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Ham Radio Above 50 MHz

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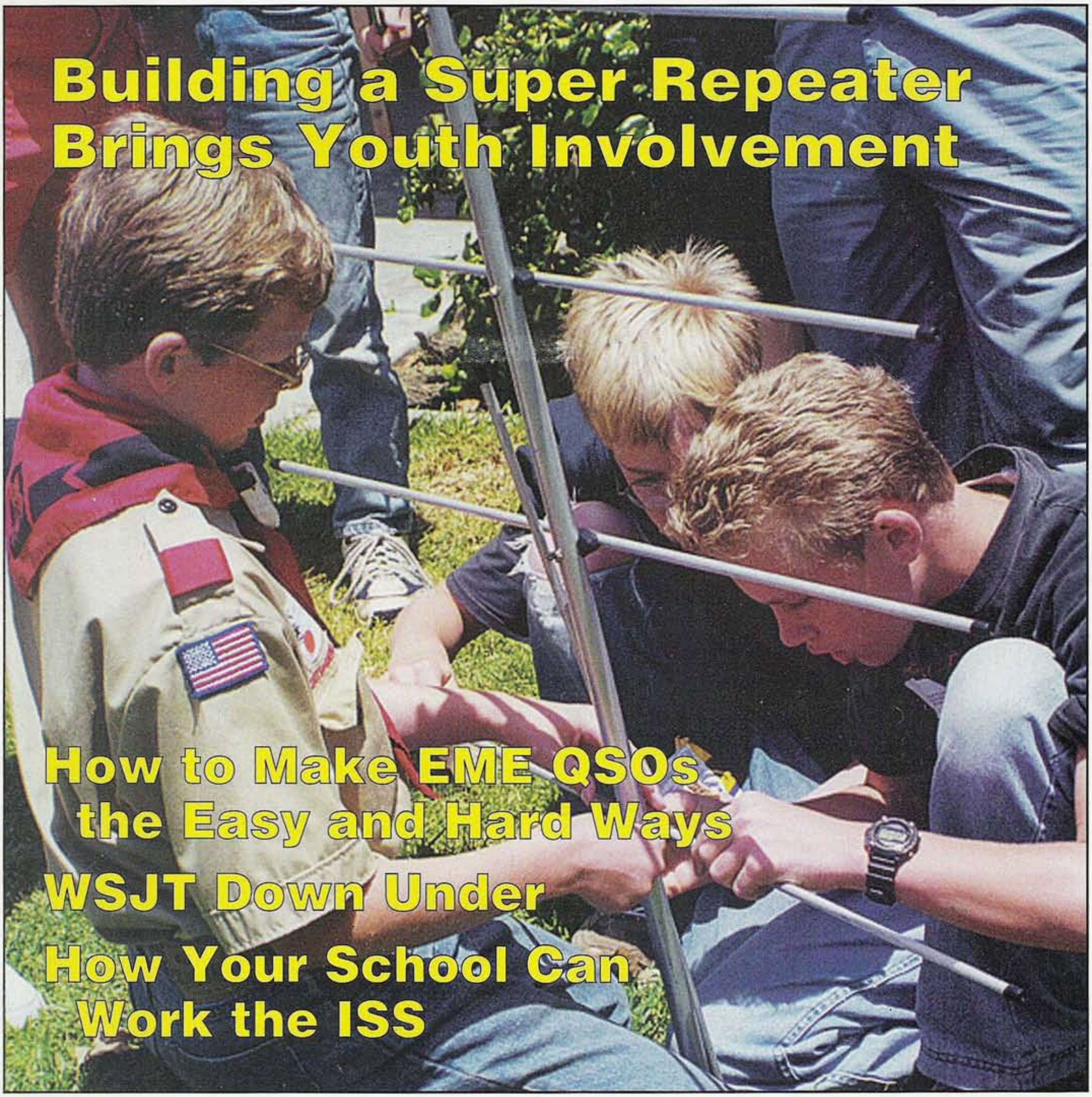

Building a Super Repeater Brings Youth Involvement

How to Make EME QSOs the Easy and Hard Ways

WSJT Down Under

How Your School Can Work the ISS

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

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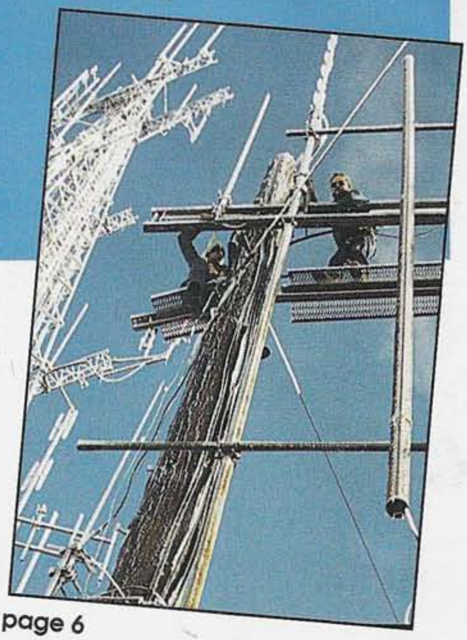


page 6

Winter 2003
Vol. 5 No. 4

FEATURES

COLUMNS

DEPARTMENTS

On the Cover: One aspect of the Super (Repeater) System is its attraction for young people. The cover photo by Gordon West, WB6NOA, shows several boys building an antenna for accessing the system. For more information on how youth in your area can get involved in amateur radio, see WB6NOA's article on page 6 and K5YFL's feature on page 10.

CQ VHF Ham Radio Above 50 MHz

LINE OF SIGHT

A Message from the Editor

It's Been One Year . . .

A year ago this January, I was in dialog with CQ Communications Publisher Dick Ross, K2MGA, about bringing back *CQ VHF* magazine. He explained to me that from the moment the first version of *CQ VHF* was merged into *CQ* magazine there had been a cry for its return as a standalone publication. Finding the market right for the return of *CQ VHF,* Dick made the decision to bring it back as a quarterly magazine and asked me to be the editor.

Having had prior experience as a quarterly publication editor (the *QCWA Journal* from 1993–1995), I was not so much daunted by the task as I was challenged by what kind of magazine should be produced. Dick explained that research indicated the new version of *CQ VHF* needed to be a couple of notches higher in technical content, but still have an appeal for the newly licensed ham interested in the VHF+ ham bands. After having now completed four issues, I believe we are filling that niche quite nicely. Even so, I am always open to suggestions for improvement.

Among my concerns are appealing to our youth. In recent years we seem to have become rather dead in the water, as other technological interests have piqued the interest of our youth and purloined them away from the hobby. However, some recent developments have begun to reverse that trend. Among these are technological and software designs that use the internet as venues for ham radio. As this issue's cover illustrates, once again young people are becoming interested in our hobby. Beginning on page 6, *CQ VHF* Features Editor Gordon West, WB6NOA, tells the story of how it's happening in southern California.

Another development that is appealing to our youth is the ongoing work in building the International Space Station. Acting hand-in-glove with the ISS is the SAREX working group. Originally known as the Shuttle Amateur Radio Experiment, it is now known as the Space Amateur Radio Experiment. Out of this has grown ARISS, the Amateur Radio International Space Station. In its thrust toward education, NASA has given priority to having the astronauts and cosmonauts who live on board the ISS communicate with schools around the world.

Taking the mystery out of how to involve your school in this area of the space program is Gene Chapline, K5YFL. His article on page 10 originally was presented as a how-to paper at the 20th AMSAT-NA symposium in November 2002 in Ft. Worth, Texas. Adding a bit of peer review to the article is Rosalie White, K1STO, of the SAREX working group.

Speaking of AMSAT-NA, in this issue we present the second paper by Richard Hambly, W2GPS, on the future of amateur satellite communications from the perspective of AMSAT-NA. Originally published in the November/December 2002 issue of the *AMSAT Journal,* it is presented here as a venue for increasing interest in amateur satellite communications. Complementing Hambly's piece is the "Satellites" column by Tom Webb, WA9AFM, who discusses the various satellites that are available today.

The last two issues of *CQ VHF* contained articles on amateur television. Not wanting to leave this mode of communication out of the picture this time, Simon Lewis, GM4PLM, presents an article on building a rather simple 23-cm ATV kit.

Moving the technical content up the ladder from the previous version of *CQ VHF* has not been an easy task. While we want to maintain our appeal to the newer hams, we also want to present a challenge for our more experienced readers. At times it has been a tightrope to walk, not having articles appear to be too technical for our lesser experienced readers, while at the same time not oversimplifying the content of the articles so that they remain of interest to the more technically oriented and more experienced readers. Nevertheless, we feel that we are finding a balance. Again, we welcome your input for improvement.

Yes, But Will It Work for Me?

In an effort to raise the level of technical content, in our premier issue of the revived *CQ VHF* magazine we published an article by Joe Taylor, K1JT, touting his then-new JT44 software, which he incorporated into his WSJT software package. In the ensuing months, use of his software has opened many doors to EME for persons heretofore unequipped to have this experience. In order to encourage others to consider EME as a mode of communications, in this issue we have an article on page 16 by Bob Kocisko, K6PF, who covers some of the practical applications of Taylor's software for EME communications.

On the other end of the difficulty continuum, Mike Melum, KL6M, tells how he put together his EME array in Alaska. Sticking with the reputation for "big" in the largest state in the U.S., Mike describes how he assembled his really big dish so that he can work those really small stations and give them that Alaska contact for Worked All States (WAS) and DXCC.

In this issue we also present a paper by Rex Moncur, VK7MO, on using FSK441 (another program within the WSJT package) for meteor-scatter work in Australia and New Zealand. His paper originally was presented at GippTech 2002, the annual Australian conference designed to encourage participation in VHF, UHF, and microwave amateur radio operations; it has been only very slightly edited for publication in *CQ VHF*. The "Down Under" ham radio community is not the beneficiary of as many meteor showers as those of us who live in the Northern Hemisphere. As a result, meteor-scatter communication has not generated a great deal of interest in that part of the world—that is, until Taylor's software program came along and opened the door to the almost daily possibility for anyone with a modest station and a computer to communicate via meteor scatter.

Drawing on the research on meteors and radio observation of them published in a little-known, 42-year-old book entitled *Meteor Science and Engineering*, by D. W. R. McKinley, Moncur makes the assumption that regular meteor-scatter communication is highly probable. Using the FSK441 software program as the key to opening the door, Moncur confirms his assumption and documents it in his article.

Because of the unique nature of Moncur's application of FSK441, I asked Shelby Ennis, W8WN, to peer review Moncur's paper and be in dialog with him concerning his observations. Ennis has already reviewed the paper, and Moncur has agreed to the dialog. Their exchange will be presented in a future issue of *CQ VHF*.

(Continued on page 83)

Building a Super (Repeater) System

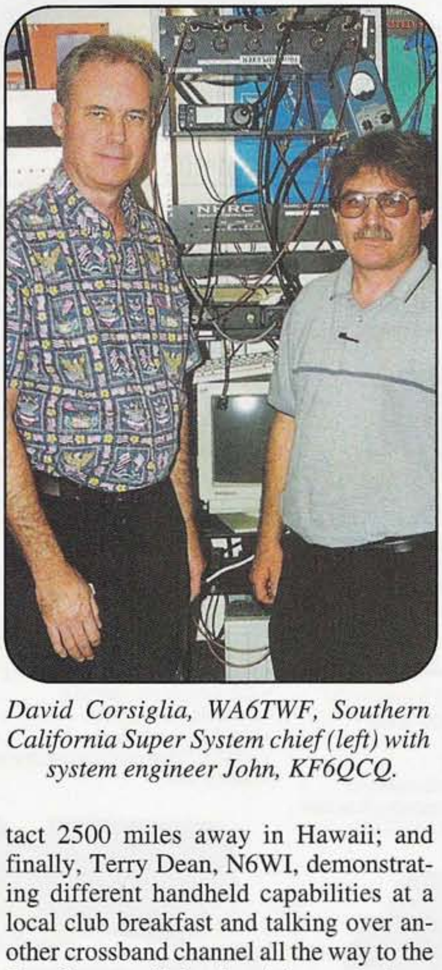
You say you have a super repeater system? WB6NOA invites you to see what it takes to set up a *really* Super System—part auxiliary station, part remote base, part crossband, part repeater, and plenty of magic and excitement.

By Gordon West,* WB6NOA

"Every week I have been trying a new mode over my Super System," says David Corsiglia, WA6TWF, a long-time ham pioneer who knows what it takes to draw a crowd. Every month members of the WA6TWF Super System get to try something new on different ham bands. Although the UHF frequency may stay the same, Dave and the *system coordinators* program a new "show" that everyone from Technician class to Extra class can work with just a little HT.

Ten independent repeaters, all with full autopatch capabilities, operate in the 70-cm band with strict system user controls; precise adherence to southern California 70-cm frequency coordination grants; and absolute compliance with FCC Part 97 rules, Subpart C, "Special Operations," which covers auxiliary, repeater, telecommand, and most important, Part 97.3(a)(7), a *cooperating system* within the definition of an auxiliary station.

A quick tune of the southern California 70-cm repeater sub-band will reveal under-utilization of coordinated repeater pairs. Call them "paper machines," or simply seldom-used private stations. More than half of the recently shuffled 20-kHz spaced repeater pairs are silent. Tune into any of the WA6TWF Super System channels, however, and listen to Wayne, KC6WDD, bringing up the IRLP (Internet Radio Linking Project) for system members to work all day; Jerry, KK6YO, managing the big 20-meter beam pulling in HF signals for some crossband excitement; David, AC6PP, and John, KF6QCQ, on another channel working the remote to a high-level, 2-meter SSB system making a tropo contact 2500 miles away in Hawaii; and finally, Terry Dean, N6WI, demonstrating different handheld capabilities at a local club breakfast and talking over another crossband channel all the way to the East Coast as if they're sitting next door.



David Corsiglia, WA6TWF, Southern California Super System chief (left) with system engineer John, KF6QCQ.

The WA6TWF Super System is going "public" to show what it takes to set up your own system anywhere in the country. David, WA6TWF, is eager to share his experience of what works, and occasionally what obstacles need to be overcome when building your own Super System empire.

Rules and Coordination

"Get started by getting frequency coordinated on one UHF 70-cm channel," suggests Bob Paquette, W6ZPL, one of the Southern California Super System administrators. "Better yet, find the owners of a high-level UHF system already on the air who might be interested in turning their system into a multi-opportunity, crossband base and begin exploring all that you might do to add components to the system that would be of interest to hams in your community," adds Paquette.

A definite prerequisite for setting up your Super System is to purchase the American Radio Relay League's *FCC Rule Book,* available at the ARRL website <http://www.arrl.org>. This almost 400-page book devotes an entire chapter specifically to Sub-part C, "Special Operations," addressing specialized activities of amateur radio, including auxiliary links, beacons, repeaters, and telecommand remote control. With plain language, there is discussion of what's legal and what's necessary to develop your own 70-cm Super Station. The specific FCC rules to which attention must be paid

The NHRC-10 Repeater Controller. (Photo courtesy the manufacturer)

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The Super System encourages young people to take part in antenna projects.

Super System demonstration for the Handi-Ham program every March.

are §97.201 through §97.221, and everything between those two!

The Southern California Super System was able to gain additional coordinated channels because of the reputation David Corsiglia had in developing repeater systems that did a lot more than just repeat a signal on the input. Dave's first big repeater system was on Catalina Island, with the distinctive repeater callsign WR6AAA. This repeater, although now under another callsign, continues to be a "family gathering spot," hosting nightly nets for kids, and technical, DX, and ham radio equipment exchanges.

Once you have coordination, and *The FCC Rule Book* under your arm, it's time to start plugging in the system functions that will attract hundreds of hams to participate in the excitement.

What's Hot?

The multi-channel 70-cm system is best known for access to the high-frequency bands, and HF isn't all that the system known for either. One channel is known for instant IRLP access. Another has attracted emergency communications operators from the WA6TWF Super System who can work with local American Red Cross volunteer communicators through a link to the 2-meter band. Finally, another channel has unrestricted autopatch capabilities.

Access on 70 cm to a remote ham station with a giant 5-element, low-band beam always draws a crowd on the air. The *Rule Book* points out that the term *remote base* is not actually defined in the FCC rules, but it would fall under "uses for auxiliary stations." The remote-base capability would be controlled by an appointed Super System control operator with a General class license or higher, who might be retired and just looking to help others find all the excitement on HF. This control operator does not necessarily need to be specifically at the high-frequency base station.

While members of the Super System—many with just a Technician class license—have fun doing school demos with a small 440-MHz HT to another station thousands of miles away, these operators are not actually part of the "system" control, but would be considered third party. System control takes place on frequencies above 222.15 MHz, meeting the requirements of FCC Rule 97.201(b). The remote base is operated under the rules for remotely controlled stations, and there must be an acting control operator whenever system users bring up the link. The WA6TWF Super System is a non-open repeater, because every user must be specifically authorized by the station's licensee to be eligible as a designated control operator of the station. If their license does not permit them to transmit on frequencies below 50 MHz, they still might be able to bring up the base and simply monitor code practice, let's say on 7100 kHz.

Here in southern California there are redundant control links above 222.1 MHz, including wire-line control, because a station may also do double-duty as an autopatch. Regardless of how many ways of legally radio-controlling the remote high-frequency station, the remote station must automatically shut down within 3 minutes in the case of control-link failure, according to FCC Rule 97.213. Also, station identification must be made at both ends of the circuit, so an adding an external controller is absolutely necessary.

The Southern California Super System first homebrewed the necessary controllers with Jim Gilliam, K6QE, the control unit designer who is also chief engineer for fire and police safety radio communications for the City of Los Angeles. Over the last 20 years, five of Jim's controllers not only kept the Super System myriad of remote bases on the air all over the southland, but also kept them 100-percent legal with regard to the rules. The controllers go between the basic repeater UHF radio and the worldwide radio, performing all the basic functions of tuning the worldwide radio via the DTMF dual-keypad tones.

"Jim spent thousands of hours building and writing software for these units," comments Corsiglia, pointing out that one of these controllers worked into a full-size, 3-element 80-meter beam and a 6-element KLM tri-bander, all up at 100 feet! This allowed Super System members to use their small 440-MHz HTs to talk worldwide, and even be able to turn the antenna via their keypad buttons.

While this may sound complicated, once the Super System users get the hang

(Continued on page 68)

How Kids Can Talk to "Space People"

How do school children talk to the astronauts in space? Thanks to a lot of volunteers, it's relatively simple, as K5YFL explains in this practical, down-to-earth article on talking to "space people" aboard the International Space Station.

By Gene Chapline,* K5YFL

Who are the "space people"? We humans of planet Earth. We haven't always been space people. In fact, only recently in our long history on Earth have we become them. When the International Space Station (ISS) became permanently occupied in October 2000, we became a species that probably will always have some of its members away from the home planet. That fact, its implications and consequences, must now be part of our children's school curriculum, because we are no longer just sending our youth out into the world, but rather into the universe. We are even planning for some of them to become future members of the away team—that is, the team away from planet Earth.

How do we prepare our youth for this future? Presently there exists an exciting way to interest our children in their future in the universe. By having students in classrooms around the world talk directly to crewmembers on board ISS via amateur radio, we are opening the window to space.

This is being done four to six times a month, and there is no lack of attention from students. Immediately after one such contact, an elementary school principal in Texas beamed! Fighting a lump in her throat, she said, "I think maybe we started some dreams this morning!" When students at a school in Mississippi completed a contact, their teacher exclaimed, "These students are going to have a very slow time landing back on planet Earth, and the parents are still on cloud nine." It's no secret that kids eagerly jump into learning *everything* about what excites them. As NASA's Director Sean O'Keefe, the father of three, said in March 2002, ". . . if it excites kids, that's what is going to get to the kids."

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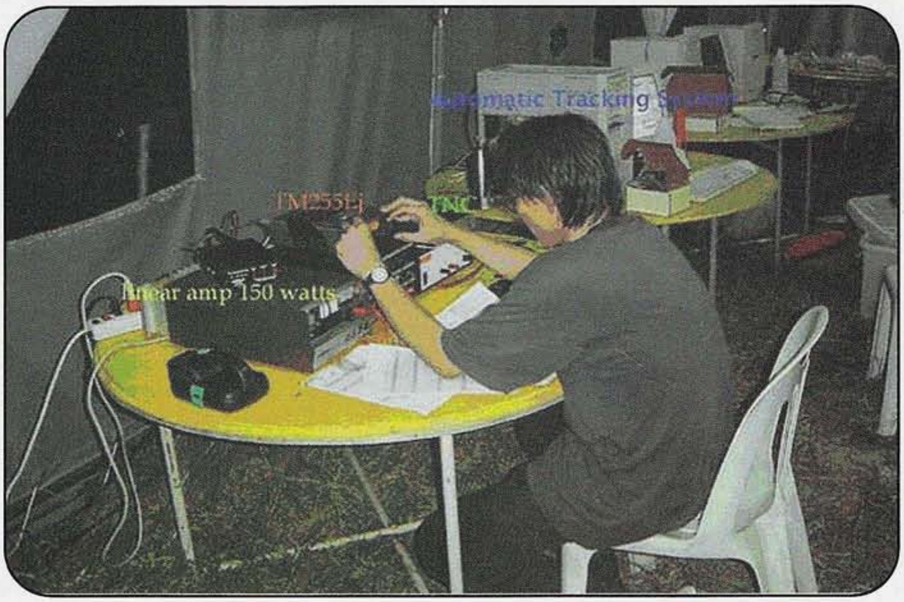

HS1RMS testing the equipment used for an ARISS attempt during the World Scout Jamboree in January 2002.

The radio contacts are being made through a program called Amateur Radio on the International Space Station (ARISS). ARISS is an international project with U.S. participation by NASA, the American Radio Relay League (ARRL), and the Radio Amateur Satellite Corporation (AMSAT-NA), a non-profit corporation. In 1996 NASA wanted a single focus for the development and operation of amateur radio on the International Space Station, and ARISS was the solution. In 1997 amateur radio organizations from eight of the 16 nations that participated in the space station program signed a memorandum of understanding, chartering ARISS. To prepare for the occupation of the ISS in the fall of 2000, the international partners then divided chores and duties. The first ARISS radio contact with a school occurred in late November 2000. Since then, ARISS contacts have been made with other schools, museums, and special events, such as the 2001 National Boy Scout Jamboree.

How does your group of kids get in line to talk to the space people? This article tells you how to put together a successful ARISS contact, taking you through a four-step process: application, preparation, the contact, and the morning after.

Application

You start with the paperwork. You have to apply. Get on the internet, go to <http://www.arrl.org/ARISS/ariss-ap.html>, print out the application form, and fill it out completely. The volunteer mentors of the ARISS Operations team need to know all the telephone numbers, e-mail addresses, and physical addresses that are requested on the form. They will have to pry them out of you later if you

Russian Cosmonaut Sergei Treschev operating the ISS amateur radio station. (Photo courtesy NASA)

don't provide them at this point. They must be able to communicate with you, especially during the last few days and hours preceding a planned ARISS contact.

When you get through the "getting to know you" part of the application, you then will encounter questions asking you about radio equipment, coordinates, and elevation. You must ask yourself, "Do I want to have a telebridge contact or a direct contact?"

Telebridge contact. A telebridge contact is easy. It's done by telephone. On either side of the telephone connection are the amateur radio stations—one on the space station and one somewhere on Earth equipped with a phone patch. The audio of the phone patch is then carried to your location by a telephone connection provided by Worldcom, Inc., which sets up the connection and picks up the tab. A moderator will talk to you and your kids over a speakerphone before and after the actual contact. When radio contact is made with the space station, you will hear the crewmember over the speakerphone, and the students can ask questions over the speakerphone. It's simple. Your only technical responsibility is to provide a speakerphone of good quality—the kind used for teleconferences. Your local telephone company should be able to give you some guidance on how to set up a good system.

Because your contact with the ISS does not depend on the spacecraft passing over your location, there is some flexibility in the scheduling of telebridge contacts. They may be scheduled at times of the day that are convenient for you and your students. However, this flexibility does not extend to days of the week, as the mission of the ISS controls this aspect of the contact scheduling.

If you opt for a telebridge contact, then skip the questions on the application that cover equipment, antennas, coordinates, and elevation. Go to the part that asks about your educational proposal.

Direct contact. A direct contact is made using amateur radio equipment set up at your location. If you are not a ham, you will need to seek the help of hams in your area, perhaps by contacting a local amateur radio club. The ARRL can advise you on how to go about this.

The amateur radio operators who participate in ISS contacts should have experience with satellite communications, and they should have the equipment necessary to accomplish a successful 10-minute contact with the space station. You should be prepared to have wires, cables, and antennas underfoot and overhead for a day or two. Everyone should be ready to be flexible, diplomatic, and able to derive fun from the special circumstances and difficulties that may be encountered. Direct contacts can be very exciting, because everyone gets to see the operation of the radio equipment, as well as make the actual contact.

The application asks you to specify times and holidays during which it will be impossible or extremely inconvenient for you to gather your kids together. Be truthful in your response, because you may find that you are assigned a pass you would rather not have when your turn for a direct contact becomes available. Time, tide, and orbital mechanics wait for no one. When it's your turn and the ISS is due to pass over your location, it's either step up or go to the end of the line. The ARISS Operations team tries to schedule contacts at reasonable hours, but unless you specify otherwise on the application, you may find yourself getting up before the chickens. If you should be assigned a dawn contact, just take some coffee, doughnuts, and breakfast tacos for everyone at the contact site. It's all part of the fun.

If you opt for a direct contact, continue filling out the application questions concerning radio equipment, antennas, coordinates, and elevation. The local ham who will be helping with the contact should fill out this section of the application. Make sure the answers are truthful, or at least will be true at the time of the contact.

Educational proposal. At the end of the application you will find a request for you to set forth your educational proposal. *Do not skip this section.* Talking to the space people is not just for the fun of it; it fulfills specific educational purposes and goals of NASA and the ARISS project. The educational proposal is extremely important. It should include specific answers to these specific questions:

1. How will you integrate the contact into the curriculum of your school or the activities of a special event sponsored by a museum or youth organization?

2. How will you involve as many grade levels as you can through essay contests, poster drawing, letter writing, and similar activities?

3. How will you involve as much media coverage as possible?

The first two questions are more important than the third. Even so, for your own planning and development of your proposal, it behooves you to answer the third question as thoroughly as possible. Media resources to consider are your local TV and radio stations, the local newspaper, educational publications, the local amateur radio club's newsletter, and amateur radio publications such as *CQ VHF, CQ,* and *QST.* You can never have too much publicity.

Upon completion of the application, send it electronically, or if absolutely necessary by mail, to the ARRL at one of the appropriate addresses given on the form. The reason for the electronic mailing is that part of the processing of the application involves converting it into an electronic form for distribution. Sending it to the ARRL already in an electronic form saves considerable time in the processing of the application.

Preparation

In perhaps 15 to 30 months you will be notified by a mentor from the ARISS Operations team that your organization's turn is approaching. (In the past, some applicants waited as long as five years.) The mentor will review the application with you to make sure that it is accurate and current. Also, he or she will answer any questions you may have.

Equipment. If you opted for a direct contact, you and the mentor will begin to make sure that the equipment and antennas, which the experienced amateur radio operator specified on the application form, really exist as an efficient ISS communications station. This must include both a primary and a backup station.

The primary station should have a 2-meter transceiver with frequency memory capable of operating in the non-standard split-frequency mode. The transceiver should feed an amplifier, putting out 80 to 150 watts of power into a 10- to 14-element circularly polarized Yagi mounted on an az-el (azimuth-elevation) rotator. The rotator must be con-

(Continued on page 66)

AMSAT OSCAR-E Project Status Update

A New LEO Satellite from AMSAT-NA

This status report about AMSAT OSCAR-E ("Echo") is an update to the presentation given at the Dayton Hamvention® last May. Articles were published in the May/June 2002 issue of the *AMSAT Journal* and the Summer 2002 issue of *CQ VHF*.

By Richard M. Hambly,* W2GPS

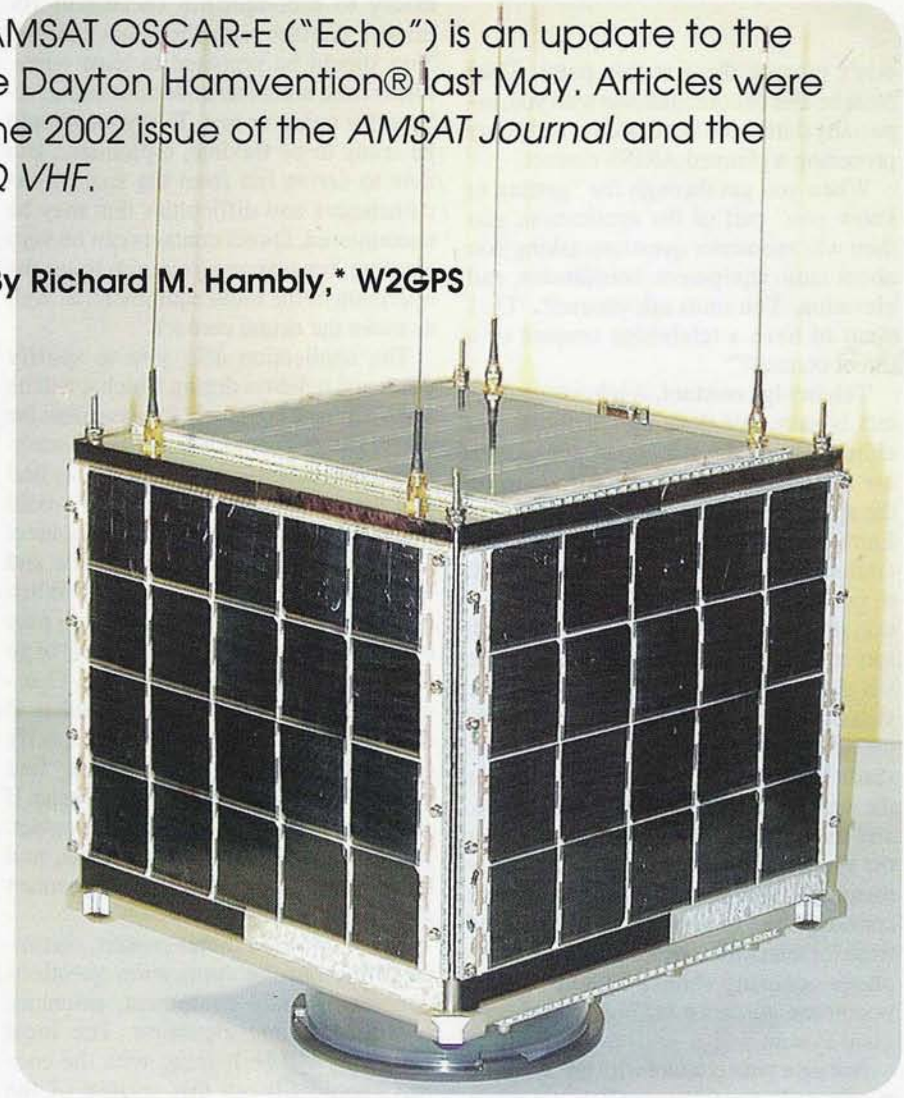

Photo A. Mechanical model of AO-E class Microsat.

Following the 2001 Annual AMSAT-NA Meeting in Decatur, Georgia, the Board of Directors met and asked Dick Daniels, W4PUJ, Tom Clark, W3IWI, and Rick Hambly, W2GPS, to review a proposal for "a new small satellite project." The team's report was presented to the board during a teleconference on January 17, 2002, and the project was approved unanimously.

In 1990 AMSAT-NA built and launched the original Microsats : AO-16, DO-17, WO-18, and LO-19. The descendants of the Microsat legacy include IO-26, AO-27, MO-30, and SO-41. Each of these Microsats has improved upon the original design, and the project team recommended that AMSAT-NA take full advantage of these improvements.

On February 8, 2002 AMSAT-NA entered into an agreement with SpaceQuest, Ltd. of Fairfax, Virginia, whereby SpaceQuest will provide AMSAT with the basic components of AO-E (photo A and figure 1) and leave it to AMSAT members to add any specialized payloads that may be desired. SpaceQuest is led by AMSAT members Dr. Dino Lorenzini, KC4YMG, and Mark Kanawati, N4TPY.

On April 20, 2002 the AMSAT Board met at SpaceQuest to see firsthand that everything was going as planned (photo B). After the tour of SpaceQuest, the board reconvened across the street in the ARRL's DC area offices, where there were presentations and an extensive review of the project. At this meeting the board agreed to postpone the launch until late 2003 in order to provide adequate time for the development of optional payloads.

The first public presentation on AO-E occurred during the annual spring AMSAT-DC symposium on May 5, 2002 at NASA Goddard Space Flight Center. The presentation was compressed significantly for the Dayton Hamvention® AMSAT Forum on May 18, 2002.

Full details of the project were published in the May/June issue of the *AMSAT Journal.* A reprint of the article appeared in the Summer 2002 issue of *CQ VHF*.

Throughout 2002 the AMSAT project team (W4PUJ, W3IWI, and W2GPS) met on a regular basis with SpaceQuest and others to review the progress of AO-E and to discuss the various optional payloads under consideration.

Features

The AMSAT OSCAR-E satellite will offer users a strong set of features even

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

before optional payloads are added. These include:

- Analog operation, including FM voice
- Digital operation, including APRS
- High downlink power
- Multiple channels, using two transmitters
- Simultaneous voice and data
- Multi-band, multi-mode receiver
- Geographically based personalities
- A true circular UHF antenna that maintains its circularity over a wide range of squint angles.

Technical Aspects

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 infrastructure of the satellite has many improvements over earlier generation Microsats, including:

- Faster and 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.

The internal subsystems were described in detail in the May/June *AMSAT Journal* article, so only a summary is presented here.

The core elements of the AMSAT OSCAR-E satellite are being provided by SpaceQuest. This relationship with SpaceQuest provides the basic platform on which AMSAT can build using optional payload trays and external modifications. 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
- A basic set of receivers and transmitters
- Antennas
- Space for optional payloads

Physical Structure

AMSAT OSCAR-E is made up of a stack of five machined aluminum modules, each measuring 23.5 mm × 23.5 mm. The height of the stack is 24.5 mm. One module is empty, and it is to be used by an AMSAT-supplied payload. Internal to the module is 200 mm × 220 mm of space with rounded corners. The height is about 50 mm. Photo C shows a typical Microsat structure.

Active Magnetic Attitude Control

Originally an optional payload, the active magnetic attitude control has replaced the passive system as one of the core satellite subsystems, which will allow the spacecraft to be oriented to favor communications in the Northern Hemisphere or the Southern Hemisphere at different times.

This attitude control system replaces the permanent rod magnets with semi-permanent electromagnets. Electronic circuits are required to polarize and to condition the magnetic rods. The Earth-pointing direction is on the order of ±20 degrees in the temperate zones, varying with orbital inclination. As this article is being written, Lou McFadin, W5DID, has the stabilization rods for winding. Doug Sinclair is designing and building the electronics to control magnetization of the rods.

Central Processor Hardware

AMSAT OSCAR-E includes an improved Integrated Flight Computer (IFC) recently developed by Lyle Johnson, WA7GXD. The improved IFC uses a new six-layer circuit board and includes a flight-proven, low-power NEC V53A processor Central Processor Unit (CPU) that runs at 30 MHz, three times faster than the previous design. In addition to its 1 MB of error detecting and correcting (EDAC) memory, it has 16 MB of RAM and 16 MB of Flash memory for mass storage.

The IFC board includes two GMSK modulators that can operate up to 115 K baud and six GMSK demodulators that can

(Continued on page 72)

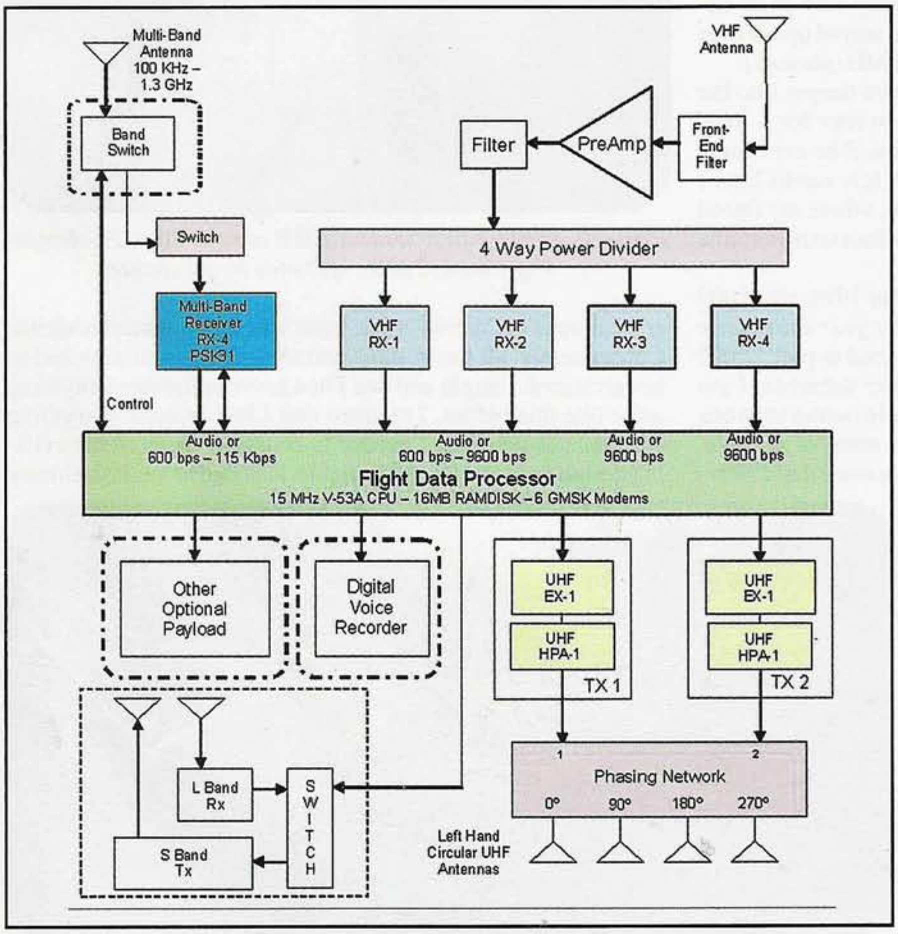

Figure 1. Conceptual block diagram of the AMSAT OSCAR-E spacecraft.

How to Build
An Alaska-Style EME Array

Most of us take our hobby seriously. Some, like KL6M, take it to a serious extreme. There is something about "Build it and they will work you." What can you expect, however, from the biggest state in the Union?

By Mike Melum,* KL6M

Obsessed! That's what my wife calls me. It all started in early 1999 when I decided to put up four 12-element Yagis on 2 meters with a 160-watt brick just to make one or two QSOs with a couple of the "big guns" on 144-MHz EME. I only wanted to make one or two QSOs so I could say I worked EME.

After many hours of studying operating procedures and how to interpret Moon propagation data, the contacts came fairly easily. By that time I was so hooked that there was no escape. Two months later I had 16 × 12-element Yagis on 432 MHz. This was mounted on a flimsy 10-foot TV-antenna-type tripod, using a light-duty Alliance HD-73 for azimuth and a U-100 for elevation. Very careful balancing of the array and good tie-downs for high winds yielded an antenna that stayed up for over a year, which brought in 57 QSOs on 432 EME (photo 1).

This was still not enough. I needed to delve deeper into the depths of EME. I had asked a friend who works for a local telecommunications company to let me know if he ever came across a surplus dish, maybe a 15 footer. A few weeks later I was invited to tour the company's excess lot, where my friend said I could have my choice of a 16- or a 30-foot transportable dish on a trailer. There was no choice!

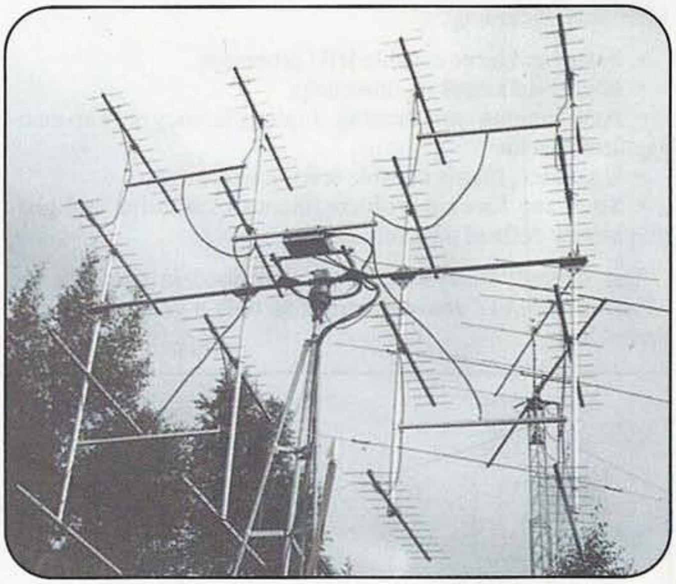

Photo 1. KL6M's first serious EME array—16 × 12-element Yagis on 432 MHz. (Photos by the author)

I got the 30-foot dish and trailer in September 1999, all 17,000 pounds of it. One note about safety: *Don't let your enthusiasm get the best of you and do anything stupid!* I tried to pull 17,000 pounds of antenna and trailer with my half-ton Suburban. I got almost all the way home before the trailer tried to outrun my truck on a small hill. I jack-knifed and had the scare of my life. Somehow I managed to survive without tipping over (thank heaven there was no traffic), but the Suburban received some permanent scars. I was very lucky. That little mishap brought me back down to earth, and I spent the rest of my time on the project aware that this was no ordinary monster I was playing with.

The Planning Stages

I spent all winter engineering a way to mount and rotate the dish, and on tower designs, az/el positioning designs, feed designs, and many other things. The transportable dish was not made to move freely. It was designed to point at one satellite for special applications of wide-band satellite communications. Consequently, all the azimuth and elevation positioning had to be fabricated. I might add that I had never undertaken anything quite like this before. I realized that I had to keep everything as simple as possible. I needed to re-use as much of the existing design and hardware as possible. I needed to retain the heavy

Photo 2. Assembling the support for the dish.

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e-mail: <melum@customcpu.com>

Photo 3. A 750-pound work of art, thanks to NL7RT.

Photo 4. How one man does a two-man job—attaching the crane bearing to the elevation platform.

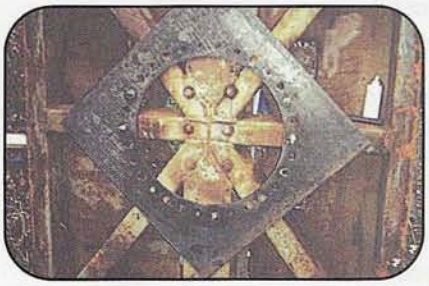

Photo 5. The top side of the az-el mount showing the two steel plates which form the top of the "sandwich."

Photo 6. Welding back together the 2 × 6 beams.

Photo 7. Another view of the professional welder working on the 2 × 6 beams.

steel structure if I planned to put together a system that would survive the extreme environment of Alaska. This meant I needed to support and rotate a mass of steel and aluminum weighing 7000–8000 pounds.

I immediately started searching for surplus materials for the project. The best find of all was in a junk yard behind a crane repair shop. I found a 30-inch, 300-pound bearing that had been removed from a crane because of failure to meet tolerance. Two cases of beer later, it was in the back of my truck. This bearing was the key to pulling off this whole project.

I also pondered the foundation design. I started out with the concept of using a large steel pipe rack with a 4-foot face and 6-inch steel legs, along with pouring a large block of concrete that was probably going to have to be at least 10 yards. Among the many dozens of folks I met in the construction, steel-fabrication, heavy-equipment, and junk business, a number of them suggested the concept of

(Continued on page 75)

Getting Started on 2-Meter EME To Work Lots More DX

Through recent developments in technology, contacts using the Moon as an RF reflector are possible even with a modestly equipped station. K6PF describes some of the associated innovations and challenges.

By Bob Kocisko,* K6PF

Living here in southern California on the west coast of the United States presents some geographical challenges for working DX on 2 meters. Of course, this applies to living anywhere when operating 2 meters DX. Propagation via the direct path, tropospheric and meteor scatter, along with sporadic-*E* have distance limitations. Achieving WAS (Worked All States), WAC (Worked All Continents), and DXCC awards is impossible when these are the only propagation modes being utilized on this popular VHF band.

With a half-million-mile round-trip path, EME (Earth-Moon-Earth) or moonbounce is the ultimate DX. Many weak-signal (CW and SSB) operators already have a station capable of limited 2-meter EME operation. The objective of this article is to inspire and motivate many hams who are already working, or wish to start working, weak signals on 2 meters to try EME in order to work a lot more DX, including many more grids, states, and countries. In addition, the tools needed to be successful with 2-meter EME will be presented. Let's get started!

The Nature of EME Basic Technical Aspects

If two stations have adequate equipment and both can see the Moon at the same time, they should be able to make contact via EME. However, several attempts may be required to achieve success. Signals are very weak echoes reflected from the Moon's surface. Typically, they are at the noise level, or even beneath the noise, occasionally rising from the noise for brief periods. Let's look at some of the technical factors that affect EME communications, particularly as they relate to 2 meters.

Polarization. The polarization of EME signals is changing constantly, which can result in no signal being heard or very deep QSB. There are two basic types of polarization:

Spatial Polarization—Spatial polarization is a function of geometry. The wavefront of an EME signal between two stations can be rotated in polarity. The amount of rotation depends upon the relative longitudes of the two stations and the position of the Moon in the sky. Most computer Moon tracking programs calculate the amount of spatial polarization and can show the optimal times to arrange skeds (schedules).

Faraday Rotation—The Earth's magnetic field causes the wavefront from the radio signal to rotate in polarization several times as it passes through the ionosphere on the way to the Moon and back, causing a cyclic fading in the received signal. At 2 meters the fade period between signal peaks (i.e., the time to rotate through 90 degrees) is about 30 minutes. At this time Faraday rotation cannot be predicted by computer software.

The adverse effects of spatial polarization and Faraday rotation can be minimized by using either fully rotatable, linearly polarized antennas—such as the collinear array at VE7BQH, which can be rotated along the x, y, and z axes—or more simply, by using cross-polarized (x-pol) Yagis, such as those used by K6PF and many other stations. Successful contacts can be made by two linearly polarized stations simply by "waiting it out" or by trying another time if the combination of spatial polarity and Faraday rotation is not favorably aligned.

Libration Fading. As viewed from Earth, the Moon appears to rock back and forth on its axis. This motion is called *libration.* The path lengths of signals backscattered from the various parts of the Moon's irregular surface are always changing, leading to quite rapid flutter. This flutter causes brief fading and enhancements of the EME signal by several dB. On 2 meters a fade or enhancement can last for up to a couple of seconds. When a brief signal enhancement occurs, this can help the small or marginal stations make contacts that otherwise might not have occurred.

Doppler Effect. Because the Moon moves in relation to Earth, there is a Doppler shift on EME signals. On 2 meters it is *approximately* +350 Hz at moonrise, 0 Hz when the Moon is overhead, and –350 Hz at moonset. Doppler shift increases with increasing frequency. This shift in a received signal needs to be taken into account by using an RIT (or clarifier) or separate VFO when listening for your own echoes or for stations on a scheduled frequency. When listening for a station, a good operating practice on 2 meters is to tune about 750 Hz on both sides of the expected receive frequency, which is the sked frequency +/- the Doppler shift. It also is best to use a wider receiver filter, such as 500 Hz, when tuning initially. Once a station is located, the receiver filters can be narrowed as necessary to improve the signal-to-noise ratio.

Sky Noise (Noise Temperature). As the Moon travels in its orbit during the course of a 28-day lunar month, it passes in front of various celestial bodies, such as our Sun and other stars and planets, which generate RF noise. Some sources are noisier than others, and any additional noise further degrades communication along the EME path.

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Most small 2-meter antenna arrays used for EME have a half-power beamwidth of approximately 30 degrees for a single Yagi, to about 15 degrees for a four-Yagi array. Because the Moon subtends an arc one-half degree as seen from Earth, the antenna is viewing a large portion of the noisy sky around the Moon.

Sky noise, or noise temperature, is measured in degrees Kelvin (K). On 2 meters sky noise varies between a low of about 175° K (rare) to over 3,000° K. The lower the better, and if it's much over 400° K, the smaller stations are not likely to hear or be heard even by the bigger stations. Noise temperature goes down in proportion to an increase in frequency.

Path Loss. During the lunar month, the Moon travels in a slightly elliptical orbit with a distance to Earth of approximately 221,500 miles at perigee (point closest to Earth) and about 252,700 miles at apogee (point farthest from Earth). This distance results in an about 2.5-second delay of EME echoes. On 2 meters the round-trip path loss is about 251.5 dB at perigee and 253.5 dB at apogee, and the path loss increases with frequency. This 2-dB difference between perigee and apogee is a significant factor in the potential for success by a small station. Therefore, most skeds are set up around perigee.

Degradation. This is a "figure of merit" calculation performed by most computer Moon tracking programs. It calculates the degradation (dgrd) in the EME signal-to-noise, in dB, at a particular Moon position and date. It compares the excess sky noise in the direction of the Moon plus the Earth-Moon separation distance in relation to the lowest possible sky noise along the Moon path and the absolute minimum perigee distance. During a monthly lunar cycle, this factor can vary by more than 13 dB at 2 meters. Small stations will have the greatest chance for success on 2-meter EME when degradation is less than 2.5 dB, and the lower the better.

Declination. This is the position, measured in degrees above or below the equator, at which the Moon appears in the sky. The maximum positive, or northerly, declination averages around +23 degrees. The best EME operating conditions for northern latitude stations are found at the highest declinations, because that offers the longest possible common operating window between two stations in the Northern Hemisphere (such as between the U.S. and Europe or the U.S. and Japan). Also, the sky noise is typically lower at higher declinations. As the Moon's declination passes through 0 degrees (directly over the equator) and into negative declination, it rises farther and farther to the south, and the operating windows for northern latitude stations diminish. *(Editor's note: The highest and lowest declination days are listed in the "Quarterly Calendar of Events" found in each issue of* CQ VHF, *and also each month in the "VHF Plus" column in* CQ *magazine.)*

Ground Gain. On 2-meter EME small stations in particular, with or without elevation of their antennas, possibly can benefit from up to 6 dB of additional antenna gain when the antennas are pointed on the horizon. Reflections from uncluttered flat ground in front of an antenna cause peaks and nulls at certain elevation angles, which can result in up to 6 dB of additional antenna gain. This assumes that one does not have a marked increase in terrestrial noise level on the horizon. Ground gain is potentially useful when the Moon is from 0 degrees up to 10 to 12 degrees on rise and set.

Moon Phases. Of the four phases of the Moon (new Moon, first quarter, full Moon, and last quarter), new Moon plus or minus one or two days should be avoided because of Sun noise. A full Moon, with stable nighttime conditions, may be favorable. When the Moon is visible during the daytime hours, ionospheric disturbances caused by the Sun can degrade EME conditions. Therefore, nighttime conditions usually are better.

Activity or Sked Weekends. Usually there are only a few days out of every month when EME conditions are favorable. Refer to the accompanying chart and related comments page at the end of this article, which is labeled "W5LUU Weekend Moondata—2003." This chart will tell you which Sundays of each month have the best possible conditions, and therefore the best chance for success. Activity or sked weekends are held during these times. *(Editor's note: These days are also listed in* CQ VHF*'s "Quarterly Calendar of Events" and in* CQ*'s "VHF Plus" column.)*

Best Time To Operate. The best time to operate 2-meter EME is when perigee, high northerly declination (for northern latitude stations), minimal sky noise, lowest degradation, and evening hours all coincide. However, this optimal situation happens only every nine years when the Moon is as close to the Earth as it ever gets. This last occurred in

1999–2000. During the balance of this nine-year cycle, maximum declination and perigee drift apart. Choosing a time when sky noise (noise temperature) is the lowest is usually the best compromise. The next time the degradation should be the lowest, and therefore EME conditions should be at their best, will be during 2007–2010. However, many very good EME contacts take place throughout the entire nine-year cycle.

What Type of Station is Needed for 2-meter EME?

First, let's look at the minimum station that could work some of the "big gun" or "larger" stations, assuming that many of the variables discussed in the preceding section are favorable. We're referring to CW EME, where code speeds are usually in the 10- to 15-wpm range, with some stations sending up to 20 wpm. Some of the bigger stations occasionally can complete contacts via SSB, but FM is not used. Also, JT44, a digital mode of communications, will be discussed briefly later. For now, assume CW.

Minimum Station: *Antennas*—A single Yagi horizontally polarized (not circular) with about 12.5 dBd gain (or about 14.6 dBi gain) with an azimuth rotator should be sufficient. Having the ability to elevate the antenna will give a lot more flexibility to when you can operate along with a lot of moontime. With no elevation, you will have only about one hour of moontime at rise and set along with the potential for ground-gain enhancement. Depending upon your QTH, however, terrestrial noise may be worse with the antenna on the horizon. Don't expect to hear your own echoes with this minimum station.

Receiver, Transmitter, and Power—Any reasonably good 2-meter receiver and transmitter or transceiver that can produce CW can be used. Either a receiver RIT (or clarifier) or split VFO will be needed to be able to compensate for Doppler shift. A narrow IF filter (such as 500-Hz bandwidth) and/or internal or external DSP capability will help improve the signal-to-noise ratio of any weak EME signal heard. A "brick" power amp with at least 150 watts output is the minimum power needed.

Preamp and Feedline—A low noise preamp with a noise figure of less than 1.5 dB is needed. For 2 meters it can be mounted in the shack, as long as good low-loss feedline is used. The shorter the length of feedline, the better. With the preamp in the shack, low-loss feedline will minimize the degradation of the receiver noise figure and maximize the amount of transmitted power getting to the antenna. Preferably, the feedline should be less than 50 feet of Belden 9913, LMR 400 or comparable. For longer runs, consider using heliax. RG-58 should never be used, and RG-8 probably shouldn't be used because of losses. Ideally, the preamp is mast mounted at the antenna. It needs to be protected from transmitting into it, either via internal RF sensing and relays when lower power levels are being used, or with a sequencer when running higher power levels.

Tracking the Moon—A computer running one of the many commercially available or shareware Moon tracking programs will be needed. Examples include "Skymoon" by W5UN, "Z-Track" by N1BUG, "MoonSked" by GM4JJJ, "Tracker" by W7GJ, and "EME Planner" by VK3UM (see reference section). These programs will tell you when conditions are optimal for EME, as well as when you and another station have a common Moon window and good polarity.

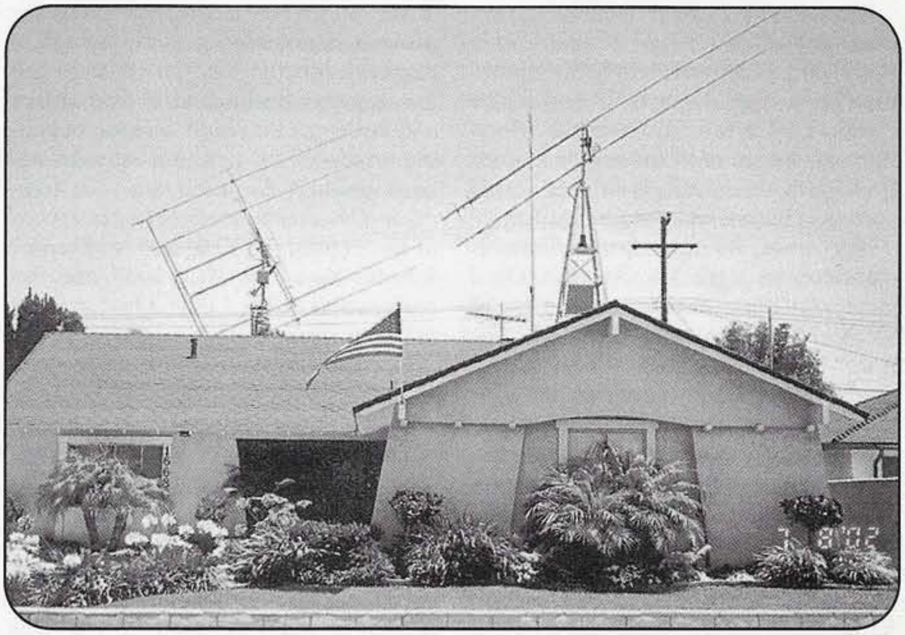


Photo A. The antennas at K6PF.

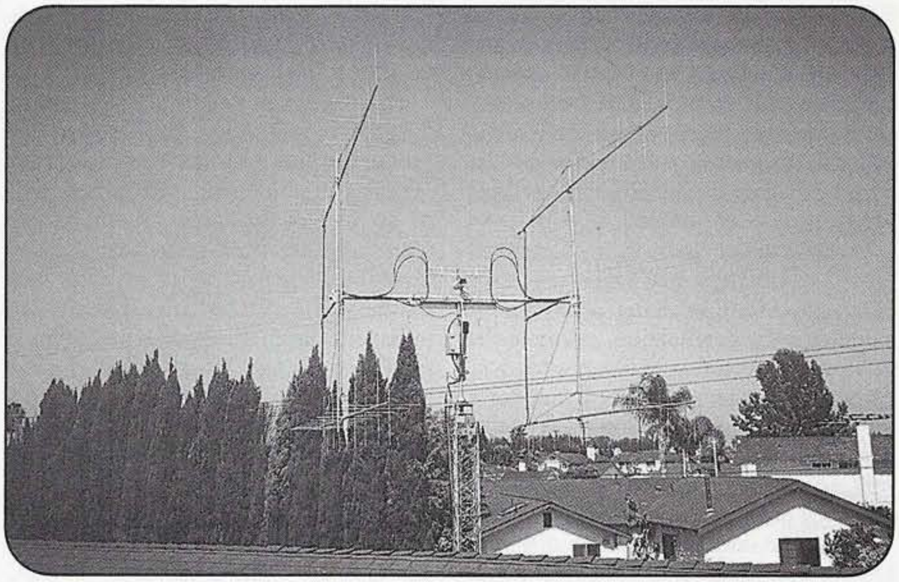


Photo B. The EME array at K6PF consists of four x-pol Yagis with a mast-mounted preamp and relays and TV camera.

Whom Can You Work With A Minimum Station? This author worked 15 initial stations on 2-meter EME during a one-year period using a single horizontally polarized 13-element Yagi with about 12.5 dBd gain (KLM 13LBA) with azimuth and elevation rotators. A Yaesu FT-726R transceiver, Timewave DSP-59+, and TE Systems "brick" with internal preamp, running about 180 watts output, were used. TE Systems amps for both 2 meters and 70 cm, along with an Astron power supply, were mounted in a weatherproof box at the base of a 9-foot roof-mounted tower. This arrangement kept the feedline loss among the power amp, the preamp, and the antenna to a minimum. All stations were worked during either 30- or 60-minute skeds.

The following is a list of some of the stations worked by K6PF and the stations' current antenna configuration. You may want to try to arrange skeds with some of them, because all of them are either "big guns" or at least "larger" stations.

K5GW (48 Yagis)
KB8RQ (8 Yagis)
VE7BQH (384-element collinear)
K1CA (8 Yagis, x-pol)
W5UN (32 Yagis)
HB9Q (8 Yagis)
IK3MAC (30 Yagis)
K9MRI (8 Yagis)
F3VS (24 Yagis horiz. and 8 vert., no skeds)
KJ9I (8 Yagis, x-pol)
SM5FRH (24 Yagis)
DL5MAE (8 Yagis)
W5LBT (24 Yagis)
OK1MS (8 Yagis)
I2FAK (24 Yagis)
AA4FQ (8 Yagis)
SM5BAE (24 Yagis)
SM2CEW (6 Yagis, x-pol)
W7GJ (16 Yagis)
WØHP (6 Yagis)
WA9KRT (16 Yagis)
K2GAL (4 Yagis, 21elements on 52-foot booms)
WØRWH (16 Yagis)
W7FG (4 Yagis, 20 elements)

More Advanced Station: The following type of station will have sufficient capability to allow you to hear your own echoes at least some of the time, and to hear, as well as regularly work via skeds or randomly, CW stations of similar size as long as EME conditions are reasonably favorable. On occasion, you may also be able to work one or two Yagi stations.

Antennas—Four Yagis with booms of at least three wavelengths long are needed. Five-wavelength booms are better. Full azimuth and elevation capability is required, and Yagis should be either horizontally polarized or cross-polarized. Arrays that are x-pol configured will result in more contacts within a given period of time, because Faraday rotation will be less troublesome. Antenna gain should be greater than 18 dBd (20.1 dBi).

Receiver, Transmitter, and Power—A good HF transceiver and 2-meter transverter are preferred, although a quality 2-meter or multi-mode transceiver will suffice. Minimum power should be in the 800- to 1000-watt range. More power is better, so running the legal power limit is best.

Preamp and Feedline—A low-noise GaAsFet mast-mounted preamp should be used with a sequencer to prevent "burning out" the GaAsFet during transmit. Usually, separate transmit and receive feedlines are used, and a high-quality transmit feedline, such as 7/8-inch heliax, is used to minimize the loss of transmit power arriving at the antennas. The feedline from the preamp output is less critical, but an overall receive-system noise figure of about 1.0 to 1.5 dB is a good design goal.

Computer—In addition to running a Moon-tracking program, programs such as "FFTDSP" by AF9Y, "DSP Blaster" by K6STI, or "Hamview" or "Spectran" by I2PHD and IK2CZL can help you locate weak signals (see reference section).

Photo A shows the antennas at K6PF. The two antennas on the 9-foot roof-mounted tower include a KLM 13LBA for 2 meters and a KLM 30LBX for 70 cm. The box on the tower houses an Astron power supply and TE Systems amps for 2 meters and 70 cm. Both antennas are horizontally polarized and have azimuth and elevation capability. The rear antennas include four M^2 2-meter XP20s for 2-meter EME. These are x-pol antennas with elements in the horizontal and vertical planes and the ability to switch between them. Photo B is a close-up of the four x-pol Yagis at K6PF.

Selecting the Best Operating Times and Setting Up Skeds

When starting out on 2-meter EME, especially if you are running a minimum-size station, try to concentrate on weekends that show conditions as "Good" or "Very Good" on W5LUU's Weekend Moondata chart, as long as it's not within one or two days of a new Moon because of Sun noise. Skeds can be run any time, not just on weekends, as long as a common Moon window exists. With any of the Moon tracking programs mentioned, it's helpful to look at conditions for several days on either side of the best Sundays on W5LUU's chart. This will identify the days that offer optimal EME conditions. Often these occur on weekdays.

There are several ways to go about proposing and setting up skeds. They include posting a message on Moon-Net checking into the 2-meter EME net on weekends, contacting a potential sked station directly via e-mail, or posting a message in real time on the EME Logger. The EME Directory, which is maintained by W5LBT, also can be helpful (see references). Moon-Net is the main reflector being used for 2-meter EME. Go to <http://www.nlsa.com/nets/Moon-net-help.html> for posting and subscription instructions. You might want to post a message on Moon-Net saying, for example, that you're just starting out on 2-meter EME and you are looking for skeds with some "big guns." See who responds. Be sure to mention your station capabilities, especially antennas, power, and whether you have elevation and are limited to your moonrise and moonset.

If you are not sure when to try a sked, ask any station replying to your posting for suggestions. "Big gun" and "larger" stations have experienced operators who are always looking for the opportunity to work a new station for a new "initial" contact. They appreciate the challenge of working small stations, and you will find them very helpful if you're just getting started. In fact, you will find many members of the EME community ready to help you with answers to any questions that you post on Moon-Net.

Another way to arrange skeds is by checking into the 2-meter EME net held every Saturday and Sunday at 1600 UTC when daylight savings time is in effect, and at 1700 UTC when standard time is in effect. The net is on 20 meters (14.345 MHz). You can e-mail Brian, W3EME, at <w3eme@mtwirefree.net> and request his help to arrange some skeds for yourself. Brian is excellent at determining times when conditions potentially are most favorable. Again, be sure to let him know your station setup.

The EME Logger at <http://dxworld.com/emelog.html> is an excellent real-

Moondata Update 2003 and Related Comments

By Derwin King, W5LUU

While a number of factors affect EME communications, the distance from the earth to the moon and the cosmic noise temperature in the direction of the moon are predictable, cyclical variables that set the basic day to day quality of the earth-moon path. Other things being equal, best EME conditions occur when the moon is: (1) at the best possible perigee and (2) near the RA and DEC. of the coldest sky along its path. Signal to noise degradation (DGRD) from these two variables, in dB referenced to the best possible, are tabulated on the accompanying page along with other pertinent data. These are for each Sunday at 0000 UT to provide a guide to the 144 MHz and 432 MHz weekend conditions in 2003.

In 2003 the average DGRD continues to increase as moon perigee occurs at increasing RA, and southern declinations where the sky noise (temperature) is generally higher. This trend will continue for the next 2 to 3 years as the position of perigee vs. RA proceeds along its near 9-year cycle. DGRD will be very low again in 2007–2010 as perigee occurs within a few hours RA of cold sky. Meanwhile don't give up. There is one *very good* weekend monthly from Jan.–May. In addition there are two good ARRL contest weekends: Oct. 18–19 and Nov. 15–16. We should quickly lay claim to these for the EME contest. In addition to weekends, there are many *good* to *excellent* days during the week, especially in Jan.–June 2003. Enjoy and good luck.

DEC. (deg): Moon declination north and south (–) of the equator. This is cyclical with an average period of 27.212221 days. The maximum monthly declination is also cyclic with a range of 18.15 to 28.72 and a period of about 19 years. Next maximum is in 9/2006.

RA (hrs): Right ascension in hours. East-west position of the moon against the sky background. Average period of RA cycle is 27.321662 days, but it can vary by a day or so.

144 MHz Temp (K): 144 MHz sky (cosmic) noise in direction of moon expressed as temperature.

Range Factor (dB): The additional EME path loss, in dB, due to an earth-to-moon separation distance greater than the absolute minimum (348,030 km surface-to-surface). Varies from a low (0 to .7 dB) at perigee to as much as 2.43 dB at apogee.

DGRD (dB): The 144 and the 432 degradation in EME signal to noise, in dB, due to the excess sky noise (assuming a very narrow beam antenna) in the direction of the moon plus earth-moon separation distance at the indicated moon position and date. During a monthly lunar cycle this factor can vary by more than 13 dB at 144 and 8 dB at 432. DGRD is referenced to the lowest possible sky noise along the moon path, to a system noise temperature of 80 K at 144 and 60 K at 432 and to the absolute minimum perigee distance. 144 and 432 DGRD are equally affected by EME distance, but at 432 the sky noise varies less.

Moon Phase: Shows new moon (NM) and full moon (FM) along with the number of days (d) or hours (h) before (–) or after (+) these events. AT NM sun noise can be a problem, while at FM the stable nighttime conditions can be advantageous.

Conditions: Summary of EME conditions as controlled by DGRD at 144 MHz and NM. Conditions may be worse, due to ionospheric disturbances, but not better than indicated. In general, 144 MHz DGRD under 1.0 dB is considered excellent, 1.0 to 1.5 is very good, 1.5 to 2.5 is good, 2.5 to 4.0 is moderate, 4.0 to 5.5 is poor, and over 5.5 is very poor. New moon can make conditions very poor.

W5LUU WEEKEND MOONDATA – 2003

For Sundays at 0000 UT

Date 2003	Dec. deg.	RA hrs.	144 MHz Temp. K	Range Factor dB	DGRD, dB 144 MHz	DGRD, dB 432 MHz	Moon Phase	CONDITIONS
Jan 05	-21.9	21.0	331	1.37	3.6	1.9	NM + 2d	Moderate
12	11.3	2.3	348	2.23	4.6	2.8		Poor
19	**23.1**	**8.6**	**186**	**1.08**	**1.4**	**1.2**	**FM + 1d**	**VERY GOOD**
26	-14.1	14.8	405	0.73	3.7	1.5		Moderate
Feb. 02	-19.6	21.6	341	1.55	3.9	2.1	NM + 13h	Moderate
09	14.5	2.9	363	2.23	4.8	2.9		Poor

time site to monitor and to arrange skeds. Because of the limited length of message, you can post on this logger, which is probably not the best place to "get your feet wet" in setting up skeds. However, it is an excellent place to go to find out who's on at any given time so you can do some listening.

An excellent shareware program with which to become familiar is SKD 87, used by Lionel as net control and by many EME operators. It can be downloaded from AF9Y's website (see references). Usually, one or more files used by SKD 87, such as "vhfsched.skd," are updated weekly and distributed by W3EME. This program is very useful for setting up skeds, because it identifies a common Moon window when spatial polarity is best, and it also helps prevent frequency and time conflicts with other stations' skeds. SKD 87 also has a feature where you can view all stations having skeds on 2 meters during a given period of time. This feature provides an excellent source of stations to listen for during your common Moon windows.

Let's look at an example of how K6PF, from his QTH, would use SKD 87 to determine when the best time would be to propose a sked with I2FAK, who uses 24 Yagis, and with W5UN, who uses 32 Yagis. Assume, for the moment, that K6PF does not have elevation and therefore is limited to operating only during his moonrise and moonset (say, Moon elevations between 0 and 12 degrees). Using either W5LUU's Moondata chart or one of the Moon tracking programs mentioned, it is determined that conditions look very favorable on January 19 and 20, 2003. K6PF's moonrise on March

16	**21.1**	**9.2**	**172**	**0.84**	**1.0**	**0.8**	**FM**	**EXCELLENT**
23	-18.2	15.5	455	0.70	4.1	1.6		Poor
Mar 02	-16.8	22.1	269	1.78	3.3	2.1	NM – 1d	Moderate
09	17.6	3.4	359	2.26	4.8	2.8		Poor
16	**18.9**	**9.7**	**185**	**0.74**	**1.1**	**0.8**	**FM – 2d**	**VERY GOOD**
23	-21.4	16.2	588	0.55	4.9	1.7		Poor
30	-13.5	22.7	244	1.97	3.2	2.3	NM – 3d	Moderate
Apr 06	20.5	3.9	365	2.28	4.9	3.0		Poor
13	**16.3**	**10.3**	**194**	**0.77**	**1.2**	**0.9**		**VERY GOOD**
20	-23.8	16.8	817	0.39	6.0	1.9	FM + 3d	Poor
27	- 9.8	23.3	244	2.07	3.3	2.4		Moderate
May 04	22.9	4.6	417	2.25	5.3	3.1	NM + 3d	Poor
11	**13.1**	**10.8**	**206**	**0.87**	**1.5**	**1.0**		**VERY GOOD**
18	-25.3	17.5	1828	0.31	9.2	3.4	FM + 3d	Very Poor
25	- 6.0	23.9	250	2.08	3.4	2.5		Moderate
Jun. 01	24.8	5.2	490	2.16	5.8	3.2	NM + 20h	Very Poor
08	**9.0**	**11.4**	**232**	**0.94**	**2.0**	**1.1**		**GOOD**
15	-26.2	18.1	3064	0.38	11.5	4.9	FM + 1d	Very Poor
22	- 2.1	0.4	266	2.05	3.5	2.5		Moderate
29	25.9	5.9	503	2.01	5.8	3.3	NM – 19h	Very Poor
July 06	**4.4**	**12.1**	**268**	**0.94**	**2.5**	**1.3**		**GOOD**
13	-26.4	18.7	1546	0.58	8.8	4.2	FM	Very Poor
20	1.7	0.9	279	2.03	3.7	2.5		Moderate
27	26.5	6.5	417	1.85	4.9	2.8	NM – 2d	Poor
Aug 03	- 0.6	12.7	313	0.82	2.9	1.4		Moderate
10	-26.1	19.4	658	0.85	5.6	2.6	FM – 2d	Very Poor
17	5.4	1.3	293	2.05	3.9	2.5		Moderate
24	26.5	7.1	355	1.73	4.2	2.4		Poor
31	- 5.4	13.3	319	0.60	2.7	1.1	NM + 3d	Moderate
Sept 07	-24.9	20.1	372	1.11	3.8	1.8		Moderate
14	9.1	1.8	313	2.13	4.2	2.7	FM + 3d	Poor
21 .	25.9	7.6	274	1.69	3.3	2.1		Moderate
28	- 9.7	13.9	343	0.34	2.7	0.9	NM + 2d	Moderate
Oct. 05	-22.9	20.9	333	1.29	3.5	1.9		Moderate
12	12.7	2.3	345	2.23	4.6	2.8	FM + 2d	Poor
19	**24.8**	**8.3**	**203**	**1.73**	**2.3**	**1.9**		**GOOD**
26	-13.3	14.4	379	0.13	2.8	0.8	NM + 11h	Moderate
Nov 02	-20.0	21.6	339	1.34	3.7	1.9		Moderate
09	16.1	2.9	364	2.31	4.9	2.9	FM	Poor
16	**22.9**	**8.9**	**171**	**1.79**	**1.9**	**1.8**		**GOOD**
23	-16.5	15.0	414	0.08	3.1	0.8	NM – 23h	Moderate
30	-16.8	22.2	266	1.29	2.8	1.7		Moderate
Dec 07	19.2	3.5	358	2.34	4.8	2.9	FM – 2d	Poor
14	**20.2**	**9.5**	**183**	**1.77**	**2.1**	**1.7**		**GOOD**
21	-19.5	15.5	453	0.21	3.6	1.1	NM – 2d	Moderate
28	**-13.4**	**22.7**	**244**	**1.20**	**2.4**	**1.5**		**GOOD**

15 is 2314 UTC, and on March 17 it is 0024 UTC. Be sure your computer clock is set to UTC time when running these programs. These dates are chosen because degradation is very low (less than 1.3 dB) and declination is reasonably high. Also, these dates are two to three days before full Moon.

Because skeds usually start either on the hour or on the half-hour, SKD 87 shows us that a sked with I2FAK on March 15 at 2330 UTC will have good spatial polarity, and the Moon's elevation during a 30-minute sked will be during K6PF's moonrise. SKD 87 also shows information about I2FAK, such as his sked frequency (144.061 MHz), name, grid, equipment, e-mail address, etc. Similarly, a sked with W5UN on March 17 at 0030 UTC looks favorable on his sked frequency of 144.041 MHz.

Armed with this information, K6PF then may choose to e-mail both stations directly to propose a sked. For example, an e-mail to I2FAK may say:

Hello Franco,

I'm just getting started on 2-meter EME, and I am running 180 watts to a single Yagi (12.5 dBd gain) with no elevation. I would like to propose a sked with you for March 15, 2003 during my moonrise, starting at 2330 UTC and running for 30 minutes on 144.061. I2FAK to start with two-minute sequences. Would you be available for this proposed sked?

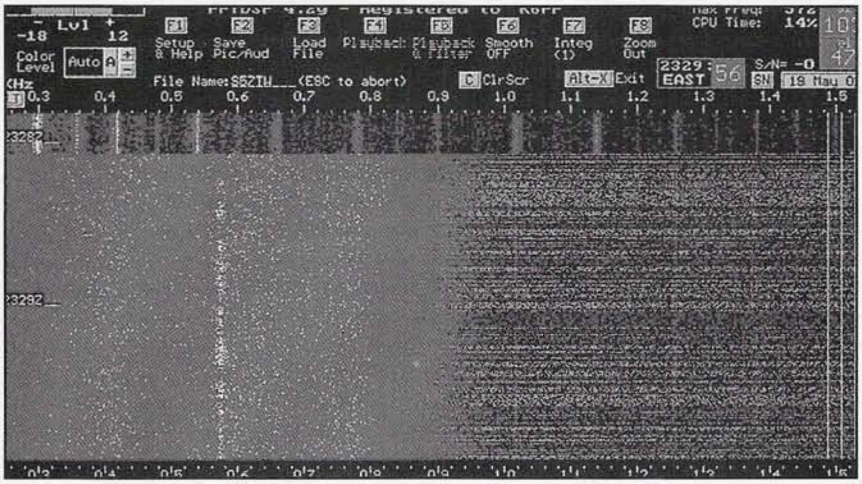
73, Bob, K6PF

Be sure to propose skeds sufficiently in advance to allow time to work out the details via e-mail.

When K6PF actually runs this sked, he will transmit on the sked frequency of

Sample FFTDSP Display

As an illustration of the wide range of EME signal strength, a sample FFTDSP display is shown here. The signal was received at K6PF using the four x-pol Yagis, an FT-726R transceiver with a 600 Hz CW filter, and a DSP-59+ with fairly wide 250- to 300-Hz audio filter. The signal-to-noise ratio on the display is referenced to a 100-Hz bandwidth.



S57TW (four 4-pol Yagis): The signal peaked at 11 dB but averaged about 6 dB S/N with lots of QSB. This type of signal can be copied, although it may take more than one sequence to copy complete callsign.

144.061 MHz. It is during his moonrise, so he will need to listen about 350 Hz higher because of Doppler shift. Actually, he will tune about ±750 Hz around the expected receive frequency (sked frequency + Doppler shift) to listen for I2FAK. The Moon tracking program that will be running during your skeds will tell you the amount of Doppler shift as well as the Moon's position in azimuth and elevation.

Operating Procedures for 2-meter EME

Skeds are usually run for 30 minutes, but 60 minutes is reasonable when a minimum-size station is involved. Sixty minutes allows for at least one complete cycle of Faraday rotation. Sequences are typically two minutes for skeds and one minute when working stations on random, although some operators prefer one-minute sequences even for skeds. Random contacts are a challenge for a small station. Just be sure that both stations agree ahead of time on both the sked duration and sequence length.

By convention, the easternmost station starts if the sked begins on the top of the hour, and the westernmost station begins on the half-hour. In the example of the sked between K6PF and I2FAK starting at 2330 UTC, I2FAK is the eastern station and K6PF is the western station. Therefore, I2FAK would transmit during the first two-minute sequence, because the sked starts on the top of the hour. It's important that your clock is set accurately when running skeds so that both transmit and receive sequences are accurate. Remember also that the mode is CW, and you will want to use a code speed in the 10- to 20-wpm range, which is the optimum speed considering conditions over the EME path, especially libration fading.

A "XMIT/RCV Sequence Sheet" available from W5UN's website is included at the end of this article. This is already set up for two-minute sequences. It is recommended that you go to this website and download a good-quality original form to keep as a master copy. Then use a copy of it for every sked. This form helps you keep track of who transmits when, and you can make notes on it as to what you are copying during each receive sequence. Also, it provides a good record for each contact when a QSO is completed.

When I'm calling I2FAK, or any other station, I do not send "de" between calls. Although many EME operators do so, it isn't necessary, and it only adds unneeded additional information that you would be trying to copy from a potentially very weak signal. In my sked example I would just send I2FAK K6PF I2FAK K6PF for the entire two-minute sequence at the start of our sked.

For a successful and valid 2-meter EME QSO, the only information required

References

1. W5UN website: <http://web.wt.net/~w5un/>. Contains a great EME Operating Primer and information on "Skymoon" and "Cwkey5" EME software.

2. N1BUG website: <http://www.n1bug.net/>. Click on the EME (Moonbounce) link. Also, under "Miscellaneous VHF 'How To' Information" click on "Getting Started in EME" and "Polarization of EME Signals." These are excellent tutorials. "Z-Track" is a software program that can be downloaded for moon tracking, etc.

3. GM4JJJ website: <http://www.gm4jjj.co.uk/>. Contains information on "MoonSked," a moonbounce scheduling software program for Macintosh and Windows.

4. W7GJ website: <http://bigskyspaces.com/w7gj/>. Contains moonbounce operating tips and information on "Tracker," a moon tracking program.

5. AF9Y website: <http://www.af9y.com/>. Click on "Moonbounce (EME) Operation." Contains information on "SKD 87," an EME scheduling program, and also information on "FFTDSP" software and applications.

6. The EME Directory can be downloaded from W5LBT's website at <http://www.qsl.net/w5lbt/>.

7. To subscribe to "The 144 MHz EME Newsletter" published by Bernd, DF2ZC, send an e-mail to <eme-news@t-online.de>.

8. The weak-signal and SETI page for W6/PAØZN is at: <http://www.nitehawk.com/rasmit>. Has interesting EME information and the "432 MHz and Above EME Newsletter."

9. For information on "DSP Blaster" software by K6STI, go to <http://www.setileague.org/software/dspblast.htm>.

10. For information on "Hamview" or "Spectran" software by I2PHD and IK2CZL, go to <http://www.weaksignals.com>.

11. *The VHF/UHF DX Book,* published by the RSGB (Radio Society of Great Britain), is available from the ARRL.

12. "'To The Moon, Alice!' – Part 1, 2-meter Moonbounce Basics," by Tim Marek, NC7K (now K7XC), October 1996 *CQ VHF*.

13. "More 'QRP' EME on 144 MHz," by Ray Soifer, W2RS, October 1990 *QST*.

14. "QRP EME on 144 MHz," by Ray Soifer, W2RS, February 1989 *QST*.

is the copying of both callsigns by both stations, as well as a signal report and acknowledgement, which usually consists of Os, ROs, and Rs. "73" is frequently sent, although it is not required for a valid QSO. Websites for both W5UN and N1BUG (see references) have excellent discussions on operating procedures for both skeds and random contacts. Because of space limitations here, please refer to those websites for more detailed information.

One operating problem that many of us have encountered should be addressed. This is being done even by some experienced EME operators, and it has kept many QSOs which should have been successful from being completed. With experience, you will have some idea of what the other station has copied and what information is still missing.

Let's assume you copied both callsigns after a couple of sequences, and you are ready to send Os. The other station is still sending both callsigns for the entire sequence. Therefore, you know for certain that he has not copied complete calls, or he would be sending Os. What you don't know is whether he hasn't heard you at all, whether he is missing only one more letter, or maybe it's somewhere between missing something and having everything you need for a "legal" QSO.

When you send Os in such a situation, it is *very important* that you still send both callsigns for 75% of the sequence, and send Os for only the last 25%. For two-minute sequences that means sending callsigns for the first 90 seconds and Os for the last 30 seconds, which will maximize the chance for the other station to hear any missing information. Such a scenario is common, and often the other station will send calls only once or twice. Because of all the excitement of copying both callsigns, they will send Os for the rest of the sequence. Because dashes are easier to copy off the Moon than dits, Os come through better than many other letters or numerals in callsigns. Over time, remembering this one important point will result in a lot more completed EME QSOs.

Digital Techniques

As part of his WSJT software program Joe Taylor, K1JT, recently developed JT44 for EME operation as an enhancement to WSJT. Many people have been experimenting with JT44, and they are having tremendous success. Visit K1JT's website at <http://pulsar.princeton.edu/~joe/K1JT> for additional information. This digital mode of communication apparently has about a 10-dB S/N advantage over CW, making it much easier for a minimum-size EME station to work a greater number of other stations than would be possible on CW, except under the best of circumstances.

At this time I have not had any personal experience using JT44, but I applaud Joe Taylor for his tremendous contribution to amateur radio. Because I get very excited upon hearing a CW signal being reflected off the Moon, my personal emphasis at this time is on improving my station so I can work many new initial stations on CW.

Good articles on JT44 appeared in the June 2002 issue of *CQ*, the Spring 2002 issue of *CQ VHF*, and the June 2002 issue of *QST*.

Conclusions

EME is truly the ultimate DX, and 2 meters is the easiest frequency on which to get started. The technical aspects of it are less challenging, and there is a much larger pool of operators on 2 meters than on higher frequencies. Nevertheless, it is still incredibly challenging and rewarding. For the weak-signal enthusiast who loves to chase more grids or who strives to earn WAS, WAC, or DXCC on 2 meters, EME is essential.

Hopefully this article has provided you with the knowledge, tools, and resources that will inspire you and motivate you to give 2-meter EME a serious try. Now you should have an understanding of some of the technical challenges. You should know who some of the bigger stations are to try to work, know how to set up skeds during the best possible times, understand the proper operating procedures, and have a list of references to help you be successful. EME is not only the ultimate DX, it is also the ultimate weak-signal form of communication in amateur radio. As with anything new, there will be challenges and there is a learning curve, but you need to persevere until you succeed.

One of the most thrilling experiences in amateur radio is to hear CW from a very weak signal that has traveled a half-million miles with only 7% of it being reflected off the Moon. It certainly gets the adrenaline going! ■

50-MHz *F2* Propagation Mechanisms

Part 1

This seminal work on 50-MHz *F2* propagation is reprinted by permission from the *Proceedings* of the 34th Conference of the Central States VHF Society, July 2000.

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The possibility of worldwide *F*-layer propagation is a particularly intriguing part of the challenge of 6-meter operation. Even the casual 6-meter operator will soon notice that there are some fairly mysterious things going on when it comes to ionospheric propagation. The more seasoned operator will notice that there are a number of prevalent patterns, but it is still very difficult to predict when the band will open, especially on a day-to-day basis. Unfortunately, there are no simple answers to this dilemma. Nevertheless, there are some pieces to the *F2* puzzle that are known and understood, and some clues to those that remain mysterious. In order to understand (however imperfectly) *when* the band will open, it is essential to have some understanding of *why* the band will open.

A discussion of why signals propagate has to begin with some basic facts about how radio waves behave in the ionosphere. There are three basic elements that critically affect this propagation:

1. The *amount* of ionization present,

2. The *angle of attack* of the incoming signal to the ionosphere, and

3. The presence of large or small *irregularities* in the ionization.

These factors play key roles in the success or failure of a communications path via either *E* or *F* layers. Although there are many external things which influence the status of the three conditions, in the end, it is the combination of these three that make or break any path. The way in which external events affect these three parameters determines what kind of propagation will occur.

Six-meter *F2* propagation is a very improbable event, from a statistical point of view. While this may seem obvious, it has a very important consequence. "Unlikely" events in complex physical systems are often the result of a *combination* of factors, some of which also may be fairly unlikely. This is certainly the case with most 6-meter *F2* activity, where propagation is almost always at or very near the ultimate edge of what is possible.

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The task of predicting band openings generally involves predicting not just one event, but the coincidence of several events, and not always the same ones or in the same combinations. In truth, we do not yet know what all the factors are, much less how they interact. On the other hand, there are a number of things that are known to be significant, and most of them involve the Sun in one way or another.

The Ionosphere and the Sun

The Earth's atmosphere extends from the surface to heights well in excess of 1000 km (or 620 miles). The density of the static atmosphere is highest near the surface and decreases progressively as one goes upwards. Most of the atmospheric mass is located very near the Earth's surface, with more than half the mass contained within just the first 6 km (or 4 miles).

The Sun, on the other hand, pours its radiation down on the atmosphere from the topside. Thus, the upper regions of the atmosphere receive the full brunt of the Sun's ultraviolet rays, x-rays, cosmic rays, and so forth. This radiation interacts with the atmosphere on its way down, and as it does, portions of the radiation are absorbed at different levels, producing ionization in the process.

The interactions between solar rays and the air molecules and atoms are very complicated. There is a whole complex of chemistry that can take place at these rarefied heights that normally has no importance at lower levels. What wavelengths are absorbed at what levels is determined in part by the chemical components and particle densities found at each level. For example, generally ultraviolet radiation is absorbed fairly high in the atmosphere, while x-rays penetrate somewhat lower, and cosmic rays go still lower.

When solar photons get absorbed, it is a result of a collision with an atom or a molecule. Often, such collisions occur with sufficient force to knock off one or more electrons from the atom or molecule struck. This leaves behind a missing (absorbed) photon and positively and negatively charged ions. Usually the positive ions are the comparatively heavy cores of the atoms or molecules, and the negative ions are the relatively light electrons. It is the electrons that play the dominant role in radio propagation.

Because different wavelengths are absorbed at different heights, the solar radiation leaves behind several distinct layers that are characterized by enhanced levels of ionization. The *F2* layer is the highest of these, both in terms of distance above ground and in terms of electron density. This layer extends from roughly 250 km (or 155 miles) above the Earth to well over 500 km (or 310 miles) on occasion, with a peak daytime electron density in excess of 10^{12} e/m^2 around 350 km (or 220 miles). Extreme-ultraviolet radiation (EUV) from the Sun is the main source of ionization in the *F* region. Table 1 shows typical characteristics of the various layers. It should be noted that the "boundaries" between the layers are ill defined, and for sake of brevity, the list of ionizing radiation is not entirely complete.

Ionospheric Radio-Wave Propagation

The Amount of Ionization. When an upward moving radio wave reaches the ionosphere, the electric field in the wave forces the electrons in that layer into a sympathetic oscillation at the same frequency as the passing wave. A certain amount of the wave energy is given up to this mechanical vibration of the electron cloud. As a result, the passing wave gets weaker.

At this point, there are two sorts of things that can happen. In the lower atmosphere, the total number of particles may be dense enough that the oscillating electrons collide with other particles almost immediately (say, in less than one RF cycle). When that occurs, the wave energy, which was converted to the mechanical electron oscillation, is now converted as heat to the atmosphere before anything else can happen. This energy is lost forever as far as the wave is concerned. This is another way of saying that the radio-wave energy is *absorbed*.

This is precisely what happens to signals below about 10 MHz when they encounter the daytime *D* layer. The average frequency of collisions between particles in this region during the day is about 10 million collisions per second. Therefore, it strongly absorbs radio frequencies below 10 MHz, but has a progressively smaller effect as the frequency gets higher.

At the other extreme, if the collision frequency within the layer is significantly less than the wave frequency, and if the electron density in the vibrating cloud is *greater* than a certain critical value, then the whole cloud can act more like a static reflector. Almost all of the wave energy is given up to the vibration in a very short distance; all the electrons vibrate in phase; and together, they reradiate the original wave energy back downward again. Thus, the wave skips off the ionospheric layer, hopefully to be received at some distant point.

It should be noted that in most cases, what actually occurs is something intermediate to these two extremes. Some amount of absorption always occurs. Moreover, as figure 1 shows, when the electron density does exceed the critical skip value, it does so gradually. Rather than a discontinuous reflection, there is a *refraction* of the wave, a more gradual bending back around toward the ground. (Sporadic-*E* is an exception; it is usually very close to a true reflection.).

Even when the critical density is not reached (and the wave passes through the ionosphere and escapes into space), a certain small fraction of the wave is reradiated by the vibrating cloud; some of this new signal goes downward as a form of *ionospheric scattering*.

Let us consider the electron density, and ignore other effects for the moment. If a radio signal is sent *straight up,* one can calculate the *critical frequency*, f_c, the highest frequency at which the ionosphere can reflect that signal straight back down:

$$F_c = \sqrt{\frac{Ne^2}{4\pi^2\varepsilon_0 m}} = \sqrt{N} \times (9\times10^{-6}) \text{ (in MHz)}$$

Here, *N* is the number density of electrons, *e* is the electron charge, e_0 is a number called the permitivity of free space, and *m* is the mass of the electron. Everything except *N* is a known constant value. The real point here is not the mathematics, but the basic fact that the highest frequency that will skip straight back down vertically is the square root of the electron density times a fixed number. For example, in order for a signal to skip at *twice* the current maximum frequency, something must increase the number of electrons by a factor of *four*.

Notwithstanding the fact that the *F2* layer retains some of its ionization even at night, all of the foregoing should make it clear that 6-meter *F2* propagation is normally a daytime affair, *unless* one lives in the tropics (more on that later).

The Angle of Attack. The above example only tells us what happens if the path of the wave strikes the ionosphere with an *angle of attack*[3] of 90° (i.e., going straight up). In the more general case, if skip is to occur, the Maximum Usable Frequency (MUF) that will bounce is determined by *both* the maximum *electron density* that the wave encounters in the ionosphere and the *angle* at which the wave hits the reflecting/refracting layer.

If a signal is sent off very near the horizon (that is, with a zero angle of radiation), because of the curvature

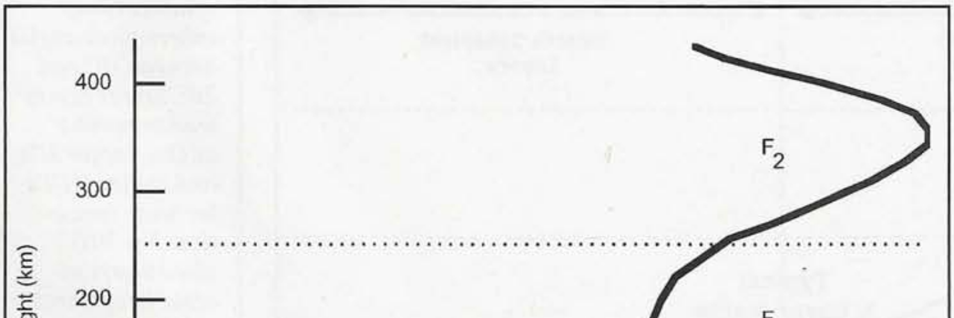

Figure 1. A typical plot of the daytime electron density as a function of height above the ground, showing the C, D, E, F1, *and* F2 *layers.*

of the ionosphere around the Earth, the signal will normally hit the ionosphere at an angle of attack between 10° and 20°. The exact value depends upon the height of the ionospheric layer and the exact angle of radiation. The MUF (represented by f_{max}) can be calculated from:

$$f_{max} = \text{cosec}(\alpha) \times f_c = M\sqrt{N} \times (9\times10^{-6}) \text{ (in MHz)}$$

where *a* is the angle of attack. Here one sees the dependence on both the electron density and the angle *a*. The cosecant term is often referred to as the *M factor*.

It is important to notice that the smaller the angle of attack, the greater the MUF. The smaller the angle becomes, the closer the waves gets to a so-called *grazing-incidence* situation. In principle, the MUF approaches infinity as the angle approaches zero!

Radio propagation is not the only place one sees grazing-incidence reflection effects. For example, everyone knows that if you toss a rock in a lake, it will break through the surface of the water and sink, never to be seen again. The same thing happens to a radio wave when it collides with the ionosphere and its frequency is above the MUF: It breaks through and disappears. However, even a rock can be made to bounce off the surface of the lake; any child can do it. The secret, of course, is that it must hit the surface at a very shallow angle—that is to say, at grazing incidence. Skipping radio waves is essentially the same as skipping stones.

If the ionosphere were a smooth sphere, simple geometry would show that M ≈ 3.4 at the *F2* layer. Because Table 1 shows that the average *E*-layer ionization is 40 times less than the *F2* layer, one might rightly wonder why sporadic-*E* propagation is so much more common and frequently produces much higher MUFs than the *F* layer.

Half the answer is that the *E* layer is closer to the Earth, and this makes the angle of attack much *smaller* than for the *F* layer. At *E*-layer heights, figure 2 shows that M ≈ 5.4. Thus, the *E*-layer MUF will be nearly *60% higher* than the *F* layer for the *same* number of electrons. (The other half of the sporadic-*E* story is that the "sporadic" process also increases the amount of ionization in *thin localized regions* to levels considerably higher than the average in the *E*-layer as a whole. Taken together, the two effects can produce very high *E*-layer MUFs.)

Ionospheric Layers

Layer	Height (km)	Density (e/m^3)	Ionizing Radiation
C	30–60	5×10^9	Cosmic Rays
D	60–90	1×10^{10}	Hard X-Rays
E	90–120	8×10^{10}	Soft X-Rays
F1	120–250	5×10^{11}	Extreme Ultraviolet
F2	250–500+	3×10^{12}	Extreme Ultraviolet

Table 1. Typical characteristics of the ionospheric layers.

It is important to note that the angle of attack is *also* affected by the radiation angle of the antenna. Especially at 6 meters where one is struggling to get the MUF up high enough, a low angle of radiation from the antenna can be very important. Here it is not just a matter of getting the longest skip distance, but one of getting any skip at all.

F-Layer Propagation for All Seasons (Except Summer)

The amount of ionization in a given layer at a given time depends upon the dynamic balance between those processes causing ions to be produced and those causing ions to be lost (i.e., by returning to their original neutral state). Put another way, the ion density depends upon the amount of radiation arriving from the Sun causing the *production* of ions, minus the *loss* of ions because of electrons being recaptured by positive ions.

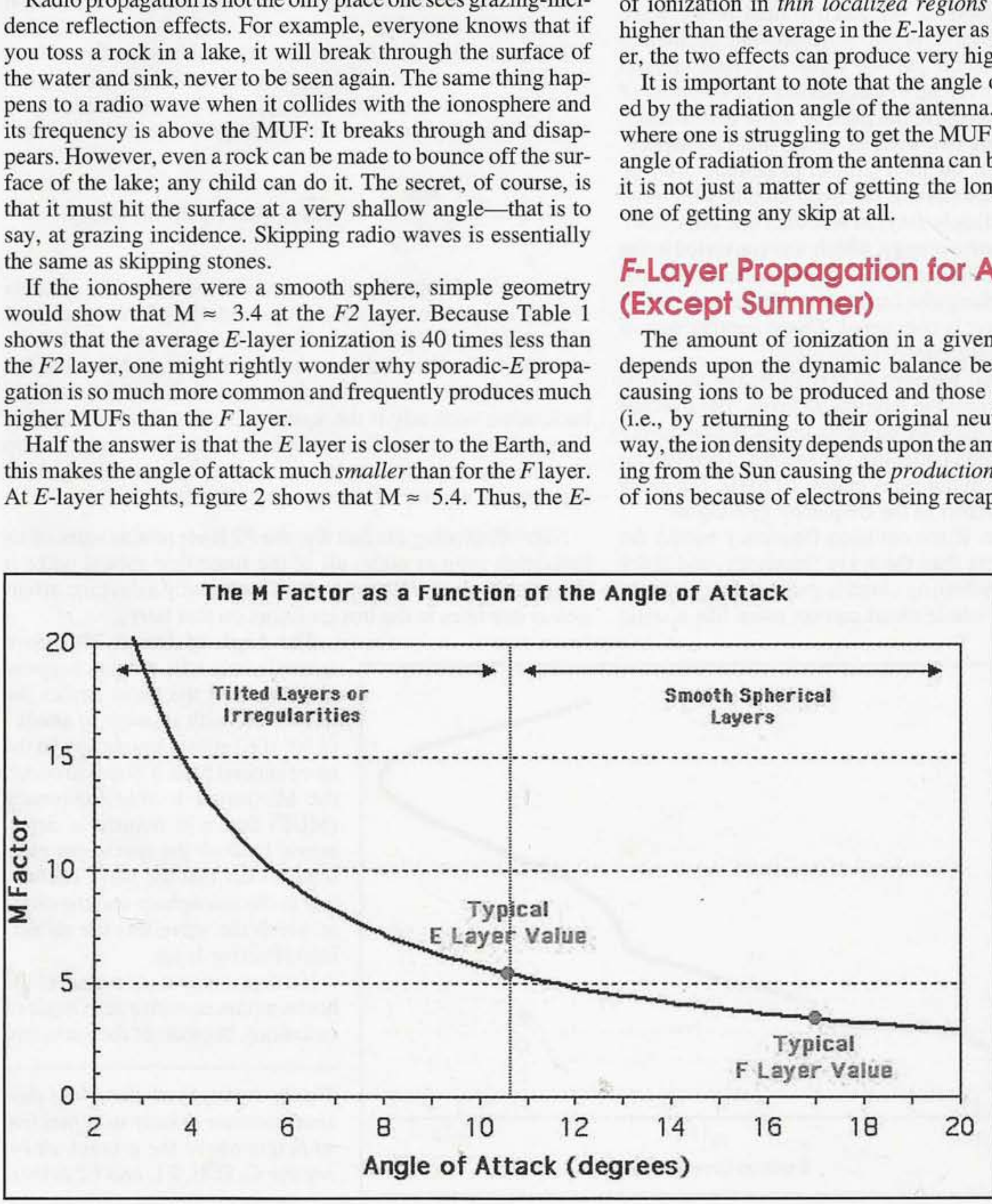

Figure 2. M varies with angle of attack. A smooth spherical ionosphere gives angles between 10° and 20°. Lower layers lead to smaller angles, larger M's, and higher MUFs for same ionization. For VHF, tilted layers or other irregularities can produce angles below 10° and provide very exciting results. In the extreme, TEP on 222 MHz and higher can result.

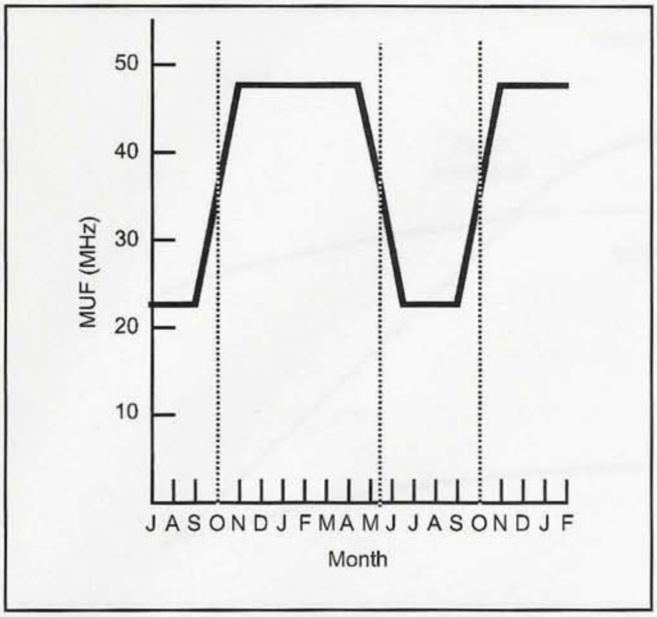

Figure 3. A schematic plot of the Northern Hemisphere variations of MUF due to the winter anomaly. The values of MUF shown are typical mid-day figures for mid-latitudes near solar maximum.

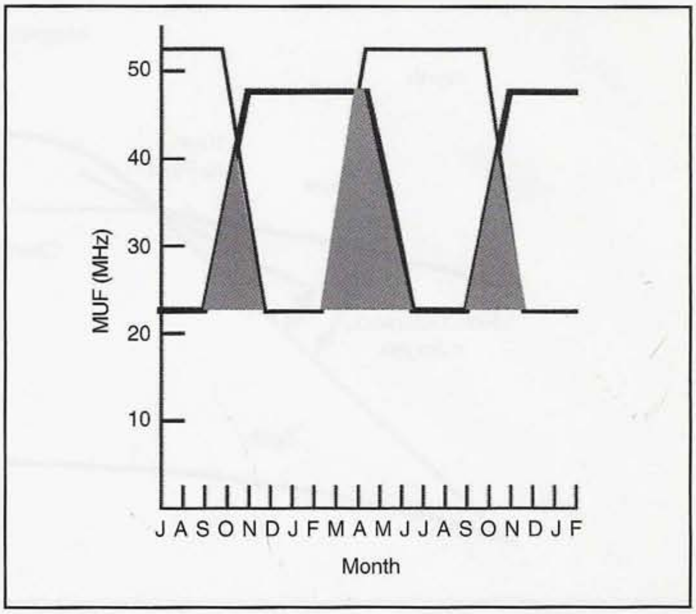

Figure 4. A schematic of the overlap of the northern and southern winter anomalies in the Western Hemisphere, as modified by the effect of the (magnetic) equatorial anomaly. The shaded areas show the most likely times for mid-latitude north-south trans-equatorial multihop.

The rates and mechanisms of these processes vary widely from layer to layer.

For example, the underlying (neutral) density of the *D* layer is much higher than that of the *F* layer. Consequently, in a given length of time, electrons and positive ions there are much more likely to collide and recombine. As a result, by comparison to the *F* layer, the maximum *D*-layer ionization is held down during the day by collisional losses, and the *D* layer disappears in minutes when the Sun goes down. By contrast, the underlying particle density in the *F* layer is much less than the *D* layer, and ions last a lot longer in the *F* layer. Even late at night, often there are enough ions left to support HF communications.

Another important effect in ion production is the angle with which the sunlight strikes the top of the Earth's atmosphere. When the rays arrive at a large angle to the vertical, the energy is spread out over a larger area, and thus, the energy density at any one spot is reduced. Therefore, fewer electrons are produced at sunset and sunrise than at high noon. In addition to this diurnal effect, there is a seasonal one as well. The local winter hemisphere is tipped partly away from the Sun and its various layers receive proportionately less radiation. Consequently, in the Northern Hemisphere fewer daytime *F*-layer electrons are produced at a given time of day in January than in July.

However, remember that production is only half the equation. There is a peculiarity in the *F2* layer, not found in the other layers, called the *winter anomaly* (figures 3 and 4). Although daytime ion production is higher in the summer, there are seasonal changes in the molecular-to-atomic ratio of the underlying (neutral) atmosphere that cause the summer ion loss rate to be *even higher*. The result is that the increase in the summertime loss overwhelms the increase in summertime production, and *total F2* ionization is actually *lower*, not higher, in the local summer months. Put the other way around, daytime *F2* electron densities, and thus MUFs, are higher in the local winter.

Measured at the "half-width," the winter peak starts in October and lasts until May or June. Most years there is a fairly flat peak between December and April. It is interesting to note that during the peak years of solar cycles 18 through 21, October was almost always the beginning half-maximum, whereas the ending half-maximum varied from April to July. The ending months were pretty consistent within a given cycle, but cycles with higher maxima favored May with an occasional April, while those with lower maxima favored June with an occasional July.

Interestingly, the winter anomaly shows the most seasonal fluctuation near solar maximum. Here, the local winter daytime MUFs are twice as high as the daytime summer values, while they are only about 20% higher during solar minimum. The central message in all of this is that, on average, *F2* propagation *between points on the same side of the equator* will be much better in the local winter and near solar maximum.

If one is interested in multihop along generally north-south paths, then the winter anomaly comes into play in another way. If it is wintertime in one hemisphere, it will be summertime in the other. For example, in January, the first hop of a two-hop path from North to South America might make it, only to have the second hop fail because of the absence of the winter effect at the second skip point. Obviously, the best times of year for such a path would seem to be in the fall and in the spring when the winter anomaly effects overlap a bit in both hemispheres.

The winter anomaly is not the only seasonal effect. Many two-hop (or more) north-south openings on 6 meters seem to have no evidence of stations at the end of the *first* hop. This is often because of the ionospheric equatorial bulge known as the *equatorial anomaly*. Somewhere within about ±20° of the Earth's *magnetic* equator there is a pronounced outward bulge in the ionosphere. The bulge itself is about 15° to 20° wide. Though generally regarded as an afternoon or early evening phenomenon, it occurs at other times as well. It is thought to be produced

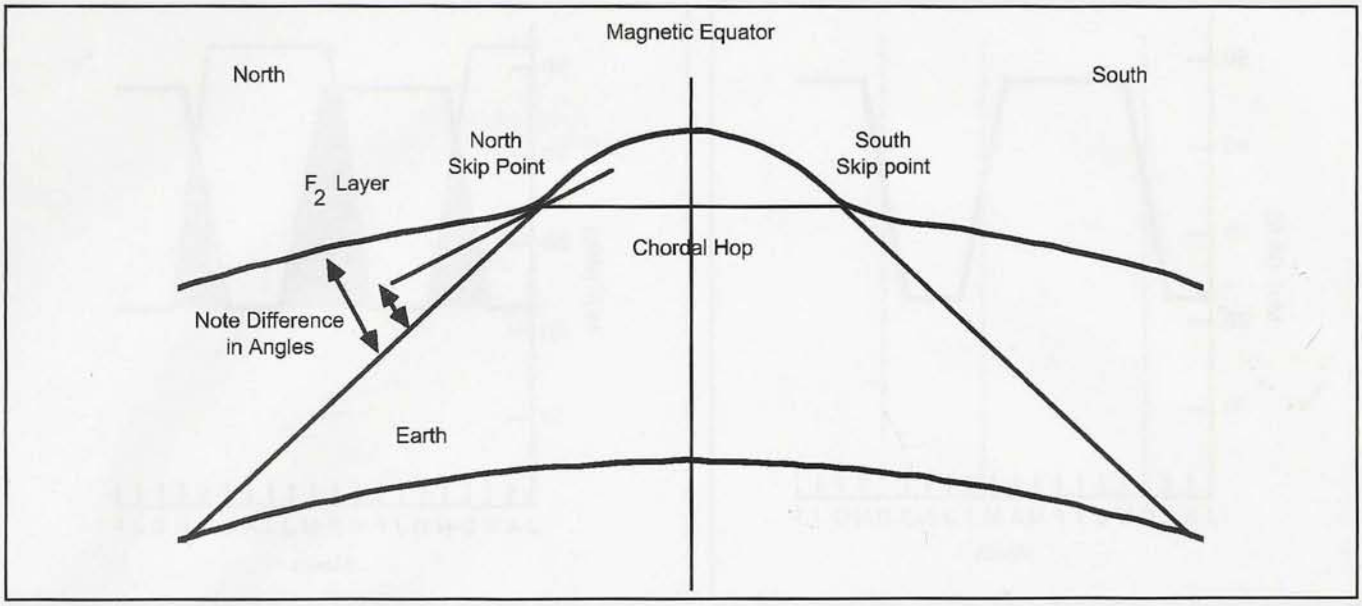

Figure 5. Diagram of a transequatorial chordal hop off the tilted north and south skip points. These points lie about 20° north and south of the Earth's magnetic equator and can be major contributors to daytime transequatorial 6-meter propagation from mid-latitudes and clearly cause nighttime TEP in the tropics.

by a combination of a persistent thickening of the *F* layer near the equator and a daily *fountain* effect. This *afternoon fountain* apparently is the result of a build up of west-to-east electric fields in the equatorial *E* layer. In combination with the Earth's magnetic field and ionospheric winds, these fields pump electrons upward from the *E* and lower *F* layer into the upper *F2* layer, thus significantly enhancing *F2*-layer electrons.

It was pointed out earlier that the angle with which the radio wave encounters the layer is also a factor in determining the MUF. The equatorial bulge produces two regions, one north of the equator and the other south of the equator, where the ionosphere is systematically tilted. Of particular interest are the points at the *corners* where the generally spherical ionosphere is bent upwards to form the bulge.

This upward tilt is such that an upcoming wave hits the near corner at a shallower angle of attack to the tilted layer than it would to the usual spherical layer. This means that it will have a higher MUF for the same value of electron density. That is, the M factor is larger than 3.4, perhaps by quite a bit. The wave is not bent all the way back toward the ground. However, it is bent enough to cross the equator and hit the tilted layer on the far side *without ever coming back to Earth.*

This so-called "chordal hop" to the second tilted region produces another small-angle reflection that can be just enough to return the signal to the Earth on the far side of the equator (figure 5). The effect is a kind of double hop with nothing in between, and at a higher MUF than could otherwise be supported. Because the "bulge" effect does produce *higher* MUFs, this is often the cause of multi-hop north-south propagation of 6 meters. Moreover, it is a fairly low-loss path. The wave never comes down at the path mid-point, so it avoids two passes of *D*-layer absorption that normal double hop would have encountered.

In order for this form of propagation to function, *both* the north-side and south-side tilted regions need to be ionized enough to make the path work. Again, if either one of these regions is insufficiently ionized, then the whole path fails. At HF, there is often a fair amount of margin, but not at 6 meters. Here, usually the best chance occurs when both sides of the equatorial bulge are equally illuminated by solar radiation, and this situation only occurs around the Fall and Spring Equinoxes when the Sun is most nearly over the equator.

Normally one would think that this would occur in late September and late March. However, the Earth's magnetic field is tilted with respect to the geographical coordinates. In the Western Hemisphere, the magnetic equator is as much as nearly 11° south of the geographic equator. This means that the "magnetic equinoxes" occur about a month or so earlier (August and February) for paths between North and South America. From the point of view of a station in North America, as the path of interest swings around farther east or west, the magnetic equinoxes are more nearly the same as the geographical ones. Consequently, the date of the magnetic equinox is dependent upon the amount of east or west component included in the north-south path, and where you happen to be on the Earth.

There is also an interaction between the balanced illumination at the magnetic equinoxes and the double-hop winter anomaly effect (which is geographical, not magnetic). For example, consider a path between North and South America. Here, it should be noted that, in part as a consequence of the location of the magnetic equator, MUFs are frequently higher over South America than North America. During the Fall Equinox period, on the northern side of a path, August is too early for much help from the (northern) winter anomaly. By contrast, the southern skip point is bolstered by both the winter and equinox effects and has a substantially higher MUF than the northern point. If this path is going to succeed, it will likely have to wait until October when the northern skip point is in better shape. Put another way, by October the northern and southern skip-point MUFs will be about the same as they pass each other going in opposite directions.

During the spring period, February as well as March and April all are still in the peak for the north end. Even though the southern point is in the summertime, it has a higher MUF to begin with, and the equinox effect adds even more. The result is that the southern point MUF may well be higher than the northern point MUF, despite the *absence* of help from the winter anomaly. In the meantime, the northern point is as good as it will ever get *because* of the winter anomaly. Consequently, for generally *north-south paths across the magnetic equator*, periods more nearly centered on October and March are usually the best, and often the spring period gives more consistent daytime transequatorial performance.

Of course, unless one has an *E*-layer link up, or some other funny business, another requirement is that the stations each be close enough to the nearest ±20° tilted skip point to illuminate that point by radio line of sight. Based purely on geometry, the southern half of the U.S. has an advantage for South American paths and the southwestern states for the South Pacific. (Early Spring sporadic-*E* can make a big difference on the mainland US.)

In Part II, which will appear in the Spring issue of *CQ VHF,* we will take a look at how these effects combine with solar effects, the afternoon fountain, and large- and small-scale ionospheric irregularities to produce a whole family of interesting propagation possibilities.

Notes

1. The Gemini Observatory is operated by the Association of Universities for Research in Astronomy under a cooperative agreement with the National Science Foundation.

2. *Angle of attack* is a borrowed aeronautical term. It is the angle between the ionosphere and the direction of travel of the radio wave. Although I prefer this particular way of looking at it, usually physics texts use its near relative, the *angle of incidence.* This is the angle between the vertical with respect to the ionosphere and the direction of the wave, that is to say, 90° angle of attack. The equations change a little, but the answers are the same. ■

A Look at Long-Range North-South Path F2-Skip on 50 MHz

During his many years on 6 meters WB2AMU has made some fascinating observations concerning transequatorial propagation. See if you agree with them.

By Ken Neubeck,* WB2AMU

Over the past several years, there have been some misunderstandings concerning the interpretation of 50-MHz transequatorial propagation (TEP) and related *F2* north-south paths. Because of limited observations over the years, little has been written on the subject. Indeed, very few VHF column writers will tackle this subject with any great confidence, frequently avoiding any discussion of the subject. Consequently, many 6-meter operators may not be adequately informed about when these events can occur, and thus they may not get the chance to observe such activity when it does occur.

With the 2001 second sunspot peak of Cycle 23, many more observations made by operators on 6 meters have reinforced the knowledge base of TEP and related *F2* north-south paths, allowing the opportunity for the actual path mechanisms to be better defined for these propagation modes.

In 2000, Jim Kennedy, K6MIO/KH6, published "50 MHz *F2* Propagation Mechanisms,"[1] in which he describes the actual mechanics of TEP. One of the terms Jim uses to explain the

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[1] *Kennedy (KH6/K6MIO), Jim, "50 MHz* F2 *Propagation Mechanisms,"* Proceedings *of the 34th Conference of the Central States VHF Society (2000), ARRL No. 257, pp. 87–105. Editor's note: Page numbers in this article refer to the original paper in the* Proceedings. *The first half of this paper is reprinted elsewhere in this issue. The second half will be published in the Spring 2003 issue of* CQ VHF.

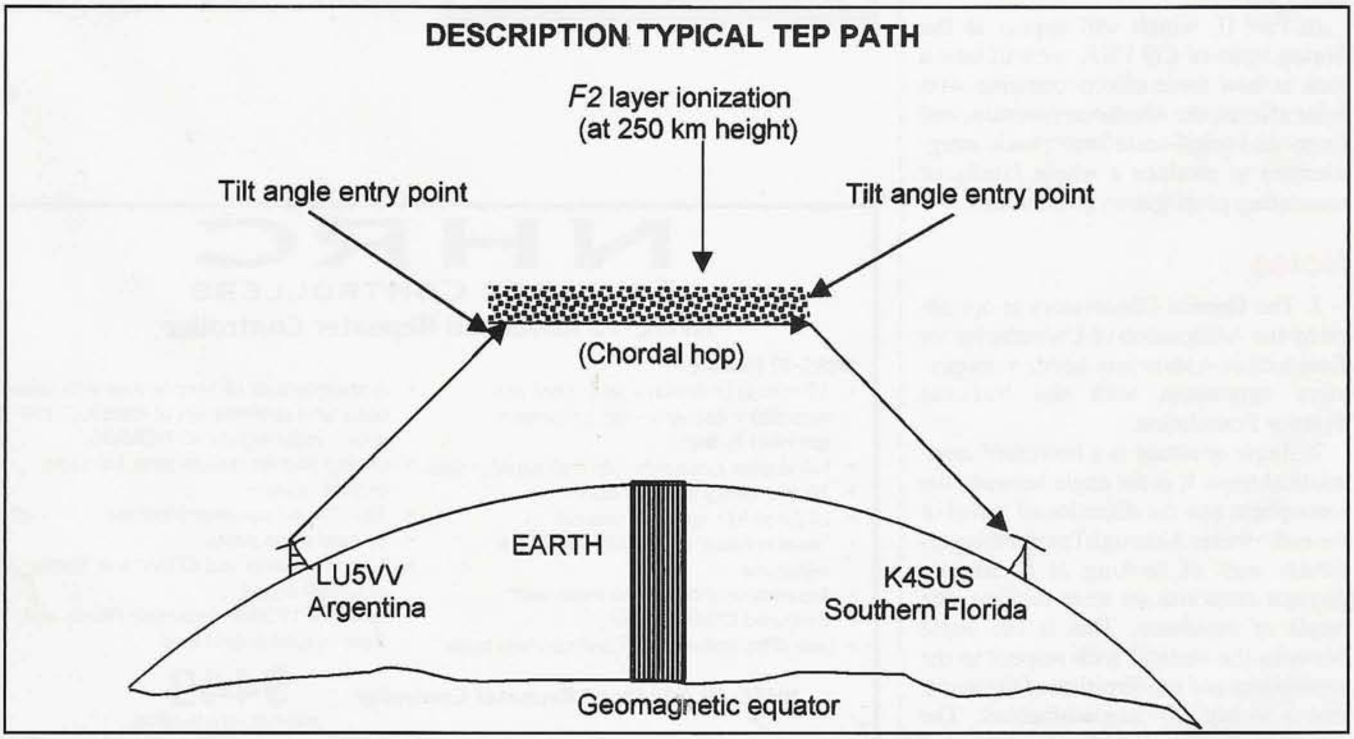

Figure 1. This figure shows how the signals are carried in the F-*layer of the ionosphere over the geomagnetic equator to create TEP. The stations involved are located at equal distances from the geomagnetic equator, and the overall distance covered is on the order of 6000 miles.*

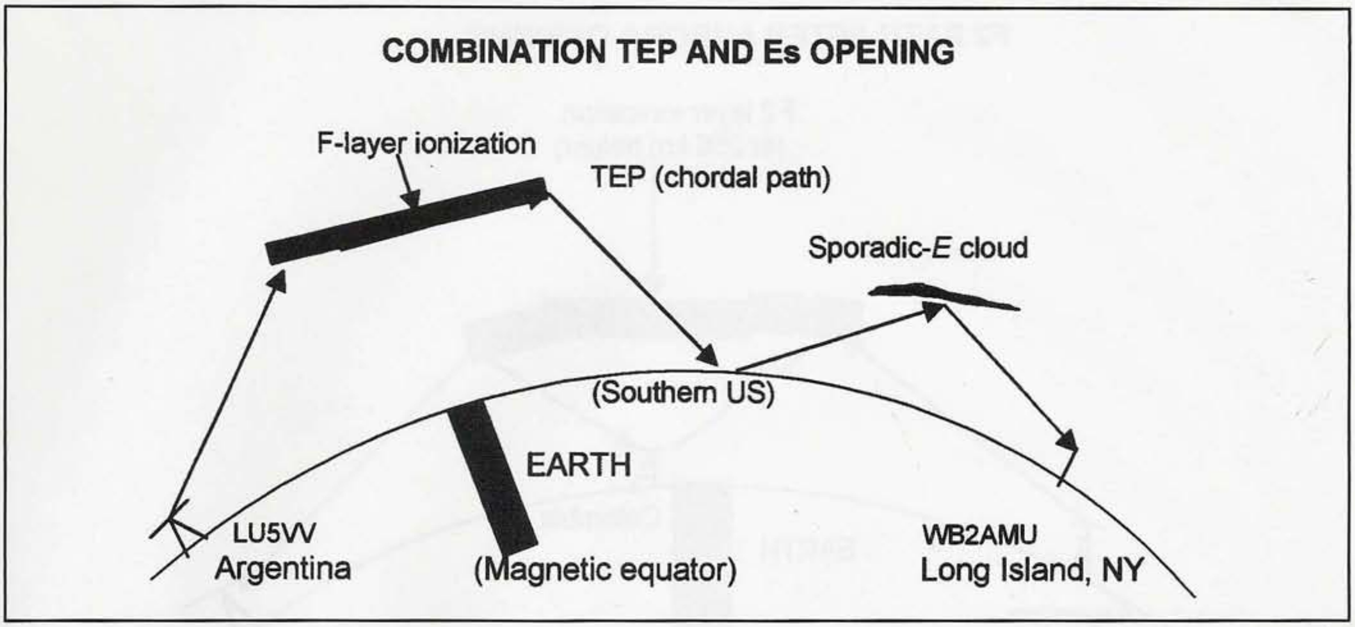

Figure 2. This combined TEP plus sporadic-E opening took place on May 25, 2000 at 6 PM local time. WB2AMU was running 50 watts from his car using a mag-mount vertical on the roof, while LU5VV was using 5 watts into a Yagi.

TEP effect is *chordal hop.* He describes the action of 50-MHz radio waves at the edges of the TEP zone as follows:

> This upward tilt is such that an upcoming wave hits the near corner at a shallower angle of attack to the tilted layer than it would to the usual spherical layer. This means that it will have a higher MUF for the same value of electron density. That is, the M factor is larger than 3.4, perhaps by quite a bit. The wave is not bent all the way back toward the ground. However, it is bent enough to cross the equator and hit the tilted layer on the far side, *without ever coming back to Earth.* (p. 94)

Figure 1 shows a typical chordal-hop TEP path on 6 meters between a station located in Miami, Florida and one in Buenos Aires, Argentina. Often this path is observed during the higher sunspot count years, and generally during the months of the fall and spring equinoxes.

As noted by Jim in his paper, the reason why the best time for north-south TEP skip is during the fall and spring equinoxes is because the winter anomaly effects for *F2* propagation overlap a bit in both the Northern and Southern Hemispheres. Otherwise, when it is winter in one hemisphere and *F2* is possible (during the higher solar-count year), it is summer in the other hemisphere (when no *F2* is present), and thus there is no chance for north-south *F2* paths between the hemispheres to occur.

During the late afternoon and evening, the *F*-layer near the magnetic equator has a build up of electron density known as the *fountain effect,* which allows for this TEP path. With regard to the fountain effect, Jim comments: "In order for this form of propagation to function, *both* the north-side and the south-side tilted regions need to be ionized enough to make the path work." (p. 94) He adds:

> For operators who have the good fortune to be in the TEP zone, the paths themselves do not have to be especially north-south. In the simplest case, the two stations are on opposite sides of the magnetic equator, although they can be at a considerable angle to the north-south line. All that is necessary is that the two ±20-degree corners be at usable chordal skip points. (p. 97)

Indeed, stations outside the TEP zone do not get in on the action unless there is a supportive mode of propagation, such as sporadic-*E* link. From my location on Long Island, New York, for example, I was able to work QRP station LU5VV during the afternoon of May 25, 2000, because of what I perceived to be an apparent sporadic-*E* link to the daily TEP occurrence between the southern U.S. and Argentina. This assumption of a sporadic-*E* link was based on the fact that generally I can hear stations in Florida via sporadic-*E* when this combination propagation mode occurs. See figure 2 for a pictorial description of this path.

Such TEP paths are a more common phenomenon on 10 meters, where stations in Argentina can be worked by a greater portion of the U.S. during the afternoon hours for many months of the year because of the longer path possible on a lower frequency. However, more ionization is needed in the tilted region to make the MUF climb from 28 MHz to as high as 50 MHz. On some occasions, Caribbean stations have been able to work into Argentina on 2 meters via TEP! Normally, the high daily solar-flux values account for the occurrence of 6-meter TEP. However, another unique circumstance can occur, and it was observed frequently during this past solar peak.

When there is high solar activity, higher geomagnetic activity will occur more often on Earth because of solar flares and coronal mass eruptions (CMEs) impacting on the Earth's geomagnetic field. Typically, it takes two days for a major solar event to affect the Earth's geomagnetic field. Even though there is high speed involved, the tremendous distance between the Earth and the Sun must be covered. A major impact can cause the *Kp*-index to exceed the value of 5 and reach as high as 9. When this high a *Kp* value occurs, the north and south aurora zones will extend into the lower latitudes, thereby increasing the likelihood of auroral backscatter contacts on 6 meters and other VHF bands.

Often after an intense auroral opening on 6 meters, north-south *F2* skip is very possible at any time during the next 24 hours. For example, after the major auro-

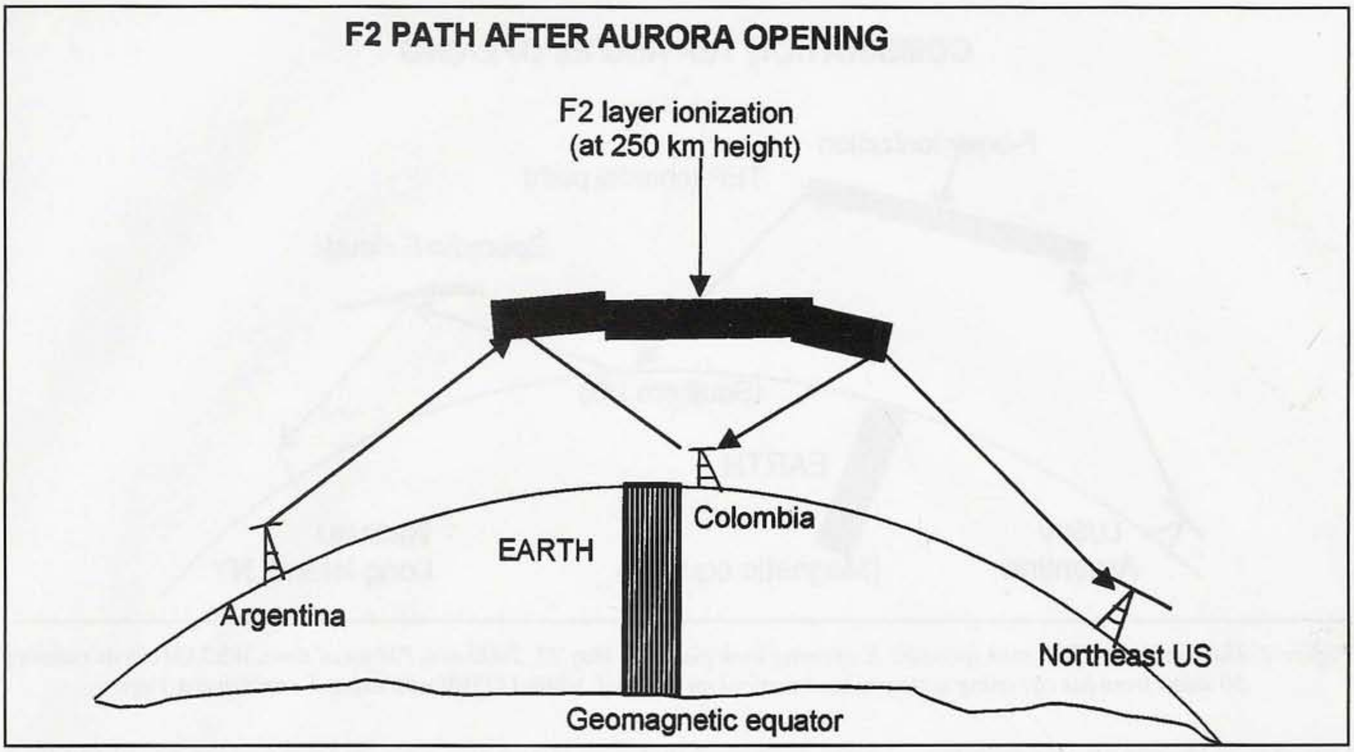

Figure 3. The situation depicted here occurred after the April 7, 2000 aurora opening, during which stations in the northeast U.S. were working stations from both the Central America area and Argentina at the same time. The only way this condition can occur is by the tilt area or entry points on the outside of the magnetic equator actually reflecting radio waves. Thus, while stations are being worked from Colombia, other signals are coming in from Argentina via two-hop F2*, covering the same amount of distance as a TEP plus sporadic-*E *path.*

ra opening of April 7, 2000 faded at around 8 PM local time, it was possible for stations in the northern part of the U.S. to work many stations in the northern part of South America, Central America, and even Argentina.

How is this situation possible? First, it appears that the same solar event that caused the extension of the auroral zone is also impacting the ionized *F*-layer around the magnetic equator, more specifically, the tilt region (or entry points) defined by Kennedy in his paper. Thus, the *F2* tilt region just below southern Florida is ionized to the point where *F2* paths on 6 meters exist between stations in the northern U.S. and into Central America, along with stations in Colombia and Ecuador in South America. The signals often are distorted, eventually becoming clearer as the opening stabilizes. The opening that occurred after the April 7 auroral event was so strong that I was able to work HP2XUB in Panama and HK3YH in Colombia after midnight using only 10 watts!

There were reports of stations in New York working into Argentina at the same time as the Central America area stations were being worked. Could this have been TEP at work? One might be inclined to say so, but the mathematics and geometry do not support it. First, the distance traveled between New York and Argentina is equal to that which is covered by a sporadic-*E* and TEP combination. At the time there was no evidence of any sporadic-*E* between stations in the northeast and the southern part of the U.S. What most probably allowed this path to happen was a double-hop *F2* path, where, in addition to the northern tilt region being ionized, the southern tilt region was also ionized in order to allow the two-hop path of about 10,000 miles to be covered. This seems to be the most straightforward explanation of the path. See figure 3 for the graphical version of the single-hop and double-hop *F2* paths present during this event.

Through the use of mathematics, we are able to figure out the probable combination required in order for these types of *F2* paths to be possible. When doing this type of analysis, the goal is to try to find the simplest set of circumstances that explain the overall event. The many observations made by 6-meter operators show that something unique happened, and it is necessary to figure out the rationale for such paths. Other similar events were observed during this past sunspot-peak period, and again, an attempt is made to try to figure out how such combinations are possible.

In April 2001 several other stations in the northeast U.S. were able to work Arliss Thompson, CEØY/W7XU, at noontime during his trip to Easter Island. At the same time, I was able to work AC4TO in Florida, which appeared to be a weak sporadic-*E* opening. The only thing I was positive about was the sporadic-*E* link to Florida. What I was not positive about was the type of propagation path, *F2* or TEP, the signal took from Florida into Easter Island.

Although the path was slightly skewed compared to the "typical" TEP path from Florida into Argentina, roughly the same distance, about 1000 miles, was covered. This distance is beyond a single-hop *F2* path, which is about 5000 miles, but it does fit into the distance of a single TEP chordal hop. It is harder to determine precisely whether this was a TEP or "special" type *F2* path because no other stations were heard from South America at the same time that Arliss was working into the U.S. The signal was weak from both Florida and Easter Island. CW was the way to go, but it was very difficult to determine if there was any TEP-type distortion. Therefore, this path was very similar to that described in figure 1 as a best-guess explanation of this particular opening. Another clue is that a period of very high geomagnetic activity, where the *Kp*-index exceeded 5 for several hours, occurred a few days earlier.

There is the risk of overreaching when trying to figure out the exact propagation mechanisms that explain these paths. However, reasonable speculations can be made about what the actual path mechanism is (*F2* or TEP) for these north-south paths, although it helps to have multiple sets of observations in order to draw better conclusions. It is acceptable to make speculations, with the necessary caveats, even though more information eventually will be needed. However, the use of math, coupled with the actual 6-meter observations, makes for a good start. ■

WSJT
Meteor-Scatter Experiences in Australia

This paper was originally presented at GippsTech 2002, the annual Australian Conference designed to encourage participation in VHF, UHF, and Microwave amateur radio operations. *GippsTech* is a hybrid name for the technical conference being held at the Gippsland, Victoria campus of Monash University.

By Rex Moncur,* VK7MO

WSJT is a radio communications computer program with a mode, FSK441, which has been designed specifically for meteor scatter. Its performance is such that it allows meteor scatter contacts on 2 meters throughout the year without waiting for showers. It works well in the range 800 to 1800 km, and typically one can complete a QSO in 20 minutes with 100 watts. The program has proven viable for portable operations in activating rare grid squares with contacts up to a little over 2000 km with a small Yagi that can be carried on the roof of a car. (1 km = .6 mile)

The Program

WSJT stands for Weak Signal communication by Joe Taylor, K1JT. It works much like PSK31 and requires a computer with sound card and an interface to an SSB transceiver. The program has two modes:

- FSK441 for meteor scatter
- JT44 for weak, steady signals—i.e., tropo scatter and EME

This paper is concerned with FSK441 for meteor scatter. The mode is called FSK441 because it uses Frequency Shift Keying to send sequential tones of 1/441 of a second, or about 2.3 milliseconds, duration. Characters are sent as three sequential tones selected from four tones. The four tones are 882, 1323, 1764, and 2205 Hz (tones 0, 1, 2, and 3)—for example, the characters A = 101, Z = 231, 1 = 001. In addition, the program uses any one of the four tones sent continuously to represent two frequently used reports— R26 and R27, roger (RRR) and 73. As they are sent continuously, a narrower bandwidth can be used, thus significantly improving performance in completing a contact.

The program sends at around 1800 words per minute and can transfer two callsigns and a report in a tenth of a second meteor or ping. This ability to work on very short pings means it can be used on the more frequent underdense pings, allowing contacts throughout the year without waiting for showers. The fact that it can be used throughout the year makes it ideal for activating rare grid squares on 2 meters that are beyond tropo and aircraft enhancement range, up to a little over 2000 km.

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Getting Operational

To get operational you need the following:

- 2 meter transceiver and 100 watts, although contacts have been made with 50 watts.
- Single Yagi of 5 to 10 elements, horizontally polarized. Elevation is not necessary.
- Computer of Pentium 75 MHz or better with sound card.
- Interface such as widely used for PSK31.
- The WSJT program, which can be downloaded at <http://pulsar.princeton.edu/~joe/KIJT/>.

When you download WSJT, it comes with an excellent *User's Guide and Reference Manual.* If you work through the manual, it will answer most of your questions.

For a description of how FSK441 works, look at Joe Taylor's article in *QST.*[1] It is fascinating to read how he has designed FSK441 to decode a signal from a random meteor burst without resorting to start codes or specific tones for synchronization.

Practical Performance

What follows are examples of practical performance of WSJT FSK441 in Australia:

- 2143 km, completed in 70 minutes (VK7MO portable VK3 to ZL3TY)
- 2028 km (VK2EI to ZL3TY)
- 2000 km, Hobart to Hervey Bay, VK7 to ZL—typical completions in 60 minutes (VK7MO to VK4TZL and ZL3TY)
- Portable operations VK8 to Melbourne and Sydney

• 1200 to 1600 km, portable operations to rare grid squares—typical completions in 15 minutes (VK7MO/P to VK3AXH, VK3UM, VK3AEF, VK3KAI, VK3FMD, VK2FLR, VK2EI, VK2FZ)

• 1000 km Sydney to Hobart, 97% completion over 4 months in 30 minutes—typical 15 minutes (VK7MO to VK2FZ)

• 650 km Hobart to Ballarat—typical completions in 45 minutes (VK7MO to VK3AXH)

Operating Conventions and Information

In VK-ZL we have adopted a number of conventions aimed at improving the prospects of contacts:

• Use the focus frequency of 144.230 MHz with 144.330 as the alternate and the same sequence on other bands.

• Use 30 second TX/RX periods.

• Southerly and easterly stations transmit in the first segment. While there are some boundary problems, these are generally overcome by the additional rules that ZL transmits first to VK and VK5 transmits first to VK2.

• To avoid confusion, do not use single-tone reports or RRRs on the focus frequency during activity sessions or when others are operating. Single-tone 73s may be used, as these are not an essential part of a QSO.

In Australia the frequency of 144.230 MHz is specifically called a focus frequency, as it is designed to focus activity on one frequency. It is not a call frequency in the sense that one should QSY after initiating a contact. The nature of meteor scatter, outside showers, is that signals rarely overlap and all can use the same frequency. Use of a common or focus frequency increases the interest as you see more pings.

Activity sessions are held each Saturday and Sunday morning from 0700 to 0800 local time in VK3 on 144.230 MHz. In UTC time this varies from 2100 to 2200 in the winter to 2000 to 2100 during daylight-savings time in VK3. Participating in the activity sessions is a good way to get started. At the end of each activity session a call back is conducted on 40 meters on 7085 kHz or close by.

News on WSJT and activities is provided on the VK-VHF reflector, where skeds can also be arranged. For further information on WSJT in Australia, visit the VK7WIA website at: <www.tased. edu.au/tasonline/vk7wia/Wsjtinoz.htm>.

Signal Reports

A report has two numbers. The first represents the duration of the meteor burst and the second the signal strength. WSJT automatically produces reports as follows[2]:

First Number

0 = 20 ms
1 = 40 to 80 ms
2 = 100 to 980 ms
3 = greater than 1000 ms

Second Number

6 = 0 to 10 dB
7 = 11 to 16 dB
8 = 17 to 22 dB
9 = greater than 22 dB

Thus, a 27 report means a burst of signal of 100 to 980 ms duration peaking at between 11 and 16 dB above the noise.

It is found that the program will often decode long burns as a number of shorter bursts, and in such cases the operator should ignore the report generated by the program and insert his own report based on his assessment of ping strength and duration.

QSO Time

The advantage of WSJT in FSK441 mode is that one can complete meteor-scatter QSOs at any time of the year without waiting for a meteor shower such as the *Leonids,* as is required for SSB contacts. WSJT is able to do this because it can take advantage of the more frequent underdense meteor trails that produce pings of a fraction of a second.

While the underdense pings are always present, they occur randomly and also vary on average as a function of the time of day and time of year.

Because of the random factor, QSOs at the same time of day and year that take an average of, say, 20 minutes will typically vary from 10 to 30 minutes, and a small proportion may take a longer or shorter time. If we exclude the random factor by working on averages, it is possible to gain an appreciation of the factors that control QSO time. These factors are listed below, and the major ones are discussed in later sections of this paper where a "QSO time factor" is derived.

• Distance
• Power at both ends
• Frequency
• Use of single tones
• Elevation of horizon at both ends
• Noise levels at both ends
• Time of day
• Date in the year
• Murphy's Law

In this paper it is assumed that the QSO time factor is inversely proportional to the rate of detectable meteor signals. This only holds where the numbers of signals are sufficiently low such that only a small percentage are duplicated in the same 30-second RX segment—a situation that applies for typical 2-meter QSOs in non-shower conditions.

I have included Murphy's Law in the above list because it covers the most frustrating reasons why one may wait for long periods to complete QSOs. These reasons include:

• Stations transmitting in the same time segment.
• Computer time is not accurate.
• Stations working on different frequencies.
• Strong power-line noise.
• Antennas not connected or pointed in the wrong direction.
• Your sked partner not getting out of bed.

While meteors do vary randomly, it is always worth considering Murphy's Law factors if one is not receiving the number of pings one would expect.

Maximum Distance

The maximum distance is determined by the Earth's curvature and the height at which both stations can see the same meteor trail. Geometry indicates that for meteors 95 km high the maximum range is 2400 km less 108 km for the total of degrees of horizon lost by both stations. Most reflections come from a common volume about 200 km each side of the center point, so when one gets to within 400 km of the maximum distance, the numbers of pings drop off, increasing the time for a QSO. Thus, QSO time starts to increase at a distance of 2000 km less 108 km for each degree of horizon lost. Poor antenna gain because of ground reflections can also reduce performance at maximum range.

Transmitter Power

McKinley[3] reports that the hourly rate of backscatter echoes is proportional to the square root of the power sensitivity of the system (p. 249). Tests with VK3AXH and VK3AEF where the power was reduced by half and the number of single-tone pings was recorded were in line with McKinley's formula. This results in a QSO time factor as follows:

Power	QSO Time Factor
400 watts PEP	0.5
200 watts PEP	0.7
100 watts PEP	1.0
50 watts PEP	1.4
25 watts PEP	2

Thus, for example, if it typically takes 20 minutes to complete a QSO with 100 watts, it will take 40 minutes with 25 watts.

Wavelength and Range

McKinley[3] gives the equations (Equation 9-3, p. 239, and Equation 9-6, p. 240) for the peak power received P_r and duration of meteor signals T_{un} from underdense pings. These equations have been reduced to the key elements below:

$$P_r \propto \lambda^3 \times \frac{1}{R^3} \times \frac{1}{(1 - \sin^2(0/2))}$$

Wavelength
6 meters 4 watts
2 meters 100 watts
70 cm 2700 watts

Range
500 km +0 dB
1000 km -8.4 dB
1500 km -13.7 dB
2000 km -17.4 dB

Scattering Angle Distance
500 km 0 dB
1000 km + 4.5 dB
1500 km + 6.5 dB
2000 km + 9.2 dB

The examples show that the received peak power that can be achieved through transmitting 100 watts on 2 meters will produce the same peak power as 4 watts on 6 meters, and that 2700 watts is required to produce the same result on 70 cm. These figures will be partially offset by lower noise levels at the higher frequencies. The range term shows a significant reduction in peak power at longer ranges, but the lower scattering angle at longer ranges partially offsets this. The combined result is that at 2000 km the peak power is only about 8 dB less than at 500 km.

The relationship for ping duration is set out below:

$$un \propto \lambda^2 \times \sec^2(0/2)$$

Wavelength
6 meters 900 ms
2 meters 1000 ms
70 cm 11 ms

Scattering Angle Distance
500 km = 8.1
1000 km = 23.0
1500 km = 36.6
2000 km = 43.4

The wavelength term works against the higher frequencies as a ping that will produce two callsigns, and a report on WSJT in 100 ms on 2 meters will be sufficient for only two characters on 70 cm. The essential element to note is that both the peak power and duration relationships work against the use of higher frequencies. Hence the challenge is to achieve the first 70-cm meteor-scatter contact in VK.

The scattering-angle term in the duration equation is most useful as it extends ping duration with distance, compensating for the loss with range and allowing the use of more frequent weaker pings. This is the reason why meteor scatter is viable at long distances. The graph in figure 1 combines the effects of the peak power and duration relationships to give the relative signal strength after various durations for the same ping.

Figure 1 shows that for short messages of 20 ms the range equation dominates so that the optimum distance is shorter at around 600 km. However, for longer messages the duration equation plays a greater role, and the optimum distance for 100-ms signals as required for two callsigns and a report is around 1200 km.

Single Tones

Figure 1 shows that short pings of 20 ms, as sufficient for single tones, have an advantage over the 100 ms required for two callsigns and report that varies from about 12 dB at 700 km, to 4 dB at 2000 km. In addition, WSJT uses a narrower bandwidth for single tones that can potentially provide up to 10 dB[2] improvement in reception. Thus, the benefit of single tones varies from around 22 dB at 700 km to 14 dB at 2000 km. Using the QSO Time Factor versus Power relationship developed in the Transmitter Power Section above, we find that at 700 km one can receive up to 12 times as many readable single-tone pings compared to 100-ms decodes, reducing to a factor of five times at around 2000 km. This improvement has been confirmed at distances of 660 km and 878 km in tests with VK3AXH and VK3AEF. The results confirm the significant advantage of completing a difficult QSO using single tones.

WSJT requires the same time (20 ms) to identify a simple message such as R26 or 73 in either single-tone or multi-tone format. Thus, the gain in going to single tones in this case is limited to the bandwidth improvement of 10 dB. Based on McKinley's square-root power relationship, a 10-dB improvement should produce an increase of around 3 to 1 in the numbers of signals decoded. Again, tests with VK3AXH and VK3AEF supported this improvement, although it was necessary to set the single-tone trigger level to the minimum of –5 and use a QRN value of 3. At these levels there are large numbers of false decodes, and thus in practice it would be difficult to achieve the full 10-dB improvement. Joe Taylor,[2] K1JT, confirmed this in advising that the theoretical improvement in going to single tones is only possible if the noise levels are low and the QRN factor can be set to a low level. He suggested that 6 dB is therefore a more realistic improvement to expect.

QSO Time Factor with Distance

We can convert the information in figure 1 for 100-ms signals, required for two callsigns and a report, to QSO Time Factor using the relationship derived in the Transmitter Power Section above, to give the results shown in figure 2. In addition, the QSO time factor will be affected by the fact that at long distances and with elevation obstruction the numbers of meteor

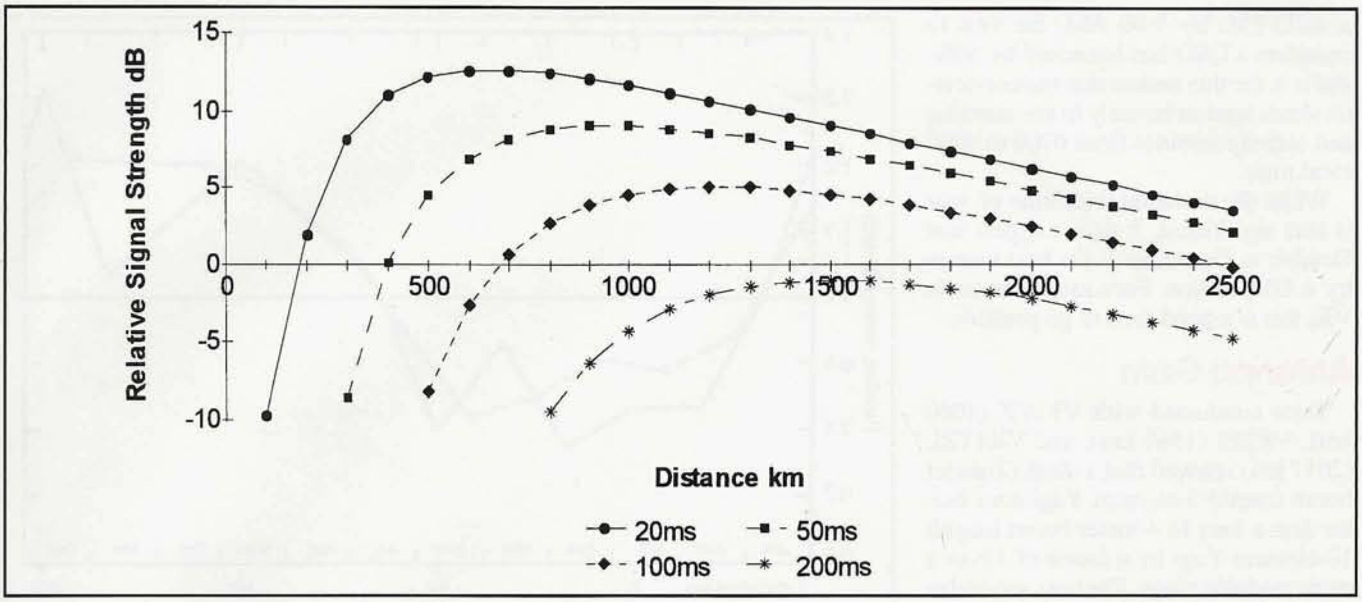

Figure 1. Relative signal strength.

trails seen by both stations is reduced. The curves for 0-degree obstruction and 4-degree obstruction have been added to give an indication of these effects based on a simple proportional reduction of the more effective 400-km common scattering area. This is a major simplification, and thus these curves should be considered indicative only.

What figure 2 means is that at 500 km it will take around ten times as long to make a QSO as at 1200 km. With a total of 4 degrees obstruction, the time to make a QSO at 1900 km is increased by five times that at 1200 km. Figure 2 confirms the observed (but not quantified) results that the best distance is between 800 km and 1800 km with elevation obstruction being a major factor at the longer distances.

Time of Day and Year

McKinley[3] gives results recorded by a number of experimenters on the variation of random meteors with the time of day (p. 113, figure 5-4) and year (p. 119, figure 5-7). While there is some variability between experimenters, one can derive reasonable QSO time factors as follows:

Local Time	QSO Time Factor
0000	1.3
0300	1.0
0600	1.1
0900	1.5
1200	1.7
1500	2.5
1800	3.5
2100	2.5

Month	QSO Time Factor
Jan	1.1
Feb	1.3
Mar	1.4
Apr	1.3
May	1.4
June	1.5
July	1.3
Aug	1.1
Sept	1.1
Oct	1.0
Nov	1.0
Dec	1.0

As an example, if a QSO takes typically 20 minutes at 3:00 AM, it will take 22 minutes at 6:00 AM, and over an hour

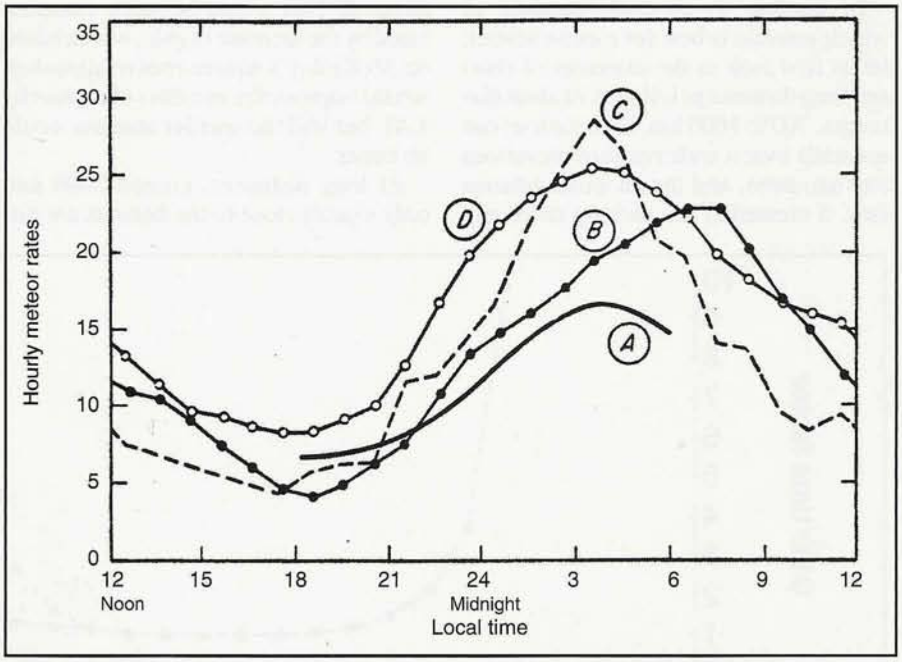

Figure 5-4. The mean daily variation of meteor rates. Curve A: Nonshower visual observations, based on data from several sources; use ordinate scale as shown. Curve B: Backscatter radar observations, 100,000 echoes; multiply ordinate scale by 50 (NRC, Ottawa). Curve C: Backscatter CW observations, 5,800 echoes; use ordinate scale as shown (NRC, Ottawa). Curve D: Forward-scatter CW observation, 210,000 echoes; multiply ordinate scale by 2 (Vogan and Campbell, 1957). (From Meteor Science and Engineering, *by D.W.R. McKinley[3])*

at 6:00 PM. By 9:00 AM, the time to complete a QSO has increased by 50%, and it is for this reason that meteor-scatter skeds tend to be early in the morning and activity sessions from 0700 to 0800 local time.

While the variation with time of year is less significant, it does suggest that October to December is the best time to try a DXpedition. Fortunately for us in VK, this is a good time to go portable.

Antenna Gain

Tests conducted with VK2FZ (1060 km), VK2EI (1360 km), and VK4TZL (2017 km) showed that a short (2-meter boom length) 5-element Yagi does better than a long (6.4-meter boom length) 10-element Yagi by a factor of 1.6 to 1 more readable pings. The tests seemed to be consistent even at the longer distances to VK4TZL, although only small numbers of signals were received at the longer distance, limiting the reliability of these results.

A more extensive test with ZL3TY (1950 km) was run to compare his 4×12-element Yagi with a single 12-element Yagi, and this showed an increase in detectable signals of around 2 to 1 for the larger antenna consistent with the gain improvement of 6 dB.

In coming to an understanding of which antenna is best for meteor scatter, let us first look at the extremes of short and long distance as follows: At short distances, 700 to 1000 km, both stations can see trails over a wide range of elevations and azimuths, and thus a small antenna (say, 5 elements) can pick up more signals. In such a situation, improving antenna gain by, say, 3 dB would result in a reduction in the numbers of meteors by a factor of 2 because of the smaller area covered. This would be partly compensated by the increase in gain, which based on McKinley's square-root relationship, would improve the numbers of signals by 1.41, but still the smaller antenna would be better.

At long distances, around 2000 km, only signals close to the horizon are visible to both stations. In addition, the azimuth angles are restricted by both the distance limitation and the fact that the "hot spots" are smaller in angular terms. At this extreme situation, a smaller antenna sees no greater area of meteor trails, and the loss of gain becomes the overriding factor.

At short distances such as 700 km, the signal comes from around 10 degrees elevation compared to around 1 degree at 2000 km. As most stations do not have ele-

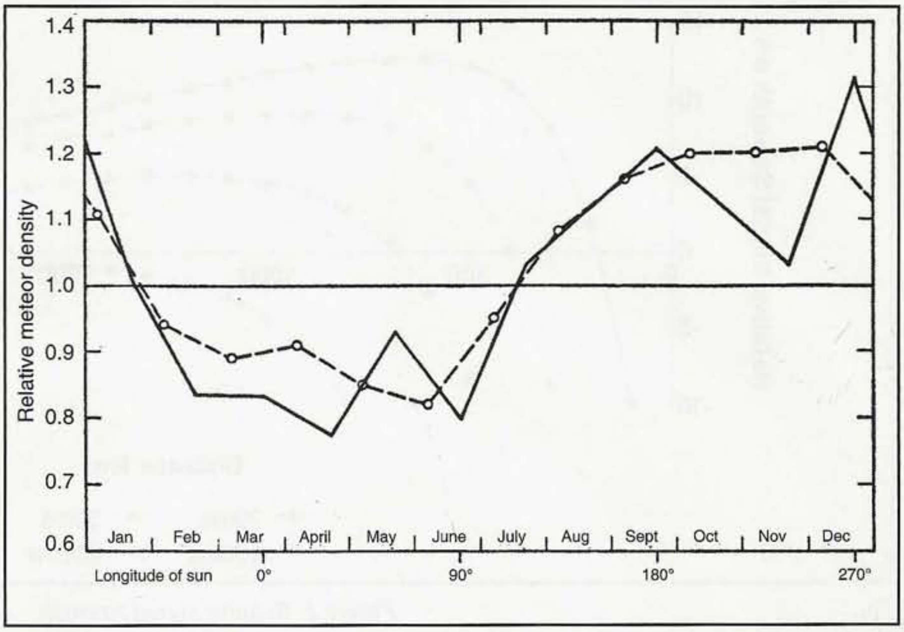

Figure 5-7. The annual variation in the relative density of nonshower meteors, corrected for the effects of the Earth's orbital motion. Solid curve, Southern Hemisphere radio observations (Weiss, 1957). Dashed curve, Northern Hemisphere telescopic observations (Kresakova and Kresak, 1955). (From Meteor Science and Engineering, *by D.W.R. McKinley[3])*

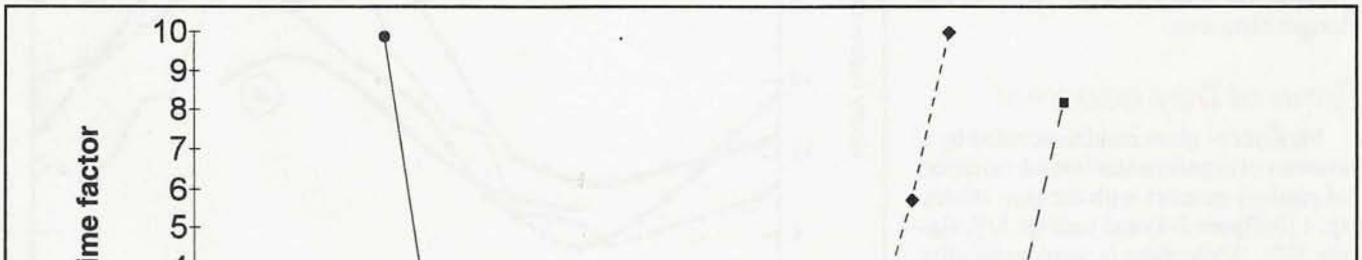

Figure 2. QRO time factor. Note: The horizon angle is the total of that at both stations.

vation control, the large high-gain antennas will miss the shorter-range signals.

A further factor is that larger antennas need to be accurately aligned on a "hot spot" by both stations to be fully effective, and this is not practical if one is looking for a number of stations—i.e., during an activity session or on an DXpedition.

Taking the above discussion and experience into account, it seems that a good general antenna for meteor scatter is a single 5- to 10-element Yagi. Even so, the higher gain antennas are worthwhile for long-distance skeds where both stations have accurately set their beams on "hot spots."

Antenna Polarization

Tests with VK2FZ showed that an antenna of the opposite polarization picks up about one tenth the number of readable pings compared to one of the same polarization. Accordingly, both stations should use the same polarization. It is the practice in VK and ZL to use horizontal polarization for meteor scatter.

Acknowledgements

This author would like to make the following acknowledgements: To Joe Taylor, K1JT, for writing WSJT and making it freely available and responding to my requests for information and clarification for this paper. To VK2FZ, VK3AXH, VK3AEF, VK2EI, VK4TZL, ZL3TY, and numerous others who got up early in the morning to run the tests which provide the practical basis of this paper.

Conclusions

As this paper has illustrated, the following are the features and characteristics of using WSJT in FSK441 mode on 2 meters for meteor-scatter communications:

- Allows reliable DX on 2 meters throughout the year
- Is best in the early morning.
- Works best in the range 800 km to 1800 km.
- Works well with small antennas (5- to 10-element Yagis).
- With 100 watts and range of 1200 to 1400 km QSOs typically take 20 minutes.
- Performance drops off rapidly below 600 km.
- Distances over 2100 km have been achieved, but with zero degree horizons at both ends.
- Maximum distance is 2400 km less 108 km for each degree of obstruction.
- Is too easy on 6 meters and too difficult on 70 cm.
- Great for portable operations on 2 meters to rare grid squares.

This paper represents many hours of research and experimentation by Australian amateur radio operators. It is hoped that it encourages others in different parts of the world to explore more fully meteor-scatter communications now open to experimentation via the WSJT software.

References

1. Taylor, Joe, K1JT, "WSJT: New Software for VHF Meteor-Scatter Communication," *QST,* December 2001, p. 36.

2. Taylor, Joe, K1JT, personal communications conducted during the course of the preparation of this paper.

3. McKinley, D.W.R. (1961). *Meteor Science and Engineering*. New York: McGraw Hill Book Company, Inc. (pp. 113, 119, 239, 240, and 249). ■

QUARTERLY CALENDAR OF EVENTS

Conventions and Conferences

Southeast VHF Society Conference: The seventh annual SVHFS Conference will be held at the Marriott Hotel, 5 Tranquility Base, Huntsville, Alabama, April 25–26, 2003. The room rate for conference attendees is $75/night single or double occupancy. For reservations call the Marriott Reservations Department, toll free, at 888-299-5174, the hotel directly at 256-830-2222, or visit the hotel website at the special link set up at the Southeast VHF Society website: <http://www.svhfs.org>. When making reservations, mention the conference to get the special rate. Make your reservation by Thursday April 3 in order to qualify for the special rate. For conference registration, also use the special link set up at the SVHFS website, or contact Neal Sulmeyer, K4EA, at his callbook address or via e-mail at: <k4ea@contesting.com>.

Dayton HamVention®: The Dayton HamVention® will be held as usual at the Hara Arena in Dayton, Ohio from May 16–18, 2003. For more information, see the Hamvention's website at: <http://www.hamvention.org>.

Calls for Papers

Calls for papers are issued in advance of forthcoming conferences either for presenters to be speakers or for papers to be published in the conferences' *Proceedings*, or both. For more information, questions about format, media, hardcopy, e-mail, etc., contact the person listed with the announcement. To date this year the following organizations or conference organizers have announced calls for papers for their forthcoming conferences:

Southeast VHF Society (see conference dates announcement above): Contact Dick Hanson, K4AND, e-mail address: <k5and@adelphia.net>. The deadline for submitting papers is March 11.

Central States VHF Society (conference dates July 25–27): Contact Joe Lynch, N6CL, at <n6cl@utulsa.edu>. The deadline for submitting papers is May 15, 2003.

Microwave Update (conference dates Sept. 25–28, 2003): Contact Jim Christiansen, K7ND, at <k7nd@att.net>. Deadline for submitting papers is July 1, 2003.

Contests

February: The second annual Six Club Winter (6-meter) Contest begins at 2300 UTC Feb. 7 and goes to 0300 UTC Feb. 10. *Rules:* Each QSO is worth one point in own country and two points for every contact made outside of own country. Hawaii and Alaska each are considered a separate country. *Scoring:* Multiply total QSO points by the total number of grids worked. All entries must be received by March 15, 2003, either by e-mail or snail mail. Web page address: <http://6mt.com/ contest. htm>. Mailing address: Six Club Contests, c/o Wayne Lewis, W4WRL, 3338 South Cashua Drive, Florence, SC 29501-6306 (e-mail: <w4wrl@aol.com>. *Awards:* Will be given out to the first-, second-, and third-place winners in each country.

May: **The Six Club WW Contest** begins 2300 UTC May 30 and lasts until 0200 UTC June 2. *Rules:* Each QSO is worth one point in own country, two points for each contact outside own country, and one extra point for each Six Club member with whom you make contact and put his/her Six Club number in your log. Note all calls and numbers must be correct and complete to count. *Scoring:* Multiply total QSO points by the total number of grids worked. All entries must be received by June 30, 2003. The website and mailing address are listed above.

Spring Sprints: These short-duration (usually 4 hours) VHF+ contests are held on various dates (for each band) during the months of April and May. Sponsored in recent years by the East Tennessee Valley DX Association, sponsorship seems to have been taken over by the Southeast VHF Society. For more information, see the society's website: <http://www.svhfs.org>.

Meteor Showers

The *Lyrids* meteor shower will be active during April 19–25. It is predicted to peak at around 2220 UTC on 22 April. This is a north-south shower, producing at its peak around 10–15 meteors per hour, with the possibility of upwards of 90 per hour.

A minor shower and its predicted peak is *pi-Puppids* (peak around 0300 UTC on April 24). Another minor shower and its predicted peak is the *eta-Aquarids* (peak around 1130 UTC on May 6).

The above information courtesy the International Meteor Organization and their website at <http://www.imo.net>.

Quarterly Calendar

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

Feb. 1	New Moon.
Feb. 2	Moderate EME conditions.
Feb. 7	Moon apogee.
Feb. 9	First quarter Moon. Poor EME conditions.
Feb. 13	Highest Moon declination.
Feb. 16	Full Moon. Excellent EME conditions.
Feb. 19	Moon perigee.
Feb. 23	Last quarter Moon. Poor EME conditions.
Feb. 26	Lowest Moon declination.
Mar. 2	Poor EME conditions.
Mar. 3	New Moon.
Mar. 7	Moon Apogee.
Mar. 9	Poor EME conditions.
Mar. 11	First Quarter Moon.
Mar. 12	Highest Moon declination.
Mar. 16	Moderate EME conditions.
Mar. 18	Full Moon.
Mar. 20	Moon Perigee.
Mar. 21	Vernal Equinox.
Mar. 23	Poor EME conditions.
Mar. 25	Last Quarter Moon and highest Moon declination.
Mar. 30	Moderate EME conditions.
Apr. 1	New Moon.
Apr. 4	Moon Apogee.
Apr. 6	Poor EME conditions.
Apr. 9	First Quarter Moon and highest Moon declination.
Apr. 13	Very good EME conditions.
Apr. 16	Full Moon.
Apr. 17	Moon Perigee.
Apr. 20	Poor EME conditions.
Apr. 21	Lowest Moon declination.
Apr. 23	Last Quarter Moon.
Apr. 27	Moderate EME conditions.
May 1	New Moon.
May 2	Moon Apogee.
May 4	Poor EME conditions.
May 6	Highest Moon declination.
May 9	First Quarter Moon.
May 11	Very good EME conditions.
May 16	Full Moon.
May 16	Moon Perigee.
May 18	Very poor EME conditions.
May 19	Lowest Moon declination.
May 23	Last Quarter Moon.
May 25	Moderate EME conditions.
May 31	New Moon. Very poor EME conditions.

—EME conditions courtesy W5LUU.

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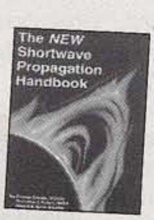

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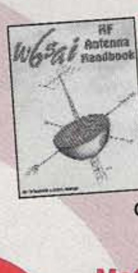

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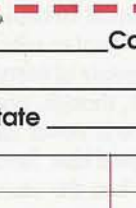

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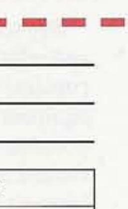

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Barging Through Britain
Part 1

Post September 11th brought new travel restrictions and new airport security. Can one still travel to a foreign country with ham equipment? Challenged by a tourist trip to the U.K., WB5TGF decided to pack his HT for some additional fun. In Part 1 of this two-part article he explains how he prepared for his trip.

By Ron Davis,* WB5TGF

The phone rang at six in the morning. When I answered, there was a familiar voice with a Scottish accent on the other end. It was my wife's sister. Without so much as a "Hello, how are you?" she asked, "How about doing something mad for Christmas?" Not being known as the sanest people on the block, I immediately said, "Why not?"

I turned over the phone to my wife so she could find out what crazy thing her sister had dreamed up. Then I went into the kitchen to start the coffee pot, all the while wondering what they were talking about. From the bedroom I heard laughter and exclamations. The only thing I could think was, "If my wife is this excited, what am I about to get myself into?"

Fear gripped me as I walked back into the bedroom. "Well?" The question hung suspended in the air like a comic-book bubble. She replied, "How would you like to take a cruise, compliments of my sister?"

With visions of Caribbean islands dancing in my head, I said, "Where to?"

She was really enjoying my discomfort. Her hand was held in front of her mouth, so I could see only the twinkle in her eye and not the grin on her face as she answered, "Barging the Midlands of England."

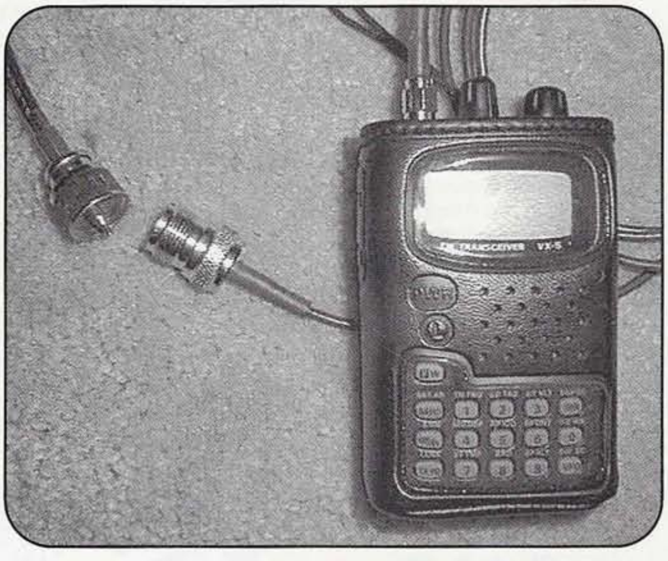
She was serious! As a Christmas gift, her sister had arranged a barefoot cruise aboard a canal barge. The first picture that popped into my mind was that of a crusty, old mariner at the wheel of a ship with a cold, wet gale blowing in his face. Then it hit me (not the gale, but the idea). I could do some great "hamming" while operating marine mobile in the U.K.!

Choice of Handheld

My wife and I regularly visit Great Britain to see her friends and relatives. Every time we go, I want to take a radio and make contacts while we are there. The hassle of carrying an HF rig and equipment has always put me off, though, and I did not have a portable or handheld radio. There is never enough time to get around to doing everything we would like. Setting up a radio and antenna has not been feasible. When the chance of living on a barge for a week came, I began to see new possibilities.

While I was at the Birmingham, Alabama hamfest in 2002, I sold some equipment and had enough money to buy a nice handheld. My friend Gene DeWitt, WA5KNV, recommended the Yaesu VX5R, which he was using at the time. I went to one of the vendors to see if he had one. He not only had one, he also had a show price below $300, including the drop-in fast charger.

*514 Will O Wisp Way, Jackson, MS 39204
e-mail: <wb5tgf@hotmail.com>



The Yaesu VX5 handheld and coax jumper cable for connecting the radio to the mag-mount antennas.

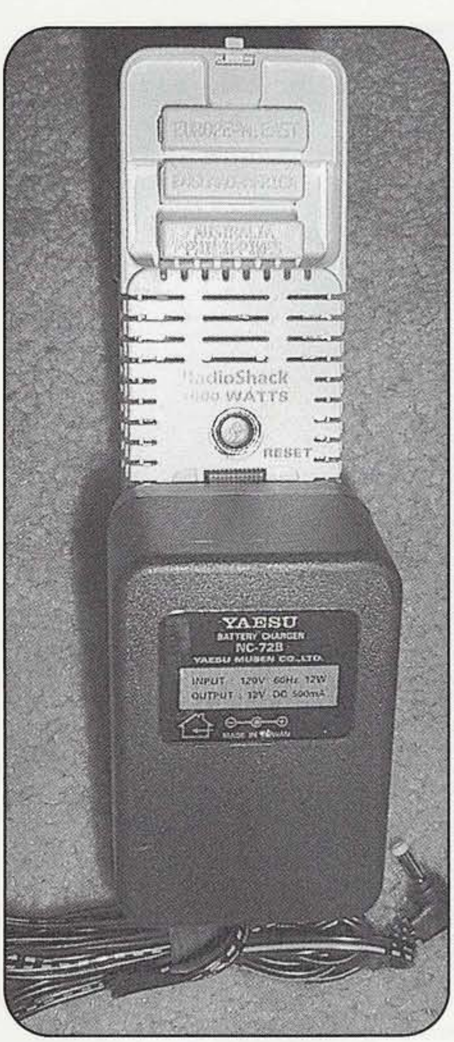
I also looked at the Kenwood TH-F6A, which had the nice feature of HF receive with SSB and CW. The drawbacks I could see at the time were the price and the low power, 220 MHz band instead of 6 meters with the VX5. I opted for the Yaesu unit.

Now I had a radio that I could carry in my shirt pocket and communicate on VHF and UHF FM. This was the perfect unit to take on the trip. A few accessories, and I could simply go to England, cruise on a boat, and operate to my heart's content (plus or minus my wife's wishes). As I was soon to find out, simple was the wrong choice of word.

The Paperwork

I had upgraded from General to Extra Class. I knew from studying the material that I would need some documents to take with me on the trip. Exactly what paperwork I needed had escaped my brain along with calculating resonant-circuit problems.

When in doubt, go to the World Wide Web. Looking for information on the web can be a daunting task, so I will do my best to give all the URLs (web addresses) in the text and/or at the end of this article. I sat down and started the search. The



Charger and European adapter.

first stop was the ARRL web page, <http://www.arrl.org>. I typed "foreign operation" in the search block. From there I found everything that I needed about operating in foreign countries.

First was the CEPT, or European Conference of Postal and Telecommunications Administration, information for U.S. amateurs. This document explains the operating privileges of Class 1: Technician Plus through Extra, and Class 2: Technician license. I read this very carefully several times to make sure of what operating I could do without running afoul of the law.

At the end of this document is a reference to FCC Public Notice DA 99-2344, which you have to have with you while operating in another country. The next part of the CEPT information was the list of countries that recognize U.S. participation in the CEPT Radio Amateur License. You must preface your callsign with the prefix that is associated with the country in which you are operating. In my case, it would be "M/WB5TGF," pronouncing the forward slash as "stroke" per the instructions and appending whether mobile or portable.

I went back to the search page and found DA99-2344—a document that is printed in English, French, and German—which states that you are authorized to utilize an amateur station temporarily in a CEPT country. Along with the DA99-2344 document, you must have in your possession proof of U.S. citizenship and evidence of the FCC license grant. These documents must be shown to the proper authorities upon request. I made copies of my license and the picture page of my passport. I put them into a bound folder along with the form, the CEPT info, and the country list.

Operating in the U.K.

Now that I had taken care of all the legal paperwork, it was time to find out about operating in the U.K. I went back to the web browser and did a search of amateur radio, Great Britain, and found <http://www.rsgb.org>, which is the Radio Society of Great Britain web page. There I found and made copies of the band plans for 2 meters, 6 meters, and 70 cm.

I studied the band plans for a while, comparing them to those in the U.S., and found many differences. For instance, the UHF band goes from 430 MHz to 434 MHz, and the frequency shift from transmit to receive is either 1.6 MHz or 7.6 MHz. The VHF band uses the same 600-kHz shift that we do, but it uses a different part of the spectrum. The 6-meter band uses a different set of frequencies and a 500-kHz shift.

My search for more information led me to Colin Dalziel, GM8LBC, who maintains a very informative web site on repeater operation in the U.K. (<http://www.coldal.org/repeater.htm>). I got much of my information on the band plans from this site.

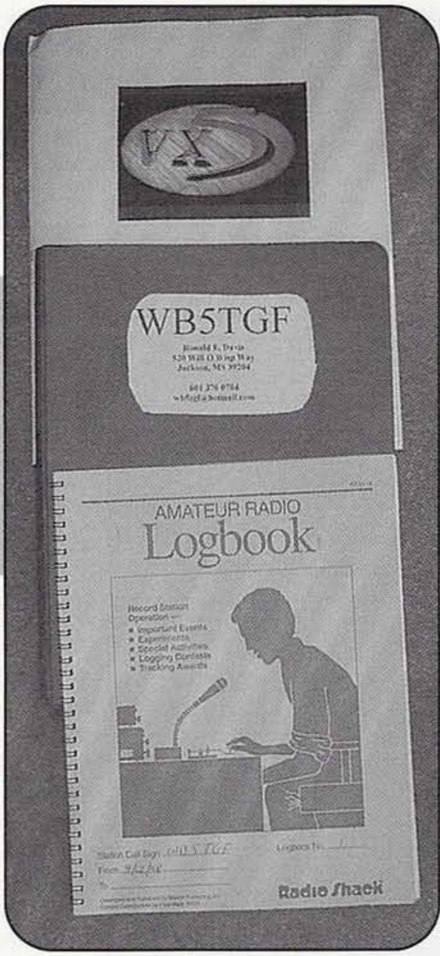
Reprogramming the HT

After gathering together all of this information, my folder was beginning to grow quite thick. It also looked as if a major reprogramming of my HT would be in order.

After I purchased the VX5R, I bought the software and program cable, but I had not used it for programming the radio. I had entered the local repeater frequencies manually. A quick check showed that I would have to program 58 channels, their

VX5 display showing programmed CW ID.

VX5 display showing programmed British repeater frequency and callsign.



All of the paperwork for the trip, including the handheld manual, folder containing necessary forms, and logbook.

associated splits, and CTCSS tones. It was time to load the software and go through one of those learning-curve things in which I usually skid off the road and into the ditch.

To my amazement, the program was easy to use. If you go to the coldal.org web page mentioned above, there is a button that says U.K. repeaters. You can get almost all the information you need about individual repeaters, their frequencies, and tones if any. I discovered that repeaters over there use 1750 burst tones and or CTCSS.

Programming the odd TX/RX shifts was no problem. The VX5 is sold in both markets, which makes this easy to do. All the input was done on the computer and checked for errors.

The next step was programming the radio. First I had to create a template of the radio, then download and save the data that I had programmed manually into the unit. I hoped that when I got home, I could put the data back without having to do the manual programming. Per the instructions, I programmed the monitor button to transmit the 1750 burst tone. I also used the CW ID feature and put M/WB5TGF into that memory. In addition, I enabled the feature that samples the receive signal and lowers the transmitter output when receiving a strong signal.

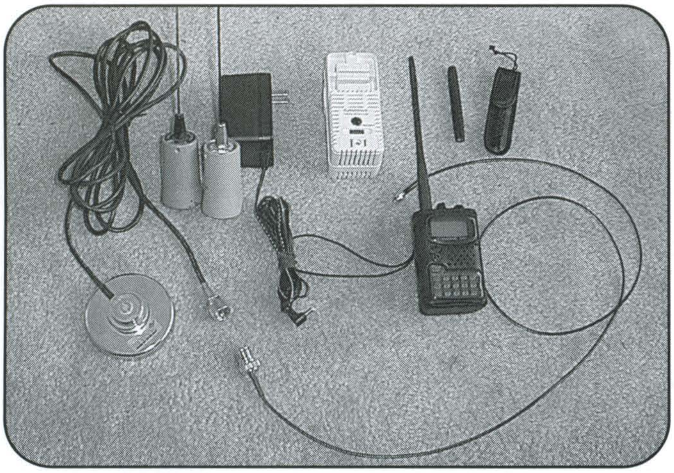
The Rest of the Equipment

Now all I had to do was gather the equipment I would need for operating on the barge. I needed to know what power sources were available and if the canal barge had a steel hull. In Great Britain the auto power is the same 13.6 VDC we have over here, but the AC is 240 volts, requiring a transformer and adapters for the different plug types.

A magnetic-mount antenna would be easier to carry over than a ground-plane base-station antenna. An e-mail request to the U.K. came right back with an answer within a few hours and confirmed that 13.6 VDC and 240 VAC were available and that the barge was indeed metal. My wife has a transformer that converts the 240 to 120 volts, rated at 1600 watts. This would be plenty for the HT charger. I could "stick" the magnetic mount to the roof of the barge and have an excellent ground plane. I rounded up a 6-meter coil and a 2-meter/70-cm coil. I had an adapter for converting the SMA connector on the HT to work with the feed line on the mag-mount. My only worry was the appearance of Murphy, who applies his law to both the wary and unwary alike.

The remaining thing to do was pack the equipment and hope the Transportation Security Administration (TSA) would not seize everything, which is something to consider when traveling with electronic equipment. When doing contract work for the airline industry, I have to carry tools and test equipment. I have had little trouble checking my tool bags, but since September 11, 2001, I do not carry tools, test equipment, or walkie-talkies onto an aircraft. Even a 2-inch-long nut-driver insert makes security personnel nervous. My concern was putting my "toys" into a bag and experiencing their disappearance into never-never land.

I planned on taking the HT and charger as carry-on. I would check to see if it was okay before checking our bags. One more



All of the equipment for the trip laid out and ready for packing.

consideration was the process of declaring items at customs. Original receipts would be with the HT as proof of purchase. The U.K. has a value added tax (VAT) which is accessed on items purchased in the country, and if I could not prove I had brought it into the country, payment would be required on leaving.

Everything was now packed, with the only real challenge having been the antenna rods. I had to apply some short radius curves to them. All the other items went into pockets in my clothes bag and in my carry-on briefcase. The next hurdle was getting all these bags to the airport.

The Trip Begins

After eight hours of driving, we arrived at Hartsfield airport in Atlanta. We had a one-way car rental from Jackson, Mississippi and had to drop off the car first. Arriving three hours early made check-in easy. Because we were first in line at the ticket counter, checking our bags and picking up the boarding passes only took a few minuets.

As I stood in line for security screening, I kept looking around for the steely-eyed counter-insurgency agent who was going to yell, "Hands against the wall and spread 'em." Well, it never happened, and my briefcase with the VX5R went straight through with no problem.

The newly trained TSA agents were very courteous and helpful. The fears of having my goodies taken from me were unfounded. The British Airways flight left at 8 PM from Atlanta, and we arrived in London at 8 AM GMT. All the way there I was wishing that the captain would push the thrust levers up and do about mach 3, but he didn't, and the trip was long.

After deplaning, we had to go through British customs. One more chance for someone to snatch my radio was a possibility. With my form DA99-2344 held in front of me like a shield, I charged ahead.

On the airplane, I had filled out a country entry card and put down the place we would be staying in Britain as "canal barge, Burton on Trent." The woman at customs looked at the card and said, "How wonderful! You are doing holiday on the canals." I said yes, and she said, "Have a nice trip." That was it. We were in!

In the next issue of CQ VHF *we'll see how WB5TGF fared making inland marine mobile contacts with his HT. —ed.*

A Modular, High-Performance 23-cm ATV Transceiver

Here's an easy-to-build design by GM4PLM using low-cost, readily built ATV modules.

By Simon Lewis,* GM4PLM

Amateur Fast Scan television has been a part of the hobby that has fascinated me since my early days in amateur radio. I can still remember the thrill of watching those early 70-cm black-and-white transmissions using a modified domestic TV set I acquired from a trunk sale. My first real introduction to Amateur Television (ATV) was as a young man through a local ham, Barry White, G8YGT. He proudly showed me his beautifully kept Pye Image Orthicon camera and home-brewed 70-cm transceiver in his small, home-built studio at the back of his house. Barry kept my imagination flowing with stories of his days as a cameraman for prestigious, and now historic, TV programs such as *Sunday Night at the London Palladium.*

Those stories and visits to his studio gave me an interest that has never left me, and over the years I have enjoyed numerous bouts of ATV activity on 70 cm and 23 cm using both home-brewed and commercial equipment. In recent years my ATV activities were curtailed because of antenna problems at my small QTH, but a recent move to a new QTH and access to wide-open space brought me back to ATV with a renewed enthusiasm to "get going again."

I was quite shocked, however, when I picked up a copy of the British Amateur Television Club (BATC) magazine, *CQ-TV.* Technology certainly had moved on during the few years I was away from it, and the pages were now packed with readily available equipment for 23 cm, 13 cm, and even 10 GHz. The impact of the SATTV (satellite TV) market was also readily visible, with some of the vendors offering a variety of modules and surplus equipment from the market for use on the amateur bands. The introduction of other technologies, such as Wireless PC networking, also seemed to be having an effect, with readily available equipment that was only dreamed of a few years before. Things certainly had moved on very quickly, but all to the ham's benefit, that's for certain!

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e-mail: <gm4plm@emn.org.uk>

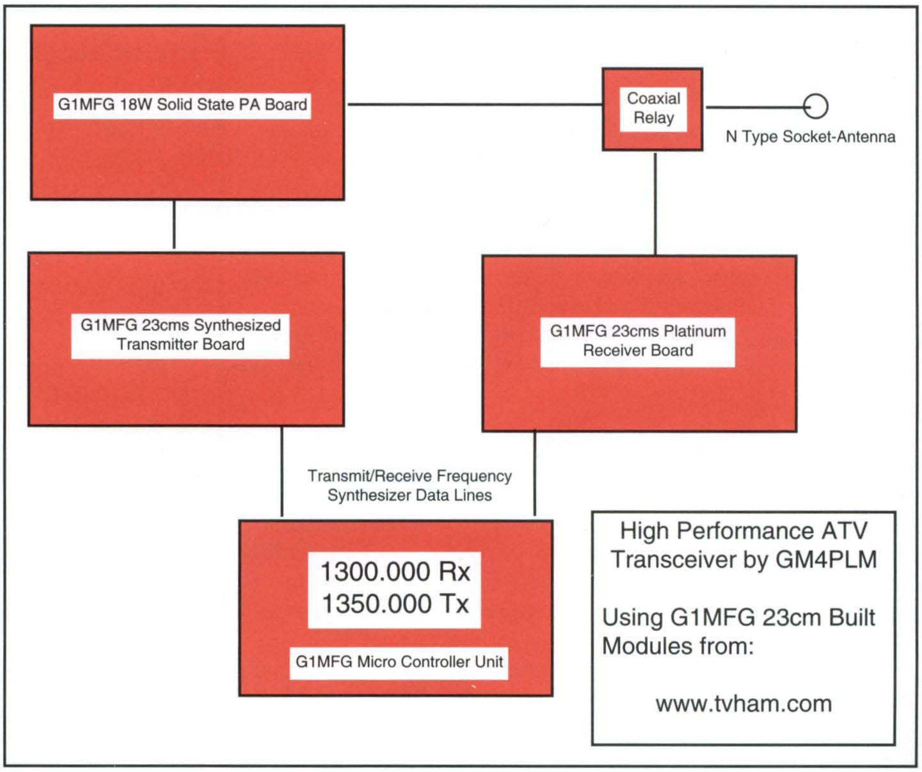

Figure 1. Block diagram of ATV station.

I decided that a good start would be to build a new station using some of the available modern components rather than try to resurrect some old equipment I had, which definitely was in need of some TLC to get it going again. Finally I decided I would build a new transceiver for the 23-cm ATV band using some of the ready-made modules available on the pages of *CQ-TV.* This course of action would allow me to construct a new transceiver that would perform well with the minimum amount of construction and alignment time. These modules certainly seemed to be able to offer quick access to the band with the minimum amount of fuss, a far cry from a few years ago.

After some deliberation I finally decided to buy some of the products from Giles Read, G1MFG. Giles runs a small, but busy internet and magazine mail-order business that specializes in ATV products (see <http://tvham.com>). He also has a great customer approach and a keen interest in home construction. I was pleased

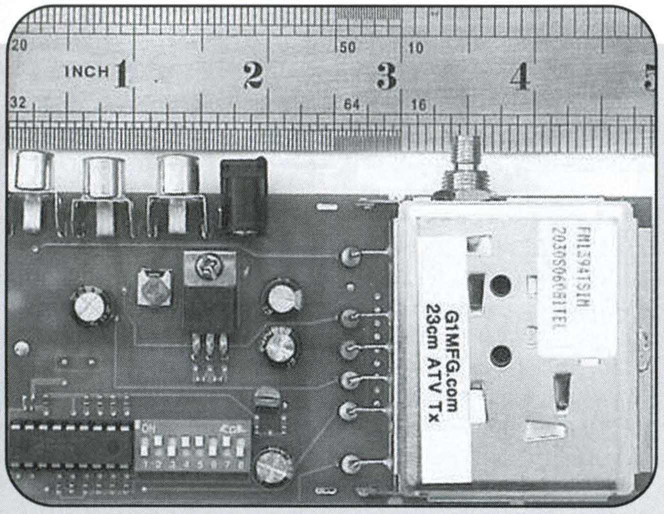

Photo A. Transmitter card.

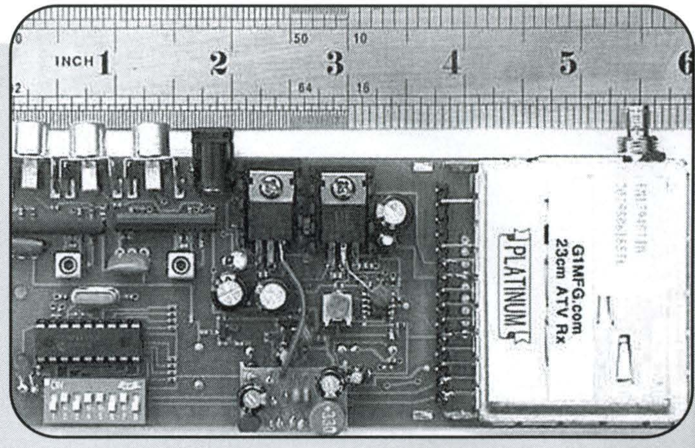

Photo B. Receiver card.

that he could answer all my queries quickly, and a set of modules was soon on its way to Scotland. Incidentally, Giles has a U.S.-based presence as well and has been featured in the American ATV magazine *ATVQ*. He has become quite well known on the other side of the pond for his ATV activities.

The modules were delivered quickly and came safely packaged, including detailed instructions for each of the modules in the form of a small booklet.

Figure 1 shows a block diagram of the transceiver that forms the basis of the transceiver I constructed. It is based on four modules from Giles—a receiver, a transmitter, a controller, and a solid-state power amplifier. The only module not supplied by Giles was the DC power supply, which is an external 13.8 VDC supply. I decided from the outset that the modules would be built into a small desktop case so that it could reside on one of the shelves where I house a lot of my equipment. Of course, you don't have to follow this construction pattern, and you can house the modules in any suitable enclosure that meets your needs. It really does not need to be anything spectacular, but I would advise using a metal enclosure, as it is an RF kit, which should be screened.

Before describing how the whole unit fits together, it's worth looking at some of the features of each of the modules, as they will work as standalone units if required.

Module 1: Synthesized Transmitter

This module comes built and working. Its Its size is just amazing! It's simply a case of mounting the unit into the chosen enclosure. As the transmitter only runs low power, at this point I decided not to enclose the unit in a smaller screened housing. I mounted it directly in the main chassis. The board measures 125 × 60 × 18 mm, and I was amazed at the very low component count. There really is hardly anything on this board!

The biggest component is a screened tinplate unit that houses all the RF components. Other than input sockets for audio/video and DC power, there is not a great deal else on the board to talk about! RF out is fed via a small microwave-type SMA socket, which is a good choice. They are easily available at low cost, perform well at these frequencies, and nicely fit miniature low-loss PTFE coax.

Frequency selection is made via an 8-way miniature PCB-mounting, DIL-style switch, which in a standalone unit selects the operating frequency from a PIC microprocessor. Frequency steps are selectable in 500-kHz steps and will cover the whole of the 23-cm amateur band. The board requires 12–18 VDC and produces between 50 and 100 mW RF output.

Module 2: Receiver

The receiver module looks similar in style to the transmitter module but is slightly larger, measuring 150 × 60 × 18 mm. Again, the board looks sparsely populated, although it has a few more components than the previously described transmitter. It is also dominated by the metal-screened RF module at one end of the PCB. RF input is again via a microwave-style SMA socket. Audio and video outputs are via phono-style sockets, with sockets for 6- and 6.5-MHz sound outputs. The DC connector is also a 2.1-mm DC-style item (tip positive).

As in the previously described transmitter, this unit requires 12–18 VDC. Frequency control is selectable in 500-kHz steps in exactly the same manner as the transmitter, using an 8-way DIL PCB switch and a PIC microprocessor. A small onboard LED shows the PLL is locked. This version of the receiver range is the Platinum model, which includes a video de-emphasis filter on the PCB.

Module 3: LCD Transceiver Controller

Although both transmitter and receiver units can act autonomously, in a transceiver it would be rather unwieldy to keep adjusting the internal DIL switches every time a frequency change is necessary. To overcome this problem, a companion controller PCB has been introduced. This module contains a PIC microprocessor, which provides the frequency control signals directly to the transmitter and receiver synthesizers instead of the onboard PICs (that are removed) and DIL switches.

There are a number of benefits, other than simply allowing easy control of both transmit and receiver modules, to be derived from using the controller module. Because frequency control is no longer restrained by the limits of an 8-digit binary number programmed by the DIL switches, the frequency-control step resolution can be increased to 125-kHz steps. This can also be used to extend the receiver range, although the

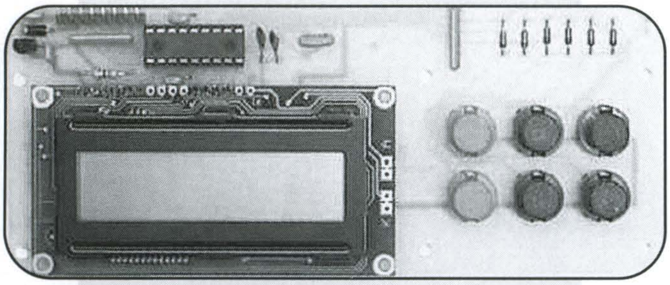

Photo C. Controller card.

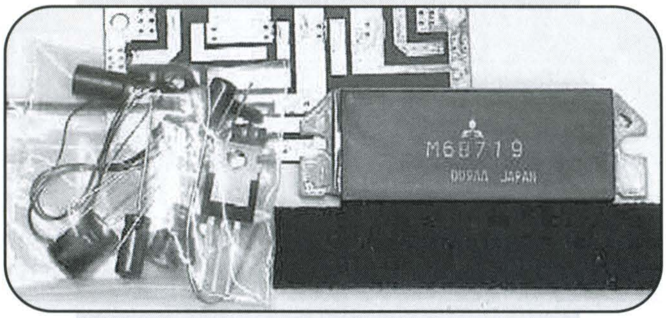

Photo D. PA card.

transmitter has purposefully been limited to only the 23-cm amateur-band range.

Frequency selection is achieved via a set of up/down tuning buttons, and the transmit/receive frequency control is displayed on a two-line LCD display. A backlit version also is now available for that added look and feel. Transmitter and receiver frequencies are controlled independently. Three VFOs are provided for both receiver and transmitter, and these act independently.

One very useful function is an "autonet" switch. This feature automatically retunes the receiver to the selected transmit frequency when the transmitter is enabled, allowing off-air monitoring of the transmitted signal. This is a particularly useful function when using ATV repeaters, for example.

To use the frequency controller module with the G1MFG receiver and transmitters, there are a number of small modifications that need to be made. These are detailed later in this article.

The controller module is designed to be mounted close to both receiver and transmitter modules. The modules can be mounted remotely up to 3 feet if required, and longer distances are possible by utilizing Phillips I2C bus driver ICs. Again, details are included in the paperwork, and use of these ICs could allow the modules to be mounted in a masthead-mounted configuration.

Module 4: Transmitter Power Amplifier

Although the transmitter modules are quite usable as they come from the supplier, their low power output does tend to limit their capability of covering any significant distance. Therefore, I decided to build some additional power amplification into the transceiver in the form of the matching G1MFG 23-cm solid-state PA. This module is designed around a Mitsubishi "black brick" PA module. Oddly enough, the G1MFG PA does not use the M57762, which is normally selected for amateur 24-cm use, but uses an M68719 instead.

There are a few minor electrical differences, but physically they are the same. The most important difference is the ability to provide around 18–20 watts of RF at around 1250–1300 MHz when driven by the G1MFG transmitter module. The module in my unit was mounted on a hefty 0.5-deg/C per watt heat sink on the rear panel of the case. Make sure the module is well ventilated, as these modules do not like to be run hot or supplied with more than 15 VDC. If you treat them badly, they tend to give up on life very quickly, and in a most expensive fashion!

You will need to feed the board with 13.8 VDC at around 5 amps. Remember to think about this for your DC wiring. The kit includes all the PCB-mounted components and the PA module, but not the heat sink, as heat sinks are heavy to post (mail or ship) and are readily available at hamfests.

Building the Transceiver

The modules are mounted into the chosen enclosure using small standoff pillars. These should be high enough so that the metal case does not interfere with the base of the PCB. The connectors and switches, both RF and DC, are mounted onto the case and wired using small-gauge wire and miniature RF coax. Audio and video lines should also be wired using coax, again to minimize the potential for interference on these signal lines. The PA DC lines are wired directly to the DC input connector using an inline fuse holder but utilizing heavier gauge wiring, as this module requires a much higher current supply.

As discussed above, both transmitter and receiver modules are capable of operating independently. However, in our case we want the units to operate together as a unit using the controller as the central transceiver control module. To achieve this goal, the microprocessors of both transmitter and receiver need to be removed, and the controller's transmit and receive data lines wired directly to the respective PCB pins of the RF modules. This is a relatively simple task, and the PICs acan be removed easily from their sockets using a small screwdriver. The documentation supplied with the modules identifies the necessary pins that must be connected on the respective modules. The PICs can be reprogrammed for your projects, as they are no longer needed unless you would want to use the modules individually again in the future.

In my unit I wired miniature coax to the pins of the audio and video connectors and brought these out to connectors on the front panel, which was the easiest method for my purposes.

Power was connected via small-gauge wiring except for the PA module, which uses much thicker wiring because of the higher currents involved. Switches for power, transmit/receive changeover, and auto net functions all were panel mounted. A fuse holder, DC power connector, and N-type antenna connector were mounted on the rear panel, as was the large heat sink for the PA module.

A small 12-volt RF relay was mounted internally to allow the single N-type connector on the

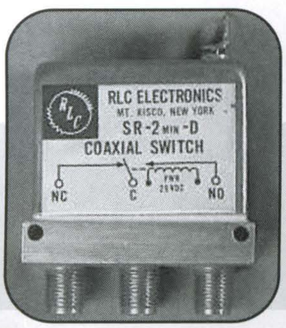

Photo E. Coaxial relay.

rear panel to be switched between transmit and receiver modules. This connector is switched using the transmit/receive control line. Make sure the relay you choose is capable of carrying the power you are running through it, and that it is also rated at 23 cm. Otherwise you will find that it becomes lossy and could turn out to be an unwitting dummy load!

RF interconnections between the modules were made using miniature PTFE coax and small SMA connectors. These connectors are an excellent choice at these frequencies. They allow good, reliable, and (more important at microwave frequencies) low-loss connections to be made between the modules. This is particularly important where (a) low-power connections are made and poor connections would lose that power, or (b) high-power microwave transmissions in the wrong type of connector can cause heating because of high losses and potential damage to RF modules and connectors alike. Choosing the right connector and cables at these frequencies is very important. SMAs are readily available these days and are quite cheap as well.

Connecting the units is a quite simply matter of wiring together the DC control lines and RF, audio, and video connectors.

Transmitter

Operating frequency range 1.2400 GHz to 1.3675 GHz in 0.5-MHz steps. *Note:* The transmitter is capable of operating outside the 23cm amateur band (1.240 GHz to 1.325 GHz).

Output power +17 dBm (50 mW) typical (minimum +15 dBm, maximum +19 dBm)

Deviation variable, typically 6 MHz

Output impedance 75 ohms nominal (works fine into 50-ohm antennas and power amplifiers)

Output connector 50-ohm SMA or 75-ohm "F." We recommend you go for the SMA version (for better RF performance)

Video input standard 1-V peak-to-peak, phono connector

Audio sub-carrier frequencies 6.0 MHz and 6.5 MHz

Audio input line level (approx. 1 V max.), phono connectors

Audio deviation 45 kHz typical

Power requirements 12 to 18 VDC, 150 mA approx, tip positive. Best results are obtained with a supply of 15 V or more.

Receiver

Operating frequency range 1.2400 GHz to 1.3675 GHz in 0.5-MHz steps

Intermediate frequency 479.50 MHz

IF bandwidth 27 MHz

Local oscillator leakage –63 dBm typical

Input impedance 75 ohms nominal (works fine with 50-ohm systems)

Input connector 50 ohm SMA or 75 ohm "F." We recommend you go for the SMA version (for better RF performance)

DC power to masthead preamp user defined, up to 18 V, 250 mA max.

Power requirements 12 to 18 VDC, tip positive, 250 mA typical, excluding preamp power

Table 1. Technical specifications. Note: These transmitters and receivers will work fine with PAL, NTSC, or SECAM video signals.

Testing

Once the unit is wired, you can carry out the basic DC tests. Once the unit has passed the initial smoke test, you can test the frequency controller tests. The two-line display should follow the up/down keys on the controller. With a suitable dummy load and power meter connected to the transmitter, you can test the output of the unit, which should be approximately 15–18 watts.

The VFO buttons and autonet functions can be checked, and that just about completes the testing. As all the modules are simple to build and there is no alignment to carry out! Now I see why I chose these modules!

On The Air

I used the modules over a couple of weeks' holiday, and I was very pleased with their performance. They certainly do the trick! Combining them, using the controller module was a good plan, and it was easy to program in a simplex channel and the local ATV repeater channels, switching between both of them with the simple push of a button. The frequency display using the LCD was bright and easy to read, providing a simple "at a glance" view of the operating frequency.

Building the units into a transceiver was simple, and with a few nights' work even a beginner can produce a quality unit that will work the first time. This simplicity has to be good for encouraging newcomers to the hobby!

The transceiver was taken on a hilltop DXpedition and proved itself out in the wilds. With the addition of a small, modern digital video camera or CCD camera module, a very compact ATV transceiver could be built for grid-hopping contests.

Overall, I highly recommend the modules as a good start, and with a very good price. Giles, G1MFG, offers an excellent service and he certainly loves his ATV!

The modules are available at <http://TVham.com> and are priced as follows: ATV transmitter, £89.99; ATV platinum receiver, £129.99; micro controller, £89.99; and 18 watt PA, £199.99. All items include shipping and handling. Also available are miniature coax and SMA plugs. Soon to be offered are metal custom cases. Price conversion to U.S. dollars is at the time of purchase. ■

The Last Hurrah for Cycle 23?

North-south path *F2* activity dominated 6 meters during the fall of 2002. What can be expected for the next few months?

By Ken Neubeck,* WB2AMU

After the great fall *F2* season on 6 meters in 2001, there was a significant amount of anticipation by veteran 6-meter operators as to what type of *F2* activity would occur in the fall of 2002. Would Cycle 23 still hang in there for more 6-meter *F2* activity? Part of the anticipation for potential openings involved the monitoring of solar flux values in the months prior to the fall period.

In the Northern Hemisphere there were several days in July when the solar flux values reached 200 or more. This high value was only of benefit to some stations located in the Southern Hemisphere (during their winter season). There was hope that these values would remain high in subsequent months, leading to the fall-winter season in the Northern Hemisphere.

The equatorial zone did produce some 6-meter *F2* activity during late September and into early October. Coinciding with that propagation, there was a good TEP (Trans-Equatorial Propagation) season along the normal paths of the southern U.S. into Argentina. Many of the stations in southern Florida were consistently working Argentina stations during the late afternoons of this time period.

On October 6 there was an extremely strong sporadic-*E* opening that linked the northeastern states into Florida at the same time a strong TEP path developed between Florida and the lower part of South America. With both the TEP path and the sporadic-*E* paths lasting for more than two hours, this led to one of the best openings for stations in the northeast U.S. to work into South America. Table 1 shows the stations I initially was able to work from my location on Long Island (grid square FN30), along with the propagation mode(s) indicated, showing the strength of this particular opening.

After 8 PM local time on October 6 (0000 UTC on October 7), via sporadic-*E* I continued to work more stations located in South Carolina, Alabama, and Louisiana, until 10 PM. With the sporadic-*E* path moving higher north, after that time my connection to the TEP path was lost. Many stations in Maine and New Hampshire still had the combined TEP plus sporadic-*E* path for another hour after that, and they still managed to work into Brazil. Overall, it appeared that the sporadic-*E* opening lasted five to six hours, which is a very long time for such an opening in October, a month when historically there is sparse sporadic-*E* activity. Both the duration and the southern direction of the sporadic-*E* opening from the northeastern states into Florida made this an incredible event!

*(Editor's note: The MUF of the sporadic-*E *event that Ken describes above briefly extended into 2 meters. Gene Zimmerman, W3ZZ, reported in his "The World Above 50 MHz" column in the January 2003 issue of* QST *that a number of stations in the Maryland, New York, southern New England, southern Ontario, and West Virginia areas made contacts into the Carolinas, Georgia, and Florida. Gene indicated that the opening lasted between 2328 UTC, October 6 and 0011 UTC, October 7.)*

Time (Z)	Callsign	QTH (Grid)	Propagation
2050	PY5CC	Brazil (GG54)	Es + TEP
2105	K4RX	Florida (EM70)	Es
2224	LW4EW	Argentina (GF05)	Es + TEP
2310	W4AXM	Florida (EL98)	Es
2315	W2GFF	Alabama (EM60)	Es

Table 1. On October 6, 2002 there was a very strong sporadic-E opening that linked the northeastern states of the U.S. into Florida at the same time a strong TEP path developed between Florida and the lower part of South America. This led to one of the best openings for stations in the northeast U.S. to work into South America. Listed are the stations the author initially was able to work from Long Island (grid square FN30), along with the propagation mode(s) indicated, showing the strength of this particular opening.

Last year's sparse *F2* activity was observed on a few days during October; the northern part of the U.S. was able to experience north-south openings into the Central America region and the northern part of South America. The first big opening that I observed was on October 24, when I was able to work TI5/NH7C in Costa Rica and HP1DCP in Panama at 11 AM. TI5/NH7C was strong at 59 plus for over an hour. Other stations were also heard over the next hour, including the HG8GR beacon and PT7NK in Brazil. Another strong opening was heard on October 29 at 9 AM local time, during which many operators in the northeast U.S. (including me) worked TI5/K1EP. For the eternally optimistic, there was hope going into the month of November that perhaps 2002 would have a decent fall *F2* season. Unlike 2001's *great* fall *F2* season, however, there were no significant reports of Europe working into the U.S. by the end of October 2002.

November Openings

North-south *F2* openings continued to come in strong at the beginning of November. On Sunday, November 3, many U.S. stations worked into Mexico, Costa Rica, Colombia, and the Galapagos for several hours in the morning. In fact, there was evidence of strong backscatter, as some stations in the northeast U.S. were hearing some of the stations in Arizona while their beams were facing the opposite direction. On November 5 another strong north-south *F2* opening occurred, and I worked HP2CWB in Panama on CW at 9:30 AM local time. Throughout the first two weeks of the month this seemed to be a pattern, where occasional *F2* in the form of north-south paths was com-

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ing through. However, there was still no evidence of significant U.S. to Europe openings or transcontinental U.S. openings as there had been a year earlier.

Solar flux values during November were dancing around the 160-190 mark, and the *Kp*-index often hovered between the values of 3 and 5. This was a significant drop-off from the many weeks of solar flux values over 200 during the fall of 2001. The high *Kp* values coupled with moderate solar flux values seemed to result in occasional north-south *F2* openings, while no east-west *F2* paths occurred. Thus, it appeared that the prediction of spotty *F2* openings for the fall was going to be the case, and it would take continuous monitoring of the band and internet web sites to help make contacts.

Then after a quiet period of a week, some interesting things started to happen again. On the afternoon of November 20 several U.S. stations in the northern states reported hearing 46-MHz Australian TV video signals coming in very strong. Shortly thereafter, a few operators in the U.S. worked a few Hawaii stations. One of the hams on Long Island who heard one of the Hawaii stations was Frank, AA2DR. At some point Frank decided to call "CQ DX" on 50.110 MHz, and at 2220 UTC VK2FHN in Australia came back to his call at 55 signal strength. Just over 11 years prior to that (late October 1991) Frank had worked VK4BRG. A few other stations in the 2nd and 3rd U.S. call areas managed to work VK2FHN before he faded out. There was probably a sporadic-*E* link involved on both ends of the path, linking to an *F2*/TEP path over the equator.

During the evening of November 20 there were reports of aurora in the Northeast and the northern Midwest states. Lefty, K1TOL, was able to work into VE7DUB via auroral-*E*. With the *Kp* reaching 5, many operators speculated on the high probability of north-south openings appearing the next day.

Well, it happened! Central America came in full blast into the northeast U.S. at 10 AM local time. I took a few minutes away from work and managed to contact TI4DJ, HP3XUG, TI5BX, and TIØ/NØKE in a matter of five minutes, followed by HP1AC 20 minutes later. At noontime HC8N in the Galapagos was activated on 6 meters by a group of operators that was preparing for the CQ WW CW Contest the following weekend.

December Conditions

After nearly a four-week drought in *F2* propagation there came three consecutive days of solar flux values over 200. On December 19 the 6-meter band again saw some *F2* propagation. This time it was Europe. Several New England stations, for example K1MIA and W1JJM, worked ON4ANT and other stations in the Netherlands. The opening was basically weak and lasted for about an hour. Later, after 1800 UTC on the same day, the West Coast came in very strong at times over the next three hours, until 2100 UTC. I was able to work K6RIM in CM87 using my portable 2-element beam setup at work. Many other stations from the 6th call area were heard on the East Coast. In addition, some stations in the middle of the U.S. were able to work into the Caribbean. Some Midwest stations worked NH7RO in Hawaii. I was beginning to think that perhaps during this present sunspot cycle there would be a little bit of *F2* activity remaining on 6 meters after all!

Conclusions

Looking at the November 2002 auroral opening and similar openings in the past on 6 meters, there definitely seems to be a direct cause-and-effect relationship between a significant aurora event and an *F2* event that follows within the next 24 hours. The same activity that enhanced the extension of the aurora from the poles area also energized the areas within 10 degrees above or below the geomagnetic equator. Indeed, it appeared that the higher the *Kp* value reached during the aurora opening, the shorter the wait for the north-south path *F2* opening to occur. For example, when the *Kp* reached 8 late in the day on April 7, 2000, during a 3-hour aurora opening there was an immediate opening into Central America minutes after the aurora subsided at 8 PM local time in the northeast U.S. When the *Kp* values reached lower levels, such as 6 or 7, the subsequent north-south *F2* opening did not occur immediately, but it did occur within the next 24 hours.

Indeed, there are many similarities between the fall of 1991 and the fall of 2002 (11 years, or one solar cycle, later), with both seasons being on the downward side of the peak, but when there was higher geomagnetic activity during the years immediately following the peak. It almost would appear that the combination of high geomagnetic activity and moderately high solar flux values (greater than 180) leads to long-range skewed paths. Also, it seems that the higher geomagnetic activity in effect shuts down the east-west *F2* paths.

Another item of interest is the relative consistency of either the HC8GR beacon or "live" stations being heard on the 6-meter band, often with no other signals appearing. If there is such a thing as a pile line on 6 meters, this particular north-south path may be one of them when the conditions are right.

Going into the *F2* season of 2002, many 6-meter operators were still hoping for that one last opening between the U.S. and Europe before Cycle 23 ends. There were approximately six to eight days of *F2* activity that were observed by most stations in the northeast U.S. during the month of November, but all of the openings were north-south. There were no prolonged openings into Europe from the East Coast or from the East Coast into the West Coast during November, a far cry from the several weeks of activity that occurred in November 2001. Wintertime sporadic-*E* activity was fairly significant during this time, with a major opening occurring on the East Coast of the U.S. for over five hours on November 30.

Last Hurrah of Cycle 23 for *F2* Propagation on 6?

There still may be some *F*-layer related propagation for 6 meters during the next six months or so. Most of this will be in the form of TEP openings, where the *F*-layer over the geomagnetic equator occasionally may have an MUF reaching 50 MHz, with stations in the TEP zone still being able to work on 6 meters. This generally would occur during the equinox months, and with the occurrence of a sporadic-*E* link in the right direction, additional stations in the northern U.S. would also benefit. Also, if a very strong aurora opening should develop, there is always the possibility of geomagnetic-induced *F*-layer activity running north and south. Often these events can be spotted when the *Kp* values reach 7 or higher.

For the most part, however, the east-west *F2* propagation for 6 meters is over for this sunspot cycle, and there will be approximately a five-year waiting period until the beginning of the next peak, in Cycle 24, roughly sometime in late 2007 or early 2008. Overall, the *F2* activity in 2000 to 2002 was very good at times, with many stations working new countries toward their 6-meter DXCC. (In fact, the number of 6-meter DXCC awards reached over 500.) In the meantime, sporadic-*E* activity, meteor scatter, and occasional aurora activity will fit the bill for 6 meters!

By Gary Pearce,* KN4AQ

FM

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

On the Subject of Repeaters and Regs . . .

How is repeater activity in your area? Busy? Kind of quiet? In the editorial in the October 2002 issue of *CQ* magazine Rich Moseson, W2VU, commented on how quiet the repeaters are around the New York metropolitan area, one of the most densely populated areas in the world. Perhaps they have actually achieved the long-fabled status of having a repeater for every ham, and no one has anyone to talk to!

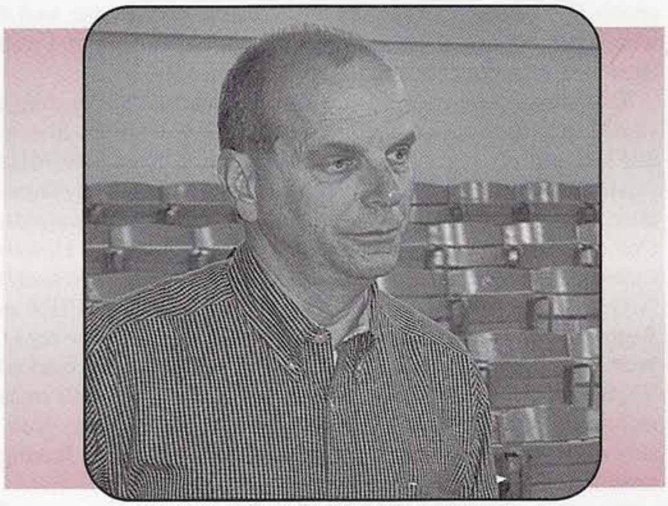
OK, probably not, but I've noticed that same curious phenomenon when driving through some of this country's big metro areas. Scanning the entire 2-meter and 70-cm bands, I found that there's not a lot of talking going on. Lots of people think things used to be busier. I'm not so sure. I've always found 2-meter FM to be a "drive-time" band, with only sporadic activity during the middle of the day. There are more repeaters than there were in the old days, so activity is more spread out. Maybe it's *so* spread out that any given repeater has a hard time achieving a "critical mass" of operation.

W2VU suggests a simple solution: Get on the air! Keep the FM rig on and announce your presence. Answer others who ID, looking for a conversation. Talk!

If you're out of practice at this sort of thing, you might want to ease into it so as not to sprain anything. A few little "Nice weather we're having. Oops I just got the call to lunch . . ." warm-ups will help get you in shape for something with a little more meat in it.

This subject reminds me of some columns I wrote a few years ago about finding people to talk to on repeaters when you're away from home. That's a common complaint; nobody will talk to you on "foreign" repeaters, but there's no problem scaring up a contact on your home machine. I put a theory to the test on a road trip: If you want to make contacts away from home, you have to make some noise. Mumbling "kn4aq listening" isn't going to cut it. "This is KN4AQ mobile, traveling through Springfield on I-40, on the way from Raleigh to Chicago. Anybody want to talk for a few minutes?" That worked. That got me contacts in towns large and small almost every time, with some pretty good contacts, too.

I'm not ham radio's most prolific ragchewer, but I managed to time out some repeaters while going off on one tangent or another. Maybe I felt less inhibited because I knew my locals weren't listening. A variation might work at home, too. The people are there. We just have to convince them that talking to us will be more interesting than listening to another 15 minutes of Rush or Dr. Laura, which leads directly to another problem that might keep some hams from getting into more conversations—"Boring Contact" anxiety. What if I get stuck talking to a real dullard? How many times can I back out, claiming that I have to "concentrate on my driving" when everybody knows I



FCC Amateur enforcement chief Riley Hollingsworth, K4ZDH, at the Raleigh, North Carolina hamfest in 2002.

collect a speeding ticket every three weeks? There's no easy way out of this. You just have to take the risk.

How to Listen to the Repeater and Not Hear Anything

Well, if all the above is true, then I'm about to solve a problem that doesn't exist—but I'll do it anyway. Have you ever needed to monitor a repeater for a call from someone, maybe a friend or spouse who was going to call you, but you didn't want to have to listen to the chitchat that goes on? I know, we just said there isn't any chitchat anymore, but maybe you use the *one* repeater in the country that does get a lot of use. You have a friend coming into town, or your wife's out running errands and might need to reach you.

You're busy, however, and the repeater has been in use all day with people talking about whatever, which could be interesting, could be boring, but it doesn't matter. You have to concentrate on something else, and the repeater's just too much distraction. Maybe you want your wife to listen for you while you're out and about, but no way is she going to listen to the gabfest.

The answer is simple, but implementation might take a little work. It's *tone.* You might call it CTCSS, PL, sub-tone, or any of the other nicknames and trade names it's picked up. I'll just call it tone, and the simple secret is: Establish a "calling tone" on your repeater, a tone other than one regularly in use. Then monitor using tone-decode set for the calling tone. Have the person you're listening for prepared to call you using that tone. The repeater can be busy all day, and you won't hear a peep until your call comes through.

OK, the repeater techs are reaching for their keyboards to fire off e-mail with their objections and complications, but hold on a

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second. I said that implementation might take some work. Here's my short list. I like e-mail, so pound away when I'm finished.

- The repeater doesn't pass tone.
- The repeater already requires tone.
- Nobody's going to understand this. Heck, *I* don't understand it.

If this list looks too short, then stand-by, because I'll have another one in a minute. To make this work, you might need some hardware, and you need a tone plan. The plan is free, so I'll start there.

The Tone Plan

If you have a carrier access repeater and the audio passband goes low enough to let some tones go through, you might be good to go. Just declare a tone frequency as a "calling tone" and educate repeater users on its use. Tell them that if they want to monitor silently, they should set their radio to decode the calling tone, and let the people who want to reach them know they need to encode the calling tone in order that they'll be heard.

So far, so good. I expect it will start slowly, maybe among some husband-wife ham teams. If you talk it up on the air, at meetings, and in the club newsletter, eventually the idea, and the value, will seep through. Then you'll need a few more rules in the tone plan. Among them:

1. No conversations using the calling tone! Let me set this up: Bob calls his wife Sue, who has been happily "un-monitoring" the repeater with the tone decoder steadfastly protecting her from whatever passes for erudite conversation on your local machine. She replies, and they chat for a few minutes. Alas, Bill and his wife Peg have also begun using the new tone plan, but now they're hearing Bob and Sue's chat. Although they like Bob and Sue, Bill and Peg were promised blissful silence, not news of the kids' day and a grocery list. Nope, the rule is that once you've made contact, you *turn off the tone* to continue your conversation.

2. No conversations using the calling tone! OK, that's the same rule, but here's a different problem. Let's say Bob and Sue are back to having that conversation with their encoders on the calling tone, and their decoders also are very much ON. Tom wants to break in to report an emergency. He drops in his call between transmissions. He says "emergency," or "break-break-break," or whatever is the custom in your region. He's wasting his time, because he's not encoding the calling tone. He has no reason to. Maybe he doesn't even know it exists. Bob and Sue are "unbreakable" because their decoders are letting no one else into their receivers.

Consequently, the tone plan consists of the fact that the tone plan exists and that you don't converse using the calling tone. Most of your club members should be able to remember that, but will your repeater cooperate?

Many carrier-access repeaters don't pass those low-frequency tones. If you already have a tone-access repeater, how do you get it to respond to, and output, a second tone?

The solution comes from our commercial neighbors in the form of a "tone panel" – something you can buy or build yourself if you're handy. In the commercial world there are things called Community Repeaters which rent access to a shared repeater to a variety of customers, such as the gas station with a couple of tow trucks, the plumber, the limo company, businesses that need radio communications but don't need and can't afford their own full-time repeater. It's like a radio party line. If you don't know what a party line is, ask Grandpa.

All these folks share a single repeater, but like your wife (I'm going with the odds here, and I apologize for the generalization.), they don't want to listen to the other repeater users. They just want to hear the calls directed to them, so the repeater owner divvies up tones to the users and puts in the "tone panel" to keep things straight at the repeater. The tone panel can do several things, but its main job is to listen to the tone from a user, turn on the repeater, and regenerate that tone on the output.

The tone-panel concept is easily adapted to ham repeaters, whether the repeater is carrier access or full-time tone, and will allow you to use multiple tones. Also, the concept is probably clear as a bell, but as we implemented it on my home repeater I found a few little wrinkles and I want to cover them here.

The first wrinkle is an advantage—tone panel as calling-tone-cop. Rule #1 is "no chatting using the calling tone," and the tone panel can enforce that for you. Commercial users typically don't ragchew, but now and then they can get windy. Other users are queued up to use the repeater, but the tow-truck driver is lost and he's getting some really detailed directions from the kid in the office, repeated several times, with additions and corrections supplied by the other tow-truck driver. To prevent one user from hogging the shared system, the tone panel has a "hog-timer" for each tone. Use up your time and your tone is disabled for a while, letting the other users get their traffic through. In our ham repeater, the calling tone gets a short hog-time setting, maybe 30 seconds, which is long enough to get the call through and switch to the primary repeater tone, and short enough to discourage a conversation.

The next thing we thought of is that we could use a whole bunch of tones, and let almost everyone who wanted to use a calling tone have his or her exclusive tone. The panel we installed would handle every CTCSS tone, and all the digital DCS tones, too. That would work, but it would also cause problems. Hams often find tones on repeaters by trial and error. If there are a bunch of tones that let the repeater key up, most hams will figure that the first tone they land on that keys the repeater is the one-and-only tone. There they are, inadvertently violating Rule #1, and if you have a hog-timer going, wondering why they can only use the repeater for 30 seconds before it doesn't hear them anymore. Thus we cut back to one or two calling tones.

Memory channels will help users implement the tone plan. To keep from fumbling with your radio, switching tones on and off, just program your radio with the repeater and the primary tone in one memory and the calling tone (with decode ON) in the next memory. Now you can switch back and forth easily.

The system is fairly simple, but it's not foolproof. It's time for one more rule:

3. Before making a call, turn decode off to see if the repeater is busy. Hams will have a hard time getting used to the fact that they might not be hearing the traffic on a busy repeater. I expect someone will get clobbered now and then because someone else forgot to switch his or her decode off before making a call and didn't realize that the repeater was in use. It already happens when people have their dual-band radio set to the wrong band, or when they have their volume turned down. Don't fret; it's not that serious.

If this idea takes off, I hope it doesn't work against the fact that we need more activity on our repeaters. It might keep more radios turned ON, at least. If you have an idea for refining the plan, please let me know.

Fear of Tone

There is a great fear of tone out there in the land. Many hams find the concept of tone baffling. It's just a low-frequency tone added to your voice audio and picked off by a decoding circuit in a receiver. Once the decoder hears the tone, you can use it to do lots of things. The two most common functions are: (1) turn on a repeater, and (2) turn on your speaker. Oh, sure, there's a column full of details, and every repeater columnist is obligated to explain tone at least once every five years. My turn's coming.

If the tone plan is doomed in any way, it is doomed by fear of tone. We're almost past the "You're Locking Me Out Because My Radio Doesn't Have Tone" era. Most of those old radios are broken, but we're smack in the middle of the "My Radio Is Too Complicated and I Can't Remember How To Program The Tone" era. I sympathize. Mr. Spock may be able to walk up to any piece of equipment and operate it correctly the first time (and for him, the pressure is intense; if he fails, he blows up the universe). You and I probably can't pick up a friend's HT and program it right off the bat, especially the tone. I defy *everyone* to program a tone in my Standard C5900 (my what?). I love the radio. It was designed by demons.

Nobody has died trying to learn how to program a radio, including programming tone. Spend some time with the manual. Ask a friend for help. You need to know this stuff.

Build Your Own?

Can we get technical here for a minute? This might be a good time for a construction article on building a multiple-tone CTCSS box. OK, but not if *I* have to do it. I am a confirmed appliance operator! I'm a writer, an idea-man perhaps, but not an engineer. I will gladly turn column space over to those of you who have something technical to contribute. In fact, the goal of *CQ VHF* is to keep the articles at a fairly high technical level, although I always try to include something that will help a new ham move on up. Drop me a line, or send an article directly to the N6CL. (I would like to see an FM-oriented story sneak through outside of this column in most issues.)

It's on the Web?

People have told me that you don't need FM construction projects in magazines because it's all on the web. Well, I don't know if it's *all* there, but a lot of it is. If you know about a good website for FM/repeater construction tips, let me know. That's something worth passing along to readers.

No Ragchewing on .52?

This is old news by now, but from comments I've heard on the air, not everyone has the whole story.

In October 2002 Riley Hollingsworth, K4ZDH, sent "Advisory Notices" to a group of Ohio hams calling attention to a complaint that they were using 146.52 MHz, the National Simplex Channel, for long periods of time (30 minutes to an hour). The notice suggested that such use did not comply with good amateur practice.

Riley got an earful after that. While many publications do list .52 as a "calling" channel, and publications often advise using it that way, it's not widely practiced. In fact, I'd like to hear from you if the hams in your area actually make a habit of moving off .52 after establishing a contact. I hear it debated now and then, but I can't say I've ever heard it done.

More likely, .52 sits empty most of the time in your town, as do the rest of the band-plan simplex channels. There have been articles and letters in the ham magazines advocating that more hams monitor .52, and complaints from hams who drive cross-country that there is never anyone on .52.

I talked to a couple of the Ohio hams who got the advisory notices, and they said that most of the time, if their informal group outside Toledo was not using the channel, it was dead. They were aware of the concept that .52 maybe should be used as a calling channel, but with so little other activity, they didn't see the point. Nobody else did it, so it didn't seem as if that suggestion was really followed.

Riley agreed and rescinded the letters, saying, "We made an error in issuing that Advisory Notice, and you may disregard it."

If I were King of FM, I might make that a rule, or at least a strong suggestion. It's not a bad idea to have a calling channel that lots of people monitor, but move off to hold a conversation, somewhat like the "calling tone" idea presented above. It's a big leap from columnist to king, however, so there's little danger of that promotion happening soon. Hams will remain free of my tyranny, and free to follow their conscience on .52.

IRLP/Echolink

In the fall 2002 column I mentioned that the FCC is looking at a pile of complaints about the phenomenon of connecting computers and the internet to ham radios—mostly FM/repeater radios. Many of the complaints come from hams who don't understand what's happening, or who just don't like new things. However, there's nothing wrong with the basic idea of an internet link between repeaters (IRLP, Echolink) or from hams computers to repeaters (Echolink). From the enforcement perspective, Riley Hollingsworth says it's a matter of control. A licensed ham must be in control of a transmitter, no matter who is pushing the transmit button or how they're pushing it.

Riley noted that new technology needs time to sort itself out. He's not looking for problems right now, although he could respond to complaints. He added, "To those critical or skeptical of Echolink or IRLP, I am told that it is rejuvenating lots of dormant repeaters, and bringing back into amateur radio operators who have not been active. If this is true, those are good developments for our Service. Also, we don't want to be too hard line in the beginning of these new technologies, because we want amateurs to be excited about experimenting and feel free to do so within the general bounds of the rules. Amateur experimentation has led to great technological breakthroughs. That is the great benefit of the service. Remember, lots of folks were severely critical of SSB and said it would destroy amateur radio. Let me know if I can help any other way."

Keep in mind that our rules are broadly written and generally flexible. They don't cover "systems" such as IRLP. The rules don't mention linked repeaters; they don't mention autopatches or connection via computer. They do cover the operation of auxiliary links, control links, and third-party traffic. The operation of new systems such as IRLP and Echolink are actually pretty well covered in the existing rules, and hams who want to participate in them should make sure their operation is legal in the context of the rules.

For example, one question that has come up involves using a 2-meter radio to link a computer to a repeater for ILRP. That's an easy way to get a VHF repeater connected to IRLP, but that radio is pretty clearly an auxiliary station, as defined by the rules:

> §97.3 Definitions.
>
> (a) (7) *Auxiliary station.* An amateur station. . . that is transmitting communications point-to-point within a system of cooperating amateur stations.

Auxiliary stations aren't allowed on 2 meters. These repeaters should be linked by radios above 222 MHz.

I've heard comments that Echolink's verification isn't all that foolproof. Echolink can turn a computer's "spacebar" into a push-to-talk button on hundreds of repeaters and individual stations around the world. More important, you can use Echolink to allow registered users to connect to *your* repeater or home station, handing the keys to your transmitters to anyone on the system.

When you register, you list your callsign, which the website says will be verified, but one ham with a vanity call registered under his previous callsign. Callsigns of dead hams have been heard. Before you connect your repeater or home station to the system, you have to ask yourself, "Do I want to take the risk?"

For many hams, the answer is "yes." There's a lot of fun and a lot of value that can come from these new systems. Nevertheless, the rules still apply!

Riley's Message to Repeater Owners

As I was talking to Riley about the IRLP and Echolink issues, he told me that he's been working on a message to repeater owners. The message is simple: Repeater owners need to solve their own problems with users, and not rely on the FCC to arbitrate every dispute. Riley's office has received too many requests from repeater owners who want enforcement action against users, and they're taking up a disproportionate amount of time compared to other areas of amateur radio.

What kind of problems do owners want solved? Owners are concerned about jamming and general bad behavior by users. If this doesn't sound like a problem in your part of the country, we could really put this part of the column in a special California edition of *CQ VHF*. That's where most of the problems lie. Even so, in California it's on just a handful of repeaters.

Riley points out that running a repeater is a voluntary activity. Nobody's forced to do it. Owners, therefore, need to take responsibility for their machine. If there are user problems, find creative ways to solve them. Identify the hams causing the problem. Tell them to stop using the repeater (You have the authority; see the next topic.). Turn off the repeater for a time if necessary. In a severe case, go to court and get a restraining order against individuals who repeatedly cause problems.

The bottom enforcement line is this: If the repeater identifies by your callsign, you are directly responsible for any recurring and deliberate (non-inadvertent) violations committed on it by the users. Running a repeater is analogous to leaving your shack door open for amateur operators to come in and use your HF station. If they break the rules, the FCC would quite logically order you to close the door and exercise control over your station, rather than use tax dollars to sort out problems that are only occurring because you leave the door open to your station.

A baffling practice of a few repeater owners is total abdication of responsibility for the machine. They leave their callsign on the repeater, assign a control operator or two, and then totally ignore the repeater. Some of them have even moved out of their repeater's coverage area and can't hear it. Riley says that these hams *are* responsible for the repeater, which bears their callsign, and they must take an active role in its operation.

For a repeater owner who does care, an intractable "user" problem is a headache. If you turn off the repeater for an hour or for a day and the problem user returns quickly, forcing another shutdown, that user soon learns where the real control lies.

If the user can force a shutdown whenever he or she wants, it's the *user* who has control, not the owner. Riley says that he understands this, and he does want to be kept informed about hams who are persistent problems. Even so, the owner has tools to use. If the owner is not willing to take steps to solve the problem, he or she should turn the repeater off.

One exception: If you've identified an *unlicensed* repeater abuser, Riley says that he is interested in taking enforcement action. This exception does not cover coordination questions, where coordinated repeaters are having interference problems from uncoordinated repeaters.

You can expect a more formal statement about repeater owner responsibility as part of an upcoming enforcement action involving the K7IJ repeater in the San Francisco area (In fact, it may have already been released by our February publication date.). That repeater, its owner, its control operators, and its users have been the subjects of multiple enforcement letters and actions dating back to 1999. Located in the hills outside Berkeley, K7IJ operates on 145.29, 223.78, 440.175, and 441.175 MHz. The callsign belongs to Bruce Wachtell. Wachtell's license address is Carson City, Nevada, but he is a shipboard radio operator who spends long stretches of time away from home.

Wachtell's license was modified to prohibit repeater operation for a time in 1999 after complaints that the repeater was out of control. The control operator was actually soliciting unlicensed operation and jamming. Wachtell reached an agreement with the FCC to return the repeater to the air because a steady stream of "users" had received warning notices or had had licenses set aside.

(Editor's note: As late as mid-December, Hollingsworth had again notified Wachtell of numerous violations on the K7IJ repeater system. In his warning letter Hollingsworth cautioned Wachtell, "If you are unwilling or unable to prevent violations on your K7IJ repeater, then your operator and station licenses will be subject to enforcement action by the Commission," thereby raising the possibility of sanctions such as fines, suspensions, and license revocations against Wachtell.)

The K7IJ repeater is a long, sad story, but K7IJ and a few like it are at the extreme end of the repeater enforcement problem. They shouldn't drive policy regarding the thousands of repeaters that are well operated. Unfortunately, to some extent they do.

Ham Kicked off Repeater

This story illustrates one of the tools a repeater owner has to keep operation clean—and it isn't even from California.

Last fall, Riley Hollingsworth confirmed that a repeater can be "closed" to a single ham while remaining open to all others. The ham in question is Billie Marshall, N8ORF, and the repeater is the Toledo Mobile Radio Association's W8HFF machine.

Riley's enforcement letter said that Marshall failed to follow the rules of operation set up by TMRA for their repeater, and emphasized that repeater owners "may take whatever steps are appropriate to ensure compliance with the repeater rules." They may "close" a repeater, but they don't have to. The repeater can be "closed" to one individual.

The letter to Marshall continued:

> Please be advised that we expect you to abide by the request to stay off the W8HHF system and your failure to do so after receipt of this letter will jeopardize your Amateur license. If you use the repeater again we will initiate enforcement action against your license, which may include revocation, forfeiture or a modification proceeding to restrict the frequencies on which you may operate "N8ORF."

Booting someone off your repeater should be a pretty extreme measure, but one you can take before you resort to asking the FCC for help.

Automatic Control

Within the K7IJ dust-up comes the question of Automatic Control. The 97.3 "Definitions" section of the rules says:

> (6) *Automatic control.* The use of devices and procedures for control of a station when it is transmitting so that compliance with the FCC Rules is achieved without the control operator being present at a control point.

This rule, instituted in the late 1970s, freed repeater owners or designated control operators from the obligation of monitoring the repeater every minute of the day. That was very nice, but what are the "devices and procedures"? They're up to you, but they have to be there! If there's a problem with your repeater, they have to work, or the repeater must be monitored full-time again (or turned off). On rare occasions (including the K7IJ case), repeater owners have lost their automatic control privilege when the FCC determined it was being abused.

Automatic control can be as simple as arranging with users to notify a control operator when they hear a problem, as long as the control operator can take quick action to correct it. It's not a license to ignore problems and pay little attention to your repeater.

Well, that's it for this time. I notice that this rounds out the first year of the new *CQ VHF*! Time's flying, so I must be having fun. I hope you are, too. See you in the spring.

CQ's Satellite and 6 Meter WAZ Awards

By Paul Blumhardt, K5RT,* CQ WAZ Award Manager

Satellite Worked All Zones

(Awards issued through December 15, 2002)

No.	Callsign	Issue date	Needed Zones
1	KL7GRF	8 Mar. 93	???
2	VE6LQ	31 Mar. 93	???
3	KD6PY	1 June 93	???
4	OH5LK	23 June 93	???
5	AA6PJ	21 Jul. 93	???
6	K7HDK	9 Sept. 93	???
7	W1NU	13 Oct. 93	???
8	DC8TS	29 Oct. 93	???
9	DG2SBW	12 Jan. 94	???
10	N4SU	20 Jan. 94	???
11	PAØAND	17 Feb. 94	???
12	VE3NPC	16 Mar. 94	???
13	WB4MLE	31 Mar. 94	???
14	OE3JIS	28 Feb. 95	???
15	JA1BLC	10 Apr. 97	???
16	F5ETM	30 Oct. 97	???
17	KE4SCY	15 Apr. 01	10,18,19, 22,23,24, 26,27,28, 29,34,35, 37,39
18	N6KK	15 Dec. 02	None!

CQ offers the Satellite WAZ award for stations who confirm a minimum of 25 zones worked via amateur radio satellite. Records for Satellite WAZ are not complete. What's missing for the majority of callsigns on the list is the zones that each station needs to reach the 40-zone mark.

To date, only one station (N6KK) has managed to confirm all 40 zones via satellite. Joe Barger, N6KK, accomplished this incredible feat via AO-13 with QSOs made from 1989 to 1993. We're certain that the "window" of opportunity for many of the QSOs was very short, with both stations having only a precious few minutes to make the contact.

If you think about it, this is a darned tough award! Reaching the 25-zone level takes coordination, dedication, and skill. You have to do your homework to figure which orbits offer the best opportunities to work those far-off zones. Working WAZ via satellites doesn't take huge antennas or lots of power, though.

How many of you satellite ops have reached the 25-zone threshold? Let's see some more applications for Satellite WAZ!

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e-mail: <k5rt@cq-amateur-radio.com>

6 Meter Worked All Zones

(Awards issued through December 15, 2002)

No.	Callsign	Needed Zones
1	N4CH	16,17,18,19,20,21,22,23,24,25,26,28,29,34,39
2	N4MM	16,17,18,19,20,21,22,23,24,26.28,29,34,39
3	JI1CQA	2,18,34,40
4	K5UR	2,16,17,18,19,21,22,23,24,26,27,28,29,34,39
5	EH7KW	1,2,6,18,19,23
6	K6EID	16,17,18,19,20,21,22,23,24,26,28,29,34,39
7	KØFF	16,17,18,19,20,21,22,23,24,26,27,28,29,34
8	JF1IRW	2,40
9	K2ZD	2,16,17,18,19,21,22,23,24,26, 28,29,34
10	W4VHF	2,16,17,18,19,21,22,23,24,25,26,28,29,34,39
11	G0LCS	1,2,3,6,7,12,18,19,22,23,25,28,30,31,32
12	JR2AUE	2,18,34,40
13	K2MUB	16,17,18,19,21,22,23,24,26,28,29,34
14	AE4RO	16,17,18,19,21,22,23,24,26,28,29,34,37
15	DL3DXX	1,10,18,19,23,31,32
16	W5OZI	2,16,17,18,19,20,21,22,23,24,26,28,34,39,40
17	WA6PEV	3,4,16,17,18,19,20,21,22,23,24,26,29,34,39
18	9A8A	1,2,3,6,7,10,12,18,19,23,31
19	9A3JI	1,2,3,4,6,7,10,12,18,19,23,26,29,31,32
20	SP5EWY	1,2,3,4,6,9,10,12,18,19,23,26,31,32
21	W8PAT	16,17,18,19,20,21,22,23,24,26,28,29,30,34,39
22	K4CKS	16,17,18,19,21,22,23,24,26,28,29,34,36,39
23	HB9RUZ	1,2,3,6,7,9,10,18,19,23,31,32
24	JA3IW	2,5,18,34,40
25	IK1GPG	1,2,3,6,7,10,12,18,19,23,24,26,29,31,32
26	W1AIM	16,17,18,19,20,21,22,23,24,26,28,29,30,34
27	K1LPS	16,17,18,19,21,22,23,24,26,27,28,29,30,34,37
28	W3NZL	17,18,19,21,22,23,24,26,27,28,29,34
29	K1AE	2,16,17,18,19,21,22,23,24,25,26,28,29, 30,34,36
30	IW9CER	1,2,6,18,19,23,26,29,32
31	IT9IPQ	1,2,3,6,18,19,23,26,29,32
32	G4BWP	1,2,3,6,12,18,19,22,23,24,30,31,32
33	LZ2CC	1
34	K6MIO/KH6	16,17,18,19,23,26,34,35,37,40
35	K3KYR	17,18,19,21,22,23,24,25,26,28,29,30,34
36	YV1DIG	1,2,17,18,19,21,23,24,26,27,29,34,40
37	KØAZ	16,17,18,19,21,22,23,24,26,28,29,34,39
38	WB8XX	17,18,19,21,22,23,24,26,28,29,34,37,39
39	K1MS	2,17,18,19,21,22,23,24,25,26,28,29,30,34
40	ES2RJ	1,2,3,10,12,13,19,23,32,39
41	NW5E	17,18,19,21,22,23,24,26,27,28,29,30,34,37,39
42	ON4AOI	1,18,19,23,32
43	N3DB	17,18,19,21,22,23,24,25,26,27,28,29,30,34,36
44	K4ZOO	2,16,17,18,19,21,22,23,24,25,26,27,28,29,34
45	G3VOF	1,3,12,18,19,23,28,29,31,32
46	ES2WX	1,2,3,10,12,13,19,31,32,39
47	IW2CAM	1,2,3,6,9,10,12,18,19,22,23,27,28,29,32
48	OE4WHG	1,2,3,6,7,10,12,13,18,19,23,28,32,40
49	TI5KD	2,17,18,19,21,22,23,26,27,34,35,37,38,39
50	W9RPM	2,17,18,19,21,22,23,24,26,29,34,37
51	N8KOL	17,18,19,21,22,23,24,26,28,29,30,34,35,39
52	K2YOF	17,18,19,21,22,23,24,25,26,28,29,30,32,34
53	WA1ECF	17,18,19,21,23,24,25,26,27,28,29,30,34,36
54	W4TJ	17,18,19,21,22,23,24,25,26,27,28,29,34,39
55	JM1SZY	2,18,34,40
56	SM6FHZ	1,2,3,6,12,18,19,23,31,32
57	N6KK	15,16,17,18,19,20,21,22,23,24,34,35,37,38,40

By Kent Britain,* WA5VJB

ANTENNAS

Connecting the Radio to the Sky

Data Antennas

According to BBC News Online (see: <http://news.bbc.co.uk/2/hi/science/nature/1860241.stm>), the British security firm i-sec successfully hacked its way into several computers throughout London by cruising around with a laptop and a wireless LAN card looking for open networks. They supposedly found lots of open networks! For example, according the BBC article, "In one 30-minute journey using the Pringles®-can antenna, witnessed by BBC News Online, i-sec managed to find almost 60 wireless networks."

I have no trouble with i-sec's James Bond style story of hacking computers while on the streets of London. What confuses me, however, is the firm's use of the Pringles® can for an antenna (photo A)!

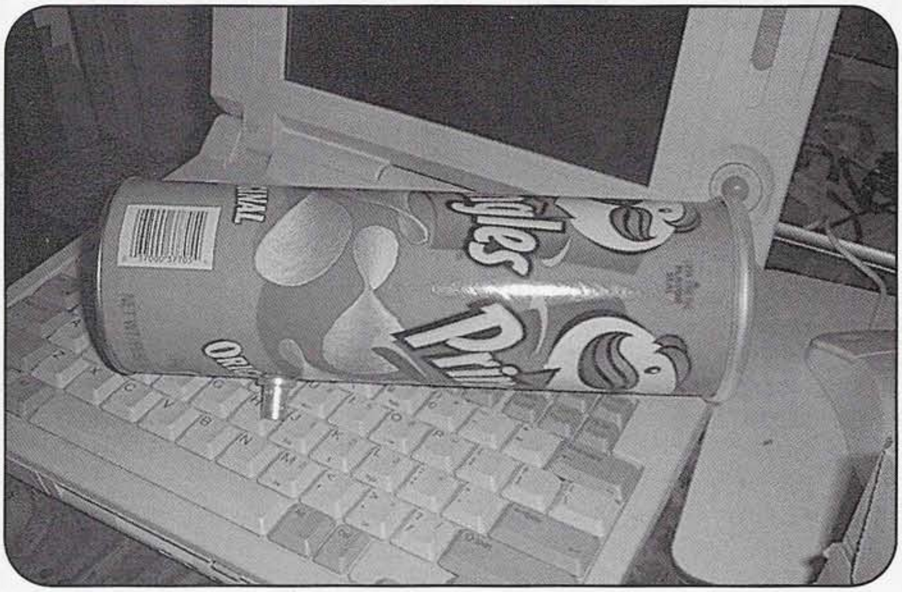

Photo A. Pringles®-can antenna and laptop.

I've built a lot of horn antennas, and the diameter of the Pringles® can is just too small for a 2.4-GHz radio wave to fit inside it. It's simply impossible for that antenna to work on that frequency! Nevertheless, in order to see if this idea really worked (or if pigs can fly), Lloyd Ellsworth, NE8I, brought several 2.4-GHz horn antennas made from Pringles® cans to the Central States VHF Society antenna contest in Milwaukee last year.

One antenna was per the BBC article (Lloyd even used a sour cream and onion Pringles® can so as to be just like the BBC antenna.), and on the other antenna the length and position of the probe had been optimized. At 2.4 GHz, gain on both antennas was less than –20 dBi, my antenna range noise floor. The Pringles® antenna in the photo was swept with my network analyzer, and it simply doesn't work below 3.0 GHz. Even so, supposedly these guys are picking up signals!

For the tube to become a properly working horn antenna, you must have a good ground connection between the coax connector and the horn (figure 1). In this case you need a good ground connection to cardboard and aluminum foil. If you don't get the connection tight enough, or twist the connector after you've tightened it, you break loose the aluminum foil. Now you have this sort of fat longwire antenna hanging out there—not a horn antenna, but at least it can pick up 2.4-GHz signals.

Here's a much better way to build a simple 2.4-GHz horn antenna: In figure 2 and photo B we have a horn antenna made from a 1-pound coffee can (Yes, as vacuum packed, it might only be 13 ounces.). Almost any $3^1/_2$- to 4-inch diameter can will work, about 100 mm if you prefer metric. Mount the probe 2 inches from the bottom of the can. Drilling the hole along the welded seam works best. The probe should be kind of fat. I find $^1/_8$-inch diameter brass or copper hobby tubing works well. Even No. 10 to No. 14 copper wire makes a good probe.

Trim the probe so that when it's mounted, the tip is 1.25 inches from the nearest side of the can. SMA, SMB, BNC, and N connectors work just fine. A SO238 at 2.4 GHz? Well, if you're that desperate, but don't expect it to talk very far.

The gain is an honest and repeatable 6.5 to 6.8 dBi. I recently saw an even smaller horn advertised as having 15 dB gain. Can I interest you in a real-estate investment? By the way, this coffee can also makes a great AMSAT S-Band dish feed.

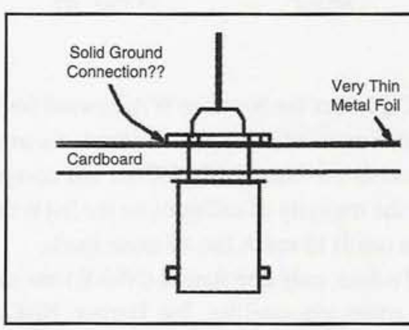

Figure 1. Pringles®-can ground connection.

915-MHz "Cheap Yagi"

The very first "Cheap Yagi" was developed for 902–928 MHz spread-spectrum service. To get a very flat response across the whole band, these antennas have a better impedance match (SWR) at the low end of the band, and a bit more gain at the high end. This averages to a consistent signal squirter across the whole band.

Many of the 915-MHz systems are designed for 75-ohm antenna systems, and some are designed for 50-ohm service; so we'll do a couple of each (photo C).

All the designs use the same driven element as shown in figure 3 and photo D.

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Photo B. Coffee-can antenna.

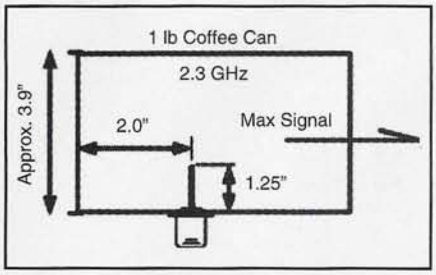


Figure 2. Using a coffee can as a feed horn.

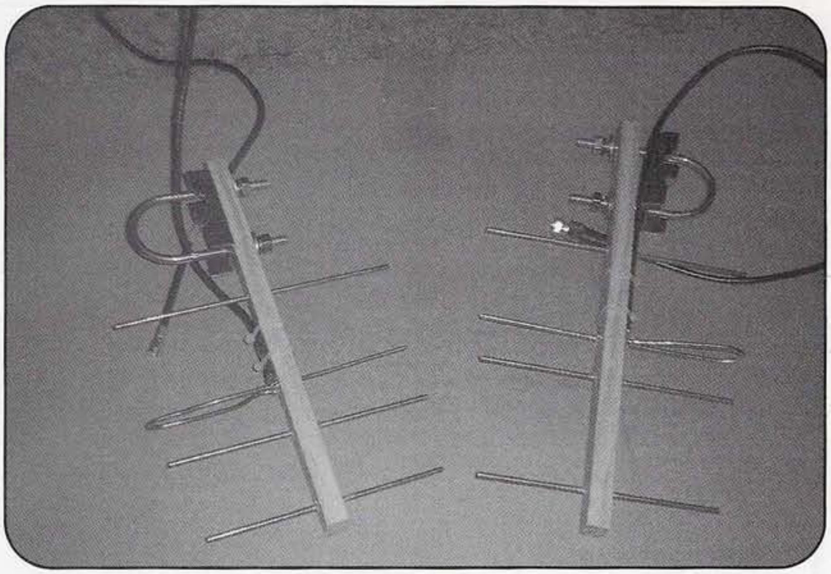


Photo C. 915-MHz Cheap Yagis: (left) 50-ohm and (right) 75-ohm.

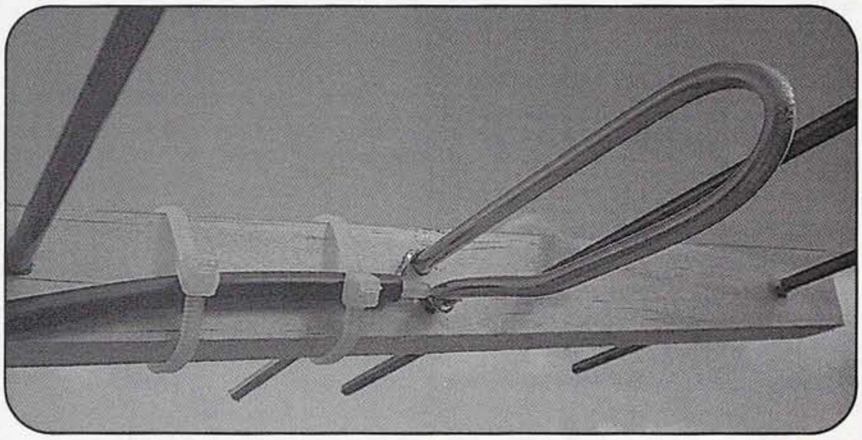


Photo D. Close-up of the 915-MHz driven element.

The width of the loop is not critical, but don't get too far from these dimensions.

The coax is simply soldered directly to the driven element. The shield goes to the center of the long element; the coax center conductor goes to the bottom tip of the "J."

If you have the test equipment, the free tip of the driven element can be trimmed for best SWR. If you just build the antennas to the dimensions, the SWR is typically about 1.5 to 1. Once I got carried away on the network analyzer and took one down to 1.02 to 1. Not that you would be able to tell any performance difference between 1.5 and 1.02, but you know how you can get carried away with these things.

By controlling the spacings and loading effects of the other antenna elements, we can design the antenna for 50- or 75-ohm service. As we have covered in previous columns, the structure of the antenna is its own impedance match. Notice that the 75-ohm version is slightly longer, and it also has slightly more gain.

The maximum possible gain of a Yagi is determined by its length. How many elements you use, and the spacing of those elements, optimize the antenna, but

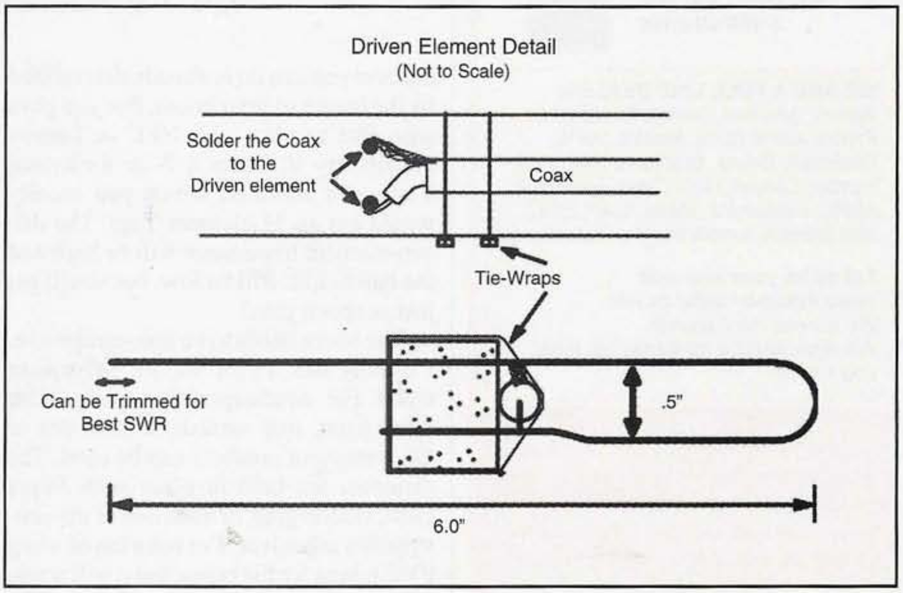


Figure 3. 915-MHz driven-element details.

915-MHz Antenna Measurements

50 ohm	R	DE	D1	D2	D3	D4	D5	D6	D7	D8
4 element										
Length	6.3	**	5.7	5.0						
Spacing	0	2.4	3.5	5.25						
Gain: 8.2 dBi										
F/B: 25 dB										
6 element										
Length	6.3	**	5.7	5.6	5.5	5.2				
Spacing	0	2.4	3.5	5.0	8.25	11.5				
Gain: 11 dBi										
F/B: 22 dB										
10 element										
Length	6.3	**	5.7	5.6	5.5	5.3	5.3	5.3	5.3	5.0
Spacing	0	2.4	3.5	5.0	8.25	11.5	15.0	18.0	21.1	24.25
Gain: 13.5 dBi										
F/B: 25 dB										
75 ohm	**R**	**DE**	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**
4 element										
Length	6.3	**	5.7	5.2						
Spacing	0	2.4	3.4	6.0						
Gain: 8.5 dBi										
F/B 20 dB										
6 element										
Length	6.3	**	5.7	5.6	5.5	5.0				
Spacing	0	2.4	3.4	6.0	9.0	12.0				
Gain: 11 dBi										
F/B: 20 dB										
10 element										
Length	6.3	**	5.7	5.6	5.5	5.4	5.4	5.3	5.3	5.0
Spacing	0	2.4	3.4	6.0	9.0	12.0	15.0	18.0	21.0	24.0
Gain: 13.2 dBi										
F/B: 20 dB										

***The same driven element as shown in figure 3 is used for all six antennas. All dimensions are in inches.*
R – Reflector
DE – Driven element
D# – Director and its number
F/B – Front-to-back ratio for the antenna

Table 1. Measurements for 915-MHz antennas.

the best you can do is already determined by the length of your boom. For you guys who like to play with NEC or Larson models, try it! Make a 7- or 8-element Yagi on a boom on which you usually would put an 11-element Yagi. The driven-element impedance will be high and the bandwidth will be low, but you'll get just as much gain!

The boom needs to be non-conductive. I usually use 1/2" × 3/4" or 3/4"-square wood. For weatherproofing, paint, clear spray paint, spar varnish, or even one of the water-seal products can be used. The elements are held in place with Super Glue, silicon glue, or even one of the construction adhesives. I'm not a fan of using PVC tubing for the boom, but it will work.

The elements are 1/8-inch diameter metal. I've used silicon bronze welding rod, 1/8-inch copper hobby tubing, 1/8-inch brass hobby tubing, No. 12 copper wire, RadioShack aluminum ground-rod wire, and even plastic tubes filled with salt water . . . but that will be a story for another time. Table 1 gives the dimensions of the antennas. On the 75-ohm version the driven element is made from silicon bronze welding rod. It's great stuff, but you almost have to have a tubing bender to work with it. The 50-ohm version is made from No. 12 solid-copper wire. Copper and bronze are much easier for soldering the coax.

Last, I have some competition in the cheap antenna department. I was invited to bring and set up my antenna range at the AMSAT-NA conference in Ft. Worth, Texas last November, measuring 19 antennas. Tony Monteiro, AA2TX,

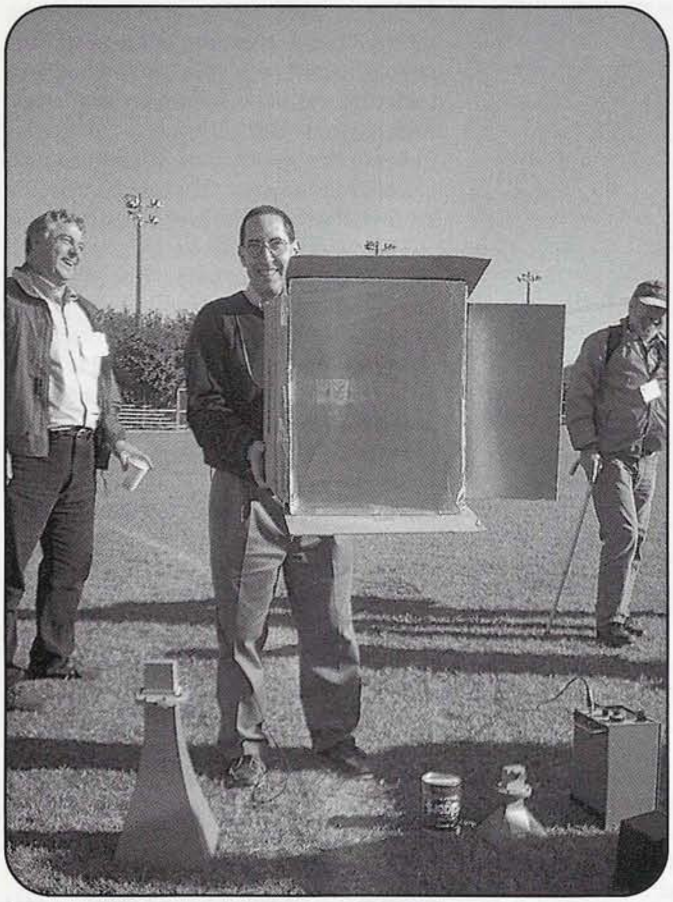


Photo E. AA2TX and his "Throw Away" S-Band AMSAT antenna.

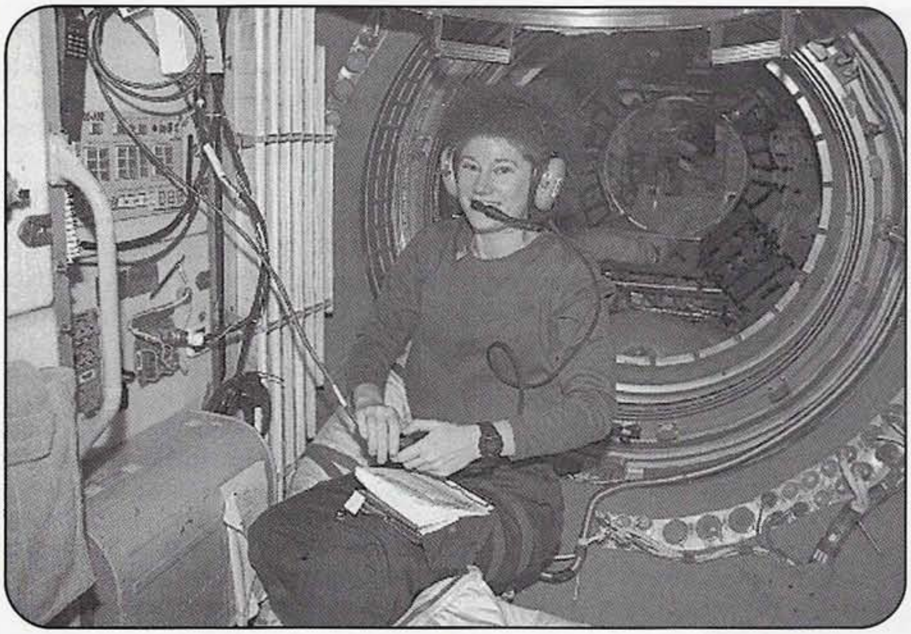
brought along a half-dozen cardboard boxes, a roll of tape, and a roll of aluminum foil. Photo E shows an S-Band "Throw Away" horn antenna he built for the group. It worked pretty well, measuring 16.8 dBi at 2402 MHz.

Letters, We Get Letters

Six meters: There were at least a half-dozen requests for a 6 meter Cheap Yagi. At the moment there is only one in the world. It's on my tower and I have worked about 20 counties with it, but the problem is mechanical. Mine is metal, built from hardware salvaged from an old TeT beam. Even I don't have the parts to build a second one, and 3/4-inch wood with ground-rod wire isn't going to hold up very well with 110-inch elements. Until I figure out a simple, reproducible way to build one, you'll have to wait.

Long Yagis: I have received four letters asking about longer versions of Cheap Yagis. At this time longer versions are not planned. There are two reasons for this. First, we are talking about thin pieces of wood. Structurally, they can't be made much longer. If the wood boom is replaced with a metal boom, the lengths of all the elements would have to change to compensate for the effects of a metal boom. Second, it's a heck of a lot of work. All of my published designs have been prototyped and tested/tweaked on the antenna range. Those long antennas take quite a while to tweak.

Please keep those letters and e-mails coming. They give me some of my best ideas for topics for this column.



U.S. Astronaut Susan Helms operating the ISS amateur radio station and sporting her Field Day participation pin. (Photo courtesy NASA)

trolled by a computer with an accurate satellite tracking program and tracking interface. Also, a receive preamp would be very helpful.

The backup station should have an uninterruptible power supply (UPS) or a battery as its power source for a separate 2-meter transceiver and amplifier with the same specifications as the ones for the primary station. The antenna can be an eggbeater-style vertical, a discone antenna, or a quarter-wave whip. Do not expect these backup antennas to perform as efficiently as the circularly polarized Yagi, though. Do not use a collinear or other vertical gain antenna, because you will have poor contact with the space station when it is overhead. The backup station is designed for operation if your building's AC power is lost. In designing this station, consider that if you have a deep-cycle marine battery and a 600-watt inverter to power a computer and az-el rotator, you can go back to using the good antenna for the backup station. Even so, do not neglect having a backup antenna just in case it's needed.

When considering where to place your antennas, be sure to mount them in the clear, free of being obscured from the predicted path of the spacecraft. If trees or buildings will block the field of a ground-placed antenna, place the antenna on the roof of the building of the contact site. If the building has a flat roof, it is easy to place a 10-foot section of tower on a base plate anchored by six cinder blocks. Place the az-el rotator and antenna on top of the 10-foot tower. Run the coax down to the room below. It's that easy.

One radio crew for an ARISS contact tried to get by with less than what they had promised on the application. They used a 4-element, vertically polarized Yagi mounted 4 feet off the ground and pointed through trees on both horizons. They made the contact, but not for the full 10 minutes!

Some hams will tell you that the specifications described in this article are overkill. It's not overkill when you have an audience of hundreds of parents, family, friends, school administrators, the media, plus ten eager youngsters ready to talk to an astronaut in space for the full duration of a 10-minute pass over their school. Other hams will tell you that they made contact with the Mir space station or the ISS using just a quarter-wave whip. They did, but not for 10 minutes. They may tell you that they worked through satellites using just a handheld transceiver and a handheld Yagi antenna. They did, but not for 10 minutes. They may have tasted success, but not for 10 minutes! A successful ARISS contact lasts a *full 10 minutes*—not four, five, or six minutes.

Choosing students. This part of the preparation is often the most difficult for a teacher or an event administrator. Somehow only a few students must be selected to ask questions of the crew. It is beyond the scope of this article to suggest selection methods for those who work with students daily. However, a suggestion on the *number* of students to be selected is in order. The magic formula seems to be ten students and 20 questions.

The 10-minute ISS pass gives enough time for about 20 questions to be asked and answered. If ten students each ask one question, going to the end of the queue after each question, every student will get at least one shot at asking a question. If more than ten students are in a queue, there is always a chance that someone will not get to ask a question, which is disheartening for any youngster, and an absolute disaster for the little ones. No one wants to wipe tears from the face of an 8-year-old, and no one wants to see such a picture in the local newspaper either.

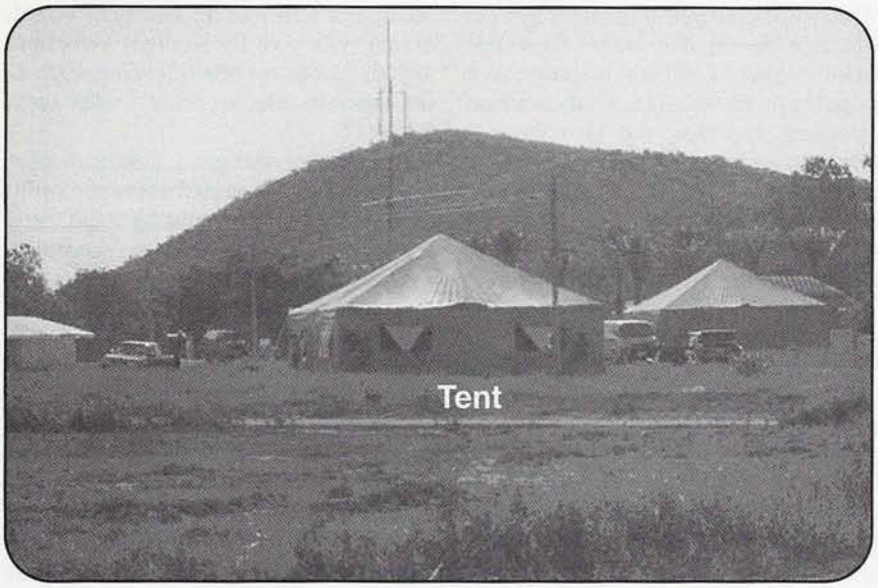
Uplink information. The mentor will ask that you provide some information that will be sent to the ISS approximately ten days before the contact. This "uplink information" consists of two paragraphs about the school, the names of the students, and the questions that each student will ask. The first paragraph about the school may consist of the school's history, its successes, or anything else that falls within the "bragging rights" category. The second paragraph should be a summary of the educational proposal, describing how the upcoming contact will be integrated into the curriculum or special activity. Then list the names of the students and their questions in the same order as they will speak to the astronaut. For example:

1. Emily Gofirst: What is the ...?
2. Steven Second: How is the ...?

Proceed until you run out of names and questions. If you have ten students each of whom has two questions, run through their names twice. For instance, in the example above Emily would be numbers 1 and 11, and Steven would be numbers 2 and 12.

The uplink information is very helpful to the astronaut who will be answering questions. It allows time to prepare concise answers. Also, it provides a backup for the astronaut for filling in the gap should there be a momentary loss in signal when a child is asking a question. It saves the time that would be consumed by the child having to repeat the question.

Systems checks. Successful ARISS contacts are the result of checking,



Site of the Thai amateur radio tent that housed the ARISS attempt station during the World Scout Jamboree operation in early January.

Nearly everyone will want to make public the photographs of the kids at the radios, and you will want to have a decent selection of pictures from which to choose. Afterwards, select a time to share pictures among the photographers. You will never know which is the ideal candid shot without everyone having shared his or her photos of the event.

The Contact

This part of the process is the easiest for you. If all goes well and as rehearsed, you will be doing nothing. The contact is between the astronaut and the kids. It's for them only, not for you. The adults on the ground are to stay away from the microphone and keep their lips zipped—no showboating or speechmaking. The 10 precious minutes of the contact are not for you to speak, but for you to observe and enjoy.

When the signals from the space station fade over the horizon, the 10 minutes will have passed and the contact will be over. The room will be silent for a moment before someone yells or claps. You then may begin to speak if you wish. Good luck, as a teacher in South Carolina said that she knew an attempt at academic instruction would be a lost cause immediately after her junior high students made the contact. Instead, she let them view *October Sky,* the movie version of Homer Hickham's book, *Rocket Boys.* That strategy was designed to maintain her goal of keeping alive the students' excitement and enthusiasm for learning.

rechecking, and checking again. On the day before the scheduled contact, do an end-to-end check of the primary and backup stations several times. Have someone with a handheld rig programmed with the ISS's transmit and receive frequencies act as a proxy ISS in rehearsal contacts. One ARISS contact failed because the ground station had its microphone gain control set to zero. An end-to-end check would have revealed the oversight.

A few hours before the contact, update your computer's Keplerian elements using a source suggested by your mentor.

- Use WWV as the source to correct your computer's clock and everyone's watches.
- Make sure you have a key to the contact site.
- Make sure your mentor has the correct telephone number for the contact site.
- Write a list of things to remember.
- Have someone with the same list help you remember.
- Have the students rehearse their questions. Run through several "mock" contacts using a chalkboard eraser as a microphone for the students to speak into. Instruct them to speak loudly, slowly, and clearly.

The 24-hour notice. Your mentor will insist that you send an e-mail notice or a fax confirmation stating that you are ready 24 hours before the scheduled contact. That little notice will keep the entire process in motion. Little things mean a lot. If you do not send the notice, the contact may be cancelled so that the crew can do other things. The mentor will send you a form to use for composing the notice.

Candid cameras. On the big day be sure to pack a camera or two for taking candid shots of the kids in contact with the ISS. Also, encourage a couple of other adults to have their cameras on hand. Make sure that it's just a couple of others taking the pictures, because too many cameras could intrude on the primary activity. Remember, the primary activity is the kids making the contact, not your taking pictures.

The Morning After

The adventure will end as it began—with paperwork. You must file a final report. The form may be filled out online at the NASA website to which your mentor will refer you. The report becomes part of a file that justifies the existence of the ARISS project and NASA's support of its educational goals. Your report helps promote continued funding and assistance for the ARISS project, and it helps keep open that window to space for other students who will follow in the wake of your successful contact.

Conclusion

The men and women who are a part of the ARISS program stand ready to assist you in any way they can to make your efforts successful. They are at your service, because they also want to tell the story of your successful contact with the space people.

The mechanical success of an ARISS contact is measured within 10 minutes. The effective success of an ARISS contact is measured in units that are still to be determined. How wide have imaginations been broadened? How deep has curiosity gone? How many more questions are now being asked silently? What wondrous answers will come?

What part will you play in answering these questions? As with all of the answers to the above questions, it is limited only by your imagination and how it reaches into the universe. ■

of transmitting and working the keypad numbers, the radio-controlled, high-frequency station leaps into action. What follows is a typical sequence used for controlling a Super System:

• Select repeater channel and check for an open frequency.

• Bring up the idle repeater with carrier plus CTCSS and sometimes a 3-digit "wake up" code.

• Give your callsign.

• Key enter "AC2" to turn on the HF remote.

• Select memory or VFO mode with keystrokes AC60 or BC61.

• Key in the frequency you want or memory channel pre-set listed on your 100-memory crib sheet. Once in the VFO mode, you may tune up or down in any frequency step of your choice above 100 Hz. Most operators tune 1 kHz on HF SSB, or 100 Hz on HF CW.

Requirements

The authorized system operator *must* possess the General, grandfathered Advanced, or Extra class license to use the high-frequency transmit capabilities of the remotely controlled station. All authorized operators may transmit ACx (x = secret) to turn on the transmitter and enable push-to-talk on any HF frequency dialed in. On the WA6TWF Super System, Dave receives more General class and higher control operator requests than hours in the day! These control operators now give the system some unique capabilities for brand-new hams.

A Technician class operator holding 5 wpm code credit is legally permitted to transmit on the 10-meter ham band between 28.1–28.5 MHz, but no transmit privileges are allowed on the 10-meter FM or other high-frequency bands. Even without transmit privileges, Technician class operators are encouraged to listen to the high-frequency bands. Such monitoring can motivate these newly licensed Technician class operators tune into the excitement of HF operation to promote enthusiasm for learning the code and upgrading the theory to get their General class license.

If the system detects no action for over 3 minutes, it times out. This time-out is associated with bringing the system up, but not associated with actual transmitting over the air. This way, Technician class operators authorized by the station licensee are permitted to control the functions of the HF system mentioned above.

One way of controlling a Super System is through the use of up-codes. Up-codes can be stored in handheld memory, so a keypad sequence would not only bring up a sleeping repeater, but also have it already to go for push-to-talk DX on 20 meters, which may take less than 15 seconds! On the WA6TWF Super System, Extra class control operators are always there to help the demonstration along.

Equipment

If a fellow ham on your system just happens to have a QTH on a hilltop, with no antenna restrictions, stand by for added excitement for your own super system! For example, the better the high-frequency base-station antenna system, the better the DX on the 70-cm link. One high-frequency linked station might include a rotatable 5-element HF beam that also might have elements for the WARC bands. For 40 and 75 meters, a separate up-code might click in a Dow Key relay to pull in a coaxial dual-band dipole for the night owls driving home. Not only does the HF remote base lend itself to handheld excitement, it also may "equip" a vehicle that just can't accommodate a big HF whip. The little 70-cm mobile or handheld on an outside mag-mounted antenna now becomes the ideal HF "link."

Tom, N6OT, and Bob, N6OX, both indicate that the HF remote base is a terrific idea, but it requires some major considerations. Among these is the need for a good HF antenna that might be pointed via the tone pad. Power output beyond 100 watts is not recommended. Who needs a kilowatt on HF, especially when with the high power comes the potential of RFI? Ironically, getting the RF out of the control lines is one of the major projects when setting up an HF remote base.

"A state-of-the-art controller specifically designed for computer-controlled, multiband, multimode HF/VHF/UHF equipment is now available for almost plug and play," comments David, WA6TWF, recommending the NHRC-10 repeater controller (<http://www.nhrc.net>).

The WA6TWF Super System has successfully used equipment from Kenwood, Yaesu, and ICOM. Presently, one outstanding HF base is running the ICOM IC-706-MK2G, with another station using the ICOM 746 Pro, and yet another station bring equipped with the ICOM 756 Pro II.

"You can control frequency, mode, scan, and memories with the NHRC-10. Also, you can add an auxiliary board, which will give up to eight switching signals to control other devices, such as the antenna-selector relay," adds Jack, KD6ZJT.

All system technical administrators were quick to point out that the controller and associated HF radio by itself need additional filtering on the controller cables and band-pass and band-reject filters when the equipment is located at the repeater site. Also, copious amounts of copper foil for equipment and controller grounding, including the homebrew feed-through RFI filter box, are a must for proper grounding of the equipment.

"The NHRC-10 is very user friendly and gives voice feedback on what is happening with the radio," adds Fred Ordway, KI6QK. This way there's never a question as to where you are on the radio dial up on the hill or at the high-frequency station at a remote location. Dig out the crib sheet, touch the keypad on transmit, and presto—a pleasing voice announces frequency, mode, and any other VFO or memory conditions.

The RS-232 serial control can change frequency, scan the bands, change to any mode, and give you a setup table of acceptable commands in the memory of the computer that's built into the controller. Once a tone command is up-linked to the repeater, the tone is routed to the controller, where it is decoded. If the decoded command fits one of the commands in the look-up table, the computer will do its job and send the specific command to the radio.

"Let's say we send the command 7*20. The computer built into the controller looks this up as a valid frequency change command for the 20-meter band, and the command is sent ASCII from the controller serial port to the transceiver serial port. The transceiver now switches to 7.200 MHz. This frequency is then digitized as voice and is sent back down the line to the operator over his 70-cm radio. The computer and the serial interfacing to the new modern transceiver have added a new dimension to ham radio linking," says Jim Gilliam, K6QE.

The idea of a distant, contest-class high-frequency station serving local hams living in an area with antenna restrictions or hams wanting to work HF bicycle mobile, or hams at the beach on an HT may increase the use of the system so much that additional channels for other activities are necessary. This "problem" is the very best thing that can happen to

70 cm, with so many other repeater systems sitting idle.

IRLP

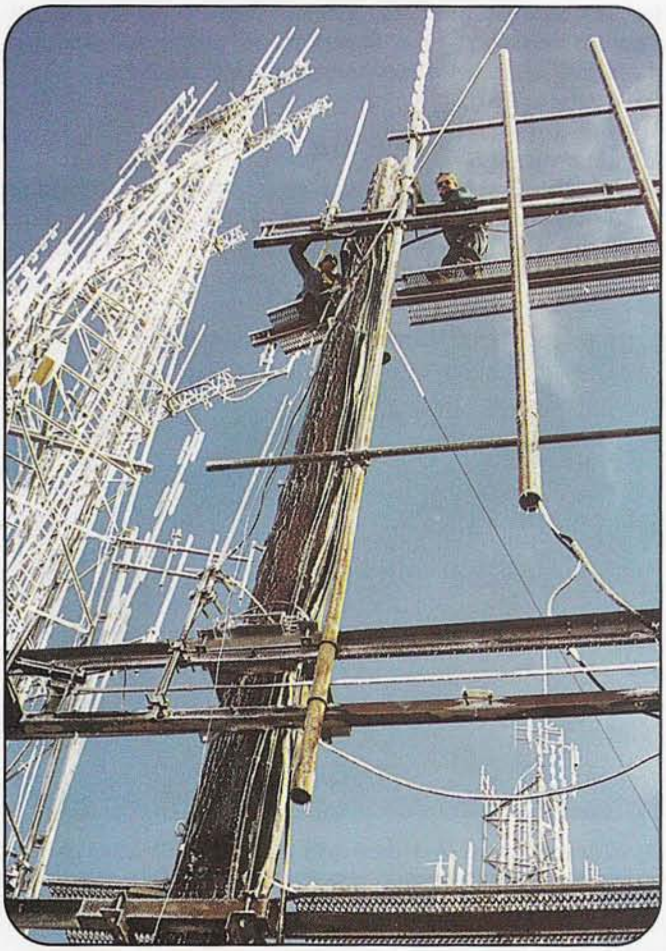
On another one of the many WA6TWF Super System channels is an almost constantly running IRLP. Accessing an IRLP node is easy. On this system, for example, you enter the code to "wake up" the repeater. Then you identify and enter the IRLP access code (varies by system), followed by the node number and a zero. A list of all node numbers and each one's status may be found on the IRLP website: <http://status.irlp.net/statuspage.html>. Next, the node may identify. Wait at least one minute to make sure that the repeater node is not currently active in a QSO. Then transmit on 70 cm, identifying yourself with your callsign phonetically, and saying whom you are calling or if you are making a general call. The WA6TWF Super System recommends always announcing your callsign phonetically, plus the words "southern California United States," and then in plain language asking if anybody is available for a short contact.

The Southern California Super System regularly conducts on-the-air training to eliminate the "fear factor" that new hams may have in bringing up contacts with hams in other parts of the world. Because the IRLP is working with computer links and not HF paths, everyone with any license from Technician class on up is encouraged to take part. Roundtables form quickly, which can attract those operators who are just tuning around the radio dial. These operators may quickly see that here is a "Super System" that goes well beyond simple repeat and autopatch.

VHF/UHF

Another remote base and dedicated channel might be devoted to yet another aspect of the hobby—VHF/UHF multi-

This clean, dual-band system gets out all over the world on the Super System remote.



Super System crew Tom, N6OT (left), and John, KE6YFV (right), working 100 feet up clearing ice from the SGC automatic HF tuner.

mode operation. David's system works with local emergency communication groups with activities on 2 meters FM, with propagation enthusiasts looking for 2-meter SSB contacts, and with hams who enjoy working FM skywave repeater communications on 10 and 6 meters. This same controller is required to meet the legal requirements of remote controlling another station.

Many hams don't realize that the simple 2-meter/70-cm cross-band repeat mode without a special identifier built into the equipment, nor the required control operator at the cross-band mobile repeater, may not meet the cross-banding legal requirements. Using the commercial controller will meet these requirements, however.

Don't Miss This

Something is still missing, however, if you think all these frequencies, radio links, and the hardware meeting the rules make the system an almost automatic daily treat for those hams who can't put HF in their vehicles or those who live in an antenna-restricted area where they still want to play HF DX on 40 at night. To borrow from the Tinman in the *Wizard of Oz,* what makes the system work is its heart. The heart of the Super System consists of those dedicated hams who enjoy teaching radio. They are constantly on the air to act as control operators

Kevin Guice, KG6MIH, who is 14 years old, talks to fellow hams all over the world from his wheelchair via the Southern California Super System. Shown in the company of his companion dog Nina, Kevin keeps his fellow classmates at El Modena High School in Orange, California fascinated by his hobby.

and system administrators. They are also there to ensure only authorized members are accessing the system control functions.

In order to further meet the rules, the WA6TWF Super System has alternate links on frequencies other than the repeater input for shutting down the system in case of unauthorized use. Furthermore, there is always someone listening to the many Super System channels! Such radio "watch schedules" are easily met by retired hams who enjoy being at the heart of major activity on the air.

"Many of our members donate their time and expertise to keep this system operating at peak efficiency, as well as to keep up with the latest technical innovations. Our system boasts many qualified technicians, engineers, and computer experts. These men and women turn into our control operators and maintain the necessary 'radio watch' throughout the day and night," comments Sharon Corsiglia, N6YNK, Dave's wife and system organizer. Also at the WA6TWF Super System is Richard, KQ6YR, who is there to help when keystrokes get mixed up; and if something should fizzle technically at a remote site, system engineer John Luthy, KF6QCQ, heads out to the rescue.

The most gratifying aspect of the system are those it has attracted as authorized system users. David has found that monthly breakfasts and luncheons attract the entire family. Every effort is made to get more kids involved with many of the system features, especially IRLP and an occasional NASA feed on space shuttle and space station operation. Speaking of kids, any system member's son or daughter who is permitted to take a 70-cm handheld to school has a radio that packs a complete contest-class, high-frequency base-station capability in a portable package. An external antenna is recommended, along with an external speaker attached to the HT, so the other kids can hear the excitement once the keystrokes have been entered.

One such young ham who benefits from the Super System is Kevin Guice, KG6MIH. Kevin provides his classroom buddies with exciting high-frequency contacts from a handheld radio and a telescopic elevated antenna attached to his wheelchair. He recently was featured in *QST* with his wheelchair operation.

The monthly rent for any ham remote base "high site" needs membership support.

Maintaining these commercial-grade UHF repeaters—with the contest-grade, high-frequency, and VHF/UHF ham equipment with computer-aided interface, along with the commercial NHRC-10 repeater controller, duplexers and isolators, and commercial-grade repeater antennas—plus the several hundred dollars a month site rental fees on top of a hill or building, indeed costs big bucks. For multiple stations a budget of $1,000 a month is lean, indeed!

Who pays for all this? The authorized operators of the Super System. Yes, there is a membership fee that goes toward the direct support of all the equipment. If anyone out there in "radio land" is getting upset over that fact that someone is charging money to talk over ham radio, I suggest you closely examine where the money is going. It's going into the equipment and literally the future of getting more kids interested in amateur radio. To accomplish this goal, the Super System attracts family membership, where the kids are ostensibly using the system absolutely free. May I further guarantee that usually there is more money going into site rental fees than can be covered by all the donations received.

What happens when the membership grows so large that members begin waiting for a channel to clear in order to work the contest HF remote station? The request goes out for additional frequency pairs, and any frequency coordinator listening in to the non-stop activity on a UHF system is going to find it mighty hard to turn down a request for an additional pair when other UHF repeaters on the band lay idle, abandoned, or only exist on paper. If there was ever a better use of UHF 70-cm frequencies, these systems, as described by the FCC rules, must be recognized as an all-new way of creating ham radio excitement all the way out to the classroom.

Free Advice and Free System Plans

The WA6TWF Super System wants to see better utilization of our UHF and microwave resources. Many of David's WA6TWF projects are not just limited to 70 cm, and some of his experimenting includes 1.2-GHz multi-mode, 2.4-GHz ATV, and even 10-GHz SSB operation.

For more information and plans on how to set up your own Super System, contact David Corsiglia at 714-680-4499. IRLP general information can be found at <http://www.irlp.net>, and a list of all nodes is at <http://status.irlp.net>. The Super System home page is at <http://www.wa6twf.com>, and technical Super System controller info is at the NHRC website previously listed. David has also started an NHRC-10 User Group at that website. Check it for the latest NHRC-10 user modifications, including information on the homebrew filter box.

As this article has illustrated, there can be a lot more to the 440-MHz ham band than just autopatches and repeaters. How can you discover what's out there? By working with those ham operators in your area who set up an ultimate Super System!

Photo B. The AMSAT Board, Project Committee, and SpaceQuest personnel at SpaceQuest on April 20, 2002.

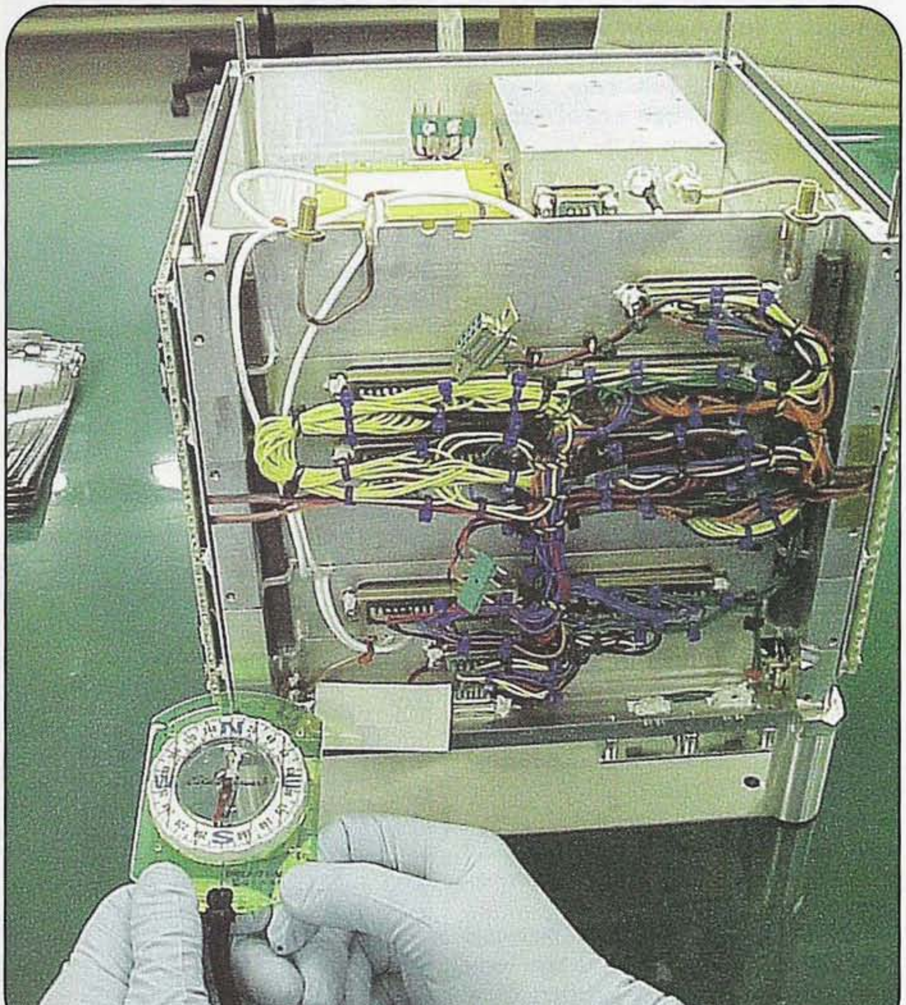


Photo C. Typical Microsat structure.

operate up to 14.4 K baud. Also included is a PL tone decoder.

Hardware and software development are facilitated through the use of the SpaceQuest "FlatSat" model (photo D).

Spacecraft Flight Software

The boot loader provides the minimum set of functions required to verify the satellite's health and load the operating system. The boot loader is being tweaked to improve the uplink.

The Spacecraft Operating System (SCOS) has been used on all the amateur radio Microsat projects to date. Harold Price has agreed to allow AMSAT to use SCOS in AO-E without charge.

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.

Power Generation and Distribution

The AMSAT OSCAR-E Power Subsystem consists of a Battery Control Regulator (BCR), GaAs solar panels, matched flight cells, voltage regulators, and a power-activation switch. The BCR converts solar-panel power to system power, managing battery charge and protection. It is a switching design with a measured efficiency of 89 percent.

Six GaAs solar panels, which are mounted on all six sides of AMSAT OSCAR-E, produce a bus voltage of approximately 16 volts. The cells that were purchased for AO-E are among the best available, with conversion efficiency of over 25%. Mark, N4TPY, will personally do the layout of the cells onto the panel. He proposes to fly without a glass cover on the cells, which requires more careful handling but gives an additional 1.5% output.

The battery configuration is a matched set of six NiCd cells at 4.4 Ah, each with a nominal battery voltage of 8 VDC.

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

Command and Control— Ground Station

The boot-loader application communicates with the satellite's boot-loader to upload code changes or to load and execute operating system tasks. The House-

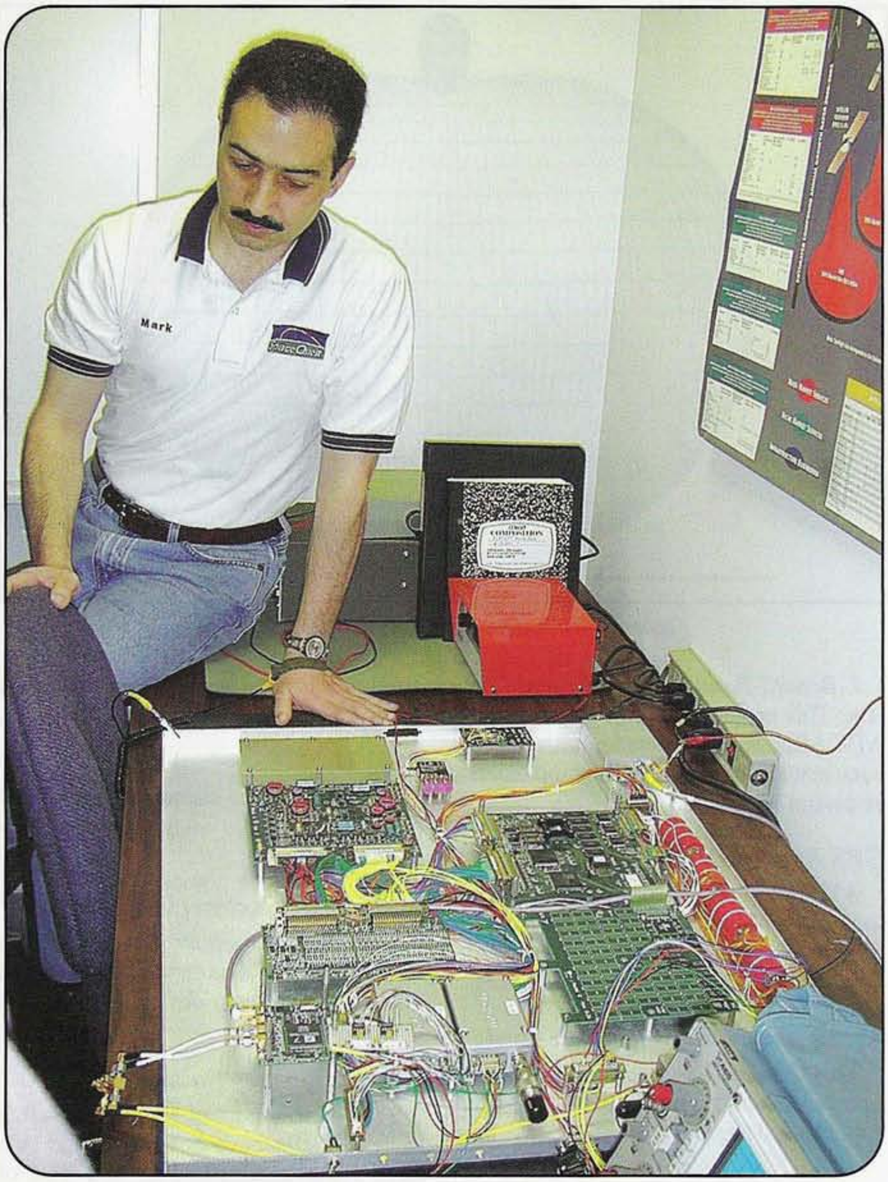


Photo D. Mark, N4TPY, with "FlatSat."

keeping program communicates with each of the tasks onboard the satellite. The Telemetry Gathering and Reporting program downloads and displays satellite health information. Each of these programs needs to be written or rewritten by AMSAT volunteers! This task has not yet been assigned.

Receivers and Transmitters

Four miniature VHF FM SpaceQuest receivers are used for both command and control, and for user links. Each receiver consumes less than 40 mW and weighs less than 50 gm.

Two SpaceQuest UHF FM transmitters provide the downlinks and can be operated simultaneously. Nominal power output is 7 watts. The transmitter modules are being redesigned to reduce their overall height and to move the connectors to one end.

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.

AO-E has a UHF turnstile antenna that is fed by a strip-line hybrid antenna-phasing network, which provides the appropriate quadrature phase and amplitude to each of four output antenna ports to produce true circular polarization over a wide range of squint angles. As currently designed, the turnstile provides left-hand circular polarization. SpaceQuest is looking into redesigning the turnstile for right-hand circular polarization, but this may not be feasible.

Three additional antennas are provided in a cluster at the center of the bottom face of the satellite. One is an 18-inch whip with dual-feed electronics to feed the LF/HF/VHF/UHF wideband receiver. This antenna is still under development. The other two are quarter-wave whips for L- and S-bands to support a proposed Mode L/S transponder.

Link Budget Data

The following data is approximate and is provided for those wishing to make preliminary link budget calculations.

Transmitter: 70-cm band, fixed frequency, crystal controlled. Power output is 12 watts maximum and is adjustable over a range of 1 to 12 watts, with the best efficiency achieved at 7 watts output. There are two transmitters that can be operated simultaneously.

Hybrid Coupler: The two transmitters are combined to feed one antenna. Loss in the hybrid coupler is about 0.5 dB or less.

UHF Antenna: 1 to 2 dBic gain (2 dBic at ±40-degree squint). See figure 2. Note that with these numbers, it is possible to exceed the FCC recommended power flux density of –125 dBw/m^2/4 kHz. When transmitting data, the waveform is GMSK ("softened" FSK, not phase coherent like true GMSK). The data rate can be set to anything up to about 56 K baud, limited primarily by the FCC channel bandwidth limit (100 kHz). To be compatible with all the radios and modems that are commonly available, normal operation will probably be at 9600 baud.

Receive Antenna: A quarter-wave whip in the center on the face that normally looks up when over the Northern Hemisphere has about 1.5 dBi (linear) gain.

Receive Cable and Filter Assembly: 1 dB loss.

LNA: 0.7 dB noise figure, 18 dB gain.

Receiver: 15 kHz bandwidth in voice or data (supports up to 9600 baud data).

Optional Payloads

The optional payloads under consideration for the AMSAT OSCAR-E mission were described previously, so only status information is provided here.

Advanced Data Communications for the Amateur Radio Service (ADCARS): A number of meetings and discussions have been held with KA9Q, W2GPS, SpaceQuest, and others. This project is difficult and poorly understood. If AO-E is to provide meaningful support for the development of this new technology, much more work will need to be done.

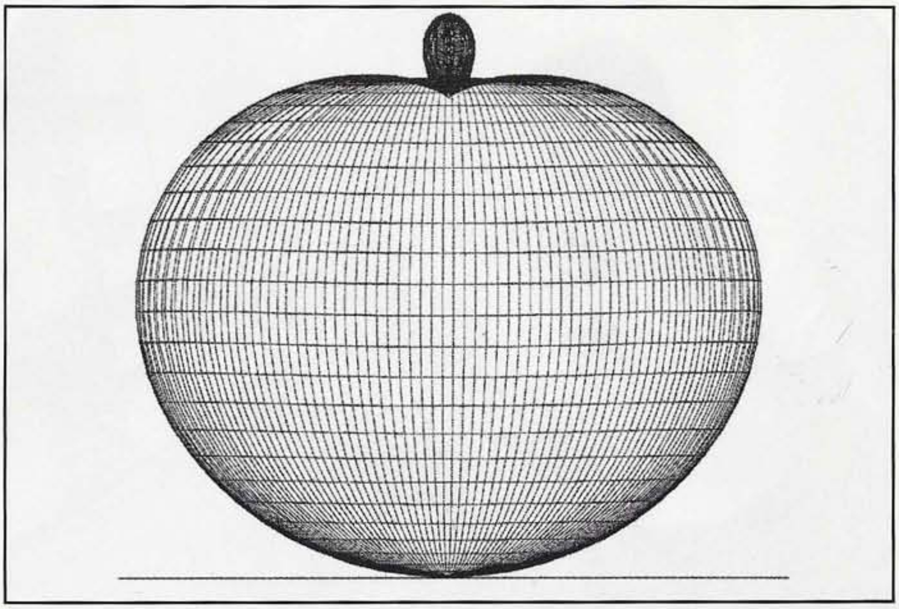


Figure 2. Turnstyle antenna radiation pattern.

L-Band/S-Band Communications System: This project may be combined with ADCARS. A project leader with experience in wide-band transmitter and receiver design is needed.

GPS Receiver

AMSAT, headed by W3IWI, is still looking for a suitable candidate. Power consumption, size, and weight of available equipment are the limiting factors.

Active Magnetic Attitude Control

This project has been embraced by SpaceQuest and is now a part of the core spacecraft design.

Audio Recorder Experiment

This experiment, proposed by KK7P, will provide the capability of recording and playing back any audio channel. The CPU is also needed to support ADCARS. There is no progress to report on this project at this time.

Low-Frequency Receiver

To become feasible, a way must be found to share the single 18-inch wideband receive whip between low frequencies using a new E-field antenna interface amplifier, and VHF/UHF frequencies, which use a more conventional interface.

APRS

APRS can be supported in various ways through software-only solutions. While it would be best to develop the software when the satellite is still on the ground, it is not essential. A volunteer is needed to do the software development.

PSK-31

PSK-31 will be supported by operational control. No additional development is necessary.

Multi-band Receiver/Antenna

This receiver is now part of the core satellite system. The capability is limited only by the antenna design, which must be finalized.

High-Efficiency Solar Arrays

This is now part of the core satellite system. Cells have been obtained that have conversion efficiency in excess of 25 percent, and when facing the sun will produce over 7 watts per panel.

Robust Telemetry Link

Discussions continue with KA9Q regarding implementation issues. This is another very valuable project that is now well understood.

Conclusion

The core elements of AMSAT OSCAR-E are now under construction by SpaceQuest. The project team is still working to finalize plans for optional payloads, which is proving to be especially difficult.

It is hoped 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 AMSAT community. ■

Photo 8. Preparing the base for the dish.

Photo 9. Lowering the dish onto the base.

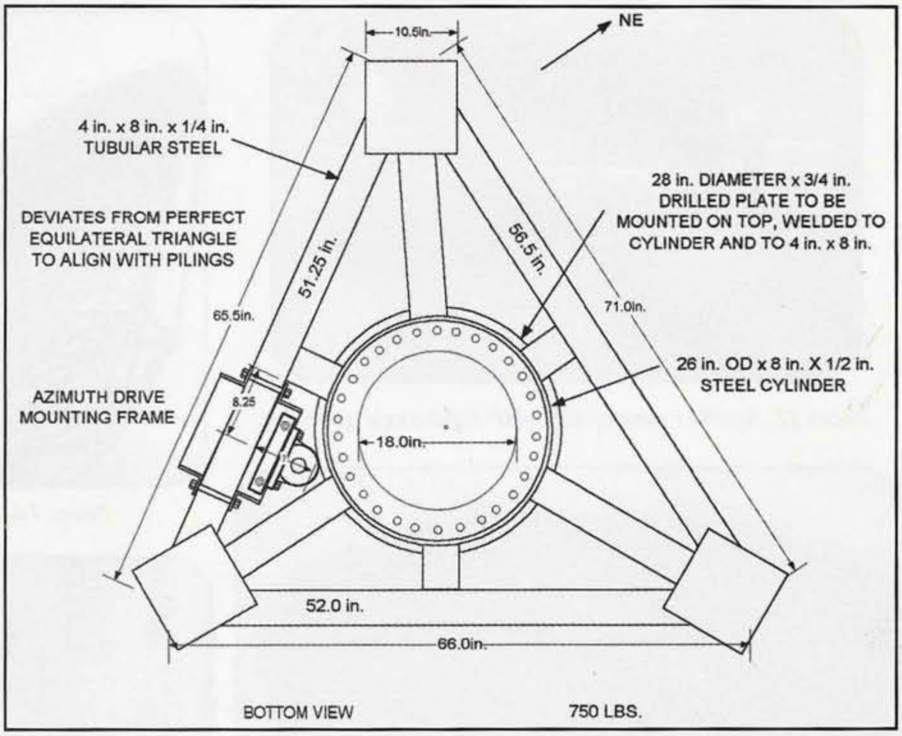


Figure 1. The attachment of the crane bearing to the elevation platform.

using pilings. I did lots of research, scratched out rough designs, and "borrowed" as much free consulting time as I could get away with. I came up with a solution consisting of a three-legged structure using 8-inch schedule-40 casings driven to a depth of 18 feet, with 12 feet remaining above ground to serve as my "tower."

Another word of advice to anyone who might undertake such a project: Get a good drawing program, and make as many drawings of concepts and designs as possible. This helped me a great deal. I made hundreds of drawings and talked to dozens of people. I showed them my ideas and listened to their ideas. It turned out to be a very valuable experience. I used the program Visio, which worked very well, but if you are lucky enough to have access to AutoCad or other such software, so much the better. I also developed many pages of detailed project schedules listing the many hundreds of individual tasks. I spent the next six or seven months of winter planning how to make this all happen in the summer of 2000.

Along with the planning, I had to deal with one of my neighbors, who expressed a great deal of concern about the location of my dish. I gave them notice of my intentions, and I raised a 40-foot push-up mast with red tape, marking various heights, such as the highest point when the dish would be pointed at the horizon, and the height of the array when parked. They invited me into their living room to see for myself the effect the dish would have on their view. They have a truly pristine view of the city of Anchorage, Cook Inlet, and the Alaskan Range. The dish would not block any of it, but it would be in full sight, just below their horizon.

I consulted a friend in the city attorney's office as well as my own attorney, and they told me that there was really nothing my neighbors could do because my construction would be well within my own property and not outside of any codes, covenants, or restrictions.

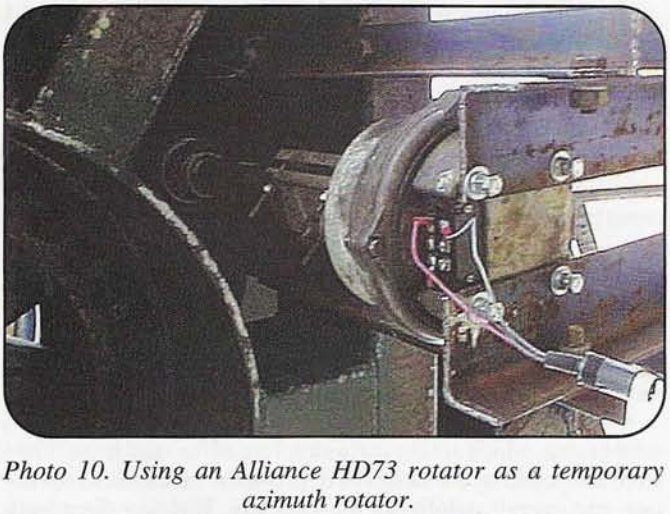


Photo 10. Using an Alliance HD73 rotator as a temporary azimuth rotator.

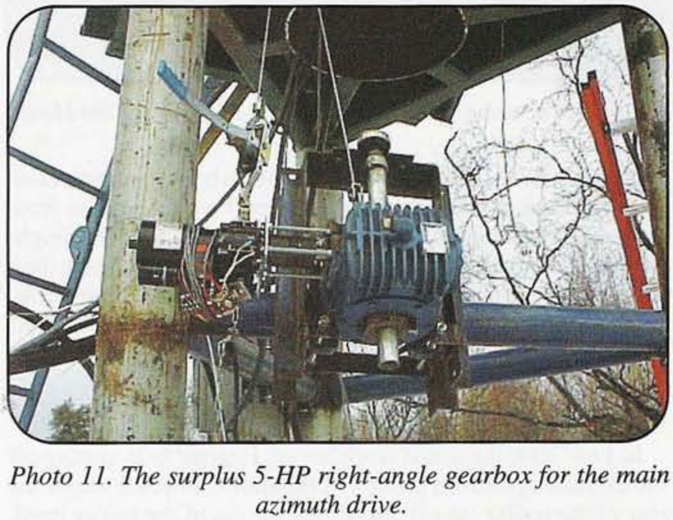


Photo 11. The surplus 5-HP right-angle gearbox for the main azimuth drive.

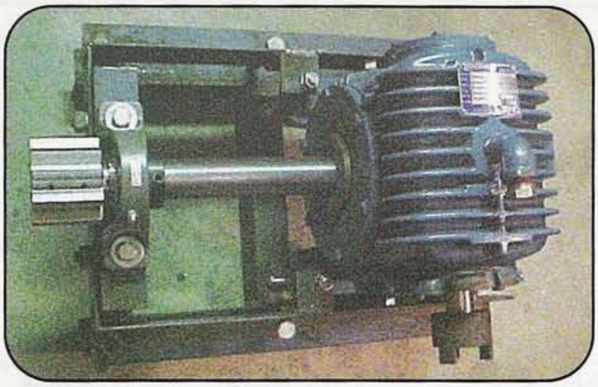


Photo 12. Another view of the 5-HP right-angle gearbox.

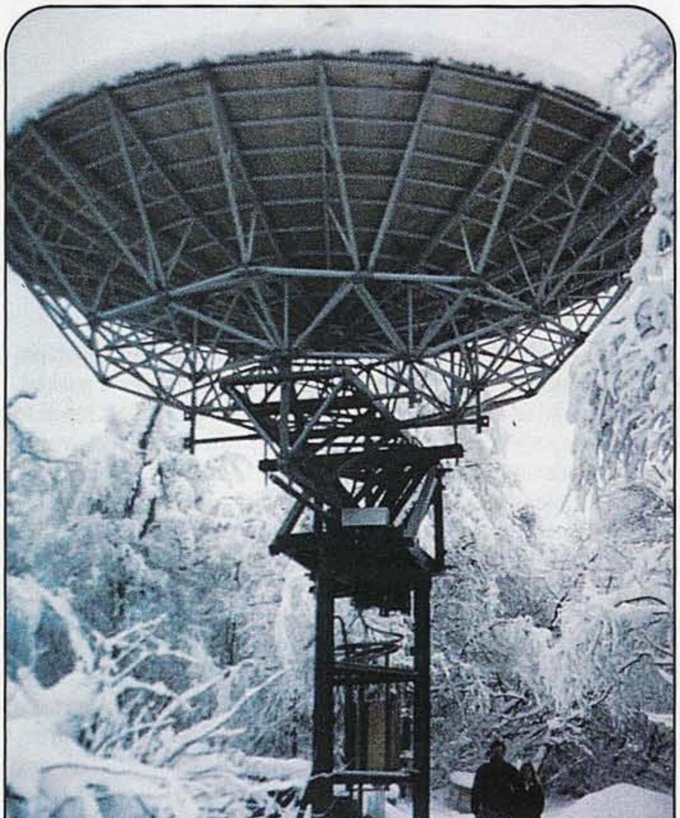


Photo 13. The completed project ready to work you off the Moon.

Photo 14. The dish with the 1296-MHz feed.

Photo 15. The author at his EME station.

Nevertheless, I chose to relocate the dish to a position closer to the front of my lot. In this manner it would be seen from the street, and it would be closer to the property line. The neighbors said that they would not object to it even overhanging their property, as long as I didn't put it in front of their view. Ironically, the final location reduced my coax run from 120 feet to 90 feet, a plus.

Construction

In June 2000 the actual work began. I started with cutting off the elevation platform portion of the trailer. Photo 2 shows the rear of the trailer cut off and sitting on top of the trailer itself.

Next I contracted for the piling foundation I described earlier. This was the single most expensive part of the whole endeavor, costing $1540 (much easier and cheaper than the concrete approach). The welding that I did not do myself was performed by a small welding firm (owned by NL7RT and his wife WL7KM), which took what was left of the transportable earth-station trailer in trade for the work.

The three pilings were topped off by a steel framework of 4 × 8 tubular steel, a $^{1}/_{2}$-inch steel cylinder for the center, and a $^{3}/_{4}$-inch steel plate to mount the large bearing. It turned out to be a 750-pound work of art, thanks to NL7RT. This was set in place with NL7RT's forklift, which just happened to have a 12-foot lift range (photo 3).

Another crucial design requirement was the attachment of the crane bearing to the elevation platform. This is how to do a two-man job with one man: I lifted the 263-pound bearing with my left hand and inserted a bolt on the opposite side with the other hand (photo 4). Photo 5 shows the final product welded, bolted, torqued down, and painted. Thirty $^{3}/_{4}$-inch bolts were used to attach the bearing. The center part of the bearing was later mounted to the tower with twenty-nine $^{7}/_{8}$-inch bolts.

A somewhat risky modification was performed on the 2 × 6 steel beams, which are the main structure of the steel truss. They were shortened by 54 inches to improve the mechanical advantage and overall stability of the structure. Welding them back together after shortening was performed by a certified welder because of the huge stresses on the structure. Once this was done, the 50-plus angle-iron sections could be assembled (photos 6 and 7).

Assembly of the aluminum truss network and dish panels took two full days, but finally I was ready for the crane. Again, I made many drawings and went through many "what-if" scenarios before committing to the crane time. The planning paid off, and the two-phase lift was completed in $2^{1}/_{2}$ hours (photos 8 and 9).

The heavy work on the project was all completed by October 9th. Just as a side note, my hernia surgery the following May went well, too.

The next month my free time was devoted to positioning controls, RF assembly, and wiring. With the very high efficiency of the crane bearing and the gearbox, I actually did my first azimuth rotation and made quite a few contacts using an Alliance HD73 rotor (photo 10)!

I was fortunate to acquire a surplus 5-HP right-angle gearbox for the main azimuth drive. A friend in Minneapolis acquired this at a garage sale (free), but shipping would have been costly, it being around 100 pounds. I lined up a free ride for it from a local friend who happened to have purchased a new truck in Minneapolis and was driving it back up the Alcan Highway (photo 11). The final configuration is shown in photo 12.

The elevation system utilizes the existing 20-ton actuator (jack-screw), which I drive with a 1.5-HP motor obtained at a garage sale for $20. I have successfully controlled the array with a TAPR TrakBox for almost two years. I'm currently working on an improved tracking system with a target resolution of $^{1}/_{100}$th degree using Hall-effect sensors.

On The Air

The system became operational in early November 2000 (photos 13 and 14), and has been used primarily on 432 MHz using a K4QI dual dipole feed design driven with a K2RIW amplifier at about 700 watts output. I'm currently using a KAØRYT cavity preamp that boasts a 0.16-dB noise figure. My transmit and receive feedlines are 100 feet of LDF7-50 ($1^{5}/_{8}$ inch heliax) and LDF5-50 ($^{7}/_{8}$-inch heliax). I have 120 initial QSOs on 432 MHz, and 16 initial QSOs on 1296 MHz (after one day of operation with a borrowed 160-watt brick). I received my best EME signal report, 589, on 1296 MHz. My mission, now that I have a "monster" system, is to help as many newcomers as possible make their first EME QSOs. So far my most impressive contacts have been with single-Yagi stations.

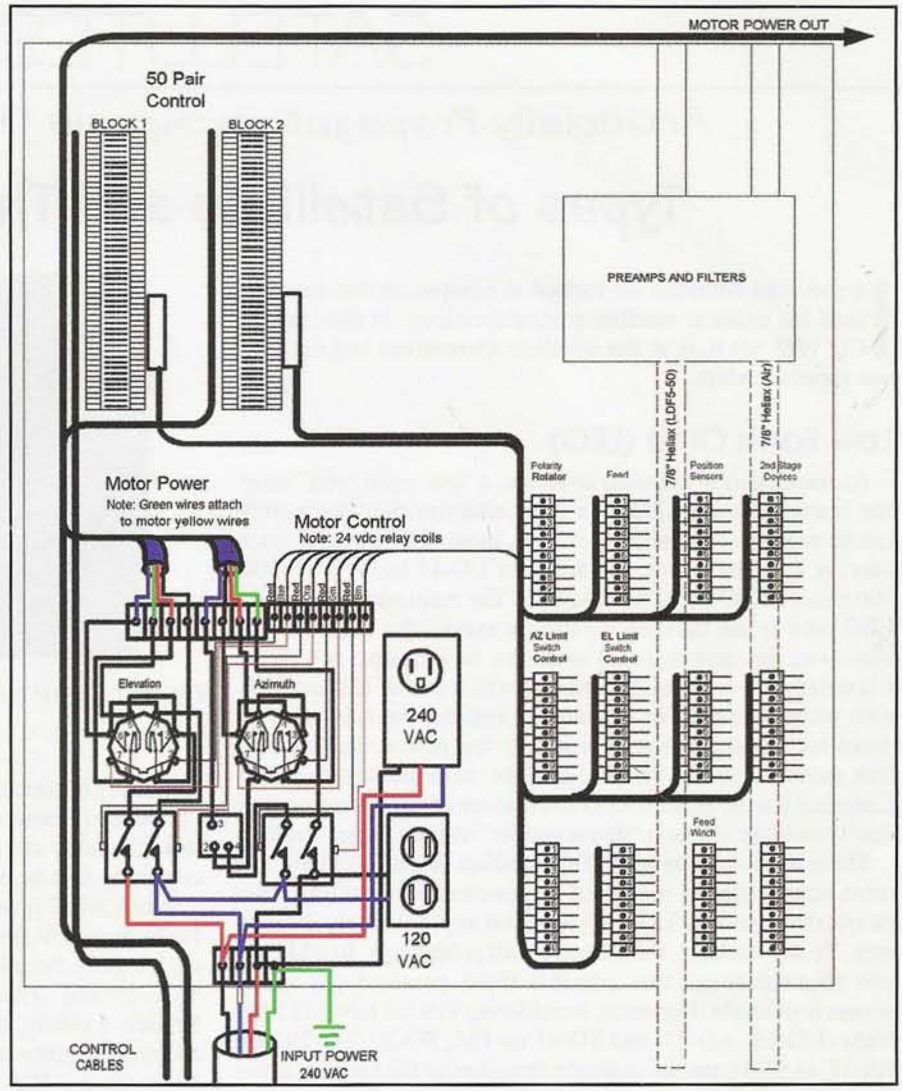


Figure 2. The tower junction box.

Summary

I've been an amateur radio operator since 1965, and I must say that EME is the biggest rush I have experienced in my entire amateur radio life. I highly recommend it. If you have any interest at all in trying it, there are dozens of hams out there who would love to help get you on the air. The foremost in my mind, as my first EME QSO, is Dave, W5UN, who has a terrific website that provides valuable insight for the beginning moonbouncer; go to <http://web.wt.net/~w5un/>.

There are hundreds more places that have EME information. A good place to look for a collection of links is at <http://www.nitehawk.com/rasmit/>. My own site is at <http://www.qsl.net/kl6m/>.

Some highly dedicated individuals provide fantastic services to the EME community. Joe, K1RQG, conducts the 432 MHz and above EME net every Saturday and Sunday at 1600 UTC on 14.345 MHz. This is followed by Lionel, VE7BQH, and the 2-meter EME net on the same frequency at 1700 UTC. A monthly newsletter is produced by Al, K2UYH, and it provides an immensely valuable service to those interested in EME; it can be seen at <http://www.nitehawk.com/rasmit/em70cm.html>. Steve, K1FO, is a storehouse of technical information, and he has designed some of the best antennas for EME, as well as some of the best linear amplifiers.

The list could go on and on. If you have the slightest interest, a wealth of information is available. Give it a try, but only if you aren't afraid of becoming hooked, like I am. I hope to see you off the Moon! ■

By Tom Webb,* WA9AFM

SATELLITES

Artificially Propagating Signals Through Space

Types of Satellites and Their Orbits

In previous columns we looked at equipment and antennas used for amateur satellite communications. In this issue of *CQ VHF* we look at the satellites themselves and the various types of orbits.

Low Earth Orbit (LEO)

As mentioned in previous columns, a "low earth orbit" satellite, better known as LEO, is in a low-altitude orbit. These orbits can be as low as 100 miles. However, most of the amateur satellites are well above that: 500 miles for UO-14 and AO-27, 800-900 miles for FO-20 & 29 and AO-7. The main advantage of the LEO orbit is the minimal equipment needed for a ground station—i.e., low power, small antennas, no preamps, and so on. It's possible to work a LEO satellite with a 5-watt HT and high-gain whip antenna! For the satellite builder, the LEO satellite downlink transmitter can be relatively low power, the up/downlink antennas can be simple, and the airframe small in size. Launches for the smaller LEO satellite are easier to find, as they don't consume as much "throw weight" as their larger cousins.

There is a downside with LEO satellites. Because of their low orbit, access time is measured in minutes. For example, even an overhead pass of UO-14 would last approximately 20 minutes. To say the least, the Doppler shift is dramatic. In addition, you might only get two, possibly three, passes a day where access is possible. However, considering that we have six LEO birds (UO-14, AO-27, and SO-41 on FM; FO-20, FO-29, and RS-15 on SSB), you have ample opportunity for satellite activity with a rather unsophisticated station. Digital satellites include AO-16, UO-22, MO-46, and GO-32. LO-19 and SO-33 are also digital satellites, but as of late December 2002 they were listed as not operational or very intermittently operational. For the latest information, check the AMSAT website: <http://www.amsat.org/amsat/news/wsr.html>. There are even two APRS birds in orbit—IO-26 and NO-44. There are also several birds waiting for operational testing and commissioning for amateur service. For operational frequencies and modes of these satellites, go to AMSAT Weekly Satellite Report, <http://www.amsat.org/amsat/news/ans.html>.

AO-7. One satellite, AO-7, has just become available . . . well, at least on a random basis (see figure 1). Launched November 15, 1974, AO-7 was designed for a three-year operational mission, but actually it soldiered on for 6½ years before total failure because of a suspected short in a nickel-cadmium battery. The satellite community was rocked in June 2002 when AO-7 was heard again!

Telemetry suggests the shorted battery had opened and allowed AO-7 to operate on its solar panels. When AO-7 enters sunlight, the bird powers up. However, as there is no power to maintain housekeeping computers and memory, the downlink

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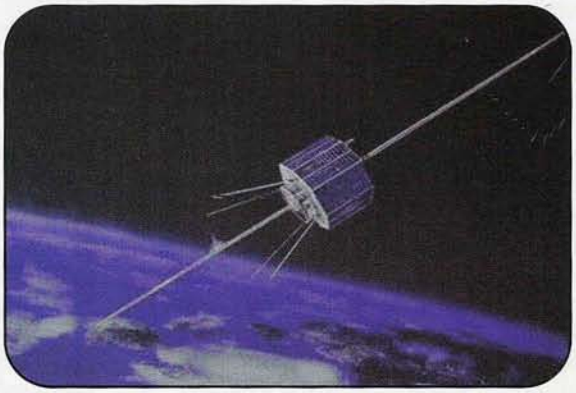


Figure 1. Artist's depiction (artist unknown) of AO-7 in orbit. (Courtesy AMSAT)

frequency is selected at random—either "A" Mode (10 meters), "B" Mode (2 meters), or "C" Mode (a low-power 2-meter downlink). Seventy-cm (435.1 MHz) or 13-cm (2304.1 MHz) beacons may also be heard.

When AO-7 powers up in the right mode (A or B), it's open for business! At first, the question was whether one could operate it legally, because the 70-cm uplink frequencies are between 432.125 and .175, which are not in the Amateur Satellite Service. Luckily, the FCC license for the satellite (Yes, even amateur satellite must have a license.) had been maintained under the call W3OHI, thus making operations "legal."

A ground command team is attempting to regain some form of control over AO-7 to at least have a less erratic operational schedule. Stay tuned. The "Lazarus" bird still has some life left in her.

OSCAR-11. One other LEO, which has been flying about since 1984, bears mentioning—the downlink-only OSCAR-11. Built as an "educational/research satellite," OSCAR-11 has been used by thousands of teachers to introduce students to the wonders of science, space communications, and mathematics. OSCAR-11 also has served the amateur satellite community as a 2-meter (145.826-MHz) and 13-cm (2401.5-MHz) beacon. Considered to be semi-operational as of mid-December, AMSAT is reporting that ground-control stations are unable to command the satellite because of low temperatures affecting the command decoder. They will attempt to command the satellite when the command-decoder temperature has risen to 15°C. For the latest information, check <http://www.users.zetnet.co.uk/clivew>.

Elliptical Orbit

During the Cold War, an effort to prevent an accidental nuclear exchange was devised which allowed the leaders of the United States and (what used to be) the Soviet Union instant communications. The Moscow-Washington Link (MOWLINK) was established to accomplish this task.

With most of the Soviet Union being at a high latitude, a geostationary satellite was out of the question, as a goodly portion of Russia would have marginal or no coverage. To solve this dilemma, a series of communications satellites (the Molynia from Russia and Intelsat from the U.S.) were put in coordinated, elliptical orbits (see figure 2). During the high portion of the orbit, Moscow and Washington had mutual access, giving the two world leaders instant communications. The Russian communications satellites were part of the "Molynia" series. Thus, the high elliptical orbit took on that name. However, it is also referred to as a "geostationary transfer orbit," or GTO. At least two satellites had mutual visual contact with Washington and Moscow at all times.

In the late 1970s, AMSAT decided that the time was right for an amateur satellite at a higher altitude and with longer access times. Although a geostationary satellite would have been ideal, the cost was prohibitive (more on that later). The GTO/Molynia orbit presented an ideal solution. It gives 8–10 hours access and coverage virtually to the entire Earth. (OK, the Northern Hemisphere is favored, but that's where most of the amateur radio population lives.) At apogee (when the satellite is farthest from the Earth) Doppler shift is minimal; at perigee (nearest the Earth) Doppler shift is very difficult to follow. There is a downside to the GTO/Molynia orbit, however. The satellite passes through the Van Allen Radiation Belts twice a day. Therefore, radiation hardening of electrical circuits is an absolute must, which in turn drives up the cost of the bird.

At present there are two amateur radio satellites in a GTO/Molynia orbit: AO-40 and the "gray lady," AO-10. At apogee AO-40 can be as much at 36,000 miles from Earth. For the most up-to-date information on AO-40 and AO-10, go to: <http://www.amsat.org/amsat/news/ans2002/wsr02314.html>. The "Eagle," a follow on bird to AO-40, will also be in a GTO/Molynia orbit, with a planned perigee of around 500 miles, but more on that later.

Manned Spacecraft

Although for all intents and purposes considered LEO satellites, manned spacecrafts are a different breed of cat—make that bird. The International Space Station (ISS), its predecessor the MIR space station, and the space shuttle (a.k.a. Space Transportation System, or STS)

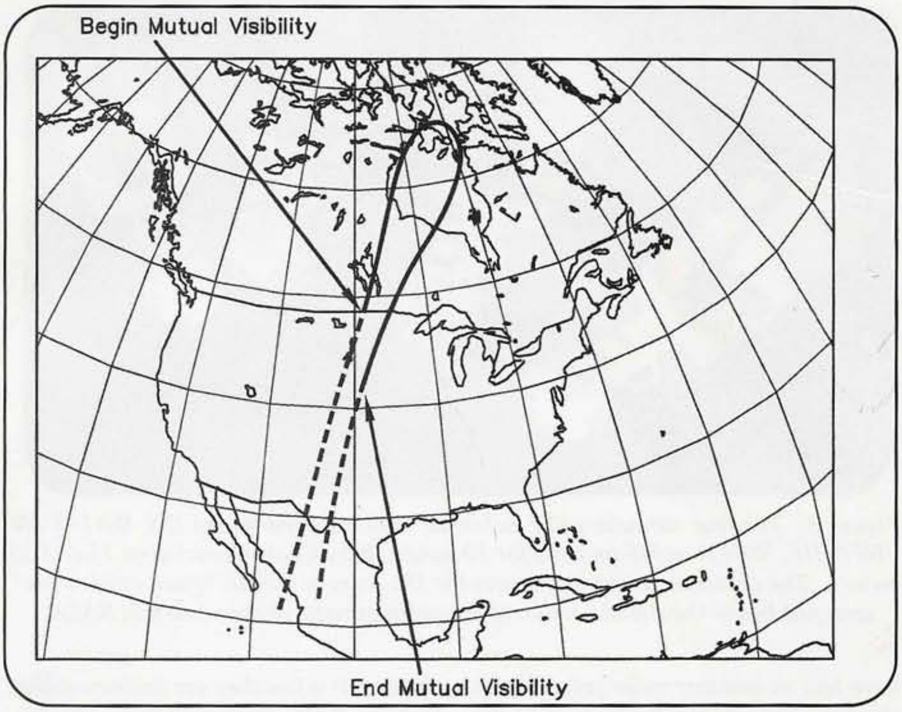


Figure 2. The elliptical orbit for Molyina provides 8–12 hours of access, depending on orbit parameters. At apogee, the farther point on the orbit from Earth, Doppler shift is virtually zero. Approaching and departing apogee, Doppler shift is present, but slow. (From ARRL Satellite Handbook, *copyright and printed with permission of the ARRL)*

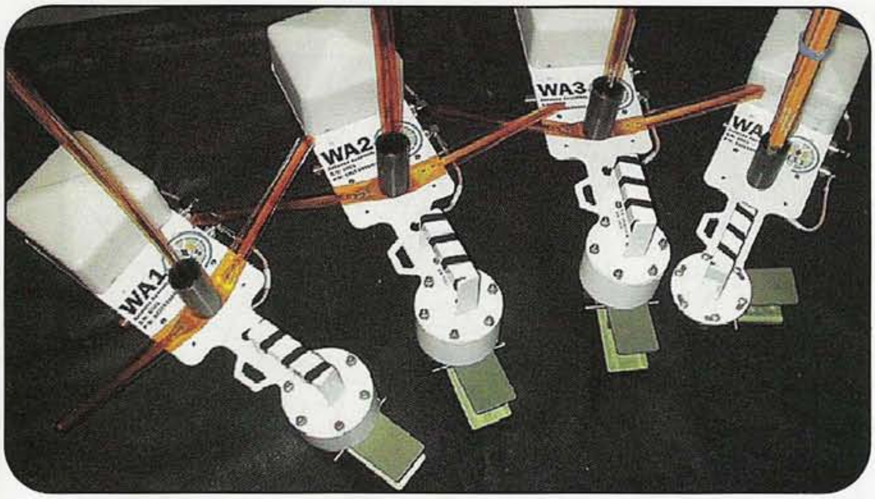


Figure 3. The four amateur radio antennas now installed on the ISS. WA1–3 are VHF/UHF; WA4 is an HF antenna for 10 meters, but will also function on 15 and 20 meters. The antennas are clapped onto the ISS using a simple "giant clothes pin" seen just below the round portion of the antenna base. (Photo courtesy NASA)

have had an amateur radio presence for several years. A goodly portion of the NASA astronaut corps consists of licensed amateurs who participate in Space Amateur Radio Experiment (SAREX) contacts with schools around the world. However, the unique aspect of manned spacecraft is that they are maneuverable. Unlike their pure satellite cousins, manned spacecraft frequently change orbit parameters (Keplarian elements) during a mission. The shuttle might change "Keps" several times a day when conducting scientific activities. Although the ISS does not maneuver as much, each time a new section is added the ISS orbit must be modified.

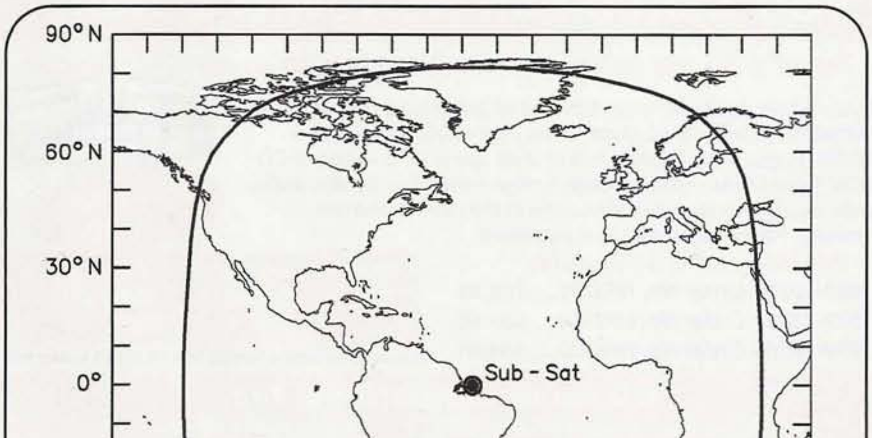


Figure. 4. The footprint of a typical geostationary satellite covers about 150 degrees (120 degrees, effectively). Three satellites would be required for world-wide coverage. (From ARRL Satellite Handbook, *copyright and printed with permission of the ARRL)*

The ISS at around 245 miles in altitude is well below most LEO satellites. It has limited amateur capability at this time; FM voice and packet are available. Its packet uplink is on 145.990 MHz; Region 1 voice uplink is 145.200 MHz; Region 2 voice uplink is 144.490 MHz; and the downlink is 145.800 MHz. The ISS crew usually keeps the packet station running on a continuous basis. When time permits, crewmembers get on the air for voice contacts. A daily crew duty schedule can be found at <http://spaceflight.nasa.gov/station/timelines/>. There is no guarantee that they will be conducting voice operations during scheduled off-duty time, but that's your best chance for working them on voice. The ISS has three callsigns assigned to it: NA1SS, RSØISS (the TNC callsign), and RZ3DZR. Recently, the last of the amateur radio antennas were added to ISS: a 2-meter/70-cm antenna and an HF antenna (see figure 3).

Over the past couple of years the space shuttle's primary mission has been to ferry additional modules to the ISS, which makes the shuttle's orbit identical to ISS. When docked with ISS, they are in fact, one spacecraft. Since the activation of the ISS, little if any amateur radio activity has taken place on board the shuttle in deference to the ISS amateur radio operations. If future ham activity does occur again on board the shuttle, it will be conducted with a specially designed HT interfaced with the shuttle's audio system. The shuttle usually operates on the same uplink/downlink frequencies as ISS. Again, the astronauts operate only during free time or for a scheduled SAREX contact. As mentioned, the shuttle's Keps might change by the hour, depending on mission activity. Therefore, if you want to "score a shuttle QSO," keeping a current set of Keps is vital.

Geostationary Orbit

Why don't we launch a geosynchronous satellite? That question has been asked of the satellite community for years. The reason is quite simple—cost. To recall the line from the movie *The Right Stuff,* "No bucks, no Buck Rogers." Putting a satellite in a geostationary orbit (the other more commonly used term) is a very expensive proposition.

First, an explanation of geostationary orbit is in order. Commonly used for commercial and government communi-

AMSAT HF Nets

Net Designation	Day	Time (local)	Frequency
AMSAT International	Sun	1900 UTC	14.282 MHz
AMSAT International	Sun	1900 UTC	21.280 MHz (inactive)
AMSAT International	Sun	2300 UTC	18.155 MHz (inactive)
AMSAT-NA East Coast	Tue	2100 local	3.840 MHz
AMSAT-NA Mid-America	Tue	2100 local	3.840 MHz
AMSAT-NA West Coast	Tue	2000 local	3.840 MHz
AMSAT-India Sat-chat	Sun	0730 IST	7.070 MHz

Local AMSAT Nets

Area	Day	Time (local)	Frequency
AR-LA-TX QCWA Net	Mon	1930	146.670 MHz (2000 during summer)
Central CA (Fresno)	Sun	2000	146.940 MHz
Central NY	Mon	2000	146.880 MHz
Central OH	Sun	2000	145.490 MHz
Colorado	Wed	2000	147.225, 224.980, 145.460, 145.160 MHz
Dallas/Ft. Worth, TX	Wed	1945	147.140 MHz
Detroit, MI	Sun	2000	145.330, 224.580, 442.800, 1282.050 MHz
Harrisburg, PA	Sun	2000	145.210 MHz
Houston Area, TX	Tue	2000	145.190 MHz (CTCSS 123.0 Hz)
Kansas	Sun	2000	145.190 MHz
Long Island, NY	Tue	2000	147.075 MHz
Los Angeles, CA	Thur	1900	145.320 MHz (CTCSS 114.8 Hz)
Portsmouth, NH	Thur	2000	146.805 MHz
Saco, ME	Sun	2000	146.775 MHz
SW Ohio	Tue	2000	145.110 MHz
Tucson Area, AZ	Wed	1900	146.880 MHz
Waltham, MA	Thur	2030	146.640 MHz
Washington, DC Area	Mon	2000	146.350 MHz

Table 1. The AMSAT nets are a great source of current satellite information.

cation satellites, the geostationary orbit gives the ground observer the impression the satellite is "stationary" over one spot on the Earth's surface. In fact, a geostationary satellite is in an equatorial orbit about 23,000 miles above the Earth, offering a coverage "footprint" of about 150 degrees. At this altitude the satellite's "period" (the time it takes to make one orbit) is 24 hours, which matches the rotation of the Earth and gives the appearance of the satellite being stationary.

This orbital plane is called the *Clarke Belt,* in honor of science fiction author and futurist Arthur C. Clarke, who in 1945 envisioned "a constellation of satellites orbiting the Earth to provide worldwide communications." Each geostationary satellite on the Clarke Belt is roughly two degrees apart. Thus, a geo-

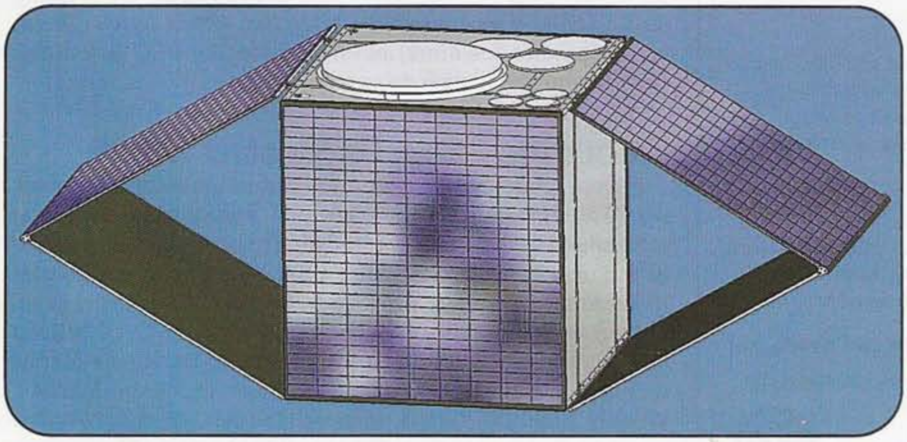


Figure 5. The Eagle satellite, scheduled for launch in 2006. The V-shaped structures are solar panels, which will fold out after orbit insertion. The unusual configuration will allow maximum solar exposure regardless of the satellite's position. (Graphic courtesy The AMSAT Journal*)*

stationary satellite must have a "station keeping" capability and 24-hour monitoring. The fees (You pay rent for a position on the Clarke Belt.) for spots on "the belt" and a commercial launch to a geostationary orbit are very, very pricey. A geostationary satellite must have high reliability, thrusters to maintain its position on "the belt," and the capability of pushing out of orbit when its service life is over to allow a new satellite to take its place. Essentially, we're talking several million dollars for just one satellite to cover approximately one third of the Earth. Multiply by three to get a system for full Earth coverage (see figure 4 and page 12-20 of *The Radio Amateur's Satellite Handbook*).

What's Down the Road?

In 2000 two design concepts for a follow-on satellite for AO-40 were presented at the Portland AMSAT conference. Recognizing the long lead time required to develop, build, and secure launch opportunities for a heavy satellite, the AMSAT Board of Directors combined the concepts and initiated the Eagle Project (figure 5). This new satellite will have a transponder complement similar to that of AO-40. The Eagle's design phase will be cut off in 2003. Integration (construction) should be completed in 2005. Launch should occur in 2006. The orbit will be the GTO/Molynia type orbit, with plans to have it complement the AO-40 orbit. See the September/October issue of *The AMSAT Journal* and the article by Richard Hambly, W2GPS, in this issue of *CQ VHF* for a detailed article on the development, design, and capabilities of the Eagle.

AMSAT is also returning to the MicroSat (see *CQ VHF*, Summer issue, p. 13), specifically OSCAR-E, as part of the next generation of amateur satellites. These will be LEO birds that can be worked easily with stationary, nondirectional antennas. An interesting note about the article just cited above: No less than 12 times, author Rick Hambly, W2GPS, states that the technology to be used in the OSCAR-E series has "been flown successfully on several LEO/Microsat missions." I'm confident this is to reassure the satellite community that the OSCAR-E series will employ tried and true technology, and you can build a LEO station with the confidence that it will get plenty of use. *(Editor's note: Hambly also repeatedly made this point during the forums he presented at the AMSAT-NA symposium last November.)*

Also, AMSAT-DL (Germany) is hard at work on the P3E. It will have an airframe similar in shape to AO-10 and AO-13. P3E is on a fast track and will be launched in a year or so, ahead of Eagle. This will clear the way for Phase 5 (P5), an attempt to get an amateur satellite to Mars—you heard me, Mars! P5 must launch within a specific time frame to reach the Mars area. Talk about some DX!

Project Echo will produce a LEO satellite with capabilities similar to the UO-14/AO-27. It will have an analog transponder and "other experimental payloads." Echo will be a continuation of the MicroSat series. The MicroSat airframe is around 22 cm square and weighs roughly 10 kg. It should see orbit in 2003.

Several scientific amateur satellites are in the works from a variety of schools, including Stanford University, Santa Clara University, California Polytechnic State Institute, Bristol University, and the University of Surrey in England.

AMSAT organizations in Argentina, France, Chile, and New Zealand have plans for amateur satellites as well. New Zealand's project, KiwiSAT, will be a MicroSat using B Mode (70-cm uplink/2-meter downlink) on FM. A full report of KiwiSAT's current status can be found in the July/August edition of *The AMSAT Journal.* You can follow the progress of KiwiSAT via the internet at: <http://homepages.ihug.co.nz/~jpsl/KiwiSAT_index.htm>.

VOXSAT is being constructed by AMSAT-LU, the AMSAT organization in Argentina. VOXSAT will be similar to KiwiSAT both in design and size. Further information on VOXSAT can be found at <http://www.qsl.net/lw2dtz/voxeng/>.

AMSAT Chile is working on CEASAR-1. Also of the MicroSat lineage, it will have J Mode (2-meter uplink/70-cm downlink) and L Mode (70-cm uplink/23-cm downlink). Under the supervision of AMSAT-F, students in France are working on SATEDU which is again a MicroSat with B Mode (70-cm uplink/2-meter downlink) and an S Mode (2.4-GHz downlink). Completion and launch dates are pending.

What's the Latest Ungarbled Word?

If there is one sure thing in amateur satellite communications it's "The times, they are a changin." Variations in operating schedules, beacons going on and off, flying into eclipse, and so on require close attention if you want to have a successful amateur satellite operation. First, go to the AMSAT internet page, <http://www.amsat.org>, and subscribe to the AMSAT bulletin board; the absolute latest into on satellite operating conditions will appear there first. For the big picture check the AMSAT Weekly Satellite Report, also on internet, at <http://www.amsat.org/amsat/news/ans2002/wsr02314.html>. The various AMSAT on-the-air nets are also a great source of current information (see Table 1). A detailed listing of national, international, and local nets can be found at <http://www.amsat.org/amsat/news/ans2002/wsr02314.html>

Line Of Sight *(from page 4)*

Speaking of pioneering work, nearly three years ago Jim Kennedy, K6MIO/KH6, presented a seminal research paper on 50-MHz *F2* propagation at the Central States VHF Society Conference in Winnipeg, Montreal, Canada. Published in the society's *Proceedings*, the paper has since been posted on several websites and reprinted in other publications around the world. We are pleased to reprint it here in *CQ VHF*, beginning this month with part one on page 24.

Kennedy's work was brought to our attention by *CQ VHF* Contributing Editor Ken Neubeck, WB2AMU, who was fascinated by the *F2* and transequatorial propagation (TEP) he experienced last year. His curiosity led him to Kennedy's paper and ultimately to his research on 50-MHz propagation and long-range north-south propagation paths. Also in this issue (page 30) is Neubeck's summary of 50-MHz propagation for sunspot Cycle 23.

Continuing our look at weak-signal propagation theory and its application is SETI columnist Dr. Paul Shuch, N6TX, who asks, "Does SETI theory hold water?" Antennas columnist Kent Britain, WA5VJB, discusses what does and does not work as an antenna for data communications.

It's Still a Hobby

As technically challenging as ham radio can be, it's still a hobby. As such, there are those of us who cannot live without our hobby for very long, so much so that we have to take it on vacation with us. Such was the case with Ron Davis, WB5TGF, who insisted on taking his handheld radio with him on vacation to Britain. Part one of his adventure appears in this issue.

While ham radio is a hobby, we do have rules with which we have to comply. "FM" columnist Gary Pearce, KN4AQ, discusses some of these regulations with FCC amateur radio enforcement chief Riley Hollingsworth, K4ZDH.

Finally, as with most hobbies, in amateur radio there are rewards for the accomplishment of one's goals. CQ Worked All Zones Awards Manager Paul Blumhardt, K5RT, gives a brief update of the Satellite and 6 Meter WAZ Awards.

It's Your Magazine

The underlying theme throughout this editorial is my interest in you, the reader. I want your input in the form of your opinions and material for publication. After one year of producing the new *CQ VHF*, I feel that we are off to a good start. I continue to look forward to your ongoing input to make this, your publication, what you want it to be.

Until the next issue… 73, Joe, N6CL

By Dr. H. Paul Shuch,* N6TX

DR. SETI'S STARSHIP

Searching For The Ultimate DX

Does SETI Theory Hold Water?

The electromagnetic spectrum, as viewed from Earth, is a noisy place. Low frequencies are plagued by galactic noise, high frequencies by quantum-effect emissions, and the whole continuum experiences a 3° Kelvin background from the residual radiation of the Big Bang. These natural radiation sources limit our ability to detect artificial emissions. In addition, the Earth's own ocean of air generates spectral absorption and emission lines, which draw a further curtain across our sky.

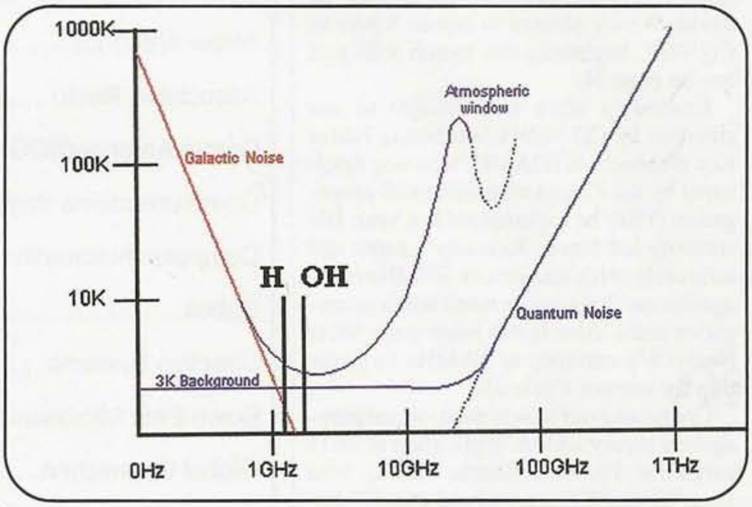
Fortunately, there are a few relatively clear windows on the cosmos. Our eyes evolved to operate in one such window, the optical spectrum. It is this window that first allowed us to observe the stars and planets. Another clear spot is in the microwave region, between about 1 and 10 GHz.

Within this so-called Microwave Window, photons (the substance of electromagnetic communication) travel relatively unimpeded through the interstellar medium at the speed of light. This is, as far as we know, the fastest possible speed, making photons the fastest spaceships known to man. Thus, the Microwave Window, where natural noise is at a minimum, is a favored region for conducting radio astronomy research, including the Search for Extra-Terrestrial Intelligence (SETI).

Toward the bottom of the microwave window, radiation from the precession of interstellar hydrogen is clearly heard in our receivers at a frequency of 1420.40575 MHz (corresponding to a wavelength around 21 cm). The Hydrogen Line, first detected by Harold Ewen and Edward Purcell at Harvard University in 1951, provided us with our first direct evidence that space is anything but an empty void. It is a veritable chemistry set. For their efforts, Professor Purcell received a Nobel prize, and Doc Ewen received his PhD—but had the distinction of writing the shortest astrophysics doctoral dissertation on record, a scant dozen pages. (My own dissertation, by contrast, ran 214 pages. I suppose if I had actually discovered something, I wouldn't have had to write as much.)

We hypothesize that any civilization in the cosmos that possesses radio astronomy already knows about the Hydrogen Line. Since there is roughly one hydrogen atom per cubic centimeter of space, the combined voices of countless hydrogen atoms produce a raucous chorus. The very first SETI studies were conducted near the Hydrogen Line, and today it still looks like a logical place to seek deliberate beacons from Beyond.

Just a little way up the spectrum, near 1660 MHz (a wavelength of 18 cm), in the 1960s a team of scientists at MIT Lincoln Labs detected a cluster of radiation lines from interstellar hydroxyl ions (OH). Like the Hydrogen Line, the Hydroxyl Lines occur near the very quietest part of the radio spectrum. They, too, should be known to other civilizations which have studied the cosmos at radio frequencies.



Water Hole diagram, courtesy of Jenny Bailey, GØVHQ, SETI League volunteer, Regional Coordinator for England.

The chemist looks at H and OH and recognizes them as the disassociation products of water, the solvent essential to the very existence of life as we know it. During the landmark Cyclops study of 1972, Dr. Bernard M. Oliver, then the vice-president of engineering for Hewlett-Packard Company (and later the chief of the NASA SETI program) hypothesized that the Hydrogen and Hydroxyl Lines constituted obvious signposts to a natural interstellar communications band, a thought which would likely occur to other water-based life-forms who had some knowledge of the radio sky. Since the H and OH Lines are visible from anywhere in the cosmos, in the quietest part of the spectrum, they are markers that are by no means geocentric.

It was Barney Oliver who dubbed the spectral region between H and OH the Cosmic Water-Hole. "Where shall we meet our neighbors?" he asked. "At the water-hole, where species have always gathered."

Fortunately, the equipment required to tune the waterhole is well within the grasp of today's dedicated microwave radio ham. Think of the typical amateur radio telescope as the cheap half of a 1296- or 2304-MHz EME system. In fact, many of the first radio amateurs to tune the waterhole for cosmic clues used their existing 23- or 13-cm moonbounce receivers to do so.

Although other regions of the spectrum hold much promise, The SETI League and other organizations concentrate a part of their resources on the Water-Hole in the hopes that there we might detect signs of other life. We only hope our theories hold water.

Editor's note: In the "Dr. SETI's Starship" column in the fall 2002 issue of *CQ VHF,* we edited the column to indicate that John Kraus, W8JK, was a Silent Key. In fact, he is very much alive and continues to serve as a Taine G. McDougal Professor Emeritus of Electrical Engineering and Director, Radio Observatory, of the Ohio State University. —N6CL

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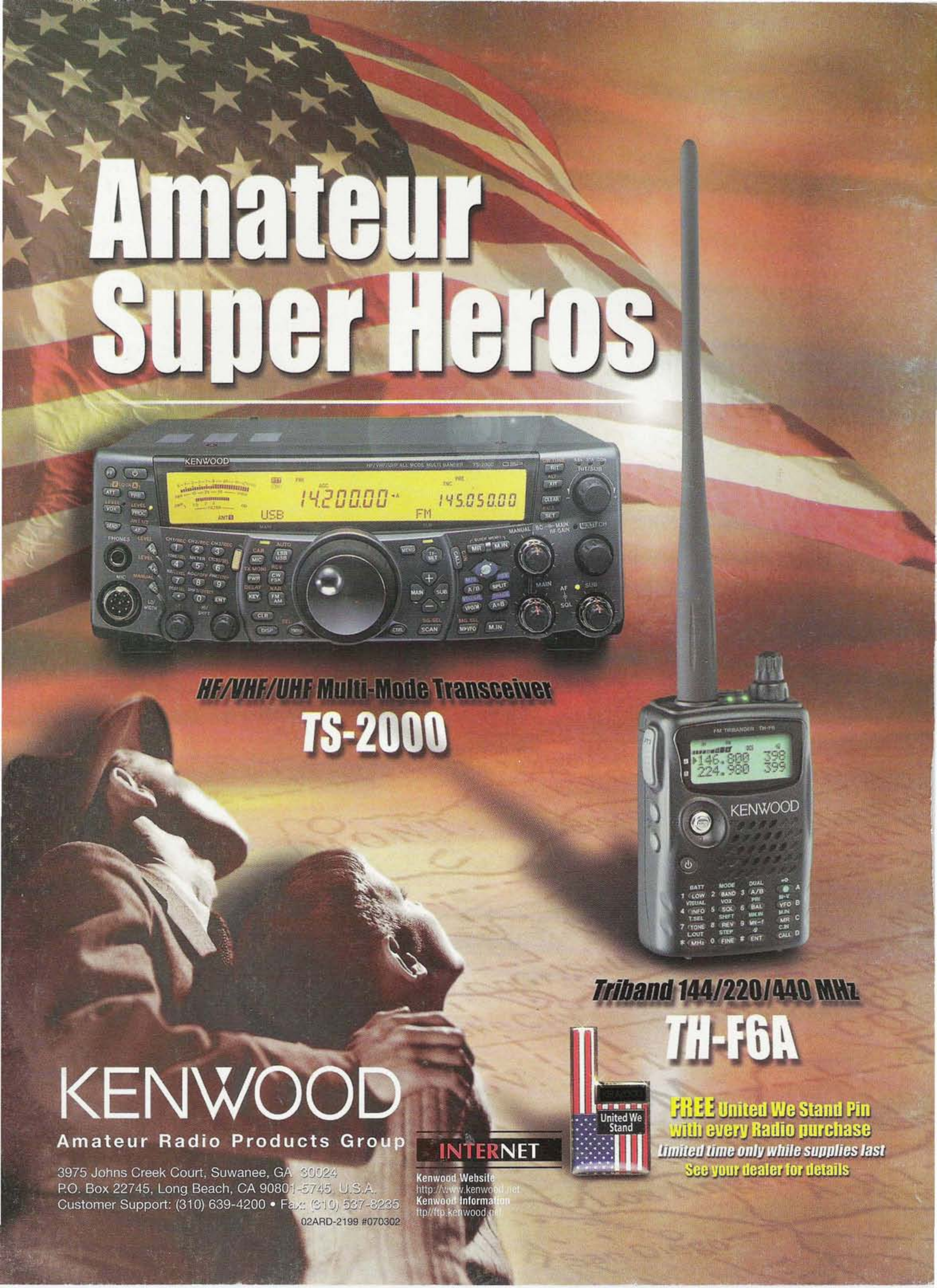

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