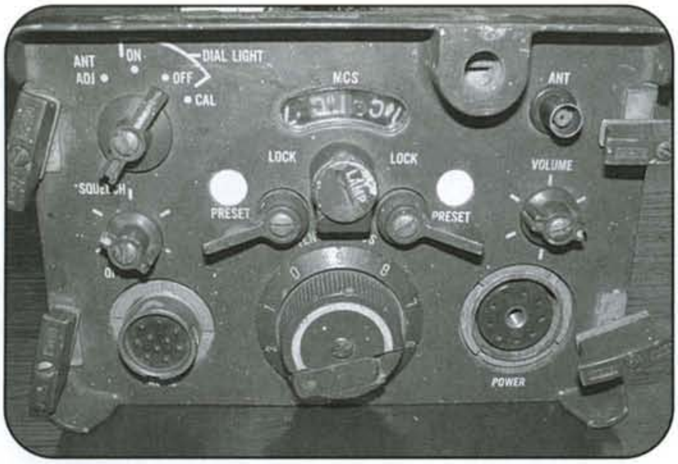
ed to full length). With a short whip one would think that the BC-611 was a VHF radio. Not so. The BC-611 was an amplitude-modulated, 80-meter radio that put out somewhere between 100 and 300 milliwatts! Most of them were rocked up on 3885 kHz at the depot and that is where they stayed for the duration.

The Army quickly found out that 80 meters was not the most effective frequency on which to conduct battlefield operations. They moved to low-band VHF (30–76 MHz) during WW II using wideband FM and carried on the tradition through the Viet Nam War.

From the end of WW II onward, the move to low-band VHF/wideband FM was not only a wise choice, it was to become a boon for frugal ham radio operators needing well-made VHF gear at reasonable cost. You have to remember that military comm gear was state of the art or slightly beyond during the time the gear was designed and fielded. Not only that, MilCom gear is unbelievably rugged. It has to be, especially when you are bouncing it all over the place while getting shot at! Therefore, especially if you were on a strict budget, procuring some surplus MilCom VHF gear, restoring it, and using it was not all that outlandish as ideas go. That is still the case today.

What's Out There

Now that we have broken the ice with a short history lesson, let's see what is actually out there that you might want to



Here is a better shot of my other RT-70, which cosmetically is in better shape than the one mounted to the AM-65. Cosmetics matter very little in the grand scheme of things. Often the more beat up the rig, the better it works! Don't ask; I don't understand it either!

obtain and use. Since this is a VHF magazine, we will dispense with the run-of-the-mill HF gear (of which there is a multitude of rigs to be had) and concentrate on some of the more common low-band VHF gear available on the used market.

Since ham radio is a technical hobby, we will endeavor to learn a little bit along the way. One of the really nice things about restoring and using MilCom gear, especially some of the older gear that uses vacuum tubes or hybrid (combination solid-state and vacuum tubes) designs, is the historical significance of the equipment itself. For instance, the AN/PRC-6 was designed around the Korean War timeframe. It was the ultimate in vacuum-tube technology of the 1950s, using the small "pencil tubes" which had no pins like normal vacuum tubes, but instead had wires extending from the glass envelope. These leads were soldered into the circuit, negating the need for sockets, which often proved unreliable under the extremes of combat. One additional benefit of not using tube sockets was miniaturization. No sockets meant that the overall package could be made much smaller physically. The PRC-6 had a long run and was used by all NATO nations and the Israeli military. As a matter of fact, the most common PRC-6s currently found on the used market are ones that were released from the Israeli army, complete with Israeli markings! They are a neat piece of history, and you can make them work with ten 9-volt transistor batteries connected in series for the plate voltage supply, three AA cells for the 4.5-volt bias supply, and two C or D cells for the filament supply. All of these batteries fit inside the PRC-6 case and will supply the necessary voltages to put the rig on the air.

Speaking of "on the air," 51.0 MHz is the 6-meter defacto squad radio frequency for ham radio operators. Of course, the PRC-6 is a crystal-controlled radio set, but the crystals are readily available on the internet at very reasonable cost. As initially designed, the PRC-6 was a single-channel radio set. However, leave it to the Germans: They produced a six-channel version that is virtually the same size and uses the same case. Sometimes these PRC-6 clones can be found on MilCom radio lists and auction sites on the internet.

Another Korean War era VHF radio set that is quite common on the used market is the PRC-10. It is one of a series of radio sets that included the PRC-8, 9, 10, and 28. All are wideband

The AN/PRC-6 Walkie-Talkie is a single-channel, 250-milliwatt output, low-band VHF (44–55.4 MHz), wideband FM transceiver. This unit uses "pencil tubes" and was pushing the state-of-the-art in the 1950s for compact design. It weighs 3.5 pounds without batteries. Since you can no longer obtain military batteries for these radios, you will have to make your own using 9-volt transistor-radio batteries (about ten in series for 90 volts B+), three AA cells for bias supply, and two C or D cells in parallel for tube filaments. The antenna is a flexible tape antenna about 2 feet long. Typical range is about 1/2 to 1 mile depending upon terrain.

Always one to lend a helping hand, my 5-year-old grandson, K.C., is posing with Pop-Pop's PRC-6 walkie. This photo gives some indication of size. If there were a full set of batteries in this radio, K.C. would have his hands full just trying to pick it up!

FM radio sets that cover various frequencies in the low-band spectrum between 27 and 54.0 MHz.

The PRC-10 is the one we want for 6 meters, and since it is fully tunable from 38 to 54 MHz, you can select any number of 6-meter frequencies. However, don't forget, 51.0 MHz is the place where all the MilCom aficionados congregate. The PRC-10 radio set is a true pack-set or man-pack radio. It is designed to be carried on the back of a soldier (the RTO—Radio Telephone Operator) and has two different length antennas—a 38-inch tape whip and a 10-foot 1-inch tubular whip. The radio weighs in at 11 pounds without battery, 20-plus pounds with battery and all accessories (H-33 handset, LS-166 speaker, H-63 headset/boom mic, and/or GSA-6 Chest Set).

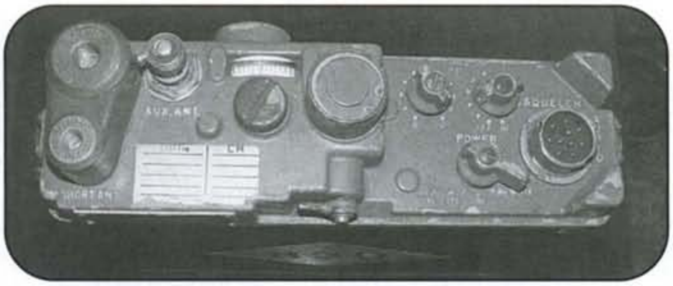
The power output of the PRC-10 is about 1 watt, and, as with the PRC-6, you will have to build your own battery pack, which is easily done using D, AA, and 9-volt transistor-radio batteries, or 45-volt batteries available on the internet and from specialty radio stores such as Antique Electronic Supply (www.tubesandmore.com) in Tempe, Arizona. A search on the internet will also yield several sources of DC-to-DC converters that are available commercially. These converters will take a 6- or 12-volt sealed lead-acid (gel-cell) battery and present the proper operating voltages for the vacuum-tube MilCom gear at the output. To date I have seen DC-to-DC converters for the PRC-6, PRC-10, BC-611, PRC-25 & 77, along with the AN/GRC-9 (HF CW/AM transmitter/receiver). Although initially expensive, these are probably the way to go in the long run, since making battery packs can become quite time consuming and bothersome.

Costs are reasonable for the PRC-6 and PRC-10s; plan on spending between $50 and $90 for the former and around $35 to $75 for the latter, depending upon cosmetic condition, accessories, etc. Recently I procured a pair of PRC-10s, in working condition, with two sets of pack hardware, two H-33 handsets, and two each of the long and short antennas for a grand total of $95, which included shipping from Louisiana. Not a bad deal at all. Internet auctions lately have had an over abundance of the AM-598 power supply/audio amplifier which mates with this radio set to provide vehicle or command-post (fixed station) operations. Prices for these accessories have been running around $50–60 without shipping.

One word of caution: Most of the military gear we will be looking at uses power supplies that take a 24-volt DC input, since that is what most military vehicles have for internal power. The easiest way to provide 24 VDC for your power supplies is to connect two 12-volt deep-cycle batteries in series and use them to power the power supply. Ultimately, the best solution would be to build a 10- to 15-amp 24-VDC supply that uses AC mains on the input. But to initially get the gear on the air, there is nothing wrong with strapping a couple of 12-volt storage or deep-cycle batteries in series to get the necessary 24 volts to run the radio gear.

Another Korean War/Viet Nam War classic transceiver that is seeing plenty of use on 6 meters is the RT-70. These radio sets were designed for vehicular mounting and for use as fixed-station assets in command posts. The AM-65 power supply/audio amplifier powers the radio set and provides audio inputs and outputs and will drive a speaker. The RT-70 is my kind of radio. It is about 7.5" × 5" × 13", weighs about 15 pounds, and covers 47 to 58.4 MHz using wideband FM. Made like a tank, these rigs are great starter radios for the newbie in MilCom radio. The transceiver is fully tunable over the 6-meter band, so you don't have to buy any expensive crystals. Power output on the RT-70 is only about 500 milliwatts, so it definitely is a QRP rig! Of course, you can feed the output of the RT-70 into a 6-meter "brick" RF amplifier (and it does not need to be a "linear amp," since we are working with FM) and boost the power to much higher levels. However, I find it kind of neat to play at the 1/2-watt level with a good antenna and have some real fun on the bands. Prices for the RT-70 are $35-50 for the radio set and about the same for the AM-65 PSU/AF amp.

The PRC-6, PRC-10, and the RT-70 all saw active use well into the Viet Nam era. They were replaced by the AN/PRC-25, a 1–2-watt, tunable (30 to 76 MHz) radio set that was a hybrid design using transistors throughout the radio except for the RF power amp, a 2DF4 vacuum tube. The PRC-25 used a self-con-



Here is the AN/PRC-10, a 1-watt, low-band VHF (38–54 MHz) wideband FM pack-set from the Korean War era. These radios were also used in Viet Nam until they were replaced by the AN/PRC-25, which subsequently was replaced by the PRC-77. The military quickly found that low-band VHF FM communications were well suited to battlefield operations. The PRC-10 is one of a family of pack-sets that covered from 27 MHz (PRC-8) through 54 MHz (PRC-10). The main tuning knob is almost in the center of the front panel, with the analog-dial frequency readout above and to the left. These sets can be carried by one individual using the ST-120A/PR carrying harness, a combat pistol belt, and the M-1945 suspenders. The battery box clips onto the bottom of the radio set. Original BU-279/U batteries are no longer available for this set. However, you can home-brew a battery pack for this radio set using something similar to the one built for the PRC-6.

This photo shows the PRC-10 with its case removed. Note the solid construction. There are a number of modules in this radio which made troubleshooting much easier. The two round connectors on the extreme left of the front panel are two antenna connectors, one for the short (29.5 inches) tape whip and the other for the much longer (10 feet 1 inch) tublar whip antenna. Obviously, the longer antenna made for more reliable communications. However, it also made a bigger target!

tained 15-volt battery in a battery box that clipped to the bottom of the radio chassis. Many guys my age "humped" a PRC-25 in the jungles of Viet Nam. Depending upon whom you talk to, reliability was fair, but coverage suffered. Batteries were always dying about the time an air strike or artillery fire mission was needed!

Enter the AN/PRC-77. This was basically the same radio as the PRC-25, but it was entirely solid state. The 77 had the same physical dimensions as the 25 but used different batteries. These tactical FM radios incorporated a 150-Hz tone squelch system that provided the RTO in the squad with some relief from listening to all the "chatter" on the primary tactical frequency.

Today you can obtain an operational PRC-25 or 77 from various sources on the internet. Prices vary, so be prepared to spend between $350 and $600 for a 77 (less for the 25), depending upon cosmetics and accessories.

Where to Start

There is quite a market for MilCom gear out there, with lots of places to buy from and, surprisingly, prices do vary quite a bit. The best thing to do is to start prowling a MilCom reflector such as <armyradios@yahoogroups.com>, <milpac@yahoogroups.com>, or one of the many military collectors clubs, for example <mrca@mailman.qth.net> (my local group here in the northeast U.S.). Start watching the postings, ask questions (believe me these guys and gals know *everything* about MilCom gear and they are only too glad to help out the newcomer to this facet of the radio hobby), watch the various internet auction sites, and, in general, do your homework before jumping in with both feet.

Procuring, restoring (in some cases), and using these old warhorse radio sets is quite a learning experience. You will have to learn how to speak "Green Radio" language, become conversant using the various acronyms associated with the military, plus you may have to learn a bit about vacuum-tube and solid-state technology in the process. All in all, that's not a bad deal. After all, this radio hobby is a technical one, so why not enjoy the ride, so to speak, and learn a little electronics theory along the way.

Another positive aspect of MilCom radio gear is that by using this gear you are keeping alive a piece of history. Remember these radios were at or beyond the state of the electronics art when they were first designed. They are rugged beyond your wildest imagination. If they could only talk, think of the all the stories they would have to tell. In addition, most of these radio sets and accessories cost thousands or tens of thousands of American tax-payer dollars to produce and field. You can buy these rigs for literally pennies on the dollar and still have a great time using them on the air.

Wideband vs. Narrowband FM

Now a word about wideband FM versus narrowband FM. The military has, up until fairly recently, depended upon wideband FM for its tactical communications. All it takes to make a wideband set compatible with our narrowband ham radio gear is to limit the amount of audio ahead of the modulator. This is done by padding the audio input to the radio, either at the handset/mic or inside the rig near the audio input connector. The best plan is to place a 5K-ohm pot in the transmit audio line of the wideband radio set and listen to the wideband rig with a 6-meter ham band radio while transmitting. Adjust the 5K pot for the best-sounding audio in the narrowband receiver. It's that simple. On the receiving side, turn up your audio gain when listening to a narrowband ham rig on your MilCom radio. Problem solved.

Summary

What I have attempted to do this time around is introduce you to a facet of the radio hobby that, while not really main stream, is intensely interesting to many thousands of hams worldwide. MilCom radio collecting/usage is not limited to the U.S. amateurs. Not hardly. MilCom radio has a worldwide following, with some of our European ham friends being in the very envious position of having access to a lot of old NATO comm gear that we, here in the U.S., would love to get our hands on. Besides, most of this stuff works on 6 meters quite well, and we all have heard the mantra that we need more activity on 6.

So what are you waiting for? Grab your duffle bag, put on your BDUs, blouse your boots, and get moving, maggot! (Sorry, lost control for a second!)

Tune around 51.0 and 51.6 MHz and listen for some of the MilCom folks using their Green Gear. With the big fascination over the last couple of years being pedestrian mobile operating on HF, how about doing it with a PRC-74, 515, or 1099 attached to an ALICE packframe? Add an HF whip antenna and you're in business! Like I said, this stuff is really habit forming, so be forewarned! In the meantime, get on 6 meters and give it a try.

If you are interested in MilCom, the one book you absolutely need to obtain is *Mil Spec Radio Gear,* by Mark Francis, KIØPF, published by CQ Communications and available directly from them in Hicksville, NY ($27.95 plus s&h). Mark's done a tremendous job of pulling together a lot of gear that is readily available, both HF and VHF, for the MilCom hobbyist. There are chapters on all sorts of gear, including the RT-70,; PRC-8, 9, & 10; PRC-6,; BC-611; PRC-41; and others. Each rig is described in detail, with how to best get it on the air, hints and kinks regarding problem areas on restoration and/or conversion to ham frequencies, what to do if the rig is DOA, etc. In all, *Mil Spec Radio Gear* presents a wealth of first-hand knowledge compiled and written by someone who has been in the hobby for many years. Mark's down-to-earth writing style makes for an easy read. He takes the newcomer by the hand and explains things in detail. If this column has piqued your interest in MilCom gear, get Mark's book. You'll be really glad you did.

73, Rich, K7SZ

By Dr. H. Paul Shuch,* N6TX

THE ORBITAL CLASSROOM

Furthering AMSAT's Mission Through Education

1000-cc Science

Do you think maybe you'd like to build a satellite, but are not quite sure where to start? That was the situation facing engineering students at Cuesta College on the central California coast a few years back. Cuesta was well suited to hosting a satellite program, being just under an hour's drive from the U.S. Western Test Range launch facilities at Vandenberg Air Force Base. Our earliest OSCARs had been launched from Vandy. Two Cuesta faculty members—Cliff Buttschardt, W7RR, and Ed English, W6WYQ—had been OSCAR-active since the dawn of the space age. Space was clearly the place, but where to start?

The students' confusion was understandable. It stemmed from the simple fact that every ham satellite to date had been custom-designed around a specific launch opportunity. It was common practice to fit a piggyback payload into a well-defined nook or cranny on a particular vehicle. OSCARs 1 and 2, for example, had semi-pyramidal bodies with curved top surfaces, optimized in mass and form factor to serve as ballast for military AGENA satellites. The Cuesta students and their advisors had no particular launch in mind. They simply wanted to build a ham satellite, stick out their thumbs, and hitchhike into orbit.

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Ed and Cliff had an answer, although it involved a clean break from past practice. Why not, they proposed, come up with a standard package for a small satellite, one compatible with launch from a wide range of boosters? With sufficient standardization, military and civil launch authorities could accommodate such payloads as the ham community might generate, and we could ride aloft on a space-available basis. Thus, the CubeSat concept was born.

Educational ham satellites are not new. Early examples emanated from university labs in Melbourne, Australia, Surrey, England, and Marburg, Germany as far back as the early 1970s. However, the CubeSat concept meant that for the first time *anyone* could play. The actual package constraints were formalized by Bob Twiggs, KE6QMD, and his students at Stanford University. Bob previously had taught at Weber State College in Utah, was the father of their small satellite program, and was the motivating force behind the WeberSat WO-18 satellite. Building upon the Cuesta College concept, the Stanford team came up with a standard cube, 10 cm on a side, 1 kg in mass, to which a whole generation of ham educational satellites was to conform.

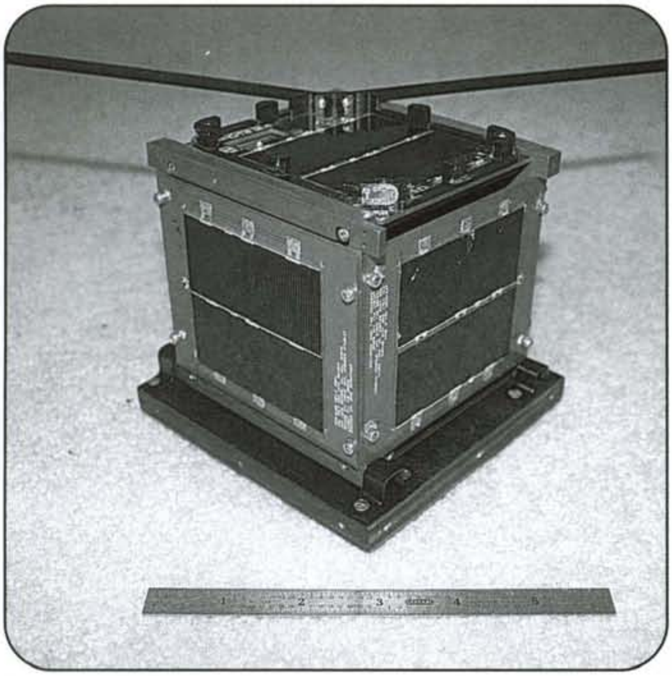
By the time the cube was codified, Ed and Cliff both had retired from Cuesta College and had moved across town to the California Polytechnic University, where they set up a satellite program to further refine the Stanford design. Recognizing that multiple pico-satellites could be accommodated by a single launch vehicle, they set about developing a common launcher interface, which doubled as an orbital insertion mechanism—P-POD, the Poly Picosat Orbital Deployer. This hollow rectangular frame, three CubeSats long, would mount to a variety of launchers with standardized hardware and a well-defined electrical connector. When triggered by a launch-sequence command, its internal ejection spring would spit three peas from the pod and into their individual orbits. Compatible with everything from Delta rockets to converted American and Russian ICBMs, the P-POD concept and CubeSat architecture together began to make satellites, and launching them, truly affordable.

Just how much technology can you cram into a one-liter cube the density of water? A surprising amount, it turns out. Once its mechanical specification was published on the web, school groups around the world started building dozens of educational and scientific missions around the CubeSat standard. These small satellites, covered with solar cells charging lithium-ion batteries, produced 1- to 2-watt power budgets in low Earth orbit, enough to power up a variety of experiments, as well as the 2-meter or 70-cm telemetry and telecommand links needed to support them. As this is being written (summer of 2006), 10 CubeSats are currently operational, with 14 awaiting an imminent launch, and over 50 more under construction around the world.

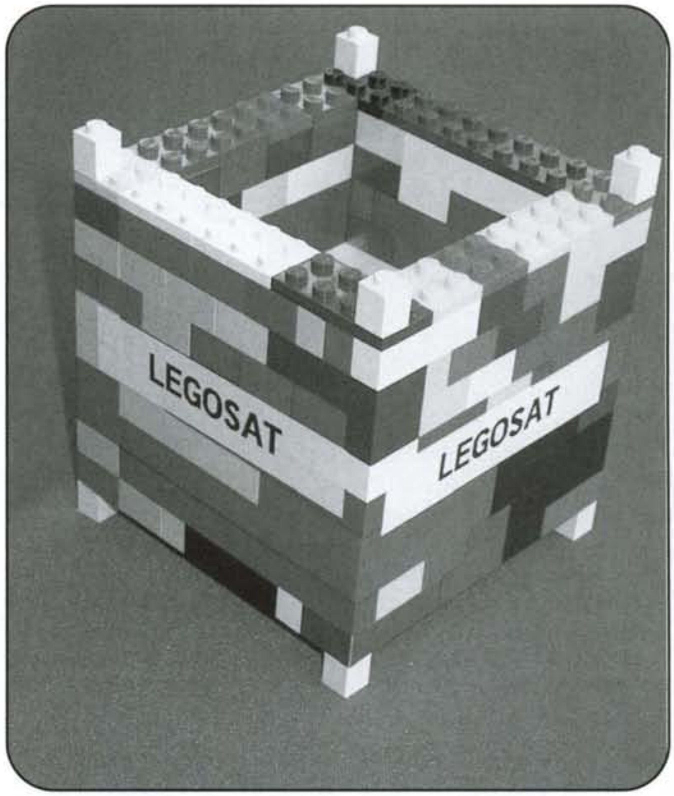
CubeSats are relatively cheap, both to build and to launch. The last dozen specimens averaged about $100,000 U.S. apiece, *including* launch costs. That may be a bit pricey for your pocket, or mine, but it's comfortably within the budget of many an educational institution.

CubeSats are quick turnaround. The typical project spans about two years, from concept to completion. That's comfortably within the lifespan of the average graduate student. Also, CubeSats are accessible, thanks to a high degree of standardization. They're not exactly "Heathkitsats," at least not just yet, but we're getting there. Today you can buy many of the necessary components, including standardized spaceframes and power-system pieces and attitude control systems and datacomm links, all in kit form. These COTS (commercial, off-the-shelf) kits free up your students to concentrate on designing and implementing the mission-specific hardware and software that will make their picosat unique.

CubeSats typically operate in the ham bands. They are eligible for IARU frequency coordination, as long as their command stations are run by licensed



An actual CubeSat, with its tape-measure 70-cm dipole deployed. A 6-inch ruler is shown below it for scale. (W3PK photo)



To become familiar with the CubeSat standardized form factor, students at California Polytechnical University first construct LegoSats, exact scale models built out of—you guessed it—Legos™. (N6TX photo)

radio amateurs within the terms of their individual licenses. It's common for a ham faculty advisor or AMSAT mentor to start the ball rolling. Typically, before their satellite even launches, most of the students on a given CubeSat team will have gotten their licenses. Thus, the potential for recruiting new hams is substantial. These hams are also pre-qualified potential AMSAT members who have already demonstrated a keen interest in satellite technology.

CubeSats end up being built and operated by hams, but are they ham satellites? That depends on how broad a brush you use to paint the ham radio portrait. The primary mission of CubeSats is education. Their secondary mission is scientific. Remote sensing is a popular application. CubeSats monitor everything from seismic activity on Earth to micrometeorite impacts in space, using ham radio to relay their images or digital data streams back to Earth. Therefore, if your notion of ham radio is restricted to ragchews and chasing DX, then no, a CubeSat is probably not a ham satellite.

I prefer to take a wider view, though. Just why should AMSAT, an organization devoted to ham satellites, support the CubeSat concept? Three reasons:

1. Many CubeSats are being designed with a built-in tertiary function, that of data relay. They can be telecommanded from the ground into digipeater mode. Thus, when they're not serving their primary and secondary missions, you will be able to use them as ham store-and-forward birds, for everything from packet traffic to APRS position monitoring.

2. CubeSats have a life expectancy that typically exceeds their mission duration. Students eventually graduate and move on to other things, but their satellites remain in orbit and fully operational. When the scientific instruments are turned off, the CubeSats are able to be repurposed into linear transponders or FM repeaters. Increasingly, CubeSat developers are addressing this eventuality early in the design cycle.

3. CubeSats are a training tool. Amateur radio has an educational mission. The two are highly compatible. Today's students, building and operating small, lightweight, low-power LEO CubeSats, are tomorrow's AMSAT members, designing, building, and operating the most sophisticated high-power, high-orbit amateur satellites you would care to imagine. Work with them now, and they'll work with us later.

Are CubeSats OSCARs? Not all, but some. Those projects that jump through the right hoops (prior IARU frequency coordination, licensing by their respective countries, control stations properly licensed, and conforming to ham radio's usual restrictions on third-party traffic and commercial use) can, if they achieve orbit and are heard on the ham bands, apply for an OSCAR number. True, these are experimental spacecraft. So were our early OSCARs; so, in fact, is every ham satellite to date. By encouraging CubeSat team leaders to apply for OSCAR numbers, we are sending them a powerful message: We hams welcome them into the fold.

How do you go about building a CubeSat? Start with a 10 by 10 by 10 centimeter cube and fill it with a kilogram of electronics. Stuff it into a P-POD along with a couple of its cousins, and hitch a ride into low Earth orbit. Thousands of hams around the world, many of them AMSAT members, are already standing by to track your satellite, copy your telemetry, analyze your data, and stake their claim to 1000-cc science.

So are CubeSats amateur radio? I, for one, vote in the affirmative.

73, Paul, N6TX

By Keith Pugh,* W5IU

SATELLITES

Artificially Propagating Signals Through Space

AMSAT's Vision – P3-E and Eagle

The AMSAT forum and the AMSAT booth activity at the Dayton Hamvention® this year featured progress reports on fulfillment of AMSAT's Vision, originally stated in 2004: "Our Vision is to deploy high earth orbit satellite systems that offer daily coverage by 2009 and continuous coverage by 2012..." Fulfillment of this vision will include the launch of P3-E and at least two Eagle satellites. Progress reports on these projects along with the Software Defined Transponder (SDX) are given below.

The SDX (software defined transponder) is shown hanging on the Dayton Hamvention® booth curtain in the upper left-hand portion. Its block diagram is shown in the upper right. WB4GCS and N4HY are shown operating the demonstration.

P3-E

P3-E was started soon after the loss of AO-40 by AMSAT-DL as a means of getting back into high earth orbit as quickly as possible and as a test bed for the German Mars Orbiter Mission. The concept is to borrow as much from AO-10, AO-13, and AO-40 as possible, update it with current technology, and secure a launch to high earth orbit as soon as possible, currently envisioned as sometime in 2007. Peter Guelzow, DB2OS, president of AMSAT-DL, prepared an excellent presentation on the current status and plans for this project. At Dayton, Rick Hambly, W2GPS, president of AMSAT-NA, gave Peter's presentation and emphasized the cooperation between AMSAT-DL, AMSAT-NA, and AMSAT-UK in the development of the spacecraft.

The spacecraft utilizes a space frame left over from the AO-10 and AO-13 days and includes power and control systems similar to the earlier designs. Of course, battery and solar cell technology advances are included in the design where possible. Maximum use of existing, qualified components minimizes the additional qualification necessary on the new spacecraft.

A full suite of modes and functions has been planned which will please both the old and new satellite users. Frequencies utilized range from VHF through microwave. Much of this versatility comes from a decision made in late 2005 to incorporate the Software Defined Transponder developed by Howard Long, G6LVB, of AMSAT-UK.

All of the major functions have been integrated and tested in the space frame and negotiations are under way for a launch currently envisioned for an Ariane V in 2007. Backup plans are being made for a Soyuz in 2008.

Software Defined Transponder (SDX)

Howard Long made an excellent presentation on SDX during the AMSAT Forum at Dayton. Howard and others from AMSAT-UK had been following the SDX ideas and progress being made by Bob McGwier, N4HY, and the Eagle Team in this endeavor. He added some ideas of his own and put together development model hardware and software to support a joint European Space Agency (ESA) and AMSAT-UK project. Howard gained acceptance of his concepts by AMSAT-DL and AMSAT-NA at a meeting in Germany in late 2005. Refinement of his hardware and software has continued and formed the basis of the very successful SDX demonstration in the AMSAT booth at Dayton this year. The hardware and software are currently being integrated into the P3-E spacecraft and are planned for inclusion in the Eagle spacecraft later.

In addition to the mode versatility, low power consumption, and other features made possible by this design, a major improvement in interference and "Alligator" immunity has been incorporated by the inclusion of auto-notching software known as STELLA (Satellite Transponder Equalizing Level Limiting Adaptor). In effect, this software allows notching or reducing multiple high-level "spikes" without affecting the transponder noise floor and low-level signals.

Eagle

Also at Dayton, Jim Sanford, WB4GCS, Eagle Project Manager, made a presentation on the development status of Eagle. While not as far along as P3-E,

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e-mail: <w5iu@swbell.net>

Jim Sanford, WB4GCS, makes contact through the SDX while Bob McGwier, N4HY, watches.

significant progress is being made on Eagle. Jim's presentation outlined the plans for modes and frequencies to be covered by Eagle, as well as the design goals, functional requirements, block diagrams, structure, and schedules. Jim also emphasized the "open design" concept of development and announced the opening of *EaglePedia,* accessed through the AMSAT web page. Emily Clarke, N1DID, implemented this concept on the web page. Through *EaglePedia* any AMSAT member can view most design details of the satellite as the project develops.

Commonality with other projects, such as P3-E, was emphasized by pointing out the SDX, IHU3, and Can-Do Bus modules. A presentation was also made on the development and definition of a set of common module enclosures.

Christina Crawford, KD8DGL, makes a contact via AO-51 with the help of KO4MA while her father looks on.

CubeSat Frequency Summary for July 26 Launch

(Thanks to Mineo, JE9PEL, for compiling the table)

Satellite	Downlink	Beacon	Mode	Callsign
SACRED	436.870	1200 baud AFSK	WA4CEW	
ION	437.505	437.505	1200 baud AFSK	—
RINCON	436.870	437.345	1200 baud AFSK	WA4CEW
ICEcube1	437.305	—	9600 baud FSK	W2CXM
KUTESat Pathfinder	437.385	—	1200 baud AFSK	KCØRMW
nCUBE-1	437.305	—	9600 baud GMSK	LA1CUB
HAUSAT-1	437.465	437.465	1200 baud AFSK	D90HP
SEEDS	437.485	—	1200 baud AFSK	JQ1YGU
PolySat CP2	437.325	437.325	1200 baud AFSK	—
AeroCube1	902/928	—	9600 baud GFSK	—
MEROPE	145.980	—	1200 baud AFSK	K7MSU-1
Mea Huaka'i Voyager	437.405/5.840 GHz	—	1200 baud AFSK	—
ICEcube2	437.425	—	9600 baud FSK	N2VR
PolySat CP1	436.845	—	15 baud DTMF, CW	N6CP

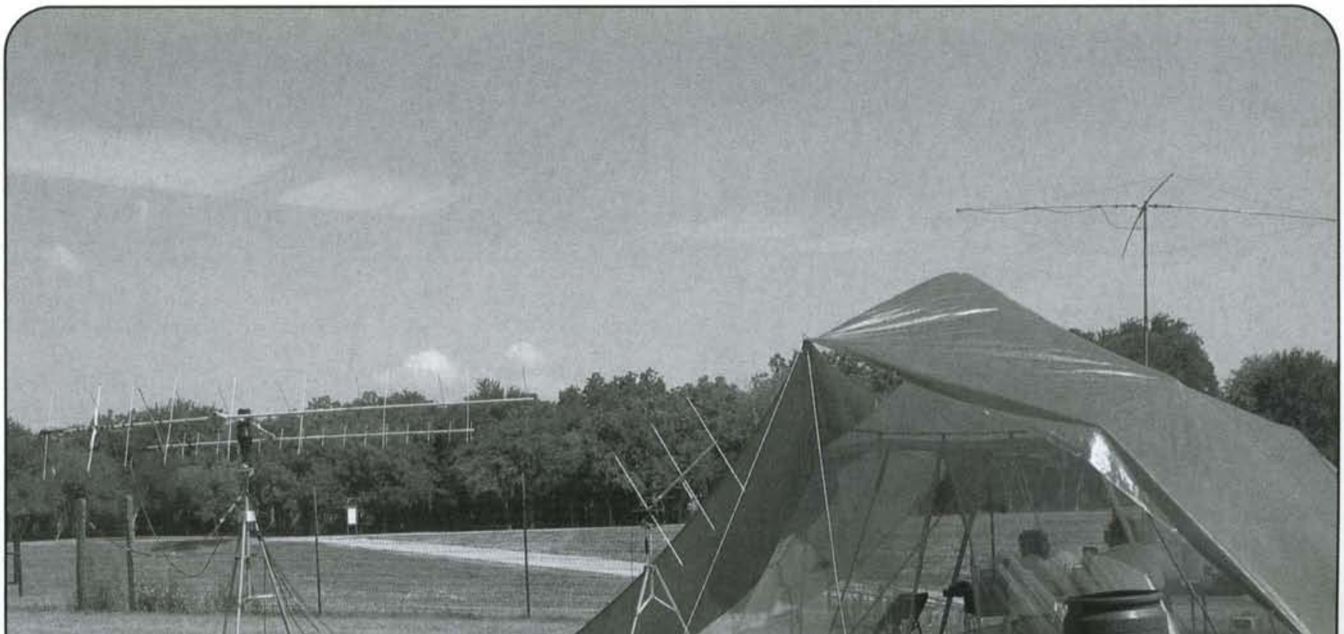
Lou McFadin, W5DID, presented unique new concepts for the Eagle Power System. These concepts included new batteries, new solar cells, and use of large capacitors for energy storage. Significant progress has been made in prototyping some of these concepts, and detailed evaluations will be made before committing to a final design.

And now to add "frosting on the cake." Actual hardware was available for some of these items in the AMSAT booth throughout the Hamvention®. Most spectacular was the SDX live demo. Radios were set up at each end of the booth, and communication was done through the SDX while also viewing the waveforms, etc. Demonstrations were done from the AMSAT outside demonstration area to inside stations through the SDX. It was very encouraging for former users of AO-10, AO-13, and AO-40 to hear the familiar sounds of 400 BPSK telemetry once again. Throughout most of Hamvention®, Jim Sanford, Bob McGwier, Tom Clark, Rick Hambly, and others were available in the AMSAT booth to answer questions and discuss the Eagle project.

Dayton Hamvention® and AMSAT's Youngest Member

All AMSAT activities at Dayton this year went well. The extracurricular activities, Pizza and Suds Bash, and Amber Rose Banquet were well attended. At the banquet we were surprised by a nice donation to AMSAT Satellite Funds from the Hamvention®. AMSAT's youngest member, Christina Crawford, KD8DGL, was introduced and honored with a certificate. Last but not least, Lou McFadin, W5DID, talked about SuitSat-1 and plans for SuitSat-2. Also worth mentioning again is the AMSAT outside demonstration area. This year AMSAT was provided with a fenced-off area near the entrance to the Ball Arena to perform demonstrations. Drew Glasbrenner, KO4MA, spearheaded the demo activity, and several successful demonstrations on AO-51, VO-52, and SO-50 were performed. On Sunday morning Drew was able to assist Christina, KD8DGL, with her first satellite contact on AO-51.

On at least one occasion Drew was able to utilize a new "435/145-MHz Cheap



Satellite station at ARRL/AMSAT, Field Day 2006.

Yagi Antenna" design from Kent Britain, WA5VJB, to make contacts through satellites. (The antenna is described in the "Antennas" column in this issue.)

Ham-Com 2006

Three weeks after Dayton, the largest hamfest in Texas, Ham-Com, was held in Plano Centre, in Plano, Texas. AMSAT again had a booth, and three talks (given twice each) and several successful demonstrations were presented. The talks were "Introduction to Amateur Radio Satellites" by Doug Quagliana, KA2UPW; "AMSAT's Vision – P3E & Eagle" by Keith Pugh, W5IU; and "Keplerian Data" by Ray Hoad, WA5QGD. All talks were well attended. Demonstrations concentrated on AO-51, VO-52, and SO-50 and were kept as short as possible to avoid the outdoor heat.

Once again the new "435/145-MHz Cheap Yagi Antenna" design was utilized successfully. Qualitatively, it performed at least as well as the commercial Arrow Antenna. This author recommends that interested parties give the WA5VJB antenna a close look. It certainly won't cost much to try one!

Field Day on Satellites

ARRL Field Day 2006 and the accompanying AMSAT Field Day 2006 were held on 24–25 June 2006. This year activity was limited to ISS, AO-51, SO-50, AO-27, FO-29, VO-52, and AO-7. Once again no high-altitude "birds" were available. The cross-band repeater on the ISS was turned on for the event and AO-51 was configured as two FM repeaters, one standard and one QRP. Operation on the ISS cross-band repeater was planned to be QRP as well. QRP operation met with minimal success on the ISS, but fared somewhat better on AO-51. Once again, the futility of using FM satellites in a contest environment was proven. Very few operators appeared to be aware of the AMSAT recommendation of only one contact per station per FM satellite. Even operation on the SSB/CW "birds" is affected by excessive ERP by a few stations making it difficult for many.

CubeSats

A record "flock" of 14 CubeSats was originally scheduled for launch on 28 June 2006. This launch was postponed until 26 July 2006 and will provide an interesting event at that time. A list of these CubeSats, courtesy of JE9PEL and the AMSAT web page, is shown in the accompanying table. It will be a real challenge to sort all this out after launch.

AMSAT Space Symposium

It's not too early to make plans to attend the AMSAT Board of Directors Meeting, AMSAT Annual Meeting and Space Symposium, and ARISS International Meeting in the San Francisco Bay Area on 5–11 October 2006. This year in particular should be good for continuing the outpouring of knowledge about AMSAT's Vision and upcoming plans for ARISS. I hope to see you all in San Francisco.

Summary

As usual, there are satellite activities to keep you busy at any time of the year; you just have to look for them. Support your area hamfests, and by all means, support the efforts of AMSAT to build the new projects—P3-E and Eagle.

73, Keith, W5IU

By John Champa,* K8OCL

HSMM

Communicating Voice, Video, and Data with Amateur Radio

The Hinternet and VPN Projects

This column is guest authored by Dave Stubbs, VA3BHF, HSMM Virtual Private Network Project Leader. He can be contacted at: <va3bhf@rac.ca>.

One of the stated objectives of the ARRL HSMM Working Group is the creation of the "Hinternet," an amateur-radio-run network that has capabilities similar to those of the internet and can operate as an alternative to it. This aim harks back to the original ideas of the creators of ampr.net in the early to mid '70s The general guiding principle in this effort is the pervasive use of radio as the "physical layer" of the network. This is, after all, an amateur *radio* pursuit.

The current work of the HSMM Working Group has some very distinct implications when considered against the goal of spanning the globe. As an example, the most common network technology under evaluation, 802.11b, is practically useful inside a quarter mile unless using high towers and directional antennas, which extend the range to less than 15 miles, or maybe up to 30 miles with very carefully applied antenna work and a bit of luck.

The HSMM OFDM modem currently under development by the Working Group has the potential to be used in several of the existing amateur bands. One of these is UHF, where the OFDM modem, if it is anything like regular FM

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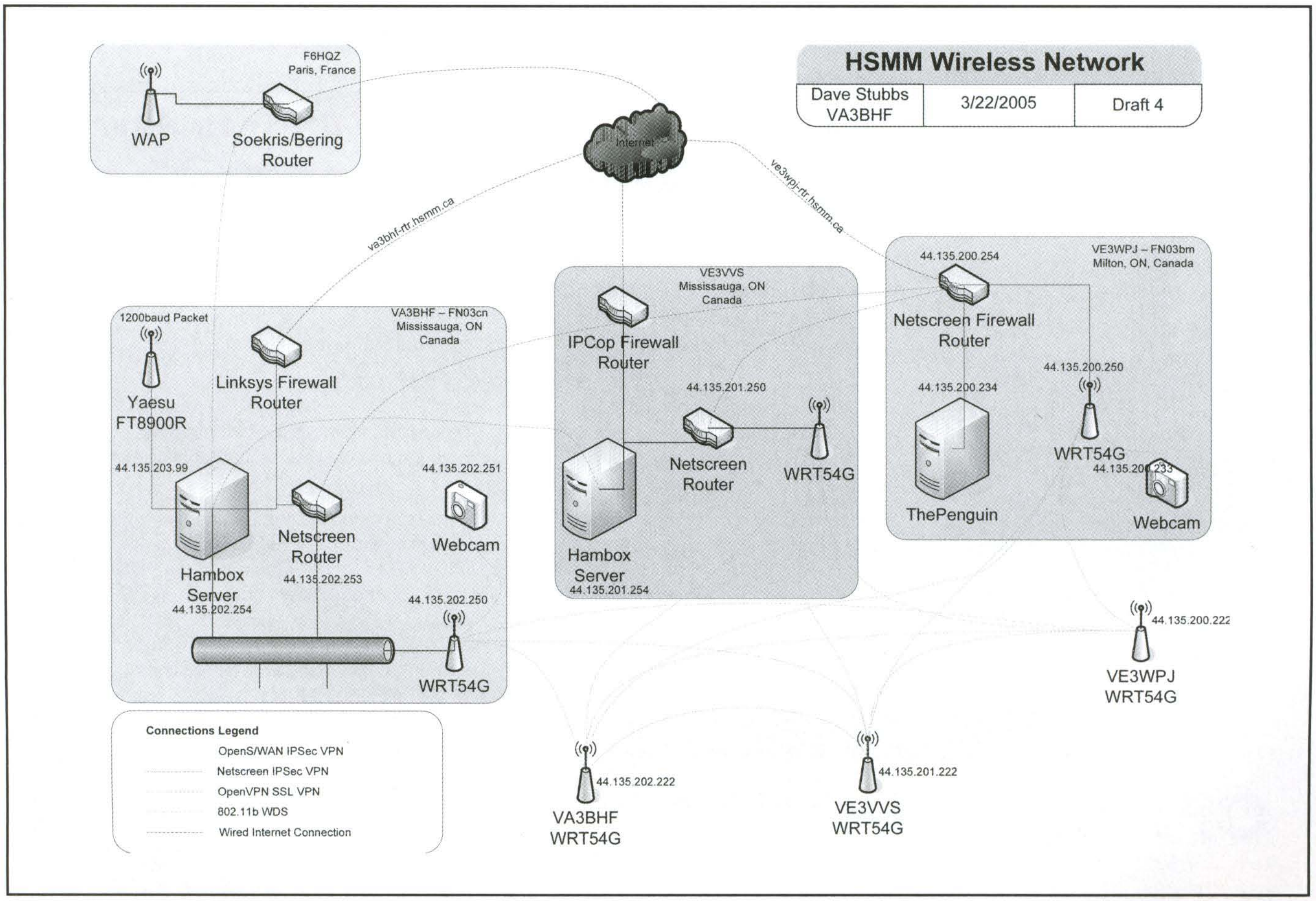

Figure 1. The HSMM Virtual Private Network test system.

Definitions and Terms

AH – Authenticated Header
ARRL – American Radio Relay League
HA – High Availability
HSMM – High Speed Multi Media
MMC – Microsoft Management Console
NAT – Network Address Translation
NOC – Network Operations Center
OFDM – Orthogonal Frequency Division Multiplexing
OSPF – Open Shortest Path First
PPTP – Point-to-Point Tunneling Protocol
RIP – Route Information Protocol
RSA – An encription algorithm that was invented in 1978 by Ron Rivest, Adi Shamir, and Leonard Adelman. The "RSA" acronym comes from the first letter of the names of the inventors.
SLA – Service Level Agreement
SSL – Secure Sockets Layer, a protocol that Netscape developed for transmitting private documents via the Internet.
VPN – Virtual Private Network
WG – Working Group

voice, will likely be able to cover somewhere up to 100 miles. There may be flash improvements from tropo-ducting and other similar phenomena, but always-up network reliability can't be based on transient effects like that. Another exciting possibility is the use of the OFDM modem on the 6-meter "Magic Band." However, it should be remembered that 6 meters, while good at times, is quite decidedly dead at other times.

The bottom line is that these methods currently being pursued are locally reliable, but over long distances they are spotty at best. To practically extend a network around the world, some other type of link is required—at least until a good long-distance RF method arrives that provides fat bandwidth around the planet, for example an AMSAT Phase III or Phase IV satellite. That link is secure, easy-to-use tunnels through the internet. Such connectivity would tie our various experimental efforts into one big, planet-spanning network, which we could begin to *use* for things such as message passing, digital group chats, voice/video conferencing, emergency communications, and other possible uses as we come up with them.

Guidelines for the Hinternet

Simple—This is for use by radio amateurs. Only some are computer/network geniuses. Wide use will require usability by more than the comp/net people.

Affordable—Should use cheap (but good) hardware, or "already have it" hardware. Should, where possible, leverage free software.

Dynamic—Should be able to adapt to a constantly changing network, with parts of it going online and offline. Realistically we are not carrier-grade NOCs. We are hobbyists. We won't have SLAs on our networks or HA setups that are always there.

Interoperable—Where possible, we should support most (if not all) of radio amateurs' favorite platforms. Practically, this would be Windows®, MacOS®, and Linux. If done correctly (i.e., simple bootable CDs or USB keys), this requirement virtually disappears, and the connecting system becomes just another "rig."

Secure—We should be able to leverage quality crypto to keep the tunnel part of our network scrambled and protected while traversing the public internet, and it should be done easily.

Interesting—While we should investigate ways to make this a simple "rig" or "appliance" to the non-network-guru ham, there should also be allowance for the tweaker and experimenter to deal with this infrastructure at his/her level. If it's boring, it will be gone soon.

Scope of Research

The following are some of the platforms and VPN technologies under active investigation. First, the operating systems:

Windows—Preferentially working on Windows 2000 and XP. Win9X is so embarrassingly obsolete it gives me hives. Windows is being evaluated, not so much for use as a core part of the network, but more as a way to get many more hams linked into it from their personal shack computers. It is expected that the Windows support will become increasingly important as we begin to "use" the Hinternet.

Linux—Debian Linux is the platform of choice, because it is commonly agreed to be the "ham friendly Linux." This includes, of course, useful debian extensions, such as Knoppix and Morphix, as applicability permits. Linux has an industrial strength network implementation, amateur radio support right in the kernel, and a veritable wealth of tunneling technologies available for use. Many of these work well when communicating with Windows machines. Linux is a main contender for the "core" part of the Hinternet.

MacOS—Preferentially working on MacOSX because it is a nice, proper, reliable, robust, stable, UNIX-based operating system with a properly accessible networking stack. The Mac, like Windows, is being evaluated as an end-point for the network. No one will be expected to donate their shiny Dual G5s to be core routers.

Embedded—In seeking to come up with a rapidly deployable, easy-to-use "rig," it is important not to rule out well-made boot-and-run solutions such as m0n0wall, which runs on a light version of BSD.

Maybe more important than the operating systems that run our network is the actual VPN tunnel technology that gets our packets around the planet. The current commercial focus on network security is driving the creation of many different VPN technologies. We only benefit from this as it provides us with a rich assortment of tools from which to choose. The technologies being evaluated are as follows:

IPSec—The ultra-secure, but very complicated crypto technology that spans almost every possible platform available. It comes native in all versions of Windows after and including Windows 2000, and shows up as the penSWAN/FreeSWAN/SuperFreeSWAN package *or* the IPSec tools package on Linux, and as KAME on BSD and MacOSX. In addition, it is built into many different routers, such as Netscreen, Cisco, LinkSys, SMC, and Nortel. It generally requires several late nights and lots of coffee to get IPSec working properly on any platform, including Windows, and it tends to give firewalls and NAT-gateways fits. Based on almost a decade of love-hate with IPSec, I categorically vote that it be relegated to the "interesting" zone, reserved for the tweakers among us. It should be noted, as an aside, that IPSec is very modular, and the AH portion of it would probably be the most technically correct method of securing amateur wireless communications without scrambling the content. However, that would still require the aforementioned late nights and coffee, and a very capable key distribution infrastructure to support it. It is also probably outside the scope of this project.

OpenVPN—The current favorite *du jour*. This is a completely free, SSL-encrypted tunnel program that runs on all of the above platforms. It relies on the very solid OpenSSH software for its crypto, and is so simple from a network point of view that it slips through firewalls, NAT-gateways, and even multiple cascaded secure corporate web proxies with ease. Its configuration takes the form of a text file (yuck for Windows users), but the file is so small that it can be understood after about 5 minutes of reading. Highly recommended.

PPTP—The drop-dead-easy tunneling technology built into all versions of Windows, as far back as Win95. Since it interoperates with Linux quite well, it has lots of promise as a quick end-point-connection technology. Concerns about security and hack-ability make its core use a bit risky. However, with a light-but-solid grasp of networking and routing basics, it is possible to set up truly massive meshes of VPNs crossing the world with this protocol—and it works quite well. Cautiously recommended.

Currently Running

As can be seen in the accompanying diagram, our test system is becoming quite extensive. What follows is a description of the setup as it exists today, with a few notes about relevant lessons learned from examining these solutions.

OpenSWAN—The VPN between Mississauga and France runs on this Linux-based implementation of IPSec.

Progress Report on the VHF OFDM Modem

By John B. Stephenson, KD6OZH

1. Introduction

The purpose of this project is to test wide-bandwidth digital transmission for applications such as image transmission in the Amateur Service on its VHF allocations. I am doing development and testing, under the auspices of the ARRL HSMM Working Group. If this system proves successful, the ARRL may petition the FCC for use of up to 200 kHz bandwidth in the VHF amateur band. The current petition for "regulation by bandwidth" requests 100-kHz maximum bandwidths on the VHF bands.

Current regulations limit bandwidths to 20 kHz on VHF amateur bands, so testing is authorized under an FCC STA (Special Temporary Authority) that is effective until September 10, 2006. It authorizes emissions with a bandwidth up to 200 kHz in the band 50.3–50.8 MHz. This frequency range is consistent with both ARRL national voluntary band plans and applicable local band plans in the Fresno, California area, where testing will be done. Specifically, in those band plans the segment 50.3–50.6 MHz is designated for "all modes" and the segment 50.6–50.8 MHz is designated for "nonvoice communications." The STA authorizes 1.5 KW peak, a 200-kHz maximum bandwidth, and 384 kbps maximum data rate.

2. Description

The modem being developed is a modification of the UHF offset frequency division multiplexed (OFDM) modem tested on the 70-cm amateur band. OFDM splits a high-rate data stream into multiple parallel low-rate streams transmitted on multiple subcarriers. As the signal propagates, it is reflected and refracted, giving rise to multiple echoes that corrupt data. OFDM slows the rate so those echoes are confined to small gaps between transmitted symbols. The technology is similar to that used on HF bands, but the data rate of each subcarrier is higher, as the maximum path length is considerably shorter.

This modem consists of software written in Verilog, assembly and C language that runs on a DCP-1 card containing a Xilinx XC3S400 field-programmable gate array (FPGA) and Oki Semiconductor ML67Q5003 microcontroller. One DCP-1 attaches to the intermediate frequency (IF) output of a modified ATR-2000 receiver at one end of the link and another attaches to small printed circuit board, with a quadrature modulator IC (Atmel U2790) and the power amplifier from the ATR-2000 at the other end of the link. The transmitter is in a fixed location (Lat: 36d 46m 30s N, Lon: 119d 46m 22s W) and can generate 150 W PEP into an 8-dBi gain vertical antenna (Diamond Antenna DP-GH62). The receiver is mobile and uses a Hamstick antenna mounted on the roof of an SUV.

The DCP-1 and ATR-2000 are documented in articles published in *QEX*. The UHF OFDM modem specification is on the ARRL website (http://www.arrl.org/hsmm/), and a new version,covering VHF operation, of the document will be published as part of this testing. Documentation of the modem hardware and source code will be made available to all radio amateurs after testing.

Three data formats will be tested. These are designed for 50-, 100-, and 200-kHz channels. Initial tests will use 750-Hz subcarrier spacing with an inter-symbol guard interval of 1/8 symbol period. This combination was selected to support relatively small channels and still have a guard interval that allows rejection of inter-symbol interference in any conceivable operating environment. Field testing of ATSC (digital) television systems showed a maximum delay spread of 90 μs and the resulting guard interval for the VHF OFDM modem is 166 μs. The resulting system should be able operate over LOS or NLOS paths in most terrain with directional or omnidirectional antennas. The signal formats use a central pilot carrier and upper and lower sidebands with 24, 48, or 96 data subcarriers plus 2 trellis-terminating subcarriers each. The subcarriers use differential 8-ary phase shift keyed (PSK) modulation with rate 2/3 convolutional coding. The resulting encoded data rates are 96, 192, and 384 kbps with user data rates of 64, 128, and 256 kbps.

3. Progress

Verilog code has been generated for the VHF OFDM modem and 95% of it has been successfully simulated. Simulation has taken longer than expected due to problems associated with IP (intellectual property) upgrades in the Xilinx development software. Modifications to the original UHF modem included:

A. Reducing the size of the finite impulse response (FIR) digital low-pass filters to allow three programmable filter stages instead of two.

B. Increasing filter coefficient precision from 18 to 24 bits.

C. Writing a new encoder and Viterbi decoder to convert from the Ungerboeck trellis-coded modulation (TCM) using a four-state encoder in the UHF modem to a bit-independent coded modulation (BICM) with eight states.

D. Modifying the fast Fourier transform (FFT) implementation to support 17-bit data and reduce memory requirements. The FFT multiplexes and demultiplexes the subcarriers.

E. Modifications in multiple modules to allow different numbers of subcarriers.

F. Converting interfaces between circuits using different clock rates from using block RAM (random access memory) in the FPGA to distributed RAM in the FPGA to free block RAM for additional filtering.

The change from TCM to BICM was made to increase performance over fading paths. The TCM scheme was originally designed for additive white Gaussian noise (AWGN) channels as encountered with telephone modems. This will be incorporated into the UHF modem specification. The filtering changes were required to support higher decimation and interpolation rates and provide a better shape factor to limit occupied bandwidth.

Once all the code has been simulated, it will be loaded onto a DCP-1 and the output checked with a spectrum analyzer. Of particular interest is the level of high-order intermodulation distortion (IMD), or splatter, that will be generated in the power amplifier. A signal generator and arbitrary function generator is also available for receiver testing.

The final test will be one-way over-the-air with measurement of bit error rates, allowable SNR (signal to noise ratio), and coverage area. Testing will also be done on the 70-cm band, either before or after the STA expires, to compare coverage areas and amplifier IMD.

It's actually a nice example of different versions of a piece of software working okay together. The Mississauga end of this tunnel runs OpenSWAN, while the France end is running SuperFreeSWAN, which is a slightly older version. The nicest thing that can be said about this tunnel is that it exemplifies well the general truth about IPSec and Linux: Once you make it through the pain and anguish of getting it all set up, it "just works." You can forget about it. Leave it there for years and years, and when you come back to it and actually need it, it's still running.

The chore of setting this up served to highlight some of the more annoying and esoteric "features" of IPSec, however. Because the Mississauga side of this tunnel is on a dynamic address, the whole "easy" part of OpenSWAN setup, which uses pre-shared keys, would not work. It was necessary to learn the more complicated RSA-key-exchange method of authentication, which allowed a dynamic-to-static tunnel to work fine. To make this setup work with Windows IPSec, it will be necessary to learn the even-more-painfully-complicated X.509 key exchange authentication method. This is still on the to-do list, but motivation in this direction is low, because it requires extensive manual configuration (death by MMC) on the Windows side as well, making it unlikely that this would achieve wide use among hams.

One major downside that has come up from IPSec testing, however, is the very different practical reality of policy-based routing. OpenSWAN tunnels do not show up on the computer as regular network interfaces, so normal routing doesn't work on them. This limits the use of dynamic routing protocols on this type of tunnel, and requires a lot of manual configuration. This should be considered a major tick against the use of IPSec.

Netscreen IPSec—some of the VPNs between the various involved parties in Mississauga have been created using Netscreen router appliances. This is mainly because we were interested in these from our day jobs and some of us had these devices sitting around. It is unlikely that these will make it into mainstream HSMM use, but they may provide a nice excuse to try Linux-to-Netscreen VPN testing. For the purposes of this project, however, it is little more than a distraction.

OpenVPN—after a little work on OpenVPN for other reasons, which proved very practical and useful, it was decided to try using this protocol for one of the HSMM VPNs previously provided by Netscreen routers. This tunnel was basically set up within 5 minutes, and full OSPF routing was completed within an afternoon. Further tests of Windows-to-Linux OpenVPN tunnels have been made and have turned out to be just as easy. Using the TAP interface, it is possible to run full OSPF and RIP routing on OpenVPN tunnels (and even mobile-mesh as well), which makes them *very* useful for extending a distributed network and having the routing "just work." For this reason, OpenVPN has enthusiastic support from this project and is recommended as a "first choice" for core network connections.

PPTP—Several of the Linux servers involved in this network have been set up with the *pop-top* server, which allows Windows clients to connect via PPTP VPNs. Tests so far have shown this to be quite reliable, although some manual configuration needs to be done on the Windows VPN advanced settings, which allow passwords to be sent in the clear. There is a possibility to mitigate this with some additional software on the Linux side, which is also on the list for future testing. For now, though, the tunnels run reliably. It would be worthwhile to do some future testing on full PPTP network-to-network routing in addition to just single clients. The pervasive use of Windows among hams makes this endeavor worthwhile.

Future Efforts

A lot of work is being done, and a lot of fun is being had at the same time. However, there is still a long way to go. While we are definitely fulfilling some of the previously mentioned guidelines (*interoperable, interesting,* at least), there is still a lot of work to be done on others (*simple,* especially). The main items follow, in approximate order of priority, from highest to lowest.

Simple BootCD Router—The main Linux system being used for this project is a powerful server, with a Gigabyte of RAM, a powerful CPU, mirrored hard disks, fault tolerant power supply, and a carefully hand-configured array of software on it, doing many things beyond the scope of this project. One of the chief goals of this project is to boil that down into a simple, boot-and-leave-it system that runs from a bootable CD on a reasonable group of readily available laptops. Once attained, there are plans to extend this to bootable USB keys and other embedded systems other than laptops.

PPTP Enhancements on Linux for Secure Authentication—An effort to add components to Linux to fully support the exchange of encrypted passwords as the tunnels get set up. This is useful for Windows clients as well as Windows Server VPNs, so it has a medium-to-high priority.

Full Router Kit Spec—This effort is an extension of the above Simple BootCD item, which specifies an easy-to-build kit using something like a Soekris embedded system board, with a ready-to-boot CF card for it.

OpenVPN in LinkSys WRT54G—Taking the idea further is the possibility of putting a major squeeze on the software requirements for the RMAN-VPN router and loading it all into the brilliantly amazing yet very cheap LinkSys WRT54G router, which is already specified in the S.H.A.R.K kit spec.

OpenVPN Windows-Linux Fully Routed—Since OpenVPN runs so well on Windows, it is worthwhile to investigate it as a full alternative to the Windows PPTP tunneling capability, especially considering its robustness, and the nimble way in which it works through firewalls, gateways, and proxies.

PPTP Windows-Linux Fully Routed—An effort to test the use of Windows Server VPN routing connected with Linux, as an option to deploy a major portion of the network on Windows, should the need arise (a sudden influx of funding dollars from Microsoft Research, for instance).

IPSec X.509 Authentication—A low-priority effort to extend knowledge of IPSec and have it fully working between Windows and Linux.

Requests from the HSMM Working Group

In short, the main request from this project is for people to get involved. As development of an easy-to-deploy kit progresses, it would be great to have some more nodes connected to this distributed network, and even get to the point where our regular conference calls are held on the network instead.

It would be great to get to the point where we do not consider a node really "deployed" unless it is connected into this distributed network.

Summary

This project, for a network-engineer-turned-ham, is a lot of fun, and also a great challenge. It is hoped that the technologies under experimentation in this effort can be put to good use as a simple method to hook together our various HSMM experimental networks, and by bringing them together, achieve a critical mass where "the whole is greater than the sum of the parts," giving us a great tool to use in communicating and supporting our emergency response services.

The ultimate goal of this project, of course, is to become no longer needed, as we blanket our planet with long-distance RF links, making VPNs no longer necessary. However, until then…

If you have any questions or suggestions about using VPNs on the Hinternet, or if you perhaps would like to get involved in the HSMM VPN Project, please feel free to contact me: Dave Stubbs, VA3BHF, HSMM VPN Project Leader, at <va3bhf@rac.ca>.

QUARTERLY CALENDAR OF EVENTS

Current Contests

August: There are two important contests this month. The **ARRL UHF and Above Contest** is August 5–6. The first weekend of the **ARRL 10 GHz and Above Cumulative Contest** is August 19–20.

September: The **ARRL September VHF QSO Party** is September 9–11. The second weekend of the **ARRL 10 GHz and Above Cumulative Contest** is September 16–17. The **ARRL 2304 MHz and Above EME Contest** is September 16–17. The **144 MHz Fall Sprint** is September 18, 7 PM to 11 PM local time. The **222 MHz Fall Sprint** is September 26, 7 PM to 11 PM local time.

October: The **432 MHz Fall Sprint** is October 4, 7 PM to 11 PM local time. The **Microwave (902 MHz and above) Fall Sprint** is October 14, 6 AM to 1 PM local time. Note: You are to operate no more than five hours, in one-hour blocks, during this contest time slot. The **ARRL 50 MHz to 1296 MHz EME Contest** is October 14–15.The **50 MHz Fall Sprint** is October 21, 2300 UTC to October 22, 0300 UTC.

November: The second weekend of the **ARRL 50 MHz to 1296 MHz EME Contest** is November 11–12.

For ARRL contest rules, see the issue of *QST* prior to the month of the contest or the League's URL: <http://www.arrl.org>. For Fall Sprint contest rules, see the Southeast VHF Society URL: <http://www.svhfs.org>.

Current Conferences and Conventions

August: EME Conference 2006 will be held in Wuerzburg, Germany from August 25 to 27. For more information about this conference, see: <http://www.eme2006.com>.

September: The 2006 **TAPR/ARRL Digital Communications Conference** will be held September 15–17 in Tucson, Arizona, at the Clarion Hotel, Tucson Airport. For more information, go to: <http://www.tapr.org/>. The unofficial information on the **Mid-Atlantic States VHF Conference** is that, if there is to be a conference, it will be held Saturday, September 30. For further information, please check the Packrats website: <http://members.ij.net/packrats/latest.htm>.

October: The 2006 **AMSAT-NA Space Symposium and Annual Meeting** will to be held October 5–10, in San Francisco, California at the Crowne Plaza Hotel San Francisco Mid-Peninsula Hotel, located at 1221 Chess Dr., Foster City, California. For more information, please see the AMSAT URL pertaining to the symposium at: <http://www.amsat.org/amsat-new/symposium/>. The annual **Microwave Update** conference dates are October 19–22, and it is to be held at the Dayton, Ohio Holiday Inn North Hotel, Wagner Ford Rd., Exit 57B on I-75. For more information, please see the following URL: <http://www.microwaveupdate.org/>.

Quarterly Calendar

The following is a list of important dates for EME enthusiasts:

Aug. 2	First Quarter Moon
Aug. 6	Very poor EME conditions
Aug. 9	Full Moon
Aug. 10	Moon Perigee
Aug. 13	Good EME conditions
Aug. 16	Last Quarter Moon
Aug. 20	Poor EME conditions
Aug. 23	New Moon
Aug. 26	Moon Apogee
Aug. 27	Poor EME conditions
Aug. 31	First Quarter Moon
Sept. 3	Very poor EME conditions
Sept. 7	Full Moon and Partial Lunar Eclipse, Europe, Africa, Asia, and Australia
Sept. 8	Moon Perigee
Sept. 10	Good EME conditions
Sept. 14	Last Quarter Moon
Sept. 17	Moderate EME conditions
Sept. 22	New Moon and Moon Apogee and Annular Solar Eclipse, mostly over the Atlantic Ocean
Sept. 23	Fall Equinox
Sept. 24	Poor EME conditions
Sept. 30	First Quarter Moon
Oct. 1	Very poor EME conditions
Oct. 6	Moon Perigee
Oct. 7	Full Moon
Oct. 8	Good EME conditions
Oct. 14	Last Quarter Moon
Oct. 15	Good EME conditions
Oct. 19	Moon Apogee
Oct. 21-22	Orionids Meteor Shower Peak
Oct. 22	New Moon. Poor EME conditions
Oct. 29	First Quarter Moon; Poor EME conditions
Nov. 3	Moon Perigee
Nov. 5	Full Moon; Good EME conditions
Nov. 12	Last Quarter Moon. Good EME conditions
Nov. 15	Moon Apogee
Nov. 17	Leonids Meteor Shower Peak
Nov. 19	Very poor EME conditions
Nov. 20	New Moon
Nov. 26	Moderate EME conditions
Nov. 28	First Quarter Moon

—EME conditions courtesy W5LUU.

Calls for Papers

Calls for papers are issued in advance of forthcoming conferences either for presenters to be speakers, or for papers to be published in the conferences' *Proceedings*, or both. For more information, questions about format, media, hardcopy, email, etc., please contact the person listed with the announcement. The following conference organizer has announced a call for papers for its forthcoming conference.

Microwave Update: A call for papers has been issue for the 2006 Microwave Update. If you are interested in submitting a paper for publication in the *Proceedings*, please contact Gerd Schrick, WB8IFM, at 937-253-3993 or e-mail: <wb8ifm@amsat.org>. The submission deadline is September 1, 2006. For more information on the conference, please see the website: <http://microwaveupdate.org/>.

Current Meteor Showers

August: The ***Perseids*** meteor shower's predicted peak is around 2300–0130 UTC between August 12–13. According to the International Meteor Organization: "Simulations by Peter Brown made some years ago suggest enhanced ***Perseid*** activity is possible this year, though perhaps not as strongly as in 2004. The timing of any enhancement, though probably not far from the expected spread of possible maxima noted here, is not known."

October: The ***Draconids*** is predicted to peak somewhere around 1430 UTC on October 8, then again around 2220 UTC on October 9. The ***Orionids*** is predicted to peak on October 21.

November: The ***Leonids*** is predicted to peak around 2050 UTC on November 17.

For more information on the above meteor shower predictions see Tomas Hood, NW7US's propagation column. Also visit the International Meteor Organization's website: <http://www.imo.net/calendar/2006/>.

By Chuck Houghton,* WB6IGP

MICROWAVE

Above and Beyond, 1296 MHz and Up

Putting 24-volt Microwave Devices to Use

I have received a few questions about how to utilize surplus 24-volt miniature SMA microwave relays to operate with 12-volt DC power supply systems. This seems to be a common problem in that 24-volt relays appear to be popping up at swap meets in increasing numbers. Don't overlook chassis that have SMA relays internal to the surplus box either. Several dealers have advertised 24-volt relays for a pretty good price, while their 12-volt counterparts are more costly ($25 minimum) and may wind up straining the experimenter's budget.

In that regard, all I can offer is my experience. I pick up SMA coax relays whenever they show up at our local swap meet, or I get them from surplus chassis junk cabinets when they are inexpensive. These relays can be used from low VHF to the upper microwave frequencies, such as 10 GHz. They exhibit great isolation and will handle moderate power for many systems, even my 10-watt TWT (traveling wave tube) amplifier for 10 GHz, where I use four SMA relays to control 10-GHz switching. I might have been lucky, though, as the surplus SMA relays I found have operated quite well for many years.

There are several versions of miniature SMA relays, including the basic SPDT switch, which seems to be most common in the more exotic latching type of relay. The difference between them externally is almost nothing. Internally the difference is quite a bit. In an SPDT-type switch there is only one relay coil internal and the normal contacts are common to one side of the relay with the coil not energized. When energized, the relay switches from common to the other side of the switch and stays in this position until the relay-coil power is removed.

In a latching relay common is tied to one side in a make condition and this side depends on which set of coils were toggled first. It has two internal coils, and when powered individually, they put the switch in position 1 to common or position 2 to common depending on which coil is powered. Power (current) flows momentarily when the coil is powered to latch the selected position and a cut-off switch disconnects the coil from power. Thereafter no further current flows in the circuit. The second coil in the scenario that was previously open is now closed to the power pin on the relay body and awaits the application of DC power to reactivate it to the make condition.

The switching of a latching relay is simple. It requires two power leads, one for receive and one for transmit. In receive common, contact is made. When transmit DC is applied to the second coil, the relay switches to the transmit common part of the switch, making the transmit contact open from common.

Other relays operate from TTL control voltages and have lamp control leads to show which portion of the coax relay is active to ports 1 and 2. If you can't figure out the contact pins' logic, try looking on the web for your part number and see what you come up with. You could just probe the relay, trying your luck, but be careful, as some relays use small steering diodes internally, and if they blow, you will need to open up the relay and possibly replace a diode. Small glass signal diodes are normally used here. If you're totally stumped, drop me an e-mail and I'll see if I can figure it out.

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e-mail: <clhough@pacbell.net>

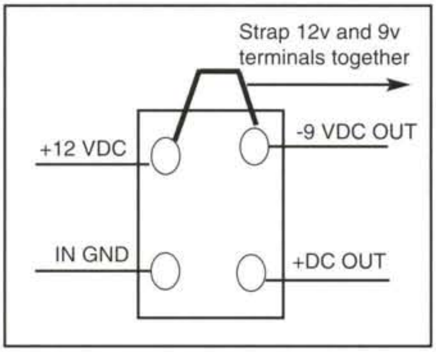


Figure 1. A DC-to-DC transformer, +12 VDC input, isolated output. Read between ground and –9 VDC = 9 volts. Read between ground and +DC Out = 12 volts + 9 volts (stacked in series with +12 VDC. Pulse Engineering part # PE-64430 is good for 400-mA intermittent use.

How to Use 24-volt Relays

The main topic to be discussed here is how to use 24-volt surplus relays from 12-volt DC sources, as in mobile or remote Field Day operations. Of course, you could power your equipment from a 24-volt battery source, but that requires carrying an extra battery.

Electronically speaking, what can be done to accommodate this power problem by using surplus 24-volt microwave relays and adapting them to 12-volt power systems? There are two solutions. One requires construction of a bucking voltage doubler. The other requires adding a miniature surplus switching power supply whose isolated DC can be put in series on top of the 12-volt control switching-relay power line. In actual operations, the latter is simple, if you can obtain such a power supply. Check surplus scrap yards that break down computers and other electronic equipment.

These switching power supplies are fairly common and might have been overlooked for many applications. They are quite small—about 1/2 inch wide and less than 2 inches square. They are rated for various voltage inputs and outputs, but the ones that seem to be just what we want are those that operate from +12 volts input and deliver +5 volts output. Most of these can handle at least 5 watts of power output at 5 volts and can be used normally or inverted for negative power requirements. This is because the power module output is not just a voltage regulator internally, but is a complete switching power supply whose input is totally isolated from its output.

Take the +12-volt normal battery supply and attach it to the DC module 12-volt input, plus to plus and minus to minus. Take the –5-volt lead from the DC module and connect it to the positive 12-volt lead, making a direct connection to the +12-volt DC lead. Now at the positive 5-volt lead you have +17 volts available. Connecting two of these in series gives you 22 volts. That's 12 volts from the primary power source and two 5-volt isolated power supplies stacked in series, each adding 5 volts to the picture for a total of 22 volts. With mobile operations and a charging 12-volt battery source, it will up the voltage on these connections to 24 volts, as the charging 12-volt battery nominally is now +13.9 or so, plus one or two series-isolated DC power modules. It's very simple and just like stacking batteries in a flashlight.

Why 5-volt switching power supplies? They are the most common for providing +5 volts DC for logic power on PC boards. While there are other voltages that fit the bill, the 5-volt switchers seem to be the most plentiful.

One other surplus item that I located quite some time ago was +12-volt input and 9-volt isolated output switching power supply in a square package. There was no label, but I knew it was a switcher, as it had only four leads internal to the sealed epoxy package and resided on the DC power supply shelf of the scrap PC board from which it was harvested. Once I recognized it for what it was, I obtained many more, as I knew what to look for. The label on some said part # PE64430.

Some part-number schemes seem complex, and while others are not. Take, for example, a surplus ASTEC power switcher with a label that says AA10B-12L-050S. While I don't know the complete information on this unit, it has been observed that it's +12 volts input and 5 volts isolated output. I have stacked one power module on top of a 12-volt DC line, and with the 17 volts have been able to use with confidence many 24-volt relays with out further modification. Adding another switcher of 5 volts isolated output gets you 22 volts for 24-volt relay-switch applications that function just fine.

Another great application is the generation capabilities of using this power module in an inverted power connection for FET bias supplies. This allows you to use a lower voltage DC positive drain power source and a negative 5-volt supply from the switcher for gate FET bias. Of course, further circuitry is necessary in any FET power supply circuitry, but the basics are there for both positive- and negative-generated voltages.

Testing the power module that did not have a label and that put out 9 volts isolated on the secondary of the switcher, I found that with a 75-ohm load it was still loafing along at 125 ma current draw. Testing it with a 24-volt relay that drew 95 ma, the unloaded power supply was 22 volts, and it did not change a tenth of a volt when power was applied to the 24-volt relay. It operated quite well on 22 volts. I was watching contact closure for relay operation with a simple LED-driven test circuit I use for coax relay contact testing.

That's just another simple idea for testing miniature SMA relays. The project is constructed out of some scraps of SMA connection coax cable tied to two LEDs operating on low voltage for watching contact closure of the relay. Being a scrounger and finding a relay that was defective, I felt I could use this simple tester to verify if and when I obtained contact closure on a few relays. It was easier to use this simple test setup than to hold a VOM set of test leads.

Most relays that I have found to be defective had dirty contacts internal to the relay. If you can pry off the cover without destroying the relay, through some simple repair you too might get lucky in salvaging a defective SMA microwave relay.

Well that's it for this time. Don't scowl at the next batch of SMA microwave relays just because they are only marked 24 volts. Take advantage of these 24-volt relays, be they SPDT, latching, or even the harder to find transfer (four-contact) relays. If you can't locate the DC-to-DC switching supplies locally, I have a small supply of both the 5-volt and 9-volt switchers available for $4 each for the 9-volt switcher and $5 each for the 5-volt switcher (continental U.S. only, and please add $1.50 for handling and postage costs).

As always, if you have any questions, please drop me an e-mail (clhough@pacbell.net), and I will answer you as soon as possible.

73, Chuck, WB6IGP

By Del Schier,* K1UHF

AIRBORNE RADIO

Using Amateur Radio to Control Model Aircraft

Electric Power Systems

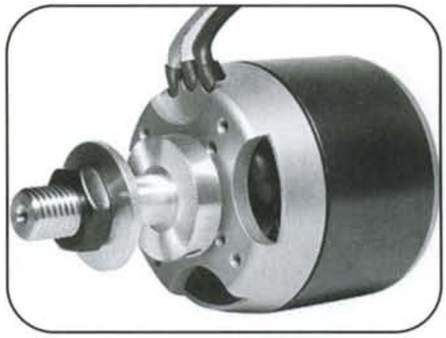
These days, electric airplanes are "where it's at." Technology in the form of lithium batteries and brushless motors makes electric power as good as wet-fuel power. Little glow plug and ignition engines work great, but they are a hassle and messy. Electric power is clean and easy.

RC airplanes have been flown with electric motors for many years, but until recently they used DC brush motors with nickel-cadmium batteries. While this older technology still works well and is inexpensive, lithium polymer batteries with three phase AC brushless motors offer a big improvement, especially in the power to weight department. Higher power to weight ratio gives higher performance and flight times.

Deciding on the best power system for an airplane can be complicated unless you purchase an airplane with a power system that a dealer or manufacturer correctly recommended. The advice of the supplier is a good starting point, but you still need to have an understanding of what your choices are.

A power system isn't just the battery and motor. It is also the speed control and propeller, and yes, the propeller may be the most important part. All of the pieces are highly interdependent, and the entire package must match the airplane.

A 600-size cordless drill brush motor.



58 amps at 36 volts AXI outrunner, 600 grams.

A Medusa Research Afterburner inrunner brushless motor.

A small AXI brand outrunner motor, 9 grams.

Motors

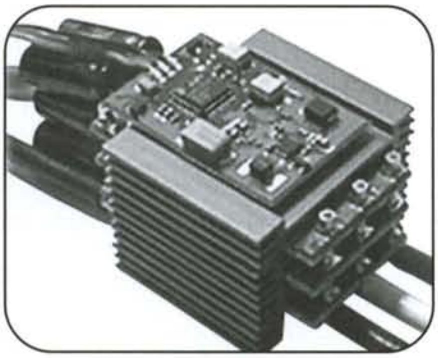
DC brush motors are inexpensive, $10 or less, as they are made in quantity for cordless drills and screwdrivers. You will also find tiny pager motors or cordless toothbrush motors in smaller airplanes. Mass-produced brush motors are called "can" motors, as they have stamped steel can housings. They usually have bronze bushings or sometimes ball bearings, and they use ferrite magnets. They come in a variety of sizes with numbers such as 350, 380, 400, and 600. A 400 size from a cordless screwdriver is a popular size for many airplanes, and a 600 from a cordless drill will power something larger. These motors range in power input from 80 to 250 watts. Compared to the more expensive brushless motors, they are heavier, lower in efficiency, have shorter life spans, and produce RF brush noise. The efficiency of a inexpensive brush motor is in the range of 40 to 60% and will be worse if it is run backwards. They have a fixed timing advance, and reverse operation kills the performance. Nevertheless, do consider these motors, because they are an excellent choice for the money and can be lots of fun. I have a 400-powered airplane with hundreds of flights on the original motor, but it is on the third battery pack.

The new rage in brushless motors made specifically for RC models is available from dozens of companies. These exotic motors are state-of-the-art and are available in just about any size or type. They range in power from a few watts to 10 kW. A 5-watt motor is the size of a thimble, and 10-kW motor is about the size of an orange. Ten kW is the equivalent of 15 horsepower and produces 66 pounds of thrust. To my knowledge, all brushless motors are three-phase AC motors with ball bearings. They use the best rare-earth magnets to achieve efficiencies of 80 to 95% or more. Without brushes to wear out and ball bearings, they last virtually forever. These motors came from computer technology, as CD-ROM drives and hard drives use AC brushless motors. In fact, RC modelers convert CD-ROM motors for use with model airplanes.

Brushless motors come in three basic styles: inrunners, outrunners, and gear drive. Inrunners are the familiar design with the rotor having the magnets and the

*e-mail: <k1uhf@westmountainradio.com>

A big Hacker Gear motor that will put out well over a horsepower.



A super-large 10-kW brushless speed control.

A Hacker Inrunner with about 200 watts of output.

Powerpole connectors connect an airplane or your ham station together.

A micro 20-ma-hr cell for an indoor airplane.

stator having the windings. An inrunner runs at high rpm. To operate at 30k to 40k rpm the prop must be small, which gives lower prop efficiency. Adding a planetary gearbox allows operation with a larger diameter prop, which gives higher system efficiency. Brush motors work well with gearboxes also. Outrunner brushless motors have the windings in the center with a large-diameter outer rotor. The large outer rotor provides the same power but at lower rpm, so it does not need a gearbox. The outrunner, without a gearbox, is a simpler solution because of the lower weight. Outrunner motor efficiency is down a bit, but gearboxes create friction and running a large efficient prop is usually more important.

Electric motors are controlled by an electronic speed control, ESC for short. An ESC is connected to the throttle channel of the receiver and gives full proportional control of the power. ESCs come in two types: DC for a brush motor and three-phase AC for brushless.

ESCs use switching FETs to control the pulse width sent to the motor. A micro controller usually does the work of generating the signal. These speed controls can be custom programmed for items such as timing, braking, soft or hard start, and other features. The programming is done with a sequence of moving the radio's throttle stick or with a USB or serial computer interface.

Lithium polymer batteries do not like being discharged much below three volts per cell, so modern ESCs have a cutoff feature to cut back the motor power when the battery reaches its minimum. ESCs also have battery eliminator circuits (BECs) to regulate the motor battery voltage by cutting the power to the motor when the battery gets low and thereby allowing for a safe amount of time for a gliding landing to take place. This provision allows for the airplane's receiver and servos to continue to function without the need for a second battery (and the added weight). The BECs connect the power through the throttle channel connector. It is important to note, however, that the BECs may or may not be able to run all of the servos in an airplane. Therefore, it is important to consider how many servos should be onboard the plane. This is particularly important in a larger model plane.

To connect the motor and the battery to the ESC, you need good high-current connections. Usually I solder the ESC to the motor leads and use Anderson Powerpoles™ for the battery side. There are many other connectors for this purpose, but Powerpoles are usually the best choice.

RC propellers are not usually variable pitch, so an airplane is like a car or bicycle with only one gear. I say "not usually," as I have a Great Planes V-Pitch prop on an aerobatic airplane that can fly backwards—yes, backwards. Since the propeller has a fixed pitch and diameter, it must be chosen carefully for a good compromise in performance. The wrong prop can cause an airplane to fly poorly or not at all, and the wrong one can burn out the motor and ESC. Burning things up is a real issue. You not only need a matched setup, but you also need cooling air past the motor, ESC, and battery.

The motor/prop combination should be matched to draw a current level for best power and efficiency. The prop should be matched to the airplane for a compromise between climb thrust and top-end speed. The ESC needs to have a rating higher than is dictated by the motor/prop/battery combination.

The battery needs a capacity for good flight times, and it needs to be able to supply the power without it overheating or sagging in voltage under load. There are many tradeoffs when choosing a battery. With the nickel-cadmium chemistry's weight and size, it is usually a matter of putting the biggest battery in the airplane that will physically fit and still let the airplane fly. Of course, you still need to consider the voltage and capacity.

Lithium polymer packs have "C ratings" to indicate their ability to provide source current for the power being drawn. A "C rating" is the capacity rating times a number as the maximum current that will supply intermittently. You will see

A Thunder Power 2-amp-hr 11.7-volt pack that weighs only 9 oz.

An FMA Cellpro battery that will fly a 40-inch airplane for a half hour.

packs rated 7C, 10C, 20C, but remember that these are intermittent, or "burst," ratings. This gets a bit complicated, as it depends on how the airplane might be flown, and also the ratings may be unrealistic. Some airplanes fly with short bursts of throttle, while others fly flat out for the entire flight. The C ratings are supposed to be a function of the pack's internal resistance. For instance, a 3200-ma-Hr pack with a 20C rating will supply 64 amps on short bursts. If it is a quality pack, it would be all right to fly with short full-throttle runs at 64 amps. However, for an airplane that always has the power on, 35 amps may be the max. Note that it depends on the quality of the pack and whether or not the ratings were realistic. A West Mountain Radio CBA can be used to determine internal resistance and to project the pack's heating and voltage drop under load. A quick static run with the motor will also show the pack's quality in terms of voltage drop and heating. If a fully charged lithium pack goes much below 3.4 volts per cell at a motor's full power draw, the pack may be damaged or not last after many charge cycles.

You do not need to trust the recommendation for an airplane. You can verify the match of the equipment with some calculations of your own. The amount of power the airplane needs depends on how you expect it to fly. Power requirements are usually specified in watts per pound. Generally, 30 W/lb is the minimum for mild performance and 150 W/lb will give super performance. At the low end, the airplane will take off and climb, but slowly. With high power it will accelerate vertically or be able to hover on the propeller at one-third throttle, provided it can be controlled in a hover. Remember, amps times volts equals watts. When calculating watts, consider that a battery's voltage will drop under load and as it discharges.

Propellers

You need to make sure you have the correct propeller. You can go online to motor manufactures' web pages to use web-based motor system calculators, but only for their motors. To select among many motors you can download and try either MotoCalc or Electricalc software, which figures out everything from a large database of motor, battery, and propeller specs. This software is a good way to check power systems before you buy or if you think you have a problem with a given setup.

Assuming you have done your homework and have picked a good power system, you still need to test it before you fly. Do a static run. A static run is very similar to what real airplane pilots do each time before they take off. On the bench, run the motor and measure the power with a meter, such as one from Astroflight or Medusa Research. A static run is a simple test to measure volts, amps, and power with an airplane stationary on a bench. Along with a static power test I also measure the thrust with a spring scale and the rpm with an optical tachometer.

A static power check is only good if the power does not exceed maximum ratings of the equipment you are developing near full power. To adjust the power, change the prop or battery. A larger or higher pitch prop gives more load on the motor and therefore more power. A larger capacity battery with lower internal resistance increases the voltage and power. More cells in a pack will have a large effect on the power. Remember that airplanes do not stand still when flying. A prop behaves differently with air moving over it. During a static run, a prop may be aerodynamically stalled and produce little load. At high speed, a prop unloads and the motor turns higher rpm with the lighter load. A static run tells only some of the story, but with the right numbers you can be fairly sure that you will not smoke your new power system and the plane will fly.

Note: Be very careful whenever you run a motor on a model airplane! Use care whenever you have power connected to the motor. ESCs have safety arming devices, but you must keep clear of a prop whenever power is connected. An electric drill motor may not sound dangerous, but a prop rotating at 20,000 rpm can cause serious injury.

Flying

Once you think that everything is ready to go, you need to do a radio check to be sure that there is no serious interference from the motor. You can lose control of your new airplane because of this! To do a range check, have a helper hold the airplane while you test all of the controls at

Heavy, but effective NiCad flight packs.

Links

AXI motors: <http://www.hobby-lobby.com/>
Astroflight: <http://www.astroflight.com>
Electricalc: <http://www.slkelectronics.com>
FMA Direct: <http://www.fmadirect.com>
Medusa Research: <http://www.medusaproducts.com>
Motocalc: <http://www.motocalc.com>
Neu Motors: <http://www.neumotors.com>
Hacker motors: <http://www.hackerbrushless.com>
Northeast Sailplane Products: <http://www.nesail.com>
West Mountain Radio: <http://www.westmountainradio.com>

The West Mountain radio CBA will test just about any battery.

An Astroflight Whattmeter goes in line to measure a power system on the bench.

various throttle settings. Put the transmitter antenna fully down and walk away at least fifty feet and make sure you have no loss of control. If you have any glitches, do not fly. Go back and reconfigure your antenna or motor installation. Keep the antenna away from the motor and ESC wiring. Make sure that your brush motor has suppression capacitors on its terminals.

Flying is the only thing that will tell you how well you made your choices and how well your power system works. If your flight times are less than you expected, or the power drops off rapidly, you may have a battery with low capacity. Check the capacity with a West Mountain Radio CBA. If you find your airplane takes off and climbs very well but it doesn't cruise too fast, you might try a prop with more pitch but perhaps less diameter. If you have the reverse problem, go the other way. If your power system cuts out prematurely, you may have a cooling or over-current problem. ESCs have thermal and over-current protection.

That's it for now. I must go QRT, but look for more on this subject in future columns. Happy flying! 73, Del, K1UHF

By Bob Witte,* KØNR

FM/Repeaters—Inside Amateur Radio's "Utility" Mode

Mountaintop Operating with FM VHF

The warm summer months are upon us, so it is a good time to get outdoors with the FM VHF gear. One fun activity is to find a local high spot for some mountaintop VHF simplex.

Mountaintopping

We generally think of the VHF and higher bands as having "line of sight" propagation. Sure, there are exceptions such as sporadic-*E* propagation, but on a day-to-day basis, VHF is all about line of sight. This naturally drives us to improving our line-of-sight distance by increasing our HAAT, or height above average terrain (photo A).

One of the most well-known and easily accessible mountains in North America, Pikes Peak, is practically in my back yard. At 14,110 feet above sea level, it is not the tallest mountain in North America, but it is one of the most well-known peaks. It is relatively easy to access, since there is a maintained road that allows you to drive to the top. If you don't want to drive up, you can always ride the Pikes Peak Cog Railway. For the physically strong, the Barr Trail provides a not-so-easy hiking route to the summit (10.7 miles and 7400 feet in elevation gain).

Whenever visiting hams find their way to the summit, their next move is entirely predictable—turn on the rig and give a call. During the summer months it is common to hear radio operators call CQ on 146.52 MHz FM from Pikes Peak, testing out their temporary but dramatic improvement in HAAT. This type of mountaintop operating is loads of fun. (Not only is VHF FM the utility mode, it is also the *fun mode*.) You never know who will come back to you . . . someone in nearby Colorado Springs or a station over 100 miles away.

Another popular mountain in Colorado with a road to the top is Mount Evans, at 14,264 feet. The road up Evans is the highest paved road in North America and is in better condition than the Pikes Peak Highway, so we often hear mountaintopping hams calling CQ from that peak. Evans is about 55 miles from my house, and I can easily hear anyone transmitting from that summit.

There are 54 peaks in Colorado with summits that are 14,000 feet or higher in elevation. A popular recreational activity is climbing to the summits of these peaks, commonly referred to as the "fourteeners." These fourteeners range in difficulty from those that can be driven up (Pikes and Evans) to ones that are a serious technical climb. Radio amateurs who also like to climb these peaks usually carry with them a handheld VHF radio. The natural desire of radio hams to operate from a high spot has produced an operating event in August called the Colorado

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e-mail: <bob@k0nr.com>

Photo A. Bob, KØNR, operating VHF FM from a mountain pass near Comanche Peak in Colorado.

14er Event. On a designated day, a bunch of hiking hams go out and operate from the summits of these mountains, working each other and working anyone else within range (photos B and C). While 2-meter FM is the most popular mode, any band or mode can be used.

The Colorado 14er Event is not a contest, but we do have an awards program for contacts with stations on the 14er summits. Contacting 15 or more of the recognized 14er summits earns the Summit Award, while *activating* 5 or more summits qualifies for the Pinnacle Award. These awards can be endorsed for a particular mode, band, QRP, etc. Any contact throughout the year qualifies for the award, not just contacts during the 14er event.

The 2006 Colorado 14er Event will be held on Sunday morning, August 13th. The primary operating hours are from 9 AM to noon local time so that the hikers can get off the summit before the afternoon thunderstorms roll in. See the 14er.org website for more details.

High Points

Not everyone has Pikes Peak in sight of their house, so I started thinking about mountaintopping locations in other states. Some searching on the internet found a great website (America's Roof) that has cataloged the high spot in every one of the U.S. states. In addition, the Highpointers Club was formed to promote climbing to the highest point in each of the 50 states. There is something about the human condition that causes us to establish goals, create lists, and pursue "checking the box" on some arbitrary activity. For hams, it might be making contacts with all of the states to quality for Worked All States. For Highpointers, it means climbing the 50 state high points. I use the word "climbing" loosely, as in many cases you can just drive to the high spot. In other cases it is an easy walk. On the other hand, the high spot of Alaska is Mount McKinley, 20,320 feet in elevation, requiring a trek of 23 miles (one way) . . . a challenging climb.

I took a look at the list of state high spots with an eye toward summertime VHF mountaintop operating. Mount Greylock is the highest point in Massachusetts and is the site of the legendary Mount Greylock Expeditionary Force VHF contesting group. Yes, you can drive up Mount Greylock, so it is very accessible. Mount Mitchell at 6684 feet in elevation is the highest point in North Carolina and the highest point east of the Mississippi River. An observation tower is located at the summit, which can be reached by walking about 0.2 mile. Next door in Tennessee, the highest point is Clingmans Dome, a popular spot in Great Smoky Mountains National Park. This summit also has an observation tower, which can be reached by a half-mile walk. At a much lower elevation, the highest point in Ohio is Campbell Hill, at 1550 feet in Logan County. According to the America's Roof web page, Florida has the lowest high point of all the states, which is Britton Hill, elevation 345 feet.

Take a look at the Americas Roof website to determine the highest point in your state. Of course, the highest spot in a state may not be the best place to try radio mountaintopping. It might not be easily accessible, and it doesn't necessarily have good line-of-sight propagation to populated areas. The Americas

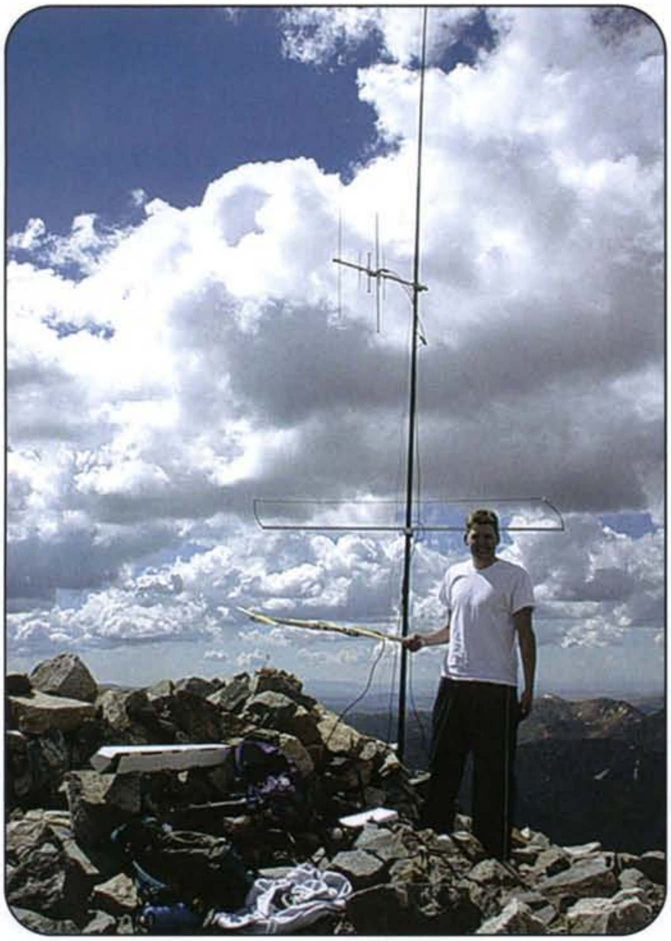

Photo B. Chris, KØCAO, doing some mountaintop operating during the Colorado 14er Event. (Photo courtesy of KØCAO)

Photo C. Peter, K3OG, operating from Grays Peak during the Colorado 14er Event. (Photo courtesy of K3OG)

Roof site also lists the highest 100 spots in each state, which may be helpful in locating a good radio hill. You may already know about some great locations in your corner of the world that would be great for radio mountaintopping. Ask some of the local VHF enthusiasts; it is likely that some of them have already scoped out the best VHF operating locations.

Wilderness Protocol

Summer is a good time to remind everyone of the *Wilderness Protocol.* From the ARES Field Resources Manual:

> The Wilderness Protocol (see page 101, August 1995 *QST*) calls for wilderness hams to announce their presence on, and to monitor, the national calling frequencies for five minutes beginning at the top of the hour, every three hours from 7 AM to 7 PM while in the back country. A ham in a remote location may be able to relay emergency information through another wilderness ham who has better access to a repeater. Calling Frequencies: 52.525, **146.52**, 223.50, 446.00, 1294.50 MHz.

The basic idea is that there are still places on Earth without mobile phone coverage, or even ham repeater coverage. Therefore, give a listen on the standard VHF/UHF calling frequencies. The primary Wilderness Protocol frequency is 146.52 MHz, with the other calling frequencies considered secondary. For completeness, the Wilderness Protocol lists all of the FM calling frequencies for the most common VHF/UHF bands. (One could make the argument that the other calling frequencies are superfluous at best and perhaps an unnecessary distraction.)

In the Fall 2005 issue of *CQ VHF* ("FM Simplex on the Road"), I gave some tips on how to keep an ear on 146.52 MHz when mobile. These ideas apply equally well to mobile and portable operation.

Mountaintop Operating

For summits that you hike to, you'll want to keep your radio gear light. For VHF or UHF FM, the obvious choice is a handheld transceiver. However, the usual "rubber duck" antenna is very inefficient, so consider taking along a more efficient antenna (photo D). Telescopic antennas that are a half-wave on the band of interest usually work particularly well. A small Yagi antenna is another good choice, since it provides gain without being too heavy. Don't forget a spare battery pack or two, depending on how long you expect to operate. It is bad news to be making a run of contacts only to have your battery go dead.

For high points that you can drive to, a mobile station with a reasonable vertical antenna will do the job. Some mountaintoppers take along a portable mast to gain additional HAAT, with either an omnidirectional antenna or a Yagi. If you use the car battery to power the rig, be aware of how long you operate so that you don't run down the battery. (I have this "friend" who did that once.)

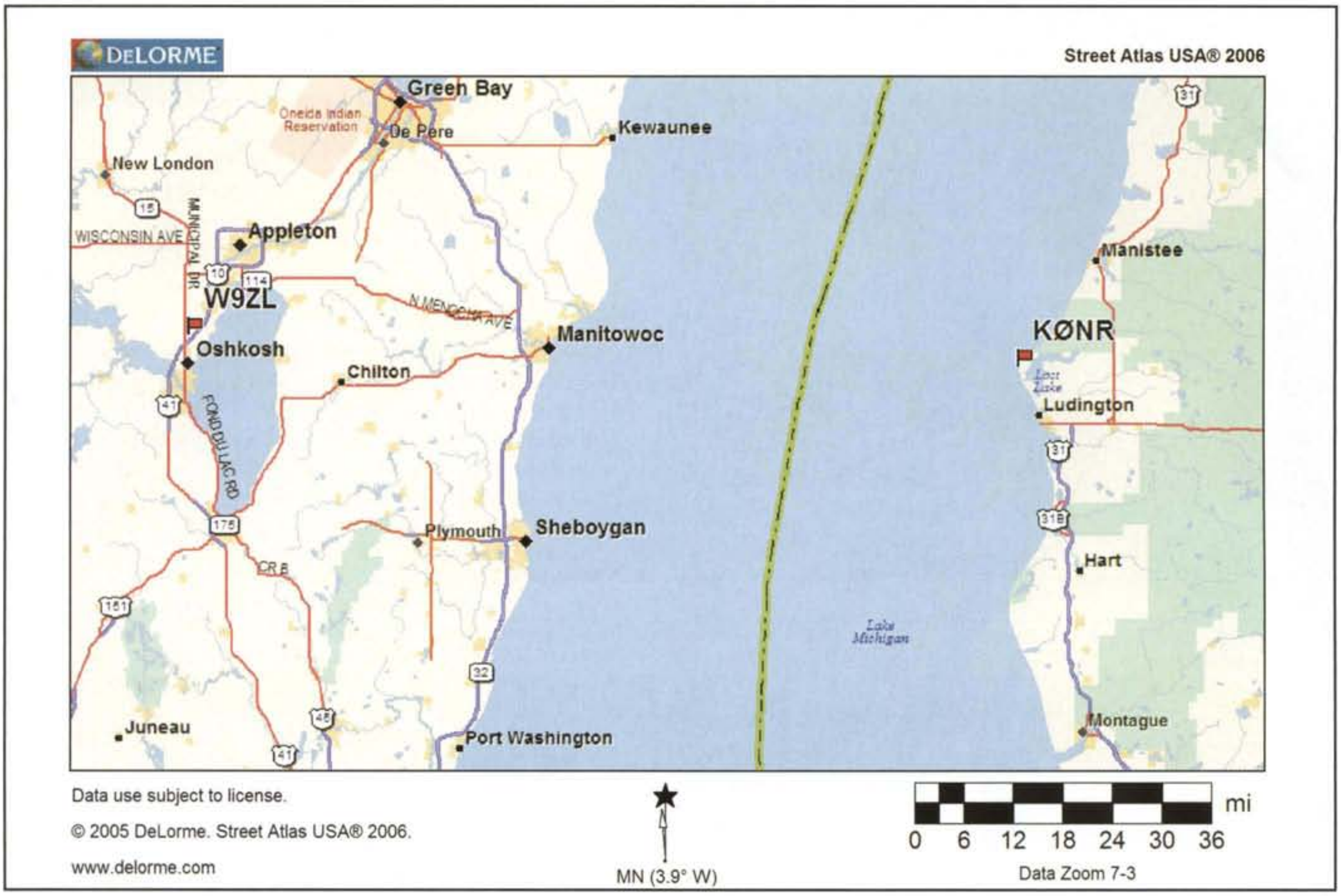

Figure 1. Map of the across-the-water 2-meter FM contact between KØNR and W9ZL.

Beach Operation Across the Water

Summertime operating is not just for the hills. During July 2005, my wife and I were walking along the beach on the eastern shore of Lake Michigan in Ludington State Park to the Big Sable Point Lighthouse. While we waited for the lighthouse to open, I was listening to 146.52 MHz on my Yaesu VX-2R handheld radio. I heard a signal coming through which turned out to be W9ZL calling. This was a special-event station, so I figured they were operating from one of the lighthouses or other location close by.

I wasn't sure where W9ZL was located, but I soon found out that it was the Fox Cities Amateur Radio Club operating at AirVenture, the famous Oshkosh, Wisconsin experimental aircraft show. This special-event station was operated by Bernie, N9YMC. Of course, this was on the "other" side of Lake Michigan, and a significant distance into Wisconsin (figure 1). I worked W9ZL using just 2 watts from the little HT. Later, I calculated that the distance of this QSO was a little over 100 miles, about 60 miles across Lake Michigan and another 40 miles across land. Not too bad for VHF QRP (with FM)!

Calling Frequency

What frequency are you going to use to call CQ from your favorite high spot? Well, the calling frequency, of course—most likely 146.52 MHz. This usually works pretty well, as many simplex-oriented operators make it a point to listen on .52. While we don't normally make long CQ calls on VHF FM, making a call such as "CQ Five Two, this is K Ø N R on Pikes Peak" is a good way to go.

One problem I've run into is when the calling frequency is tied up with lengthy contacts by other hams. If the frequency is in use, I generally just stand by and wait for them to finish. If it seems appropriate, I might break in and chat with them.

Disclaimer: It is difficult to write authoritatively in a national ham magazine about VHF issues that often tend to be regional in nature. What works in rural areas with lower population density may not apply in New York City. Ignoring that, I'll jump in with both feet (maybe with one in my mouth; who knows?).

What is the purpose of a calling frequency? Back in the old days of crystal-controlled rigs, it was important that we had common channels crystalled so we could talk to one another. We typically only had a dozen or so channels, so having a common calling or simplex frequency (or two) was an obvious thing to do. These days, we have synthesized 2-meter FM rigs that cover the entire 4-MHz band in 5-kHz steps. Now the purpose of a calling frequency is, well, for *calling*. You use 146.52 MHz when you want to establish contact on the band, lacking any other information. For example, if I know my buddy Steve, KØSRW, is going to be listening on the 146.94-MHz repeater, I'll call him there. If I know the local DX crew hangs on out 146.46 MHz, I'll make a call there. However, when I don't have any other information, and I am making a call or listening for a call, I go to the calling frequency. Why? *Because that's what*

Photo D. Longer antennas provide better performance than the standard short "rubber duck" antenna.

it's for! If I am out of repeater range and I just want to talk to someone on simplex, I try the calling frequency.

The Three-Minute Rule

There are two ways to make a calling frequency useless:

1. No one ever uses the calling frequency (nobody there, nobody home).
2. The calling frequency is always tied up due to lengthy contacts.

Thus, we need to encourage hams to monitor and use the calling frequency, but not monopolize it. We don't have to be extreme about it. Perhaps a "three-minute" rule of thumb: If I am in a contact with another station on the calling frequency for more than 3 minutes, it is time to change to a different frequency. This opens up the frequency for other hams to use it. Just as important, it keeps the long ragchew sessions away from the calling frequency. These long sessions have a tendency to discourage monitoring of 146.52 MHz. One ham recently told me that he tries to keep a receiver tuned to .52 for anyone just passing through the area who might need some help, but when some of the locals get on the frequency and chat for an hour, the radio gets turned off.

There, I said it: *The calling frequency is for calling, not for ragchewing.*

VHF/UHF FM Calling Frequencies

6 meters	52.525 MHz
2 meters	146.52 MHz
1.25 meters	223.50 MHz
70 cm	446.00 MHz
23 cm	1294.5 MHz

Summary

I hope this article stimulates you to do some portable FM VHF operating. I'd love to hear about interesting hilltops and VHF contacts that you've experienced. Let me know if you have thoughts on the use of 146.52 MHz. Whatever you do, get outside, turn on the radio, and have some fun. Also, visit my weblog at <k0nr.blogspot.com>.

73, Bob KØNR

References

The Pikes Peak website: <http://www.pikespeakcolorado.com/>.
Colorado 14er Event website: <http://www.14er.org>.
Americas Roof (high points in 50 states): <http://americasroof.com/usa.shtml>.
Highpointers: <http://highpointers.org/>.
Mount Greylock Expeditionary Force (W2SZ/1): <http://www.mgef.org>.
ARES Field Resources Manual: <http://www.arrl.org/FandES/field/aresman.pdf>

Photo E. Bob, KØNR, making 2-meter FM contacts with a hand-held radio at the Big Sable Point Lighthouse. (Photo courtesy of KAØDEH)

By Tomas Hood,* NW7US/AAAØWA

PROPAGATION

The Science of Predicting VHF-and-Above Radio Conditions

The New World of VHFing

High-frequency radio enthusiasts can hook up a light bulb and communicate with the world, when propagation conditions are "just right." Better yet, just string up some wire, tune it up to a transceiver, and talk around the world.

At least, that's how things work from the perspective of DXers enjoying the worldwide around-the-clock excitement of HF signals propagating when the Sun is popping with flares and peppered with sunspots during the peak years of a solar cycle. However, this cycle is just about at its end, and quiet solar conditions have all but put a wet towel on worldwide around-the-clock HF propagation.

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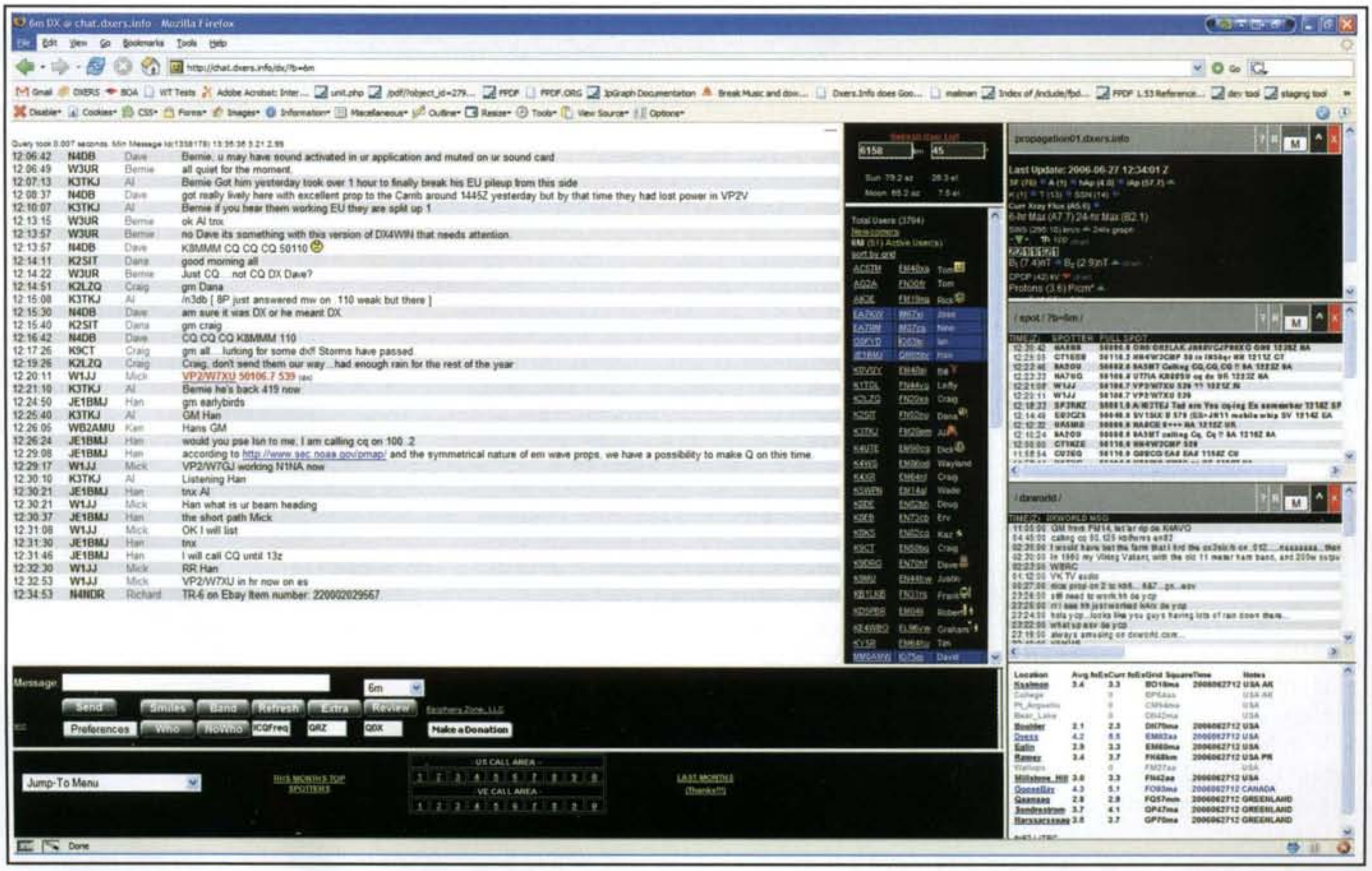
While HF radio DXers long for the coming upswing of the next solar cycle, Cycle 24, rumor has it that the folk on VHF and higher frequencies are out in full force, working "real radio." They cook their meals in front of their portable parabolic dish antenna, while trying to set new distance records. They bounce signals off the moon or off plasmatic meteor trails. Their DX is a raspy-sounding Morse code signal propagated by way of backscatter, aurora, and sporadic-*E*. A VHFer has to have more than a wet noodle or the losses will make the antenna system nothing more than a dummy load (at best, although read about a VHFer who could work a local repeater using a wet T-shirt).

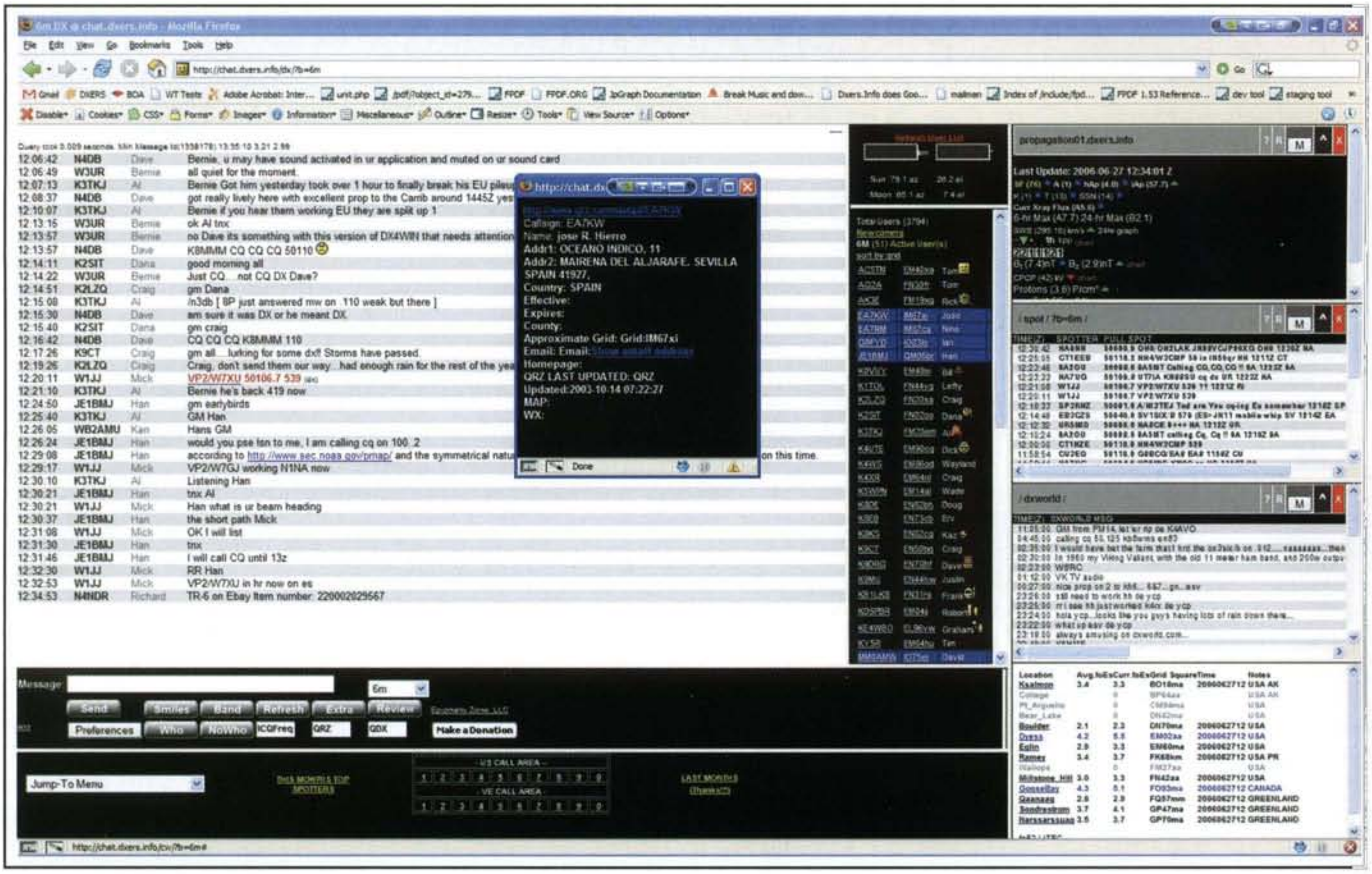
Propagation on VHF and above is not quite the same as it is on HF. Sure, *F*-layer refraction takes place at times on 6 meters and a bit higher, and it is true that sporadic-*E* works on HF, but there is a whole different and exciting set of modes and techniques unique to VHF and up.

Is it possible to predict propagation conditions and DX openings on the frequencies above 30 MHz? Are there reliable models that enable us to forecast sporadic-*E*, aurora, tropospheric ducting, and other known (or unknown) propagation modes?

After many decades of on-air experience, the amateur and scientific communities are still struggling to find a practical understanding of the complex modes of propagation unique to VHF and above. While decades of weak-signal and long-range (DX) operation on VHF exist, most of this historical information is contained in contest and special event logs. More



The live display of 6-meter operators as spotted and mapped at the <http://chat.dxers.info/> site that Tim Havens, NN4DX, provides to the VHF community.



Looking up a callsign of a spotted 6-meter operation on QRZ is as easy as a mouse click. (Image from <http://chat.dxers.info/>)

significantly, most of this historical data is sparse and the number of operators limited. There has been no historical, worlwide data, simply because there hasn't been a large enough population of VHF operators active in weak-signal long-distance DXing. The research done by the scientific community is helpful, but also limited to very specific research. There is a great opportunity for us amateur radio scientists to unlock the secrets of propagation on these higher frequencies.

True worldwide exploration of propagation on the amateur bands above 30 MHz has only recently become a reality. The number of active, on-air amateurs on VHF/UHF has only recently reached a level high enough to support true research of regional, national, and worldwide VHF/UHF DX. A concerted effort is under way to record daily activity worldwide. More accurate DX clusters where grid-square information is recorded for both ends of the QSO, e-mail reflectors and on-line forums for real-time discussion of current conditions, and repositories of logs are all ways we are increasing our knowledge. In addition, detailed geomagnetic and solar data is at our disposal through the internet, as well as real-time monitoring of the ionosphere, weather, and propagation.

An Example of the New World of VHFing

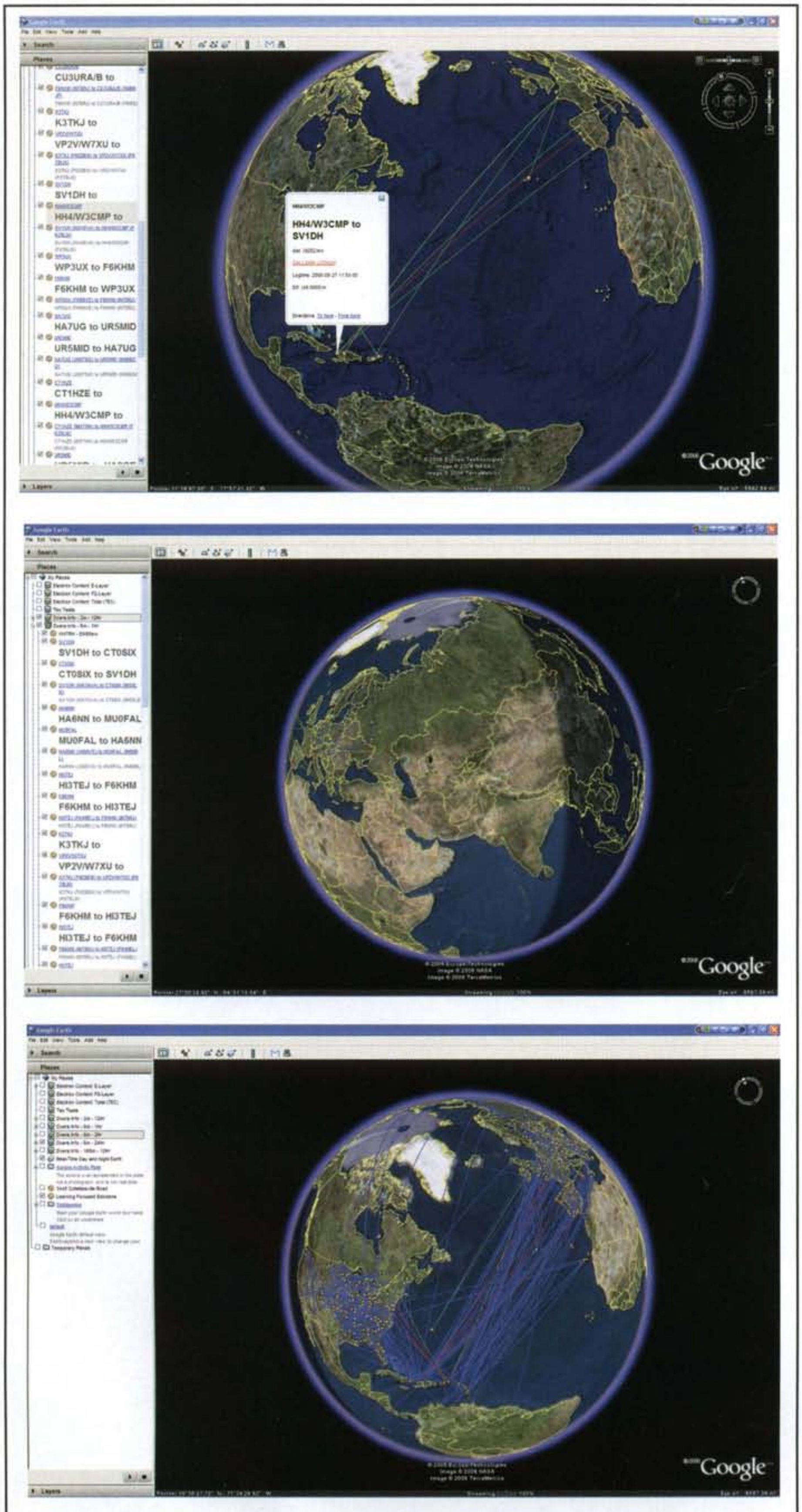
Back in November of 2000, Tim Havens, NN4DX (then N1RZ), living in northern FN44 (Whitefield, NH) started a basic internet chat website that catered to some of the specific needs that very active 50-MHz experts had requested. Along with this functionality and links to other informational websites, Tim provided website tools to calculate Maidenhead Grids from latitude and longitude coordinates and to view calendar dates when the moon would be visible for earth-moon-earth (EME) operations.

When some of the content found on various other websites became stale or unavailable, Tim decided to start getting involved with locating root sources for the data that VHF operators rely on when determining propagation conditions on 50 MHz.

Some of the propagational indicators were so reliable that he was able to provide alert information as to when possible sporadic-*E* (*Es*) might exist, or when auroral conditions were optimal for 50 MHz and above.

In mid-2001 Tim was working for a maps-and-driving-directions company <www.mapblast.com> and got the idea that he could take spotted packet traffic and show their great-circle shortest radio paths by using maps that plot in real-time where the VHF signals were propagating. Today, the maps that Tim's tools create are updated every minute of the day with nearly-real-time data. This most likely was the first web-based map representing DX packet cluster data. The map site is hosted at <http://maps.dxers.info/>.

This site started out as a simple chat website and then evolved into a mapping site which has the ability to allow hams to visualize the live paths as they are occurring and to allow them to make wiser choices as to how they can best take advantage of current conditions. Likewise, many hams have come to know that if nothing is showing on these maps, most likely conditions are quite flat. Many of the world's premiere DXpeditioners stay in close contact with the community found at Tim's site in order to maximize the expeditions' exposure and improve their log book line counts.



Examples of Tim's Google Earth DXers (spot and QSO) plot. (Images courtesy of Google Earth/Tim Haven)

Dxers.info is to the 6-meter operator what the Yagi is to the transceiver. Nowadays in this ever-changing, technologically advanced age, serious 6-meter DXers are using every tool at their disposal to gather and exchange information about possible 6-meter DX paths. More than ever before, rare DX operations "check in" from some remote spot on the globe and learn and talk to the rest of the 6-meter community. Then they go on to make actual QSOs, because they are armed with the knowledge of when and where to look for openings and stations to work. In decades past, many rare or remote HF DX stations tried turning on the 6-meter rig once or twice, but then gave up as they failed to make any contacts, let alone hear any activity (yeah, I am even guilty of that).

Now, due in large part to Tim's project, there are much fewer of those stations failing on 6 meters. Efforts by these operations are succeeding and the operators are becoming among the converted! Also, when there's no propagation on VHF, the community bands together at Tim's site and talk with "the guys" (we need more ladies on the DXing segments above 30 MHz!) about 6 meters and the required equipment. This is crucial to operator skill enhancement and station development.

As Dan O'Connell, WA7TDZ (CN92, Oregon), testifies, "Without a doubt, Tim has created a world-class website that not only encompasses a different real-time chat room for each VHF band, but also a magnificent real-time world map, showing the QSOs currently taking place. This marvelous tool is unprecedented for understanding current conditions, especially for *Es* on 6 meters, but also is especially helpful in forecasting when conditions may be especially good for your location. The ability to actually talk to the DX operator at the same time is especially helpful in 'snagging' that new one."

Recently Fusion Numerics <http://www.fusionnumerics.com/> based in Boulder, Colorado made available a web service which allows Tim's site to be able to query various altitudes around the entire globe for the Total Electron Content at a given altitude. Tim is able to demonstrate this using Google Earth. The results are very interesting at foEs (the maximum ordinary-mode radio frequency that is refracted by a sporadic-*E* cloud in the *E* layer of the ionosphere) and foF2 (the maximum ordinary-mode radio frequency that is refracted by the *F2* layer of the ionosphere). The results have proven to be powerfully useful in spotting DX openings, especially when the maps plot radio paths that have been reported by packet cluster spotters. Tim's Google Earth (see <http://earth.google.com/>) project site can be viewed at <http://www.dxers.info/google/earth/> along with some helpful tips on its use.

Over the past six years the site has grown to a group of about 3800 registered users. Most of these operators are very active at 50 MHz and above. Many are also active EMEers. Alan Benoit, WQ5W, reports how critical Tim's project has been in his activities:

The 2006 *Es* season opened up very promising, much better than 2005, from here. We had several nice Caribbean openings and even an opening into EA8. However, nothing could have prepared me for the incredible opening to JA the evening of Sunday, June 4.

The prelude to the opening was pretty normal. Sunday morning we had a nice stateside opening and EH8BPX was readable for a few hours straight and we had QSOs at 14:46Z and 17:29Z. Several 5's also reported working into CT3 and CT but I couldn't hear them. In the afternoon, the band opened to the Caribbean and I worked FY1FL for a new one at 21:51Z.

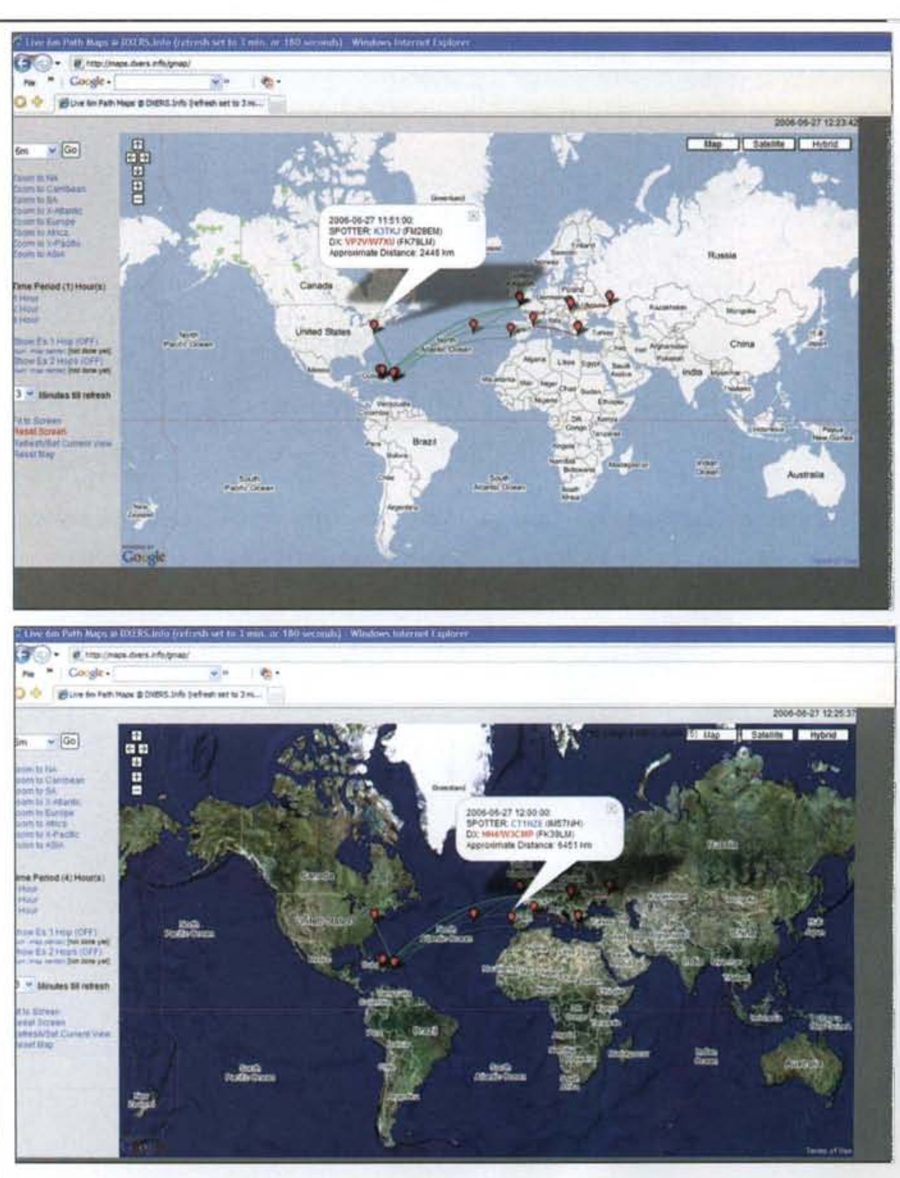
What happened next was the most incredible thing I have ever experienced on 6 meters. I was about to shut down the rig and go out for the evening when I checked the DX cluster one final time at around 5:15 PM local (22:00Z). I noticed with interest that NL7Z in Alaska was being worked in west Texas on SSB. I had only worked one KL7 on 6 meters ever before that—and that QSO was after midnight local time—so I had to give a listen to see if I could hear him. Sure enough, he was a solid 5-7 and he responded to my call immediately.

I then saw on [Tim's] 6-meter chat room page <http://chat.dxers.info/?b=6m> that JH2COZ was going to call CQ on 50.096 CW. I had never worked or even heard a JA on 6 meters, so I didn't think much of it, but I figured, "What the heck? I'll listen for a couple of minutes before heading out the door."

So, I tuned to 50.096 and to my amazement there was JH2COZ calling CQ with a solid 559. I gave him a call and he came back immediately and I had worked my first JA ever! I then went up the band and started calling CQ and had many JA's come back to me!

Over the [nearly] next three [and a half] hours I worked 42 JA stations in 10 different grids! The signals were on the weak side in many cases, but all were solid Q5 copy. They were much stronger and more readable than

Example of Tim's Google Earth DXers (spot and QSO) plot showing aurora-mode (AU) activity as well as the auroral oval. (Image courtesy of Google Earth/Tim Haven)



Examples of VHF DX spotting maps with spot information shown in a pop-up box. (Images from <http://maps.dxers.info/>) →

the often ESP copy we get on EU stations from here. It felt and sounded very much like the 10-meter JA runs we get in contests at the top of the sunspot cycle. A couple of times during the run I thought it was over, only to have more JA's come back to my CQ's a few minutes later.

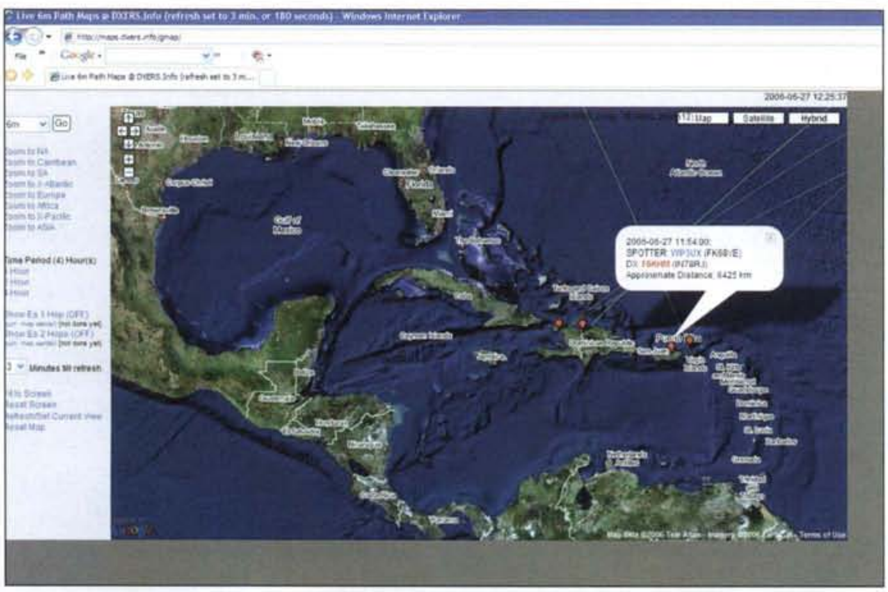
In between the JA's, I also worked KL8DX and several VE7's. I worked my last JA at 01:51Z. It was a great experience sharing the thrill of this opening with the guys in [Tim's] 6-meter chat room. They seemed to be as thrilled and amazed as I was about this. Their encouragement and kind words made the experience even better!

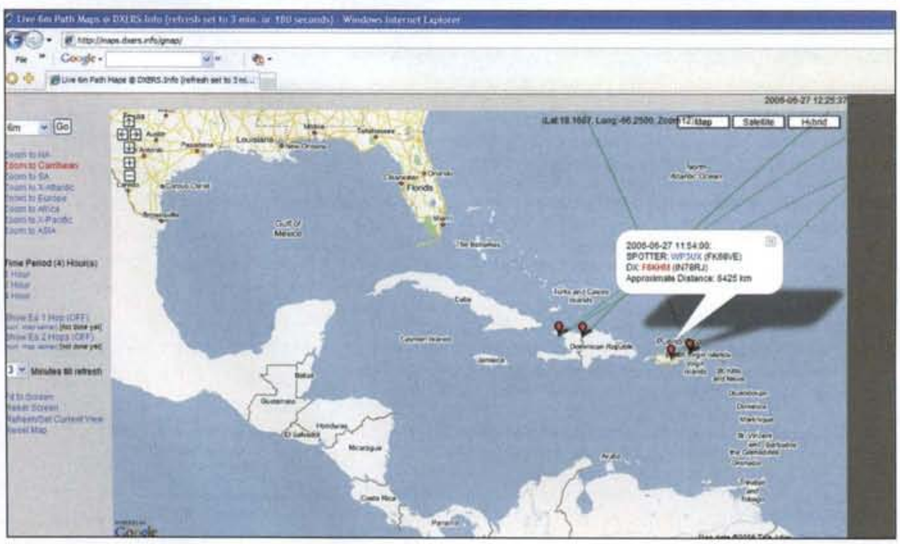
Looking back at my log, the distances worked were between 6166 and 6567 miles. This is incredible considering that at this part of the sunspot cycle and time of the year this had to be sporadic-*E* propagation. This would suggest 4–5 hops of at least 1500 miles on these QSOs. A lot has to go right for this to happen. Some of the more experienced locals tell me that this kind of *Es* opening to JA hasn't happened in Dallas-Fort Worth since the late '70s. I feel very lucky to have been a part of it and won't ever forget it!

As a footnote, the next night there was a JA opening that extended into Arkansas, Oklahoma, Missouri, and Illinois with stations even as far east as Florida working JA. I never heard any signals that night despite constant tuning to the DX spot frequencies. Oh well, no complaining; that's 6 meters!

There are alerts posted in the chat area of Tim's site that draw your attention to things such as spikes in the foEs and foF2 at the global ionosonde sites. (For a basic understanding of what an ionosonde is, refer to <http://www.wdc.rl.ac.uk/ionosondes/ionosonde_basics.html>.) Many of these sites can be seen by clicking on the blue circles of the <http://maps.dxers.info> pages.

Tim's site also reveals that many hams are interested in auroral propagation and monitoring things such as Cross Polar Cap Potential (CPCP) <http://www.dxers.info/reports/prop/cpcp.html>. These tools all are intended to allow you to make educated guesses at what is currently occurring in the ionosphere and to help you make informed choices as to how you can best exploit these conditions to fulfill your DXing desires. Visit Tim's site <http://www.dxers.info/> and see what's new!





Perseid Meteor Shower

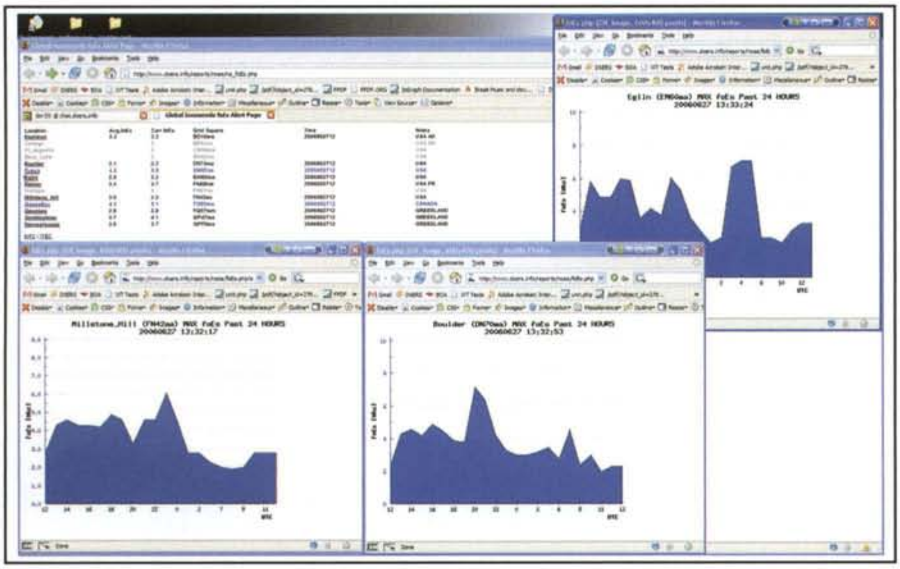
One of the most reliable yearly meteor showers is the *Perseid.* The *Perseid,* like other meteor showers, is named after the constellation from which it first appeared to have come. This shower's constellation is Perseus, which is located near Cassiopeia. *Perseids* favor northern latitudes. Because of the way Comet Swift-Tuttle's orbit is tilted, its dust falls on Earth's Northern Hemisphere. Meteors stream out of the constellation Perseus, which is barely visible south of the equator.

Lewis Swift and Horace Tuttle, Americans working independently, discovered a comet in August 1862. Three years later Giovanni Schiaparelli (of Martian "canali" fame) realized it was the source of the August *Perseid* meteors. The comet, known now as Comet Swift-Tuttle, leaves a trail of dust that Earth passes through during August.

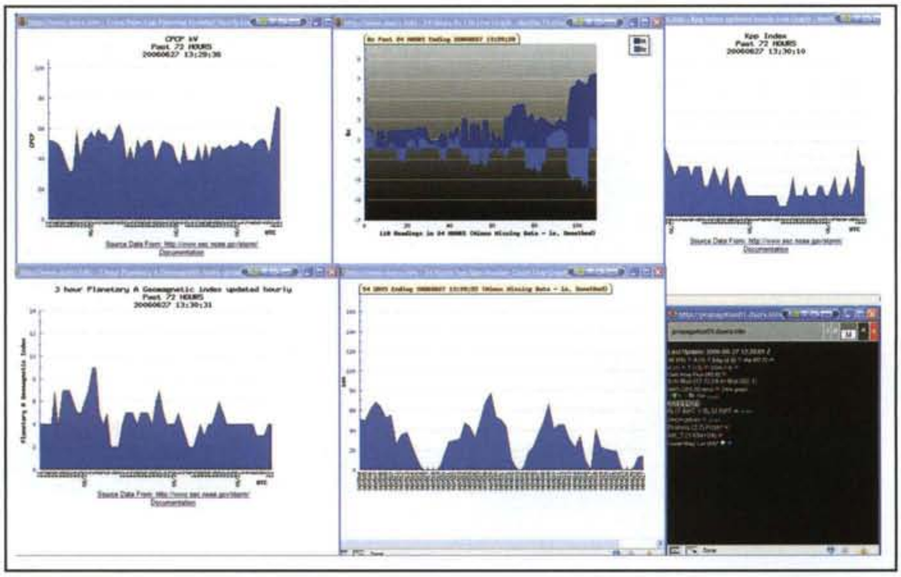
This year, the *Perseids* should peak between 2300 UTC August 12 and 0130 UTC August 13, although other peaks on August 13 are expected at around 0200 UTC and again at 0900 UTC. Simulations made by Peter Brown a few years ago suggest that enhanced *Perseid* activity is possible this year. However, it is not expected to be as strong as the 2004 shower. The number of visual meteors is expected to be about 100 per hour. It is possible, using high-speed CW, to realize a much higher hourly rate, since many meteors that are not visible might contribute to the ionization necessary for long-distance contacts.

The *Perseid* shower begins slowly in mid-July, featuring dust-size meteoroids hitting the atmosphere. As we get closer to August 12, the rate builds. For working VHF/UHF meteor scatter, this could prove to be an exciting event.

The best time for working the *Perseid* VHF/UHF meteor scatter in North America is during the hours before dawn, as early as midnight, but more likely peaking after 2:00 AM until about 5:00 AM local time.



Ionosonde-based charts showing sporadic-E conditions. (Image from <http://maps.dxers.info/>)



Additional propagation charts at Tim's <http://www.dxers.info/> website.

The characteristic *Perseid* burn is bright white or yellow and typically lasts less than a half second. The brighter meteors usually leave a persistent train or "smoke trail" that lasts a second or two after the meteor has vanished. This is not really smoke at all, but rather ionized gas created by the meteor passing through the atmosphere at tremendous velocities. It is this trail that potentially reflects the VHF radio signal.

Other Meteor Showers of Summer

There is very little anticipation of significant *Draconids* activity this year. The *Draconids* is primarily a periodic shower that produced spectacular, brief meteor storms twice in the last century, in 1933 and 1946. Most recently, in 1998, we saw a moderate peak of a ZHR (zenith hourly rate) reaching 700. This was due to the return of the stream's parent comet, 21P/Giacobini-Zinner, returning to perihelion. If there is an outburst of activity, the possible peak timings would span 1430 UTC and 2220 UTC on October 8, to 0407 UTC on October 9, 2006. The *Draconid* meteors are exceptionally slow-moving, a characteristic that helps separate genuine shower meteors from sporadics accidentally lining up with the radiant. This is a good shower to work meteor-scatter mode, since we might see storm-level activity this year.

Meteor activity improves substantially for the *Orionids* later in October. The *Orionids* shower is active from October 2 through November 7, peaking on October 21 at 2000 UTC. The hourly rate could reach about 30 meteors per hour this year. This is expected to increase in the next two years.

For more information, take a look at <http://www.imo.net/book/print/838>. Go to <http://www.meteorscatter.net/metshw.htm> for a very useful resource covering meteor scatter and upcoming showers.

The Solar Cycle Pulse

The observed sunspot numbers from April through June 2006 are 30.2, 22.2, and 13.9. The smoothed sunspot counts for September through December 2005 are 25.9, 25.5, 24.9, and 23.0.

The monthly 10.7-cm (preliminary) numbers from April through June 2006 are 89.0, 81.0, and 80.1. The smoothed 10.7-cm radio flux numbers for September through December 2005 are 87.8, 87.4, 86.7, and 85.4.

The smoothed planetary *A*-index (*Ap*) numbers from September through December 2005 are 11.8, 11.6, 11.1, and 10.4. The monthly readings from April through June 2006 are 11, 8, and 8.

The smoothed monthly sunspot numbers forecast for August through October 2006 are 10.5, 10.3, and 9.1, while the smoothed monthly 10.7 cm is predicted to be 73.7, 72.7, and 71.5 for the same period. Give or take about 12 points for all predictions (that means that the smoothed sunspot figures could be zero for any of these months, since we are now at solar cycle minimum).

(Note that these are preliminary figures. Solar scientists make minor adjustments after publishing, by careful review.)

Feedback, Comments, Observations Solicited!

I am looking forward to hearing from you about your observations of VHF and UHF propagation. Please send your reports to me via e-mail, or drop me a letter about your VHF/UHF experiences (sporadic-*E*, meteor scatter?). I'll create summaries and share them with the readership. I look forward to hearing from you. You are welcome to also share your reports at my public forums at <http://hfradio.org/forums/>. Up-to-date propagation information is found at my propagation center, at <http://prop.hfradio.org/> and via cell phone at <http://wap.hfradio.org/>.

Until the next issue, happy weak-signal DXing. 73 de Tomas, NW7US

Six Meters *(from page 7)*

ers. One is at 75 feet and the other is at 40 feet. Interestingly enough, for the majority of QSOs I used the 40-foot antenna, as it produced the best signal-to-noise ratio, due to the fact that signals were equally strong on both antennas, but the 40-foot antenna was quieter. However, as the opening closed, the antenna at 75 feet was the best, as signals disappeared from the 40-foot antenna. *(Editor's note: Alan uses a Kenwood TS-2000 plus a Commander VHF1200 amp at 1 KW.)*

Looking back at my log, the distances worked were between 6166 and 6567 miles. This is incredible, considering that at this part of the sunspot cycle and time of the year this had to be sporadic-*Es* propagation. This would suggest 4–5 hops of at least 1500 miles on these QSOs. A lot has to go right for this to happen. Some of the more experienced locals tell me that this kind of *E* opening to JA hasn't happened in Dallas-Fort Worth since the late '70s. I feel very lucky to have been a part of it and won't ever forget it!

As a footnote, the next night there was a JA opening that extended into Arkansas, Oklahoma, Missouri, and Illinois with stations even as far east as Florida working JA. I never heard any signals that night despite constant tuning to the DX spot frequencies. Oh well, no complaining. That's 6 meters!

All told, Alan worked 42 Japanese stations via CW over a period of three hours and 24 minutes. Distances ranged from 6166 to 6500 miles. He worked the JA1, JA2, JA3, JA7, JA9, and JAØ call areas, covering the following grids: PM84, PM85, PM86, PM94, PM95, PM96, PM97, QM05, QM08, and QM09. Another Texas station that worked into Japan on June 4th was K5RLA, Carla Dyer, who used 100 watts into a 6M7JHV antenna at 50 feet to work (beginning at 2325 UTC) JHØRNN, followed by JA7QVI and JA7SJI.

This opening was not confined to just Texas, as Jon Jones, NØJK, in Kansas managed to get in on the action. His job required him to work on the weekend, so during breaks he set up a homemade two-element Yagi on a mast that connected to the radio in his car while parked on the top part of a parking garage. Jon had a break late in the day on the 4th, and at 2341 UTC on 50.100.6 MHz he worked JA7QVI (QM08) on CW; 559 reports were exchanged both ways. Jon notes that he probably would not have been able to make the QSO with a vertical roof-mounted antenna on his car and that the portable beam design that he used (using plans from the book *Six Meters, A Guide to the Magic Band,* by WB2AMU and available from Worldradio books), gave him enough punch to complete the contact (photos B and C).

A number of operators have to rely on portable and mobile setups in order to operate on 6 meters because of work situations or antenna restrictions in their area. The 6-meter band is great for these hams! It does help, though, when one station in a long-range QSO has a super antenna setup such as that of JA7QVI.

There was be even more activity the next day, with another U.S. to Japan opening on 6. This time veteran 6-meter operator Rick Roderick, K5UR, from Arkansas was involved. Rick had worked some of the JA stations the day before, so he was on the lookout for more of the same. This time Rick worked over 130

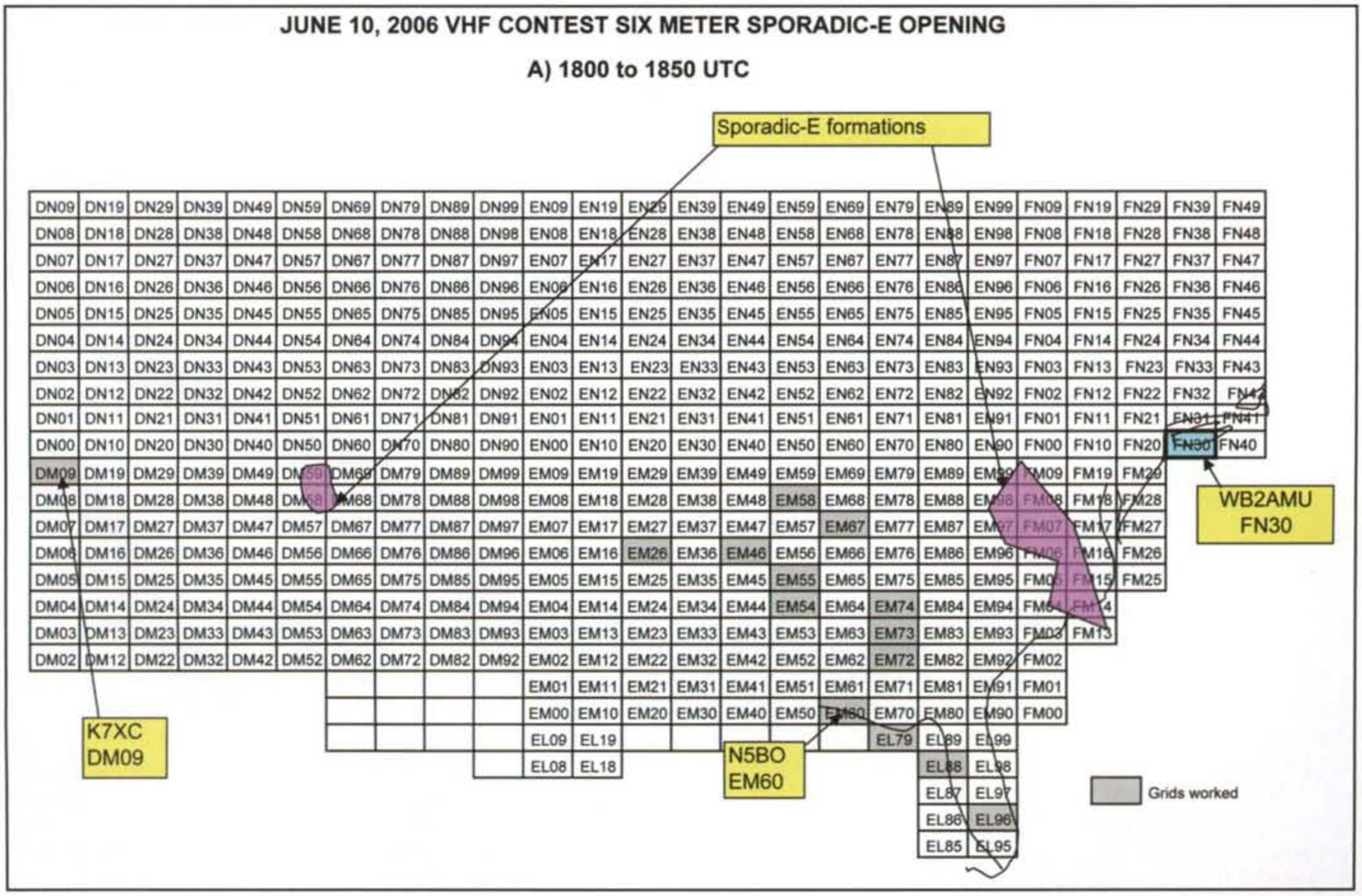


Figure 2A. This is the opening hour of the ARRL June VHF Contest. Using the midpoint method, a rough mapping of the sporadic-E formations can be created. N5BO is highlighted on this map for reasons that will be seen in the next figures, where the conditions change when the formations move north.

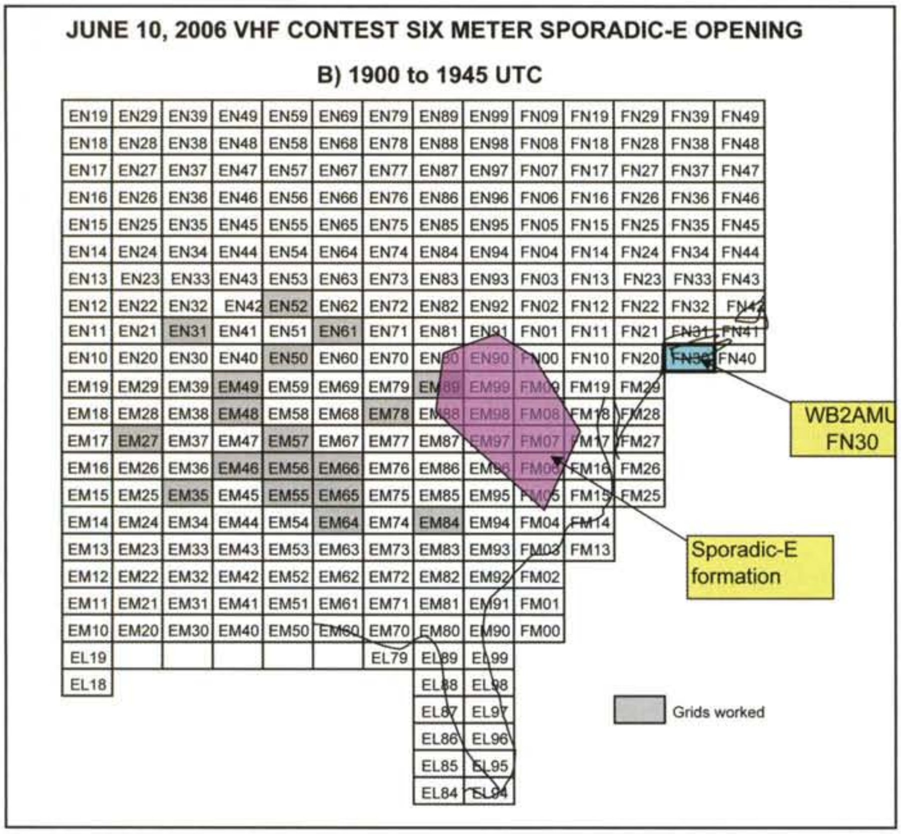


*Figure 2B. Here the sporadic-*E *formation in the east has moved northward, causing the loss of conditions between the southern tier stations and the northeast U.S. The western sporadic-*E *formation has dropped out but will reappear shortly.*

JA's in a solid run for almost two hours (from 2353 UTC, June 5 to 0145 UTC, June 6). His first JA was JA9LSZ, and many of the subsequent stations were loud (over S9). Rick noted that the pile-up was huge. He could have worked split frequency if he had wanted to, as at times there were so many stations calling.

EU to NA Openings

In the summers of 2004 and 2005, transatlantic 6-meter QSOs were not too plentiful, even in the northern tier states of the U.S. and northeast Canada. June 2006 saw a welcomed change in this trend.

Throughout the month of June there were openings between Europe and North America. One opening occurred on June 9th, when Pat Rose, W5OZI, in Texas worked into western Europe and had QSOs with G3WZT, ON4IQ, CT1HZE, and EA7KW. K5RLA worked ON4IQ on June 9th as well.

Another interesting opening took place on June 12th at 1200 UTC, when Bob Billings, VE1YX, worked a string of 30 western European stations in the UK, Italy, and a few in Hungary in a period of 20 minutes on SSB 50.115 MHz! It appeared that this would be a better summer for transatlantic sporadic-*E*.

One thing that seems to be consistent is a number of these openings appear to be narrow in scope. For example, when VE1YX works into Europe, Lefty Clement, K1TOL, in Maine (grid FN44) does not always hear Europe at the same time, and vice versa.

June VHF Contest Report

The 2006 ARRL June VHF Contest was the weekend of the 10th and 11th. With June VHF contests we always hope for a major sporadic-*E* opening to increase the number of stations that can be worked, in addition to those that are worked by line-of-sight. For the past few years, the June event has predominantly been a line-of-sight affair for many in the U.S. and Canada, with occasional one-hour sporadic-*E* openings. In June 2005, there was a major aurora opening for the last part of the contest, and it covered much of the northern U.S. and Canada.

Every once in a while, you have that dream opening on 6 meters during a major contest. In the past, I actually had a few good sporadic-*E* openings that occurred during the VHF contest, but for the most part these openings tended to be of short duration and maybe a handful of stations were worked. Prior to June 2006, the last great June VHF contest opening that I had was during the first two hours of the June 1991 event.

Prior to the beginning of the 2006 contest, I worked a station in Missouri while mobile. I thought that at least there was the possibility of a decent sporadic-*E* opening during the contest.

I operate in the QRP portable category, and I go to the nearest hill here on Long Island. It is 250 feet high with good line-of-sight in all directions. It took about ten minutes to set up a three-element Yagi on a mast at 10 feet in an umbrella stand with a Yaesu FT-690 hooked to a portable battery. I could not set up the antenna any higher, since it was very windy. With about three minutes to spare, I could hear that there were already some strong signals breaking through on 6 meters.

When the contest began at 1800 UTC, there was bedlam on 6 meters. Activity extended from the bottom of the band all the way up to 50.310 MHz! I used the two VFOs on the FT-690, with one set in the SSB portion and the other in the CW portion of the band. I was constantly switching between the two VFOs, because as a QRP operator, I knew that I could not hold a frequency, so I had to resort to search-and-pounce tactics.

I was having very good success running CW and surprisingly also SSB, particular in the 50.200–50.300 MHz range. Double-hop sporadic-*E* was coming in, and I picked up Tim, K7XC, in DM09 on CW 20 minutes into the contest! For the first hour I worked many different grid squares at a good clip, initially into the EM and EL grid fields. By the second hour, I was working EM and EN grid fields.

I fully expected the opening to fade after an hour or so, but surprisingly it kept going for several hours. During the second hour (1900 UTC), I ran a string of 33 stations, which is a very good rate for a QRP station. At two hours into the contest I worked three stations consecutively via double-hop sporadic-*E*: W7GJ (DN27), VE5ZX (DO62), and VE5UF (DO61). It was truly amazing how my puny 10-watt signal broke the pile-up of two-land stations on W7GJ, Lance Collister. I realized that I had no hope of breaking the pile-up on SSB, so I used a standard QRPer technique of calling Lance on CW. On the second shot Lance said, "Who is that station on CW?" Then

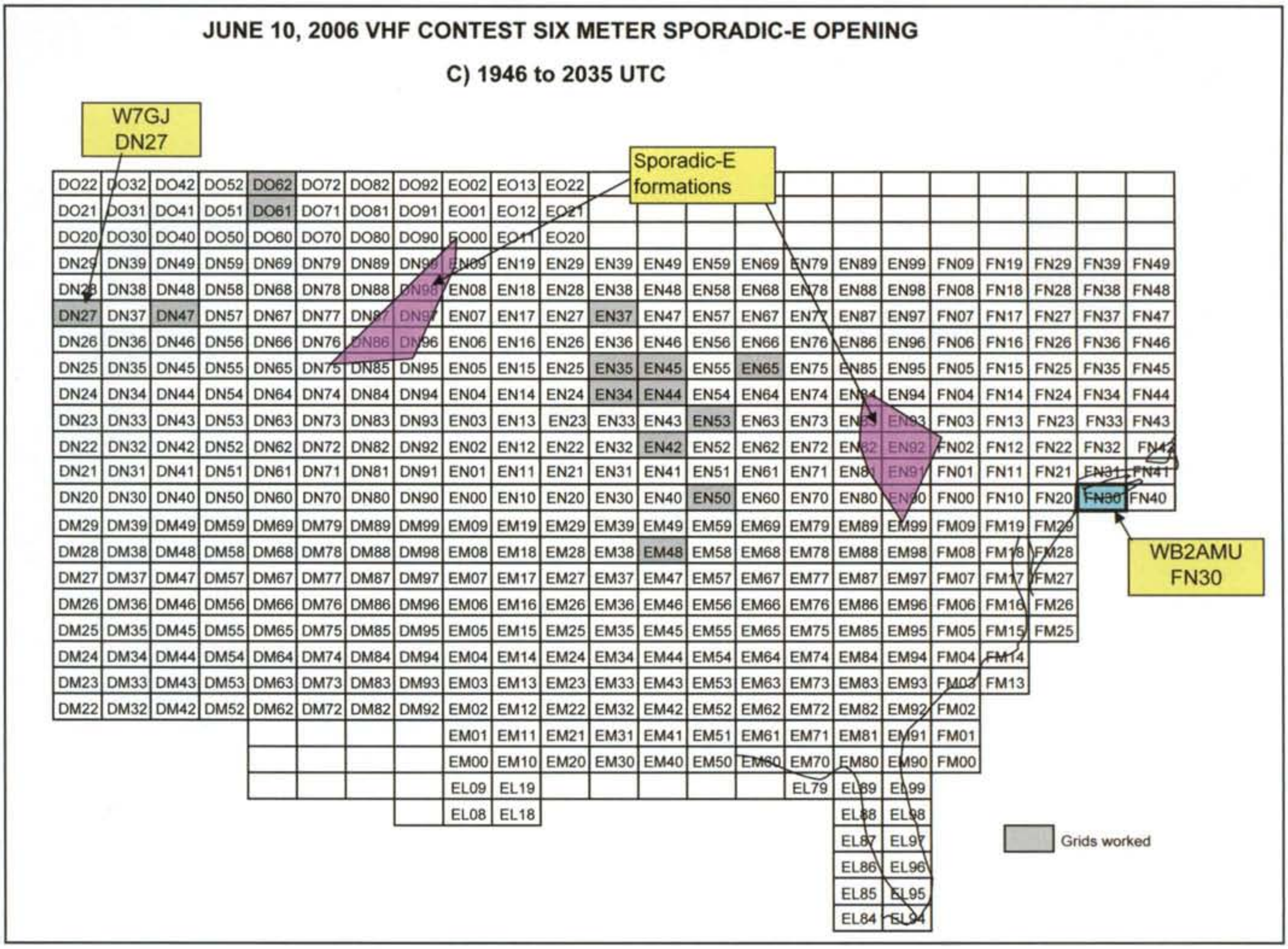


*Figure 2C. About two hours into the contest both active sporadic-*E *formations in the U.S. have continued to move toward the north, and by this time stations in Montana can be worked by WB2AMU. In another hour WB2AMU is able to work double-hop into the CN grid field in the state of Washington running QRP!*

I came back and he worked me, despite the fact that there were kilowatt stations calling him on SSB!

Lance wrote to me after the contest: "Yes, many thanks for calling on CW! You couldn't believe the QRM! I have never had a double-hop opening like that in my 10 years on 6 meters. Often I could get only one or two letters of a call. I was amazed how strong the stations actually were when they were calling one at a time! Even stations I could barely discern through the QRM were S9 when everyone else stood by!"

I also worked another station in Montana via two-way SSB—K7BG in DN47. Unfortunately, I missed K7USB in DN17 at around the same time. I have never heard so many stations on 6 meters in my life, except for Field Day 1998. There were between five and ten stations at a time on CW in the CW portion of the band and the QRM was incredible, making it

The three-element MFJ Yagi that WB2AMU used during the June VHF contest from his portable location on Bald Hill in Farmingville, Long Island. He could only get the antenna up 10 feet in the air on that Saturday, because the winds were very strong.

The FT-690 six-meter radio that WB2AMU used in the contest. The radio has 10 watts output, but that did not seem to be an issue with the good openings that were present.

hard to copy some stations, particularly if there was QSB on the signal. I worked stations as high in the band as 50.310 MHz, for example N4JH.

There were also a lot of rover stations in the 4-land call area that were ready to be worked! One station that I worked from EM73 was AF4OD, Bill Capps, and he reported the following:

> I was running behind on my planned schedule for the contest. I left home about 2 hours late. I was busy trying to get transverters for 903 and 1296 running. I'm not a super technician; I can hook up some wires and hope for the best. I left my QTH here in Auburn, Alabama (EM72)and was planning to drive all the way to Tennessee to grids EM65 and EM75 to begin the contest there. During the entire drive north I monitored 6 meters and the band was full of stations.
>
> Since I was behind schedule, I located a large field beside a manufacturing plant in EM73 just 10 minutes prior to the contest. I pulled into the field and used my KU4AB loop on the back of my Suburban to work around 60 QSOs in the first hour. I was CQing around 50.225. There were lots of people calling. After about an hour, I noticed a slowdown in QSOs, so I quickly drove to another grid, EM63, which was about 10 minutes away, and made some more QSOs. I'm still learning how to be a rover station, as I can't seem to get all the QSOs and multipliers that other rovers get. My score was in the 31,000 area, with about 225 QSOs overall and I forget how many multipliers I worked.

After the contest, Justin Fountain, N5BO, from EM60 in Florida, reported to me that he had solid signals for the first hour of the contest, and then there was minimal sporadic-*E* activity on 6 meters for the next several hours. Indeed, from both Justin's and Bill's reports, and as shown in figures 2A, B, and C (covering the first three hours of the contest), the sporadic-*E* formation located in the eastern U.S. was moving northward, and both N5BO and AD4OD would lose out on a lot of the skip QSOs. It is also noted that the western sporadic-*Es* formation was in and out, and it too was moving northward.

I had to take a short break to run an errand, and when I came back to the hill at 2200 UTC, the band was still open, this time to the EN, DN, and CN grid fields. The two sporadic-*E* formations that were in play before were continuing to move northward. I worked WDØT (DN94), K7RAT (CN85), and NU7J (CN88) via double-hop using CW.

Here are some statistics from my perspective to show the depth of the opening. Of the 80 or so contacts I made during the first four hours of the contest, 43 were above 50.200 MHz and another 23 were made in the CW portion, below 50.100 MHz. Less than 20 QSOs were made by me between 50.125 MHz and 50.200 MHz! It was just too crowded and noisy!

Photo C. This is the antenna setup of JA7QVI, who was on the other side of many QSOs on 6 meters during the June 4th opening. It's quite a setup! (Photo courtesy of JA7QVI)

By 2330 UTC the band had quieted down. It was a blur to me, and I just looked for the strongest signal in the clear and often could work that station.

The next day I returned to the hill at 6 AM local time to try to work local grids via the four bands that I had. Six meters opened to eastern Canada by 1400 UTC, and I picked up more new grids that I needed. The band died by 1500 UTC. Later it opened to the south, and I picked up seven more grids I needed in the EL, FM, and EM fields.

In the contest I worked over 110 QSOs on 6 meters, covering 74 grids! I picked up some valuable multipliers on 2 meters, 220 MHz, and 432 MHz as well, making this my best portable QRP effort ever!

This particular contest seemed to be very good for the portable QRP station category. Indeed, signals were so strong that power did not seem to be much of an issue a good deal of the time. One QRP operator I know is Art, N2AU, who runs 5 watts. He worked 75 QSOs on 6 meters, covering 60 grids. Of course, there were many super-stations that made over 500 QSOs on 6, with more than 100 grids worked.

Another QRPer who provided input for this article is Curt Roseman, K9AKS, located in the Midwest. The Midwest received the benefit of skip in two directions—toward the west and toward the east. Curt ran QRP with 10 watts to a five-element Yagi about 7 feet off the ground. He almost worked VUCC on 6 meters, with 98 grids worked. The openings were good for him, because they were widespread geographically, allowing him to maximize the number of grids worked. He noted that the name of the game in a multi-band QRP operation is to work as many grids as possible on 6 meters and spend time getting contacts on the higher bands where they count more. Curt also noted that at least two stations in the Midwest made over 1000 QSOs

Time (UTC)	Callsign	Freq. (MHz)	Mode	Notes
1112	VP2V/W7XU	50.106	CW	Strong for hours
1115	V47KW	50.101	CW	Jimmy in for hours
1152	5T5SN	50.095	CW	Nicolas logged me as 339
1240	VP2V/W7XU	50.106	SSB	Strong signal
1327	V44KAI	50.110	CW	Heard throughout the morning
1428	W4/G3MOJ	50.091	CW	Very strong
1600	K7TOP	50.180	SSB	Barry coming in via two-hop skip from AZ (DM43)
1607	XE2MX	50.105	CW	QSB
1627	K6GXO	50.140	SSB/CW	Had to use CW to work him
1540	W4HLR	50.150	SSB	Howard was using 3 watts!

Table 1. Here is a list of calls that I worked when I had the chance at my work QTH on June 29. I set up a two-element beam hanging from a tree branch, with about 75 watts out from my FT-100 in the car.

on 6 meters during the contest: K9NS in Illinois (1282 QSOs, along with 258 grids) and K9MU in Wisconsin (1108 QSOs).

There was some reported 2-meter sporadic-*E* in the northern states of the Midwest that occurred late on Saturday evening. I often checked 2 meters, because at times the skip was shortening up on 6 meters. However, I only found one or two local stations on 2 during Saturday, because 6 was too busy!

Dave Ripton, K2SIX, from FN20 in nearby New Jersey, mirrored my observations, noting that Saturday was fabulous with the openings into the Midwest and the far Northwest. He noted that he worked Lance, W7GJ, and Bob, VE1YX, in a 15-minute period and suspected that Bob may have been coming in via backscatter. He only operated about 15 hours on Saturday and Sunday, but he did get 104 Q's in 55 grids on 6 meters. Dave noted that anyone looking for South Dakota, North Dakota, Wyoming, and Montana for Six Meter Worked All States would have had an easy time, since there were multiple stations on from those states. He worked stations up to 50.350 MHz, as it made sense to be above 50.200 to escape the QRM. He noted, "Most of the savvy 6-meter operators did go up there." Dave noted, as I did, that over 50 percent of our QSOs on Saturday were above 50.200 MHz. Again, spreading out during a major opening makes all the sense in the world.

On Sunday I was able to return to my hilltop location and concentrate on local stations. At about 9:30 local time, I was hearing stations from eastern Canada coming in via sporadic-*E*, and I was able to work a handful of them. I was surprised to work via short-distance sporadic-*E* the super 6-meter station W1VHF in grid FN64 in Maine. It was manned by John ("Mick") McManus, W1JJ, and Dennis Motschenbacher, K7BV. After the contest I found out that they worked around 780 contacts during the contest, and all together during their stay 1500 stations on 6 meters!

Other June 6-meter Operations

The next week was the annual SMIRK contest on 6 meters, and while conditions were similar to the VHF contest weekend, there were a number of sporadic-*E* openings during the contest. Indeed, Jay Buscemi, K2OVS, reported that the sporadic-*E* skip shortened up on 6 meters on Sunday afternoon, and there was a 2-meter opening from the Northeast into Georgia and Florida. Throughout much of June,there continued to be occasional European openings into the U.S. For example on June 20th, N5BO in Florida worked F5MMF at 1300 UTC.

For Field Day weekend, I operated a 6-meter station on eastern Long Island with the Peconic Amateur Radio Club, W2AMC, using a three-element Yagi on the 100-foot bluffs of the north shore of the island facing the Long Island Sound. At the start of the contest there were about two hours of sporadic-*E* activity into Ohio, Michigan, Indiana, and Illinois. Sporadic-*E* activity was moderate on Sunday, with stations in the south being worked, and I worked one double-hop QSO to Arizona and heard a few others.

I was surprised at how many CW stations were available to be worked for double the QSO points. In the past, I noticed that 6 meters was often where many Field Day groups put their most inexperienced operators, but I see that this trend is changing. Also, more respect for the 50.100 to 50.125 DX window was observed, with fewer intrusions.

Summary

The multiple-sporadic-*E* opening that occurred on the Saturday of the June VHF contest seemed like a once-in-a-lifetime event where everything lined up perfectly for many stations in the U.S. The large number of stations on 6 meters showed the increase in activity on this band over the years.

While many openings on 6 meters are fleeting in nature, the internet has helped spot stations on 6. Spotting is not allowed during the VHF contest, but it really was not needed, since the band was wall-to-wall signals.

Was there any particular reason for the extremely good conditions? Perhaps the lack of geomagnetic activity was one reason. (The *K*-index did not go above 3 the entire weekend.)

Remember that sporadic-*E* formations do not cover broad regions for long periods of time. Thus, the localized formations are subject to the variations in conditions in specific areas of the *E*-region. It is like rolling the dice, particularly during a VHF contest, as to whether you will have good conditions or not. It is truly . . . location, location, location!

The big question is what kind of conditions will July bring? There may be some RF fireworks on 6 meters to join the July 4th fireworks!

Postscript

During the last week of June, there were a number of Caribbean 6-meter DXpeditions. Well-known 6-meter expeditioner Jimmy Treybig, W6JKV, operated from from St. Kitts as V44KV. In addition, Dick Hanson, K5AND; Arliss Thompson, W7XU; Alan Brown, K5AB; amd Nolan Thompson, NØLAN, operated from the British Virgin Islands as VP2V/W7XU. One of the stronger days of propagation occurred on June 29, when both stations had a good signal strength into much of the eastern U.S. early in the morning (1100 UTC). Also, Antigua was activated again during the last week of June by V25V (operated by GØVGJ). A number of other resident Caribbean stations were around that day as well, such as PJ7TM and V44KAI.

Radar Data... *(from page 14)*

between 4,000 m and 12,000 m (13,000–40,000 ft). However, the *hail shaft*—where the hail actually reaches the ground—is only one or two miles across.

Using Radar Data to Predict Propagation

Most of the continental United States is covered by the NEXRAD (Next Generation Radar) network shared by the FAA, NOAA, and the Department of Defense. The raw data from these radar sites is made freely available to anyone on the internet. The most familiar manifestation of this data is presented in the form of the color radar maps available on the web. [ref. 4]

The NEXRAD radars operate at 3 GHz and record three sets of raw data: reflected power from the target, the "spectral width" of that reflection, and wind velocity data. The first is an indication of *how much* precipitation the target contains, and the latter two are used in determining wind velocity information. Precipitation particles are smaller than $\lambda/10$ at this frequency (i.e., < 1 cm), so meteorologists can use the NEXRAD with Rayleigh scattering equations to estimate rainfall. Meteorologists apply complex algorithms to these sets of raw data (often programmed into the radar itself) to detect severe-weather events such as large hail, damaging winds, and tornados. This same data has the potential to provide information to amateur radio operators wishing to attempt forward-scatter communications. In order to adapt it for that purpose, we need to understand how the radar operates and how to interpret the information it provides.

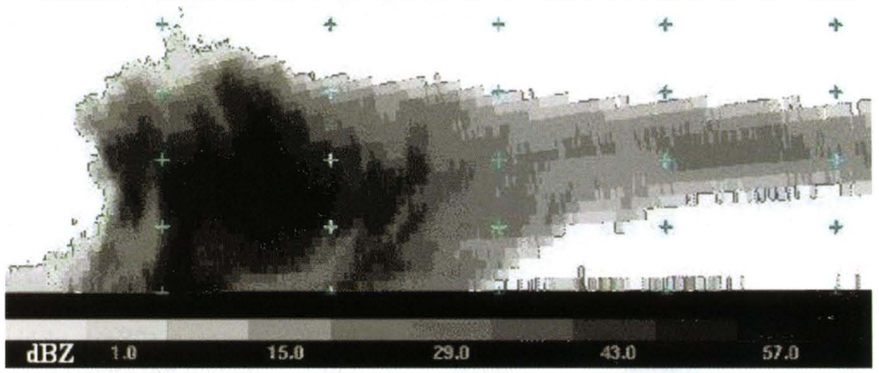


Figure 11. RHI scan of a supercell at 3 GHz showing a storm core of hail and rain. Darker colors represent stronger radar returns. Vertical divisions are 4000 m. View is from the south.

The NEXRAD makes *plan position indicator* (PPI) scans. These are scans in which the elevation angle of the radar is fixed while making a 360° azimuthal sweep. This is similar to how aircraft radars work, except that the scan rate is much slower. The radar can reconstruct RHI scans (similar to the one in figure 11) by making several such sweeps at different elevation angles. The different scans can be combined like an onion peel to produce a 3-D picture of the weather. [ref. 5] The collection of all scans at all elevations is called a *volume coverage pattern (VCP)*.

The NEXRAD has two main VCPs: *clear-air* mode and *precipitation* mode (figure 12). Clear-air mode is the most sensitive and is used to detect weakly reflective objects. The radar moves more slowly in this mode in order to integrate more reflected energy from a given volume of air. When the radar is clear-air mode, most of what is displayed is airborne dust, insects, and birds. Fine snow is also a very poor reflector, so the clear-air mode is often used in the winter to detect snowfall. It takes about 10 minutes for the NEXRAD to complete a VCP in clear-air mode.

The precipitation mode is used for analyzing the vertical structure of storms. It makes many scans from 0.5 to 19.5 degrees to give information on vertical storm structure. The National Weather Service provides this information in two different forms on its web server—either as a *base reflectivity* or *composite reflectivity* image. The base reflectivity shows the reflectivity of the lowest elevation scan (usually 0.5°). The composite

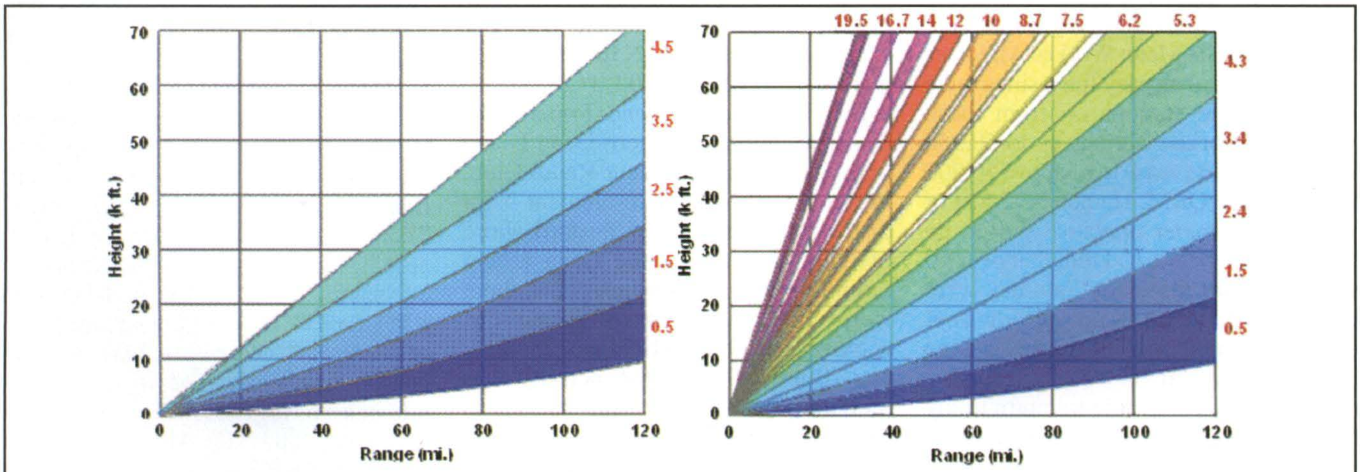
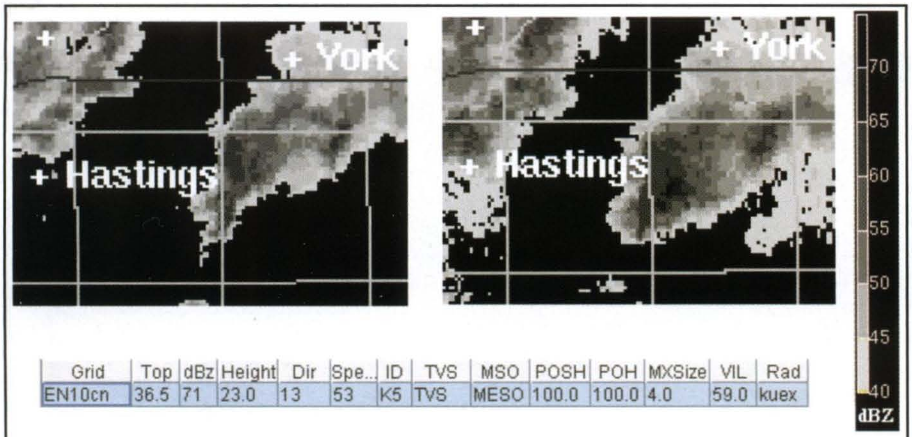


Figure 12. (Left) VCP for clear-air mode. (Right) VCP in precipitation mode. Numbers on the top and right of the figures indicate the elevation of the scans in degrees. The curvature of the Earth limits the lowest visible altitude at long distances. (National Weather Service images)



Grid	Top	dBz	Height	Dir	Spe..	ID	TVS	MSO	POSH	POH	MXSize	VIL	Rad
EN10cn	36.5	71	23.0	13	53	K5	TVS	MESO	100.0	100.0	4.0	59.0	kuex

Figure 13. (Left) Base reflectivity of severe storm east of Hastings, NE. (Right) Composite reflectivity of same storm showing a large amount of hail and water held aloft by a very strong updraft that is not visible on the base reflectivity scan (11 May 2005). Entry from the storm attribute table suggesting extremely large hail and a possible tornado.

reflectivity image displays the highest reflectivity out of all of the elevation scans. [ref. 6] The NEXRAD is able to complete a precipitation-mode VCP in about 5 minutes. A comparison between the base and composite reflectivity can reveal a large scattering volume at high altitudes (figure 13).

The measurable reflectivity from objects in the atmosphere can vary over eight orders of magnitude (e.g., from air turbulence on a clear afternoon to large hail in a severe thunderstorm), so the NEXRAD reports reflectivity on a logarithmic scale. This value is measured on a scale from –20 to +75 *dBZ*. *Z* is a measure of reflectivity per unit volume, and it is a way of taking the distance between the radar and the target out of the equation. That is to say, a distributed target that has a reflectivity of 55 dBZ is 55 dBZ if it is 20 miles or 200 miles from the radar site, provided that the target fills the entire beam path. This is important to know when reading a radar chart labeled in dBZ, as large reflectivity values far from the radar are not any more reflective than those same values near to the radar, even though the echoes themselves are weaker in terms of total reflected power. This dBZ value is derived from the Rayleigh equations and assumption discussed above, summed over all of the particles (assumed to be many little electric dipoles) present in the volume of the radar beam. The following offers a rough guide to the dBZ scale:

1-mm diameter raindrop per m^3 = 0 dBZ
2-mm diameter raindrop per m^3 = 3 dBZ
Light rain = 20–30 dBZ
Moderate rain = 30–40 dBZ
Heavy rain = 40–50 dBZ

Avid radar watchers will recall seeing values of 60+ dBZ regularly in severe thunderstorms. These abnormally high values are usually a sign of medium to large hail. While ice itself is a poor scattering medium (about 5 dB weaker than a raindrop of the same volume), hailstones can grow much larger than water droplets. This can easily make up the difference between the two. Moreover, a hailstone can get a coating of water as it is hurled around inside the storm below the freezing line. This gives it the appearance of a *very* large raindrop. Hail is bad news for meteorologists trying to predict accurate rainfall amounts using radar reflectivity (not to mention to hapless automobiles below), but great for hams wishing to work DX on the microwaves. This effect of hail is readily seen in the large reflectivity values in the supercell of figure 13.

For our purposes, we can think of the dBZ values reported by the NEXRAD as a measure of backscatter at 3 GHz. We can use that measure of backscatter to extrapolate what propagation might be like at other frequencies. If we assume the storm has no hail in it, we can count on Rayleigh scattering to give us a fairly accurate model of propagation through 10 GHz. Since the scattered signal is inversely proportional to λ^4, 10 GHz should be about 12 dB stronger than at 5 GHz, *ceteris paribus*. This is indeed something that has been observed in prac-

Storm Table

Grid	Top	dBz	Height	Dir	Speed	ID	TVS	MSO	POSH	POH	MXSize	VIL	Rad
EM44pv	18.4	51	4.2	74	19	V8	NONE	NONE	0.0	0.0	0.0	10.0	knqa
EM45sd	11.3	53	5.4	45	8	A8	NONE	NONE	0.0	0.0	0.0	9.0	knqa
EM44rv	12.2	48	8.0	60	24	R7	NONE	NONE	0.0	0.0	0.0	7.0	knqa
EM44pu	10.1	48	4.7	NEW	NEW	K1	NONE	NONE	0.0	0.0	0.0	6.0	knqa
EM44lm	16.3	44	8.4	NEW	NEW	A2	NONE	NONE	0.0	0.0	0.0	5.0	knqa
EM45uc	12.0	51	7.1	NEW	NEW	G2	NONE	NONE	0.0	0.0	0.0	4.0	knqa
EM44ru	8.4	46	3.8	NEW	NEW	B8	NONE	NONE	0.0	0.0	0.0	4.0	knqa
EM45tj	8.5	45	8.5	84	16	J1	NONE	NONE	0.0	0.0	0.0	3.0	knqa
EM44wl	10.5	39	5.1	69	16	G0	NONE	NONE	0.0	0.0	0.0	2.0	knqa
EM44wn	9.6	40	4.4	57	16	Z1	NONE	NONE	0.0	0.0	0.0	2.0	knqa
EM44qx	8.3	41	3.8	NEW	NEW	E2	NONE	NONE	0.0	0.0	0.0	2.0	knqa
EM44nu	17.3	41	11.9	125	10	A0	NONE	NONE	0.0	0.0	0.0	2.0	knqa
EM45wg	9.1	45	9.1	NEW	NEW	T1	NONE	NONE	0.0	0.0	0.0	2.0	knqa
EM45pe	7.5	42	7.5	47	21	N0	NONE	NONE	0.0	0.0	0.0	2.0	knqa
EM45wl	9.0	43	9.0	33	20	Y9	NONE	NONE	0.0	0.0	0.0	2.0	knqa
EM45th	8.5	46	8.5	6	2	C2	NONE	NONE	0.0	0.0	0.0	1.0	knqa
EM44xr	10.4	39	10.4	80	22	Z8	NONE	NONE	0.0	0.0	0.0	1.0	knqa

Figure 14: Example storm table from Memphis NEXRAD Radar (KNQA) on 5 May 2005 at 11:50 AM as displayed by RainScatter.

tice. We can expect signals on 3.4 and 2.3 GHz to be accordingly weaker.

Very high dBZ values from the NEXRAD are indications of hail and that Mie scattering is starting to take effect at the higher microwave frequencies. Propagation will probably be strongest when the storm is located on the great-circle path between the two stations. Very high dBZ values are also an indication that rain-scatter QSOs may possible at 3.4 and 2.3 GHz—not something very common with the ERP of most ham stations.

For a propagation path to exist, the scattering volume must be above the horizon for both stations. Fortunately, each NEXRAD provides a *storm attribute table* that includes information about each storm cell within 214 miles of the radar site. This table includes information about maximum reflectivity, height, location, speed, direction, estimated precipitation (both rain and hail), as well as information for severe weather prediction. Figure 14 shows the storm attribute table for the Memphis radar during an outbreak of small, convective thunderstorms.

Of particular interest are the "top" and "height" categories. The echo top is the highest altitude (in 1000's of feet) that the radar detects precipitation (>18.5 dBZ reflectivity). The "height" category is the altitude at which the maximum reflectivity (the dBZ value) was recorded, and is a rough indication of how much scattering material is present in the storm core. It becomes possible to calculate the visible "footprint" of a storm to estimate its useful scattering range at microwave frequencies.

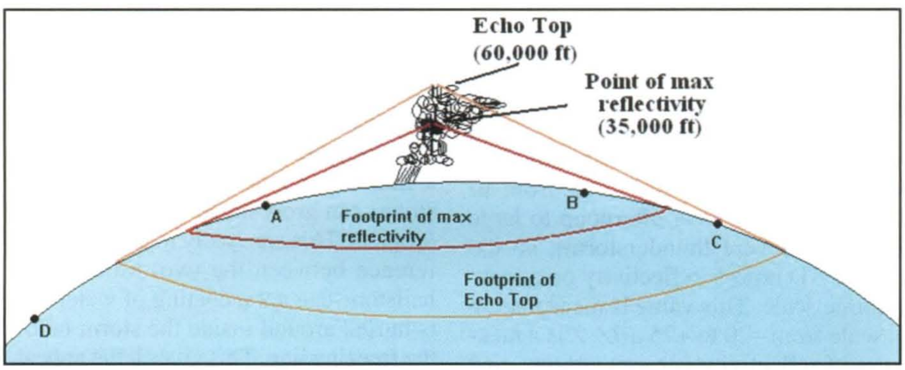


Figure 15. Footprint of a supercell thunderstorm with echo tops at 60,000 ft.

Figure 15 shows how the "top" and "height" data can be used to predict propagation paths. Stations A and B can both see the point of maximum reflectivity and have the potential for very strong signals. C can communicate with both A (forward scatter) and B (backscatter). D is unable to participate because the storm is below the horizon. The diameter of echo top's footprint is more than 600 miles for a 60,000-ft storm. [ref. 7]

Another useful category is the *vertically integrated liquid* (VIL) estimation. This is a measure of the amount of liquid water that could be condensed out of the storm core measured in kg/m^2. Large VIL numbers in a convective thunderstorm are indicative of a large amount of water, thus larger water droplets and more effective scattering at microwave frequencies. The TVS and MESO categories provide information on severe weather events. TVS stands for *tornadic vortex signature*—a sign of a possible tornado. MESO stands for *mesocyclone*—a term for large-scale storm rotation. Both of these phenomena correlate with strong updrafts in the storm core.

RainScatter Software

Storm Attribute Tables usually can contain a massive amount of data on a stormy day; a single radar site may have 50 or more storm cells identified. Calculating footprints for each one becomes a

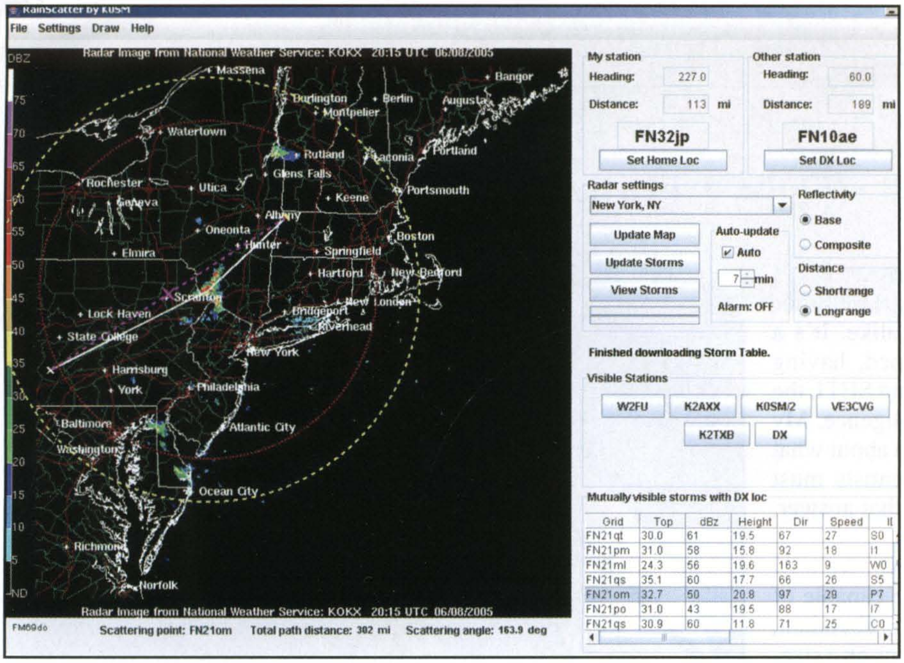


Figure 16. Screenshot of RainScatter *version 1.0. The window at the left is the radar image provided by NWS with the storm's footprint overlayed. Bearing and distance information is in the upper right. The storm attributes table is shown at the bottom right. Above the storm attributes table are buttons that will filter the storm table to show only storms that are mutually visible with that station.*

chore if it is done manually, and since large storms often move at 50 mph or faster, time is of the essence. Sorting out the possible propagation paths is something best done with a computer.

This is where the *RainScatter* software comes in (figure 16). [ref. 8] *RainScatter* downloads the Storm Attribute Tables and quickly calculates the footprint for each storm. This data can be overlaid onto the radar reflectivity maps provided by the National Weather Service, also available on the internet. This makes finding and tracking potential paths much easier for the operator. In addition, one can store locations of other stations and filter only the storms that are mutually visible to both. *RainScatter* does not take all of the guesswork out of rain-scatter communication, but it does provide the operator with data to make informed decisions.

RainScatter has the potential to mobilize activity on 10 GHz and other microwave bands when it may have otherwise gone unnoticed. A large supercell can persist for hours, opening up the possibility for QSOs over an entire region of the country. Everyone running the software will be able to see the same accurate picture of the weather and know which storm is in range and how much potential it has for rain-scatter propagation.

RainScatter can reduce our reliance on VHF liaison for 10-GHz DX. First of all, the path for the 2-meter liaison is often not the same as the skewed microwave path. Given the footprint of a very large storm, two stations may have a harder time finding each other on VHF than they would on 10 GHz. Secondly, large thunderstorms can provide scatter communication well beyond what a VHF station can provide, especially when one considers the amount of noise generated by a thunderstorm. This is even more the case for those operating portable 10-GHz stations. One can imagine the awareness of large thunderstorms adding an exciting twist to the summer contests, or just spicing up a lazy summer afternoon.

Notes

1. A_r is the *effective area* of the antenna. This can be calculated from the gain: $A_r = (\lambda^2/4\pi)\log(g)$ where g is the gain in dBi.

2. θ is the scattering angle measured in the plane of polarization. This creates the dipole radiation pattern we see in figure 1.

3. WA1MBA provides the radiation patterns for all amateur bands above 10 GHz. At the time of this writing I am not aware of any rain-scatter communication on amateur radio frequencies at 47 GHz or above. However, the radiation patterns have very strong forward-scatter lobes at millimeter wavelengths. (See T. Williams, WA1MBA, "Rain Scatter, SHF and EHF," in *Proceedings of Microwave Update '99,* ARRL, 1999, pp. 150–163.)

4. The national radar mosaic showing the coverage of all ~140 radar sites is available from the National Weather Service at <http://weather.noaa.gov/radar/mosaic/DS.p19r0/ar.us.conus.shtml>. A description of the available radar products is provided by the NWS's Telecommunication Operations Center at <http://www.nws.noaa.gov/tg/rpccds.html>. This site provides a link to the FTP server.

5. The National Weather Service does not provide RHI scans on its web server. Such information is usually reconstructed from the raw data by third-party programs in use by researchers and severe-weather analysts.

6. For more information on the NEXRAD radars and the NWS's web-based products, see <http://radar.wrh.noaa.gov/radar/radinfo/radinfo.html>.

7. It will be interesting to see which numbers have a greater effect on propagation. The echo top measurement may only have reflectivity of 18.5 dBZ, which is not a very strong reflection. This suggests that the height of maximum reflection might be a more useful indicator.

8. *RainScatter* is freely available under the GNU Public License at <http://frontiernet.net/~aflowers/rainscatter>. It requires a Java Runtime Environment (JRE) 1.4.2 or later.

By Dr. H. Paul Shuch,* N6TX

DR. SETI'S STARSHIP

Searching For The Ultimate DX

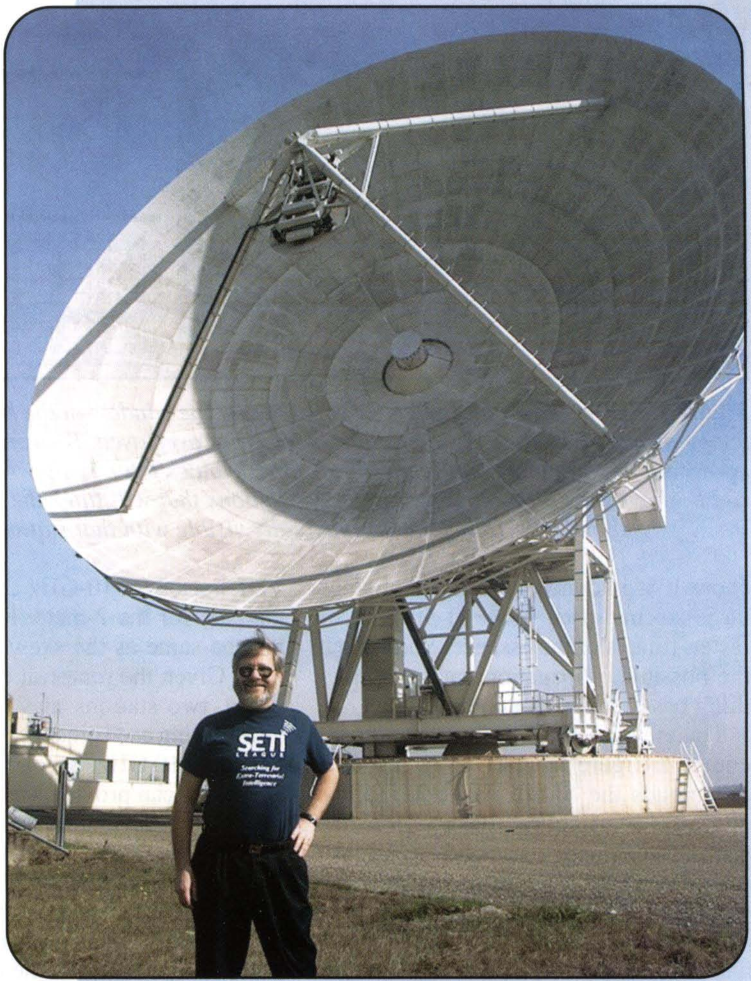
This I Believe

"So, Doc, do you believe in extraterrestrials?" I hear this question frequently, from family and friends, students and strangers alike. It's a question to which I've become accustomed, having invested a significant life-fraction in pursuing SETI, the scientific Search for Extra-Terrestrial Intelligence. My usual answer is that the search isn't so much about what I believe as it is about finding truth. Scientists must always separate faith from fact. However, that answer, I realize, is a cop-out.

Thanks to recent astronomical discoveries, we now know for certain that we live in a universe capable of supporting life. The skies are filled with stars abundant, and we have now detected unseen companions on a sizeable fraction of them. Among the multitudes of observed planets are a fair number with conditions capable of supporting life. Intelligence confers survival value, as does the ability to communicate, so it's not a big stretch to envision hundreds of communicative civilizations calling to us across the cosmic void. Recent advances have brought us to the brink of contact, and yes, I do believe we have the capacity to cross that brink. But do we have the will?

SETI is a multi-generational enterprise. After a half-century of dedicated research, we are no closer to the proof we seek than we were at the outset. I believe that the journey upon which I have embarked will be completed by my distant descendants. That thought is humbling, but also motivating.

For perhaps the first time in human history, we live in a universe in which the notion of extraterrestrial life has become a testable hypothesis. Today as never before, we possess the tools, the technology, and the tenacity to embark upon a journey to answer that fundamental question which has haunted humankind since we first realized that the points of light in the night are other suns: *Are we alone?*



The author is seen here with some of the equipment used to calibrate our place in the cosmos.

"So, Doc," asked a shock jock on morning radio not long ago, "do you believe in extra testicles?"

"No," I answered with equal flippancy, "I believe two should be enough for any man. Now let's talk about SETI."

SETI involves searching the unknown, seeking the familiar. If we do the search, and we do it right, some generations from now our offspring will have arrived at one of two possible outcomes. Either they will have detected incontrovertible evidence of our cosmic companions, or not. If the former, the implications for human life are self-evident. But what if the other? What if, after centuries of searching, we come up dry? Might this lead, in the long term, to a widespread belief in the sanctity of life, and the precious place our home world holds in the heavens? Perhaps a lack of SETI success will return us to a pre-Copernican perspective. Maybe it will encourage us to treat our planet with renewed reverence.

The search will, in time, show us either that we are not alone, or that we are. Either outcome, I believe, will change forever humanity's place in the cosmos. 73, Paul, N6TX

Note: This I Believe <http://www.npr. org/thisibelieve/> is a national media project in the U.S. that invites Americans from all walks of life to write about and discuss, in just 500 words, the core beliefs that guide their daily lives. The statements are shared in weekly broadcasts on National Public Radio. This essay is Dr. SETI's contribution to that project.

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