CQ VHF Ham Radio Above 50 MHz

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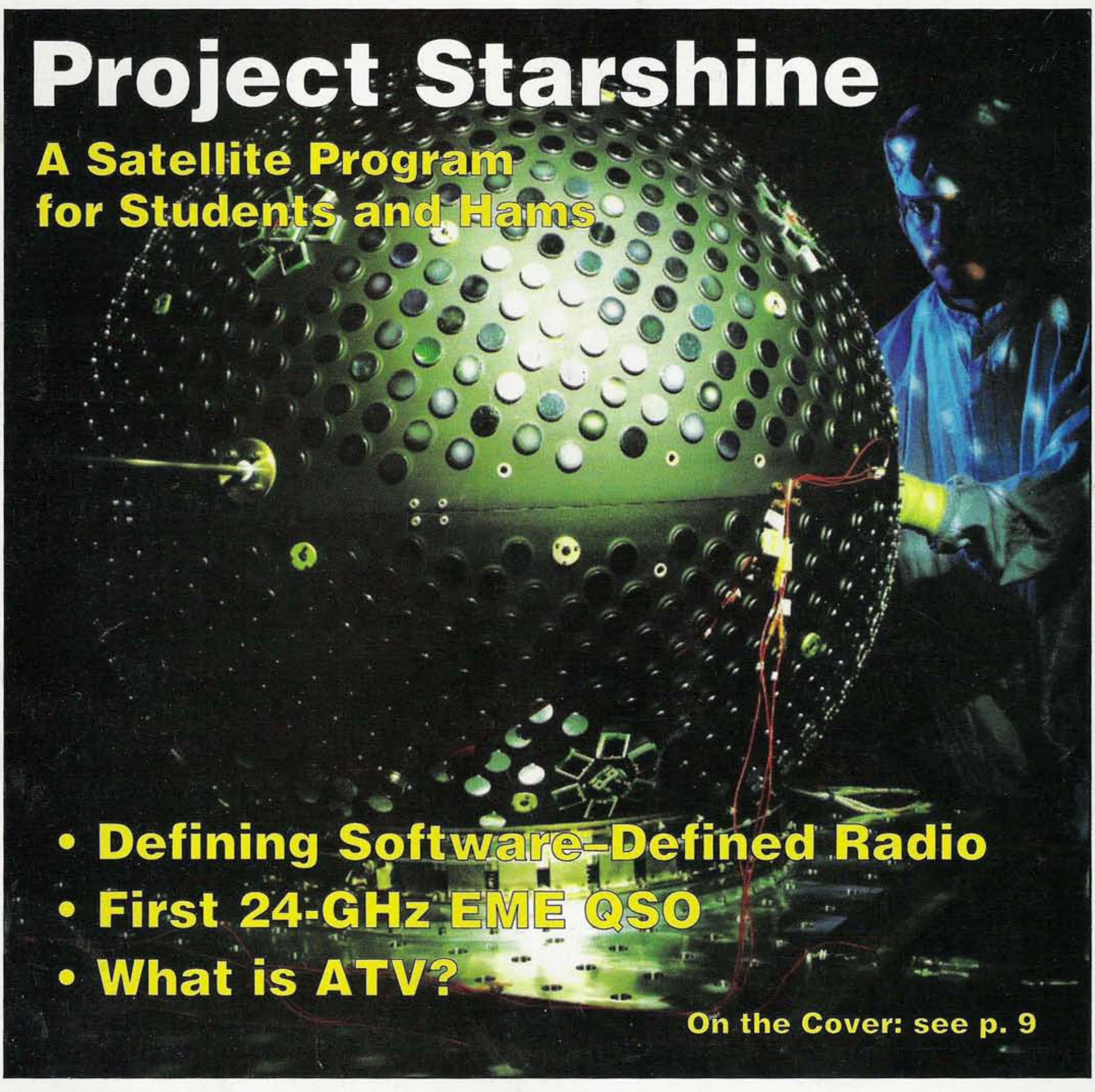

Project Starshine

A Satellite Program for Students and Hams

- **Defining Software-Defined Radio**
- **First 24-GHz EME QSO**
- **What is ATV?**

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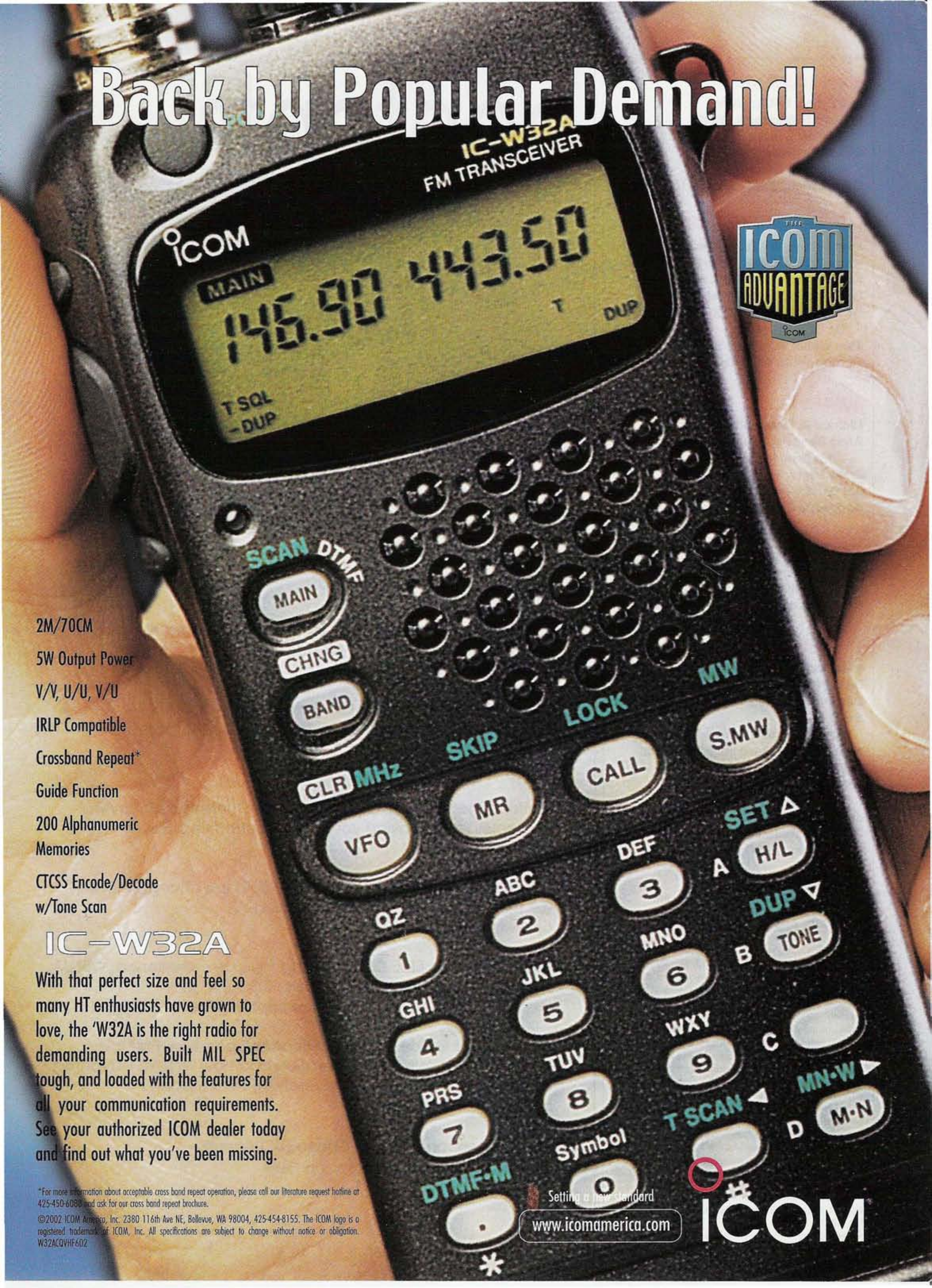
■ VHF/UHF Weak Signal ■ Microwaves ■ Amateur Satellites
■ Repeaters ■ Packet Radio ■ Projects ■ Interviews
■ Plus...Reviews, Product News, and much more!



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CQ Communications, Inc.
25 Newbridge Road
Hicksville, NY 11801 USA.

Offices: 25 Newbridge Road, Hicksville, New York 11801. Telephone: (516) 681-2922. FAX: (516) 681-2926. E-mail: cq-vhf@cq-vhf.com. Website: http://www.cq-vhf.com. CQ VHF (ISSN 1085-0708) is published quarterly (4 times a year) by CQ Communications, Inc. Periodical postage pending at Hicksville, NY and additional offices. Subscription prices (all in U.S. dollars): Domestic—one year $25.00, two years $45.00; Canada/Mexico—one year $35.00, two years $65.00; Foreign—one year $38.00, two years $71.00. Government Agencies: Subscriptions to CQ VHF are available to agencies of the United States government, including military services, only on a cash with order basis. Requests for quotations, bids, contracts, etc., will be refused and will not be returned or processed.

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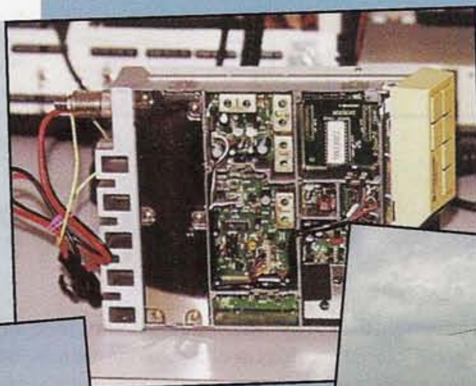

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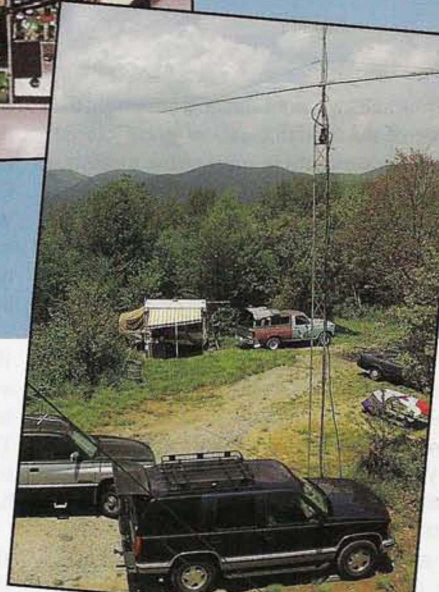

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COLUMNS

DEPARTMENTS

CQ VHF Ham Radio Above 50 MHz

LINE OF SIGHT

A Message from the Editor

How?

In journalism school students are taught that one of the fundamentals of good journalism is every article must strive to answer the questions who, what, why, when, where, and sometimes how. Within the pages of the new *CQ VHF* we have made a commitment to move the level of technical expertise higher than that presented in the previous version of the magazine. In order to do so, we are striving to answer the last question—"how."

In this issue's "Op-Ed" piece author Neil Dabb, KC7GCL, tells us how to further involve our families in the hobby. In the lead story, "Project Starshine," author Bobette Doerrie, N5IS, gives us information on how to get children involved in building a satellite. She also informs us about a program underway that strives to figure out—at least in part—how propagation is affected by the Sun.

During this quarter there are a number of VHF-and-above contests. In his article "Working the VHF/UHF and Microwave Contests as a Rover" author Dan Evans, N9RLA, draws from his experience as a Rover to tell us how to successfully work the contests in this category.

In an article reprinted from *The AMSAT Journal* entitled "AMSAT OSCAR-E" author Rick Hambly, W2GPS, tells how AMSAT will answer the continuing interest in amateur satellite communications with the unveiling of the AMSAT OSCAR-E project. Gerald Youngblood, AC5OG, in his article "The 'Soft' Radio," introduces us to how software-defined radios work.

In "The First 24 GHz EME QSO" authors Al Ward, W5LUA, and Barry Malowanchuk, VE4MA, tell us how they made the first EME QSO on this very difficult to operate microwave band. In "A Beginner's Guide to Meteor-Scatter Operation, Part I" and the accompanying sidebar "The *Perseids:* The 'Old Favorite'" Shelby Ennis, W8WN, tells how meteor-scatter propagation can be used to complete QSOs on some of the VHF-plus ham bands.

"The Aviator's Solution to Shack Noise" relates how author Michael Schell, KF2LF, adapted a technique used by aviators to reduce the problem of background noise in the ham shack. In "A 900 MHz Parrot Repeater" Jim Labor, KE4NZG, tells how he built a repeater for an under-utilized ham band.

Combining modern 21st century technology with a 19th century form of communications in order to communicate between mountaintops via the Sun is the subject of "Morse Code via Mountaintop Heliograph" by Edward Butler, KF6DXX. In his "Antennas" column, Kent Britain, WA5VJB, tells us how to build really cheap 2-meter, self-matching antennas.

In this month's "Satellites" column Tom Webb, WA9AFM, covers the various radios available that have enabled so many to communicate via amateur satellites over the years. The "FM" column by Gary Pearce, KN4AQ, tells how the FM mode of communications has become known as the "utility mode."

Features editor Gordon West, WB6NOA, along with several of his expert friends, writes about how to communicate via tropospheric ducting in "Tropospheric Ducting, Myths and Truth." In "What is ATV?" Dave Ratliff, W5ATV, writes about how hams communicate via amateur television, and in the accompanying sidebar your editor tells how one ham radio club used ATV during its recent Field Day operation. Finally, in his column "Dr. SETI's Starship" author Dr. Paul Shuch, N6TX, tells how the interest in looking for extraterrestrial communications got started among the scientific community.

What about other items in this issue? In "Letters to the Editor" you tell us how we are doing. While some of you gave us flattering kudos (which we really appreciate), others took the time to tell us how to improve the magazine or fix an article that appeared in the spring edition of *CQ VHF*. At least a couple of you told us how disappointed you were with some part of the magazine or the magazine as a whole. All of your comments are welcome, because they are instructive, telling us where we need to make improvements and/or what changes we need to make to the magazine. The "Quarterly Calendar of Events" lists other opportunities within our niche in which we can participate, whether it is by way of operating events or conferences.

Finally, our advertisers tell us how much they believe in *CQ VHF* by their wanting to be a part of it. In turn, you can tell them how much you appreciate their support by buying the products or services they offer.

How are we doing? I addressed this question a bit in my coverage of "Letters to the Editor" above. You too can be a part of the answer to this question by writing to us. You also can contribute to the success of the magazine by encouraging others to subscribe and by submitting material for future issues.

Satisfied?

While we are on the subject of encouraging others to subscribe to *CQ VHF,* I must mention that we also rely on your spreading the word about the magazine, as word-of-mouth is far and away the most important source of advertising. Statistics show that every dissatisfied customer tells ten others about their dissatisfaction. On the other hand, only three satisfied customers tell others of their satisfaction.

If you are happy with what you are reading in *CQ VHF,* then we ask you to be among the three to tell others. If, on the other hand, you are not satisfied, then please tell us first. Obviously, we cannot please everyone. However, it is our intention to satisfy your thirst for good, quality-content VHF-and-above articles, and we need to hear from you to know that we are on the right track.

The Lineup

Articles that we are working on for the fall issue include Part 2 of Shelby Ennis's "Meteor Scatter Propagation Beginner's Guide," plus sidebar information on the *Leonids* meteor shower. Speaking of the *Leonids,* because of the potential for a meteor storm your editor is planning a historical look at that shower as a way of understanding why we can expect a storm this fall in some parts of the world.

Features editor Ken Neubeck, WB2AMU, will reflect more on what took place on the Magic Band of 6 meters a year ago this fall. Columnists Kent Britain, WA5VJB; Gary Pearce, KN4AQ; Dr. Paul Shuch, N6TX; and Tom Webb, WA9AFM, each will again contribute to *CQ VHF* in the fall issue.

It is too soon to discuss a number of the feature articles that are in the works for the next issue. What we *can* say, however, is that nowhere else will you get as extensive VHF-and-above coverage as in this, your magazine. In short, I must say that I am really excited about what is in queue for you!

Until the next issue…

73, Joe, N6CL

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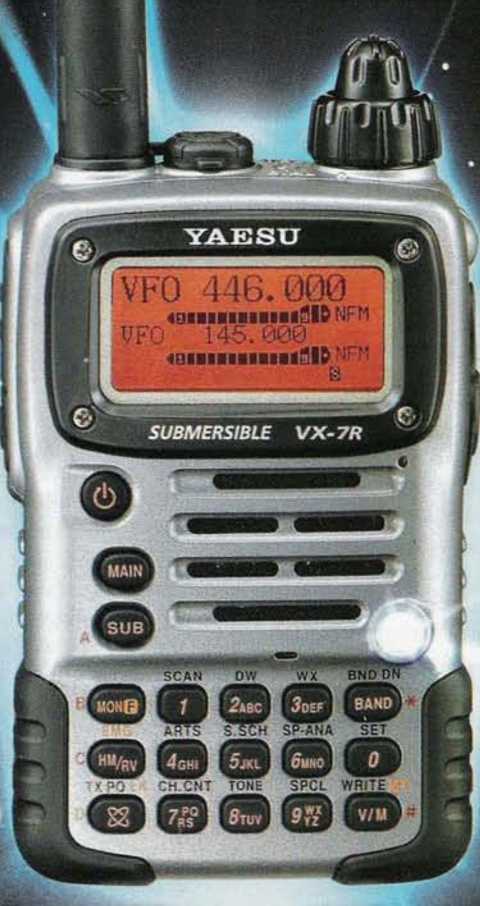

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By Neil Dabb,* KC7GCL

OP ED

One Reader's Opinion

Ham Radio and The Family

We know that the typical family unit consists of various members. As I describe these family members, perhaps you will recognize some of them.

Teens: Teenagers are interested in TV, food, clothes, and loud music. School is the place where they congregate to discuss the injustices imposed on them by the older generation, the newest fads in music and clothing, and the most recent episode of their favorite TV show. Teachers will attest to the fact that if teens show a spark of interest in anything, it is either a mistake, or the child is ill and should be sent home immediately.

Parents: The parental unit is typically the foe to teens except on payday, or shopping days, when they supply the massive amounts of sustenance needed for both teens and other children in the household. Their hobbies may include ham radio, among other things, and they would like nothing better than to have each of their children follow in their footsteps. They have become experts in the act of juggling the needs of work, children, each other, and the various hobbies they pursue.

Youth: Young children move through various stages of physical and emotional needs. They learn how to learn, how to read, and exactly how to annoy their siblings and parents. They are intensely curious about the world they live in and frequently are known to ask the "why" question. Languages are easy to learn for them (and isn't Morse Code a kind of language?), and if properly led, they may even develop an interest in amateur radio.

Grandparents and the rest: Grandparents, aunts and uncles, cousins, and a myriad of other relatives find their way into the mix of family life, too. Also included in many family units are the in-laws.

How do we get any or all of these different groups interested in, let alone involved in, the same thing? It may seem like "Mission: Impossible" (see March 1999 *CQ VHF*, pp. 38–41) or "The Impossible Dream" (October 1999 *CQ VHF*, pp. 36–38), but as I wrote in those articles, it may be difficult but it is not impossible. For those of you who may have missed the articles, what follows is a brief overview.

Mission: Impossible

Getting Young People Interested In Ham Radio

From the outset it should be noted that not everyone wants to become an amateur radio operator (much as we would like to think otherwise). Some general ideas for getting and keeping young (and even not so young) people interested would be to make it fun and let them get their hands on the equipment.

There is a great "fascination factor" that goes along with radio. Activities such as scouting, camping, science fairs, school clubs, DXpeditions, Field Day, and SAREX (the Space Amateur Radio EXperiment sponsored by NASA) all are good opportunities to get young people interested in ham radio.

*#7 USU Trailer Court, Logan, UT 84341-2883
e-mail: <neild@cc.usu.edu>*

The Impossible Dream

Kids Learning and Remembering Radio Facts

First, everyone has his or her own learning style, and what may seem like common sense to one may make no sense to another. Part of the reason amateur radio is such a valuable hobby is because the operators are almost constantly playing with the equipment and trying to figure out better ways of doing things. Hands-on is a wonderful way to learn.

Next, it's much easier to teach (or learn) 100 concepts than to try to memorize the answers to 900 questions. Classes, software, books, and other operators all are available to help anyone who you can get interested in the hobby. Young people have an easier time learning Morse Code than older people; take advantage of this fact. Remember, if at first you don't succeed, try, try again.

Ham radio is (or at least should be) a family activity. Here are some areas where ham radio and family life are a good fit:

Communication. Isn't that what ham radio is all about? We go to great lengths to communicate with operators around the world. Why not spend some of that time communicating with family members who share the interest? As family members travel, why not make the effort to see if they can contact the home front? How better to practice your DX skills? In my case, I can pull my daughter's voice out of the static much more easily than I can an unfamiliar voice. Families need to talk, and ham radio is mostly about talking.

Time. Taking the time to develop any kind of relationship is a major key to its success. Time spent working together on ham radio projects can be just as rewarding as time spent on vacation or participating in any other activity. In fact, why not combine the two? How about a DX vacation? Sometimes just staying in touch while on vacation (because we all know how well we stay together on vacation!) can be a nice way to use ham radio. Think of the possibilities.

Shared Interests. Part of what makes a good friend is shared interests. While you can't *pick* your family, there's no reason why you can't have shared interests and allow those interests to help you and your family become friends.

It is not uncommon to open a newspaper and find a picture of five generations of family members seated together. How many cases of three or even four generations of hams could we find if we put our minds to it? Recently, in the monthly profile section of our local newsletter there was a picture of a large family, and in the text were the callsigns associated with many of them. Ham radio should be the ultimate family activity.

I would like to see more coverage of family amateur radio activities in the literature. Of course, there is always the need for technical and practical information, but stories of three and four generations of hams, family DX outings, and how ham radio is bringing families closer together are some of the other topics that would be appropriate on a regular or even just occasional basis in a publication. What do you think? ■

Project Starshine

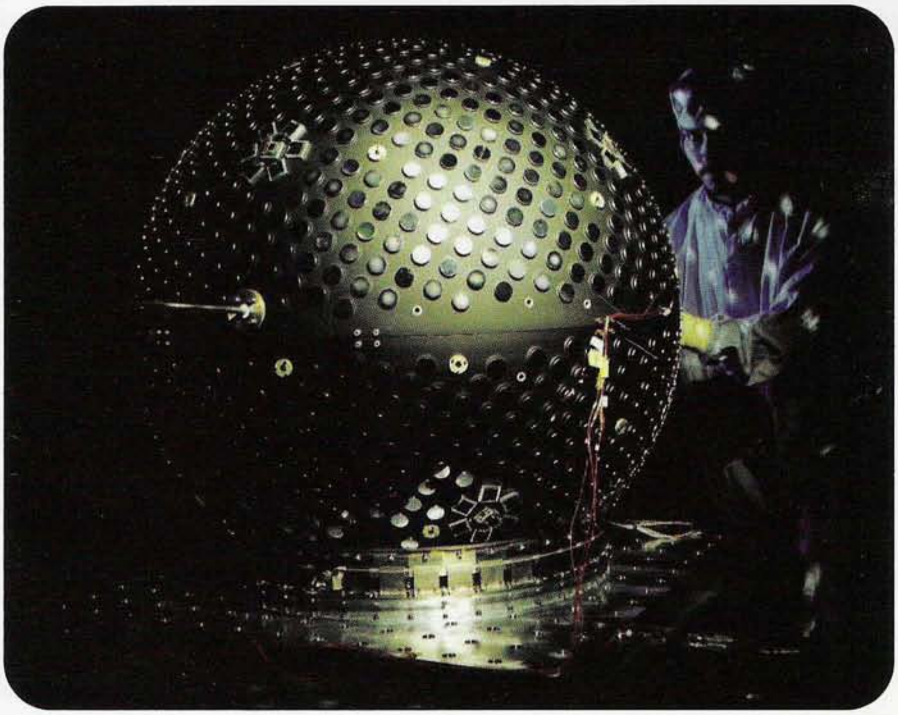
Satellites, Students, and Hams

What do students, mirrors, and amateur radio operators all have in common? The answer has nothing to do with grooming. Rather, the answer is satellites. N5IS tells us about a very practical, hands-on involvement in our hobby for students across the country—and even around the world!

By Bobette Doerrie,* N5IS

Gil Moore, N7YTK, had a dream. While you may not know Gil, chances are you may know one of the children who is part of the reality that has grown from his dream. Gil's dream was a project to involve students in building satellites and participating in scientific research.

Students polish all of the mirrors in the Starshine series of satellites described below. These mirrors attach to spun-aluminum structural hemispheres, and there are about a thousand mirrors per satellite. Imagine how a student's eyes light up when he or she hears, "You are going to get a chance to help polish a mirror that will be sent up into space on a satellite."



The assembled Starshine 3 satellite at the U.S. Naval Research Laboratory. Starshine lead mechanical engineer John Vasquez is inspecting the satellite prior to its flight-acceptance vibration test. Shown in the photo are some of the 1500 student mirrors, 31 laser retroreflectors, and seven solar-cell experiment clusters that are mounted on the satellite's surface. Also visible are the Lightband separation system, which deployed the satellite into orbit, as well as one of the two communication antennas that will broadcast satellite spin-rate data throughout the satellite's expected three-year orbital lifetime. (NRL image by photographers Michael A. Savell and Gayle R. Fullerton, and courtesy Gil Moore, N7YTK)

Past and Future Launches

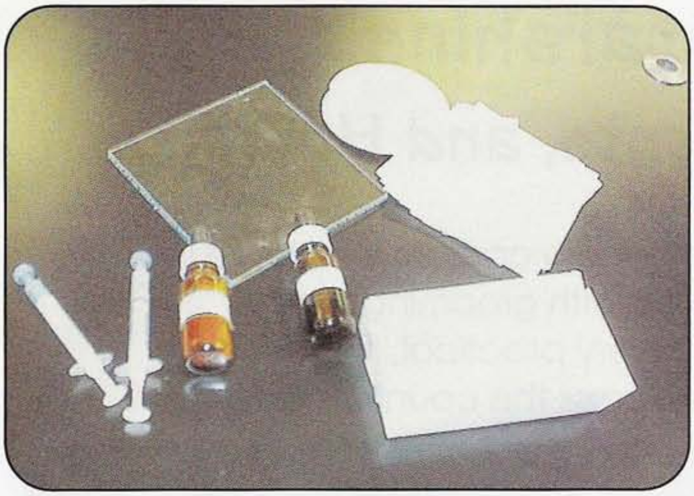
Three satellites, known as the Starshine series, have been sent up into space so far. Their mission is to study the changes in the Earth's atmosphere caused by solar activity.

Starshine 1 consisted of a hollow aluminum sphere 48 cm (19 inches) in diameter and covered with 878 polished aluminum mirrors, each of which was 2.5 cm (1 inch) in diameter. Approximately 25,000 children in 660 schools in 18 countries polished these mirrors. The crew of the Space Shuttle *Discovery* deployed Starshine 1 on June 5, 1999. It remained in orbit for eight months, slowly spiraling down because of drag in the Earth's upper atmosphere. It was consumed by aerodynamic heating approximately 80 km (50 miles) above the Atlantic Ocean off the coast of Brazil on February 18, 2000.

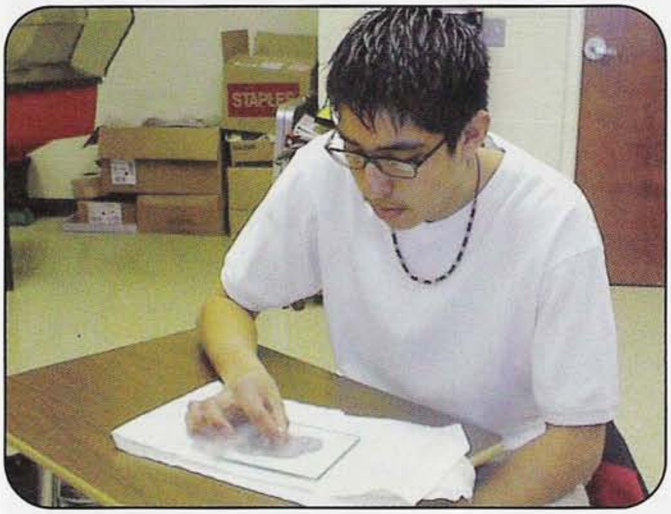
Starshine 2 was the second satellite in the series to benefit from student involvement. Approximately 30,000 students in 26 countries around the world polished its 858 mirrors. The crew of the Space Shuttle *Endeavor* deployed Starshine 2 on December 16, 2001. When the satellite was deployed from the *Endeavor,* it was rotated with a special cold-gas spin system to spin at five degrees per second. Because of the solar activity, Starshine 2 ended its flight sooner than expected and flamed down on April 26, 2002.

Starshine 3 went into orbit on an Athena I unmanned launch vehicle from the Kodiak Launch Complex, Alaska, on September 29, 2001. Its much more ambitious venture included 31 laser retroreflectors which permitted a special tracking device to follow it, an integrated power supply, an antenna array, signal-conditioning circuitry, and an amateur radio

*Rt. 2 Box 504, Booker, TX 79005
e-mail: <bdoerrie@yahoo.com>



The mirror-polishing kit.



The polishing process.

telemetry transmitter. Because the sunspots are showing a double peak in solar activity, the satellite has experienced a greater degrading of its orbit than expected. It should re-enter the atmosphere and flame out in December 2003, about one year earlier than originally predicted.

NASA has firmly manifested the Starshine 4/5 dual-satellite experiment on the STS-114 Shuttle mission to the International Space Station (ISS) in January 2003. This satellite will actually be a satellite and a sub-satellite. Instead of releasing an inflatable balloon from inside the Starshine 4 satellite, a 4-inch (10-cm) hollow aluminum sphere, Starshine 5, will be released shortly after Starshine 4 is deployed from the shuttle. Both Starshine 4 and Starshine 5 will carry 31 laser retro-reflectors on their surfaces, and they will be tracked by the International Satellite Laser Ranging (ISLR) Network and by the U.S. Space Command. In addition, Starshine students will visually track the faint flashes of sunlight reflecting from 1000 polished mirrors mounted on the surface of Starshine 4. All of these data will be combined to determine the orbit of Starshine 4.

In contrast, Starshine 5 will not have any mirrors and thus will not be visible to the naked eye, so orbit determination will be totally dependent on ISLR and Space Command tracking. By comparing the orbital decay rates of Starshine 4 and Starshine 5 it will be possible to determine the density of the Earth's atmosphere more precisely than has been possible on previous missions.

The plan for Starshine 6 is to include mirrors and a packet component. However, because of the reduced Shuttle launch schedule for the next few years, secondary payloads such as Starshine may have to wait until 2005 or 2006.

Mirror-Polishing Process

The mirror-polishing process appears to be simple, but it turns out to be more complex than the instructions indicate. The process has only three steps the students must perform: take an aluminum blank (it resembles a large, flat-topped nail), grind off the majority of scratches and machine circles with aluminum-oxide slurry, and then polish the blank to a very high sheen with two grades of diamond paste. The instructions, however, are very detailed and specifically say to move the mirror on the grinding slurry in small figure-eights. The students discovered that there are three variables in that last sentence, and they tested each one:

1. The slurry has to stay a slurry, not become a thick paste.

2. Adding water or more liquid slurry prevents the mirror from having deeper areas ground into it from the thicker areas of aluminum oxide.

3. "Small" is not in some students' working vocabulary; enthusiastic football players don't think small! Unfortunately, large figure-eight motions produce mirrors that are not flat, but rather have rounded edges. Figure-eights are not circles. Therefore, doing circles for the figures causes the mirror to have strange galaxy shapes on the face, requiring the mirror to be redone.

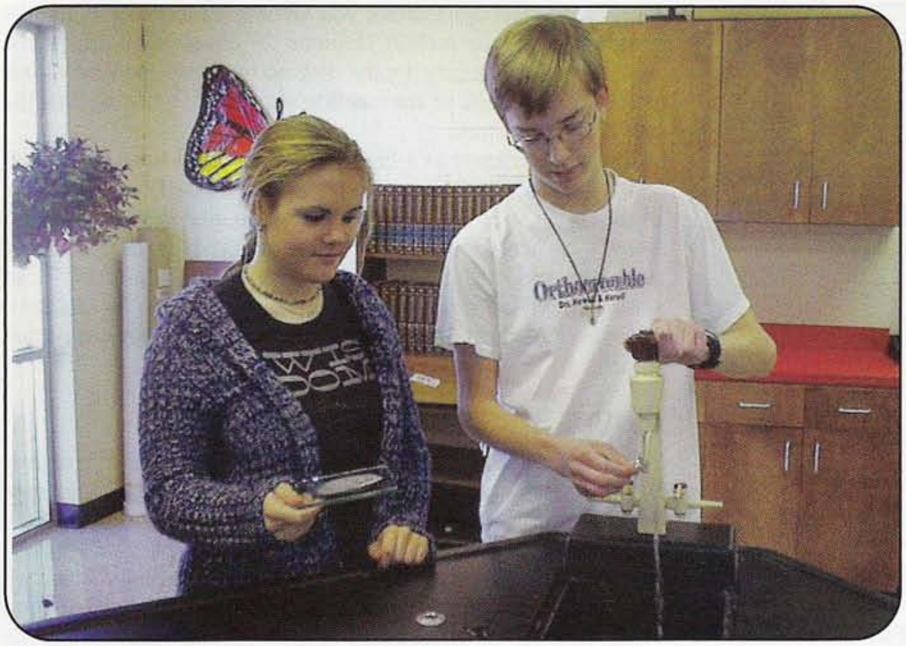
After the students' faces shine with pleasure at completing the above tasks, there is still one more hurdle to overcome: The flatness has to be tested with a glass "flat" that is carefully cleaned and placed on the mirror face. Lightwave interference produces "Newtonian Rings" that define the flatness. The two best mirrors in the kit are returned for possible flight use; the third one stays with the school for its display case.

The Research

Satellites and radio communications are both affected by solar emissions, in particular solar flares. Solar flares are a sudden brightening of electromagnetic radiation from the Sun across the entire spectrum from gamma rays through visible light to radio emissions. Solar flares appear to be caused by a sudden release of magnetic energy that builds up in the solar atmosphere. Plasma is heated to tens of millions of degrees, and electrons, protons, and heavy nuclei are accelerated almost to the speed of light. If these atomic particles are stopped in the solar atmosphere, they produce X-rays and gamma-ray emissions which travel at the speed of light, reaching Earth 8.3 minutes after they leave the Sun.

Solar flares are very different from coronal mass ejections (CMEs), although sometimes the two may be related. A CME travels more slowly and takes two to four days to arrive. One such CME occurred on January 6, 1997. On that date the Solar and Heliospheric Observatory (SOHO) coronagraph showed a mass ejection from the Sun that headed directly toward the Earth. This CME was probably responsible for the loss of an AT&T satellite and transmission loss of numerous TV channels.

The large influxes of very fast moving charged particles also cause communication disruptions in HF and VHF radio transmissions. NASA's Imager for Magnetopause-to-Aurora Global



The moment of truth after the polishing process has been completed.

Exploration (IMAGE) satellite showed that the outer atmosphere diverts some of the dangerous energy from reaching the Earth's surface. The *F*-layer of the ionosphere, a charged layer normally located approximately 160 to 500 km (100 to 310 miles) above the Earth's surface, responds to the influx of charged particles carried by the high intensity in the magnetosphere. Two of the *F*-layer's features worth noting are that in daylight it divides into two layers, *F1* and *F2,* with the *F2*-layer being closer to the Sun. Also, because of the *F2*-layer's closer proximity to the Sun, it is more vulnerable to the effects of the Sun's geomagnetic activity, and thus provides the reflectivity for long-distance (in excess of 4000 km, or 2500 miles) communications. At mid-latitudes the ionosphere/thermosphere is heated during active times. This heating produces an increase in the height of *F2* to 1000 km (approximately 630 miles) during active times, which is caused by an increase in the density of neutral particles, which increases the loss of ionization at the *F2* altitude.

In addition, many of the charged gas particles become trapped in the Earth's magnetic field and spiral along the lines, accelerating to enormous velocities. Because the field lines form a kind of donut-shaped pattern around the Earth, the particles form a plasma cloud that encircles the Earth during the storms. Very large storms are fairly rare, but when they occur, they appear mostly at solar maximum, about every eleven years. We currently are coming off a double-peaked solar maximum, and the activity in the Sun is still fairly high but declining rather rapidly.

One of the visual effects of this increased solar activity is an increase in aurora activity, both in intensity and in the areas of the Earth affected by aurorae. Depending on the intensity of such solar activity, aurora sometimes can be seen as far away from the Earth's North and South Poles as the mid-latitudes.

This exacerbated level of geomagnetic activity is what is directly causing the degradation of the Starshine satellites' orbits. It is the purpose of the Starshine Project to document this degradation via the various satellites employed throughout the life of the project.

Characteristic	Type/Value
Center Frequency	145.825 MHz
Data Rate	9600 bps
Modulation	Narrow-band FSK
Deviation	±3 kHz
Baseband encoding	Differentially-encoded Non-Return to Zero
Scrambling	G3RUH
Protocol	AX.25 packet radio—APRS packet
Uplink/Downlink Multiplexing	Half duplex
RF Transmit Power	1.25 watts from RF power amplifier
One suggested receiver	Kenwood TH-7D
Antenna	Pair of quarter-wave monopoles fed 180 degrees out of phase

Table 1. Starshine 3 communications system parameters.

The Purpose and Your Involvement

The main purpose of the Starshine satellites is to determine the density of the ionosphere as it bulges in response to solar energy. The same ionospheric effects that cause problems for amateur radio communication also bring the Starshine satellites spiraling down, as well as slow their initial rotation. The information gleaned from the research can help atmospheric investigators and hams looking for band openings as well.

At this point you may be wondering, "Why the mirrors?" As they reflect the light from the Sun, these mirrors are visible against the star background with the naked eye. As the satellite rotates, the light from these mirrors appears to flash on and off. Observers measure the timing of these flashes as well as the position of the satellite in relation to their observation points on the Earth's surface as a way of determining the satellite's declining spin rate and decaying orbit.

There are several ways amateur radio enthusiasts and others can become involved with the ongoing Project Starshine. Observers can choose two levels of difficulty when they consider being part of the project: a beginner level that involves just timing five flashes with a hand timer; and an intermediate level that involves much more exact records, with a team approach to cover all the tasks. For more information on visual observation and tracking, see the website "A Beginner's Guide on How to Track Starshine," <http://azinet.com/starshine/guide_beg.htm>.

The amateur radio transmitter in Starshine 3 is another way to participate in the adventure. How does one know when and where to listen? The Starshine website, <http://www.azinet.com/starshine>, has detailed information.

One of Starshine 3's primary objectives is to involve more school children in radio

The unfinished prototype of Starshine 5 that is under construction by Skip Dopp of the Bridgerland Applied Technology Center. (Photo courtesy Project Starshine)

science. As part of this mission, science data from experimental solar cells mounted on the surface of the satellite will be downlinked in a manner that will allow schools and radio amateurs to participate in collecting the data. For this reason, the downlink has been designed for compatibility with standard amateur satellite radio ground stations. It is also compatible with Kenwood TH-7D hand-held radio terminals. The TH-7D radios contain built-in AX.25 terminal node controllers (TNCs) and RS-232 ports. Consequently, you can receive Starshine 3 downlink signals directly for recording on a standard laptop or desktop computer.

Schools that purchase TH-7Ds or similar radios will be able to receive the Starshine 3 signals with their identifying "STRSHN3 N7YTK" data header in a very simple manner. We ask that you forward your received packets as soon as possible to a special radio data collection website, <http://www.epulation.com/ starshine>, created for us by Michael Tolchard.

The Starshine 3 Communications System downlink uses 9600 bps frequency-shift keyed (FSK) signals at 145.825 MHz. Downlink transmissions initially will occur at two-minute intervals. (The interval will be shortened to every 30 seconds if the surface-mounted solar cells charge the on-board batteries satisfactorily.) The Starshine 3 Communication Systems parameters are given in table 1.

How do you know when and where to look for the Starshine satellites? After all, what an observer sees is just the sunlight from one mirror over 200 miles up in space. Amazingly, this surface is sometimes as bright as Venus. The process is essentially straightforward. The website <http://www.heavens-above.com> has the visible times for a number of satellites, including the Starshine series. To access this information, you will have to register with a name and password, and either enter your latitude and longitude or find your town on the list.

Once this registration process is complete, you select the satellite you are hoping to observe and the program brings up a chart of times for observation during the next ten days. Clicking on the date on the chart produces a star chart, with the path of the satellite marked by a line against the background of stars.

In my experience as a high school teacher I have found two kinds of students—those who know the constellations and may even have a very high-quality telescope, and those who don't know that there are names for the patterns of the stars and have no awareness of the phases of the moon. A "Star Party" can remedy the latter problem, and it can be for hams, for students, or for both hams and students! Invite your local astronomy club to help.

Future Participation

The deadline for applying for participation in the mirror program for Starshine 4/5 was March 31, 2002. However, there are several more Starshine satellites planned for sometime in the future, and all of them will need mirrors. Gil, N7YTK, is hoping to fly a ham transmitter and receiver on Starshine 6. As we said earlier in this article, though, we may have to wait for a while because of the reduced Shuttle launch schedule for the next few years.

Amateur satellites such as the Starshine series sometimes have "Orbiting Satellite Carrying Amateur Radio" or OSCAR designations (i.e., AMSAT OSCAR-40). The Starshine satellites can qualify because there are only three requirements besides requesting the designation in writing:

1. The spacecraft's use of frequencies in the amateur bands must have been coordinated before launch through established IARU/AMSAT frequency coordination.

2. The spacecraft must have achieved orbit successfully or have been deployed.

3. One or more transmitters must have been activated successfully in the Amateur Satellite Service.

If you are interested in inspiring a teacher in a nearby school to become part of the Starshine Project, have him or her go to <http://azinet.com/starshine/>. If you are interested in more information about the project, check the detailed website, or direct any questions to: Gil Moore, N7YTK, Starshine Project Director, 3855 Sierra Vista Rd., Monument, CO 80123. ■

Additional Information
(URLs and References)

http://hesperia.gsfc.nasa.gov/sftheory.htm (solar-flare theory)
http://iacg.org/iacg/campaign_3/paper.html (scientific discussion of solar research)
http://nmp.jpl.nasa.gov/st5/science/storms.html
http://sohowww.nascom.nasa.gov/explore/faq/flare.html
http://www.eham.net/DX/propagation (This site has a large number of links.)
http://www.geocities.com/w5dxs/propagation.htm (radio-propagation theory)
http://www.nas.edu/ssb/swmeteorology.html (solar-weather information)
http://www.sec.noaa.gov/ (The NOAA Space Environment Center)
http://www.sunspot.noao.edu/PR/eruption.html (National Solar Observatory site)
http://solar.spacew.com/ (Solar Terrestrial Dispatch URL; includes near real-time MUF map)
http://www.qsl.net/ki0eg/propagation/propprimer.html (The Ionosphere and What it Does, by Peter A. Norgard, KIØEG)
Radio Auroras, by Charlie Newton, G2FKZ, Radio Society of Great Britain, 1991, ISBN 1872309038
Science News, Vol. 161, May 18, 2002
The NEW Shortwave Propagation Handbook, by George Jacobs, W3ASK, Theodore J. Cohen, N4XX, and Bob Rose, K6GKU, CQ Communications, Inc., 1995

AMSAT OSCAR-E
A New LEO Satellite from AMSAT-NA

The next AMSAT-sponsored satellite, AMSAT OSCAR-E, represents "a step forward in the evolution of Microsat technology," according to author and project team member Rick Hambly, W2GPS. Here Rick introduces us to the satellite, its major subsystems, and the possible additional payloads that might be included.

By Rick Hambly,* W2GPS

AMSAT-NA has embarked on the construction of a new Low Earth Orbit (LEO) satellite that will be called AMSAT OSCAR-E, or "Echo," until it achieves orbit and receives the next sequential OSCAR number. Keith Baker, KB1SF, was referring to this satellite when he introduced a new "MICROSAT-class project" in the "Apogee View" column of the March/ April issue of *The AMSAT Journal.*

Notice that with this satellite AMSAT is returning to the practice of designating LEO satellites by sequential characters. This was last done for AMSAT OSCAR-D, which became AMSAT OSCAR-8 after launch and commissioning. AMSAT didn't use letters for the first four Microsats and the Phase 3 series started again with "A."

It has been 12 years since AMSAT-NA built and launched the original Microsats in 1990, and more than 8 years since AO-27 was launched in 1993. AMSAT OSCAR-E will put AMSAT-NA back in the satellite business while providing an improved companion for AO-27, which has been very popular with hams for the past 8 years, but is getting old. Space and power are available for one or more optional payloads that will be provided by AMSAT volunteers.

The AMSAT OSCAR-E project team is led by Dick Daniels, W4PUJ, and includes Tom Clark, W3IWI, and Rick Hambly, W2GPS. Oversight of the project team is provided by the AMSAT-NA executive committee and the Board of Directors. The core of AMSAT OSCAR-E will be built by SpaceQuest, Ltd., a company that is owned and staffed largely by AMSAT-NA members, including Mark Kanawati, N4TPY, and Dino Lorenzini, KC4YMG.

The remainder of this article will be divided between an overview of the core satellite systems and descriptions of candidate optional payloads. (The information in this article borrows heavily from "Microsat Mission Study Report" by Mark Kanawati, N4TPY, commissioned by AMSAT-NA and submitted by SpaceQuest, Ltd. to AMSAT-NA on January 9, 2002.)

AMSAT OSCAR-E: Core Subsystems

In the decade since AMSAT-NA built the Microsats, SpaceQuest has made many improvements to the Microsat concept. AMSAT OSCAR-E's core subsystems closely resemble those of the original Microsats but show the benefit of years of development and technology advancements.

Figure 1. This photograph was taken during a joint meeting of the project team and the AMSAT-NA executive committee with SpaceQuest on February 8, 2002. Shown, clockwise from the left, are Linda Jacobsen (SpaceQuest); Art Feller, W4ART (AMSAT-NA Treasurer); Rick Hambly, W2GPS and Dick Daniels, W4PUJ (AMSAT OSCAR-E project team); Dino Lorenzini, KC4YMG (SpaceQuest); Robin Haighton, VE3FRH (AMSAT-NA President); and Keith Baker, KB1SF (AMSAT-NA Executive Vice President). In attendance, but not shown, was Mark Kanawati, N4TPY (SpaceQuest).

The subsystems that make up the core elements of AMSAT OSCAR-E are:

- The physical structure
- Attitude control
- Central processor hardware
- Spacecraft flight software
- Power generation and distribution
- Command and control—ground station and satellite
- A basic set of receivers, transmitters, and antennas
- Space for optional payloads

The satellite with just this set of subsystems will have an impressive array of functions, including FM voice operation (EasySat), 9600 bps data channel(s), and a multi-band receive capability.

AMSAT OSCAR-E is a Microsat-class spacecraft weighing approximately 10 kg. The spacecraft consists of five solid-alu-

*e-mail: <w2gps@amsat.org>

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Figure 2. A mockup of AMSAT OSCAR-E in front of an original AMSAT Microsat.

minum trays, each with four walls and a bottom stacked to form approximately a 10-inch cube structure. A top cover is provided for the top tray. Six solar panels attach to each of the six sides for power generation. In addition, several antennas protrude from the top and bottom surfaces. The photo shown in figure 2 is an example of what the AMSAT OSCAR-E structure might look like, although the antennas will be quite different. Note the similarity to AMSAT's original Microsats, as shown by the full-size model in the background. These original Microsats were AO-16, DO-17, WO-18, and LO-19. They were followed by the descendents of that legacy, including IO-26, AO-27, MO-30, and SO-41.

Internally the spacecraft consists of a various electronic subsystems including:

- 4 VHF receivers
- 2 UHF transmitters
- 6 modems
- Flight computer
- RAM disk
- Batteries
- Battery charger and voltage regulators
- Wiring harness
- RF cabling
- RF switching and phasing networks
- 56 channels of telemetry and
- Magnetic attitude control

Figure 3 shows a conceptual block diagram of the AMSAT OSCAR-E spacecraft. The items enclosed in dashed lines are not a part of the basic AMSAT OSCAR-E mission, but are under consideration as secondary payloads.

Physical structure

AMSAT OSCAR-E's overall structure consists of a stack of five machined aluminum modules. Each module measures approximately 9.5 inches × 9.5 inches. The height of each module is adjustable up to a total of 9.5 inches. The nominal useful internal area is approximately 8 inches × 7.5 inches. Each module houses a different spacecraft subsystem.

Modules are interconnected by RF cables and a wiring harness carrying power, inter-module data, telemetry, and control signals. Four machined rods running the height of the spacecraft are used to bolt the assembly together. Figure 4 shows a photo of a typical Microsat structure.

AMSAT OSCAR-E employs a passive thermal control system and has no onboard propulsion. Almost all of the satellite's surface area is covered by solar cells. Some surface area is required for antenna mounts and launch-vehicle interfaces. The remaining surface area is covered with thermal absorbing and reflective tape to balance the spacecraft's thermal behavior.

A separation mechanism needs to be designed to adapt the satellite to a particular launch vehicle. Finalizing the separation mechanism will await selection of a launcher, although one version already exists for the Russian Dnepr launcher due to SpaceQuest's previous use of that launch vehicle. Dnepr is a de-militarized Russian ICBM.

A standard commercial shipping container will be used to transport the AMSAT OSCAR-E to the launch site.

Attitude control

The basic AMSAT OSCAR-E passive attitude control system consists of two permanent magnets that align the satellite's vertical axis with the Earth's magnetic field, four hysteresis damping rods that control the satellite spin rate, and reflective/absorptive tape that causes the satellite to rotate about its Z-axis as a result of solar photon pressure. This simple, no-power technique has been demonstrated to work well on several previous Microsat missions. The solar-induced spin averages out the thermal load on the satellite, while the permanent magnets allows one end of the satellite to point generally towards the Earth.

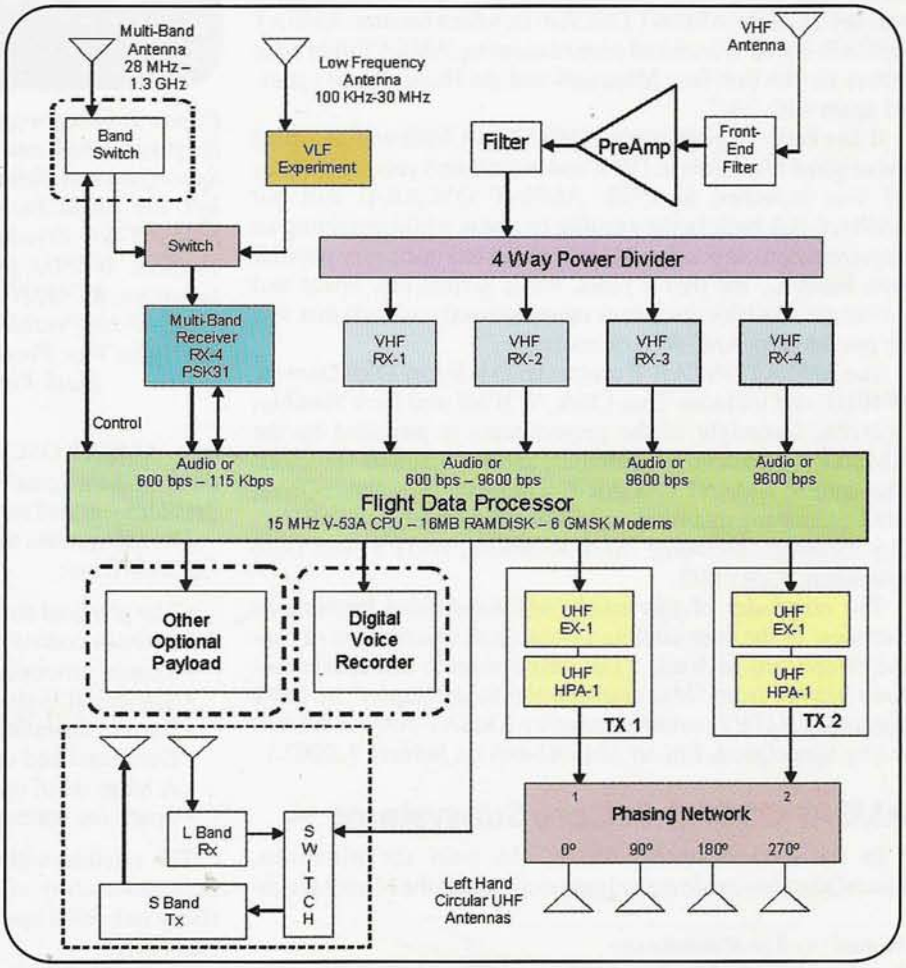


Figure 3. Conceptual block diagram of the AMSAT OSCAR-E spacecraft.

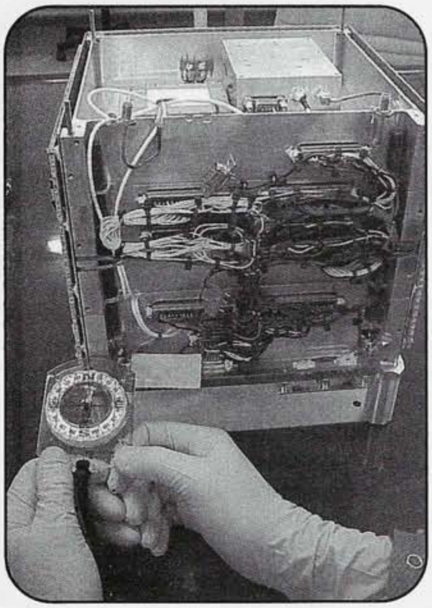


Figure 4. Typical Microsat structure.

The many advantages of this simple passive attitude control system are offset by one significant limitation: The permanent magnets cause the satellite to make two rotations per orbit, resulting in one face favoring the Northern Hemisphere and the opposite face favoring the Southern Hemisphere. The Earth-pointing direction is on the order of ±20 degrees in the temperate zones, varying with orbital inclination.

Central processor hardware

AMSAT OSCAR-E includes an Integrated Flight Computer, which incorporates the central processor unit (CPU), random access memory (RAM), RAMDisk, and modems. All of these functions are incorporated on a single, multi-layer, both-sides-populated PC board.

The CPU is a flight-proven, low-power NEC V53A processor. This processor first flew in 1993 on AO-27 and has flown on a number of LEO missions since. It is based on an ×86 core and runs the Spacecraft Operating System (SCOS), also flight proven on numerous spacecraft (see figure 5).

The processor is clocked at 29.412 MHz, running the bus at 14.7456 MHz. This yields three times greater processing throughput and three times faster interrupt response than previous missions using this processor.

The boot ROM uses a standard CMOS EPROM running a variant of the Microsat Boot Loader (MBL). The EPROM is divided into two sections, alternately mapped into memory space with each RESET command. Thus, if a partial failure of the EPROM occurs, the satellite operating system can still be booted. This technique has been flown successfully for several years.

The main memory system is error detecting and correcting (EDAC) using bit-wise triple-mode redundancy (TMR). TMR allows the safe use of wide-word memory, in this case 512K×8 static RAM (SRAM) chips. The overall EDAC memory size is one megabyte. A portion of this memory space is remapped to allow the boot read-only memory (ROM) to occupy the highest memory addresses.

A RAMDisk consisting of 16 megabytes of serial-accessible static memory is provided for bulk storage of data. This memory has no hardware error-correction mechanism, so error control must be handled in software. This technique has been used successfully since the Microsats launched in January 1990.

A 16-megabyte NAND-Flash memory is included for rapid re-booting of the operating system and application tasks after RESET. This is modeled after the successful FLASH operating system image reload facility of IHU-2 aboard AO-40.

Six GMSK modems are included. At least one will be fixed-rate for primary command and control of the spacecraft. Each modem is attached to a dedicated multi-protocol serial port based on the NEC 72001 SCC. Two of the modem uplink channels are fitted with firecode detectors to provide ground-commandable RESET regardless of the state of the CPU. The variable-rate modems can go as slow as 600 bit/s and as fast as 115.2 kbit/s. The uplink and downlink data rates are set independently. Two of the modems are DMA-capable; the other four are interrupt-driven only. Care must be exercised to ensure the CPU is not overloaded with interrupts during mission planning and general spacecraft operation.

Up to eight open-collector N-channel FETs provide power switching control (low-side switching), and several bits of 3.3V CMOS-level I/O are included. A pair of SPI ports is available for command and control functions to various modules in the satellite.

Approximately 56 channels of telemetry will be gathered on board AMSAT OSCAR-E. Eight-channel telemetry boards with 10-bit analog-to-digital converters are located in four of AMSAT OSCAR-E's trays. A Serial Peripheral Interface (SPI) bus links the telemetry boards to the central processor. Twenty-four telemetry channels are built into the Battery Control Regulator (BCR) board. The telemetry includes:

- All of the solar panel voltages, currents, and temperature
- Battery voltages, currents, temperature, and charge polarity
- BCR regulated voltages and currents
- Temperature of the receiver, transmitter, central processor, and switching regulators
- Multi-band receiver signal-strength indicator and
- The high-power amplifier output and reflected power on both transmitters

A dedicated SPI bus is used to channel the telemetry from the BCR and the individual telemetry boards to the central processor.

Spacecraft flight software

The boot loader provides the minimal set of functions required to verify the satellite health and load the operating system. The boot loader runs on the initial power up, and whenever a software or hardware reset occurs. Because it resides in permanent memory and cannot be changed after launch, the boot loader is simple, robust, and proven.

The boot loader provides the capability to:

- Send acknowledge beacons
- Upload new software
- Download memory locations
- Peak and Poke memory and I/O
- Load software from FLASH or error-detecting and correcting memory (EDAC) and
- Execute operating system by command or timer

The Spacecraft Operating System (SCOS) has been used on all of the amateur radio Microsat projects to date. The operating system and the housekeeping task are contained in EPROM and are moved into RAM for execution by the boot loader. In addition to detailed telemetry reporting, the housekeeping functions include control of the power system, transmitters, and receivers. If needed, it can also support minimal attitude control. As was the case for the boot loader, the operating system and minimal housekeeping task are unchangeable after launch. However, updated versions of these programs can be uploaded and executed after launch. In order to be robust and proven, this version of the housekeeping is kept as small as possible. The list of off-the-shelf programs that execute as tasks include:

• Memory file manager (M-FILE) from Surrey Satellite Technology Ltd (SSTL)

• PACSAT File Transfer Level 0 (FTL-0) from SSTL

• Transmitter Scheduling and Power Monitoring from SpaceQuest and

• Supervisor Task Loader and Monitoring from SpaceQuest

The Mission Software provides complete control over all aspects of the satellite, including experiments and attitude control. This software can be loaded into FLASH from the ground after launch, which allows for flexible development and deployment of new software. The complete set of software should include:

• Multitasking Spacecraft Operating System (SCOS) from BekTek

• Advanced Task Supervisor

• TX and RX mixing and control

• Telemetry monitoring, storage, and reporting

• RAMDISK management and PACSAT protocol

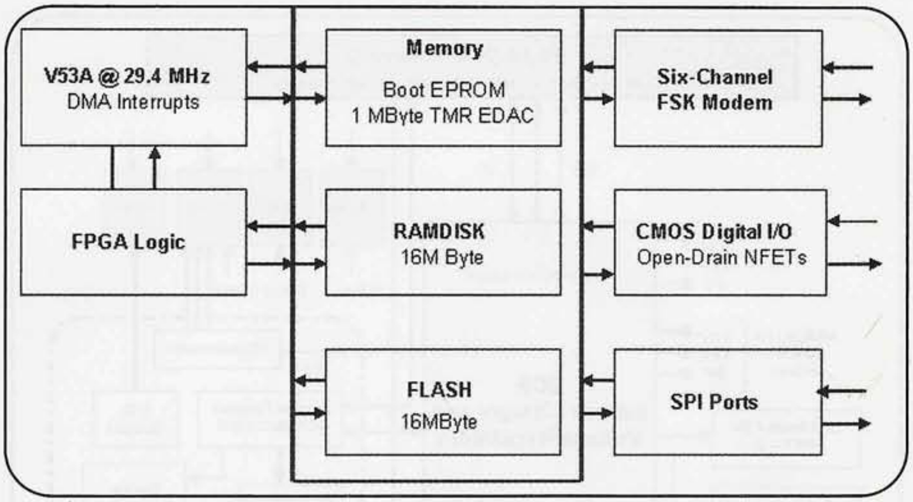


Figure 5. AMSAT OSCAR-E central processor unit (CPU).

• Scheduling for regional satellite access

• Magnet torquer and IR attitude control

• Optional experiment control

• Additional experimental tasks, such as the digital recorder

Power generation and distribution

The AMSAT OSCAR-E Power Subsystem consists of a Battery Control Regulator (BCR), six GaAs (Gallium Arsenide) solar panels, matched flight cells, voltage regulators, and a power activation switch. A block diagram of the power subsystem is shown in figure 6.

The BCR provides a power control system designed by SpaceQuest for small satellites. Its function is to convert solar-

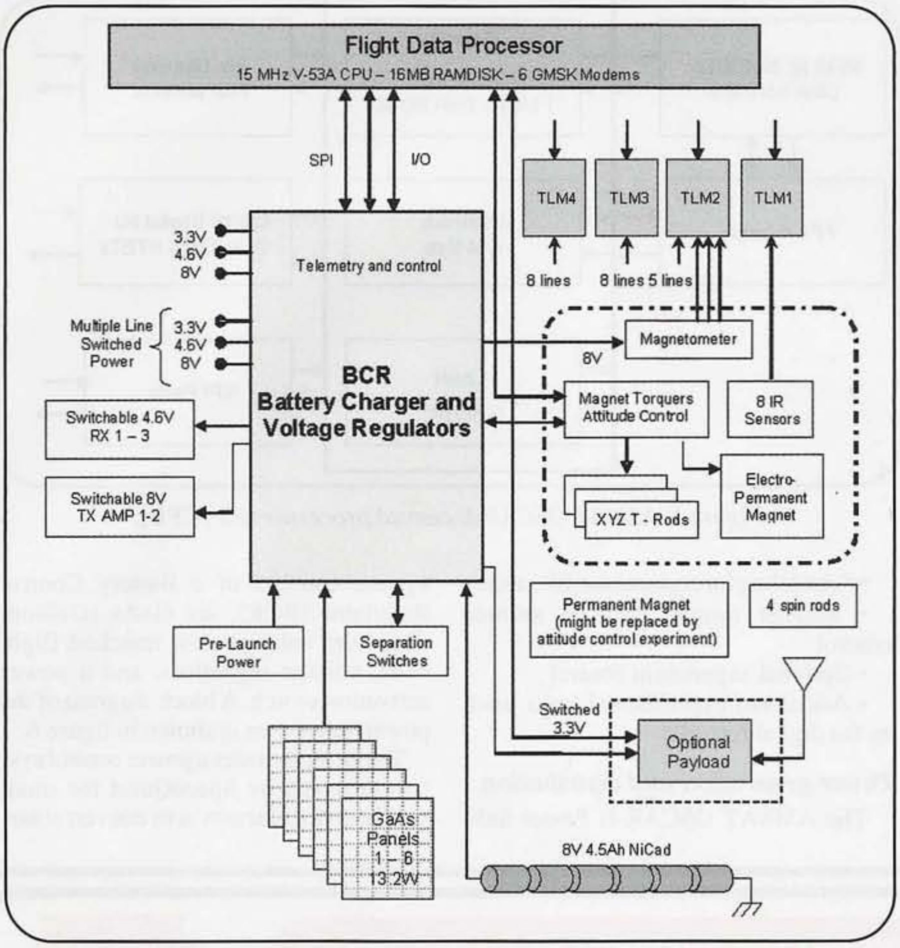


Figure 6. AMSAT OSCAR-E power, telemetry, and attitude control block diagram.

panel power to system power, and manage battery charge and protection. The BCR takes power from solar panels with necessary restraint so as not to draw too much current and lose panel efficiency. The main converter on the BCR uses this solar-panel power to charge the system battery, with similar restraint so as not to overcharge the battery. The battery-charge system sets maximum charge voltage according to cell temperature, to maximize charge storage while avoiding overcharge and cell heating. The charge regulator is also prevented from reducing solar-panel voltage below a preset voltage, to maximize panel output power. The maximum battery-charge voltage set point and the minimum solar-panel voltage set point can be adjusted by external computer control. The battery-charge regulator is a switching design with a measured efficiency of 89 percent.

The BCR is designed to operate autonomously, with CPU supervision for fine-tuning of default parameters. The BCR will safely manage battery charge during the critical period after separation and before ground operators establish control. On-board software can then fine-tune the solar panel and battery-charge-limit set points for maximum performance with minimum attention.

The GaAs solar panels, which are mounted on all six sides of AMSAT OSCAR-E, produce a bus voltage of approximately 16 volts. The cells have not been selected yet, but the minimum efficiency will be 19% and cells with efficiencies of up to 28% are available. The choice depends on their price and availability at the time the solar-panel decision is made.

The battery configuration is six NiCad cells at 4.4 Ah each with a nominal battery voltage of 8 VDC, depending on temperature and charge state. These matched batteries have been flown successfully on previous Microsat missions and are well characterized on orbit.

The BCR provides multiple switched 8-V lines for both transmitters and other high-power applications. There are also 3.3-V and 4.6-V switching regulators, capable of over 250 mA output each, with multiple switched and unswitched outputs.

Separation-switch circuitry is included on the BCR to turn off all systems while the satellite is mounted on the rocket. An external connection port is provided with two levels of separation switch override to safely charge satellite batteries and test the satellite while it is mounted on the rocket.

Command and control—ground station and satellite

The Bootloader Command and Control application communicates with AMSAT OSCAR-E's bootloader to allow the user to upload necessary code changes, or to load and execute the operating system and tasks. This program will need to be rewritten for AMSAT OSCAR-E. The current version of this software runs under DOS.

The Housekeeping Command and Control program communicates with each of the tasks onboard the satellite. It must be customized to support each additional task. Its primary use is to configure the satellite. The housekeeping command and control software is also currently DOS based.

The Telemetry Gathering and Reporting program is a standalone Windows® application that will need to be developed for downloading and displaying satellite health information. This application would monitor a serial port, listening to the telemetry downlink and whole earth data files.

A basic set of receivers, transmitters, and antennas

The VHF antenna consists of a very thin quarter-wave (18-inch) vertical whip mounted in the center of the top surface of the spacecraft. This piano-wire antenna connects to the spacecraft with a standard SMA connector, and has been flown on several previous Microsat missions.

The antenna feeds the low-insertion-loss bandpass filter prior to entering the GsAsFET Low Noise Amplifier with a noise figure of less than 1 dB and a gain of 18 dB. Additional filtering is accomplished by a second bandpass filter. A four-way power divider channels the incoming signal into four VHF receivers.

Four miniature VHF FM SpaceQuest receivers are used both for command and control and for user links. Each receiver consumes less than 40 mW and weighs less than 50 gm. Typical sensitivity is –122 dBm. The receiver's IF bandwidth can be configured prior to flight at either

15 kHz or 30 kHz, based on data-rate requirements. They are capable of passing either analog or digital data up to 14.4 kbit/s. All of the receivers are fed directly into GMSK modems on board the Flight Data Processor. These receivers have flown successfully on several low-earth orbiting spacecraft.

AMSAT OSCAR-E has two SpaceQuest UHF FM transmitters that have been flown on several previous Microsat missions. Each transmitter contains a PLL-based exciter and a Motorola high-power amplifier. The unique characteristics of this design include its small size, low mass, high efficiency, on-orbit adjustable output power from 1 to 12 watts, and its nominal operation at 7.5 volts. Analog or digital data rates up to 56 kbit/s and beyond are possible.

The overall gain of the UHF power amplifier is 39 dB, generating up to 12 watts of RF output with a single carrier at more than 60% efficiency excluding the 2-mW exciter. Both transmitters can be operated at the same time into a single antenna system. High power on the UHF downlink is needed to offset the extra path loss at UHF frequencies balancing the VHF uplink. High downlink power will also permit transmissions at higher data rates and/or enable true hand-held voice or data operation. The high efficiency reduces the heat generated and absorbed in the spacecraft and increases the useful life of the transmitter. The measured output of the UHF high-power amplifier at 40 °C is shown in figure 7.

AMSAT OSCAR-E has a UHF Turnstile Antenna that is fed by SpaceQuest's hybrid antenna phasing network consisting of a strip-line circuit that provides the appropriate quadrature phase and amplitude to each of four output antenna ports with less than 0.5 dB of insertion loss.

AMSAT OSCAR-E: Candidates for Optional Payloads

The following are brief abstracts describing the optional payloads under consideration for the AMSAT OSCAR-E mission. Other outstanding proposals have been suggested but were rejected in the first cut by the project team for a variety of reasons, including feasibility, value to the ham community, cost, power budget, and risk. It is almost certain that more cuts will have to be made, because it is not possible to support all the remaining payloads on a single satellite the size of AMSAT OSCAR-E.

1. Advanced Data Communications for the Amateur Radio Service (ADCARS)

This payload supports the proposal by KA9Q and others for applying digital encoding techniques to improve communication links and bandwidth utilization. This system would use a wide-band TDMA single-frequency data link to support multiple simultaneous users and modes (voice, data, video, telemetry, etc.). The downlink will be S-band, due to the bandwidth requirements. The uplink will be L-band if the single-frequency TDMA wide-band uplink is implemented.

2. L-Band/S-Band Communications System

This payload, proposed by KAØESA of AMRAD, describes a capability similar to that required to support the ADCARS experiment.

3. GPS Receiver

This payload was proposed by W3IWI and W2GPS. Unfortunately, the NASA PiVoT GPS receiver that we had hoped to carry will not be available. If a receiver of the right size and low power requirement can be found, this payload will be reconsidered.

4. Active Magnetic Attitude Control

This experiment has the potential for significantly improving the stabilization of the spacecraft. Several possible attitude control system (ACS) configurations will be investigated. The simplest ACS concept is to replace the permanent magnets with semi-permanent electromagnets. While physically passive, electronics are required to polarize and condition the magnetic rods. Another more involved ACS concept is to use three miniature torque rods for attitude control and a magnetometer for attitude determination.

5. Audio Recorder Experiment

This experiment, proposed by KK7P, will provide the capability for recording and playing back any audio channel. It is particularly useful in recording data from the multi-band receiver to support the low-frequency experiment (see below).

The ADCARS experiment team has recognized that, with minimal changes, the hardware for the Audio Recorder Experiment could also serve the ADCARS needs for computing resources.

6. Low-Frequency Receiver

This experiment, proposed by AMRAD, uses the LF capability of the on-board multi-band receiver (see #9) to study LF propagation phenomena from the unique observation point above the ionosphere, particularly at 136 kHz.

The receiver and antenna whip are already on the spacecraft, but a new E-field antenna interface amplifier and antenna switching hardware will need to be designed if this project is to be supported.

7. APRS

This payload will provide a generic APRS digipeater to support and encourage mobile and handheld satellite digital communications. The target ground system assumes a user with a 9600-baud integrated TNC/radio with an omni antenna, either an HT or a mobile. The spacecraft simply digipeats all UI packets addressed via the paths of APRSAT, RELAY or WIDE. The spacecraft digipeater does callsign substitution like all APRS digipeaters and substitutes its own call after it digipeats the packet.

While it is not optimal for portable and mobile users, incorporating an APRS capability in the spacecraft can be done within the spacecraft basic bus, requiring no additional hardware if 9600 FSK is used with VHF uplink and UHF downlink. The downlink will have to share bandwidth with spacecraft telemetry and other data downlinks. Some switching capability in one of the receivers may be required.

The implementation of APRS that is being considered would also allow for a *store-and-forward mode,* where copies of APRS packets are saved until the satellite is in range of a known APRS Internet Gateway station, when the APRS data can be downloaded at high speed on an encoded data link for high reliability.

8. PSK-31

Proposed by WB4APR, transponding using the PSK-31 technique can be accomplished using the communications capability of the basic spacecraft bus. Uplink would utilize 10-meter SSB reception through the multi-band receiver (see below). Downlink would be via one of the UHF transmitters.

9. Multi-band Receiver/Antenna

Proposed by SpaceQuest, this receiver has already been tested in space and can provide a receive capability over a wide range of frequencies from LF through L-band. The development of the antenna is challenging, and it is currently unclear if the broadband antenna would be optimized for LF/HF (through 30 MHz) or for VHF/UHF (10 meters through UHF) or both. A separate antenna will be provided for L-band.

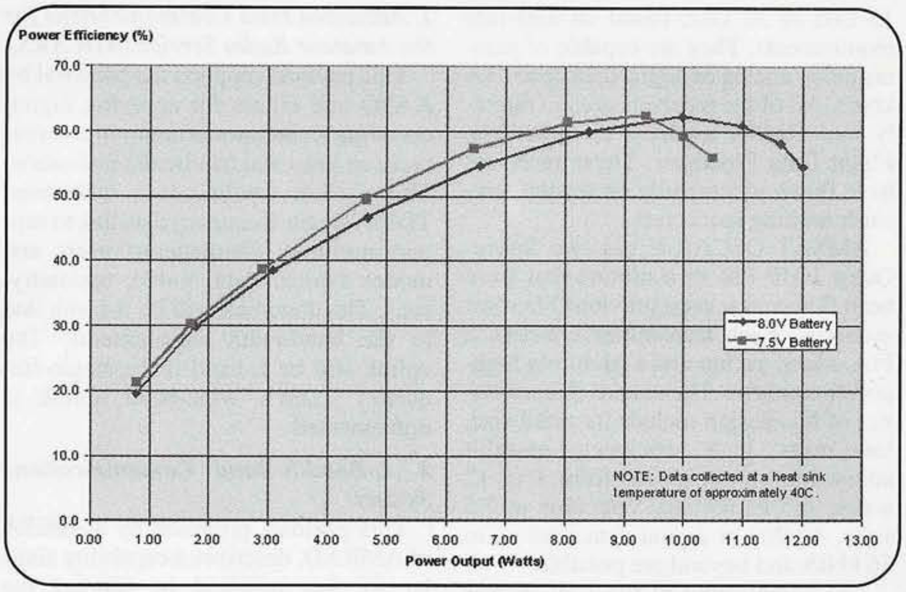


Figure 7. UHF amplifier RF power output vs. efficiency.

10. High-Efficiency Solar Arrays

Included in the SpaceQuest proposal to AMSAT, the additional power that would be made available for the experiments would clearly benefit the experiments. Efficiencies of up to 28% might be achieved using a combination of *flexible cells* with a new mounting and substrate design invented by SpaceQuest.

11. Robust Telemetry Link

This experiment would demonstrate the value of using FEC and interleaving encoding techniques to improve telemetry reception by ground stations. This technique was developed by KA9Q and others for AO-40, where it is now being considered for implementation.

Summary

The core elements of AMSAT OSCAR-E are under construction now by SpaceQuest. The AMSAT OSCAR-E project team is working to finalize plans for the optional payloads.

There is the possibility that a launch opportunity might arise before the optional payloads can be ready. If this happens, it is conceivable that the spacecraft would be launched as an *EasySat* only, with few, if any, optional payloads. However, it is considered likely that AMSAT OSCAR-E will be the first in a series of new low-cost LEO satellites, each to carry optional payloads of interest to the amateur community.

AMSAT OSCAR-E will be a step forward in the evolution of Microsat technology, with better receivers, higher power transmitters, and new operating modes. The user community will see a strong set of features from the basic satellite, even before optional payloads are added. These include:

- Analog operation including FM voice
- Digital operation including high-speed APRS
- Higher downlink power
- Multiple channels using two transmitters
- Can be configured for simultaneous voice and data
- Has a new multi-band, multi-mode receiver
- Can be configured with geographically-based personalities.
- Has a true circular UHF antenna that maintains its circularity over a wide range of squint angles.

For those with an interest in the technical infrastructure of the satellite there are significant improvements in AMSAT OSCAR-E:

- Faster, more capable IHU processor
- Higher data rates on downlinks
- Autonomous, self-healing, high-efficiency power management system
- Upgraded, highly capable software package
- Store and forward with continuous monitoring and geographically defined data forwarding.

These are only partial lists of new and improved capabilities. Notice that there are some tantalizing items in these lists that have not been explained in this article. They will be explored in future articles. AMSAT OSCAR-E is expected to be a very popular satellite. ■

Working the VHF/UHF and Microwave Contests as a Rover

During the late summer and early fall the ARRL sponsors several VHF/UHF and microwave contests. For those of us who cannot operate from our home stations, Rover operation is the next best alternative for participating in these contests. *CQ VHF* commissioned expert Rover operator N9RLA to write about strategies.

By Dan Evans,* N9RLA

I am a QTH-challenged, VHF+ weak-signal operator. Many of you may know me as N9RLA/R, the "no budget" Midwest Rover. Several years ago, while living in an antenna-restricted neighborhood, I decided to try VHF contest Roving. I have been firmly hooked ever since! Over the years I have gained experience and learned a great deal from the experts. I now would like to impart some of my experience and knowledge to you in the hopes that it will help you in your Rover VHF/UHF and microwave contest efforts. For the uninitiated, a "Rover" is a contester who operates mobile from more than one grid square. Most VHF contests have a separate Rover category.

Maximizing Your Points Per Mile

The approaching VHF/UHF and microwave contests and the ARRL September VHF QSO Party are tailor-made for Roving. The weather is usually pleasant and activity is high. To take advantage of these activities as a Rover, we need to focus on a strategy to improve our contest efforts. VHF contesting (and contesting in general) boils down to making as many contacts as possible while picking up as many multipliers as possible. As a Rover, you have the advantage of being able to add more contacts and multipliers by moving your station to various grid squares. The key to doing well is making the most of this advantage, or maximizing points per mile.

*444 Lynhurst St., Scottsburg IN 47170
e-mail: <n9rla@yahoo.com>

The author at the microphone.

Adding a second op: Nothing will help your Rover station more than adding a second operator. This will allow one of you to operate the contest while the other drives, an important safety factor. With my current setup I usually run solo, and except for a few FM contacts, I don't operate while moving. I just don't think it is safe to drive, work the radio, and keep track of the log all at the same time. When I am in motion, I turn on the tape recorder and try to make contacts on FM, which is a lot simpler. However you do it, remember that nothing is more important than safety.

When you are stopped, you become a small multi-op team, which is a big advantage when 6 meters is open. Dedicating one operator to 6 meters during a band opening will allow you to take full advantage of the opening, while still being able to pass stations up to the higher bands for more points and multipliers.

Considering the above advantages, you should try to add a second operator to your Roving whenever possible. This is also a great way to introduce someone to the fun of VHF contesting and Roving.

Setup time: A second pair of hands can be a big help with setup, particularly when it comes to antennas. You can't make points if you aren't on the air, so reducing setup time is a must.

The amount of antenna setup time usually involves a trade-off between using large antennas with lots of gain or using smaller, more portable antennas with a somewhat smaller signal. Can you get by with using fixed-mounted loops, or do you need the extra range of a Yagi for each band? The region in which you are Roving will play a big role in this decision.

Here in the Midwest I need to be able to work into neighboring states to pick up contacts. Being restricted to operating with small antennas is a liability. What works best for me is a telescoping push-up mast with the antennas fixed in place. That way I can lower the antennas for travel, but still erect them easily and quickly by myself.

When you are putting together equipment for your Rover station, always focus on keeping setup time to a minimum. Practice setting up before the contest so you will have a good idea of how long it takes to get everything ready.

Route planning: The fine art of route planning is always a challenge. Again, the key is to focus on maximum points per mile. Operating from grid corners (the locations where four grid locators intersect) is a great way to keep travel time to a minimum while activating the most grids.

There are times, however, when it is worth the extra travel time to operate from a good hilltop. While operating from sites near grid corners is more efficient, the extra range that the hilltop provides will allow you to make more contacts. A Rover needs to have a schedule of when to operate and when to travel, and then stick to it.

I like to plan my travel for those times when there are lulls in activity. For example, for the start of a contest I pick the grid corner on my route farthest away from home. This way I can leave several hours before the contest starts in order to reach the first grid. Allow yourself plenty of time to reach your first grid and complete setup before the contest starts, as there is usually peak activity in the first hour.

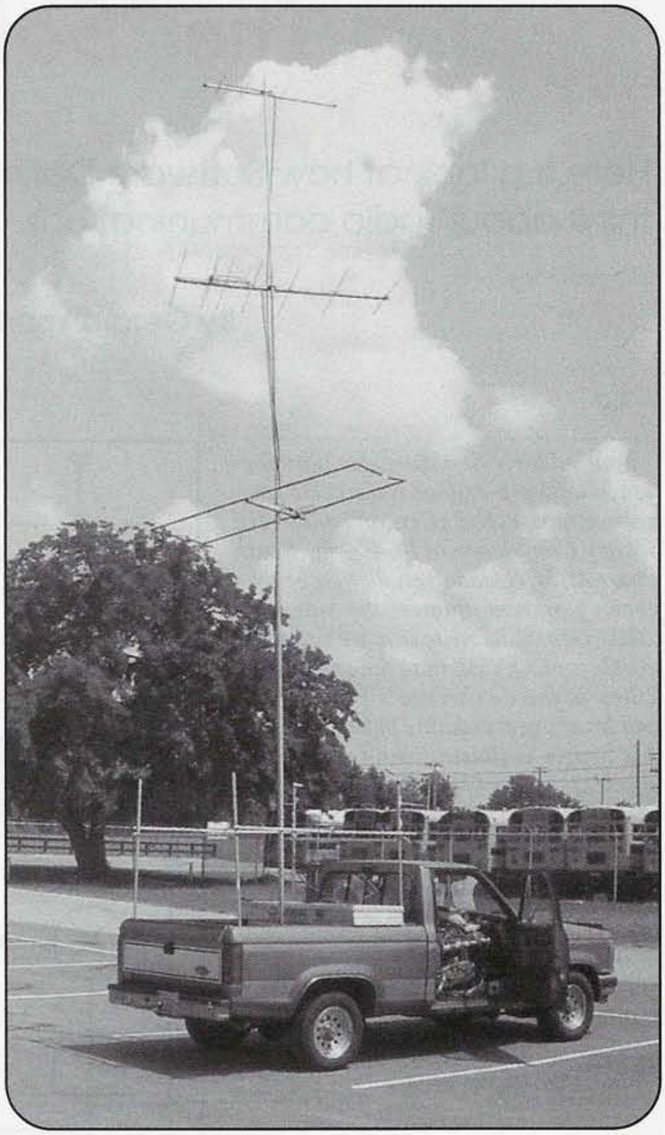
A big lull in activity generally occurs during the nighttime hours of a contest. While with most contests there are points to be obtained overnight for the diligent, a few hours of sleep seems to be much more productive for me.

After a good rest I start out very early in the morning (around 4 AM) for one of my favorite hilltops, deep in the heart of EM69. This hilltop adds about 1.5 hours to my travel time, but it is a very good site. I try to be there and ready as early as possible to take advantage of the peak activity on Sunday morning.

One of the toughest parts of route planning is finding good spots from which to operate. Altitude is everything with VHF, so a good high spot is *great*! If these high-altitude locations are too far away or inaccessible, then they are not much help. If there is no high-altitude spot available, then you have to improvise.

In EN60 and EN70 I operate from mall parking lots. There are no hills in that area. Occasionally, I also have used a roadside park-and-rest area. Basically, you just need a spot where you can get off the road and be out of the way for an hour or so. Whenever possible, try to locate good sites before a contest. Mark Herson, N2MH, has put together a web page to help find Rover sites: <http://www.intac.com/~mherson/rovesite.htm>.

Publicity: Once you have your route planning done, it's time to look at advertising. It's hard to make contacts from those rare grids if no one knows you are there! The best way to share your plans is via the VHF internet e-mail reflectors, such as <vhf@w6yx.stanford.edu>, <VHFcontesting@contesting.com>, and <Rover@mailman.qth.net>. I also gather and post the plans of contest stations on The Rover Resource Page at <http://www.qsl.net/n9rla>. Try to let everyone know your plans a week or two ahead of the contest.



N9RLA Rover station in EM88.

You will also want to let everyone at your local club know your schedule. Announcing your plans at the local club meeting will not only add more contacts, it also will inspire new folks to join the fun of VHF contesting.

This is an opportune time to request scheduled contacts as well. Making a few skeds is a good way to pick up QSOs and multipliers during the off-peak times of a contest.

Summary

I hope these tips will help you maximize your points per mile. Taking along another person, minimizing your setup time, choosing your sites in advance, and careful planning and advertising should add more points to your contest Rover score. The upcoming contests are the perfect time to go Roving *(see the "Quarterly Calendar of Events" in this issue for details—ed.).* Get out there and have fun! ■

The "Soft" Radio

Here is a look at how Software Defined Radios will change the way we think about radio communications.

By Gerald Youngblood,* AC5OG

Your editor's first extensive introduction to software-defined radio (SDR) theory was at last year's Central States VHF Society Conference in Ft. Worth, Texas, where AC5OG made a challenging introductory presentation on the subject. I asked Gerald to write a more extensive article for CQ VHF *than the one he published in the conference's* Proceedings, *and he obliged with this material. While this article is illustrative of a 40-meter application, as Gerald points out, the beauty of the SDR radio design is instant reprogramming to the frequency of your choice.*

This piece also provides an overview of Gerald's four-part series which began in the July/August 2002 issue of QEX. *Our thanks and appreciation go to* QEX *Editor Doug Smith, KF6DX, for his cooperation and assistance to Gerald in his preparation of this article. —N6CL*

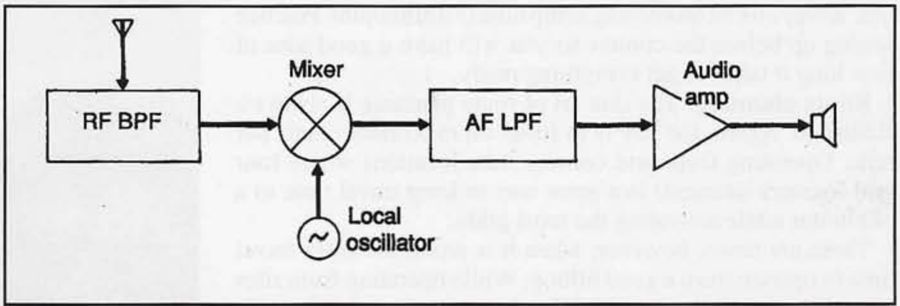


Figure 1. Simple direct-conversion receiver.

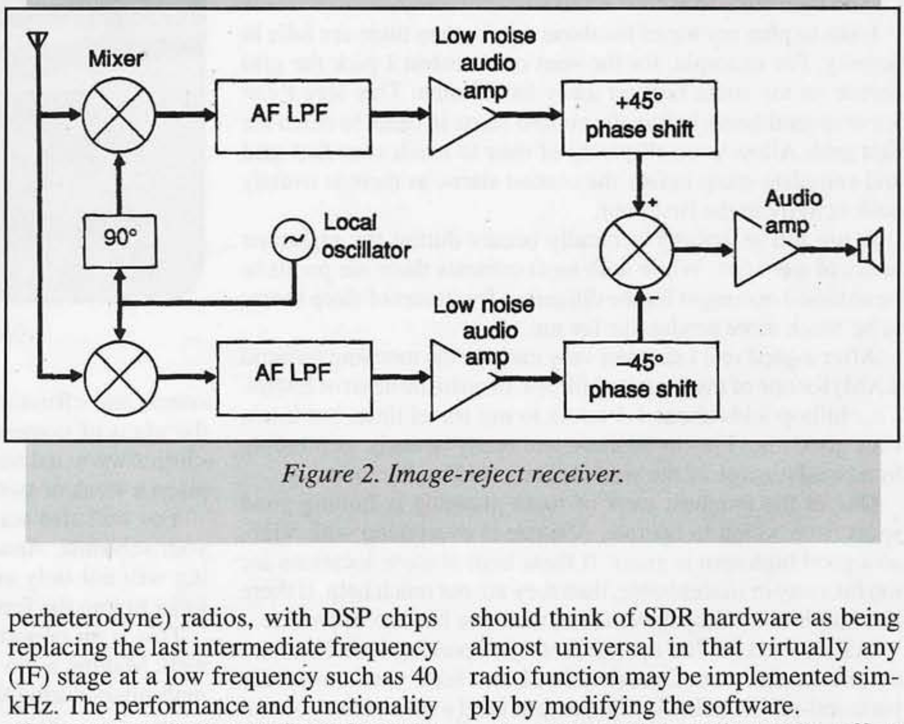


Figure 2. Image-reject receiver.

A revolution is occurring that will change the way amateur and commercial radios are built, used, and maintained. Since the beginning of radio communications, the functionality and performance of a radio was virtually fixed from the time it was manufactured. A design began with a set of specifications that were, in turn, converted into schematics that were subsequently converted to printed-circuit-board assemblies. Aside from hard-wired field modifications, there wasn't much that could be improved or upgraded.

More recently, most amateur and commercial radios incorporate *digital signal processing (DSP)* technology to provide improved filtering and noise reduction. Typically, these have been designed around traditional multi-conversion (superheterodyne) radios, with DSP chips replacing the last intermediate frequency (IF) stage at a low frequency such as 40 kHz. The performance and functionality of the DSP radio is still fixed from the design stage and therefore cannot be modified by the user.

Enter *software-defined radios (SDRs).* The SDR is a radio in which most or all frequency control, modulation/demodulation formats, and bandwidths are *defined in software* and thus can be changed after the construction process. One should think of SDR hardware as being almost universal in that virtually any radio function may be implemented simply by modifying the software.

In commercial radios this offers tremendous flexibility and cost savings when upgrading to new modes of operation, as is being demonstrated in new wireless-phone base stations. For the amateur radio operator, it means that over time one radio may perform many enhanced functions such as new data, weak-signal, and digital voice modes.

**8900 Marybank Drive, Austin, TX 78750*
e-mail: <gerald@sixthmarket.com>

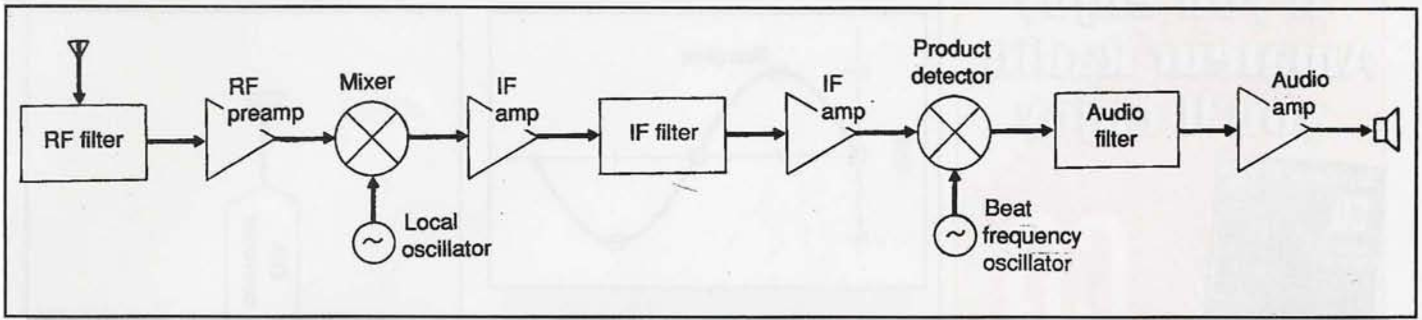


Figure 3. Superheterodyne or filter-method receiver.

SDRs also offer the potential for significant improvement in price/performance over traditional analog radios.

A Look Back at Hardware Radios

To understand SDR concepts, let's first take a look back at the primary hardware architectures that have dominated radio construction. In this article I will focus on receiver technology, because in many cases transmission is the reverse operation of receiving. Virtually all of the principles used in DSP and SDR technologies are analog concepts converted to digital. The principles and the math are the same; however, we can do things with much more precision and flexibility in software.

Figure 1 illustrates one of the simplest receiver architectures—the direct-conversion, or D-C, receiver. The RF carrier from the antenna is bandpass filtered and mixed directly with a local oscillator tuned to the carrier frequency. The mixing process produces outputs at the sum and difference of the carrier and local-oscillator frequencies. The subsequent low-pass filter easily removes the sum frequency, leaving only the difference frequency at zero Hertz. Not surprisingly, this architecture is also frequently called a *zero IF receiver.*

The D-C receiver is wonderfully simple and offers very high dynamic range if properly designed. One problem with this architecture is that when we mix the local oscillator with the carrier, we generate an unwanted image frequency that cannot be filtered out. This image is actually the opposite of sideband. Unless we are listening to an AM signal, this unwanted image will increase the noise level at the receiver output.

To solve the problem, *image-reject* receivers were created as illustrated in figure 2. These are also referred to as *phasing-type, Weaver-method,* and *quadrature down-conversion receivers*. There are a number of different ways to construct an image-reject receiver, but one common analog method is illustrated here. While this method is not widely used today in commercial amateur radio gear, it is the primary architecture used in SDR designs.

The image-reject receiver is similar to the D-C receiver in that the RF carrier is directly converted to zero Hertz; however, instead of one mixer, it incorporates two. While both mixers are driven from a single local oscillator, one mixer is driven directly and the other is delayed by 90°. This means we now have two copies of the incoming carrier that are 90° out of phase (or in *quadrature*) with one another.

We then low-pass filter and amplify the respective signals before shifting the phase plus and minus 45°, respectively. The math actually works out so that we now can add or subtract the shifted signals to receive the lower or upper sideband, respectively.

There is a problem, however, in that slight variations in analog component values result in amplitude and phase differences between the two channels that reduce opposite sideband (i.e., image) suppression. An excellent discussion of how this quadrature down conversion works is available online in an article by Richard Lyons entitled "Quadrature Signals: Complex But Not Complicated." It may be downloaded from the web at <www.dspguru.com/info/tutor/quadsig.htm>.

Until the 1960s, the image-reject receiver was very popular. At that point, high-performance filters became available that allowed inexpensive construction of multiple-conversion *superheterodyne* (or *filter-method*) receivers similar to that shown in figure 3. Superheterodyne receivers have two or more mixing stages with intermediate-frequency (IF) filtering and amplification.

With high-quality crystal or mechanical filters, excellent opposite sideband suppression is possible. The tradeoffs in this approach, however, are increased complexity, images caused by mixing the frequencies from multiple stages, and potentially reduced dynamic range compared to the image-reject method.

In a superheterodyne design, the RF carrier is filtered and usually preamplified before mixing the signal to an intermediate frequency such as 9 MHz or 455 kHz. Many modern receivers use first IF frequencies in the 70 MHz range to spread out the image frequencies so that they are much easier to filter. The signal is then amplified and filtered at the IF frequency before being applied to one or more subsequent mixing and filtering stages.

In figure 3 is shown a dual-conversion example where the second conversion is from the IF frequency to audio or zero Hertz (just as we saw in figure 1, except the carrier begins at the IF frequency). This stage is often called a *product detector,* because it is a multiplication process that creates "products" of the *beat-frequency oscillator* and the IF carrier frequency.

That's enough of the history. It's time to move on to SDR architectures and how they relate to the examples we have just discussed. To learn more about receiver architectures before moving on, please read the appropriate sections of the *ARRL Handbook for Radio Amateurs.*[1]

SDR HardwareArchitectures

The first thing that one needs to understand is how an analog radio-frequency signal can be converted to digital numbers to be processed in a computer and translated back to analog again as sound. This is accomplished through a process called *digi-*

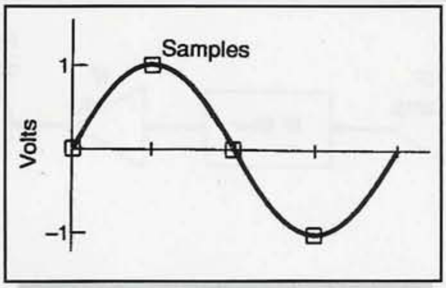


Figure 4. Digital sampling of a sine wave.

tal sampling. (For further study on digital sampling[2, 3], refer to the references provided in the endnotes.)

A radio-frequency carrier can be thought of as a sine-wave voltage that completes a 360° cycle in a time equal to the inverse of the carrier frequency. In 1933 Harry Nyquist proved that one only has to sample a signal at a rate slightly greater than twice the signal's highest frequency component in order to accurately recreate the signal mathematically.

Figure 4 illustrates a sine wave that is sampled at four times the frequency of the waveform. Note that when we sample a 1 V peak sine wave at 0°, 90°, 180°, and 270°, we will measure 0 V, 1 V, 0 V, and −1 V, respectively. If, for example, the sine wave had a frequency of 40 kHz and we sampled the signal at 160 kHz, we would get one sample every 6.25 ms (i.e., 1/160,000).

All SDRs use *analog-to-digital converters,* also called *ADCs,* to digitally sample analog signals so that a computer can process them. To convert back to analog, a *digital-to-analog converter (DAC)* is used. Most computers today include a sound card that allows audio frequencies up to 20 kHz in bandwidth to be recorded and played back by the computer. The sound card digitizes the incoming sound with an ADC and then stores the sampled signal in computer memory.

Applications may then use the samples to perform various types of signal processing such as graphic equalization (tone control) or amateur radio digital modes such as PSK31. In fact, a PC with a reasonable-quality sound card provides much of the hardware needed for a powerful SDR.

SDRs use three primary hardware architectures to convert the radio frequency (RF) signal to analog: *superheterodyne with IF sampling, quadrature*

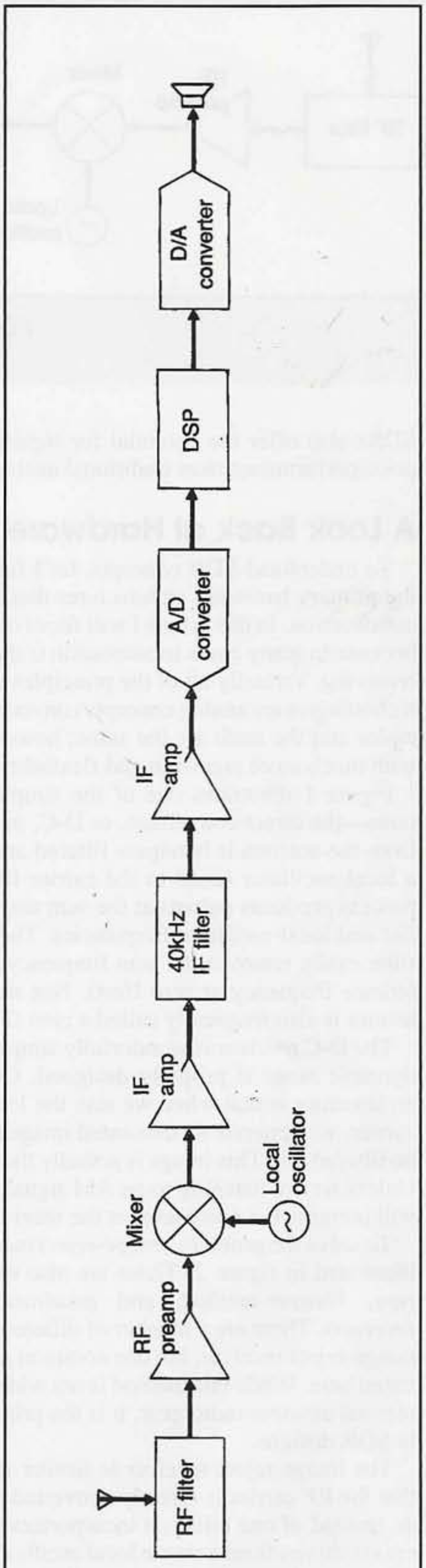


Figure 5. Superheterodyne receiver with low IF sampling.

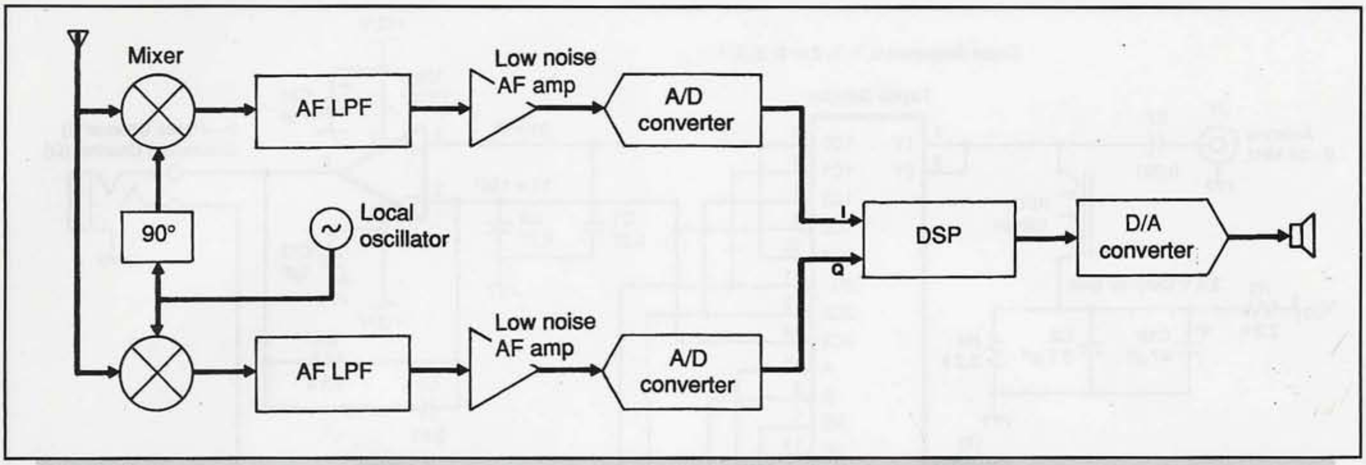


Figure 6. Quadrature down-conversion and sampling receiver.

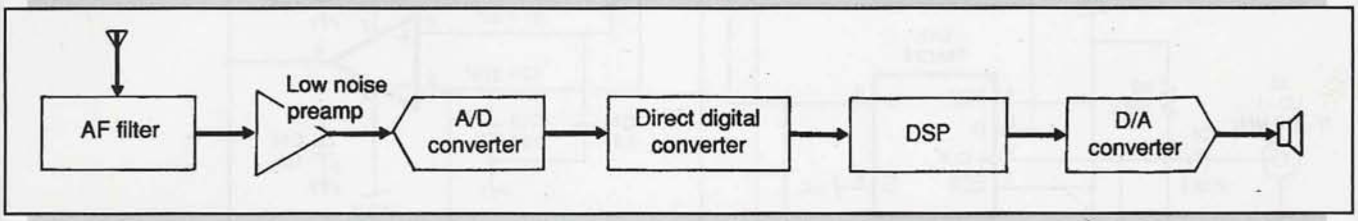


Figure 7. Direct-digital-conversion receiver.

down-conversion to baseband (another word for zero IF as described above), and *direct digital down-conversion (DDC)*. As technology improves, the goal is to move the A/D conversion as close to the antenna as possible so as to remove the imprecise nature of analog circuitry.

The technology now exists to simultaneously sample the entire HF spectrum in real time. The main problem is the dynamic-range limitations of the ADC.

Most DSP transceivers on the market use the superheterodyne with IF sampling architecture similar to that shown in figure 5. The product detector, beat-frequency oscillator, and audio filtering shown in figure 3 are replaced by digital circuitry and software in the digital signal processor. A typical IF frequency might be 40 kHz. After A/D conversion, the signal is mathematically translated from 40 kHz to 0 Hz and filtered using high-performance, flexible digital filters. However, this is really still an analog radio with a digital back end.

The technology really starts to get interesting when we examine the other two methods of conversion. Figure 6 shows a *quadrature down-conversion and sampling receiver* where the A/D conversion replaces the phasing and summation functions shown in figure 2. With this architecture, we are able to convert from RF to quadrature baseband in a single step. With the information from the two channels of digitized signals, we can extract and filter the signals within a bandwidth of two times the sampling rate of the ADCs. *(Note: We are able to double the bandwidth because the two channels effectively double the sampling rate.)*

With the advent of very-high-speed ADCs and DDCs, it is now possible to sample signals at rates of up to at least 100 MHz[4]! This means that with a system similar to the one shown in figure 7, we can simultaneously digitize large chunks of the HF spectrum. We can then digitally down-convert the signal to baseband for subsequent filtering and signal processing.

From the diagram, one can see that virtually every feature of the radio may be controlled and upgraded through software. Such a radio would not become obsolete quickly because new features and enhanced performance are just a software download away.

A PC SDR Example

I first became interested in software-defined radios after reading Doug Smith's 1998 article series in *QEX* (see endnote 3). Noting how PCs with sound cards were being used to deliver new digital modes such as PSK31, I decided to explore how a complete SDR could be built using a PC and a minimal amount of external hardware. I also decided to use Microsoft Visual Basic for the development language to allow rapid development and ease of maintenance.

For this project I chose the quadrature down-conversion and sampling architecture shown in figure 5. I used a very interesting approach called a Tayloe Detector[5] to achieve the quadrature down-conversion. Figure 8 shows the single balanced version of the Tayloe Detector that I used in my first prototype.

The Tayloe Detector has a number of advantages over traditional mixers: In addition to down-conversion, it functions as a very high-Q tracking filter centered at the carrier frequency. It also exhibits an ultra-low noise figure of ~1 dB. I describe the Tayloe Detector as well as some of the basics of digital sig-

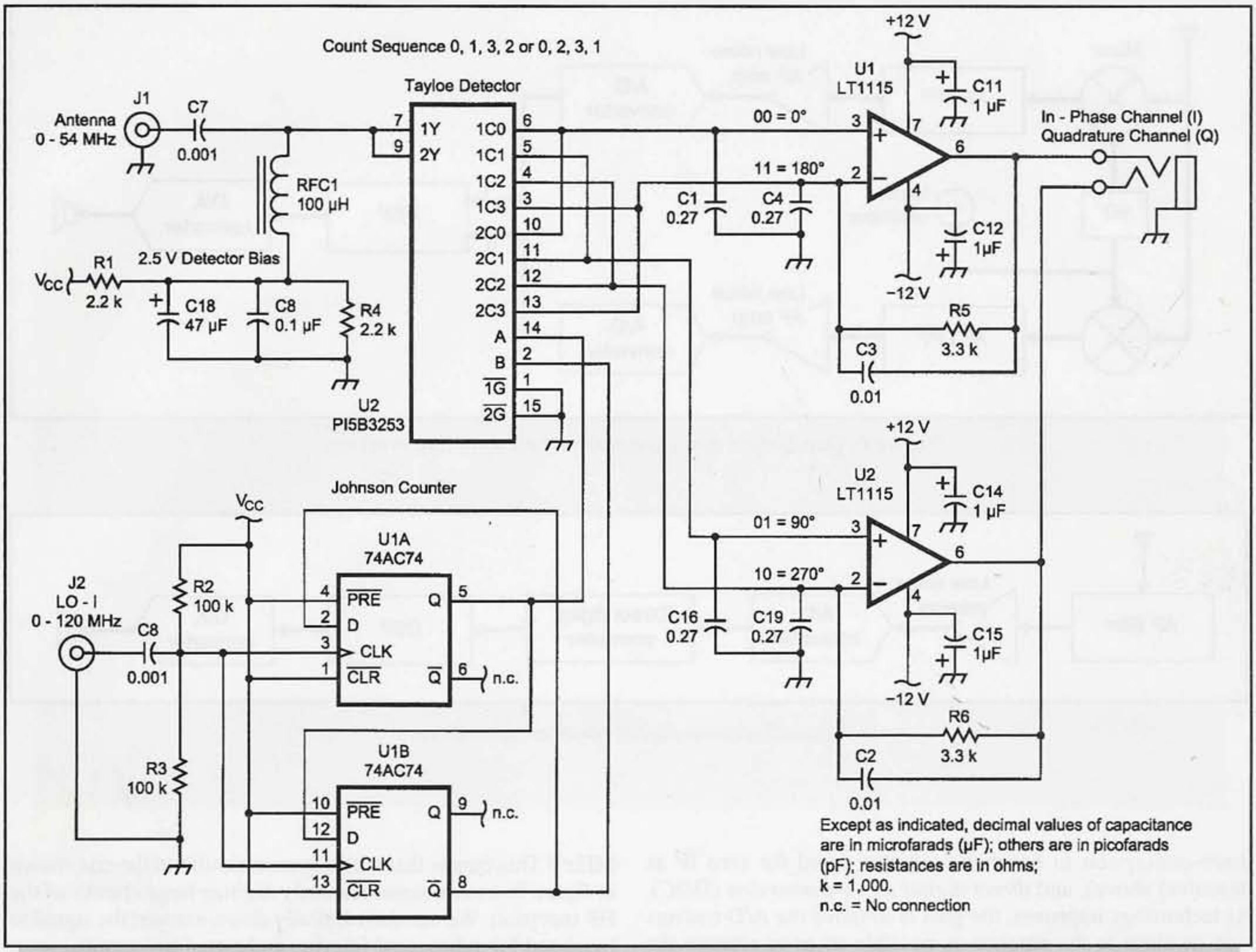


Figure 8. Tayloe Detector quadrature down-conversion. (Artwork courtesy QEX)

nal processing in more technical detail in the July/August 2002 issue of *QEX*.[6]

The SDR-1000 transceiver is the result of many hours of study and development. Figure 9 is a screen shot of the front panel showing a 20-kHz wide spectrum display of the 40-meter CW band. A number of CW signals are visible on the display. The user can tune to any one of the signals simply by clicking the mouse on the display. Ten predefined filters are provided, along with separate continuously variable filters for CW and SSB.

Figure 10 is a screen shot that shows the filter shape of the 500-Hz bandpass filter. To generate the display, I fed an antenna noise bridge into the SDR-1000 to fill the spectrum with wideband noise. The SDR-1000 uses a very-high-performance filtering method called FFT[7] fast convolution filtering with 2048 digital filter taps.

As one can see from the display, this is truly a "brick wall" filter. The shape factor from 3 dB to 60 dB is 1.05[8]! Also, note that stop-band attenuation is greater than 120 dB. As a reference, the Inrad 705 crystal filter marketed for the Yaesu FT-1000MP has a 6 dB to 60 dB shape factor of 2.6.

The beauty of the SDR is that there is a virtually endless supply of features and enhancements to be added to the radio. Therein lies the real fun. Many times when I have a new idea, within five minutes to five hours it has been incorporated as a new feature in my radio. Try that with hardware!

Imagine some of the amateur radio applications for SDRs:

- Multimode voice and digital transceiver
- Competition-grade HF-6m radio
- Total digital remote control over the internet
- High-performance IF for microwave use
- Ultra-weak-signal work (below the noise)
- Digital voice modes
- Dream it and code it modifications

SDRs Now and in the Future

SDRs today offer performance and functionality that were heretofore completely out of reach for the average amateur operator or experimenter. Virtually all of the concepts employed in SDRs have been around for many years. Why then is now the time?

Three things seem to be driving the availability of cost-effective SDR solutions: the explosion of digital wireless communications systems (PCS), the ever-increasing processing power of the PC, and tremendous advances in mixed-signal integrated-circuit performance (analog and digital on the same chip).

At the moment, there are few off-the-shelf products that will allow the amateur to experiment with SDRs; however, that will change soon. Products are on the way that will allow any PC to become a SDR through a simple connection to either the sound card or the USB port.[9] I also hope to make the SDR-1000 available in kit form sometime later this year.

What are the disadvantages of SDR technology? I have had a hard time thinking of technical disadvantages. The real problem is education and access to information. To help rectify this problem, the ARRL has formed the SDR Working Group[10], of which I am a member. The mission of the group is to encourage experimentation and use of SDRs, educate the amateur community in SDR technology and applications, and fulfill one of the important missions of the Amateur Radio Service—to "contribute to the advancement of the radio art."

Notes

1. *The ARRL Handbook For Radio Amateurs* (Newington, Connecticut: ARRL, published annually), refer to sections on mixers, modulators, and demodulators as well as receivers, transmitters, and transceivers.

2. Smith, Doug, *Digital Signal Processing Technology* (Newington, Connecticut: ARRL, 2001), pp. 2-1 through 2-16.

3. Smith, Doug, "Signals, Samples and Stuff: A DSP Tutorial (Part 1)," *QEX*, March/April 1998, pp. 8–11. This article along with parts 2–4 is available on the ARRL website at <www.arrl.org/tis/info/sdr.html>.

4. See the Texas Instruments GC4016 Digital Downconverter at <www.ti.com/sc/hpa7107u>.

Learning More

The best way to get started in SDRs is to make up one's mind to do so. For me it was just like learning Morse Code. The hardest part was deciding that I had the ability to do it. Learning and applying it was the fun part. The first thing one needs to do is read more about SDRs. Here are some resources I recommend to help in this task:

Free, or Almost Free

• The ARRL website has a number of SDR articles at <www.arrl.org/tis/info/sdr.html>, including those on the DSP-10 by Bob Larkin, W7PUA, and a great *QEX* series on DSP by Doug Smith, KF6DX. The SDR Working Group has committed to expansion of SDR information available on the ARRL site.

• One of the best free resources about DSP on the web can be found at <www.DSPGuide.com>. It not only explains DSP in terms that are reasonably understandable, it also provides example source code in Basic.

• Another good resource is <www.DSPGuru.com>, which provides a number of good articles, including one (recommended earlier in this article) about quadrature signal processing called "Quadrature Signals: Complex, But Not Complicated," by Richard Lyons.

• Check out Bob Larkin, W7PUA's DSP-10 at <http://www.proaxis.com/~boblark/>.

• If one is into ultra-weak-signal work and EME, then Lief Åsbrink, SM5BSZ's website at <http://ham.te.hik.se/homepage/sm5bsz/> is an excellent resource, especially the part about Linrad.

• Follow my four-part technical article series about the SDR-1000 design in *QEX* beginning with the July/August 2002 issue (see endnote 6).

For Purchase and Deeper Study

• Doug Smith's new book from the ARRL entitled *Digital Signal Processing Technology* provides an excellent introduction to DSP from an amateur radio viewpoint (see endnote 2).

• R. G. Lyons has written one of the more readable technical books on DSP called *Understanding Digital Signal Processing,* from Addison-Wesley, 1997 (Reading, Massachusetts).

• Another excellent book that delves deeper into DSP communications theory is *Digital Signal Processing in Communications Systems* by M. E. Frerking and published by Nostrand Reinhold, 1994 (New York, New York).

What Next?

Start reading some of the excellent resources on the web and keep alert to a number of articles that are in the works. If you are interested in connecting with others who are experimenting in this area, feel free to e-mail me at <AC5OG@arrl.org>.

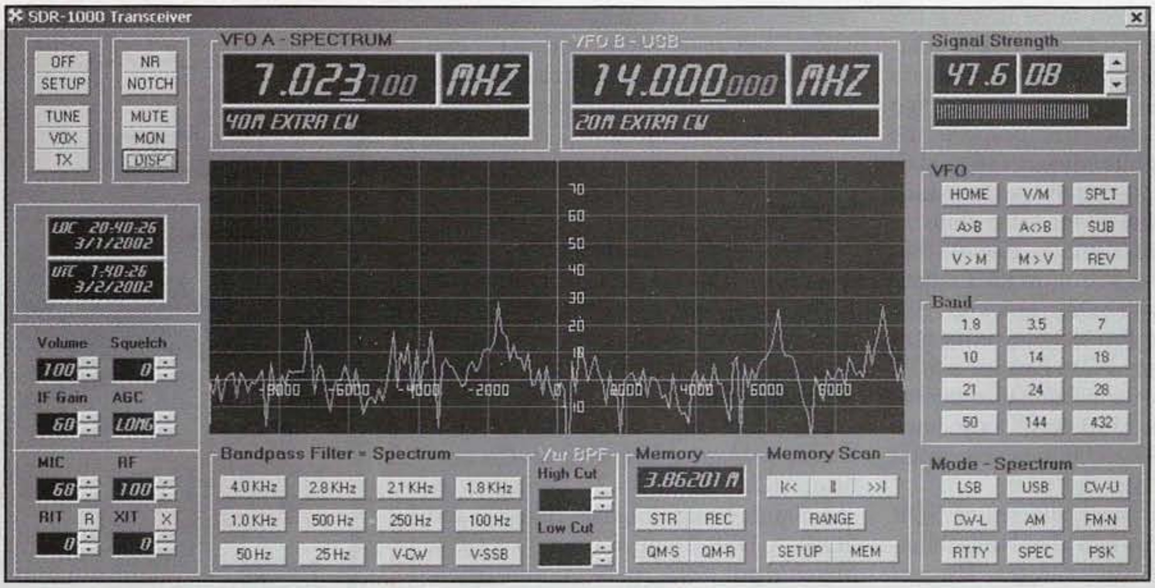


Figure 9. SDR-1000 front-panel interface with wide spectrum display.

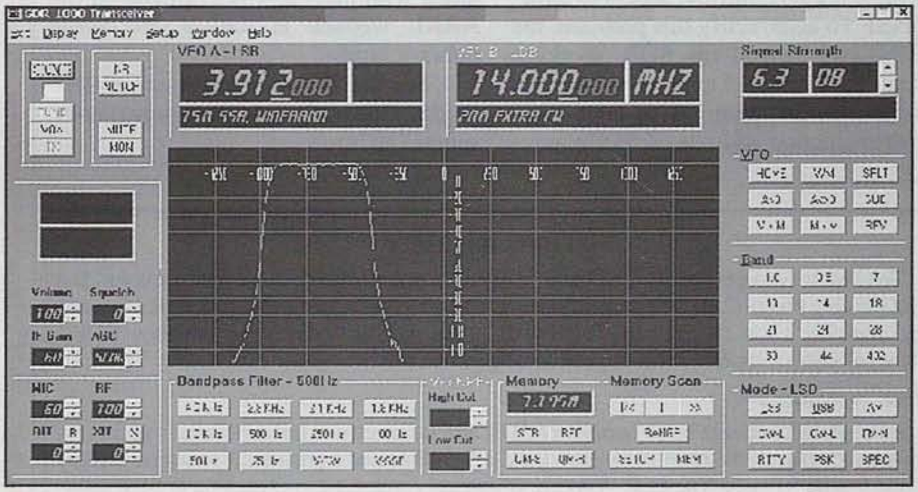


Figure 10. 500 Hz filter shape and stop-band attenuation using FFT fast convolution filtering.

5. Tayloe, Dan, N7VE, "Letters to the Editor, Notes on 'Ideal' Commutating Mixers (November/December 1999)," *QEX,* March/April 2001, p. 61. Essentially the same circuit was described earlier in an article by D. H. van Graas, PAØDEN, "The Fourth Method: Generating and Detecting SSB Signals," *QEX,* September 1990, pp. 7–11. This circuit is very close to a Tayloe Detector, but has a lot of unnecessary components.

6. Youngblood, Gerald, AC5OG, "A Software Defined Radio for the Masses, Part 1," *QEX*, July/August 2002.

7. *FFT*, or *fast Fourier transform,* is a method of signal sampling originally developed by French mathematician Baron Jean Baptiste Joseph Fourier in ca. 1807. The equation known as the Fourier transform is a mathematical process in which one can separate any periodic function into underlying sine and cosine functions. In April 1965, by way of attempting to filter noisy signals, Bell Laboratories researchers James W. Cooley and John W. Tukey gathered research that led to the development of the discrete Fourier transform (DFT), which later became known as the fast Fourier transform (FFT), a method of Fourier analysis which decreased the number of calculations needed to analyze the waveform, thus making it infinitely easier to factor out "noise" from the waveforms being analyzed. In this SDR application, FFT works like a spectrum analyzer to convert signals from the time domain (similar to that viewed on an oscilloscope) to the frequency domain. See the website <http://www.netnam.vn/unescocourse/computervision/chap9.doc> for a more in-depth explanation of FFT.

8. Many manufacturers rate their filters from 6 dB to 60 dB. The 3-dB point is actually a better measurement of the noise-power bandwidth of a filter and is a more stringent requirement than the 6-dB point.

9. Expanded Spectrum Systems has just released a kit called The Time Machine which provides a straightforward quadrature mixer that will allow SDR experimentation. It currently runs at fixed crystal frequencies, but input filters are available for most of the amateur bands. More information is available at <http://www.expandedspectrumsystems.com/>. Another interesting system uses the direct digital conversion approach with the AD664 and AD6620 sampling at 65 MHz. It will communicate with the PC through a USB port. The web link is <http://www.rfspace.com>.

10. Members of the ARRL SDR Working Group include Lief Åsbrink, SM5BSZ; Gary Barbour, AC5WO; Bob Larkin, W7PUA; Mike Marcus, N3JMM; Douglas Smith, KF6DX; and Gerald Youngblood, AC5OG. ■

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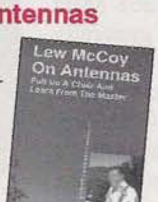

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The First 24-GHz EME QSO

With improvements in receiver design and the introduction of new software, Earth-Moon-Earth (EME) communication has become accessible to an increasing number of VHF+ operators. Some EME veterans, looking for a new challenge, are seeking to complete EME contacts on increasingly higher ham bands. A year ago W5LUA and VE4MA were the first to complete an EME QSO on 24 GHz. Here is their story.

By Al Ward,* W5LUA, and Barry Malowanchuk,† VE4MA

On August 18, 2001 at 1419 UTC VE4MA and W5LUA completed the first 24-GHz Earth-Moon-Earth (EME) QSO. Achieving this QSO required years of engineering effort by both Barry, VE4MA, and myself (Al, W5LUA), with help from several other interested hams. Photos 1 and 2 show VE4MA and W5LUA with their 24-GHz EME antenna installations.

Photo 1. Barry, VE4MA, and the 2.4-meter dish for 24 GHz.

EME History

The first amateur moonbounce contact, on 1296 MHz, was made in 1962. Since then moonbounce QSOs have been accomplished on all amateur bands from 28 MHz through 10,368 MHz. Over the past ten years EME contacts on all microwave bands through 10,368 MHz have been commonplace, and generally occur on a monthly basis.

Accomplishing EME contacts on the next highest amateur band, 24 GHz, represents an enormous leap in technology from that used on the lower frequencies. Most of the standard construction techniques do not work very well at 24 GHz, and moonbounce requires very high-performance systems. Consequently, moonbounce at 24 GHz represents a supreme technological challenge!

Technology

For those thinking about 24 GHz EME, the following three components should be carefully considered: The recent improvements in low-noise microwave transistors make it possible to create good low-noise amplifiers, although this still takes a great deal of skill and patience to achieve. The commercial satellite industry operating in the vicinity of 14 GHz has created efficient parabolic antenna reflectors that might be useful with reduced-efficiency at 24 GHz.

Even so, as it has been in the past with the lower frequency experimental EME work, obtaining high transmitter power still represents the biggest individual challenge to success on 24-GHz EME. Devices called TWTs (traveling wave tubes) which generate high power for frequencies up to 14.5 GHz have become fairly commonplace on the surplus market. However, they are very scarce for 24 GHz. Pushing the lower frequency TWTs up in frequency is possible but requires a considerable amount of patience.

The Path to The Moon and Back

Beyond the technological challenges, the high path loss adds a further barrier. The minimum EME path loss to the Moon at 24 GHz is approximately 297 dB. Furthermore, the 24-GHz band is

*e-mail: <al_ward@agilent.com>
†e-mail: <ve4ma@shaw.ca>

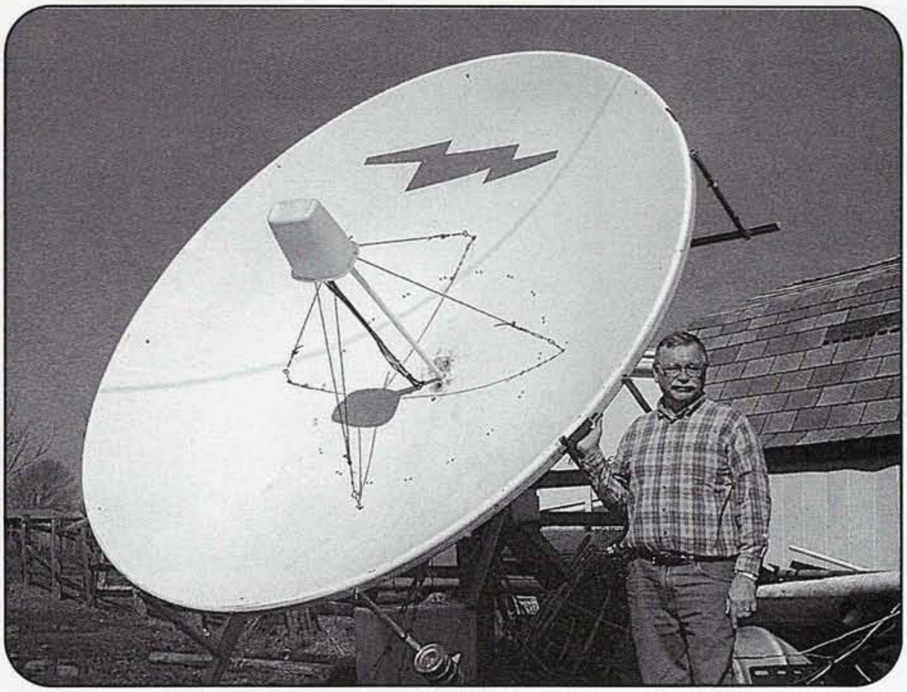


Photo 2. Al, W5LUA, and the 3-meter dish for 24 GHz.

also severely affected by water-vapor absorption in the atmosphere. In high-humidity weather situations such as fog or rain, this absorption of the signals all but rules out trying to make any type of DX QSO, let alone trying to complete an EME QSO.

As with all narrow-band microwave work, frequency calibration and stability are details that cannot be overlooked. Variations in these factors between radios are especially troublesome when tuning slowly for a really weak signal while also trying to aim a narrow-beamwidth parabolic dish. Completion of many moonbounce QSOs on the lower microwave ham bands eventually became easy—but only after finding the other station's signal!

At VE4MA a well-calibrated frequency counter was used, while at W5LUA a rubidium standard was used to lock a Hewlett-Packard signal generator as a reference. Because of our calibration efforts, at the time of our initial QSO both stations were within a few kHz of where we expected to find one another. Even so, before we were well calibrated, it was not unusual to find each other up to 15 kHz away from the expected frequency of the other's signal.

Because of the relative motion of the Moon with respect to the Earth, there is a shift in frequency of the reflected signal as it returns to Earth. This shift in frequency, known as Doppler shift, increases with frequency such that at 24 GHz there is a maximum of ±70 kHz of shift.

While the Doppler shift is easily predicted, there are, however, significant differences in the values predicted by different software programs. Ironically, the old program Real Track, by Mike Owen, W9IP, seems to be the best, being within 500 Hz.

With the difference in latitude between VE4MA and W5LUA the Doppler shift between us differed by a maximum of approximately 12 kHz. Frequency setting can be confusing, although it is easiest if the first receiving station corrects the transmit frequency for its echoes so as to fall on the echoes of the first transmitting station.

The rough texture of the moon's surface produces a spreading of a signal that is directly proportional to the increase in frequency, albeit with differing resultant copy of the received signal for each ham band. For example, at 2.3 GHz the loss of symbols within a character can make copy of an otherwise strong signal very difficult. Progressing up to 5.7 GHz, in contrast, a CW signal sounds quite musical and is easy to copy, with several discrete carriers being heard close together. At 10 GHz the signal is somewhat like aurora on 6 or 2 meters.

As we contemplated the challenge of 24 GHz, the big question for us was "Would the aurora sound be worse than what we hear on 10 GHz?" The answer turned out to be no. Paradoxically, the narrower beamwidth of the type of antenna we used, being less than the subtended angle of the Moon (i.e., less than 0.5 degrees), seems to actually produce less spreading than at 10 GHz. The characteristic buzz still sounds pretty much like 10 GHz EME (or 2-meter aurora), but it is less severe.

Systems at VE4MA and W5LUA

VE4MA had the good fortune of acquiring a Prodelin 2.4-meter (8-foot) offset-fed dish that was originally intended for 14/12-GHz remote broadcast uplinks. Looking like one of the direct-broadcast mini-dishes, this reflector is very flat, and in theory was thought to provide very high efficiency and perhaps even as much gain as the larger 3.0-meter center-fed Andrew dish at W5LUA (see photos 1 and 2).

A fringe benefit of an offset-fed dish is the ability to locate all the electronics at the feed point without introducing blockage of the dish's capture area. The theoretical gain at 24 GHz was expected to be near 55 dB over an isotropic radiator, with a 3-dB beamwidth of 0.28 degrees.

Antenna pointing is a significant problem, as the dish has a 1-dB beamwidth of 0.16 degrees, and the Moon moves across the sky at a rate of 15 degrees per hour. Consequently, the antenna pointing must be updated about every 60 seconds minimum! Peaking of the antenna is accomplished manually and is assisted through the use of a "Moon Noise Meter" such as a General Radio 1216 or 1236, which displays the relative value of the Moon's thermal noise being received.

A W2IMU feedhorn was built using plumbing parts and sheet copper as shown in photo 3. The final results with the new W2IMU feedhorn, carefully optimized in front of the reflector, were 2.3 dB of Moon noise and 15 dB of Sun noise! This was truly outstanding and the basis of much optimism for completing our initial QSO.

A transverter is used to convert the 24-GHz signals to an IF of 432 MHz. The transverter at VE4MA is homebuilt and uses surplus components, which significantly minimized the work required. An ICOM IC-490 70-cm multimode transceiver is used as the IF. A separate 432-MHz to 28-MHz receive converter drives

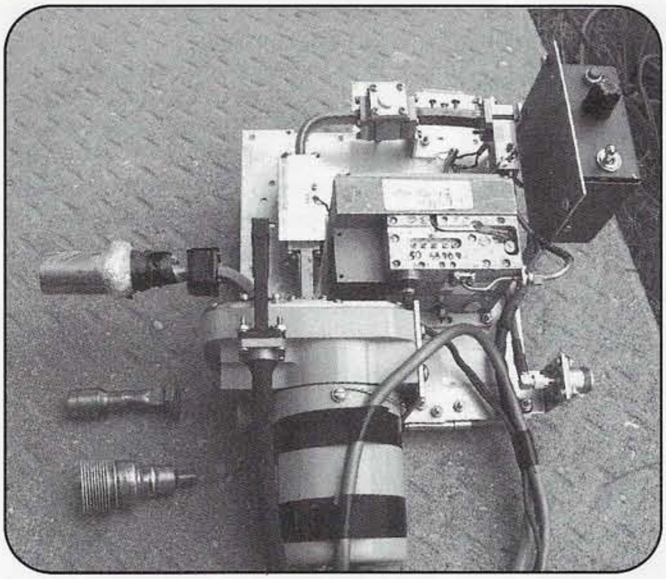


Photo 3. The 24-GHz feed assembly (Rx converter and waveguide switch) and lower gain W2IMU feedhorn.

Photo 4. Back structure for the 3-meter dish at W5LUA.

an HF receiver and the Moon noise meter. The system is linear and highly stable so that CW, SSB, and even FM modes can be used, if signal levels permit.

The receiving preamplifiers can be home built, but achieving the very best noise figures can be extremely difficult. Having a good noise-figure measurement system and the patience to tune the amplifiers is important. The best results of 2.3-dB noise figure were with an Agilent ATF36077 PHEMT (Pseudomorphic High Electron Mobility Transistor) FET. The preamplifier uses WR-42 waveguide, as coaxial input would be too lossy at 24 GHz. The WR-42 waveguide input also provides a convenient method of tuning for lowest noise figure with screws at the appropriate positions. The best results were obtained with a three-stage preamplifier from DB6NT. This unit delivers an extremely impressive 1.55-dB noise figure and 28-dB gain, which represents the state of the art and was well worth the cost!

The antenna at W5LUA is a 3-meter Andrew prime-focus dish with an f/D ratio of 0.3 (f/D: the dish focal length to diameter ratio; an f/D of between 0.3 and 0.6 is considered to be typical [see photos 2 and 4]). According to Andrew, the 3-meter dish is rated to 30 GHz with proper back structuring to optimize the dish's surface.

The dish really began to perform well when a back structure, which looks like a tic-tac-toe board, was mounted to the backside of the dish. The eight points of the back structure allowed for optimization of the dish's surface by pushing or pulling on the back of the dish to enhance the accuracy of the dish's surface.

As opposed to using the popular "string test" to optimize the plane of the dish, the back structure was used to stress the dish in an attempt to optimize Sun noise. The end result was an increase in both Sun and Moon noise. In the March timeframe, when I first received my Moon echoes, the system was receiving 12.5 dB of Sun noise and 1.3 dB of Moon noise. The Sun noise is a 3-dB improvement over what was obtained prior to optimizing the dish surface. System noise figure at the time was 2.25 dB. The feed is a scalar feed optimized per the *W1GHZ On-Line Antenna Handbook* (see <http://www.w1ghz.cx/antbook/contents.htm>).

The transverter is also homebrew and is mounted behind the dish on a shelf along with the TWT. The transverter uses surplus 23-GHz modules, which provide 50 milliwatts of drive power for the TWT. Cascaded homebrew LNAs were used to set the system noise figure. The LNA used to hear my first echoes on 24 GHz is a homebrew, two-stage W5LUA design using a pair of Agilent Technologies PHEMT devices, which provided a 2.25-dB system noise figure. I have since acquired some lower noise-figure devices which have produced a 1.75-dB system noise figure.

The transverter is dual conversion with a first IF of 2304 MHz and a second IF of 144 MHz. The 144 MHz is piped into the shack. My IF radio is an ICOM IC-271. I sample some of the 144-MHz IF signal and down-convert it even further to 28 MHz. The 28-MHz signal feeds both a GR-1216 IF amplifier for measuring Sun and Moon noise and a Drake R7 receiver. Although I used my IC-271 for nearly every EME and tropo QSO I have made through 10 GHz, I admit that the R7 receiver produced an easier-to-copy signal off the Moon on 24 GHz. The late microwave EMEer Paul Wilson, W4HHK, originally used the Drake R7 receiver for his IF on 2304-MHz EME so it is carrying on the EME tradition.

Transmitter Power Amplifiers

As mentioned above, transmitter power is the most difficult undertaking. Modern solid-state amplifiers are available on the surplus market up to about 1 watt, but above this power rating we must rely on TWT amplifiers (TWTAs). Most surplus 24-GHz rated TWTAs are instrumentation units that are rated at only 1 watt output, while lower frequency TWTAs (i.e., 12–18 GHz) are usually rated to about 25 watts. All TWTAs usually are capable of considerably more power if the focusing voltages are optimized for the specific frequency of interest.

The initial work at VE4MA focused on trying to get Varian and Hughes 18-GHz instrumentation amplifiers to move up to 24 GHz. Unfortunately, these amplifier units often become surplus because the power supply and/or the TWT itself is defective. The best results obtained with

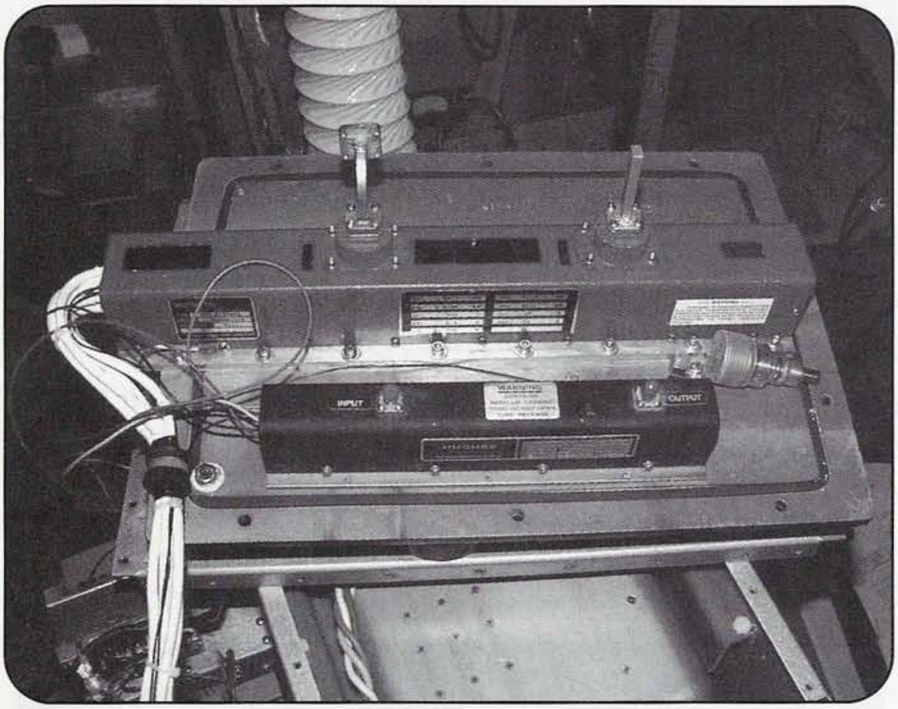


Photo 5. 80-Watt 32–38 GHz Varian TWT, Hughes 10-Watt TWT, and glass 2C39 tube.

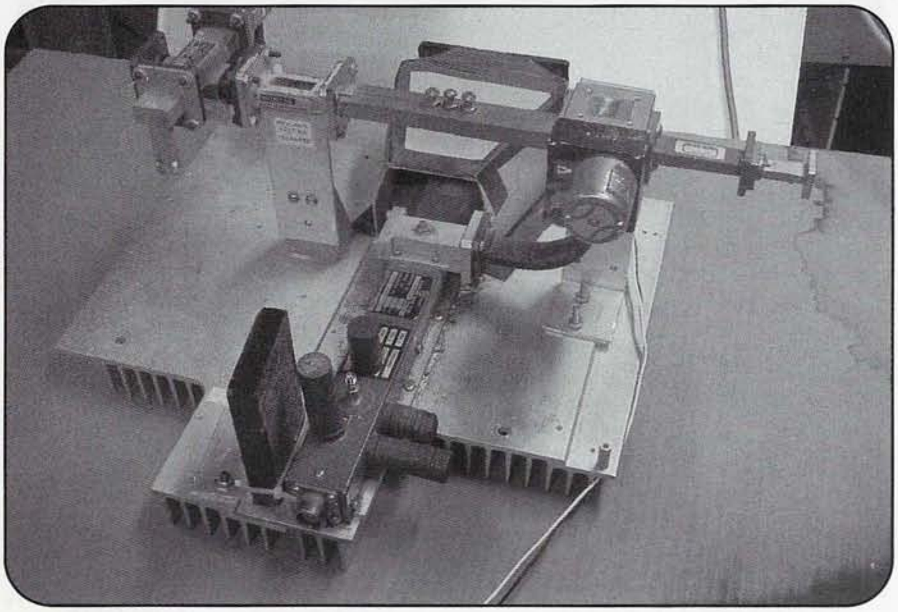


Photo 6. VTU-6191 TWT bandswitched for 10 and 24 GHz.

a Hughes 1177 (10-watt model) TWTA was 5 watts output with only about 17 dB of gain. Notably, the low-frequency minimum gain specification is 30 dB. With such low gain, a driver of about 100 mW is required. The Hughes 1277 (20-watt model) TWTA was also tested with very poor results The best results were obtained with a Hughes 1177 amplifier driving a Logimetrics 10-watt, 8–18-GHz amplifier (ITT tube). With this arrangement VE4MA was able to achieve 11 watts on 24 GHz.

VE4MA was able to acquire four Varian 100-watt 28-GHz TWTs and power supplies. However, these TWTs proved to be narrow-band "coupled-cavity" tubes and produced no output at 24 GHz.

(Continued on page 80)

A Beginner's Guide To Meteor-Scatter Operation—Part I

Once considered one of the "esoteric" VHF propagation modes, meteor scatter has become the easiest way for small 2-meter stations to acquire new grids in the 500–1200 mile range. In this two-part series W8WN explains the basics of meteor-scatter propagation and how one can take advantage of it to complete QSOs on several of the VHF+ ham bands.

By Shelby Ennis,* W8WN

"Did anybody else hear that signal?"

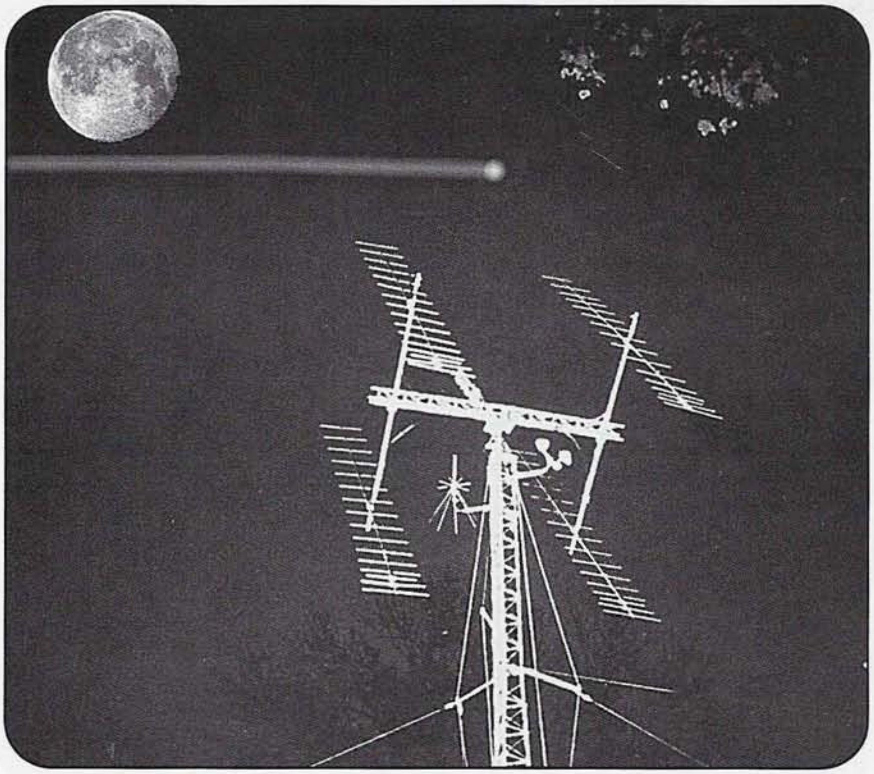
Multi-mode VHF transceivers and small horizontal Yagis are now common. Many people have learned that SSB is great for keeping schedules with friends in nearby communities, providing much greater distance and more frequency choices than FM. In much of the country, daily rag-chew QSOs can be heard every morning.

Occasionally, these operators may notice some other signals on the band, and they might try to work enhanced tropo on 144.200 MHz. Because their power is usually low, their antennas are not up high, and their experience with extended-range operation is somewhat limited, the number of contacts they make via this method is generally minimal. If friends at the local radio club talk about the big tropo opening or the big aurora last week, there is often no comprehension of what they are talking about.

When it comes to meteor scatter, most people who operate 2 meters have never heard a burst or a ping (see "Definitions of Meteor-Scatter Terms" box). If they were to hear either one, chances are they would have no idea what caused it.

When the *Perseids* meteor shower produced several big outbursts in August about ten years ago, I was listening on 144.200 MHz. There had been occasional overdense bursts and flurries of bursts. Things had been quiet for a while. Then a station in a nearby grid, whose call I did not recognize, called me. Soon it became apparent that he knew nothing about meteor scatter, about the great shower going on, or about all the DX that was occasionally being heard.

Before I was able to explain a little about it (which really wasn't a good idea on 144.200 MHz), a huge overdense burst began. Stations in the New England states popped in and increased in strength to S9 and above, as the operators gave quick "CQ-scatter" calls. Within a few seconds, stations farther south were coming through, and 144.200 MHz became pure bedlam. A mass of strong signals from the northeast, plus a few locals, seemed to be calling simultaneously. This activity continued for about two minutes, and then the signals disappeared.



A dramatic shot of a meteor gracing the night sky at the author's QTH.

**465 Springfield Rd., Elizabethtown, KY 42701*
e-mail: <w8wn@arrl.net>

Definitions of Meteor-Scatter Terms

Blue whizzer: slang for a large, overdense burst.

Bolide: a meteor that appears to explode.

Burst: visually, the sudden flare due to disintegration of a meteor; radio, the sudden appearance of a signal due to scattering or refraction from a meteor train. Usually used with overdense bursts.

Circumpolar: a shower whose radiant appears never to set, rotating around the celestial pole but always above your horizon (depends on your latitude).

Comet: a celestial body, apparently left over from the formation of the solar system, having a more or less solid head surrounded by a nebulous luminescent cloud and an elongated curved tail when the head approaches the sun.

Diurnal variation: a cyclic change that varies regularly throughout a 24-hour period.

Doppler: the apparent change in frequency caused by the changing distance between a radiation source and an observer.

Dust trail: a concentration of cometary debris bunched together (for example) by a resonance with the orbital motion of Jupiter.

Efficiency (also called effectivity): relative effectiveness of propagation in a particular direction from the trails of shower meteors. Can be used to determine the optimum time for communication over a particular path, given the astronomical coordinates of the radiant.

Fireball: a meteor brighter than Venus (magnitude –4).

FSK441: a digital HSMS mode, part of the WSJT program.

Hot spot: a point located halfway between two stations, off to one side of the mid-point, where the number of suitably oriented meteors is statistically at a maximum.

HSCW or HSCW MS: meteor scatter using Morse code at speeds greater than 100 wpm (500 lpm).

HSMS: meteor scatter at speeds greater than 100 wpm (500 lpm).

IOS: ionospheric scatter; see scattering.

JT44: a digital slow-speed, weak-signal mode used for EME, tropo scatter, IOS, etc. Part of the WSJT program.

Local time: standard time at your location.

LPM: letters per minute (Letters Per Minute = Words Per Minute × 5).

Meteor: a streak of light or "shooting star" seen in the atmosphere.

Meteor storm: a meteor shower producing a ZHR greater than 1000 per hour.

Meteorite: a fragment of a large meteoroid that survives the passage through the atmosphere and falls to Earth.

Meteoroid: a small particle that enters the Earth's atmosphere.

Overdense burst: the burst produced by a larger particle, caused when the electron density exceeds critical and the column begins to behave like a metallic reflector. Reflections may last several to many seconds in length.

Perihelion: the point of closest approach to the sun by a celestial body.

Periodic: occurring or appearing at regular intervals, but not necessarily yearly.

Ping: a very short (usually <1 second) underdense burst caused when the ionization of the meteor train is sufficient to only scatter the impinging signal.

Ping jockey: slang, an amateur radio operator who regularly operates meteor scatter.

Radiant: the point in the sky from which meteors associated with a given shower appear to originate.

Refraction: the change of direction of a radio wave when it passes obliquely from one medium into another in which its wave velocity is different.

Scattering: irregular and multiple refractions of a radio wave caused by small irregularities in the propagation medium; in this case, changes in electron density in the *D*- or *E*-layers of the ionosphere.

Shower: meteors which, if their paths are backtracked against the sky, all seem to come from the same small area.

"Slow CW": Morse code slower than 100 wpm (500 lpm); (sometimes, code slower than 50 wpm).

Specular: reflected without scattering, as from a mirror.

Spike: a sudden, intense enhancement.

Sporadic: meteors that seem to appear randomly, not part of any recognized shower.

Train: the luminous track of ionization left by an entering meteoroid.

Tropo: shorthand for propagation affected by refraction and/or scattering in the Earth's troposphere.

Tropo scatter: scatter of a radio wave caused by irregularities in the troposphere.

Underdense ping: see ping.

UTC: Coordinated Universal Time; formerly known as Greenwich Mean Time or Zulu Time. All MS schedules are made in Universal Time.

WSJT: Weak Signal communications program by K1JT.

Zenith: the direction or part of the sky directly overhead.

ZHR: Zenithal Hourly Rate; the number of meteors that an observer would expect to see under a dark country sky if the radiant was directly overhead. Since a person's viewing situation is seldom this good, the observed number of meteors usually will be well below the ZHR. On the other hand, using sensitive radio techniques, the number of recorded pings will often be many times the visual ZHR.

I waited until the band was quiet. Then I called the nearby station to take him off frequency and try to explain what was happening. I called again and again. He didn't reply, and I haven't heard him since. Apparently, the explosion of signals scared him so much that he pulled the plug! He was neither the first nor the last operator during those *Perseids* "spikes" in the early '90s who was heard near 144.200 MHz asking what was happening, or calling long, plaintive tropo-style CQs, with no understanding of the DX that was all around him.

If all you work is 144-MHz FM voice or packet, you probably have never heard a meteor ping. If you do much 50- or 144-MHz beyond-the-horizon work, you have no doubt heard many pings, and you are probably at least somewhat familiar with meteor-scatter (MS) operation. Your all-mode VHF rig may be too new, or you may not realize how MS operation in North America has changed in recent years. If you fit either of these categories, then this article will give you some basic information. For those who are familiar with MS but have never really studied this means of propagation, certain parts of the material presented here will go into a bit more detail on the subject. In addition, there will be some tips on using the newest operating methods that can enable even a rather small station to complete MS contacts nearly every morning.

Meteor Showers

The Old Way of Making an Occasional DX Contact

When amateurs began to actively use MS in 1955–57, most operation was confined to the major meteor showers. Besides the three regular large showers (the August *Perseids,* the December *Geminids,* and the January *Quadrantids*), operation was soon being attempted during the smaller showers. The publication of W4LTU's first article on meteor scatter[1] brought a small number of stations to MS in 1957 and 1958. People realized that meteor bursts that were long and strong enough to be usable on 144 MHz were very infrequent, except for the brief peaks of the "big three" annual showers. Soon nearly all 144-MHz MS operation was confined to these periods. On the other hand, 50-MHz operators learned quickly that well-equipped stations could make MS contacts nearly any morning of the year. For many years the 6-meter band had a number of stations calling "CQ scatter" every weekend morning.

Amateurs on 2-meter MS would spend the month prior to the "big three" showers setting up schedules. Prior to the advent of the internet, home computers, VHF SSB, or even VFOs on VHF, schedules normally were made by mail (or occasionally by long-distance telephone), with each pair of stations usually making three to five schedules for a shower. During the *Perseids,* six to eight hours of schedules for three or four all-night sessions were not unusual. Semi-automatic keys ("bugs") and later automatic keyers (no memories) were manipulated manually with speeds usually in the 20–50 wpm range. In order to automate things somewhat, I put a half twist in a 30-second loop of 1/4-inch audio tape (making a 60-second Möbius strip[2]) and used it to key a sensitive relay, which made the long nights of schedules much easier.

In 1974 W4LTU published his second article on MS operation.[3] SSB was beginning to be used on the VHF bands, and soon most meteor-scatter operation was being done on SSB because of the higher speeds possible (a "fast talker" can call at about 200 wpm). A period of 15 seconds became standard, often with a short break in the middle, hoping to catch that one big, overdense "blue whizzer" which would allow a complete contact on one burst only. However, nearly all 144-MHz operation was still confined to the "big three" showers.

Meteor Showers Bring Much Fun

The reason for operating solely during the peaks of these showers is because it is only during the peak of a major shower that enough long pings and overdense bursts are available to support "slow CW" or SSB transmissions on 144 MHz.

The meteors we experience during the various showers are debris, which is shed by comets in their passage around the Sun. If the Earth in its orbit around the Sun crosses the orbital path of a comet, the Earth's atmosphere sweeps up some of the comet's debris. The closer this event happens to the time of the parent comet's passage, the larger the shower is likely to be. Most of the comets and showers are old, and their debris streams are now too sparse to produce much of a shower. The *Perseids, Geminids,* and *Quadrantids* are young enough, however, to produce good showers, yet they are old enough for the debris to be well dispersed along the comet's orbit. Therefore, we do not expect large year-to-year variation.

As the outbursts of the *Perseids* during the early 1990s remind us, though, there are exceptions to this general rule. A "meteor shower" is said to exist when the meteors all appear to have come from the same small area of the sky. This phenomenon is only because of perspective, of course, since meteors of the same stream move along parallel orbits in space. The *radiant* is the point in space from which the meteors of the shower appear to originate. As a rule, meteor showers are named after the constellation in which the radiant lies. The number of meteors does not need to be large—only enough to establish a pattern. In fact, many of the smaller showers have a ZHR (Zenithal Hourly Rate—see definitions at the end of this article) of ten or less. There are dozens of recognized meteor showers (see the lists published by the International Meteor Organization,[4] American Meteor Society,[5] etc.).

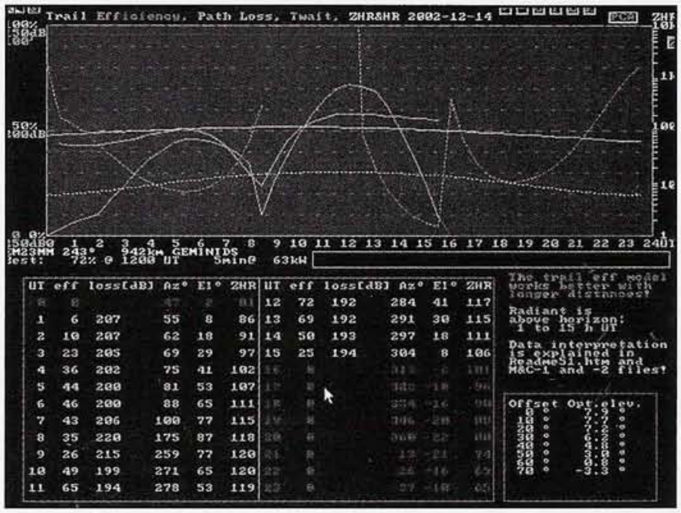


Figure 1. A screen shot of OH5IY's MS-Soft meteor-scatter software program.

The "big three" showers still provide the primary opportunity for SSB meteor-scatter contacts, with the August *Perseids* remaining the favorite (see sidebar for more on the *Perseids*). The December 10–14 *Geminids* often has a rate which is as high as, or even higher than, the *Perseids.* However, the *Geminids* has never been as popular as the *Perseids,* probably because of the time of year (the holiday season as well) and its lower velocity.

The January 1–4 *Quadrantids* is usually the smallest of these three meteor showers. It has a very sharp peak, lasting only an hour or so, and if you catch it you may be rewarded with a very good shower. If you miss the peak, you may wonder if there even was a shower. The time of the peak is somewhat variable, and the best radio meteors tend to peak some hours earlier than the visual meteors. The peak may be rather intense, but the post-maximum is very short. Once the Earth has swept through the core, it leaves the stream very quickly.

If you want to know the peak time of a particular shower, you can get the "best guess" from the various meteor websites, or from OH5IY's *MS-Soft* program.[6] Except for the *Leonids* (more specifically, the *Leonids* predictions of Asher, McNaught, et al.), none of the listed peaks is more accurate than about ±12 hours. Many predictions are not even that accurate. The time and date simply are based on the best approximation of the time of the Earth's crossing of the meteor stream that year. These streams may be multiple, may have concentrations, and may have had their orbits changed because of gravitational attraction by Jupiter. Besides Jupiter's perturbations, there are several other mechanisms that can change the orbit of the particles or spread the particles out in the orbit (or even somewhat prevent them from spreading). At this stage of meteor science most of the listed peak times are not intended to be exact.

Besides these three showers, a few others occasionally may produce large displays. For example, the June *Boötids* produced an outburst in 1998 with rates ranging from 50 to over 100 meteors per hour for over half a day. The big excitement for the past

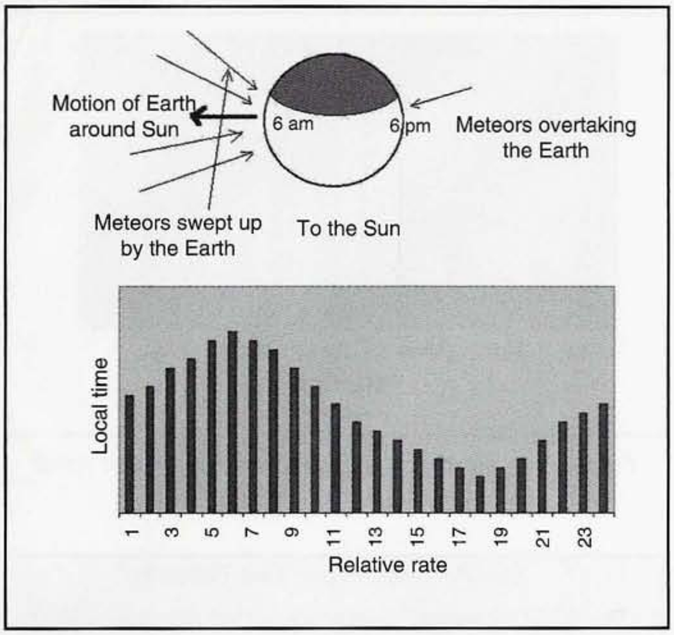


Figure 2. The increase in sporadic meteors beginning with the early morning hours and then declining during the course of the day until once again increasing in the late afternoon. This figure illustrates why there is an increase.

three years has been the *Leonids*. With the perihelion passage of the parent comet, P. Tempel/Tuttle, in February 1998, it was hoped that another "storm" (a ZHR greater than 1000 per hour) such as the one we had in 1966 would be observed. While the 1966 rates were not reached, they did briefly reach storm rates in 2001,[7] and the so-called "fireball storm" of 1999 produced one of the most beautiful displays most of us have ever seen. If you were not involved in any of these events, the November 2002 peak is predicted to be the last major display in our lifetime (and probably for about a hundred years).

The dust-trail analyses (of David Asher, Robert McNaught, Esko Lyytinen, and others) have brought the art of predicting the *Leonids* to a real science. For more on this subject, go to the bottom of the HSMS Hot News page,[8] and then go to the websites of the various researchers. Put November 19, 2002, around 0400 and 1040 UTC on your calendar, and watch for last-minute information.

It's All in the Timing

More important than being aware of the exact time of the peak (except for showers such as the *Quadrantids* and *Leonids,* which have very sharp peaks) is knowing the proper time for making schedules in different directions. The optimum time for a given direction is when the radiant location is at 45 degrees (or, for practical purposes, about 30 to 80 degrees) above the horizon.[9] While communication is possible at other times, the number of usable meteors is usually greatly reduced. This phenomenon is called the *efficiency* (also called the *effectivity* in some of the older programs and charts). Because the radiants of the various showers trace different paths across the sky, the characteristics of these showers in different directions will vary considerably. For example, with the *Perseids* there is no good time for a north-south (N-S) path, but NW-SE and NE-SW paths can be great at the proper time.

As a shower's radiant rises in the east, crosses the sky, and sets in the west, the geometry of the incoming meteors will vary continuously, which means that the optimum schedule direction will continually change. OH5IY's *MS-Soft* program can figure this out for you (see figure 1), or you can use W4LTU's tables. Of course, if the radiant is below the horizon, you aren't going to have many shower meteors available for use. During every major shower a number of stations will be on calling CQ after CQ on SSB when the shower is on the other side of the Earth.

Some of the showers seem to have a larger percentage of long, overdense bursts because of the higher percentage of larger particles. The difference between the long, overdense bursts and the tiny, formerly unusable pings is the amount of ionization, which is related to the mass and velocity of the particle.[10] The cosmic specks we are talking about are tiny. There is still uncertainty regarding the actual masses of the majority of the usable meteors, ranging from a tiny fraction of a gram to several grams. Their composition apparently varies from the grains-of-sand type to "dustballs," with porous, crumbly material being the most common.[11] Because of such great velocity, their kinetic energy is sufficient to produce the ionized train.

The underdense pings are produced when the ionization is only enough to scatter the radio waves. If the ionization is intense enough, the incident wave does not penetrate the column freely and the wave is refracted, as though from a metal cylinder, giving rise to a specular reflection. This is why even small stations can use overdense bursts, as they can be almost as effective as a sporadic-*E* cloud. Unfortunately, overdense bursts are so rare outside the peaks of major showers that they are worthless for routine communications on 144 MHz.

Sporadics—and those "Abominable Pings"

Meteor showers provide an interesting, concentrated period of operation and the opportunity to use SSB. If you work only SSB on 144 MHz, the "big three" showers, plus the *Leonids,* are your only chances to do much. The occasional overdense bursts of the few major showers provide very little occasion for contacts when compared with the daily influx of sporadic meteors. Even though the duration of these pings is usually very short, the number of tiny pings available on many mornings may surprise you.

"Sporadic" meteors are those which constantly bombard the Earth and are not associated with any known shower. These sporadics are of two types: comet debris and material from the asteroid belt. (Some interstellar dust also is collected by the Earth. However, most of this dust is so small, about the size of the particles in cigarette smoke, that it would not produce usable ionization.)

Debris from collisions in the asteroid belt is regularly picked up by the Earth. These chunks of asteroids can be much larger than the typical comet debris (remember some of the recent disaster films?). Fortunately for all of us, most of the debris is pebble-size or smaller, but some of it is large enough to produce an occasional fireball that lights up the sky for hundreds of square miles.

Most of the "sporadics" are probably comet debris from long-extinct shower streams that have been spread out and are no longer identifiable as such. These meteoroids are tiny, not producing enough ionization to create an overdense burst along with its specular reflection. They give rise to what once was called the abominable "ping" by W4LTU, because amateur radio operators were incapable of using these underdense trails until the 1980s. These pings typically are very weak and very short—less than one-half second in length. In half a second the typical operator can speak approximately two letters of a call. Because of the weakness of the signal, only the peak of the ping is likely to be strong enough to be usable. Therefore, with SSB the average ping would produce a short "uh" or "ah" or some other meaningless single syllable, and using 25-wpm CW is no better. The nature of CW allows more of the signal to be used, but the speed is much slower, giving only part of one letter. These examples are for very good pings. Most are much shorter.

The number of sporadics varies greatly according to the season of the year. They also vary over the course of a 24-hour period, hour to hour, and even minute to minute. Some of the fluctuations can be explained easily, while others seemingly are purely random (They may not be, but there is presently no way to be sure.).

The most obvious variation is the diurnal change. The maximum number of sporadics occurs around 0600 local time, with the minimum about 1800, which is the result of the Earth's moving through space at 31 km/sec. At 0600 local time, overhead meteors are moving toward the onrushing Earth, and even very slow ones are swept up. At 1800, however, only those meteors with a velocity greater than that of the Earth are able to catch up and enter the atmosphere, which results in a much smaller number of meteors in the evening (see figure 2).

There is also a yearly cycle of sporadic meteors. The number dips to a minimum in February and March, begins to increase around May, reaches a peak about June–August, enters a secondary peak about October–December, and then rapidly declines again to the minimum (see figure 3). Meteor-scatter operation is typically in the doldrums (but still possible) during the February–April period. There are no major showers, almost no minor showers, and fewer than usual sporadics.[12] It has been so bad that on two occasions during the poor period I even failed to hear KØXP on our morning 15-minute schedules! (We completed contacts 80% of the time, averaged over a two-year period, with a 94% completion rate during the best times of the year.[13])

Conditions may also vary greatly even from minute to minute. It is not unusual to have a 10-minute period with three to five pings per 30-second period, then have fewer than one ping per period for the next 10 minutes, followed by another increase. The reason for these short-term variations is not known. Most of the meteor researchers say that it is only statistical variation, which, undoubtedly, much of it is. Recently some people have wondered if there was not some type of actual physical grouping at work. (Hams and a few visual observers have reported this phenomenon for many years.)

Burn, Baby, Burn

Meteoroids range from sizes smaller than the particles in cigarette smoke, which float through the atmosphere without ionizing, to those so large that they survive their fiery encounter with the atmosphere and reach the ground as meteorites. The size of interest for MS communications is approximately that of a grain of sand, and it is estimated that over 100 million of these hit the atmosphere each day. Entry velocities range from 11 to 72 km/sec (24,600–161,000 mph) with an average veloc-

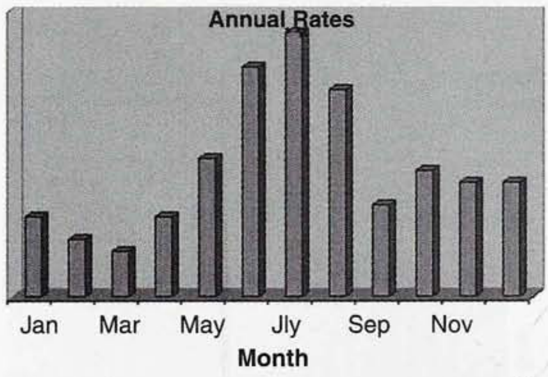


Figure 3. By month, the annual increase in meteor rates.

The *Perseids*: The "Old Favorite"

This is still the favorite shower of most MS enthusiasts. Debris associated with this shower has been observed for at least 2000 years, as the stream has a very stable, highly inclined orbit which protects it from strong planetary perturbations. Its parent comet, P. Swift-Tuttle, had been seen only in 1862 until it returned in 1992.

In spite of predictions of marginal increased activity, in 1991 the *Perseids* caught many by surprise when it suddenly surged with an outburst on the order of 500 per hour. The next several years produced great showers, with a new "spike-type" peak at an unexpected time. Hams made contact after contact in the largest meteor showers since the 1966 *Leonids* storm!

The *Perseids* have now returned to their normal rate, which is still one of the highest of any of the annual showers. The overall *Perseid* activity consists of two components: one flat and very broad activity level lasting for five weeks, and another level which causes the sharp peak rates. The main part of the *Perseids* is usually considered to run for about five days, August 10–14, with the major peak predicted for this year on August 12 at about 1720 UTC. This usually is a fairly broad peak. There often are enough usable meteors to make schedules worthwhile over the full three- to five-night period.

The *Perseids* is a high-velocity shower (60 km/sec) and circumpolar for those in the mid-northern latitudes, reaching a minimum altitude at about 1730 local time. (This means a few might be available at any time of day or night, although the geometry will be poor.) They generally are not good for north-south (N-S) paths, but can be very good for NW-SE (2400-0500) and NE-SW (0800–1200) paths. The radiant is too high for good E-W paths, but possible (0500– 0800). (Times are in *local* standard time.)

Many observers, both visual and radio, have reported the impression that the *Perseids* sometimes appears in groups. This was explained away some years ago as a "misleading statistical feature." However, more recent data has raised the question once again.

Which is better for the *Perseids*, HSMS or SSB? In recent years there have been many comments—for example, "If I had only been running *xxx* for that schedule, it would have been easy!" (insert either HSMS or SSB, for comments both ways have been heard). The *Perseids* is known for its good bursts, and some years have almost *no* underdense pings! Thus, SSB may be the preferred mode, especially near the peak.

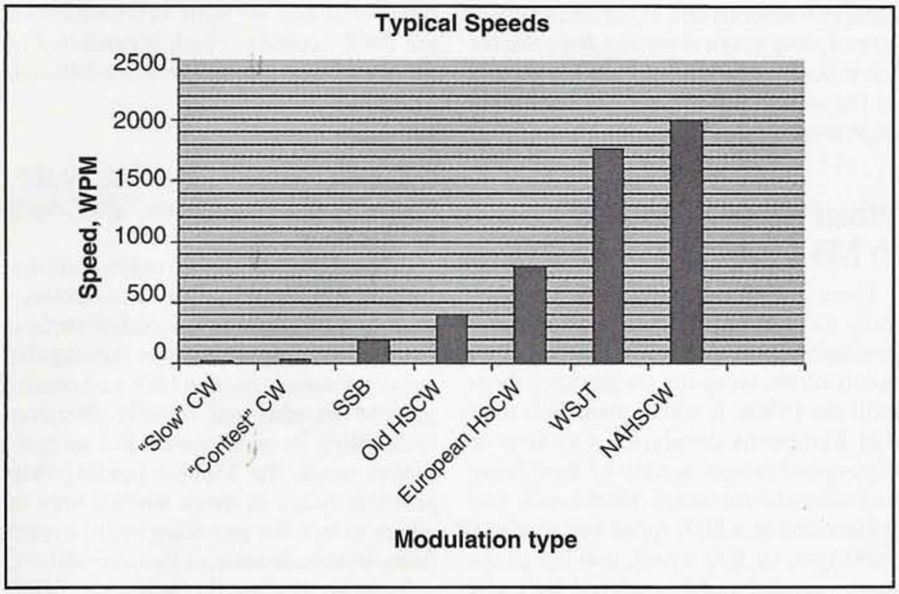


Figure 4. A comparison of the speeds of the various modes of communication used for meteor-scatter work.

ity of 45 km/sec,[14] depending upon whether their orbit is approaching the Earth head-on or from behind. All meteors in a given shower will have the same velocity, while sporadics can have a wide range of velocities.

The height where meteors ionize is usually between 80 and 120 km, with the higher velocity particles ionizing at the greater heights. A recent study[15] seemed to show a second group of the high-velocity *Leonids* ionizing at twice the normal height—about 250 km. However, no other indication of this extreme height has been found, and it is believed by many that this report was an artifact of the radar being used.[16]

Because the ionization height is about the same as the *E*-layer, the distances covered by meteor scatter are approximately the same—650–2250 km (400–1400 miles), with the 950–1900 km (600–1200 miles) range being the easiest to attain. Maximum distances are, of course, determined not only by the ionization altitude, but also by the effective height of the antennas. Thus, distances beyond 2250 km are seldom achieved, with 1900–2150 km being the usual maximum distance for the average station. Distances under about 600 miles are also difficult unless the antennas are elevated. Also, side scatter (both stations aiming at a common point about 400 miles from each) is used sometimes for shorter distances.

Most of this article has dealt with the 144-MHz band, which is where most meteor-scatter activity takes place. MS is much easier on 50 MHz, and becomes more difficult as one goes higher in frequency. Both the received power of the signal and the duration of pings decrease rapidly with shorter wavelengths. The received power or signal strength varies approximately as the cube of the wavelength, while duration varies approximately as the square of the wavelength.[17]

On 50 MHz random MS is possible nearly every morning of the year with moderately equipped stations. However, 50-MHz SSB MS seems to have fallen out of favor. (There are a fair number of stations on 6 meters daily looking for HSMS schedules, though.)

The 222-MHz ham band has seen very little MS activity, probably because of the small number of stations on this band. Those operators who have tried it, however, have found it to be less difficult than expected.

Likewise, 432 MHz has seen little—very little activity—with most of the activity taking place in Europe. Meteor scatter on 432 MHz requires power and patience. One-hour schedules are typically run during showers, and the Europeans suggest slightly elevating the antenna in order to null as much ground noise as possible.

Higher frequency bands are generally considered to be unlikely candidates for MS operation, although 902-MHz contacts may be possible between well-equipped stations and experienced operators during major showers. No contacts have been reported on this band, and as far as it is known, no attempts have been made.

What Has Changed in MS Operation?

Even though the daily influx of sporadic meteors had been known since the beginning of meteor astronomy and communications, amateurs seldom used them until the 1980s. It was at about this time that Europeans developed a system of high-speed meteor scatter by modifying audiocassette recorders. Morse code was transmitted at a high speed (up to about 2500 lpm, or 500 wpm), and the pings were recorded and then played back at a slower speed. This is several times faster than SSB, and provides a more usable signal because of the difference in the modulation. While this idea goes back to the very beginning of meteor scatter communications in Project JANET[18] and was used by some of the early North American meteor-scatter operators (using two- or three-speed reel-to-reel tape recorders), it never caught on over here.

Over the ensuing 15 to 20 years, Europeans not only made many contacts during the major showers, they also began making regular contacts every morning using only the daily influx of sporadics. The number of MS contacts and the number of grids worked rapidly increased for the Europeans, while North Americans continued operating only SSB (or, for a few, 25-wpm CW) during the major showers.

There were several reports published concerning what Europeans were able to do, but North Americans seemed to take little or no notice of all this increased MS press. Over the years attempts by several different amateurs were made to introduce high-speed CW meteor-scatter operation over here, but as far as is known, no contacts were ever made. It is difficult to make a contact when you are the only one operating! Consequently, Europeans continued to make MS contacts all year, nearly every day, while the rest of the world was stuck in the past (see figure 4).

In Part II of this article, modern high-speed meteor-scatter (HSMS) methods, as well as techniques for both SSB and HSMS operation, will be described. There will also be some information on the 2002 Leonids, *which is predicted to reach storm levels on November 19!—ed.*

Notes

1. Bain, Walter F., W4LTU, "V.H.F. Meteor Scatter Propagation," *QST*, April 1957, pp. 20–24, 140, 142.

2. Named after German mathematician August Ferdinand Möbius, a Möbius strip is a continuous one-sided surface that can be formed from a rectangular strip by rotating one end 180° and attaching it to the other end, thereby effectively doubling its surface area. For meteor-scatter work, the Möbius (audio) strip provides twice as much surface area in which to tape the incoming audio stream from the transmission of the other station.

3. Bain, Walter F., W4LTU, "VHF Propagation by Meteor-Trail Ionization, *QST*, May 1974, pp. 41–47, 176. Reprinted in Pocock, Emil, W3EP, ed., *Beyond Line of Sight*, pp. 108–115, American Radio Relay League, 1992.

4. <http://www.imo.net/>

5. <http://www.amsmeteors.org/>; see also Gary Kronk's web page at <http://comets.amsmeteors.org>.

6. <http://www.sci.fi/~oh5iy/>

7. See *wgn,* bimonthly journal of the international meteor organization, Vol. 29, No. 6, December 2001.

8. <http://www.qsl.net/w8wn/hscw/papers/hot_news.html>

9. See note 2.

10. White, Ian, G3SEK, ed., *The VHF/UHF DX Book*, Vol. 1, First Edition, p. 2-55, Radio Society of Great Britain, 1995.

11. McKinley, D. W. R., *Meteor Science and Engineering*, pp. 120–127, 169, McGraw-Hill, 1961.

12. McKinley, *op. cit.,* p. 148.

13. Ennis, Shelby, W8WN, "Utilizing the Constant Bombardment of Cosmic Debris for Routine Communication," *QST,* November 2000, pp 28–32; <http://www.qsl.net/w8wn/hscw/papers/realold.html#W8WN/K0XP>.

14. McKinley, *op. cit,* p. 109, 135–137.

15. Brosch, Noah, et al., "Meteor Observations from Israel," *Earth, Moon, and Planets*, special issue, 2001.

16. See <http://www.qsl.net/w8wn/hscw/prop/brosch.html> and <http://www.qsl.net/w8wn/hscw/prop/mardoc.html> for more on the *Leonids* observation.

17. See note 2.

18. McKinley, *op. cit.,* p. 246. ■

North American VHF and above DX Records

Courtesy Al Ward, W5LUA, and North Texas Microwave Society (http://www.ntms.org)

Band	Distance miles (km)	Call Signs	Date
144 MHz			
Aurora	1347 (2167)	KA1ZE (FN31TU)—WBØDRL/WAØTKJ (EM18CT)	February 8, 1986
Auroral-*E*	1389 (2236)	VE4AQ (EN19LU)—K5MA (FN41QO)	June 9, 1991
FAI	1472 (2370)	WØLD (DM78PU)—WA4CHA (EL88QA)	June 19, 1993
IOS	1775 (2856)	K5JL (EM15DP)—VE1ALQ (FN65VH)	November 8, 1999
MS	1960 (3154)	K5UR (EM35WA)—KP4EKG (FK68VG)	December 13, 1985
Sporadic-*E*	2259 (3635)	WA7GSK (DN13SO)—W4FF (EL96AM)	May 29, 1998
TE	3933 (6328)	KP4EOR (FK78AJ)—LU5DJZ (GF11LU)	February 12, 1978
Tropo C	1687 (2714)	WB4MJE (EL94HQ)—VE1KG (FN84CM)	November 5, 1994
Tropo P	2954 (4754)	KH6HME (BK29GO)—W1LP/MM (DL51CE)	August 21, 1999
Tropo A	1469 (2365)	W1JSM (FN43NC)—VP5D (FL31UT)	May 10, 1988
222 MHz			
Aurora	1298 (2088)	WC2K (FM29PT)—W5LUA (EM13QC)	March 13, 1989
MS	1306 (2102)	K1WHS (FN43MJ)—W7XU (EN13LM)	August 13, 1998
Sporadic-*E*	1364 (2195)	W6QIW (DM04CK)—W5UWB (EL17AX)	February 14, 2000
TE	3670 (5905)	KP4EOR (FK78AJ)—LU7DJZ (GF05RJ)	March 9, 1983
Tropo A	1152 (1854)	WA4LOX (EL87SK)—WP4O (FK68KM)	February 26, 1998
Tropo C	1345 (2167)	W5UWB (EL17AX)—K2YAZ (EN74AX)	October 11, 1998
Tropo P	2574 (4142)	XE2/N6XQ (DL29CX)—KH6HME (BK29GO)	July 15, 1989
432 MHz			
Aurora	1182 (1902)	W3IP (FM19PD)—W5LUA (EM13QC)	February 8, 1986
MS	1268 (2040)	W7XU (EN13LM)—N6RMJ (DM14CP)	November 17, 1998
Tropo C	1370 (2204)	KM1H (FN42HR)—WB4MJE (EL94HQ)	December 16, 1992
Tropo P	2574 (4142)	XE2/N6XQ (DL29CX)—KH6HME (BK29GO)	July 15,1989
Tropo A	1413 (2273)	W1RIL (FN42AH)—VP5D (FL31UT)	May 10, 1988
903 MHz			
Aurora	54 (87)	K3HZO (FM18QP)—WA3NZL (FM19JG)	November 8, 1991
Tropo C	1082 (1741)	KØVXM (EL98PJ)—N5WS (EL09RU)	May 22, 1998
Tropo P	2523 (4061)	KH6HME (BK29GO)—N6XQ (DM12JR)	July 13, 1994
1296 MHz			
Tropo C	1287 (2071)	WB3CZG (FN21AX)—K2DH (EM13PA)	November 29, 1986
Tropo P	2574 (4142)	XE2/N6XQ (DL29CX)—KH6HME (BK29GO)	July 15, 1989
2304 MHz			
Tropo C	1000 (1609)	W5LUA (EM13QC)—KØVXM (EL98PJ)	May 1, 2002
Tropo P	2469 (3973)	KH6HME (BK29GO)—N6CA (DM03TR)	July 14, 1994
3456 MHz			
Tropo C	936 (1507)	W5LUA (EM13QC)—KQ4PI (EL99HK)	May 2, 2002
Tropo P	2469 (3973)	KH6HME (BK29GO)—N6CA (DM03TR)	July 28,1991
5760 MHz			
Tropo C	738 (1187)	W5LUA (EM13QC)—W9ZIH (EN51NV)	November 12, 1994
Tropo P	2469 (3973)	KH6HME (BK29GO)—N6CA (DM03TR)	July 29, 1991
10368 MHz			
Tropo C	797 (1282)	W1LP/MM (DL34JA)—WB6CWN (DM04EG)	September 20, 2001
24192 MHz			
Tropo C	233 (375)	K6GZA/6 (CM97HM)—AD6FP/6 (DM04MS)	September 16, 2000
47040 MHz			
Tropo	108 (174)	W4SW/4 (FM08US)—W3IY/3 (FN10FF)	November 14, 2001
75.5–81 GHz			
LOS	110.5 (176.8)	WØEOM/6 (CM88QQ)—KF6KVG/6 (CM97AE)	March 1, 2002
119.98–120.02 GHz			
LOS	7.25 (11.67)	WØEOM/6 (CM87WJ)—KF6KVG/6 (CM87UK)	October 19, 1999
142–149 GHz			
LOS	38.3 (61.6)	W2SZ/4 (FM07FM)—WA4RTS/4 (FM08IB)	January 01, 2001
241–250 GHz			
LOS	4.55 (7.32)	WA1ZMS/4 (FM07JJ)—W4WWQ/4 (FM07JI)	February 23, 2002
Above 300 GHz			
LOS	0.3 (0.5)	WA1ZMS/4 (FM07JI)—W4WWQ/4 (FM07JI)	March 1, 2002
Visible LASER 394 to 750 THz			
LOS	154 (248)	KY7B/7 (DM42OK)—WA7LYI (DM34TF)	June 8, 1991

Notes:

FAI—Field Aligned Irregularities
IOS—Ionospheric Forward Scatter
MS—Meteor Scatter
TE—Transequatorial

Tropo C—Tropo between locations on the continent
Tropo P—Transpacific tropospheric modes
Tropo A—Transatlantic tropospheric modes
LOS—Line of Sight

The distances given for the 120, 145, 241, and the 322 GHz records are based on actual latitude and longitude of both stations. All other records are based on center-to-center of 6-digit grid-squares.

The Aviator's Solution To Shack Noise

If background noise is a fact of life in your shack and loud enough to interfere with your ability to receive signals, then KF2LF says an aviator's noise-canceling headset might be the answer, as long as you have the budget for a professional solution.

By Michael C. Schell,* KF2LF

Thirty volts low! The prop claws at the air, sending vibrations through the frame of the craft. I drop the power and look at the tense faces beside my rig. Life and contesting lie mirrored in them—rigid, silent, waiting for the start.[1]

Yet another fan clatters to life and brings me back from the contest on Roosevelt Field in 1927 to my noise-filled basement in 2000. My shack is in the furnace room with the following fans/noise sources—furnace, water heater, and linear amp. Amateur radio has been my hobby for decades and has kept me close to my dream of flying. While my eyesight prevented me from piloting an airplane, ham radio has enabled me to "travel" to different continents as a "radio flyer." The yearning to fly led me to a solution to my noise problem.

First, let us define the problem quantitatively. The ambient noise level with just my Ten-Tec OMNI and computer running is 40.0 dB as measured with a calibrated audiometer. This situation is acceptable with the Heil Proset headset, which provides a reasonable amount of noise reduction. However, if either the furnace or water heater fan is on, the noise level increases to 48 dB, and when *both* units are running, the noise level increases to 52 dB! For reference, a vacuum cleaner raises the din to 81 dB. Normal intelligible speech is in the range of 400 Hz to 3500 Hz[2], with Morse Code at 700 Hz. The human ear is most sensitive to the audio frequency range from 2 kHz to 5 kHz. The fan noise occupies the same frequency range. The fan-generated background noise is equivalent in amplitude to normal conversational speech; hence the desire to attenuate and cancel the distraction.

It is beyond the ability of the Proset to wipe out these increased noise levels. Even David Clark Model 10 ear protectors and the Koss Pro 4AA headset do little to eliminate the noise. Pilots of propeller-driven planes have the same problem, and to a much greater extent. How did Lindbergh tolerate his 33-hour transatlantic flight with the Pratt and Whitney Whirlwind engine blasting in his ears? His solution was stuffing his ear canals with cotton, but that was no solution for my problem. I still wanted to hear the radio signals.

*11 Fellview Drive, Pittsford, NY 14534
e-mail: <mschellur@earthlink.net>

The David Clark Model H10-13X headset rests behind the electronic noise-canceling module (Model X-L) with the stereo phono plug for the earphones and the aviation microphone plug.

Modern pilots use headsets with electronic noise cancellation (ENC). A quick trip to the David Clark website revealed the Model H10-13XL headset with passive noise attenuation at 27 dB (500 Hz), rising to 32 dB (2500 Hz). The electronic noise cancellation adds another 15 dB.

I ordered the headset (street price $650) and have been using it for several months. In the passive mode the noise reduction is very impressive, with the fan noise reduced to a background level that is quite tolerable. The ENC is even more impressive. With the ENC active, the fan noise is obliterated completely and is not discernable during a QSO.

The headset is very comfortable, which is a considerable achievement in my case (hat size $7^{3}/4$). In addition, the audio and comfort of the H10-13XL surpass that of the other headsets I've tried. This is to be expected, since the comparison is between amateur radio gear and professional pilot headsets. The performance increase is accompanied by the cost of a professional headset. In many cases, the noise can be decreased simply by the passive attenuation of a pilot headset. However, you have to pay the price: Passive headsets such as the David Clark Model H10-30 range in price from $120 to $250, while ANR/ENC headsets from Clark, Telex, and others range from $500 to $680. The cost of a passive noise-reduction headset for pilots is comparable to current amateur radio gear prices. For total noise elimination, the Model H10-13XL is my choice, even with the $650 price tag.

Now back to piloting the Ryan NYP from New York to Paris . . . or is it the OMNI from New York to wherever the bands will take me?

Notes

1. The first paragraph of this article is adapted from page 181 of *The Spirit of St. Louis,* by Charles Lindbergh, Charles Scribner's Sons, 1953.

2. Cameron, John R., and Skofronick, James G., "Physics of the Ear and Hearing," Chapter 13 in *Medical Physics* by Wiley-Interscience.

Resource

For further information on the Model H10-13XL noise-canceling headset contact: David Clark Co., Inc., 360 Franklin Street Box 15054, Worcester, MA 01615-0054; phone 508-751-5800; fax 508-753-5827; e-mail: <SalesWWW@DavidClark.com>; web: <http://www.davidclark.com>.

A 900-MHz Parrot Repeater

Multi-Access Amateur Use of 33 cm (902–928 MHz)

We amateurs almost forget that we have an amateur band in the 902–928 MHz frequency spectrum. So totally loaded with non-amateur users, this band seems to be unattractive to many of us. In spite of this, KE4NZG decided to go ahead and build a repeater for this band. Making sure that it was accessible to as broad a group of amateurs as possible, Jim also included inputs on three separate bands.

By Jim Labor,* KE4NZG

Loud and clear out of the scanner tuned to 919.300 MHz came: "KE4NZG testing 900-MHz repeater...." I had just completed transmitting the identical statement on 446.900 MHz to test the UHF input/access to my recently installed homebrew 900-MHz repeater. Seconds earlier a similar test proved that the 145.170-MHz VHF input also worked. After years of the concept bouncing around in my head and components being joined together, my 900-MHz repeater was built, installed, and status *active!*

I had adhered to the saying "use 'em or lose 'em" by launching a repeater that not only operated with input on 907.300 MHz, but also permitted hams without that capability to access it through inputs at 145.770 and 446.900 MHz. Now I could actually make use of this 33-cm band and also provide the use of the 902–928-MHz spectrum to other hams in my area.

I built my repeater around a Standard GX-3000K commercial, 800-MHz land-mobile transceiver (photo A). This unit is a conventional, non-trunked, 64-channel, 25-watt radio. Modification to convert it to 900-MHz operation proved easy with very minimal degradation.

The brain for this well-designed FM two-way radio is a 16K 2716 EPROM integrated circuit. This EPROM was reprogrammed to operate on channel one only, with an input frequency of 907.300

*925 North Halifax Avenue, 1010 South Tower, Daytona Beach, FL 32118
e-mail: <Labor_J@popmail.firn.edu>

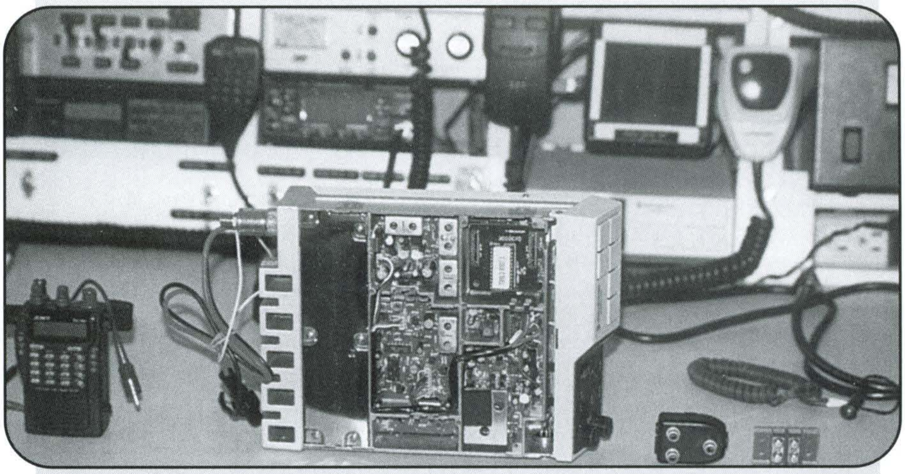


Photo A. Standard GX-3000K business-band conventional, non-trunked, 64-channel, 25-watt, 800-MHz transceiver.

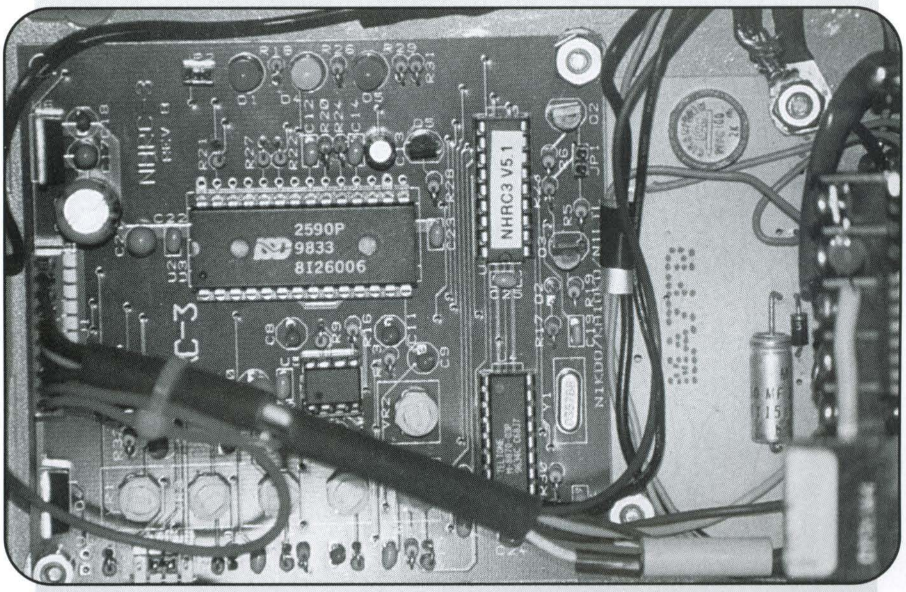


Photo B. NHRC-3 repeater controller.

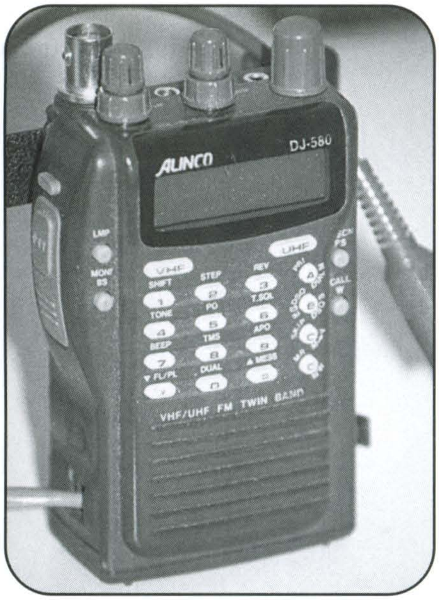


Photo C. Alinco DJ-580 dual-band HT.

MHz and an output frequency of 919.300 MHz. Nestled back in its socket, the newly reprogrammed EPROM was ready to command external circuits.

The next step was to realign the receiver section and retune the transmitter. As it turned out, realigning the receiver was accomplished with only seven points of adjustment. Likewise, only seven points of adjustment were required in the transmitter section.

With just over 13 volts of DC power to the system (under-load), RF power output at 919.300 MHz was a stable and consistent 21 watts. A salvaged Motorola Flexar DC power supply accommodated with ease the 7-amps total current requirement of the complete system.

An NHRC-3 repeater controller (photo B) was integrated into this system. It was selected for several desirable features, including a 90-second stored speech function, DTMF remote control, and multiple programming options. In addition, the "Special ID Mode" permits real-voice identification while operating in simplex mode.

The "parrot" simplex mode was selected as an inexpensive approach, since an 800/900-MHz duplexer alone could cost well over the total investment in this 900-MHz repeater project. Also, this simplex parrot operation serves well for experimenters—key your microphone, speak, unkey, then hear the results.

To provide 2-meter and 70-cm access I chose a spare Alinco DJ-580 dual-band HT (handie-talkie). The HT accommodates the 145.770-MHz and 446.900-MHz receive process. A Comet GP-3 antenna with gain of 4.5 dB on VHF and 7.2 dB on UHF serves as the receive-only antenna. The decode tone of 103.5 Hz was programmed to offset false keying of the 900-MHz transmitter by the HT-style receiver. A Comet KP-20 antenna was selected for the 900 MHz segment. This antenna features a $7^{1}/_{3}$-foot vertical element rated at 7 dB gain at 915.000 MHz.

Several types of coax were tested for loss and attenuation at 919.300 MHz. These tests were made using the 21 watts from the GX-3000K. The results revealed that quad-shield 75-ohm RG-6 cable is very effective. It is also inexpensive. A good match and transfer of RF power to the KP-20 from the GX-3000K was achieved. This RG-6 quad-shield feedline is very easy to work with, while using simple but effective F-type connectors

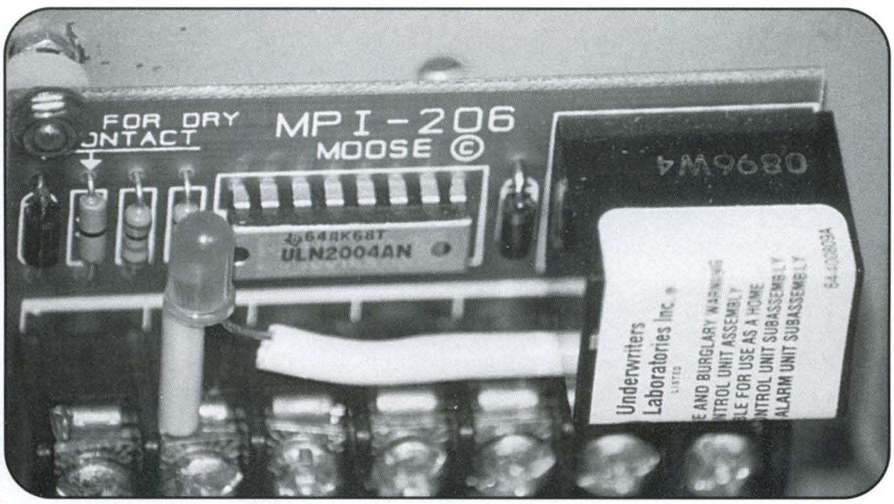
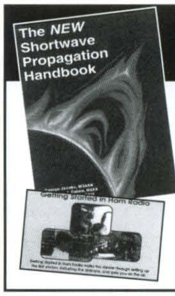


Photo D. Sentrol MPI-206 universal relay board.



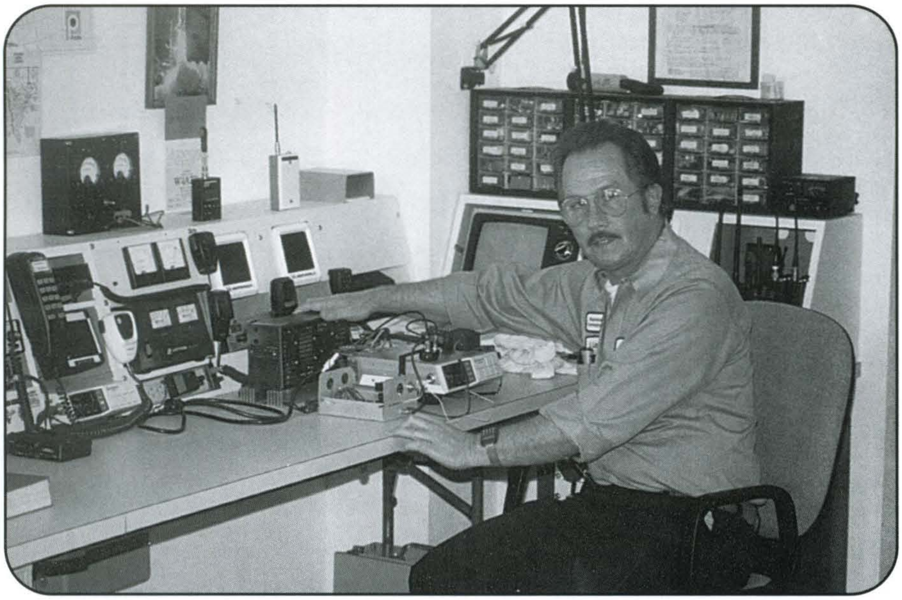


Photo E. The author checking the power supply for heating under load conditions.

Photo G. External view of the completed 900-MHz repeater.

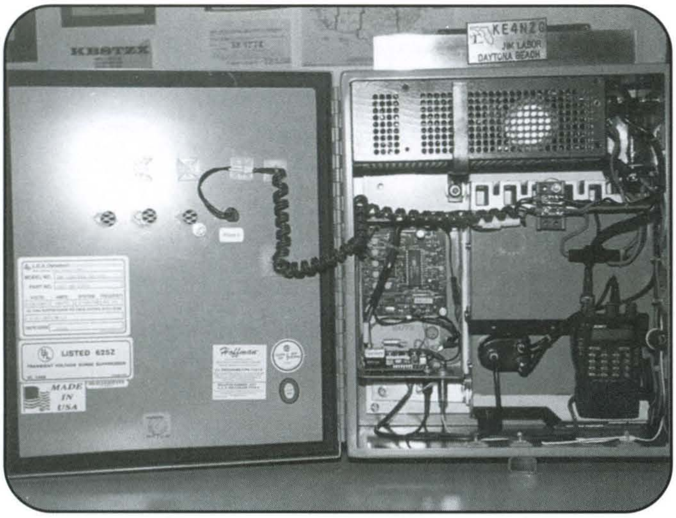


Photo F. Internal view of the completed 900-MHz repeater.

Components and Parts List

- Standard GX-3000K business-band conventional, non-trunked, 64-channel, 25-watt, 800-MHz transceiver
- NHRC-3 repeater controller
- Alinco DJ-580 dual-band HT
- Comet GP-3 dual-band, 2m-70cm base vertical antenna
- Comet KP-20 900-MHz base vertical antenna
- RG-6 quad-shield coax cable
- Homebrew-type N- to F-connector adapter (See text for details.)
- Sentrol MPI-206 universal relay board

for termination. Incidentally, CATV coax along with the F-connectors is useful for the gigahertz region.

Because N-male to F-connector adapters essentially are unavailable, I fabricated my own using a standard RG-8 style male N-connector and a chassis-mount F-connector. I attached and carefully soldered these together while maintaining 100-percent shielding with minimal insertion loss. At least 90 percent of base-station antennas available for the UHF spectrum and above terminate using female N-connectors. Therefore, my homebrew adapters provide efficient interface to F-connected RG-6 cable.

A more difficult task than homebrewing the adapters was locating a useful COS (carrier-operated squelch) line in the Alinco HT to provide the NHRC-3 controller requirement for a triggering voltage for transmit PTT (push-to-talk) action. I was only able to find a maximum derived positive-going voltage of 2.2 volts DC, so I began a quest to provide an unsquelched setting of at least 6+ volts.

Finally, to accommodate the NHRC-3's desired keying input voltage, an option using a Sentrol MPI-206 (universal relay board) was employed. The MPI-206 provides a 12-volt plus (switched) line using the low 2.2-volt triggering input. A nice aspect of the MPI-206 is that it can be triggered by either a positive- or negative-going voltage input with a source as low as an astounding 3 milliamps!

The task of locating the unsquelched DC-plus voltage required by the NHRC-3 controller in the receive section of the GX-3000K pin 13 of QR-56 was much easier. A TK 10420 integrated circuit provides a substantial +8 volts. Also, the low-noise, high-sensitivity receive function necessary at 900 MHz is available with the GX-3000K with its squelch threshold sensitivity at a very usable 0.03 microvolts. Two 25C 3358 RF amplifiers in the front end provide these features. Typical frequency cut-off approaches 1100 MHz. The GX-3000K business-band transceiver played a very important role in making this 900 MHz repeater project move forward from inception to reality.

I realize that details are lacking in this article, but my primary purpose was to report what was done. For anyone interested in duplicating my efforts, I will be happy to provide details. Please contact me at the e-mail address at the beginning of this article. If you are in the Daytona Beach area, please feel welcome to use the repeater. ■

Repeater Inputs and Output

Repeater inputs: 907.300 MHz, 446.900 MHz, and 145.770 MHz
Repeater output: 919.300 MHz

LETTERS TO THE EDITOR

Editor, *CQ VHF:*

I just received *CQ VHF* Spring 2002 in the mail today. I've been looking forward to its return. I have the March–December 1999 issues; I enjoyed the magazine very much. I still subscribe to *CQ*. I enjoy HF somewhat, but my first love is VHF/UHF. I am currently involved in 50, 144, 222, and 432 MHz weak-signal activity; VHF packet; APRS (both mobile and base); VHF/UHF TV DXing; and I am learning about the digital modes on VHF (SSTV, PSK-31, WSJT, etc.). Heck, I'll even work FM simplex on 2 meters during some good tropo openings.

I've been a ham since January 1997. Most of that time I've been on VHF/UHF. I use the above modes for propagation along with monitoring the Propagation Loggers most of the time. People would be surprised how useful packet is in seeing which direction the propagation is coming from and from how far. TISH:KD5CJR-6 node is eight miles from me. It is very useful to see the Nodes List on it.

I'm passing the word that *CQ VHF* is back and looks to be very informative and interesting. The most interesting articles to me are the ones of actual operator setups (Rover, EME, weak signal, Ssatellite, etc.). I am enjoying reading about the KAØY "dish" and the Rover setup of W7DHC. Wow! That is awesome stuff and it gives people like me ideas.

Thanks again and keep up the good work.

Jeff Dover, KU4WW (via e-mail)

Editor, *CQ VHF:*

I just received my first issued of *CQ VHF* and it's great. The articles are written at a good technical level and provide much needed information for the VHF/UHF enthusiast. I think that this magazine will also create new VHF/UHF enthusiasts within our amateur community. I'm glad to see it's a "can't put it down" magazine!

Greg Sarratt, W4OZK
President, DeKalb County Alabama Amateur Radio Club
Technical Coordinator, Alabama ARRL Section (via e-mail)

Editor *CQ VHF:*

I picked up the Spring 2002 edition of *CQ VHF* on a chance trip to Ham Radio Outlet in Atlanta. Overall, this is a good effort! The article by K1JT on JT44 was the most readable and informative article on a new mode I have ever had the pleasure of reading. Another A+ goes to "Cheap 435 MHz AMSAT Antennas." But [quoting the "Dr. SETI's Starship" column] "sightings, abductions, Roswell, crop circles, Area 51 ... have defied explanation"? Only if one suffers from some sort of psychosis. Leave this sort of drivel to Art Bell; you are right on target without it. "Truth, not tolerance!"

Mark Christopher, WR8Y (via e-mail)

Editor, *CQ VHF:*

First, let me add my congratulations on the return of *CQ VHF*. I think it fills a definite void for the V/U community.

I read the article by VE3ERP on page 42 in the spring issue re parabolics and wanted to add some comments. I recognize that this is an introductory article and not an in-depth study, yet I feel it would have been more appropriate if the author had used vocabulary that is commonly found in literature on this subject. That way someone wishing to learn more about parabolics would not have to relearn the basics.

Regarding the shape of a parabola: For RF purposes at least, the shape is classed by the focal length to depth (f/D) ratio as opposed to "acceptance angle"—a term I have never encountered, although it may be in use in fields other than RF.

Under the heading of "Does Size Really Matter?" I believe the term *efficient* is misused. A larger dish is not necessarily a more efficient receiver of signals. Dish efficiency is a function of how accurately the surface conforms to the ideal mathematical curve and also perhaps hole size if mesh is used. If the feed is included, then efficiency of the feed itself also needs to be included, as well as how the feed illuminates the surface. This need not be a technical issue, as an analogy of a floodlight illuminating the surface can be made.

Finally, figure 4 is incorrectly referred to as a Smith Chart, when in actuality it is a polar plot. In practice, even polar plots are not nearly as meaningful for parabolas as is a rectilinear plot, as this type of plot gives more immediate information as to sidelobe levels and how many degrees off the main beam the sidelobes are located. This information may be gleaned from a polar plot but with less accuracy and involving more time.

For those wishing additional reading I highly recommend Paul Wade's (W1GHZ) "On-Line Antenna Book" at: <http://www.qsl.net/n1bwt/preface.htm>. This is a wonderful source of parabolic surface and feed information for the beginner right up through the seasoned antenna engineer.

Dale Parfitt, W4OP (via e-mail)

Morse Code via Mountaintop Heliograph

While Morse code may be taking a back seat in the world of communications, diehard hams who love to practice the art will continue to find ingenious ways of doing so. Dipping back to 19th century technology and adding the communications of 21st century VHF ham radio, KF6DXX describes how he uses Morse code to communicate mountaintop to mountaintop via the sun. As magicians say, "It's all done with mirrors!"

By Edward Butler,* KF6DXX

This article is, in part, a follow-up to a previous article ("2-Meter Mountaintopping with Mirrors") which appeared in the February 1999 issue of *CQ VHF*. It also describes further investigation into the art of sending Morse code via heliograph between mountain peaks. Some of the techniques and equipment utilized in this project were discussed in the above-cited article.

Along with my fellow hikers in the Palomar Amateur Radio Club (PARC), I have explored many interesting areas of our local mountains and deserts here in southern California. Several years ago we decided to try mirror signaling between some of the peaks on which we were hiking. This activity took on a life of its own, and as we became more involved in it, the distances between the mountain peaks we chose gradually increased.

In the spring of 1999, Bob Gonsett, W6VR, and Tom Chester, KF6HPS, on Keller Peak (7882-foot elevation) in San Bernardino County, California exchanged signals with my station on Cuyamaca Peak (6512-foot elevation) in San Diego County over a 90-mile path.

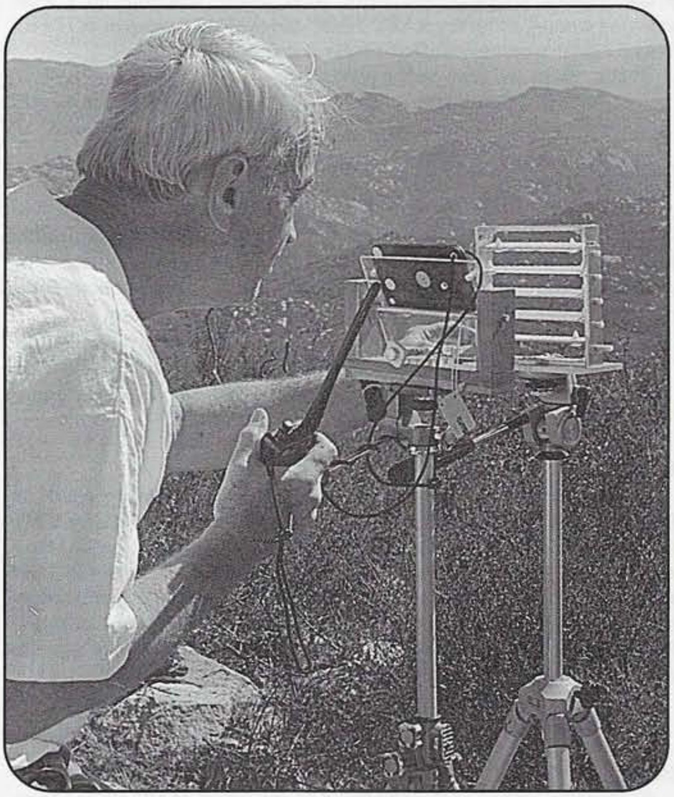
On February 24, 2002, John Lee, KT6E, Jeff Carlson, KG6AXR, and Ray Deza, KF6ISS, on Mount San Antonio (10,062-foot elevation) in San Bernardino County completed a 110-mile non-code mirror signal exchange with my station on Cuyamaca Peak in San Diego County.

Radio communication between peaks using our 2-meter radios was essential to confirm that we had seen signals from the opposite peak. We used 147.555 MHz simplex or "triple nickel" for our 110-mile contact between peaks. Battery power and a rubber-duck antenna proved to be all we needed for our line-of-sight liaison communications.

Shutter Design

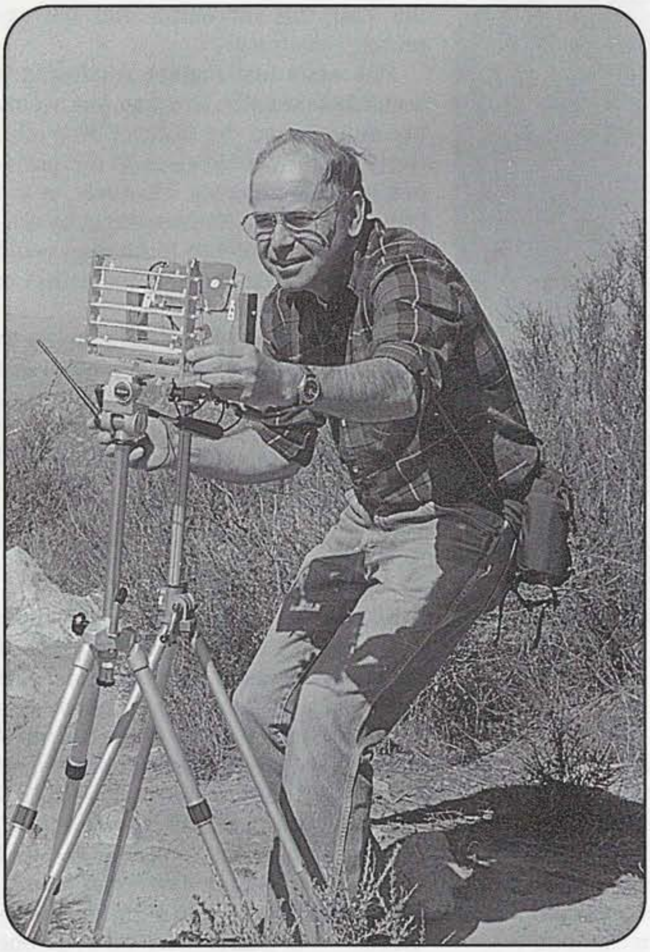
A few years ago, I started looking into the possibility of sending an actual message with mirrors—heliograph Morse code, which turned out to be quite a challenge. Numerous ideas for a suitable mechanism were considered but rejected because they were either impractical or too expensive. After considerable digging, I decided that a mirror aimer and a separate shutter with louvers would be the most workable approach.

In researching this project, I found two books which were extremely helpful in planning the design of my heliograph shutter. These books are *Great Days of the Heliograph,* by



Ed, KF6DXX, sending heliograph Morse code from a mountaintop in southern California. A heliograph is a device designed specifically for using sunlight reflected off a mirror to send messages.

*4722 33rd St. Apt. 12, San Diego, CA 92116-1806
e-mail: <ebbutler@juno.com>



Bernie, N6FN, practicing with the heliograph on Iron Mountain.

Lewis Coe, and *Apache Wars: An Illustrated History,* by E. Lisle Reedstrom.

After several months of trial and error with various shutters, I came up with a design using five horizontal louvers, each about 1.10 inches wide by 6.00 inches long. The louvers are attached to axles cut from a 0 .125-inch diameter drill rod.

The frame is made of aluminum extrusion with a cross section of 0.125 inch by 1 inch. The ten axle holes in the frame had to be hand honed to match the axles, which, as it turned out, were slightly oversize. A small tension spring activates the shutter return after each keystroke. With some judicious calculation, I managed to keep the keystroke length relatively short at about one-half inch. The first prototype shutter represented about 40 hours of work, while the second and third were copied with slight modifications to the original design and took about 16 hours each to build.

Setup and Sending Technique

The half-inch keystroke length is quite adequate for sending a very rapid series of Morse code dits. On the other hand, the dahs are deliberately made about five seconds in duration for the purpose of making it easier for the receiving station to distinguish them from dits.

Initial aiming of the mirror is done with the shutter set aside and out of the light path. Our 2-meter radios are used for feedback while the mirror is adjusted during the aiming process, which continues until the receiving station reports seeing a steady beam of reflected sunlight.

Mirror and shutter are mounted on separate tripods, and once a steady beam of light is achieved, the shutter is quickly placed in the light path (in front of the mirror). The approximate rate of movement of the sun across the sky is 15 degrees per hour. Therefore, frequent adjusting of the mirror is necessary to keep the light beam on target.

Maintaining accurate aiming is done by using a simple, but ingenious method which was developed by the U.S. Army in the 1880s and is described in detail in Coe's book. A dark-colored patch or piece of tape is placed on one of the shutter louvers. A similar patch placed on the face of the mirror creates a shadow area in the beam of reflected light. Once the beam is reported to be on target, the shutter must quickly be placed in front of the mirror so that the shadow falls on the louver patch. The shutter is then opened briefly several times so the receiving station can confirm seeing flashes of light.

As the mirror's shadow spot drifts with the sun's apparent movement, the mirror must be adjusted about twice a minute to maintain alignment. It is important to move only the mirror and not the shutter or the tripods.

First Field Test

Finally, it was time for a field trial to see if I could send readable Morse code with a mirror and shutter. On July 21, 2001,

The mirror aimer (left) and shutter (right) with the shadow spot used for alignment visible on the louvers.

Bernie LaFreniere, N6FN, stationed himself on the 2696-foot elevation Iron Mountain, located east of Poway, California. About 12 miles to the south, I hiked up the 1591-foot elevation Cowles Mountain, with all my signaling gear, two tripods, and a 2-meter handheld radio.

After waiting about 20 minutes for the morning haze to burn off, I began sending flashes northward to get my light beam on target, which took only a few minutes. Then we were ready for our first heliograph Morse code transmission.

At first Bernie experienced difficulty distinguishing the dits and dahs I was sending him. After transmitting a few trial letters for demonstration purposes, I was able to send several complete words which he received without error! To say the least, this successful trial was extremely satisfying.

This was a first attempt, conducted at a speed of probably less than four words per minute, and the distance was relatively short in comparison to our previous non-code signals. However, it did prove that transmitting messages by sunlight using 19th century technology could still be an interesting and fun project in the 21st century.

We were aided, of course, by having 2-way radios at our disposal, which was an advantage obviously not enjoyed by our predecessors. On the other hand, we didn't have professionally manufactured equipment and Army Signal Corps training as they did.

A Little Physics

When viewed from Earth, the sun's disk occupies about one-half degree of arc in one's field of view. Likewise, the sun's image reflected by a mirror as a beam of light is also about one-half degree wide. If one reflects sunlight onto a wall using a square mirror, the patch of light on the wall will be square at first. Moving back some distance, one will observe that the light now forms a disk.

Interestingly, the size of the disk is independent of mirror size, although one must move farther back with a larger mirror before the light forms a disk. A larger mirror, however, will make a much brighter and more intense disk than a smaller mirror. Disk size approximately equals the tangent of 0.5 degrees times distance.

Note: One should ***never*** view the sun directly, or through any optical device, including mirrors. Aiming a beam of sunlight at another person or vehicle can be very dangerous.

For a fascinating description of the power of sunlight and mirrors, I highly recommend the book *The Mirror And Man,* by Benjamin Goldberg (1975).

Postscript

In the future I hope to increase the distance between our signal stations and transmit a complete message along an extensive path between several mountain peaks.

I am indebted to those fellow hams who initially stimulated my interest in mirror signaling. Their help, their encouragement, and their willingness to trudge up many high peaks so we could exchange signals are appreciated.

Some of the accessory tools used in mountaintop heliography.

QUARTERLY CALENDAR OF EVENTS

Conventions and Conferences

The **ARRL and TAPR 21st Annual Digital Communications Conference** is scheduled for Sept. 13–15 at the Denver Marriott Southeast Hotel, Denver, Colorado. This is an international forum for radio amateurs to meet, publish their work, and present new ideas and techniques. Presenters and attendees will have the opportunity to exchange ideas and learn about recent hardware and software advances, theories, experimental results, and practical applications. Topics include, but are not limited to, software-defined radio (SDR), digital voice, digital satellite communications, Global Position System (GPS), precision timing, Automatic Position Reporting System® (APRS), short messaging (a mode of APRS), Digital Signal Processing (DSP), HF digital modes, internet interoperability with amateur radio networks, spread spectrum, amateur radio use of 802.11 technologies, using TCP/IP networking over amateur radio, mesh and peer to peer wireless networking, emergency and Homeland Defense backup digital communications, using Linux in amateur radio, and updates on AX.25 and other wireless networking protocols. For more information and conference registration, visit the website: <http://www.tapr.org/tapr/dcc/index.html>.

The **9th Annual Pacific Northwest VHF Conference** will be held in Bend, Oregon, on Sept. 27–28. Sponsored by the recently formed Pacific Northwest VHF Society, the event will kick off with a Friday evening no-host "Pizza Bash," where old friendships can be renewed and new ones made. Saturday's program will include a catered breakfast and a daylong schedule of well-known speakers. At the end of the day a brief annual business meeting of the Pacific Northwest VHF Society will be held. Cost for this conference is $25.

A flyer and registration form are available in electronic format from the society's web page at <http://www.qsl.net/pnwvhfs/>. For those without internet access, information may be obtained by sending a note and SASE to Pacific Northwest VHF Society, P.O. Box 527, Preston, WA 98050.

Normally held in August, this year the **Eastern VHF/UHF Conference** will be held Oct. 24–27 at the Radisson Hotel, Enfield, Connecticut, in conjunction with the **Microwave Update Conference**. It is sponsored by the Northeast Weak Signal Group. For the latest information and reservations visit: <http://www.microwaveupdate.org/>.

The **20th Space Symposium and AMSAT-NA Annual Meeting** will be held Nov. 7–11 at the Lockheed Martin Recreation Area, which is located in the North Texas Metroplex, Fort Worth, Texas. The nearby AmeriSuites Fort Worth/Cityview has been designated as the official hotel. Make your reservations as soon as possible by calling the hotel directly at 817-361-9797 (don't use the web-page form), and ask for the AMSAT group rate ($75/day plus taxes). For more information visit the AMSAT-NA website <http://www.edtexas.com/amsat/>.

VHF+ Calendar

Aug. 4	Very good EME conditions.
Aug. 6	Highest Moon declination.
Aug. 8	New Moon.
Aug. 10	Moon perigee.
Aug. 11	Very good EME conditions.
Aug. 15	First quarter Moon.
Aug. 18	Very poor EME conditions.
Aug. 19	Lowest Moon declination.
Aug. 22	Full Moon.
Aug. 25	Moderate EME conditions.
Aug. 28	Moon apogee.
Aug. 31	Last quarter Moon.
Sept. 1	Highest Moon declination. Very poor EME conditions.
Sept. 7	New Moon.
Sept. 8	Moon perigee. Very good EME conditions.
Sept. 13	First quarter Moon.
Sept. 15	Lowest Moon declination. Very poor EME conditions.
Sept. 21	Full Moon.
Sept. 22	Moderate EME conditions.
Sept. 23	Moon apogee.
Sept. 29	Last quarter Moon, highest Moon declination. Very poor EME conditions.
Oct. 6	New Moon and Moon perigee. Good EME conditions.
Oct. 12	Lowest Moon declination.
Oct. 13	First quarter Moon. Very poor EME conditions.
Oct. 20	Moon apogee. Moderate EME conditions.
Oct. 21	Full Moon.
Oct. 26-27	ARRL International EME Competition first weekend.
Oct. 27	Highest Moon declination. Very poor EME conditions.
Oct. 29	Last quarter Moon.
Nov. 3	Moon perigee. Good EME conditions.
Nov. 4	New Moon.
Nov. 8	Lowest Moon declination.
Nov. 10	Poor EME conditions.
Nov. 11	First quarter Moon.
Nov. 17	Poor EME conditions.
Nov. 18	Moon apogee.
Nov. 20	Full Moon.
Nov. 23	Highest Moon declination.
Nov. 23-24	ARRL International EME Competition second weekend.
Nov. 24	Moderate EME conditions.
Nov. 27	Last quarter Moon.

**EME conditions courtesy W5LUU.*

Contests

July 2002–June 2003: The annual Central States VHF Society States Above 50 MHz Contest began on July 1 and will end on June 30 of next year. The object of the contest is to work as many U.S. states and Canadian provinces on each of the VHF+ ham bands as possible. Winners of the contest are acknowledged at the society's annual conference held the fourth weekend of July. First through third place receive a plaque while all other winners receive certificates. More information and entry blanks may be found on the society's website: <http://www.csvhfs.org>.

August: The **ARRL UHF and Above Contest** is scheduled for Aug. 3–4. The first weekend of the **ARRL 10 GHz and Above Cumulative Contest** is Aug. 17–18.

September: The **ARRL September VHF QSO Party** is Sept. 14–15. The **144 MHz Fall Sprint** is Sept. 16. The second weekend of the **ARRL 10 GHz and Above Cumulative Contest** is Sept. 21–22. The **222 MHz Fall Sprint** is Sept. 24.

October: The **432 MHz Fall Sprint** is Oct. 2; **Microwave (902 MHz and above) Sprint** Oct.12; **50 MHz Fall Sprint** Oct. 19. The first weekend of the **ARRL International EME Competition** is Oct. 26–27.

November: The second weekend of the **ARRL International EME Competition** is Nov. 23–24.

Complete rules for the ARRL contests may be found in the *QST* issue the month prior to the contest or the month prior to the first weekend of contests extending over two months. Complete rules for the Fall Sprints may be found at the Southeastern VHF Society (sponsor) website: <http://www.svhfs.org>.

Meteor Showers

August: The ***Perseids***—on page 42 of this issue Shelby Ennis, W8WN, discusses the possibilities for this year's *Perseids* meteor shower. The important date and time to remember are Aug. 12 at 1740 UTC.

October: The ***Draconids*** is predicted to peak somewhere between 0315–0630 UTC on Oct. 9. The International Meteor Organization is suggesting the remote possibility of a storm, with the peak favoring Asia east to western North America.

November: The ***Leonids***—a rare double-peak meteor storm is predicted for this year's *Leonids* meteor shower. First, at 0356 UTC on Nov. 19 western Africa, western Europe, northern Canada, and northeastern South America should experience storm levels. Next, at 1036 UTC most of North America will experience storm levels of meteor-scatter propagation. For more information on this storm see the fall issue of *CQ VHF* and the VHF-Plus column in the Nov. issue of *CQ* magazine. For more information on the above meteor-shower predictions visit the IMO's website: <http://www.imo.net>.

By Kent Britain,* WA5VJB

ANTENNAS

Connecting the Radio to the Sky

Really Cheap Antennas for 2 Meters
Self-Matching Antennas

The simplified feed of this self-matching antenna design uses the structure of the antenna itself for impedance matching. The design started with the driven element and loading effects, while the other elements provide the impedance matching back to 50 ohms. No Gamma rods, no Deltas, no Ts, no other impedance-matching methods and their complex parts are needed.

There are some design compromises for the feed impedance. These are the asymmetrical feed, simple measurements, wide bandwidth, and the ability to grow with the same spacing. In addition, we are trading some gain for a clean pattern. While you might squeak another 0.5 dB out of a "Cheap Yagi," it is going to be complex and difficult to build the antenna. The self-matching antenna presented here can be built for about $5. When it comes to dBs per dollar, the design will be hard to beat.

The antennas were designed with YagiMax and tweaked in NEC, and the driven element was experimentally determined on the antenna range. Typically, you will see about 8-dBi gain with a bit over 20-dB front-to-back ratio for the three-element version. The four-element version measures 9-dBi gain with a 30-dB front-to-back ratio, while the six-element version give you 11-dBi gain with about 35-dB front-to-back ratio.

It is possible to go longer than six elements. Dave Blaschke, W5UN, has had good luck with 16-foot-long wood boom Quagis in the past, but I felt that a six-foot boom, using a 3/4-inch wood, with six elements was about the limit for Rover operations. I will not publish a design I have not prototyped and tested on the antenna range. Because extremely long Yagis take up a heck of a lot of room in the garage, I have not developed any longer versions. (To give you an idea of my problem, I just stood in the middle of my garage and counted the antennas stacked around. I counted 116 antennas! Now for the scary part: That 116 number is just the top layer!)

*1626 Vineyard, Grand Prairie, TX 75052
e-mail: <wa5vjb@cq-vhf.com>

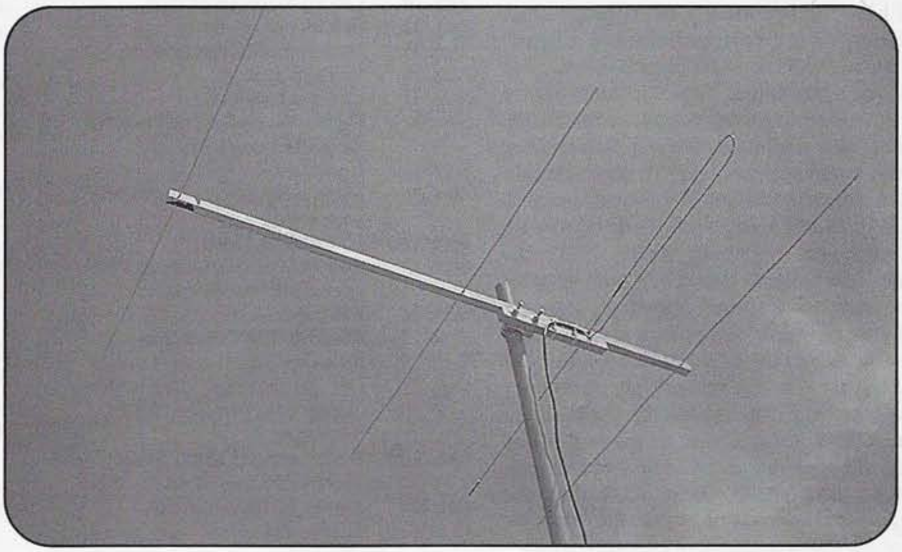


Photo 1. A 2-meter "Cheap Yagi."

Construction

The boom is 3/4-inch square, or 1/2-inch by 3/4-inch wood (see figure 1). I put a brace where the driven element and U-bolt holes had weakened the wood, which was a personal choice. Aluminum rod, hobby tubing, #10 or #12 solid-copper wire, and solid ground wire were used as elements. A drop of "Super Glue," epoxy, RTV (room-temperature vulcanizing), or my favorite, "Liquid Nails," can be used to hold the elements in place. Regarding the U-bolt, please note that I replaced the usual hex nuts with wing nuts. The wing nuts are very handy at Rover sites or for Field Day. If you expect your antenna be out in the weather much of the time, a

Number of Elements		Reflector	Driven Element	D1	D2	D3	D4
3	Length	41.0	*	37.0			
	Spacing	0	8.5	20.0			
4	Length	41.0	*	37.5	33.0		
	Spacing	0	8.5	19.25	40.5		
6	Length	41.0	*	37.5	36.5	36.5	32.75
	Spacing	0	7.5	16.5	34.0	52.0	70.0

See figure 2 for details on the driven-element (DE) dimensions.

Table 1. Dimensions for the 144.2 MHz SSB and AMSAT "Cheap Yagi." In tables 1 and 2 all dimensions are in inches. Spacings are all from zero starting at the reflector. Reflector and Directors are made from 3/16" diameter material. If you can't find 3/16-inch diameter material and want to use 1/8-inch material for the elements, you need to make the 1/8-inch diameter element .25 inch longer to compensate for the smaller element material.

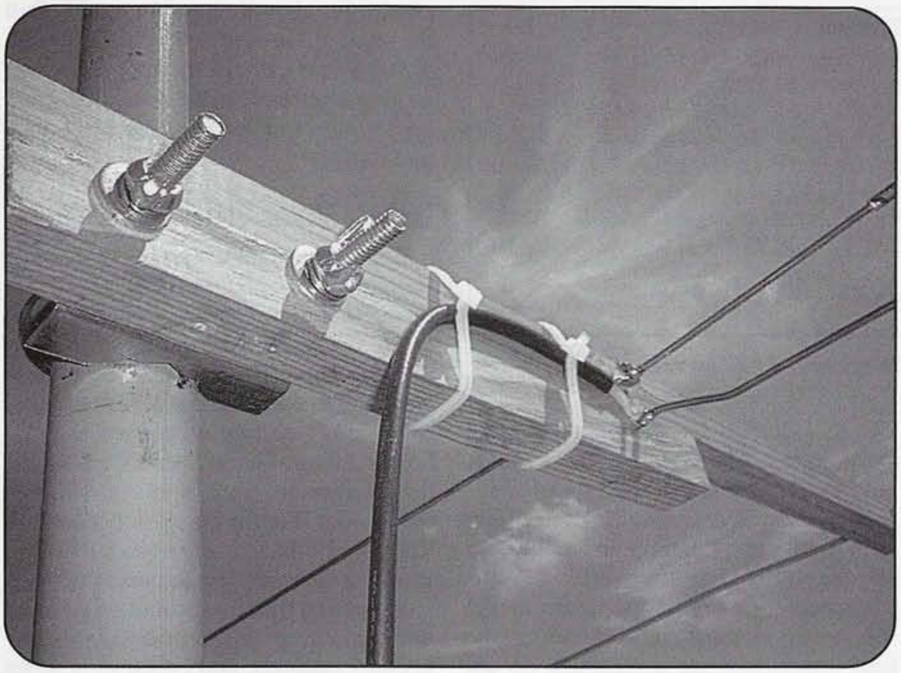


Photo 2. The driven element and U-bolt.

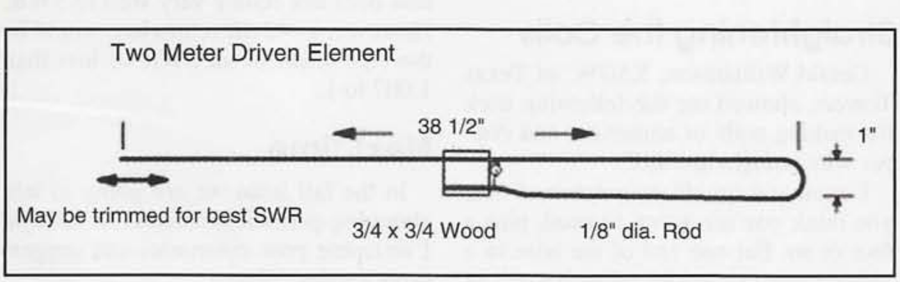


Figure 1. Dimensions for the driven element used on all versions of the 2-meter Cheap Yagi.

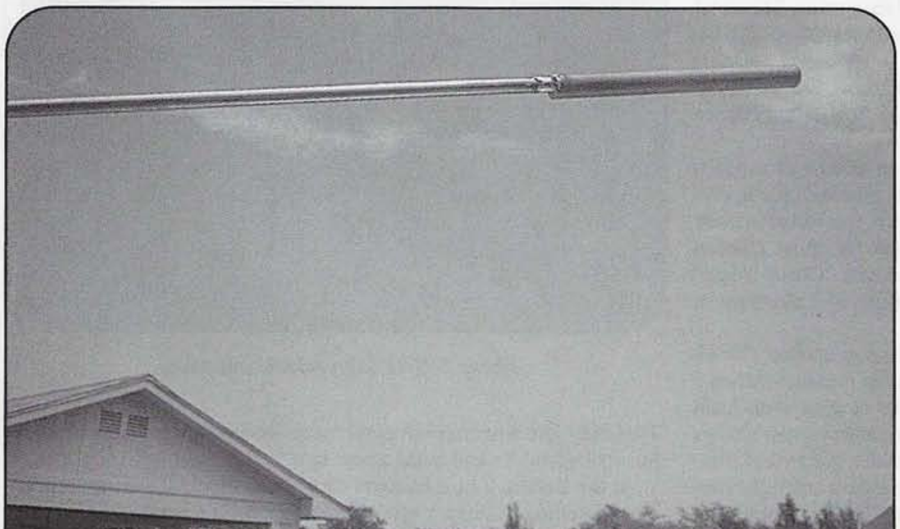


Photo 3. Small pieces of brass or copper hobby tubing slipped over the ends of the driven element can be moved during testing to find the best element length.

Number of Elements		Reflector	Driven Element	D1	D2	D3	D4
3	Length	40.5	*	36.5			
	Spacing	0	8.5	19.75			
4	Length	40.5	*	37.0	32.5		
	Spacing	0	8.5	19.0	40.0		
6	Length	40.5	*	37.0	36.0	36.0	32.25
	Spacing	0	7.5	16.25	33.5	51.0	69.0

**See figure 2 for details on the driven-element (DE) dimensions.*

Table 2. Dimensions for the FM-optimized "Cheap Yagi."

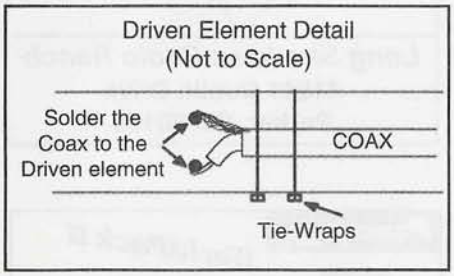


Figure 2. Attaching the coax to the driven element.

quick coat of spar varnish, clear spray paint, or even house paint will waterproof the boom.

The Driven Element

A good hard-drawn copper wire or hobby brass tubing can be used to build the driven element (photo 2 and figure 2). For this design I used silicon bronze welding rod. The welding rod is cheap, easy to solder, and stiff. If you look carefully, you will see where I used a few inches of hobby tubing to splice two shorter pieces of welding rod.

Computer programs just cannot model this driven element well. Therefore, the best dimensions are determined on the antenna range. The loop is about an inch wide, but the spacing is not critical.

Straightening the Coils

Gerald Williamson, K5GW, of Texas Towers, showed me the following trick for making coils of aluminum and copper wire straight and stiff.

Uncoil and cut off the amount of wire you think you are going to need, plus a foot or so. Put one end of the wire in a vise (or use a strong friend with a pair of pliers). Put the other end in a drill. Pull the wire so it is tight, with 20–30 pounds of force, and with the drill put about two turns per foot twist in the wire. The stress hardens the soft metal and makes it nice and straight!

Using Your Cheap Yagi

Build the antenna reasonably close to the dimensions, and the SWR will be less than 2 to 1. The low SWR is safe to use on the air without having to actually check it; 1.5 to 1 is a more typical SWR. You are welcome to tweak it. For my tweaking, I use a small section of copper or brass hobby tubing slipped over the end of the driven element. Slide it in and out, and then solder it at the best point (photo 3). The hobby tubing is also a quick fix if you trimmed the end a few too many times.

To see just how low I could go, I played with the driven-element design on my network analyzer, and I got it right down to the uncertainty in my directional coupler, about 42 dB return loss (RL). Return loss does not equate very well to SWR. However, a –42 dB return loss would be the equivalent of an SWR of less than 1.007 to 1.

Next Time

In the fall issue we are going to talk about log-periodic antennas. As always, I welcome your comments and suggestions for this column.

Reader Feedback

My article "Cheap 435-MHz AMSAT Antennas" published in the spring edition of *CQ VHF* generated over 50 responses. The most common comment was "I don't understand how that shorted-out driven element can work!"

Well, there are a lot of antennas that are a DC short. Examples are folded dipoles, J-poles, and even a Ringo Ranger. It is an impedance thing—take my word for it. It works just fine!

Three readers even ran the antennas through computer models. NEC-based programs have trouble modeling the driven element, giving some unusually low impedances. However, if you just substitute a regular dipole for the driven element and look for about 18-ohm impedance, you will get a good approximation of a "Cheap Yagi." NEC programs don't model the closely spaced parallel elements in the J driven element very well, however.

One of you even redesigned the antenna, and squeaked .32 dB more gain out of it. The tiny little detail is that all dimensions were to the nearest .0001 inch! Come on, guys, this is done with hand drills, wood, and ground rod wire! With Yagi antennas you are always making trade-offs among bandwidth, impedance, gain, and construction tolerance. With a variable impedance match and tight construction tolerances, it is possible to get another $^1/_2$ dB out of a Yagi of the same length, but it is not going to be cheap, nor easy to build.

An interesting comment was made by a backpacker. He says he just wads up the antennas and sticks them in his backpack. When he gets to the mountaintop, he kind of straightens the elements.

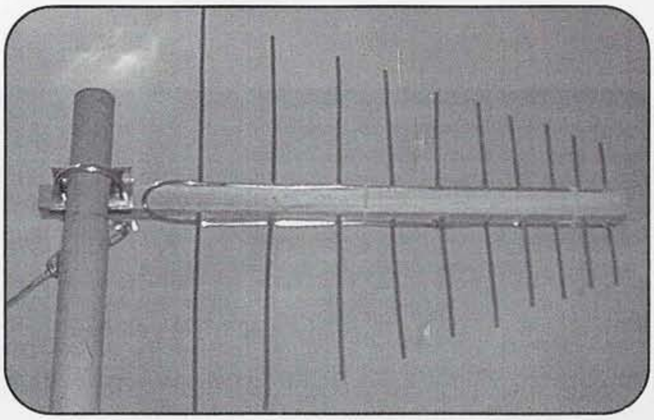


Photo 4. UHF log-periodic antennas.

Typically, the antennas are good for about ten straightenings before he must spend $3 and build a new one.

At the Belton, Texas hamfest earlier this year I saw an enterprising lad selling "Cheap Yagis" for $25 each. The most amazing part was that he actually sold at least one!

The strangest reader comment, however, was a request to develop a 692-MHz 72-ohm version. These "Cheap Yagis" are now being used by several Cubans to pick up UHF TV out of Florida!

By Tom Webb,* WA9AFM

SATELLITES

Artificially Propagating Signals Through Space

Now That I Can See It, What Do I Need to Talk to It? Earth to OSCAR—Over

When last we gathered here, our discussion was about software with the premise "You can't work 'em if you can't see 'em." Proceeding on the assumption that we all have selected a tracking program that fits our needs, we'll focus on what is needed in the shack to communicate via satellite. Again, when asked, "What does it take to get on satellite?" after suggesting a good tracking program, I'll ask what equipment you already have.

Most folks unknowingly already have gear in their shack/car/back pocket to work satellite; a multi-mode VHF/UHF mobile or base rig, a dual-band handheld, or one of the newer "DC to light" mobile transceivers can work the low earth orbit (LEO) satellites with ease. That old 10-meter multi-mode transceiver sitting in the corner of your "Turbo Belchfire 5000" HF/VHF/UHF base rig has a great potential as an intermediate frequency (IF) for a converter or transverter. Our discussion this time will cover the specific features you should be looking for in a satellite rig, the newest gear available, some oldie but goodie rigs that still hold their own, and a bit of history of some of the gear that led the way into the age of amateur satellites.

Photo 1. The ICOM IC-910H is the latest offering from ICOM for satellite work. The 910H is 2 meters/70 cm only with 1.2-GHz option. It replaces the IC-821H. The "set-and-forget" features are menu driven, with frequently used functions on the front panel. The small size and light weight are great for portable operation or limited desk space. (Photo courtesy RigPix, <www.rigpix.com>)

Features, Bells, and Whistles

In selecting equipment for satellite communications there are a few requisite features, and quite a few "bells and whistles" (nice to have, but not show stoppers).

First, and foremost, you will need VHF and UHF capability; a transceiver or transverter will do nicely, but let's focus on things all in one box. All-mode is best (FM, USB, and LSB), but if you plan to stay just with the LEO birds, FM will do just fine. For communicating with the high-orbit birds (AO-10 and AO-40), full duplex will be needed—i.e., hearing your own downlink signal. A transceiver specifically designed for satellite work will have this feature; a separate transmitter and receiver will also allow this if the manufacturer provides an optional interface. For the LEO birds, full duplex is nice, but you can work them without it.

Your rig will need a headphone plug, as hearing your own downlink signal could result in what we call in polite terms *audio coupling*—i.e., feedback. For transmit control, VOX is nice, but again, that is not required. The main advantage of having a VOX feature is it frees your hands for other activity. Variable power output is a real plus. The LEO birds can be accessed with just a few watts; the high-orbit birds require output in the 75–100 watt range.

The one feature almost exclusive to satellite equipment is *auto-tracking*. This feature allows the uplink and downlink frequencies to change simultaneously to compensate for Doppler shift. For high-orbit birds Doppler shift is relatively slow, and manual tracking works nicely, but auto-tracking is a great feature to have and makes operating a breeze. With FO-20 and 29, which use SSB, however, Doppler shift approaches the speed of light and auto-tracking is almost a must.

If you are going to use preamplifiers on the mast, converters, or transverters, a rig that supplies 12 VDC through the coax saves a lot of time, effort, and expense. With converters, be careful not to put a signal up the coax with the converter online. Some rigs put a very brief, but very lethal, burst of RF up the coax when first turned on. Get into the habit of switching unprotected converters and preamps offline after you finish operating or before powering up the rig.

The Latest Shiny, New Gear

If you are looking for the latest, greatest box packed with all the technology known to humankind, there are only three rigs currently on the commercial market specifically designed for amateur satellite work: the ICOM IC-910H, Kenwood TS-2000, and Yaesu FT-847.

ICOM IC-910H. The IC-910H (see photo 1), which graces your author's shack, is a follow-on to ICOM's IC-821H (more on the 821 later). The 910H arrives with 2 meters and 70 cm standard issue; there is an optional 1.2-GHz module also available. Choices of USB, LSB, FM, and CW are available, as are digital inputs. The 910H, as the "H" implies, has a high-power capability—up to 100 watts on 2 meters, 75 watts on 70 cm, and 10 watts

**10421 SE 55th, Oklahoma City, OK 73150*
e-mail: <tmwebb@ionet.net>

with the option 1.2-GHz module. On the low end of power output, 5 watts is the minimum on 2 meters and 70 cm, 1 watt on 1.2 GHz. Why ICOM didn't allow the power control to take the output to zero will remain one of the mysteries of the age.

Size is one of the big advantages with the 910H ($9^{1}/2$" wide by $3^{11}/16$" high by $9^{13}/32$" deep). To achieve this small package, there is no internal power supply—12 VDC from a 25-amp external supply, if you please. The 910H weighs in at a mere 10 pounds, so mobile and portable/ Rover activity is quite convenient.

A flip-down stand provides a good view of the large LCD screen, which improves ventilation. The cooling fan comes on whenever you transmit, which is a bit disconcerting at first, but it assures the operator that cooling air is always moving through the rig.

The 910H has separate connectors for 1200- and 9600-baud packet. A separate accessory socket also provides connectivity for digital communications. Two meters and 70 cm have their own antenna connectors.

For terrestrial/repeater work, each band has 99 regular memories, six scan memories, and one call frequency. For satellite communications, ten memories are available. There is a grand total of 212 memories! There is no feature to skip a memory channel during scan, but with a scanning speed of 20 channels/second at the high rate, and ten channels/second at the low, a skip feature would not be of much use.

A warning concerning the microphone connector: Voltage is present on the audio input pin to run electret microphones. If you plan to use a microphone that can be damaged by voltage, install a blocking capacitor!

The price for the IC-910H is hovering around $1200 at this time.

Kenwood TS-2000. Kenwood's most recent entry into the satellite arena (the TS-790A was their previous effort) is the TS-2000 (see photo 2). First introduced at the 2000 Dayton Hamvention®, the list of its features seemed to include every capability a ham could want: HF; 6-meter, 2-meter, 70-cm, 220-MHz receive (no transmit, go figure); an optional 1.2-GHz module; DSP filter; full duplex for satellite work; a built-in TNC; and a fist full of connectors on the back.

The TS-2000 comes in four versions: the "off the shelf" model; the standard model with a remote control head for mobile work (also known as RC-2000); or the TS-B2000, which has no front panel and uses the remote head exclusively. The fourth version, the TS-2000X, comes with the aforementioned 1.2-GHz module already installed. By the way, the 1.2-GHz module must be factory installed (no do-it-yourself), so if you have any thoughts of operating L mode (1.2-GHz uplink) or ATV, you might give serious thought to the "X" version from the get go, as the factory installation later is an additional $75 over the off-the-shelf price of the TS-2000X.

Power output is 100 watts (25 watts on AM—yes AM!) from 1.8 MHz to 148 MHz, 50 watts on 70 cm, and 10 watts on 1.2 GHz. As with the IC-910H, the minimum power is 5 watts, 1 watt on 1.2 GHz. As mentioned, the TS-2000 has a generous complement of antenna, accessory, and interface connectors on the back. The rarely seen "RX ANT" (i.e., receive-only antenna) is present for converters. The 2000 also has a unique feature for AO-40 operators using S mode (2.4-GHz downlink): The actual receive frequency (2.4 GHz), rather than the IF frequency, can be displayed. This feature goes all the way to 19.999 GHz!

Photo 2. If you want features, you have to have buttons, and the TS-2000 has lots of features to go with that front panel full of controls. With HF, 6 meters, 2 meters, 70 cm, a factory-installed 1.2-GHz option, DSP, and built-in TNC, it has just about everything a ham could want. (Photo courtesy Kenwood Communications)

The built-in TNC is intended for packet-cluster tuning and Kenwood's "Sky Command II+" feature. Sky Command would give the capability of remotely controlling the 2000 with a compatible HT. However, that function is not yet authorized by the FCC. The TS-2000 can be yours for around $1700, the TS-2000X around $2000.

Yaesu FT-847. The third satellite rig in our trio is the Yaesu FT-847 (photo 3). Yaesu made a bit of history when it introduced the 847. It was the first amateur transceiver to include HF, VHF, and UHF all in one package (before you IC-706 operators howl in protest, the original 706 only went to 2 meters; 70 cm came later). The 847 is a feature-packed unit with not only standard-issue HF capabilities, but with full-up satellite capability as well. Essentially, the 847 was the next-generation replacement for the much-loved FT-736 (more on the 736 in a bit). Yaesu underscored the flexibility of this unit by tagging it the "Earth Station."

The 847 gives you 100 watts from 160 through 6 meters and 50 watts on 2 meters and 70 cm. Like the TS-2000, it has AM capability with 25 watts output.

The rear panel sports four antenna connectors: HF, 6 meters, 2 meters, and 70 cm. Unfortunately, Yaesu didn't provide a 1.2-

Photo 3. The "Earth Station," as Yaesu calls the FT-847, was the first amateur radio transceiver to cover HF, 6 meters, 2 meters, and 70 cm. The 847 replaces the "satellite workhorse," the FT-736. The 847 is the only amateur radio transceiver to include the Alaskan emergency HF frequency. (Photo courtesy RigPix)

GHz option. It is likely that they presumed most L-mode fans would go with a mast-mounted transverter. There is no "receive only" antenna connector, but several 847 support pages on the internet provide a modification to add this handy feature. (The 847 enjoys a world-wide following, with several excellent internet support pages.)

The 847 is slightly larger than the IC-910H and about half again as heavy, but it still is a compact unit, occupying minimal desk space. You can change the background color of the large, easy-to-read dial to either blue or orange.

One feature not found on any other amateur transceiver except the 847 is its capability of operating on 5.1675 MHz (single channel only), the emergency communications frequency for Alaska. The one feature absent on the 847 is VOX. The official company statement is "Satellite operators don't use VOX, and since this is really a satellite radio, it isn't needed." The absence of VOX on the 847 has been the subject of spirited debate. If you really must have VOX, a third-party unit is available through International Radio, also known as InRad (http://www.qth.com/inrad/index.htm). In addition, InRad offers several filter options for the 847.

The FT-847 currently is priced at around $1300 after manufacturer/dealer incentives.

Oldies but Goodies

Yaesu FT-736. The FT-736 (photo 4) is the "Grande Dame" of satellite rigs. Introduced in 1987 as a replacement for the FT-726, it is a "plug-and-play" all-mode satellite rig. Its predecessor, the 726, released in the early 1980s, comes only with 2 meters as standard issue with two open slots for other bands. The 70-cm (There were two 70-cm boards, one for the lower half and one for the upper half of the band.), 6-meter, and the full-duplex boards are operator-installed options. The 726 has 10 watts output, no auto-tracking, and no VOX. Despite the lack of "bells and whistles," the 726 is a solid, basic satellite rig. However, the all-mode 736 has it all—right out of the box: 2 meters, 70 cm (full band), full duplex, 25 watts out, two open slots for additional bands, and an array of features usually found on upscale HF rigs. Owner-installed options include 6-meter, 220-MHz, 1.2-GHz, and HF boards.

The HF board is a little-known option. It covers 10 meters (for Modes A, KA, KT, and transverter duty), 15 meters, 12 meters, and (believe it or not) 11 meters! The HF board provides 10 watts out on all bands, and it is great for working QRP on 10, 12, and 15 meters. An external ATV adapter is also available.

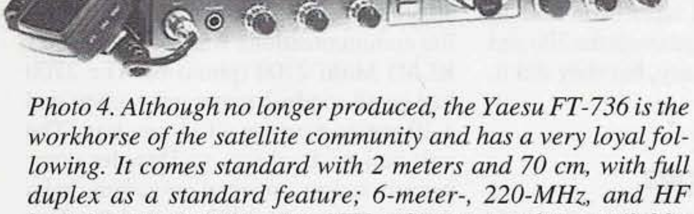


Photo 4. Although no longer produced, the Yaesu FT-736 is the workhorse of the satellite community and has a very loyal following. It comes standard with 2 meters and 70 cm, with full duplex as a standard feature; 6-meter-, 220-MHz, and HF boards are options. An ATV adapter is also available. (Photo courtesy RigPix)

Both the FT-726 and 736 have internal power supplies, but the units can be run on 12 VDC with adapter cables. Although no longer produced, the 736 is still considered the workhorse of the satellite, EME, and VHF/UHF community, and the rig has a very loyal following. Both rigs can still be found at hamfests, but don't expect to get a well-equipped 736 at a cheap price!

ICOM IC-821H. The IC-821H was the first of the compact, all-mode satellite rigs. Its predecessor, the IC-820H, was introduced in 1994. Although the 820H had excellent specs, it was badly flawed as a satellite rig. The ICOM folks revisited the design, and the IC-821H was the result.

The 821H has 2 meters and 70 cm, full duplex, and a collection of impressive features. To keep the unit small, an external 12 VDC is required. It provides 35 watts on 2 meters and 45 watts on 70 cm. Unlike the 910H, the 821H has no provision for additional bands—i.e., 1.2 GHz.

Operation is fairly intuitive with the "set-and-forget" functions on the menu, with frequently used functions on the front panel. For PacSat operators, the 821H has excellent characteristics at both 1200 and 9600 baud. One clever feature allows the operator to "spot" a frequency and tune away, and when you tune back over the "spot" frequency, the radio beeps at you. An ICOM unit just prior to the 820/821H was the IC-970—a respectable satellite rig from the technical standpoint, but big (*real big*) and very pricey. The 970 didn't remain in the ICOM stable long.

Photo 5. The Ten-Tec 2510B was produced in the early 1980s. The first edition, the 2510, had "operating" issues and was called back and redesigned, resulting in the 2510B. The unit was configured with a 2-meter/10-meter converter and 70-cm 10-watt transmitter. A PTO circuit allowed auto-tracking. It was a clever design for its day. (Photo courtesy Ten-Tec)

Ten-Tec 2510B. The 2510B (photo 5) was produced in the early 1980s. The first edition, the 2510 (like the IC820H), had "operating" issues and was called back for redesign, which resulted in the 2510B. The unit was configured with a 2- to 10-meter converter and 70-cm 10-watt transmitter. An external 10-meter receiver was required for downlink receive. To conduct communications, the 10-meter IF is first set to 29 MHz. Using the 2510B main tuning knob, find a downlink signal. Press the

Speaking of Single-Digit OSCARs… OSCAR 7 Returns from the Dead

In the main text of his column, WA9AFM reminisces about early satellite stations "way back when," when OSCARs—Orbiting Satellites Carrying Amateur Radio—had single digits. Well, much to everyone's amazement, one of those single-digit OSCARs has made a surprise return to the ham bands! Here's what was known at press time:

After a silence of some two decades, the AMSAT OSCAR-7 satellite returned to the air in mid-June, according to AMSAT and the ARRL. The satellite was launched in 1974 and operated for more than six years before going silent in 1981 after a battery failure. No one has any idea how long the satellite might remain active, and both organizations caution that certain contacts through AO-7 may not be strictly legal under today's rules.

According to the ARRL, Pat Gowan, G3IOR, was checking out some interlopers on the 2-meter amateur satellite sub-band when he heard a "*very* familiar" slow-speed CW beacon which he later determined to be OSCAR 7. Several satellite enthusiasts made contacts via AO-7 over Field Day weekend. AO-7 Project Manager Jan King, W3GEY, said he was "blown away" by the news and speculates that the satellite's batteries, which shorted as they failed 21 years ago, are now somehow "un-shorting" and putting the spacecraft back on the air. However, AMSAT officials say they are certain that the batteries are not actually storing power, but simply allowing the satellite to run off the solar panels whenever it is in sunlight, creating what King calls "a daytime only satellite." It now edges out AO-10 (launched in 1983) as the oldest functioning amateur satellite.

Legal Questions

The transponders on AO-7 are set up for both Mode A (2 meters up, 10 meters down) and Mode B (70 cm up, 2 meters down), and the mode that is activated appears to be strictly random. Changes in international radio rules over the past 30 years have removed the AO-7 Mode B uplink frequencies of 432.125–432.175 MHz from the range permitted for satellite uplinks, now allowed only in the 435-438 MHz subband. AMSAT reminds operators visiting its website that "Potential users should realize that when they are uplinking to a satellite, they are no longer operating in the Amateur Service but instead operating in the Amateur-Satellite Service." In addition, the ARRL notes that FCC rules require that space stations (satellites) be controllable from Earth, and it is not known yet whether that is possible *(Ed. note: AO-10 has been operating for years without any ability to control it from Earth, and no one has questioned the legality of AO-10 contacts on that basis.)*

The bottom line, according to King, is the amazing discovery that even "a cheap spacecraft built by a bunch of hams, without very many high reliability parts and without designing for a radiation dose like this, can last for 27+ years in space as far as a majority of its electronics is concerned."

If you have some of the equipment Tom discusses in his column, especially for Mode A (for which there are no real legal issues), download the latest Keplerian Elements for AO-7 or check the AMSAT website (www.amsat.org), and make some "old-time satellite" contacts before this one goes away again!

AO-7 Frequencies

Mode A: Uplink 145.850–145-950 MHz; Downlink 29.400–29.500 MHz

Mode B: Uplink 432.125–432.175 MHz (use of these frequencies may be illegal; see notes above); Downlink 145.920–145.980 MHz

Beacons: 29.500, 145.700 MHz, 435.100 MHz (Additional beacon on 2304.1 MHz was never activated.)

"Spot" button (which produces a steady CW signal), adjust the 10-meter IF until you hear your own downlink signal, and then release the button. You are now in an auto-tracking mode with a PTO circuit doing all the work (a clever design for its day).

Unfortunately, the recall and redesign delayed the 2510B from reentering the market, and newer feature-packed satellite-oriented equipment captured the satellite community's attention. At Ham Com in Dallas this year I suggested to the Ten-Tec folks that they revisit the 2510B with the thought toward optimizing it as an "S" Mode rig; we'll see what the future brings.

But What About…

What about using the IC-706MKIIG, FT-100D, FT-817, dual-band HTs/mobile rigs for satellite communications? Well, yes and no. For the LEO satellites on FM (ISS, UO-14 and AO-27) they will do a good job. Although not full duplex on Mode J (2-meter uplink, 70-cm downlink), by using a single-channel uplink (2 meters) and tuning for best downlink signal (70 cm), mobile/portable satellite communications is easily accomplished.

It is possible to work one of the LEOs using a regular mobile antenna. However, for portable work many folks use the famous "Arrow Dual-band Antenna" (more on that another time). Regardless of which rig you might use for LEO communications, keep the power low; 5 watts often will be quite enough.

As mentioned, without full duplex (being able to hear your own downlink signal), adjusting for Doppler is very difficult for working the likes of AO-10 (yes, it's still working) or AO-40. Having said that, some folks have been able to work the high-orbit birds with the 706 and FT-100D. It wasn't easy, but they did it.

When OSCAR was Single Digits

OSCAR 3, launched in March 1965, was the first amateur satellite that was actually used for amateur communication, with 2 meters for uplink and downlink. OSCAR 4 used a 2-meter uplink and 70-cm downlink, the first Mode J configuration. In the early days, bird chasers had to cobble together stations, as no dedicated satellite equipment was on the market and the available equipment was really suited to space communications. As birds were launched, Mode A quickly became the dominant mode, 2-meter uplink and 10-meter downlink. Most folks used some form of CW transmitter, as 2-meter SSB rigs were few and far between (and rather pricey). By using any SSB HF rig, the 10-meter downlink was easy.

What could be called the first piece of amateur radio equipment built for satellite communications was the FDK (later KLM) Multi-2700 (photo 6). The 2700 had an all-mode 2-meter transceiver and a 10-meter receiver all in one box. The unit had no tracking, so Doppler compensation was a manual operation. In its day, however, the 2700 opened the door to equipment specifically designed for

Photo 6. The FDK (later KLM) Multi-2700 was the first amateur radio transceiver designed with satellite communications in mind. It's a 2-meter all-mode transceiver and 10-meter receiver all in one box. Although there was no interface between the 2-meter and 10-meter units, the single-container design led the way to the satellite rigs we enjoy today. (Photo courtesy RigPix)

satellite communications. The 2700 is a rare item nowadays. You might find one sitting on a table at a hamfest, though. Don't overlook the 2700 as a backup rig or even as an IF rig.

Other early pieces of equipment were the ICOM/Yaesu/Kenwood "twins"—i.e., the single-band, all-mode rigs on VHF or UHF.

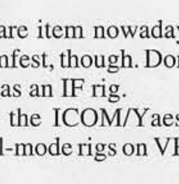
ICOM had a neat series of "mini" rigs which were *very* basic. They were in a vertical format and had internal battery capability and a built-in or external antenna. The IC-202S was the 2-meter version; the IC-402 was for 70 cm. Also, there was a 6-meter model, the IC-502. ICOM has had a long history of "twin" rigs. One accessory, the CT-16, permits some of the ICOM "twin" series to track for Doppler compensation.

Yaesu had several "twins." One pair was designated the FT-480R for 2 meters and the FT-780R for 70 cm. They had 10 watts output and a clever desk-mount console, which allowed for a common microphone. Yaesu also produced two great "back-packing" rigs, the FT-290MKII for 2 meters and the 790MKII for 70 cm. Again, no tracking was available, but they had "snap-on" 25-watt amps, internal battery supply, and pretty decent specs. For Rover/mountaintop work and satellite communications they are a dandy combination.

Kenwood has offered several single-band VHF and UHF all-mode mobile rigs with similar capabilities, including the TR-751 for 2 meters and the TR-851 for 70 cm. Kenwood seemed to favor the base-rig market with the likes of the 2-meter TS-811 and the 70-cm TS-711. Keep an eye out for some of the older single-band gear, which is still quite usable for satellite work, especially as an IF for transverters.

One More Time

At the risk of repeating myself (Okay, I'm repeating myself, as I said this in my first column.), get a copy of *The Radio Amateur's Satellite Handbook* by Martin Davidoff, K2UBC. This is the "bible" of amateur satellite communications. Published by the American Radio Relay League, it's available for $25 through a variety of amateur-radio supply houses, from the ARRL, or from AMSAT Headquarters (850 Sligo Avenue, Suite 600, Silver Spring, MD 20910-4703; telephone 301-589-6062).



By Gary Pearce,* KN4AQ

FM

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

Utility Mode?

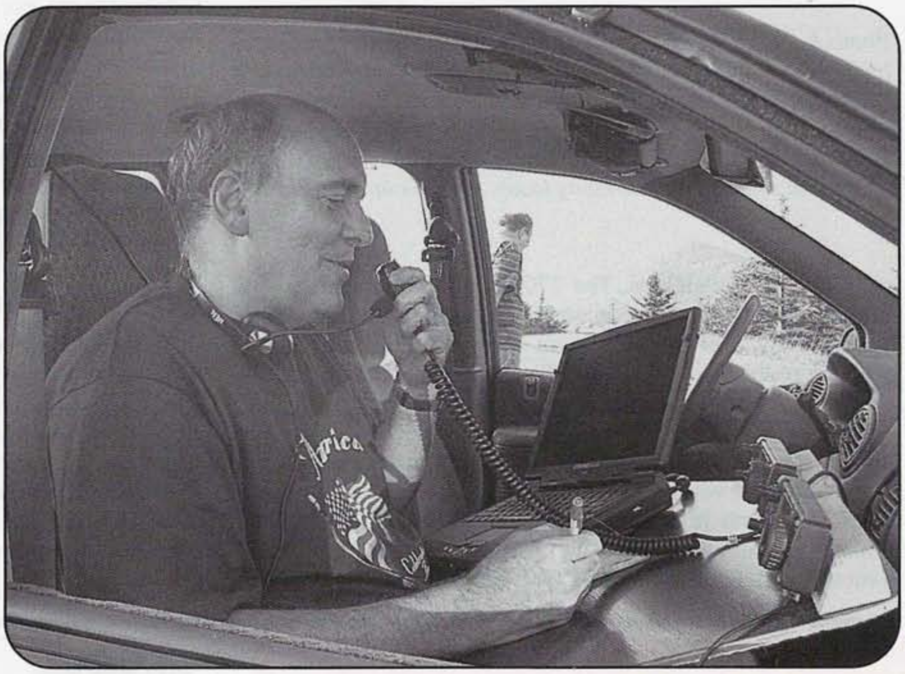
It is great to see *CQ VHF* back in publication. I subscribed to the magazine, starting with the original edition in January 1996, and I was sorry to see it go. Thanks to Joe Lynch, N6CL; Rich Moseson, W2VU; Dick Ross, K2MGA; the advertisers; and you, the readers, for bringing it back! The spring issue looked terrific. I am honored to be among such prominent people in amateur radio. Now what's this about "Utility Mode" at the top of this month's column?

As the spring issue of *CQ VHF* was preparing to launch, Joe, N6CL, sent me an e-mail asking what "tag line" I wanted up at the top of my column, as all the regular columns have them. I thought, "'FM, the Fun Mode' has certainly been beaten to death." Besides, aren't all amateur radio modes fun modes? What mode do you operate just for the pain and frustration of it? Okay, there's DX, meteor-scatter, HF traffic nets, moonbounce, CW, QRP, weak-signal VHF-UHF, microwaves, contests, and a slew of digital modes. Most of ham radio is fun!

Now that we've narrowed down the audience, let's get back to the question. What could I say "different" about FM and repeaters? I'm normally a rather creative guy, although my high school English teachers (what, all nine of them?) might beg to differ. Deadline loomed, and nothing was coming to me.

Earlier this year I wrote an editorial for the SERA *Repeater Journal* that led to the idea. The editorial was in praise of outgoing editor Wayne Williams, K4MOB (now a Silent Key). Wayne had been editing the *Repeater Journal* for 23 of its 26 years of continuous publication. Without doing any research or really giving the idea much serious thought, I wrote that the *Repeater Journal* was the only FM-oriented magazine, or column, to survive over the years. I noted that *QST* had dropped the FM/Repeater column years ago, and even *CQ VHF* had gone out of production.

*116 Waterfall Court, Cary, NC 27513
e-mail: <kn4aq@arrl.net>



Jim (Coz) Cosby, WA3RQD, operating with Will Pope, N3WP, as N3WP/Rover. The pair traveled from Philadelphia, PA to Mt. Mitchell, NC (6684 feet high, the highest peak east of the Mississippi). You can drive right up to the parking lot on the summit of Mt. Mitchell. The mountain sits on the eastern edge of the Smokies and offers an unobstructed view in a wide arc from northeast to southwest. During their trek they operated on 50, 144, 220 (FM), and 432 MHz.

Of course, *CQ* Editor Rich Moseson announced that *CQ VHF* was going back into production just as I sent that edition of the *Repeater Journal* to the printer. I also had completely forgotten about Bill Pasternack, WA6ITF, and his columns in *WorldRadio* (and before that, in *73 Magazine*). Bill has single-handedly kept FM and repeater journalism alive continuously at the national level since the early 1970s. He credits *73* Editor Wayne Green, W2NSD, as being one of the few to recognize the rise of FM, giving the mode significant publication space in its early years.

While all that is very nice, the fact remained that there was something wrong in FM-land. Almost all active hams have an FM rig around somewhere, whether it is an HT hanging from their belt, a mobile under the dash, or a rig at home collecting some dust at the corner of the operating desk. Two-meter FM is said to be the most popular amateur band/mode by far. However, this practically universal mode of operation has been unable to sustain much in the way of publication.

I did some research, which opened my eyes. The several hundred-thousand hams who operate FM and repeaters are not a "market." They do buy radios, but as a group they do not join organizations, nor do they subscribe to magazines. My findings are especially true among the subset of those hams who operate *only* FM and repeaters (the "shack-on-the-belt" ham, as some hams refer to them). This population would be most of the huge number of code-free Techs licensed since 1992.

The original *CQ VHF* was designed to appeal to those hams (and to introduce them to the other VHF modes for which their Tech license qualified them). They did not, however, "bite" in large numbers. They did not join the ARRL, despite the League's going to bat for them in support of the code-free Tech. Here in the southeast, they do not support the SERA *Repeater Journal,* a regional magazine that is purely about FM/repeaters, in anywhere near the numbers one might expect.

My Narrow Perception?

I have been a ham since 1965 (age 15). Today I have an Extra class license, and I operate some HF (mostly SSB and digital, with CW limited to occasional bouts at Field Day). Since my beginning days as a Novice with a Heathkit Twoer, I have been a VHFer. I went through the 2- and 6-meter AM days with a Heath Seneca and Utica 650; then SSB with a Gonset Sidewinder and Hallicrafters HA-2 transverter. What really flipped my switch as in my early days of ham radio was an old, single-channel Motorola 80D on 146.94-MHz simplex installed in the car of a teenage friend's father.

For you newer hams, this is an exercise in nostalgia, which I do not have space here to explain, although I wish I could. I *will* note that the Motorola 80D was an FM radio, which began life in a police car or a taxicab somewhere. The Motorola 80D was a huge, heavy all-tube radio which sat in the trunk and improved traction on the ice. Below the dash was a control head with volume, squelch, microphone, and speaker.

Why this radio and the many that followed appealed to me more than anything else, I can't explain. Maybe it was the "police" radio aspect; maybe it's because it was similar to the CB radios I'd used before I became a ham (back in the clean days when CBers used callsigns, real names, and decent language). Certainly it had something to do with local communications. I liked talking with the guys around town much better than talking with someone I did not know in New York, California, or around the world. I liked the idea of a bunch of hams all clustered on a single frequency, and for me, exotic DX was talking to someone 300 miles away on 2 meters.

It wasn't long before I learned about repeaters (all four of them in the Chicago area at the time), which enhanced the FM experience immeasurably. My interest in VHF SSB waned. I had attended some of the early Central States VHF Conferences in the late 1960s, but I never felt quite at home there. Putting up a multi-element array and building a VHF kilowatt seemed beyond my means and interests. Getting involved in a local repeater group felt comfortable; this was someplace where I could really participate, and I gobbled up all the available literature.

It started with copies of a small newsletter out of California called "The Chronicles of 76." This was just a local effort to document and make fun of the hams who put up repeaters and remote base radios around Los Angles. Then there was WA6ITF's "Looking West" column and the other articles in *73*. Also, there was a short-lived publication called *FM Magazine* out of Michigan. Later there was the FM/repeater column in *QST*, as well as the ARRL's old *FM and Repeater* manual.

While my field of view in amateur radio covered the whole spectrum, so to speak, the sharp, clear center was VHF FM. I was on the leading edge of a serious boom in a new mode of operating, which was all very exciting. Then . . .

Just Another Mode

While I wasn't looking, FM became just another mode, or at least that's the consensus I got from some of the guys who have been doing amateur radio publishing a lot longer than I have. In the 1950s SSB was an up-and-coming mode, and the magazines had columns devoted to it—how to use it and who was on it. You wouldn't think of devoting a column to SSB today, would you? Maybe AM?

Some columns devoted to sub-sets of amateur radio have lasted for decades. VHF/UHF is one. That's the weak-signal side of VHF, not the FM side. Digital modes go through enough reincarnations to maintain interest. DX, contesting, QRP are holding their own, but not FM/repeaters? *QST* Editor Steve Ford, WB8IMY, suggested a reason, which gave me the idea for this column's "Utility Mode" tag line. He said, "Our research has shown that while FM users comprise a very large portion of the amateur community, the majority tend to perceive their FM activity more as a 'utility' function rather than a hobby." He added that FM operation is local. If you don't live in Seattle, you wouldn't be very interested in a new repeater on the air there, would you?

I shouldn't have been surprised. I've often felt that the people who build and maintain repeaters are unappreciated by most of the people who use the repeaters. The repeater is just a public utility, like the power company or the phone company—a hole in the band that makes signals go farther.

Now that I've thoroughly beaten myself down, let's see if I can get back up again and stand tall!

While the vast FM-user community may not feel much like a community at all, there is at least a half-vast community of hams who build repeaters, run repeater clubs, do band planning and coordination, and generally focus on FM. There always seems to be a new crop of hams coming along who are trying to learn the ins and outs of repeaters. Now and then, there is something really new, such as the IRLP. Maybe even some of those shack-on-the-belt users are interested in what makes this utility mode tick, which is one kind of ham that the new *CQ VHF* is designed to reach, and that's where this column will be pointed. I think that there are many aspects of FM that make it unique, such as things that hams who build and operate in the FM universe will enjoy reading and writing about.

Help Wanted—and I'm going to need a little help here. Some of the articles ought to be fairly technical, and I am not an engineer. Everything I learned about repeaters and technology came through ham radio, mostly learned at the elbows of hams who really know their stuff. In his spring issue editorial, Joe, N6CL, said, "Each one of us has a story," and he asked readers to share theirs by writing articles for the magazine. I'll ask the same thing. Think of something you know, something that other FM-oriented hams might find interesting, and drop me a line at <kn4aq@arrl.net>.

I was discussing this column with a friend I rely on for technical advice, and he said, "How many ways can you write an article on how to tune a duplexer or modify a MASTER II?" Well, let's find out. I might even get creative enough to come up with a better tag line for the beginning of the column!

Thinking Thin

They say one can't be too rich or too thin, but one can be too narrow! Several of the new FM rigs on the market, for example the Kenwood TH-F6, include a "Narrow" mode. If you've been around the block more than once, you've been calling the 5-kHz FM deviation we run today "Narrow Band FM," or NBFM. If you've stumbled across this setting on the radio (and didn't read the manual), you might have said, "Well, this must be the setting I need" and punched whatever button it took to lock it in.

BZZZZZ! Wrong answer, but thanks for playing the game. Pick up your parting gifts on the way out of the studio.

It's time to recalibrate your vocabulary and check your radio's settings. The rules of the game have changed.

Back before the turn of the century, the FCC launched a campaign to create more channels for commercial and public-safety radio. Since there are "slim pickins" on the spectrum tree, the other way to create more channels is to make the ones we have skinnier. Take advantage of advances in technology that allow us to reduce deviation, improve stability, roll off the higher audio frequencies, process the audio a bit, and tighten the receiver filters, and *voilà!*—a mode that used to gobble up 16 to 20 kHz of spectrum now uses only 11, allowing us to squeeze in a new channel between each old one. Your new standard: 2.5-kHz deviation, a tighter maximum of 3 kHz for the highest audio frequency, and 12.5-kHz channel steps. The price—obsolescing all the current radios and making everyone buy new ones.

To the old timers, this is *déjà vu* all over again. That's exactly what started the amateur radio FM boom back in the 1970s. In the 1960s, to make more commercial and public-safety radio channels, the FCC cut the deviation from 15-kHz "wideband" to 5-kHz "narrowband," and doubled the channels by cutting the channel width in half. Overnight, millions of expensive FM radios were traded in. Some of the economic sting was reduced by the fact that the solid-state revolution was getting underway. Companies and police departments were trading in those big, heavy tube rigs for—well, not quite as big, but still pretty heavy transistor jobs.

Pre-Boom

Where did the old radios go? A lot of them went to the crusher (makes you want to cry), but enough of them found their way into ham radio for almost free. Suddenly there was a boomlet in FM and repeater operation, which wasn't *the* boom, just a little pre-boom that set the stage for the big boom a few years later, after a bunch of repeaters had been built. The ham channels filled up quickly, and hams had to adopt the 5-kHz bandwidth to make more channels. The sting of making all those radios obsolete was soothed by the fact the original radios were dirt cheap big, clunky, tube boat anchors, and that ICOM, Yaesu, Kenwood, and a few other Asian and American manufacturers started turning out small, solid-state rigs designed for the ham market. Might as well make them narrow band. Then the big boom of the early 1970s got underway.

As I said, time to recalibrate your vocabulary. That old "wide-band FM" is ancient history. Five-kHz deviation FM, the bandwidth we all use today, is now "wide," and the new 2.5-kHz standard is "narrow." The FCC has had to back off its timetable for total implementation of the new standard in the commercial world. Current users can stay "wide" for a while, but all newly created services are required to adopt the narrow mode. The Family Radio Service is one of the first examples. New services in the 220-MHz and 700-MHz areas will all be narrow, too. To be FCC certified, new commercial radios will have to be "narrow-ready," although they can be wide-compatible dual-mode.

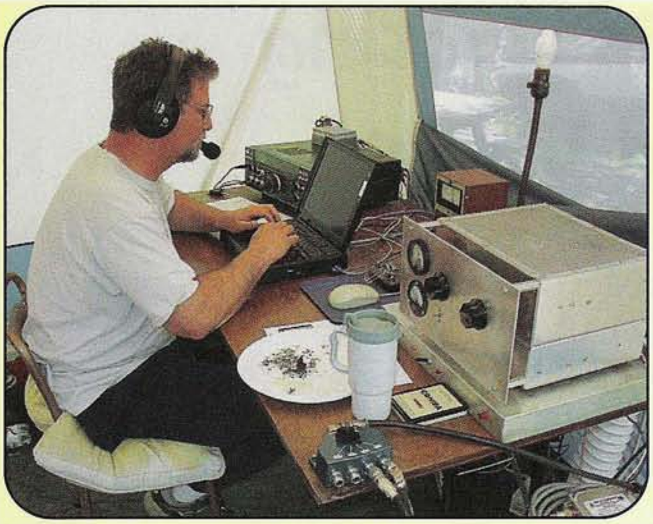
As long as the manufacturers had to build the narrow stuff for the business band, they started incorporating it in their ham equipment too, as a second mode. It sort of future-proofs the radio. Should ham radio ever adopt the new narrow channels, the radios with the narrow mode built in would still be usable.

Will ham radio go narrow? Perhaps. The 2-meter band is "full" in most metropolitan areas (and even most rural areas) of the country, and hams still want to put on more 2-meter repeaters. Most areas, except California, have room on 220 and 440 for a few more repeaters, but that's going fast. Ham radio has a mammoth "installed base" of 5-kHz FM radios, and there will be tremendous resistance to replacing them. We buy them ourselves; there are no corporate profits or municipal taxes to draw on for radio budgets. I suspect it will take a more sweeping change, such as a move to all-digital radios with really tiny RF footprints, to pry the 5-kHz radios from our cold, dead fingers (Sorry, I got carried away there.). The FCC is looking at digital for the business boys in 10 to 15 years. Place your bets.

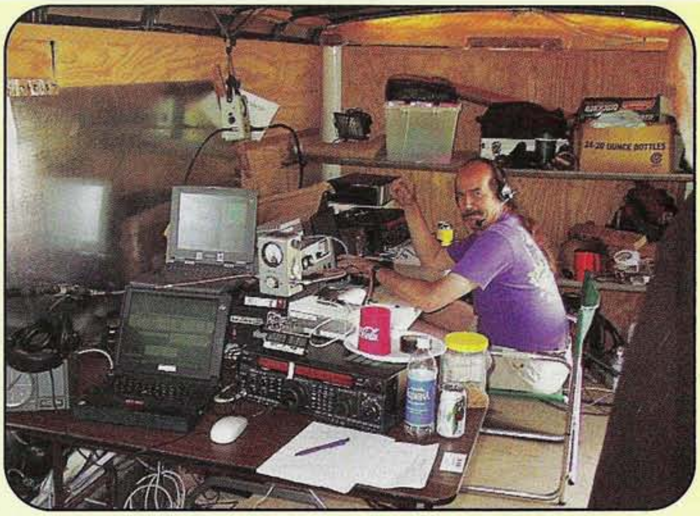
Oh, I almost forgot. What happens if you select the "narrow" mode in a current radio when everyone else is "wide"? Your transmit audio will sound low and a little muddy—low because you'll be down at least 3 dB from the widebanders, and muddy because while we say our audio is tailored for 300 to 3000 Hz now, our radios really have a gentle rolloff at 3000, and there is plenty of energy above that frequency. The new standard sets 3000 Hz as a brick wall, and there is nothing above it. The pre-emphasis/de-emphasis is handled differently (that sounds like meat for another column). If your radio switches in narrow IF filters, too, your squelch might chop closed on voice peaks. Some of the new radios do; some don't.

Now don't get me started on audio quality of current FM operations. There's an epidemic of low audio out there already,

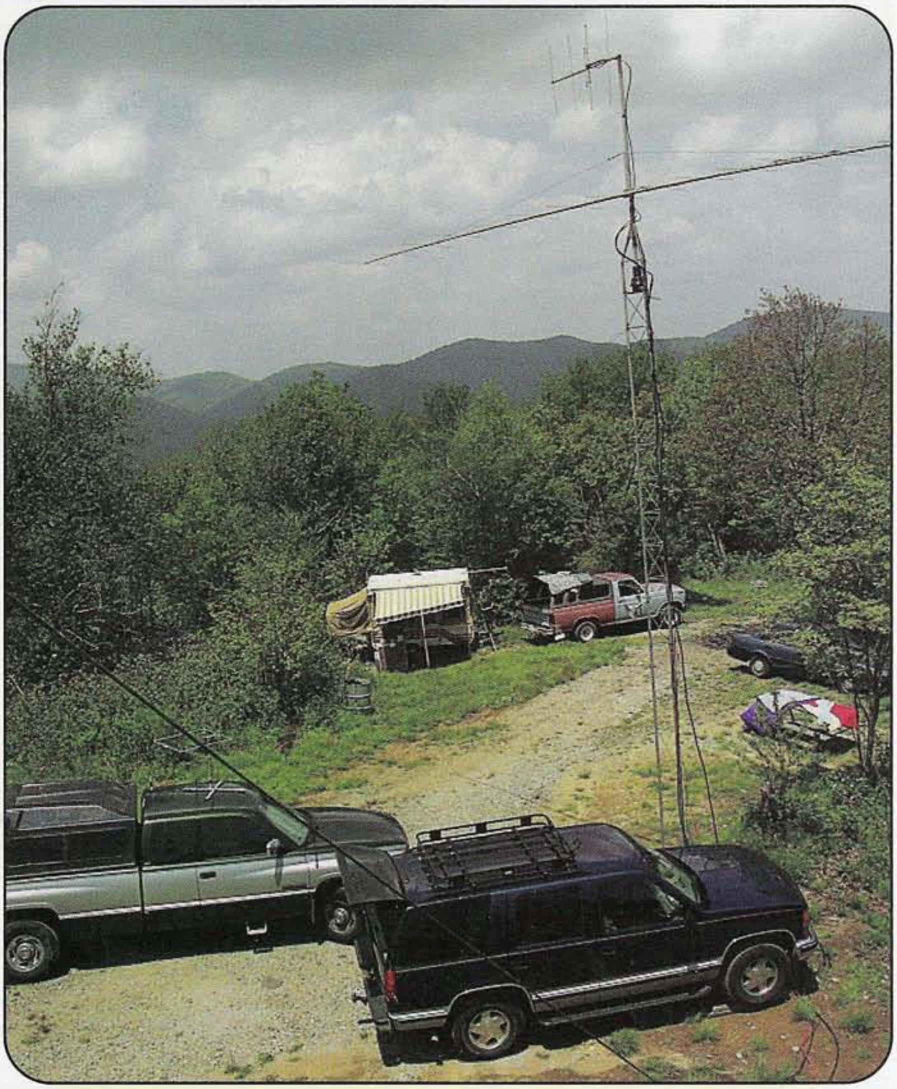
The Kenwood TH-F6 in the FM narrow mode.



Neal Sulmeyer, K4EA, one of the Fourlanders who was also on in the contest.



Paul Yeager, W4SKI, one of the operators of the Fourlanders VHF/UHF Contest Team (W4NH) who operated in a recent contest from the Mile High Campground off the Blue Ridge Parkway near Cherokee, North Carolina.



The 2-meter beam used by the Fourlanders Contest Team.

and few rigs have microphone gain controls to correct problems easily. If everyone is telling you your audio is low and muddy, check your manual. You may just be narrow.

More Help Wanted

The word I'm getting is that repeater owners are having a harder and harder time finding good tower space at affordable rates (or free). As tower management and ownership is transferred to the hands of professional management companies, some ham repeaters are even being kicked off towers they have long called home, unless they can come up with full commercial rates (hundreds of dollars a month, or more! Rule of thumb: \$1/foot of HAAT/month). Ham radio public-service value? Sorry, we have a business to run.

If you run a repeater on a commercial tower, tall building, or mountaintop, I would like to hear from you, whether you have a good relationship going or whether you have had trouble. In the next column we'll paint a portrait of the tower scene for ham repeaters. I know that this subject can be a sensitive one for many repeater owners, so I will keep most of the published details general, and your information will be confidential, unless you have a story that can be published. That number to dial is, as always, my e-mail address at the beginning of the column. See you in the fall!

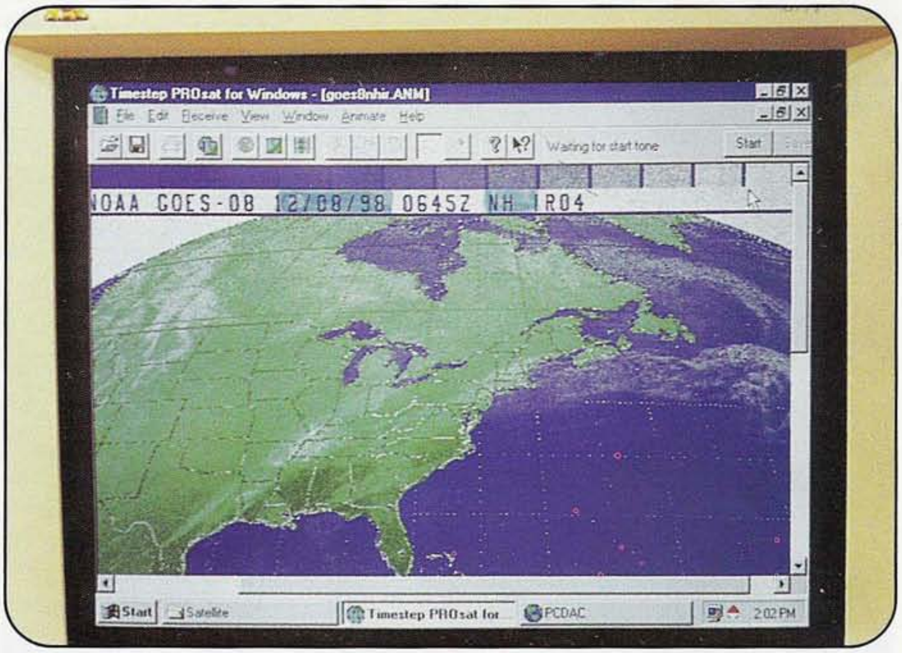
Tropospheric Ducting Myths and Truths

Three well-defined, stable, high-pressure systems form every summer, providing weak-signal operators the excitement of VHF and UHF voice contacts over 1000 miles away. WB6NOA interviews some experts who blast the myths and know the truths about this atmospheric phenomenon, which hits the bands from July through September.

By Gordon West,* WB6NOA

Weak-signal VHF and UHF operators always look forward to summertime band openings when their signals will travel hundreds and even thousands of miles through the troposphere in the presence of a stable high-pressure system or an approaching storm front. Weak-signal operators may establish wide-open band conditions by using single sideband first, by CW, and by PSK 31. Once the duct has formed, other modes of operation—including FM, slow-scan television, APRS, and 6-MHz-wide amateur fast-scan television—may continue to span 1000 miles and farther.

In an effort to get the "straight scoop" on these openings, I interviewed several of the regulars on the VHF+ ham bands. Adding my own observations and investigations to their views, what follows is our effort to confirm the facts and dispel the myths of the whys and wherefores of these band openings.



This big East Coast high put Florida into Nova Scotia at S9 on 2 meters.

***Fact:* Tropo ducting depends on the weather.**

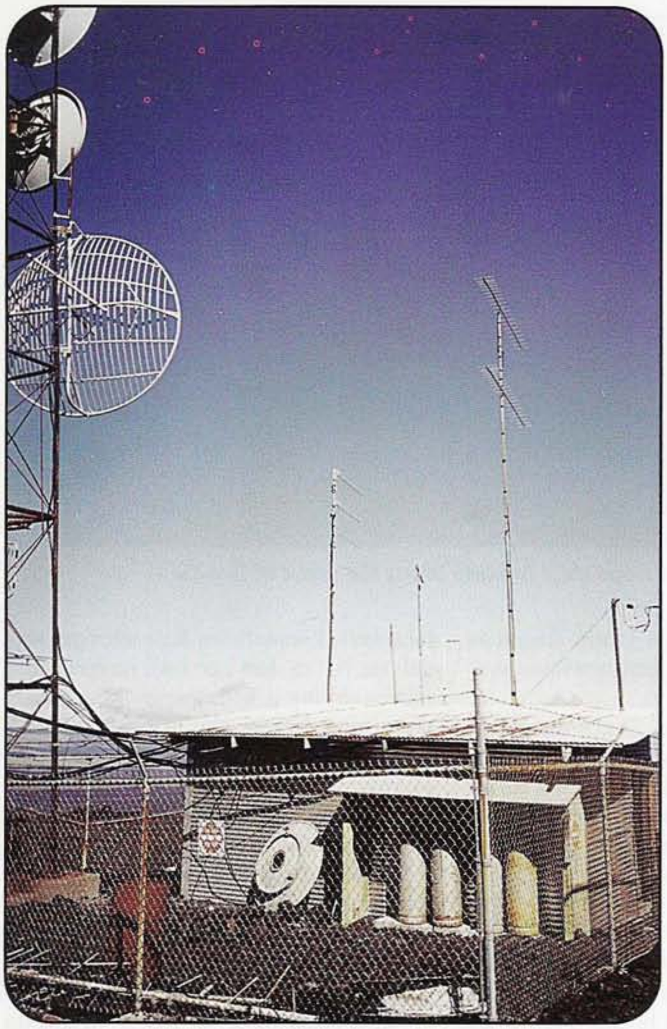
Absolutely correct! Abnormal weather conditions will lead to a stratification of layers within our atmosphere, up to 10,000 feet. This is the troposphere. Temperature, air pressure, and water-vapor content all decrease in normal weather. Air pressure decreases with altitude in an approximate logarithmic manner, about 1 millibar for every 10 meters of altitude. Temperature decreases 20 degrees Fahrenheit for every mile of altitude, up to 40,000 feet. Water-vapor content decreases with altitude as well.

The "normal" radio-wave refraction is approximately 1.000345, leading to VHF/UHF range nomographs which illustrate typical "line of sight" expected ranges at 4/3 of the geometric horizon. This is where our "20 percent beyond line of sight" statements come in when teaching new hams about how far they might expect to work through a local repeater.

Summertime, however, brings *abnormal* weather patterns to North America (as well as south of the Equator), and these weather patterns begin as huge thunderstorms. These thunderstorms begin to brew in the zone of convergence at the zero degree Equator. The warm rising air invisibly travels northbound, and between 30 degrees north latitude to 45 degrees north latitude it develops into a high-pressure stationary cell. These high-pressure cells slowly rotate clockwise (anti-cyclone) and begin to become much heavier than the air below, creating subsidence.

As this cell of high pressure begins to drop because of its compressed weight, it may bottom out around a mile above the ocean or flat earth terrain and develop into a visual layer, which weather persons refer to as an *inversion layer*. It's

*CQ VHF *Features Editor, 2414 College Dr., Costa Mesa, CA 92626*
e-mail: <wb6noa@cq-vhf.com>



The tropo tin shack and beacon tower of Paul Lieb, KH6HME, is up 8200 feet on the side of a volcano in Hawaii. From this location Paul beams signals to the mainland West Coast.

easy to see when you step outside—just look for that sharp boundary between brown air and blue air! Also look for the specific altitude where rising smoke mysteriously flattens out over the horizon.

The inversion layer will usually trap pollutants within it, and with very little surface wind, you can predict another lousy day in "Smogville." However, it's going to be a great day for VHF/UHF weak-signal operators!

The three most pronounced, stable, high-pressure systems that always appear in July and August are the California/ Hawaii high, the Bermuda high, and the Texas/Tampa high. You might find as many as three additional smaller, stationary high-pressure cells over the United States, too, triggering the summertime, high-pressure, tropospheric duct.

Myth: **There is no correlation between tropical disturbances and hurricanes forming south of the established tropospheric ducting conditions.**

One well-known and well-respected VHF/UHF columnist claims that there is no correlation between tropical disturbances and hurricanes forming south of the established tropospheric ducting conditions. However, Robert Cook, W6PGA, performed a 20-year study of the California/Hawaii tropospheric duct and the greatest occurrence of this duct plus the incidences of other North American ducts occurring from July 10 to September 22. Analysis of these detailed records, as well as records maintained by Paul Lieb, KH6HME, and this author *absolutely disagree* with the above-unnamed columnist. A hurricane or tropical depression almost *always* leads to *enormous* VHF, UHF, and microwave tropospheric ducting conditions.

Fact: **Careful analysis of weather charts may clearly predict the formation of tropospheric ducting conditions.**

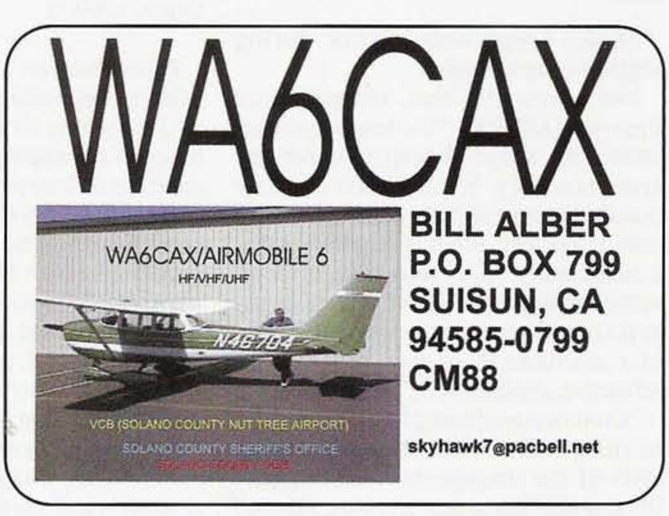
Look for a stable, high-pressure system with a minimum of 1020 millibars of air pressure and wait for the 1020 isobar to fall over your area and coincide with another station hundreds or sometimes thousands of miles away.

"The figure of 1020 millibars is my magic number for most long-haul tropo ducting band openings," reports Bill Alber, WA6CAX, detailing his logbook and aeronautical weather reports when he worked band openings from Texas to Tampa, and from Miami to Nova Scotia. Bill is also a summertime "regular" working San Francisco to Hawaii.

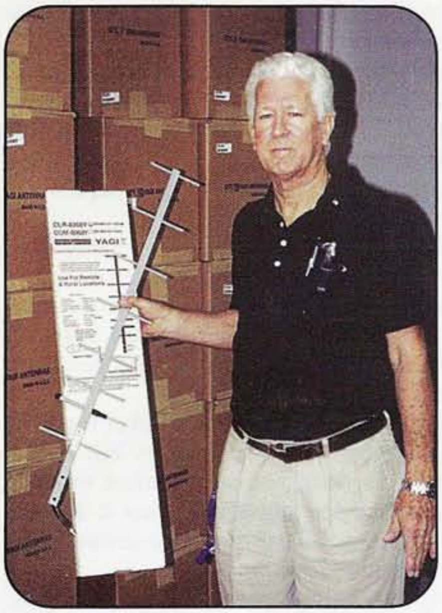
If you have an HF rig and your computer plugged into it with a simple weather facsimile program, tune into the five-times-a-day weather facsimile broadcasts detailing pressure isobars:

California/Hawaii
4344.1 kHz upper sideband
8680.1 kHz upper sideband

An ATV signal on 426.250 MHz over a 2500 mile path.



The tropo mobile station of Bill Alber, WA6CAX.



Tom Glaze, K4SUS, shows off his 900 MHz mini-tropo beam.

A good tropo duct forming along the coast of Hawaii.

12728.1 kHz upper sideband
17149.3 kHz upper sideband
9980.6 kHz upper sideband
16133.1 kHz upper sideband

Texas to Florida
4316.0 kHz upper sideband
8502.0 kHz upper sideband
12788.0 kHz upper sideband

East Coast corridor including Atlantic to Europe
6338.6 kHz upper sideband
9108.1 kHz upper sideband
12748.1 kHz upper sideband
10534.1 kHz upper sideband
13508.1 kHz upper sideband

North America (as reported by N7STU)
<www.iprimus.ca/~hepburnw/tropo.html>

***Myth:* Tropo only occurs during high-pressure events.**

Not necessarily true, reports Bruce Eggers, WA9NEW. "The term *tropo duct* creates the image of both an upper and lower boundary. While such is certainly possible, it is neither hardly required nor usually present. What is required is that a sufficiently super-refractive layer of sufficient depth lies above a layer of air, again of sufficient depth, with something of a near-normal, or even slightly sub-refractive, gradient of N," reports Eggers.

"Common are frontal layers and early-morning radiational cooling of the lower layer of the atmosphere," adds Eggers, illustrating that many exciting ducting events have occurred along sharp approaching, widespread storm fronts as opposed to only with high-pressure systems overhead.

Many central United States weak-signal operators wholeheartedly agree that VHF and UHF signals may scoot along the side of a major storm front just as easily as bouncing around overhead within a temperature inversion.

***Myth:* Only CW or SSB can do tropo.**

When a tropospheric duct forms, certainly the very first trace of a distant CW beacon is only heard in the CW mode. Once the path begins to build to beyond S-5, SSB communications will easily work over the path.

"At signal strengths of S-9 and higher—very common in a good tropo ducting event—almost any type of wide-band modes will propagate," comments well-known "magic band" VHF expert Tom Glaze, K4SUS.

***Disagreement:* Signals are weaker on higher frequencies.**

"I have been monitoring the Hawaiian beacons for years, and with equal gain antennas on 2 meters, 432 MHz, and 1296 MHz, I have never heard a higher band come in stronger than a lower band," comments Julian Frost, N3JF. Most avid weak-signal operators may agree—when the 2-meter band opens for tropo above signal strength 9, expect 432 MHz tropo to begin to show up. When 432 MHz tropo pounds it at S-9, expect 1296 MHz tropo to come in strong.

Tom Glaze disagrees: "[While] another myth is that tropo conditions fall off in signal strength as the frequency band increases, I sometimes hear stronger signals on 70 cm than I do on 6 meters and 2 meters during a widespread temperature inversion." Glaze, who is most active on 6 meters from his home QTH in south Florida, where tropo conditions peak in the summer, also explained that the actual depth of the inversion-layer boundary points will act much like a wave-guide and propagate certain bands better than others.

***Myth and Fact:* Polarization is important.**

"You must have similar polarization for weak-signal tropo work to occur, and cross-polarization where one station is vertical and the other station is horizontal won't lead to any meaningful results at all," comments Ben Hathaway, N6FM, Santa Cruz, California. I agree; shift your antennas to a cross-polarization configuration and the signal disappears. Never have I witnessed polarization shift during tropospheric ducting events; both stations must have the same polarization for the circuit to work.

During an intense high-pressure tropo event between Texas and Key West, two mobile stations made contact, quite by accident, on 146.520 MHz FM. Each operator also had a single horizontal loop antenna for 2 meters, and both operators switched over to the loops and signal strength was almost identical. When they tried cross-polarization, the path went completely out.

However, there appears to be no significant benefit of one polarization over another, *other than* almost all weak-signal VHF/UHF tropo operators *only* run horizontal polarization.

Myth: **Only weather maps may predict tropo.**

"I can smell it when we are going to have a band opening," comments Frank Moorhus, AA2DR, on Long Island, New York. He adds, "When the Atlantic high settles in, I can smell the trapped air, see it hanging on the horizon, and I can even tell you who I'm going to be hearing on the band about 600 to 800 miles away. The best conditions are always found when there is almost no wind, the air stinks, and it's a great day to stay inside and play radio. Moorhus is best known for his radio museum of multi-mode VHF/UHF portable, mobile, and base-station equipment. Frank also has the largest collection of new and used horizontal loop antennas, which he collects and hoards.

"Not necessarily so," comments world tropo record holder, Paul Lieb, KH6HME. "Here at the Mauna Loa volcano tropo operating site up 8200 feet, I have sometimes worked the West Coast mainland in pouring warm rain. Yes, the temperature is elevated, but rain showers seem only to affect the higher microwave bands where 2 meters and 432 MHz still make it through," adds Lieb, whose best record from his location is to a station in the state of Washington.

Myth: **Tropo comes and goes quickly.**

"I have seen the band open for up to a week," comments Ken Neubeck, WB2AMU, fellow *CQ VHF* columnist. "Tropo on 6 meters may occur several times a day before the band opens on 2 meters and 432 MHz. Because most of my operation is on the Magic Band, I can let people know that tropo time is coming," adds Neubeck, pointing out that detecting 6-meter tropo might require a dual-polarized antenna system because some 6-meter beacons are vertically polarized, yet others are horizontally polarized. Keep in mind that same polarization is essential for long-range tropo ducting.

Myth: **Tropo only occurs in the summer.**

"We *anticipate* high-pressure tropospheric ducting in the summer, but storm frontal tropo ducting may occur in the fall and spring," comments Shawn Sobus, N9OKJ, near Chicago. Chicago hams will sometimes have a path to the East Coast near Virginia Beach, and sometimes will get all the way down to the Texas Gulf coast.

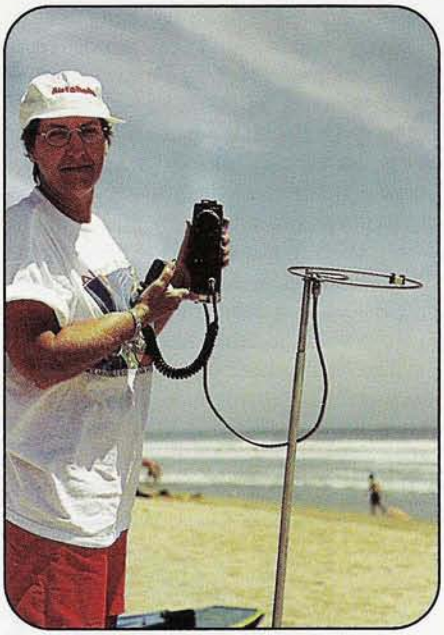
Myth: **Tropo is widespread.**

"Tropospheric ducting over major distances may terminate, like a waveguide, into a relatively tight area," comments Tom Walker, N6TVZ. He adds, "Two stations attempting to work the long-range tropo station may alternately hear that distant station peak at one QTH, and drop into the noise at the other QTH, even though they may live just 10 miles apart! When Hawaii comes in, it's like a garden hose that is slowly swishing up and down the coast. … For an hour or two, southern California hears the signal, and then it slowly fades away and San Francisco now has the opening."

Fact: **Multiple openings may occur.**

Many weak-signal operators confirmed multiple, simultaneous reception of a distant tropo station, leading to hams in Fort Lauderdale, Miami, and Key West, all picking up Nova Scotia two years ago for three days in July. Signal strengths would selectively peak and dip over a 10 to 20 minute period between all three locations, sometimes everyone getting a peak, yet other times two stations at a dip with the other station at a peak.

"The atmosphere during tropospheric ducting is like the mixing of distinctly different fluids and letting them settle into layers. We have found that a 10-degree



Suzy West, N6GLF, reached Hawaii from the West Coast of the U.S. with 2 watts and a halo antenna.

WB6NOA works out to 2500 miles with this tropo dune-buggy setup.

temperature change within the elevated tropospheric duct is sufficient to open a VHF/UHF path for as long as that suspended layer remains undisturbed," adds Paul Lieb, KH6HME.

Among Lieb's souvenirs of tropo openings are temperature plots he has made of the prominent cloud layer that extends from California to Hawaii, as seen as a band of gray on a facsimile weather chart, plus photographs at his tropo-ducting volcano location. "The trigger for this tropospheric duct is always that tropical hurricane to the south," smiles Lieb, agreeing with this author that a tropical disturbance to the south will trigger intense tropospheric ducting many times.

***Fact:* A big antenna is best.**

A good horizontally polarized beam antenna will lead to early tropospheric ducting condition discoveries. A list of VHF/UHF propagation beacons is another good way to "pop the duct" first. Without the beacons, one might not know that the band is actually open to that distant station—unless you live in Hawaii, where Hawaiians hear stateside FM music stations coming in all over the FM band (88 to 108 MHz) radio dial as their propagation indicators!

***Fact:* Ducting is most pronounced over ocean waters.**

Everyone agrees that the more pronounced lapse barrier between sinking dry air and ocean air triggers a good tropospheric duct path. The colder the ocean waters, the greater the pronounced difference in air temperatures.

"Surface winds cause ocean waves, which result in a tremendous increase in the surface area between liquid water and air. Result: Evaporation! Evaporation tends to cool the water, which then acts like a heat sink and cools the air in contact, but adds to the total moisture content of the air. We then have a boundary layer of relatively cool, but nearly saturated air topped by a layer of much warmer though relatively dry air. In the region between the boundary layer and the air aloft, we have a region in which the air temperature increases with altitude and the vapor pressure decreases with altitude. We now have a superrefractive layer, and, *Bingo!*" comments Bruce Eggers, WA9NEW, in Raleigh, North Carolina.

"After 13 years of attempting and making contacts on most of the microwave bands, KH6HME and I finally made the shot from Hawaii to California on 2304 MHz," comments Chip Angle, N6CA. Ultimately, they also made it at 5760 MHz. Equipment consisted of a totally home-brew transverter built by N6CA running 12 watts output to 4-foot dishes and 1.5-dB noise-figure receivers. They are a direct conversion to 28 MHz. The 4-foot dishes have interchangeable feeds for 2.3 GHz all the way up to 10 GHz, and require about 5 minutes for the feed change-outs. KH6HME in Hawaii runs continuous CW beacons on 144.170, 432.075, and 1296.00 MHz. Throughout all of North America there are plenty of weak-signal propagation beacons found at the bottom end of the 2-meter and 430-MHz bands.

***Fact:* You can fly out of a duct.**

"During a period of intense tropospheric ducting to a distant station 1000 miles away, I found the noted 10-degree temperature inversion up at 2500 feet altitude. As I flew higher, the signal disappeared. When I flew lower, the signal disappeared. This tells me that going to a mountaintop to work into a tropospheric duct might be the last thing one would want to do if everyone down at the beach is hearing the distant station 5 by 9," states Bill Alber, a private pilot whose airplane supports all sorts of horizontal omni antennas for tropo-ducting tracking.

"I can remember the day that I watched Gordo down at the beach work Hawaii, 2500 miles away, on a little portable ICOM SSB 2-watt transceiver. I just about fell over in the sand," adds Alber.

I almost did, too! You never know where the tropospheric path might provide an opening to each end of the circuit.

For technical reading on tropospheric ducting, I recommend the RSGB's *VHF/UHF DX Book*, available from most amateur radio dealers. Have fun this summer working some VHF/UHF tropo DX! ■

What is ATV?

There is a small but dedicated group of ham radio operators who, when they are on the air, would rather be seen than heard. Ironically, it is much easier to see these hams than one would imagine. W5ATV has written the following basic guide for receiving (and being challenged to transmit) amateur television signals.

By Dave Ratliff,* W5ATV

What is ATV? In some circles it stands for All-Terrain Vehicle. However, for us ham radio operators it stands for Amateur Television.

Yes, radio amateurs have fast-scan† TV-type signal privileges on several UHF and above ham bands! As it turns out, it's not all that complicated to get into ATV because it's fairly easy to receive ATV pictures. All you need is your cable-ready store-bought TV. With no pun intended, let's look into this special-interest area within our hobby.

Across the U.S. there are many communities that have an active ATV group or club, or ATV component of a local ham radio club. In the Tulsa, Oklahoma area two amateur radio clubs currently have ATV repeaters on the air. The Tulsa Repeater Organization (TRO) has a UHF/ UHF repeater, and The Tulsa Amateur Radio Club (TARC) has a UHF/900 MHz repeater. Ironically, both repeaters use the same 434.250 MHz input frequency. In other locations, another popular ATV frequency is 439.250 MHz.

An ATV repeater works like an FM repeater, retransmitting the input signal it receives on a separate output frequency. Again, in the Tulsa area the TRO repeater retransmits the input signal on 421.250 MHz, and the TARC repeater retransmits the UHF signal on 913.250 MHz. Other repeaters retransmit on the 1.2- and 2.3-GHz ham bands.

Receiving an ATV Signal

There are two ways to receive an ATV signal. Let's look at the cheap and easy way first.

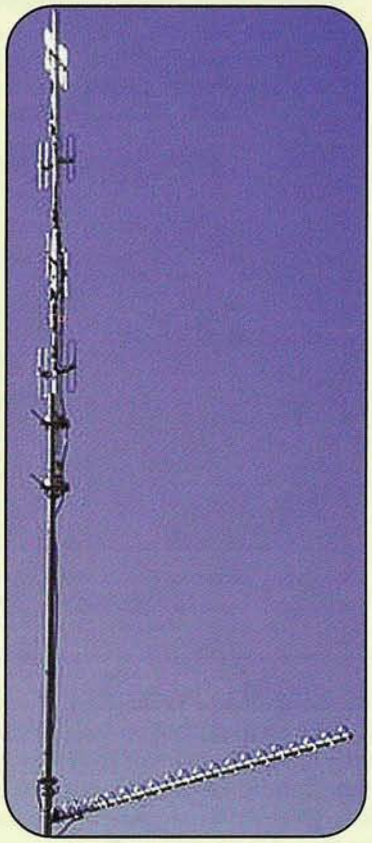
Getting back to that cable-ready TV you probably own, you may be able to pick up the signal directly, without any other equipment. The input frequencies of 434.250 MHz and 439.250 MHz can be found on cable channels 59 and 60, respectively. The 421.250-MHz output signal can be found on cable channel 57. The 913.250 MHz signal can be found on cable channel 144. Please note that I am referring to the cable channels,

*3215 W 40th Street, Tulsa, OK 74107
e-mail: <w5atv@cox.net>

† Amateur radio operators are allowed to transmit both fast-scan and slow-scan television pictures. Fast-scan television, because of the huge (6 MHz) bandwidth required, is only allowed on amateur radio frequencies on the 420-MHz and above ham bands.

The author poses for his ATV camera in the ham shack. (Photo courtesy W5ATV)

The Tulsa Repeater Organization's ATV repeater. (Photo courtesy TRO)



Antennas for the Tulsa Repeater Organization's ATV repeater. (Photo courtesy TRO)

ATV on Field Day

By *CQ VHF* Editor Joe Lynch, N6CL

While Field Day is a time for serious amateur radio activity, it is also a time for fun and creativity. This past June, members of the Tulsa (Oklahoma) Amateur Radio Club (TARC) combined all three of these aspects of Field Day and used amateur television (ATV) to document and cover their activities.

Among the creative Field Day activities was the transmission of ATV signals from the club's Field Day site, Chandler Park, located on a hill west of Tulsa. ATV coverage was not limited to the ground either. Private pilot Christopher Stevens, KC5BEJ, flew his home-built two-seater helicopter around the site and into west Tulsa, ferrying Tim Diehl, KB5ZVC, who manned an onboard portable ATV transmitter. The signal from that transmitter was retransmitted on the TARC ATV repeater throughout the Tulsa metro area.

Also participating in the community relations activities were the Tulsa Life Flight evac helicopter (operated by two local hospitals) and the Berryhill Fire Department (located in the county of Tulsa).

Mark Duensing, KD5DLL, acting as an impromptu air traffic controller, coordinating the landings of the two helicopters that visited the Tulsa Amateur Radio Club's Field Day site. (Photos by N6CL unless specified otherwise)

Tim Diehl, KB5ZVC, operates the camcorder while Christopher Stevens, KC5BEJ, prepares to take off in his home-built two-seater helicopter.

As part of community relations, Tulsa Life Flight flew its emergency air evac helicopter to the TARC's Field Day site.

Aerial scene of TARC Field Day site transmitted by KC5BEJ Air Mobile ATV. Note the use of the camcorder's character generator for the required station identification. (Photo by KB5ZVC)

not the regular TV channels! Your TV must be programmed for the cable channels, rather than the over-the-air channels. Consult the instructions that came with your TV to see how to program it for the cable channels.

As far as antennas for receive are concerned, anything goes! By agreement with the local weak-signal operators who hang out on 432.100 MHz and use horizontal polarization for their antennas, ATV signals generally are vertically polarized. If you are trying for DX, you will want a horizontally polarized antenna because most ATV DXers come from the weak-signal community and use this type of antenna. However, if you want the flexibility of both vertical and horizontal polarization, a satellite antenna that enables you to switch between the polarizations will serve you well.

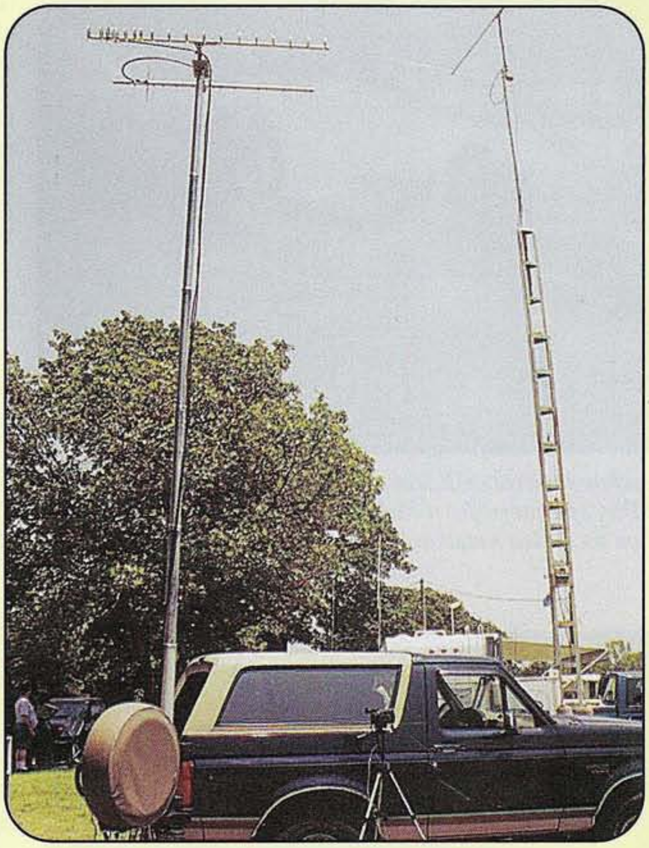
Some folks do great with a UHF or dual-band mag-mount antenna. If you own a UHF beam, try it. Build a cheapie vertical cut to the output frequency. Rabbit ears work just fine (with appropriate tin foil, of course)! You might even

All of this community support was videoed live and retransmitted on the TARC ATV repeater.

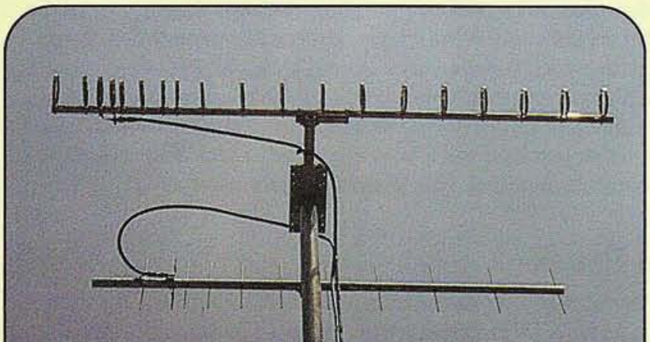
While there was plenty of fun to go around, all of this ATV ham radio activity had a serious side. Several members of TARC are storm spotters, and having onboard ATV in their vehicles aids in coverage of storms that affect Tulsa and nearby communities in northeastern Oklahoma.

Excellent cooperation between TARC and local government agencies has been the backbone for amateur radio participation in local emergencies. Activities such as Field Day serve both as training exercises and a means of continuing to cement good relations between amateurs and local government and non-government emergency service providers.

KB5ZVC operates his portable ATV station from the bed of his pick-up truck.



Tim, KB5ZVC, uses this truck for his in-the-field ATV and other amateur radio activities. The ATV antennas are on a pneumatic-driven collapsible mast.



Atop the pneumatic-driven telescoping mast are KB5ZVC's ATV antennas—a vertically polarized 434-MHz Yagi and a 900-MHz loop Yagi.

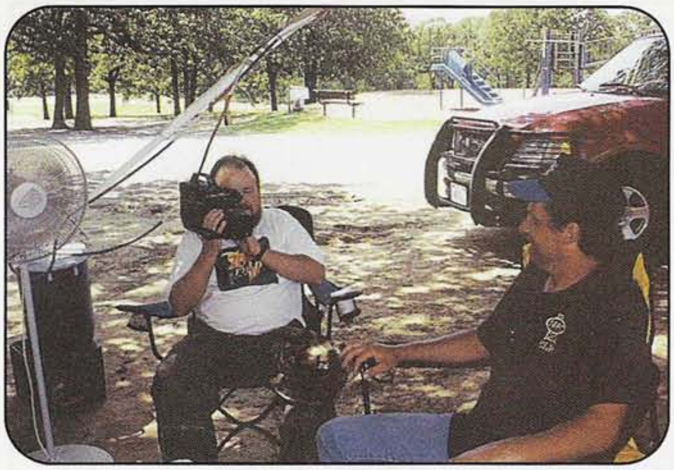
Members of the Berryhill Fire Department participated in community relations activities associated with the Tulsa ARC's Field Day activities. The activities were televised live to other area amateur radio operators via the TARC ATV repeater.

try an old bedspring. Almost any line-of-sight antenna should work in your local area. As I said, anything goes for receive! Of course, the best low-loss coax you can find gives the best results.

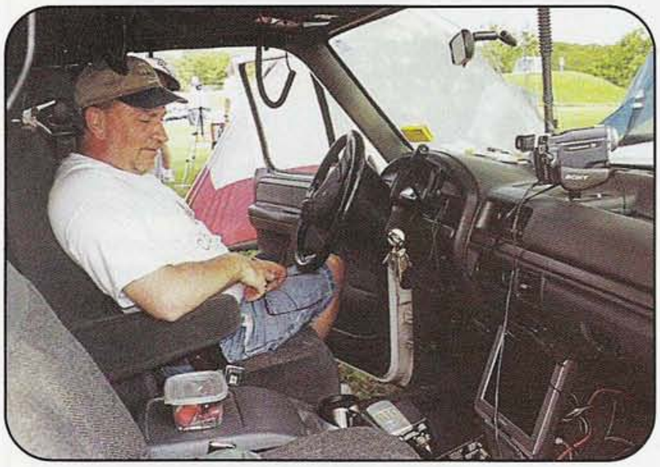
Okay, you have a cable-ready TV, you have tried the direct method, and you cannot receive cable channel 144, or you can receive the ATV repeater but you have little or no picture, or the output of the local repeater is on one of the higher microwave frequencies. You might want to try an ATV down-converter. This device goes between the coax from the antenna and the back of the TV or monitor. It brings the signal received into your TV, usually on channel 3. There is a tuning dial (potentiometer) on the front panel to give you a much better tuning range on your set.

Most ATV converters also have a GaAs-FET (Gallium Arsenide Field Effect Transistor) front end to give you a little signal amplification. Of course, there are several options for other preamps.

What about audio? While some ATV operators use the audio signal on the ATV



The author interviews Eddie Chandler, KD5JGA, one of the Field Day operators, for a Field Day documentary that will be aired on the Tulsa Amateur Radio Club ATV repeater. (Photo via N6CL)



Dave Smith, KD5OIJ, operates ATV mobile using the flat screen positioned over the transmission hump. Note that while it may be justifiable to operate mobile ATV as a storm spotter (with the local weather radar appearing on the screen), in some states it is illegal to operate a moving vehicle with a television screen in view of the driver. Please consult your local law-enforcement authorities before proceeding with your mobile ATV activities. (Photo via N6CL)

frequency, many others work ATV in conjunction with a local repeater or simplex frequency, usually on 2 meters. Check with your local ATV operators to find out what they are using for an audio liaison or coordinating frequency.

Incidentally, the local simplex coordinating frequency depends on which ATV frequency you are using. Generally, if you use 439.250 MHz, the coordinating frequency you will use is 144.340 MHz; if you use 434.250 MHz, the coordinating frequency is 146.430 MHz. The principle reason for the difference in these two frequencies is to prevent the third harmonic of the 2-meter signal from interfering with the ATV signal.

For the 2-meter transceiver you use for the coordinating frequency, you will want a vertical antenna with some gain. Having this 2-meter radio available will allow you to participate in a round-table with other ATV operators, and an omni-directional antenna will preclude the need to rotate your antenna to hear each of the other stations.

Now it's simply a matter of finding out what frequency is used by ATV operators in your area, finding out where the signal is coming from, and connecting the right kind of antenna and rotating it. There is nothing to stop you from joining in on the round-table discussion on the coordinating frequency. Watch out, though, you just might get hooked!

Transmitting

What if you've seen those other hams' pictures and the ATV bug has bitten you? How about transmitting? No big deal!

Most ATV transmitters are low power, ranging between 1 and 20 watts. Usually that's all that is needed. There are also transceivers which transmit and receive in one package. ATV linear amps are available, but you probably won't need one. Of course, you must have the correct transmit crystal installed to key the repeater.

For a camera, almost any camcorder will work. All you need to know is if it produces the National Television System Committee (NTSC) video. Don't be too concerned about this feature, because the NTSC standard covers about 98% of the camcorders in the U.S. However, don't bother asking the guy at the pawnshop; he won't know.

Should the camcorder have the marking PAL or SECAM, you can't use it. These are foreign formats. They are so rare in the U.S. that it's almost not worth mentioning them, but I have seen them in pawnshops or on e-Bay.

If the recording section of the camcorder is no longer functional, don't worry about it. All you need is a good picture from the camera section. You can pick up some real bargains on camcorders that have broken recording devices. Again, just make sure the video output is all right. You need a camcorder or camera with an RCA-type video output jack. A BNC-type, with a suitable adapter, available from RadioShack, is also acceptable. Fortunately, this covers most video cameras. Old security cameras work just fine also. Is your camera black and white? No problem. Remember, this is *amateur* television.

On The Air

Here is some important information about making ATV contacts: Most ATV contacts are not initiated by putting a signal on the air and calling "CQ ATV." Contacts are arranged when someone gets on the local ATV coordinating frequency and announces that he or she is going to put a video carrier on the air.

Once you have your station assembled, simply connect your camera to the "video in" connector on your transmitter, connect your vertically polarized antenna to your transmitter output, check to make sure the frequency is not in use, and begin sending pictures.

Here are some suggestions of pictures you may want to show: your smiling face, pictures of your shack, or your latest project. Convince the YL to smile for the camera. Pets are always good, too. Needless to say, if you are transmitting through a club repeater, remember these are family repeaters, so to speak. Do not show anything offensive or in bad taste. This could result in the loss of your license and that of the club, as well! Just use common sense.

Station identification is required, just like when you're on the air with audio. A lot of cameras have built-in character generators. These are ideal for identification purposes. You can also hold up a simple block-letter sign with your call on it every 10 minutes or so. This fulfills the legal requirements.

As with any other type of QSO, a form of signal report exists for ATV contacts. ATVers use a rating system of 0 to 5, preceded by the letter "P." For example, a signal that just shows the sync bars in the snow is rated P0; a very snowy, almost imperceptible signal is P1; and a clear signal with no snow is P5. Some operators go so far as to split the signal reports into tenths. Thus, a signal with just a small amount of snow is a P4.5.

Don't forget portable ATV. I have done several remote operations at parks, parades, Field Day, and so forth. For a portable operation, you have the same station requirements as you do with a fixed station. What's different is that you are using portable power and antennas.

The Future

What's in the future for amateur television? ATV operators are sending the digitized signal from computers over ATV. Infrared cameras that began to appear on the surplus market following Operation Desert Storm have given ATV operators the ability to make night-scene transmissions.

Ballooning is another way ATV is used. Weather balloons that go up to over 100,000 feet and show the Earth and edge of space over a 500-mile radius are launched with GPS receivers that translate and superimpose the coordinates with the video signal so that these coordinates appear across the bottom screen.

Here's an idea for your club: When the Tulsa club stations are not being used as repeaters (which is about 90% of the time), they broadcast the live radar from the TV station weather departments. I don't care what kind of weather setup you receive on the internet. I don't care what kind of weather station you have at your home. Nothing beats your own private real-time radar 24/7 at home—free! Both of the Tulsa amateur radio clubs are very grateful to the local TV stations for allowing them to continually "tap" into their radar signals.

Sources

"Okay," you ask, "where do I get the 'stuff' to do this ATV?" One great source is PC Electronics (2522 Paxson Lane, Arcadia, CA 91007; phone 626-447-4565; <http://www.hamtv.com>). I have purchased several pieces of their equipment and am very satisfied. Another source is ATV Research (1301 Broadway, Box 620, Dakota City, NE 68731; 402-987-3771; <www.atvresearch.com>).

If you do an internet search on ATV, you will find all kinds of sources of equipment, ATV clubs, and lots of other info, including "how to" articles (such as this one at <http://www.qsl.net/w5ias/atv.html>). One ATV organization is Amateur Television of North America (<http://www.qsl.net/atna/>). A popular ATV magazine is *ATV Quarterly*, published by Harlan Technologies (5931 Alma Drive, Rockford, IL 61108; 815-398-2683; <www.hampubs.com>). Also, look in *The ARRL Handbook* and *The ARRL Operating Manual* for more information.

Do you have other questions? Feel free to write to me or e-mail me at the addresses listed at the beginning of this article. I'll try to help as best I can. See you on ATV!

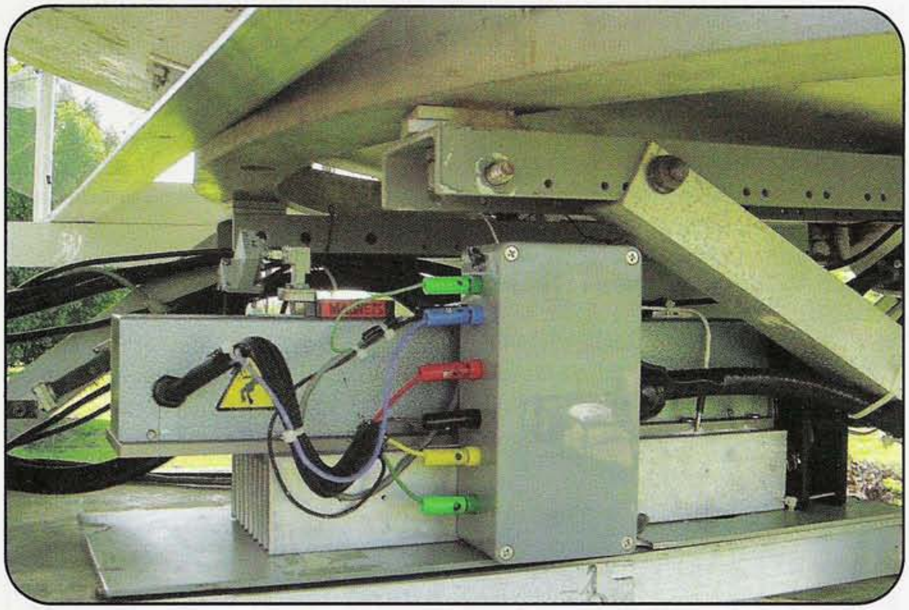


Photo 7. TH-3864C TWT mounted behind the dish. Note the high-voltage junction box and magnet.

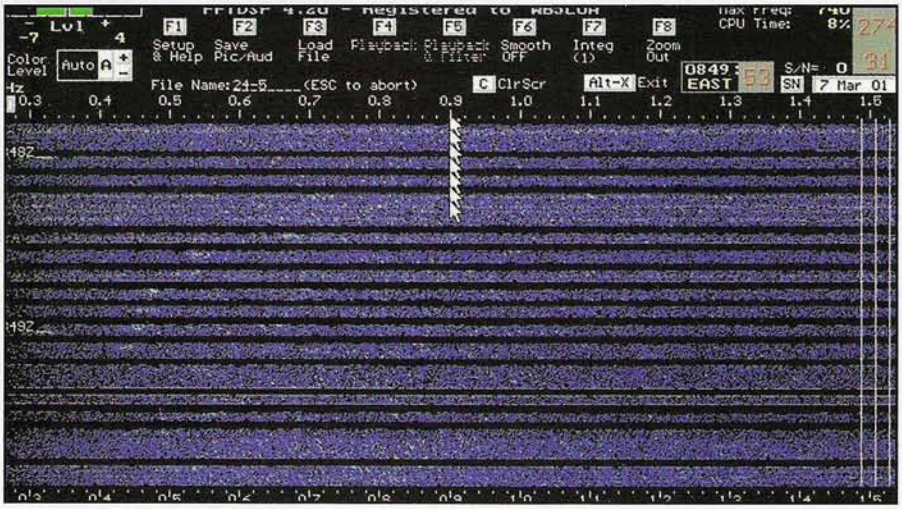


Photo 8. AF9Y DSP software used to document W5LUA's first 24-GHz lunar echoes.

After the original tubes did not work out for us, I was able to acquire four different 100+ watt, 26–30+ GHz TWTs which are wideband Helix-based tubes. Paul Drexler, W2PED, donated these tubes to the EME effort. Many thanks to Paul for his generous donation!

Barry spent time modifying the 23- and 12-kV sections of the coupled-cavity TWT power supply to create 15- and 6-kV supplies, and compensating for filament and control-anode voltage changes for the new tubes. Initial tests with an NEC 150-watt tube failed, as the tube proved to have an open helix.

Barry's focus was then on further power-supply modifications to match the three remaining tubes. The second unit Barry tried was rated at 80-watts output from 32–38 GHz, so it was not clear how well it would operate at 24 GHz (see photo 5). After the addition of external waveguide tuners, extensive use of extra magnets for refocusing, and dramatic adjustment of the Helix voltage from 13.6 kV up to 14.7 kV, the unit produced 75 watts at 24 GHz. Presently, Barry is using an NEC LD7235A producing 110-watts output in the shack. The resultant power at the feedhorn is approximately 70 watts, after a run of EW-180 waveguide.

At W5LUA my initial success in generating power on 24 GHz came after retuning my VTU-6191 TWT. The VTU-6191 TWT is a 14.5-GHz 80-watt tube that works very well at 10,368 MHz, producing 100 watts with some additional waveguide tuning (see photo 6).

I decided to try to see if this tube could be pushed to 24 GHz. Most TWTs can be coaxed up in frequency by lowering the Helix voltage. Unfortunately, lowering the Helix voltage towards the lower specified limit of the tube generally will raise the Helix current and cause trip-outs if one is not careful. With generous use of small "refrigerator magnets" and some waveguide tuning, I was able to generate nearly 10 watts at 24 GHz with 50 milliwatts of drive. Once when I was having a discussion with John Schroeder, K5ZMJ, about tuning his TWT with magnets, John made the comment that he had some very big magnets. I thought, "Why not try one and see what happens?"

The first thing I noticed was that it was a lot easier to trip out the Helix current when placing the magnet in the "wrong" position! After careful positioning near the input waveguide connector, I was able to get nearly 20-watts output, a gain of 3 dB over my previous best. At this power level I was able to hear my first echoes off the Moon in March 2001.

Note the bandswitch between 10 and 24 GHz as shown in photo 6. When I operate 10 GHz, I *must* remove the large magnet!

As mention above, Paul Drexler donated several TWTs to the EME cause. I was able to bring up the Thompson TH-3864C TWT, designed for 28 GHz, to produce 80 watts at 24 GHz without any additional waveguide tuning (see photo 7).

The only problem encountered with the tube was high Helix current. The normal no-drive Helix current was very near the 5-mA absolute maximum limit. In an effort to reduce this current, I placed a magnet about the size of a domino at a location very near the input waveguide flange. The result was that the Helix current was cut in half without adversely affecting output power. At present, the TWT is mounted on a shelf behind the dish and is connected to the T/R relays through about 1 meter of WR-42 waveguide, thereby producing 65 watts of power at the feed.

Initial Operating Results

First Echoes at W5LUA: As mentioned above, I was first able to copy my echoes on March 6, 2001; they were weak but CW readable and not just "imagination." System noise figure was 2.25 dB, and the power level at the feed was 18 watts. I was able to use the AF9Y DSP software to get a picture representation of my first "echoes" (see photo 8). The black area represents the time period in which I was transmitting. The blue (noise) area represents the receive passband. The white area shows the received echo, which is slowly drifting down in frequency as the Moon sets in the western sky.

First 24 GHz EME QSO: When VE4MA and I completed our first 24-GHz EME QSO after exchanging M/M reports,[1] I was running 70 watts at the feed and VE4MA was running 60 watts. The weather was cool and clear at VE4MA, while it was cloudy, hot, and humid at W5LUA.

One should appreciate the efforts required to do these early tests. Both stations were using Moon noise peaking on receive, which requires interruption of transmit periods about every 30 seconds. W5LUA was using a video camera for visual Moon aiming of the dish, and both of us needed decently calm weather to keep the dishes properly oriented at the Moon.

Further Operating Experience

As tough as it was to make that initial 24-GHz QSO, subsequent QSOs have become routine. Both of us have made skeds just about every month since the initial QSO. Since that first QSO we have worked one another a total of ten times, with "O" copy signals most of the time. We also have used this time to test improvements to our systems, encourage other stations to listen, and learn more about 24-GHz EME conditions.

Among our experiments were power-level tests that determined the minimum necessary power level to make a contact. As a reference, good "O" copy signals are always received at the 60- to 70-watt level. Decreasing power levels by 3 dB still produced good signals. Decreasing power by 6 dB down to the 15-watt level produced weak but still copyable signals.

Over the course of our experiments both of us have been heard by G3WDG, RW3BP, VE7CLD, and AA6IW, all of whom were eager to work us and each other. Not surprisingly, the biggest challenge for these operators was finding transmitter power, and in some cases building a power supply. All stations have been using dishes that range from a 2.4-m offset fed to a 4.5-m prime focus unit. Furthermore, all are using preamplifiers with an approximate 2-dB noise figure.

In April of this year several new stations became operational and additional QSOs took place. Among the new QSOs, RW3BP worked W5LUA, VE4MA, and AA6IW. In additional, VE4MA worked AA6IW and VE7CLD.

WA7CJO also has high power and is expected to be on the air shortly. LX1DB, CT1DMK, OH2AUE, OK1UWA, and more recently PAØEHG have built receiving equipment, so the interest is increasing.

Conclusion

It seems unlikely that moonbounce operation on 24 GHz will ever become as routine as moonbounce QSOs on the lower frequencies. However, now that several additional stations have become operational, regular, repeated QSOs will happen. The preparation work that is required for these additional 24 GHz QSOs continues to remain very high. The ability to generate RF power will still restrict the possibility of 24-GHz EME to a small number of people fortunate enough to find a 100-Watt TWT tube. Hopefully, more big TWTs will be found and there will be more operators who accept the challenge.

[1]*Ed. Note: EME signal reports for frequencies higher than 432 MHz are T, M, or O. A signal report of T is to be sent if something was heard in the noise, but there were not enough characters to put together complete calls. An M report is the minimum acceptable report, signifying that complete calls were received. A signal report of O represents good copy of multiple sets of complete calls.*

 (from page 84)

the groundwork for how one might search for intelligent signals from beyond.

The article appeared in 1960, while Drake was making final preparations to launch his Project Ozma. In the article Philip Morrison (formerly W8FIS) and Giuseppe Cocconi included a table that listed likely stars to survey, and topping the list were Drake's two selected targets. The Cornell professors discussed frequencies to tune and settled on the hydrogen line, just as Drake had done. In fact, the published proposal and the secret search bore a striking resemblance to one another, considering that neither player had any knowledge of the other.

The birth of modern SETI is a prime example of what I call the "Parenthood Principle," which is seen so often in science: When a great idea is ready to be born, it goes off in search of a parent. Sometimes it finds more than one.

As the scientific expression goes, the cat was out of Schrodinger's bag[1] and Drake had to go public. Thanks to Morrison and Cocconi, Frank Drake ended up with far more publicity than he had bargained for. While many in the academic community arched their eyebrows, the public was captivated. SETI truly was an idea whose time had come.

The Project Ozma search itself proved something of a disappointment. No intelligent life was detected save for interference from what we presume was a classified military aircraft. (I believe Frank Drake may have discovered the U-2 spy plane, but had the good sense to maintain reasonable silence on the subject.) However, the seeds planted by Drake at Green Bank in 1960, now fertilized by more than 40 years of progress, have brought SETI out of the realm of the unmentionable and into the scientific mainstream. The dozens of searches conducted since then (some of them by radio amateurs) have yet to turn up any definitive evidence of our cosmic companions. Nevertheless, not only have we yet to scratch the surface, we haven't even felt the itch.

Had Frank Drake done nothing more in the search for life in space than conduct Project Ozma, his place in history would still have been assured. Not one to sit by idly, Drake went on to host the world's first conference of SETI scientists at Green Bank in 1961. His agenda for that historic meeting was what is now known as the Drake Equation, which graces the pages of every contemporary astronomy textbook. Planned to simply identify the factors related to the emergence of technological extra-terrestrial life, the Drake Equation can be "solved" for the number of other communicative civilizations in the Milky Way galaxy. It is an elegant tool for quantifying our ignorance.

That, as they say, is only the beginning.

73, Paul, N6TX

Reference

1. Schrodinger's cat refers to early 20th century scientist Edwin Schrodinger's effort to explain quantum mechanics, a branch of physics that is designed to explain how fundamental particles, such as electrons, interact with one another. His proposal was to put a cat into a bag with a fragile bottle of a deadly poison, a hammer, and a radioactive atom. If the atom decayed, then a mechanism would detect this decay and swing the hammer at the bottle of poison, thereby breaking it and killing the cat. If the atom didn't decay, the mechanism wouldn't move the hammer, the poison would stay in the bottle, and the cat would live.

The ensuing debate following Schrodinger's proposal centered on the state of the atom and the state of the cat, neither of which could be predicted without examining them, which ultimately meant taking the cat out of the bag and thus ending the experiment. The ethereal conclusion was that the cat was both dead and alive at the same time, thereby prompting the notion of parallel universes.

In this column, author Shuch uses the coined expression "the cat is out of Schrodinger's bag" as a way of explaining how people working totally independent of each other can (nearly) simultaneously come up with the same idea. Such was the case of the Morrison and Cocconi team and Drake, who independent of one another (nearly) simultaneously proposed the hydrogen line as the most likely location to look for signals from extra-terrestrial intelligent communicators. The logical explanation that these men (nearly) simultaneously came up with the same idea of looking at the hydrogen line is found in explaining how the cat got out of Schrodinger's bag and whether or not the cat was alive when it did get out of the bag. ■

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By Dr. H. Paul Shuch,* N6TX

DR. SETI'S STARSHIP

Searching For The Ultimate DX

In The Beginning

In the beginning there was Frank Drake, and Frank Drake's word was . . . silence.

You really can't blame him. The year was 1959, and Drake was a newly minted Harvard University Ph.D. The ink on his diploma was as wet as he was behind the ears. Drake had just started his new job at the National Radio Astronomy Observatory (NRAO) in Green Bank, West Virginia, when he got this outlandish idea about searching for intelligently generated microwave signals from the stars.

*Executive Director, The SETI League, Inc., <http://www.setileague.org>
e-mail: <n6tx@setileague.org>

Whom was he going to tell? For a green astronomy post-doc to evidence interest in extra-terrestrial life back then would have been professional suicide. Only a fool would have admitted publicly to such interest, and Frank Drake was no fool.

Drake quietly set about the process of designing the search and setting up the equipment for Project Ozma, which was to become the first salvo fired in the newly emerging science of SETI, the Search for Extra-Terrestrial Intelligence. His idea was to use the 26-meter diameter Howard Tatel radio telescope at Green Bank (see photo) during its off-duty time to survey two nearby sun-like stars (*Tau Ceti* and *Epsilon Eridani*) for microwave evidence of other technological civilizations. He planned to search on the 1420 MHz resonant frequency of hydrogen atoms, the most abundant substance in space.

"Ours is a radio-polluting civilization," reasoned Drake. Because of this potential propensity for many, many radio signals in the universe, might not others similarly give away their positions by their radio emissions? Perhaps, Drake hoped, other civilizations might be less discrete than he was being. Furthermore, where better to give themselves away than on the hydrogen line, where radio astronomers on any planet could already be expected to be tuning their receivers?

Then the Cocconi and Morrison article came out. "Searching for Interstellar Communications" was a brief letter in the British scientific journal *Nature*. In it the two Cornell University professors laid

(Continued on page 82)

The Howard Tatel telescope at the National Radio Astronomy Observatory, Green Bank, West Virginia, was home to Project Ozma, the world's first modern SETI search. The 85-foot dish is still in use, more than four decades later. (SETI League photo)

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