ISSN 1085-0708

CQ VHF Ham Radio Above 50 MHz

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Winter 2004
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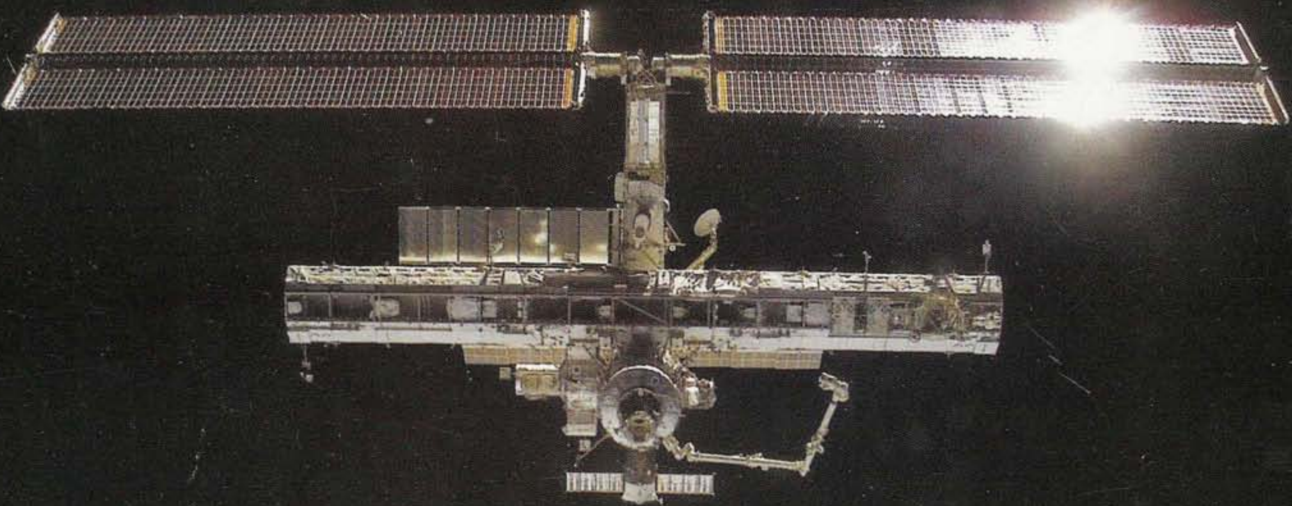
Amateur Radio on ISS Enters Phase 2



- **A Lifetime Dream Flies Across the Atlantic**
- **New Life for an Old ETO Alpha Amplifier**

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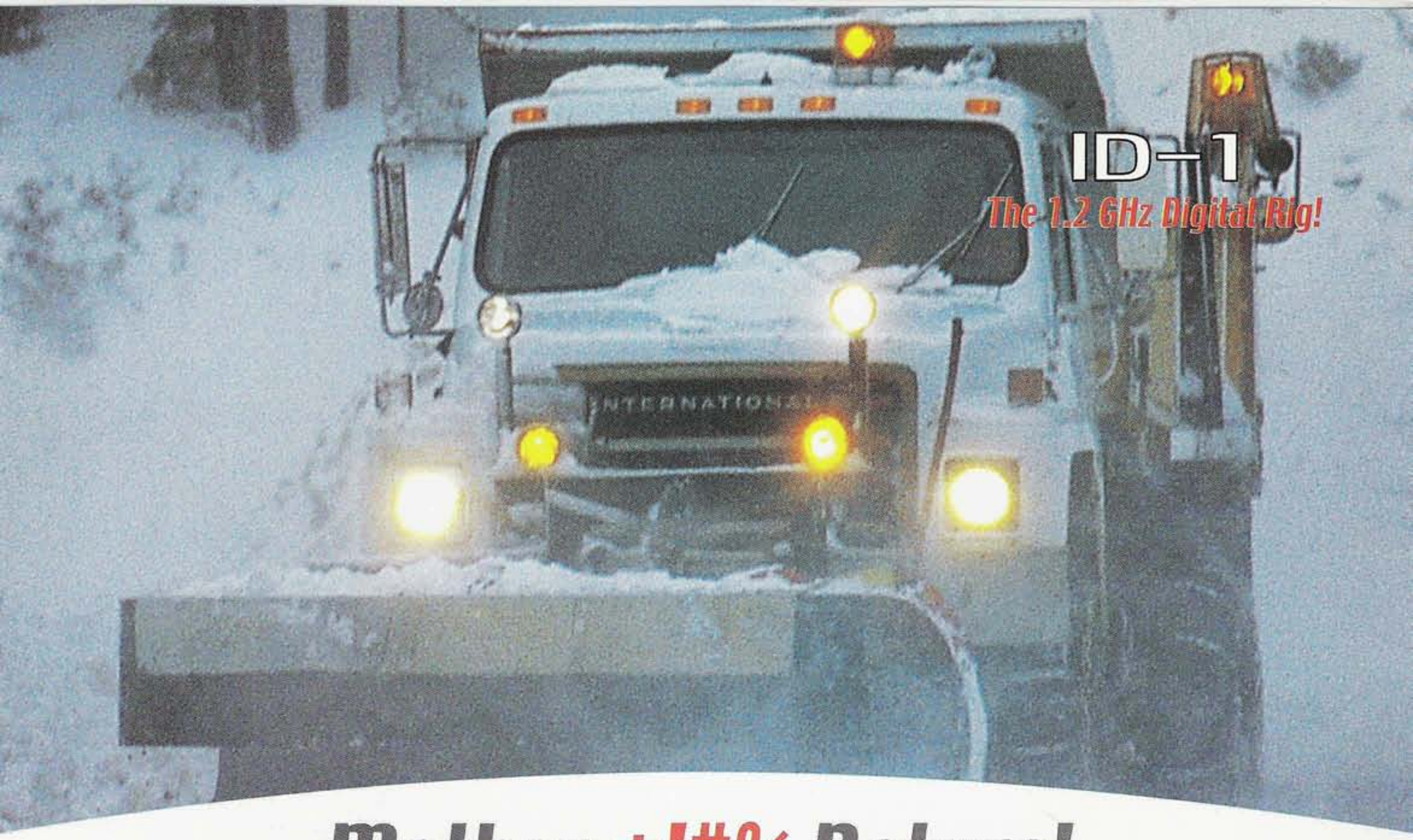

Mother *!#% Nature!

RC-24 Control head shows all operating information and is included with ID-1.

Don't get left in the dark! Regardless of what Mother Nature throws at you, keep track of the latest events with Icom's new 1.2 GHz rig, the ID-1. While traditional Amateur Radio allows you to talk to hams in the neighborhood, or around the world via IRLP, Point to Point communications with the ID-1 can give you high speed 128K data. Thats up to 4 times the speed of dial-up!

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Printed in the U.S.A.

Postmaster: Please send change of address to CQ VHF Magazine, 25 Newbridge Rd., Hicksville, NY 11801

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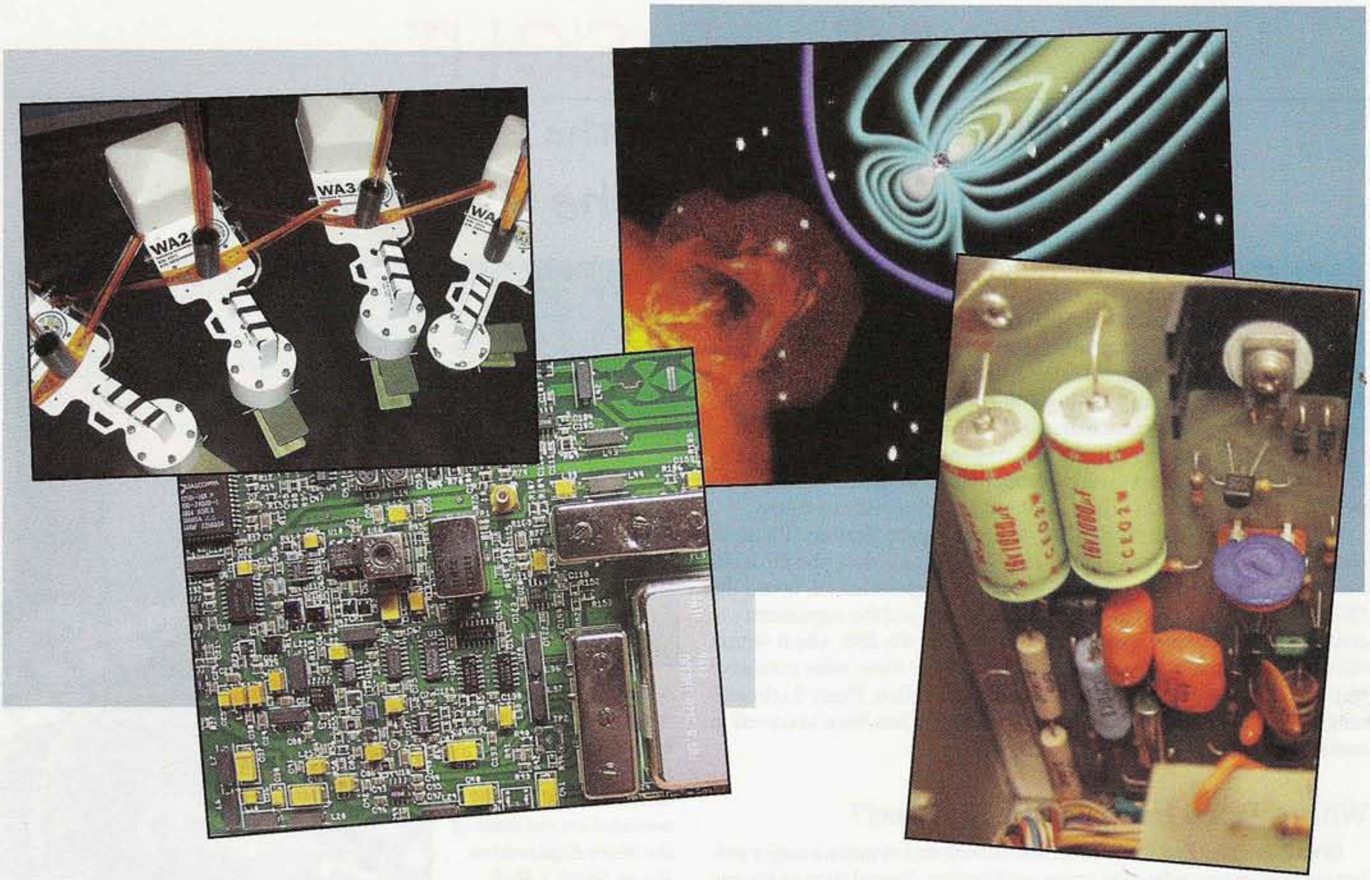
Winter 2004
Vol. 6 No. 4

FEATURES



COLUMNS

DEPARTMENTS

ON THE COVER: Since November 2000, earthbound hams have been able to contact the ham radio licensed space crew members on board the International Space Station. However, such contacts have been hampered due to the limitations of the equipment. Now, with the introduction of Phase 2, amateur radio operations on the ISS have turned a significant corner. In this issue's lead article, KA3HDO, et. al. describe the technical aspects of Phase 2. Inset photo: It took a lifetime for W3FQF to achieve his goal of flying a model airplane across the Atlantic Ocean. Pictured is landing pilot Dave Brown holding the airplane shortly after he successfully landed it on Mannin Beach, Ireland.

CQ VHF Ham Radio Above 50 MHz

LINE OF SIGHT

A Message from the Editor

Amateur Radio—On the Air, In the Air

In this issue of *CQ VHF* we feature two different, but similar airborne amateur radio applications—the use of amateur radio to fly a model airplane across the Atlantic Ocean, and the introduction of Phase 2 of amateur radio operations on board the International Space Station. In "A 6-Meter Rig Flies the Atlantic" Maynard Hill, W3FQF, tells of his lifetime dream of flying a model airplane across the Atlantic Ocean, a feat that he accomplished last August. It's a fascinating story of how one man took his interest in flying model airplanes from balsa models driven by rubber-banded propellers to an electronically controlled model flown more than 1800 miles over a body of water.

In "Amateur Radio on the International Space Station: Phase 2, Hardware Systems" Frank Bauer, KA3HDO, et al., describe the technical side of the next phase of amateur radio operation on board the ISS. For the past three years we hams have enjoyed the opportunity to contact the ham radio licensed crews on board the ISS, albeit within the confines of the limits that Phase 1 presented. Now, after extensive testing of the equipment and its eventual certification, Phase 2 is beginning to roll out, and Bauer, et al., describe what has been involved in making it happen.

A plaque commemorating the astronauts who died in the tragic Space Shuttle Columbia *accident is mounted on the back of the Mars Exploration Rover Spirit's high-gain antenna. Mars Exploration Rover engineers designed the plaque. The astronauts are also honored by the new name of the rover landing site, the* Columbia *Memorial Station. This image was taken on Mars by Spirit's navigation camera. (Top photo via NASA; bottom photo via NASA/JPL)*

Where Does Ham Radio Go Next?

In mid-January President Bush was anticipated to make a major policy announcement related to space exploration. Speculation in the run up to his announcement involved a debate as to whether to complete the construction of the ISS, abandon the ISS in favor of a permanent base on the Moon as a jumping off point for a trip to Mars, or attempt a direct shot to Mars. Whatever the plan turns out to be, amateur radio will be there. Long ago, thanks to the pioneering work of people such as the late Roy Neal, K6DUE, NASA realized the importance of the role that amateur radio can play in the space program, both from a health-and-welfare perspective and as a public-relations tool for NASA, and even as a last resort redundancy link of communications for the space crews.

It is fascinating to speculate what it would be like to have a permanent base on the Moon. Now, thanks to Joe Taylor, K1JT, and his WSJT software development, even a modestly equipped ham radio station can be used for EME communications. With the establishing of a ham radio station on the Moon, communications with hams at that base would be even easier, considering the signals would be making only the one-way trip to the Moon. While NASA anticipates a possible permanent return to the Moon in 2018, it is also possible that private groups such as Artemis Society International (see <http://www.asi.org/>) could be on the Moon much sooner. No doubt, even with these private concerns, amateur radio will play a role in these exploration adventures.

Lest We Forget

As we learned last year, space exploration is not risk free. It was about a year ago when a hugely successful space shuttle mission came to a tragic end over the skies of Texas. Looking up into the morning sky on February 1, 2003, "Antennas" columnist Kent Britain, WA5VJB, observed the following and reported it in his Spring 2003 column:

> I knew that a landing was planned for the morning, and I had hoped to watch it go by. Normally it's just a distant fuzzy dot in daylight, although the pre-dawn passes can be spectacular as it passes over North Texas, headed for Florida. This time I saw a contrail.
>
> "How odd," I thought. "The shuttle usually doesn't leave a contrail." It was quite a show, however! I thought it was interesting that they were not headed toward Florida. They were approximately ten degrees too far south, and some of that apparent angle was amplified by the unusually steep decent angle. Twenty seconds later I saw a bright dot separate away. Strange, as I didn't know of anything they could jettison.
>
> Then they passed below the buildings in downtown Dallas. Minutes later I heard that NASA had lost contact, and I had witnessed the breakup of *Columbia.*
>
> I realized immediately that the angle and speed meant they had lost control of *Columbia* well before I saw the first streak of that contrail. Only then would they have plunged that steeply into the atmosphere. The debris trail passed about 50 miles south of my QTH.

Kent's comments are typical of those of so many of us who have some level of involvement in the space program. We hams identified with the program principally via our hobby's connection. When three of our fellow hams—Mission Specialists Kalpana Chawla, KD5ESI, Dave Brown, KC5ZTC, and Laurel Clark, KC5ZSU—lost their lives on board the *Columbia,* we in the ham radio community especially felt the loss. Indeed, it was the underlying thought of many of the ham radio volunteers who participated in the debris recovery that they were doing so for their fellow hams who had died in the disaster.

In memorializing the tragedy, a plaque has been placed on Mars as part of the Mars Exploration Rover Mission. Engraved on the plaque are the crew's names and images of *Columbia,* NASA's emblem, the U.S. flag, and an Israeli flag in honor of Ilan Ramon, the Israeli payload specialist who also was on board the shuttle.

We can never forget that space exploration is not without risks and that fellow hams can pay, and have paid, the ultimate price for our quest to know more about our universe.

Until the next issue...

73 de Joe, N6CL

A 6-meter Rig Flies the Atlantic

Sometimes a dream takes a lifetime to accomplish. Here W3FQF tells the story of his lifetime dream of flying a model airplane across the Atlantic.

By Maynard Hill,* W3FQF

At age seven, after several failures I built my first model airplane that actually flew. That rubber-band-powered creation of balsa and tissue paper smartly climbed to altitudes near 30 feet and sometimes stayed up for as long as 30 seconds! This joyous achievement was the start of a 70-year addiction to a balsa-and-glue habit. I confess that I simply must have the stuff! I built models during high school, during 2½ years in the Navy in WW II, during college, and during 52 years of marriage and family life that occasionally got a little rocky because of my obsession.

After two years of struggles that could rightly be called failures, in 1949 I successfully flew a radio-controlled model airplane. Success was a vague sort of thing in those days. What actually happened is a friend towed my 10-foot-span glider to about a 250-foot altitude. It made several figure-8s as it descended, and was steered to a landing about 200 feet from where it was anchored to the ground by a cable attached to a 20-pound black box that was almost as big as a bread box. This achievement led to a permanent addiction to the fascinating joys of radio-controlled flight.

The radio equipment I used in 1949 was a commercial version of a system that had been developed by the Good brothers. Walt, W3NPS, and Bill, W81FD (later W2CVI), were identical twins with an identical zeal for radio-control. Their first RC flights had been made in 1936, and historians credit them with being the first hobbyists and radio amateurs to fly RC in the United States, and perhaps in the whole world.

*2001 Norvale Road, Silver Spring, MD 20906
e-mail: <gabbyhill@aol.com>

Radio-control pioneer Walter Good, W3NPS, stabilizes the wing of his "Guff" model at the RC event of the AMA National Model Airplane Championships in Minneapolis in 1947. His twin brother Bill, W81FD, was the pilot, hidden behind Walt aside of the 6-meter Yagi antenna.

The Good brothers' post-war RC equipment was made and marketed by Harry Geyer under the logo of Beacon Electronics. The airborne stuff, with its batteries, weighed about 2 lbs. with a ½-hour battery supply—gross by today's standards, but remarkably light and small for 1949 vintage radios. The receiver was a super-regenerative type operated on the 6-meter ham band. The heart of the unit was a 3A5 vacuum tube whose plate current flowed through a magnetically polarized super-sensitive relay. The filament of the 3A5 needed 100 ma @ 1.5 volts. The plate current was 6.0 ma @ 45 volts. These two rivers of electrons add up to about 0.42 watts, a Niagara compared to modern PCM (pulse code modulation) receivers.

It would be a blatant misnomer to call an afternoon at the field a "flight session." Most often a couple of hours of relay adjustment, range testing, and battery checking ended with one attempt to fly. I just cannot resist telling the younger generation of hams about the key technical problem: The 3A5 tube drew 6 ma when the super-regenerative hiss was alive. This current dropped to about 4 ma when the 6-meter carrier wave signal was received. The polarized relay contacts had very fine-pitched threaded screws to set the armature to hair-trigger from the insulated point to the electrical contact

point. Sometimes the 45-volt B+ battery would sink out of its useful range before the adjustment was completed. The choice was to go home or stick an expensive spare in there and start over.

Enough of this! The joy of a successful flight far outweighed the frustrations.

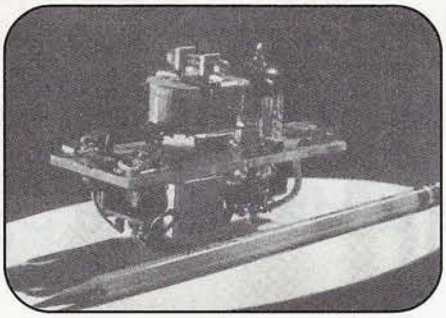
Past Records

During the 1950s Walt Good became my patient mentor and my very good friend. He helped me build and fly his new dual-proportional control system, which he called TTPW, for two-tone pulse width. Almost everybody called the system "too tough to piddle with," but I succeeded and became a fairly hot aerobatics stunt pilot who came close to being on the American team that went to the first FAI World Championships for RC Models in Zurich, Switzerland in 1960.

In 1962, Walt Good pulled some strings with the British organizers and got me appointed to be the chief judge at the second World Championships in Kenley, England. The Soviet Union sent a team to this event. I was shocked by the crudeness of their models and RC gear. I was very surprised to learn that a lapel pin worn by Pietr Velitchkovski, one of the team members, identified him as a "Hero of the Soviet Union." He had earned this honor by setting seven world records for radio-controlled aeromodels.

On our return from Kenley, Walt and I persuaded fellow members of the D.C.R.C. club to hold some record trials. We figured it ought to be easy to beat Velitchkovski with our superior RC stuff. On July 3 and 4, 1963, with help from the Navy, we assaulted Velitchkovski's altitude record of 7100 feet. We did this in the restricted air space at the Navy base in Dahlgren, Virginia. Four competitors passed Velitchkovski's mark. I went the highest, 13,328 feet, nearly doubling the Soviet record.

This event stimulated a third serious addiction related to aeromodeling. I abandoned aerobatic competition and started on a campaign to set world RC records. Instead of being at the mercy of human judges who might be biased or inaccurate for many reasons, record setting is a competition controlled by the laws in Mother Nature's arena. Success is rated in terms of rigid numbers, and the judges are tape measures, clocks, and other technical devices. In short, I found it great fun to set up a challenge, to work on the technical problems, and eventually, to achieve the goal. You know when you are successful, and there's no one to blame for failures but yourself.



The airborne receiver of 1949 vintage, a Good brothers RC system made by Beacon Electronics Company in Pittsburgh, PA. The Fahnstock electrical clips did dual duty as a place to attach rubber bands as an anti-vibration suspension.

All of Velitchkovski's records were overtaken by 1970. By 1999 I had gone on to set a total of 23 world records, 21 of them in the major categories of piston-motored altitude, distance and speed in a straight line, distance and speed in closed circuit, and duration. The other two were soaring glider altitude and speed. The first ten or so set during the 1960s were fairly easy. The still-current altitude record of 26,990 feet was moderately difficult, and the last ten were downright tough! Typically, the development and testing took up to two years and a couple of crashes before success was achieved. We chased models using convertibles barreling at 70 mph on Interstates. I flew countless hours on a racetrack path to perfect distance models, ultimately setting a closed-course distance record of 1301 km with a 13-hour flight. Exciting boredom! I survived 33 hours and 39 minutes of solo piloting to set a duration record in 1992.

Back then there was a "Hail Lindbergh" rule that said one man must pilot the model during the entire flight. Amateur radio technology was used to reduce the problems of lack of sleep and changes in metabolism to manageable levels. A 70-cm band Yaesu walkie-talkie was used as a beacon located on the ground near the pilot's position. A homemade direction-finding receiver on board the airplane was mated to the rudder to make the model loiter automatically over the beacon. Also, a 10-milliwatt downlink telemetry transmitter on the 2-meter band sent down data about airplane and engine performance. A loud claxon sounded if something needed the pilot's attention. I was half asleep on a chaise lounge much of the time. Happily, since then the rule has been changed to allow team efforts.

Further discussion of these past records can't be included here, but if you are interested in learning more about them, a bibliography of 26 of my publications can be obtained from the librarian at headquarters of the Academy of Model Aeronautics in Muncie, Indiana.

The Possibility

An accompanying photograph shows two models that convinced me that it might be possible for a "true" model airplane to fly across the Atlantic Ocean from Newfoundland to Ireland. A "true" model airplane for RC records cannot exceed 5 kilograms (11.023 lbs.) gross weight (with fuel), and it cannot use an engine larger than 10 cc (0.6 cu in.) displacement. "Old Faithful IV" had a fuel load of 4.4 lbs. when it was launched on its 33-hour 39-minute record flight. "Marvelous Martha," the smaller model, weighed 5.5 lbs. empty and thus had a 5.5 fuel capacity, within the rules limit. "Martha" and a sister called "Stretcher" established four very difficult distance records between 1994 and 1998. "Martha" holds the current closed-course distance record of 1301 km (808 miles). Two cross-country records (328 miles and 427 miles) were set by chasing the model with a pilot in a convertible that barreled down Interstate routes 81 and 95. A GPS receiver in the convertible recorded the speed of the model to be about 70 mph in level flight (there was little or no wind). This number was verified by clocking lap times over the 1 km closed course during record flights in 1994 and 1998.

At a speed of 70 mph, the drag due to lift of this model is negligible compared to what aerodynamicists call profile and skin friction drag. I have built a dynamometer to measure horsepower, and simple arithmetic yielded a value of 0.019 for Cdo (drag coefficient at zero lift). This number labels her as cleaner than the famous high-performance, long-range P51 Mustang of WW II. The Mustang has a Cdo of 0.021 if all the bugs are washed off the wings' leading edge.

The dynamometer also yielded numerical values for what is called "specific fuel consumption" of the engine—i.e., how many pounds of fuel are needed to make one horsepower for one hour. My simplistic way of thinking told me that if I slowed the model to half of 70 mph, the

(Continued on page 68)

Amateur Radio on the International Space Station

Phase 2 Hardware System

The International Space Station enters a new phase of amateur radio operation. Here the authors give the details of how this has come about.

By Frank H. Bauer,* KA3HDO; Sergej Samburov, RV3DR; Lou McFadin, W5DID; Bob Bruninga, WB4APR; and Hiroto Watarikawa, JJ1LYU

The International Space Station (ISS) ham radio system has been on-orbit for over three years. Since its first use in November 2000, the first seven expedition crews and three Soyuz taxi crews have utilized the amateur radio station in the Functional Cargo Block (also referred to as the FGB, or Zarya module) to talk to thousands of students in schools, to their families on Earth, and to amateur radio operators around the world.

Early on, the amateur radio operators on the International Space Station (ARISS) international team devised a multi-phased hardware development approach for the ISS ham radio station. Three internal development phases—Initial Phase 1, Mobile Radio Phase 2, and Permanently Mounted Phase 3—plus an externally mounted system were proposed and agreed to by the ARISS team.

The Phase 1 system hardware development, which was started in 1996, has since been delivered to ISS. It is currently operational on 2 meters. The 70-cm system is expected to be operational later this year on SSTV.

Since 2001, the ARISS international team has worked to bring the second-generation ham system, called Phase 2, to flight qualification status. At this time, major portions of the Phase 2 hardware system have been delivered to ISS and will soon be installed and checked out.

This article provides an overview of the Phase 1 system for background and then describes the capabilities of the Phase 2 radio system. It will also describe the current plans to finalize the Phase 1 and Phase 2 testing in Russia and outline the plans to bring the Phase 2 hardware system to full operation.

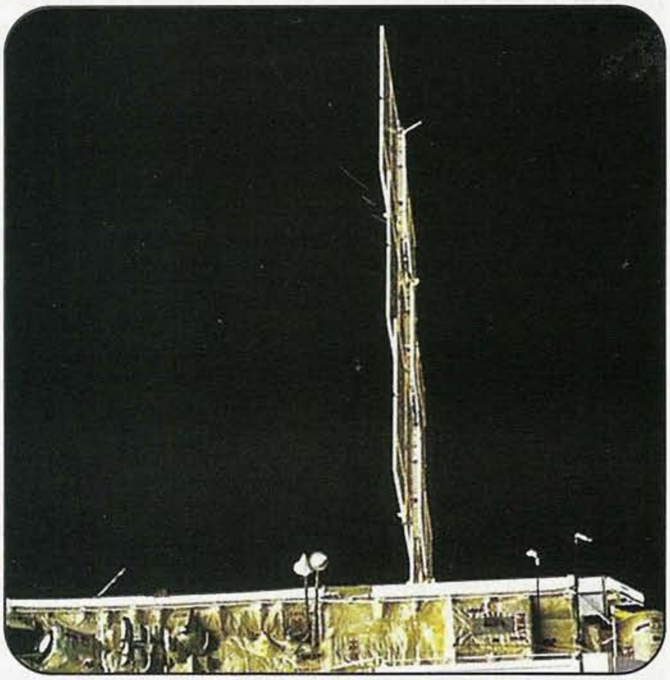


Figure 1. FGB 2-meter antenna locations.

Ham Radio Equipment Specifics

The ISS ham radio equipment will reside in two locations inside the ISS and at least one location outside the ISS. Two-meter (144-MHz) operations primarily will be conducted inside the Functional Cargo Block (FGB), named Zarya, using antennas that supported docking of the FGB with the Russian Service Module. These antennas, designed for use near the 2-meter band (see figure 1), no longer support docking and can be used permanently by the ARISS team. This is the current location of the 2-meter portion of the Phase 1 ISS ham radio station. The FGB radio system represents a minimal capability that allows the ARISS team to support school-group contacts and packet communications on one band, the 2-meter band.

The ARISS team's vision of supporting several different international users at the same time on separate frequency bands and different modes (voice, data, television, etc.) requires several different antenna systems. The ARISS-Russia team, led by Sergej Samburov, RV3DR, provided this foundation through the installation of four ham radio antenna feedthrough ports on the Russian Service Module. With these antennas in place, the primary location of the ham station will reside inside the Russian Service Module (SM) named Zvezda. The ham station will be installed near the SM dining table (see figure 2). Simultaneous multi-band operations can be conducted with these two (SM and FGB) station locations.

The ARISS team is also working with the international space agencies to install externally mounted amateur radio equipment

*e-mail: <ka3hdo@amsat.org>

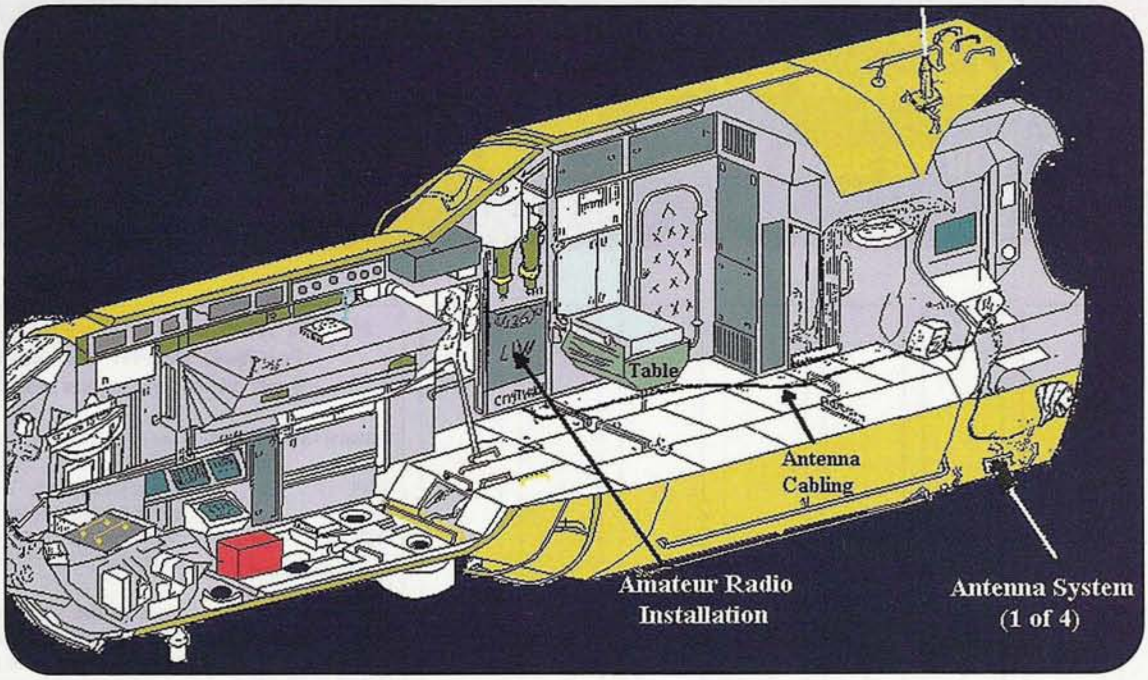


Figure 2. ARISS hardware in Service Module.

on the ISS. This hardware will enable the crew to communicate with Earth-bound radio amateurs and school students using handheld systems that can be moved throughout the ISS. It also will support communications experimentation that will enable students and radio amateurs to receive telemetry data from ISS.

Phase 1 Hardware System

Hardware Overview. The ARISS team has developed all the hardware elements for the Phase 1 radio system. These hardware elements have been flown to ISS on three shuttle flights. The Phase 1 system supports voice and packet (computer-to-computer radio link) capabilities. Packet radio has several capabilities, including an APRS Instant Messaging type system and a Bulletin Board System that allows radio amateurs to store and forward messages and allows the orbiting crew to send e-mail to all hams or to individuals.

The Phase 1 ham radio system was developed primarily in the US. However, extensive testing and coordination with the ARISS-Russia team was required, since it is installed in the ISS Russian segment. The initial portion of the Phase 1 ISS ham radio system was launched onboard the STS-106 Space Shuttle *Atlantis* mission on September 8, 2000. This system consists of two hand-held Ericsson MP-A transceivers for 2 meters and 70 cm, a power adapter, an adapter module, an antenna system, a packet module, a headset assembly, and the required cable assemblies (see figures 3, 4, and 5). This configuration can be operated in the attended mode for voice communications and either the attended or automatic mode for packet communications.

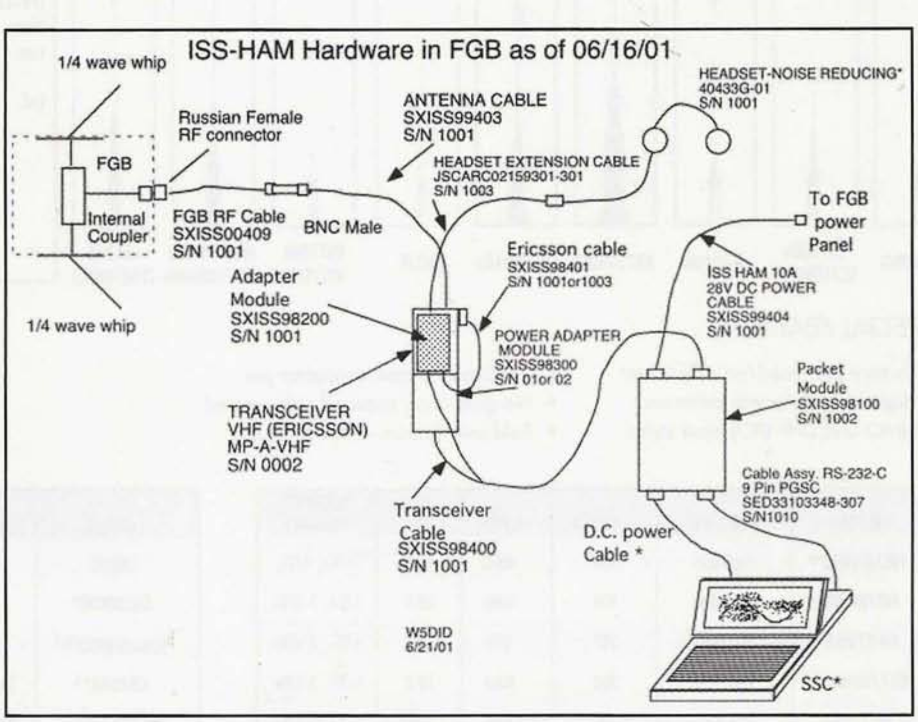


Figure 3. ISS ham Phase 1 system in the FGB.

Additional ARISS Phase 1 hardware was deployed during two additional shuttle flights to ISS. This hardware included an additional Packet Module on the STS-105 Discovery flight on August 10, 2001 (see figure 6), and additional cables and modules to support simultaneous 2-meter and 70-cm operation on the STS-

(Continued on page 62)

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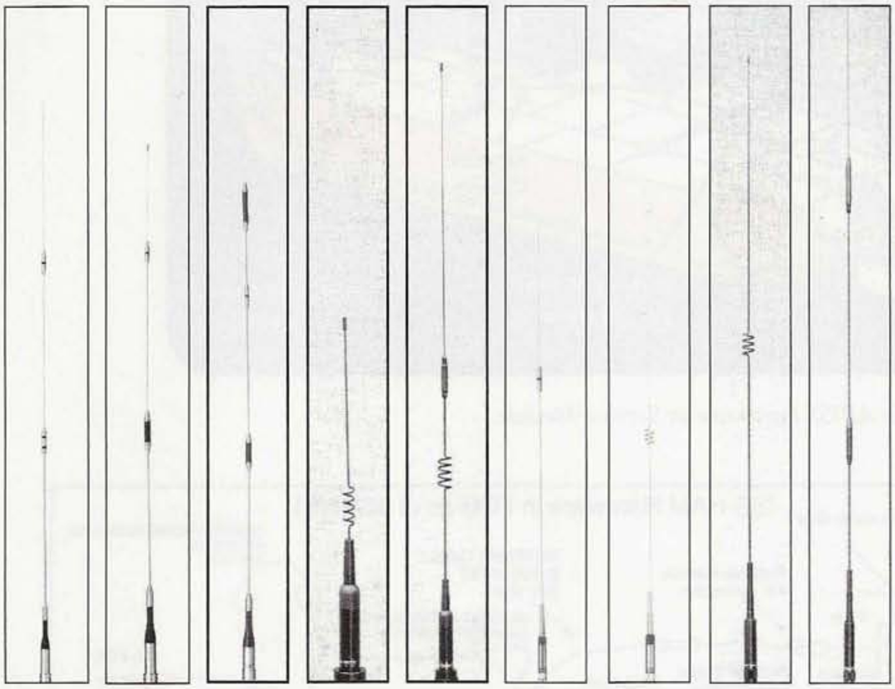

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(76–120 receive only)

Watts:	600 P.E.P.
Loss:	0.2 dB LPF 0.3 dB HPF
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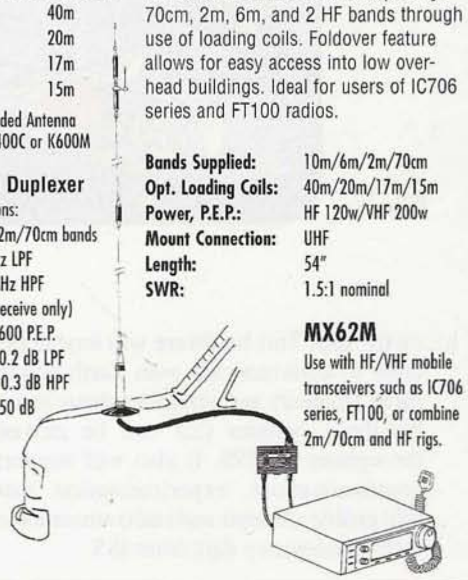

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Bands Supplied:	10m/6m/2m/70cm
Opt. Loading Coils:	40m/20m/17m/15m
Power, P.E.P.:	HF 120w/VHF 200w
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MODEL	BAND (MHz)	WATTS	CONN.	HT. IN.	ELEMENT PHASING
NR72BNMO*[6]	2m/70cm	100	NMO	13.8	1/4λ, 1/2λ
NR73BNMO	2m/70cm	100	NMO	33.5	1/2λ, 1-5/8λ
NR770HA[7]	2m/70cm	200	UHF	40.2	1/2λ, 2-5/8λ
NR770HNMO[8]	2m/70cm	200	NMO	38.2	1/2λ, 2-5/8λ
NR770RA	2m/70cm	200	UHF	38.6	1/2λ, 2-5/8λ
SG7000A*[6]	2m/70cm	100	UHF	18.5	1/4λ, 6/8λ
SG7500A	2m/70cm	150	UHF	40.6	1/2λ, 2-5/8λ
SG7500NMO	2m/70cm	150	NMO	41.0	1/2λ, 2-5/8λ
SG7900A*	2m/70cm	150	UHF	62.2	7/8λ, 3-5/8λ

* Not recommended for Magnet Mount
6 Grounding required.
7 NR770HB same specifications but in black finish.
8 NR770HBNMO same specifications but in black finish.
9 52-54MHz only

MODEL	BAND (MHz)	WATTS	CONN.	HT. IN.	ELEMENT PHASING
NR2C	2m	150	UHF	55.5	1/2λ+1/4λ
SG2000HD*	2m	250	UHF	62.6	1/2λ+3/8λ
SG6000NMO*[6,9]	6m	150	NMO	39	1/4λ
CR224A*[6]	2m/1-1/4m	150	UHF	68.5	7/8λ, 2-5/8λ
CR320A*[6]	2m/1-1/4m 70cm	200 100/200	UHF	37.4	1/4λ, 1/2λ 2-5/8λ
CR627B*[6,9]	6m/2m/	120	UHF	60	1/4λ, 1/2+1/4λ/
CR627BNMO*[6,9]	70cm	120	NMO	60	2-5/8λ

1/4λ rated in dBi.

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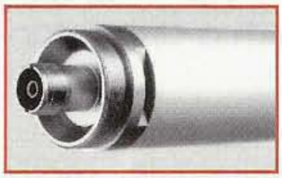
X500HA (UHF-Conn.) X500HNA (Type-N Conn.)

Ruggedized Base/Repeater Antenna



COAX CONNECTION AT BASE END

HEAVY DUTY BASE/ RADIAL ASSEMBLY

STRONG JOINT COUPLINGS

X50NA

The X50NA is an excellent choice where ruggedness is required in a medium–gain, dual-band, base/repeater application.

Features

- Wide frequency bandwidth
- Heavy duty fiberglass radome
- Stainless steel mounting hardware and radials
- Type–N Cable connection
- Compact size for easy mounting/ installation

Specifications:

Freq.: 2m: 144–148MHz
70cm: 440-450MHz
Power: 200 watts
Wind Rating: 135 MPH (no ice)
Height: 5.6 feet

X500HNA

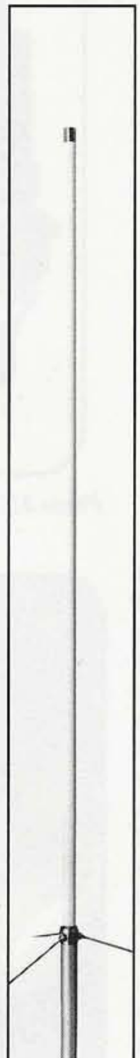
Diamond Antenna's best base station repeater antenna. Designed for strength and performance, the X500HNA is pretuned to achieve maximum gain in both the 2m and 70cm amateur bands.

Features

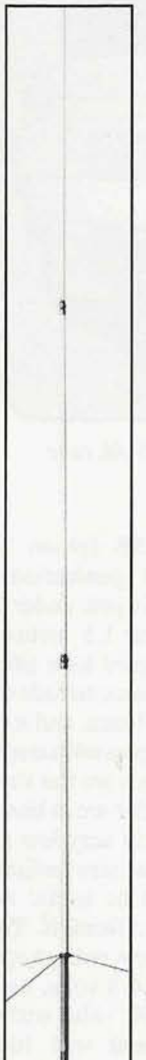
- Heavy duty fiberglass radome
- Overlapping outer shells for added strength
- Stainless steel mounting hardware and radials
- Strong–waterproof joint couplings
- Type–N Cable connection
- Wide band performance

Specifications:

Freq.: 2m: 144–148MHz
70cm: 440-450MHz
Power: 200 watts
Wind Rating: 90 MPH (no ice)
Height: 17.8 feet



X50NA



X500HNA

DIAMOND Mono-Band Base/Repeater Antennas

MODEL	BAND (MHz)	WATTS	CONN.	HT. FT.	RATED WIND MPH (No. Ice)
CP22E 1	144	200	UHF	9.0	90
DPGH62 1,6	50	200	UHF	21.0	78
F22A	144	200	UHF	10.5	112
F23A	144	200	UHF	15.0	90
F718A 2	440	250	N	15.0	90

DIAMOND Dual-Band Base/Repeater Antennas

MODEL	BAND (MHz)	WATTS	CONN.	HT. FT.	RATED WIND MPH (No. Ice)
X50A	144/440	200	UHF	5.6	135
X50NA	144/440	200	N	5.6	135
X200A	144/440	200	UHF	8.3	112
X510NA 3	144/440	200	N	17.2	90
X510MA	144/440	200	UHF	17.2	90
X500HNA	144/440	200	N	17.8	90+
X700HNA	144/440	200	N	24.0	90
X2200A	144/222	150	UHF	11.5	112
U200	440/1240	100	N	5.9	135

DIAMOND Tri-Band Base/Repeater Antennas

MODEL	BAND (MHz)	WATTS	CONN.	HT. FT.	RATED WIND MPH (No. Ice)
U5000A	144/440/1240	100	N	5.9	135
V2000A 4,6	52/144/440	150	UHF	8.3	110
X3200A 5	146/222/440	100/200	UHF	10.5	112
X6000A	144/440/1240	100/60	N	10.5	112

1 Heavy duty aluminum construction.
2 F-718A: 440-450MHz., F718L: 420-430MHz.
3 X510NJ: 144-147/430-440MHz.
4 1/4λ rated in dBi.
5 2m: 146-148; 100 watts
6 52-54MHz. only; DPGH62 adjustable from 50-54MHz.

Most requirement: 1.4"-2.4".

BAND: 144=144-148MHz., 222=222-225MHz., 420=420-430MHz.,430=430-440MHz., 440=440 450MHz., 1240=1240-1300MHz.

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Russian Power Tubes in Amateur Radio, Part II

In the Fall 2003 issue of *CQ VHF*, ND2X began this two-part article on Russian power transmitting tubes, covering general information and triodes. This time he continues with a discussion of tetrodes and sources of tubes.

By Paul Goble,* ND2X

As was stated in part one of this article, I have been the beneficiary of information on Russian power tubes from some extraordinarily knowledgeable hams from QTHs ranging from my home state of Texas, across the U.S., west to Japan, and east to eastern Europe. We covered triodes last time and will now move on to tetrodes. The tetrodes I will cover are the GS-3A, GS-15B, GS-23B, GS-36B, GU-43B, GU-74B, GU-78B, and GU-84B. There is tube-specific information gleaned by this author, either as empirical measurements or from specific experiences of hams around the world.

Tetrodes

GS-3A: The GS-3A tetrode (photos 21 and 22) is designed for water-cooling; no air cooler is associated with this tube. It is rated at 3000 watts of anode dissipation to 800 MHz. All indications are that the GS-3A should perform well from 70 cm down. Internal construction appears almost primitive, with large bolts holding control and screen grid cages in place. Photo 23 shows the coaxial arrangement of the tube elements. At this writing, this tube is under investigation. A water-cooler design is presented at <http://www.nd2x.net/kd5fzx-gs3aH2O.html>. Results of the design and prototype of a 70-cm PA will be "published" at <http://www.nd2x.net/kd5fzx-gs3a.html> when testing has been completed and data are available. This tube is priced at around $50 plus shipping, when it can be found. Pictures of the GS-3A, the water cooler installed on the tube, and the internal structure are shown in photo 7.

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e-mail: <nd2x@arrl.net>

Photo 21. The GS-3A tube.

Photo 22. The GS-3A tube with the water jacket.

GS-15B: The GS-15B (photo 24), another of the newer generation of Russian tube designs, is just under 2.5 inches tall and less than 1.5 inches in diameter. It has a designed tube life of over 2000 hours. It is a planar tetrode with a cathode diameter of 11 mm, and it can support currents of 400-plus milliamps in amateur service. The grids are flat sheets with window openings that are in line for low intercept, resulting in very low grid currents. Small physical size indicates that the GS-15B might be useful well beyond the 1-GHz specification. Tests also show that the filament voltage specified for 6 to 6.6 volts (6.3 volts, nominal) can be run at 5500 volts without decreasing emission and will likely extend the indicated 2000-hour tube life.

Sockets are not available and are constructed as part of the PA designs in which this tube is used. The anode cool-

Photo 23. Inside the GS-3A tube.

Photo 24. The GS-15B tube.

er cannot be detached, but an effective water cooler has been developed in spite of this and is presented at <http://www.nd2x.net/kd5fzx-gs15H2O.html>. The GS-15B has been available for $10 to $25, depending upon the source. It is used in the current Russian equipment inventory, and it is increasing in price to the amateur market.

Application: The GS-15B is rated at 200 watts of anode dissipation through 1000 MHz. Appearances are not deceiving in this case, and initial tests showed the GS-15B to indeed be viable above 1000 MHz. It has since been demonstrated that it will provide on the order of 15.5 dB gain and is thermally stable to 300-plus watts output at 23 cm. Prototyping showed it to be a surprisingly strong performer; PAs have been designed for both 33 cm and 23 cm. Based on excellent results from the initial 23-cm models, approximately two dozen of a single-tube 23-cm PA have been built. This design and all documentation necessary to reproduce it are presented at <http://www.nd2x.net/kd5fzx-gs15s.html>. Also at this writing, a single-tube 33-cm prototype, virtually a scaled version of the 23-cm PA, is nearly complete. A 4× GS-15B model has been designed, and many of the parts are ready for assembly of a prototype. Expected performance of the four-tube design is full legal-limit output with something on the order of 50 watts of drive. Data will be published for all amplifiers as they become available. The high efficiency of the 23-cm PAs support the contention that this tube should also function on the 13-cm band. Design and prototyping will occur as time permits.

Photo 25 shows a 23-cm GS-15B PA designed and built by Mats Bengtsson, KD5FZX. It produces 350 watts output with 10 watts of drive. Anode water-cooling is used. Since the air cooler does not detach as with the triodes, the tube cooler is machined (photo 26), a jacket cut to length (photo 27) and installed (photo 28) along with a cap (photo 29) and hose barbs. Then the assembly (photo 30) is heated and soldered with judicious use of a propane torch and allowed to cool slowly to room temperature.

GS-23B: The GS-23B (photo 31) rated power is generally considered to be similar to the 4CX1600U. It has a designed tube life of over 1000 hours. It is a true coaxial tetrode, with elements arranged concentrically, one inside the other. At higher frequencies, radiated heat from the plate plus the dissipated power in the screen will mechanically change the screen, resulting in a change in plate/screen capacitance which can affect PA tuning. The *only* way to minimize this problem is to have *good* (preferably water) cooling to eliminate the heating from the plate to the screen. It all has to do with the mechanical design and assembly of the tube. If the grid cage and

(Continued on page 73)

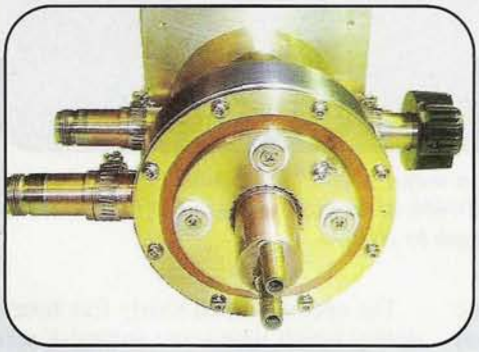

Photo 25. The GS-15B PA designed and built by KD5FZX.

Photo 26. The GS-15B tube cooler is machined.

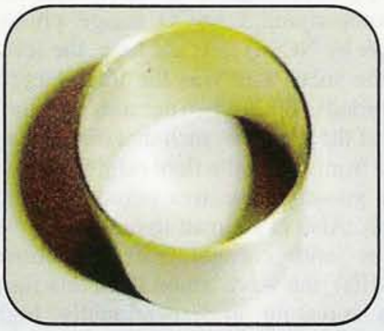

Photo 27. The GS-15B jacket cut to length.

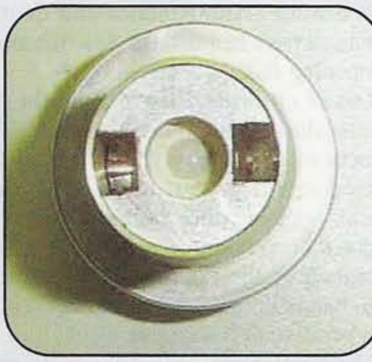

Photo 28. The jacket is installed.

Photo 29. The jacket, showing the cap.

Photo 30. The jacket, showing hose barbs.

Fall 2003 Aurora Events and More

The hits of solar Cycle 23 just seem to keep on coming. Here is WB2AMU's report on the significant happenings of October and November last year.

By Ken Neubeck,* WB2AMU

As solar Cycle 23 progresses toward its conclusion, both the sunspot count and the solar-flux values continue to ratchet lower than they were a year ago. However, recent solar activity suggests that this cycle still lives, in the process providing unexpected excitement on the VHF ham bands. What follows is documentation of some of the excitement that took place this past fall.

October 2003

On October 28, 2003, at 1048 UTC, a major solar-flare explosion was observed erupting from designated solar region 10486, at the high level of X17 (see the accompanying LASCO image photograph by NOAA). At the time, the level of the solar flare was the third largest recorded in the last two decades. The timing of the flare was such that the sunspot area from where the flare originated was in a geo-effective area pointed toward Earth. Also in contrast to previous solar flares and coronal mass ejections (CMEs), the wave action from this flare was traveling at exceptionally high speeds, in excess of 1200 km/sec.

With the high speed and the geo-effective direction, impact was expected during the day of October 29. While HF operators were expecting radio blackouts and fading up to 30 MHz, VHF operators had expectations of major aurora events if the planetary *K* value was to reach or exceed 7. Typically, such events take about two days to travel from the sun to the Earth, but the exceptionally high speed of this particular event caused it to arrive in only one day!

Impact took place at around 0900 UTC on October 29, and by 1200 UTC aurora openings were being observed on 6 meters in northern Europe. However, with

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On October 28, 2003, at 1048 UTC, a major solar-flare explosion was observed erupting from designated solar region 10486, at the high level of X17. (LASCO image photograph by NOAA)

the all-important *Bz* value (the magnetic field intensity in the all-so-important north-south direction) showing magnetic-field intensity not quite favoring southward, it took a while after impact for activity to show up in the US. By 1900 UTC aurora appeared on both the 6- and 2-meter bands in the US and Canada. The opening was fairly strong, as it reached into a number of the southern US states. It was during this time that the three-hour planetary *K* value reached a peak of 9.

From my QTH on Long Island I observed strong aurora signals on 6 meters from the neighboring grid squares in Connecticut, Massachusetts, New Jersey, Pennsylvania, and Delaware. I also heard some signals on 2 meters from the Virginia area. There were many visual observations of aurora in the US, although unfortunately my area was heavily overcast, which blocked viewing.

The opening lasted nearly five hours, during which time some auroral-*E* was heard. For example, at around 8 PM local time I heard some stations and beacons from the Midwest that were auroral-*E* in nature. However, no significant *F2* openings toward South America and Central America were heard at the time the aurora opening faded.

Out of curiosity I listened on the HF bands during the aurora event. The effects of the X-level flare were detrimental to a large part of the HF bands. Local signals were weak, exhibiting signs of deep fading. Certainly, it affected much of the popular amateur radio ham bands in one way or another, either in a positive or a negative way!

These types of openings on VHF continue to amaze newcomers to the VHF bands because they generally are not observed by most of the operators on the HF

(Continued on page 60)

Using Antenna Simulation Software to Reconfigure Existing Antennas

Is tinkering with your Yagi antenna a fearful task? Using antenna modeling software, K3YWY takes the mystery out of reconfiguring your Yagi.

By Charles W. Pearce, Ph.D.,* K3YWY

The antenna simulation software now available to amateurs certainly has moved antenna construction from "cut and try" to "calculate and build," especially for Yagi-style antennas, obtaining professional-style results. In addition to the original design, I've used such software to analyze and reconfigure existing antennas.

In my situation, I had a number of Yagis I wanted to cut down for use in my rover station.[1] In your situation, at a hamfest you may have obtained a Yagi without documentation and now you would like to know its characteristics, or you might have an antenna to which you want to add some elements, increasing the antenna's gain. In either case, you can use simulation software to guide you. I used YW, Yagi for Windows®, obtained with *The ARRL Antenna Handbook,* for the examples described herein, but other simulation programs should work equally well.

The author holding the 222-MHz antenna described in the text.

Procedure

To characterize an existing antenna, use a tape measure to make accurate measurements of element lengths and spacing in inches or metric units, as required by the program you are using. Once you have the described antenna as an input file to your software, you can add or delete elements and see what effect it has on antenna gain and pattern as well as the feed-point impedance. You can also change element lengths if you are interested in altering the antenna's resonance point or bandwidth characteristics.

Examples

My roving buddy, N3LJK, and I had obtained a FINCO 220-MHz 10-element Yagi without documentation at a hamfest (see photo). Simulations indicated the gain to be 12 dBi for the 9-ft. boom design. This antenna was too long for our rover station, but because its construction was a two-piece boom, it was easy to remove the front part of the antenna, leaving a 4.5-ft. long Yagi. Next I modeled it as a 5-element, 4.5-ft. long antenna, which produced a clean radiation pattern with a gain of 10 dBi and a front-to-back ratio of 11 dB at 222 MHz. The program also indicated that the existing gamma match would work in this new configuration, as measurements later confirmed.

Another hamfest special I have is a Cushcraft 432-MHz Yagi which consists of two 10-element Yagis on a 4-ft. boom and which was originally used for satellite work with a phasing harness to produce circular polarization. The size was feasible for roving, but it looked like too many elements for the boom length. I was also concerned about its resonance point. Modeling showed gain of 13 dBi and a front-to-back ratio of 17 dB at 432.5 MHz, with a decent enough radiation pattern. Consequently, I remounted one of the Yagis on a different 4-ft. boom and sold the other Yagi on the original boom at a hamfest.

Other Possibilities

Because modeling is much cheaper than "cut and try," you can try some zany things before you put the hacksaw to the aluminum. You still may need to do some experimental work, but the modeling should let you know if your desired result is feasible. For example, if you have limited space on your tower or if you are a rover like I am and can't stack too many

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e-mail: <cpearce@fast.net>

Parameter	3-element 222-MHz Yagi	222 antenna + 432 antenna
Gain (dBi)	9.1	9.5
F/B ratio (dB)	10.7	11.9
Impedance (ohms)	25.7 + j11.9	28.6 + j11.9
SWR*	1.0:1	1.0:1

**Using a gamma match.*

Table I. The results of the author's modeling a 3-element 222-MHz Yagi with a 6-element 432-MHz Yagi placed 6 inches in front of it. The modeling predicts very little effect by the front antenna on the rear antenna. If anything, it improves its performance slightly.

Parameter	10-element 222-MHz Yagi	Reflector, 2-meter dipole
Gain (dBi)	12.7	11.9
F/B ratio (dB)	19.5	20.5
Impedance (ohms)	49 – j3.4	48.7 – j12
SWR*	1.0:1	1.0:1

**Using a gamma match.*

Table II. In this case, the author modeled changing the reflector of a long-boom 222-MHz Yagi antenna to be the length of a dipole on 2 meters.

antennas vertically, consider the following approach:

Instead of stacking beams vertically, place a higher frequency antenna in front of another on the same boom. The front-to-back ratio of the higher frequency antenna will effectively isolate it from the antenna to its rear, but how about the rear antenna? How does the antenna in front of it affect its characteristics? I modeled a 3-element 222-MHz Yagi with a 6-element 432-MHz Yagi placed 6 inches in front of it. The results are shown in Table I. As you can see, the modeling predicts very little effect by the front antenna on the rear antenna. If anything, it improves its performance slightly.

Here's another possibility. You have a long-boom Yagi on 222 MHz, but you would like to add some 2-meter capability. I modeled changing the reflector of the 222-MHz antenna to be the length of a dipole on 2 meters. The results are shown in Table II.

Once again, this looks as if it could work. The modeling was done as a solid element, but the 2-meter dipole acting as the reflector at 222 MHz would have the coax as a stub at its midpoint. In this case, there is some difference between what was modeled and the real-world configuration, but the modeling indicates it may work.

Summary

Whether it's modifying an existing antenna or trying to see if some outlandish configuration may work, antenna modeling can be a valuable addition to your toolbox.

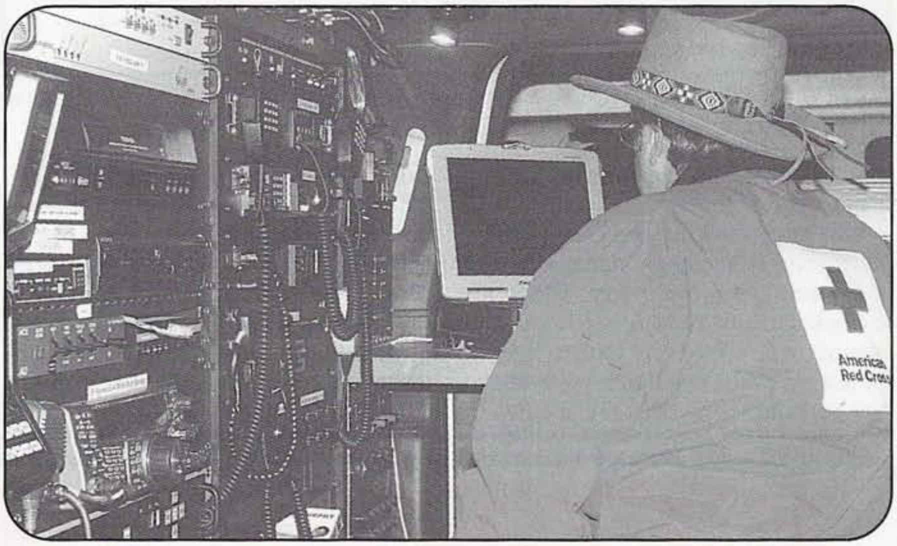
Reference

1. "I Rove; Therefore I Am," C. W. Pearce, K3YWY, and W. L. Ziegenfus, N3LJK, *CQ VHF,* Spring 2003. or <www.thegridrangers.org>.

A Broadcast-Quality Earphone

Recent southern California firestorm evacuation shelter comms demand improved earphone capabilities. Here WB6NOA provides some ideas for solutions to the problem.

By Gordon West,* WB6NOA


A Red Cross communications vehicle assisting during the southern California firestorms.

During the southern California firestorms ham radio operation at 20 simultaneous evacuation shelters quickly revealed who was listening and who was not.

"When I place a call to a shelter communicator, I expect that operator to be listening continuously to his handheld. If it takes more than three calls to that specific shelter operator, I will find a replacement," commented Stan Lord, KA6NMB, an ARES control operator. "Now I realize that big evacuation shelters such as the Norton Air Force Base all-steel hangar may be a communications challenge, but the well-prepared ham operating his or her handheld transceiver must not miss incoming radio traffic for the station," added Lord, a veteran emergency communicator who insists on good radio monitoring techniques during "real" events.

At the Norton hangar shelter, which housed 500 evacuees, the signal strength from the base station within the hangar to personnel within the facility with HTs was not the cause of missed calls. The radio operator walking among the evacuees simply may not have heard the call come over his or her handheld or speaker/microphone.

What does and does not make for good reception? Something as simple as where you have your handheld can make a major difference. For example, holding the handheld so the rubber-duck antenna is clear of your body will create dramatically improved reception. Conversely, wearing the handheld on your belt usually leads to calls that don't make it through to the antenna resting up against your mid-section. Locating your handheld chest-high will improve reception, especially if you swap out the small rubber duck with the very long, flexible single-band or dual-band whips.

"Speaker microphones may help get the incoming signals up to earshot of the operator when the speaker/mic is worn on a shoulder epaulet," added Lord. "But down among the sleeping clients in the middle of the night, any audio out of any type of speaker is not acceptable, because it will disturb the weary evacuees, who are trying to get some sleep."

The obvious answer to good audio is the traditional earphone. You can buy them just about anywhere, for almost all ham radio handhelds, and just about any programmable scanner will accept one of three common earphone plug configurations. The most common is the 3.5-mm mono earphone plug. Kenwood handhelds use a 2.5-mm earphone plug, and Yaesu handhelds use a 3.5-mm stereo earphone plug.

While earphone impedances are all over the board, most ham radio handhelds and the majority of handheld programmable scanners have enough audio to drive the earphone to a comfortable level. In addition, ham radio accessory manufacturers such as MFJ, Premier, and Heil have a variety of headsets that work swell with specific types of ham radio transceivers.

Important: *Make sure you use the headset recommended for specific ham handhelds.* For instance, the MFJ deluxe headsets are available in three varieties: the MFJ-2881 with twin plugs for ICOM, ADI, Alinco, Radio Shack, and some Yaesu radios; the MFJ-288K for twin-plug operation in Kenwood handhelds; and the MFJ-288Y for the Yaesu VX-5R and ICOM IC-Q7A, which take a single multi-shaft plug for both TX and RX. The Heil equipment is, of course, the ultimate in a commercial headset for base, mobile, and HT operation, plus there are some dandy (and quite clever) ear and boom mic setups from Premier.

In noisy environments it may take a dedicated earphone to channel the audio

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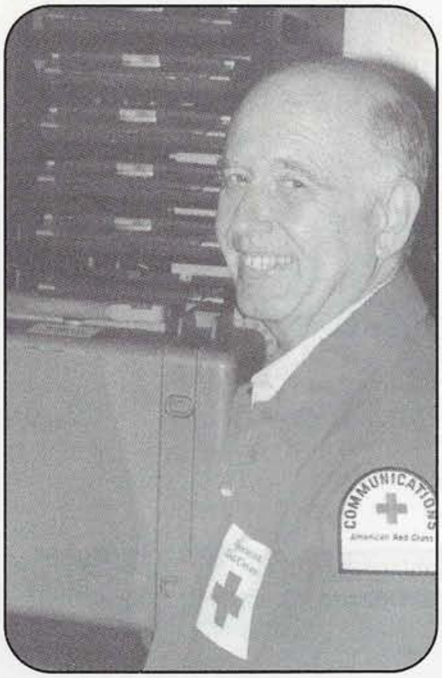
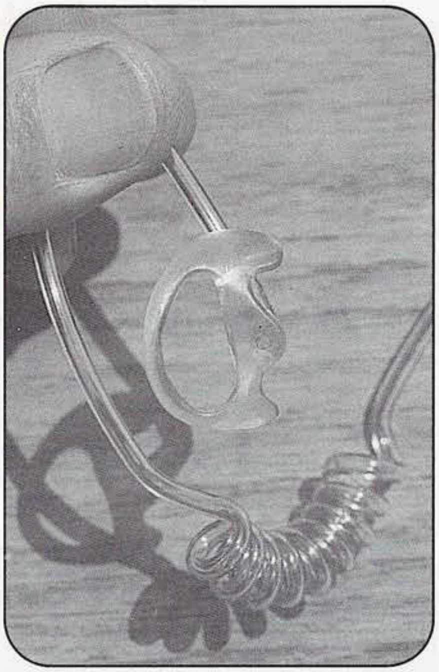


Red Cross ham operator W5BYG prepares to set up computers at the shelter.



The Ear Pro system, which allows the user to hear vital communications as well as surrounding sounds.

into your ear canal. The problem with the earphone stuffed into your ear is that when you get back to a quiet environment, you may need to remove the earphone in order to hear what someone is saying to you. Also, the relatively heavy earphone constantly in your ear canal often will lead to fatigue. You pull the earphone out to give your ear canal a rest, and that's exactly when the emergency coordinator is calling you over the air!

Ear Pro

I recently discovered a commercial earphone and a commercial mic/phone that I see regularly on the television. It is identified on TV by the almost invisible earpiece attached to a nearly invisible coiled plastic audio tube, going to a lightweight transducer, which turns your radio speaker output into acoustic sound that travels up to the ear. Best of all, the ear insert doesn't occlude your hearing, because it has open area in the center, allowing outside sounds also to get to the ear canal. The radio audio is channeled directly into the ear canal, so you hear every radio call loud and clear.

Ear Pro Communications, Inc. originally designed the professional tactical ear units for commercial radios and the public-safety market. The firm also saw a need for something for the casual radio operator who does not necessarily require the more heavy-duty systems favored by SWAT officers. Instead of it costing over $75 for an ear audio system, the price is now down to about $25, which includes the correct type of plug for your particular type of HT or scanner.

At the end of the flexible tubing is the capability to go with several different types of ear-canal phones: a squishy one that helps minimize outside noises or a custom-molded ear-canal system that specifically blocks outside noises; an amplified outside audio enhancer; custom and non-custom "whole" ear systems specifically to allow in outside audio plus your radio audio; and a host of other configurations that *could* include remote mic, remote push-to-talk, VOX, and other types of amenities for your HT.

Ear Pro's system also allows you to customize how long or how short the distance is for the audio going up the clear, flexible tube. A short tube run, without the curly cord, delivers more sparkling high-frequency sounds. The standard flexible, clear tube offers an ear-pleasing natural sound, and an extremely long clear tube is only suitable with radios that have plenty of audio output—such as a mobile or base station for weak-signal work.

During the recent firestorm shelter assignments, I took on several all-night assignments. The earphone system from Ear Pro was my choice, and it stayed in my ear all night without being uncomfortable. I could still hear surrounding noise out of the same ear that held the nearly transparent, non-custom, flexible open earpiece. What a great way to hear my HT without the traditional heavy headset or earphone covering up my hearing capability in that ear!

Several of us at the shelter carried our radio equipment in chest packs, which kept the antennas always in the open for radio calls coming in from distant shelters, too. We could hear everything!

If you're planning on attending an upcoming radio event where you're going to need a headset for an extended period of time, consider the advantages of a lightweight audio tube that you can barely feel in your ear and that will deliver the kind of audio you are expecting from your handheld, mobile, or base transceiver.

Contact Ear Pro Communications, Inc., 2980-C McClintock Way, Costa Mesa, CA 92626; telephone 714-435-0442 or 888-327-5992; fax 714-435-0488; e-mail: <info@earprocom.com>; web: <http://www.earprocom.com>.

Conversion of the ETO Alpha 374 HF Amplifier to a 6-meter Monoband Linear Amplifier

New opportunities for a vintage HF amplifier on the 50-MHz "magic band."

By George Hall,* N2CG

I've been operating on 6 meters for the past 25 years and personally have witnessed substantial growth on this band. Back in the mid 1970s, 6 meters seemed to go out of favor with manufacturers of new equipment. Most of the 6-meter ops were using rigs that were made 10 to 20 years earlier. I got on the band using a 15-year-old transverter.

Six meters sure has come a long way, so much so that many DXpeditions now make it a point to have a 6-meter station operational in addition to 160 and HF bands. Today one can still purchase used 6-meter equipment, but there are quite a few new 6-meter monoband and HF + 6 meter transceivers and linear amplifiers from which to choose.

However, purchasing one of these new 6-meter or HF + 6-meter linear amplifiers may be out of your price range, or perhaps you can't justify the high cost versus usage quotient, which was my concern. If this is your situation and you possess some basic electrical and mechanical skills, then don't overlook the large untapped market of good used HF linear amplifiers that can be modified to a 6-meter monoband linear amplifier.

Such was the case when I considered modifying my rarely used over-quarter-century-old ETO Alpha 374 linear amplifier after reading Dick Hanson's article in *QEX.*[1] I drew a schematic of how I planned to modify the amplifier and then contacted Dick with my proposed modification. He made some changes and stated that the ETO Alpha 374 should be an excellent 6-meter conversion candidate. (See figure 1.)

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The ETO Alpha 374 conversion to a 6-meter monoband amplifier.

This article describes a rather simple conversion approach resulting in reasonable output efficiency. All parts needed for this project are readily available and the total cost is less than $150 if you purchase all new parts, with the exception of the vacuum variable capacitor which can be found at flea markets or surplus companies for a fraction of the original new cost. Another benefit of this conversion approach is that the entire RF deck is removed virtually intact, so the amplifier can be restored to its original design without too much difficulty (taking detailed disassembly notes and some photos is highly recommended).

The main objective of this article is to show fellow amateurs that with a handful of parts and basic skills, you can easily modify a vintage ETO Alpha 374 HF amplifier and make a formidable 6-meter monoband powerhouse.

The Conversion Process

Important: *Make sure the power cord plug has been disconnected from the power source, and power-supply capacitor and bleeder resistors have been fully discharged before proceeding.*

Photo 1. The ETO Alpha 374 amplifier chassis is constructed in two even sections with the power supply, control board, cooling fan, control switches, meter, and meter function switches on one side and the entire RF deck on the other side. Since the amplifier's weight is almost entirely on the power-supply side, making the unit rather lopsided for handling, it is highly recommended that the power-supply transformer be removed. This will aid in the handling of the amplifier while performing the conversion.

To remove the power transformer, first make absolutely sure that the power cord has been disconnected from the power source. Remove the two screws on the back of the cover lip to remove the cover. The high-voltage shorting "crowbar" switch located on the HV rectifier PC board must be deactivated by removing it entirely from the circuit. Next, disconnect the two wires (make identification

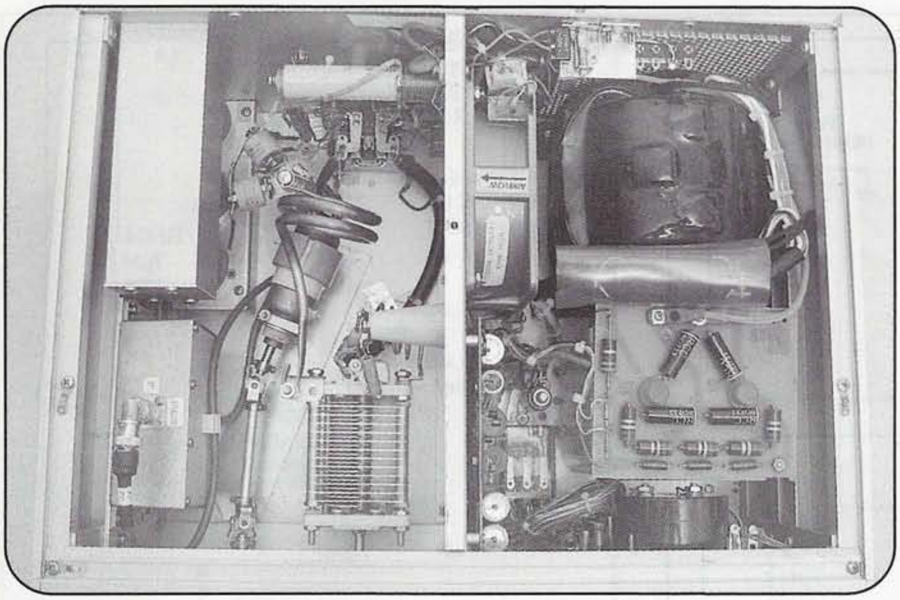

Photo 1. Top view of the converted ETO Alpha 374 to 6-meter monoband amplifier. The right half contains the power supply section. Starting at the upper right and going clockwise in order: the transformer, HV rectifier PC board, meter and related circuitry, CB-2 plug-in control board, cooling fan, and cover interlock switch. The left half contains the RF deck section. Starting at the upper left and going clockwise in order: the PA tubes assembly with air chamber, pair of blocking capacitors, plate choke, T/R relay, L3 tank coil, TUNE vacuum variable capacitor (located below L3), L4 (located below the porcelain standoff), LOAD air variable capacitor, and tuned input "T" match subassembly.

marks before disconnecting to aid when reconnecting) from the HV PCB. Remove the pair of nuts and flat washers. Lift the HV PCB off the threaded studs and position the HV PCB away from the transformer. Remove the cover interlock switch assembly and place it away from transformer. Disconnect the multi-position plug/jack connectors. Remove four each 1/4-20 screws and hardware from the bottom of the chassis. Firmly grasp the power transformer and pull straight up to remove it from the amplifier.

Photo 2. The RF deck containing the TUNE and LOAD variable capacitors, BAND switch, and associated tuning capacitors, coils, and toroids is assembled as a complete subassembly module. Thus, it is relatively easy to remove this subassembly as one unit. After the RF deck subassembly has been removed from the amplifier chassis, remove the 17–170 pF TUNE (original C26 and now designated C4A) air variable capacitor from the RF deck subassembly. This capacitor will now be installed in the LOAD position of the amplifier and secured in place. Install one of the original knobs (or another knob to your liking) so that the indicator points to "0" at full open and "10" at full mesh. The remaining RF-deck subassembly parts will not be needed for this project. All remaining original RF deck items (antenna T/R relay, SWR-meter control circuit, RF input jack, RF output jack, PA tube(s) subassembly with air chamber, and pair of blocking capacitors) will remain intact or modified when called for in the following instructions.

Removal of PA tubes and associated parts: Remove the PA tubes' horizontally mounted air chamber by removing the four securing screws and pulling upward to dislodge the tube chimneys from the PA tubes. The tube chimneys should remain glued to the air chamber. Remove the plate clips from each PA tube and carefully remove each tube from its socket; stow these tubes in a safe location. Unsolder the filament (violet heavy-gauge wire) from the rearmost feed-

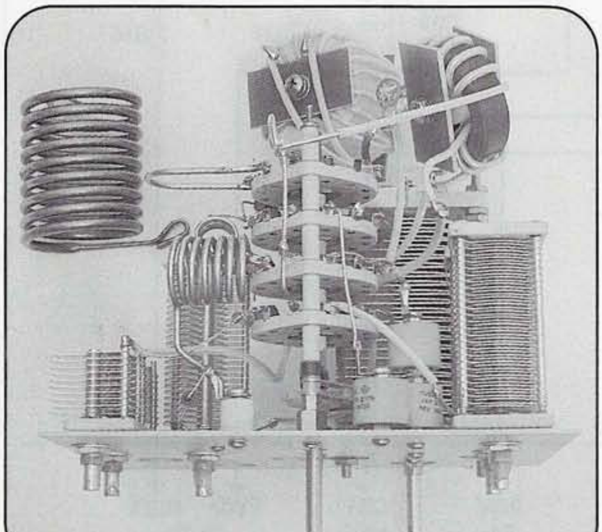

Photo 2. View of the original ETO Alpha 374 HF RF deck subassembly and original tank coil removed from the chassis.

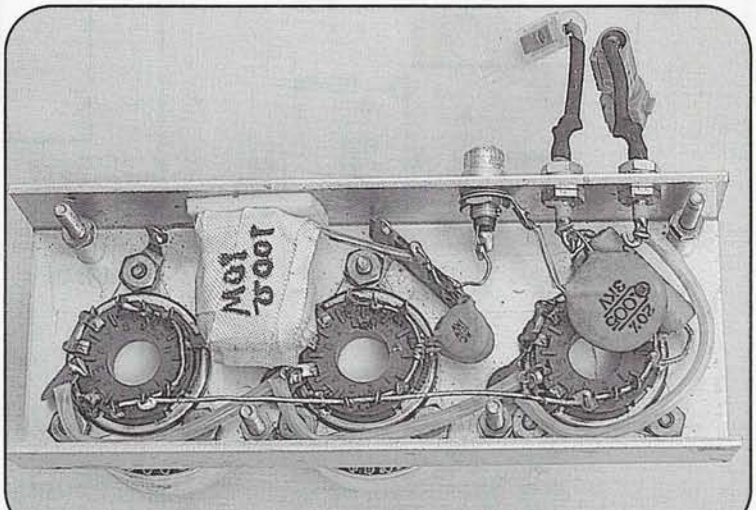

Photo 3. Close-up of the interior of the PA circuit "C" channel.

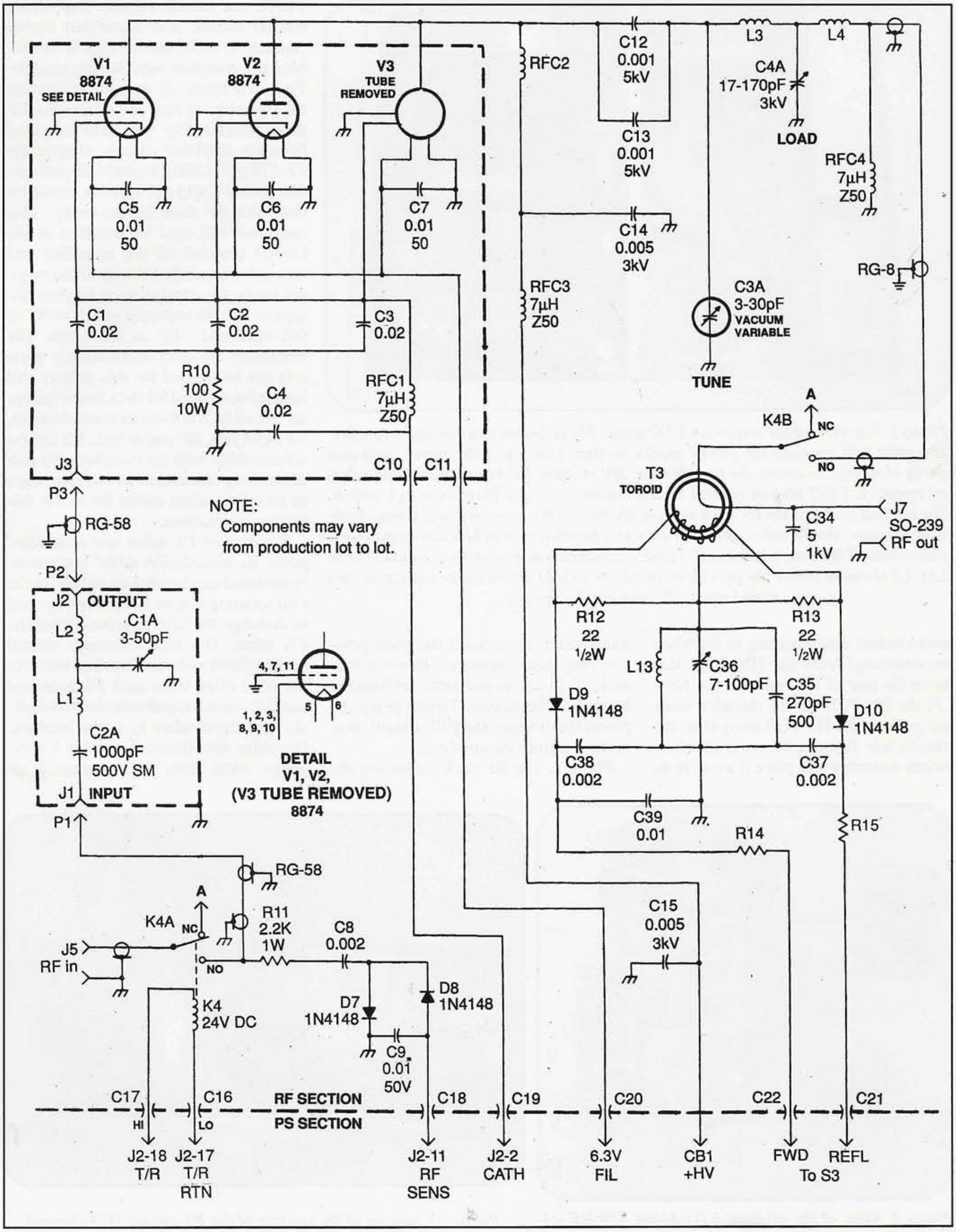

Figure 1. Schematic of the ETO Alpha 374 conversion to a 6-meter monoband amplifier.

Parts List for RF Section of ETO Alpha 374
Converted to a 6-meter Monoband Linear Amplifier

C1A: 3-50 pF/500 volt trimmer
C2A: 1000 pF/500 volt silver mica
C3A: Jennings CADD-30 series vacuum variable 3-30 pF
C4A: 17-170 pF/3 KV air variable (LOAD)
C1, C2, C3, C4: .01 to .05 mFd/500 volt disc ceramic
C5, C6, C7, C9, C39: .01 to .05 mFd/50 volt disc ceramic
C8, C37, C38: .001 to .005 mFd/500 volt disc ceramic
C10, C11, C16 through C22: 2300 pF/500 volt feedthrough ceramic
Note: C10 and C11 were not indicated in original schematic. C10 is the feedthrough capacitor for the cathode line; C11 is the feedthrough capacitor for the filament line.
C12, C13: 1000 pF/5 kV transmitting ceramic
C14, C15: .002 to .005 mFd/3 kV disc ceramic
C34: 5 pF/1 kV disc ceramic
C35: 270 pF/500 volt dipped silver mica
C36: 7-100 pF mica compression trimmer

D7 through D10: 1N4148, 1N914B or equivalent

J5: RCA phono-jack chassis mount
J7: SO-239

K4: DPDT 15 amp, 26 VDC Allied B0T6-D

L1, L2: 9 turns, #18 AWG, 5/8 inch diameter, 1 inch long
L3: 2 turns, 1/4 inch diameter tubing, 2 inch diameter, 1 inch long
L4: 4 turns, #10 AWG, 1 inch diameter, 1 3/8 inch long
L13: 1 mH miniature molded choke
Note: "L13" is not indicated on schematic, but is the only coil (except for toroid T3) in the RF wattmeter circuit and is marked "1 mH."

R10: 100 ohm/10 watt noninductive
R11: 2.2 K ohm/1 watt composition
R12, R13 : 22 ohm/1/2 watt composition
R14, R15: *Original parts list stated "Selected in production: 1/4 watt comp." Actual parts used in project amplifier are 12 K ohm/1/4 watt composition*
RFC1, 3, 4: 7 µH Z50
RFC2: 30 turns, #22 AWG on 3/4 inch diameter porcelain rod; winding is 13/16 inch long

T3: *No information given on original parts list*

V1, V2: Eimac 8874 (3CX400A7) ceramic metal air-cooled or equivalent

through capacitor; then unsolder the cathode (red light-gauge wire) from the feedthrough capacitor next to the coax-cable opening. Next cut the RG-174 type coax cable at any point outside of the "C"-channel opening. Remove the PA tube subassembly (mounted on aluminum "C"-channel platform) by removing the four securing screws and associated hardware located on the underside of the amplifier chassis. Pull straight up (some slight back- and-forth motion may be necessary) on the "C"-channel subassembly to remove it from the amplifier chassis. Finally, unsolder and remove the remaining length of RG-174 type coax cable from the terminal and ground connections of the T/R relay K4a. This length of coax cable may be discarded.

Photo 3. *Modification of PA circuit:* Remove T2, the broadband input toroid. Next remove 15-µH RF choke L1. The five-parallel-mounted, 470-ohm, 2-watt resistor pack that makes up the R10 100-ohm, 10-watt swamping resistor pack remained in place on this project amplifier.

Install and solder a 7-µH Z50 RF choke in place of the original L1 RF choke now designated RFC1. Install a chassis-mount phono (RCA) jack, now designated J3, in the existing hole (no drilling necessary) where the RG-174 type coax originally passed through. Install a jumper, #20 AWG buss wire with

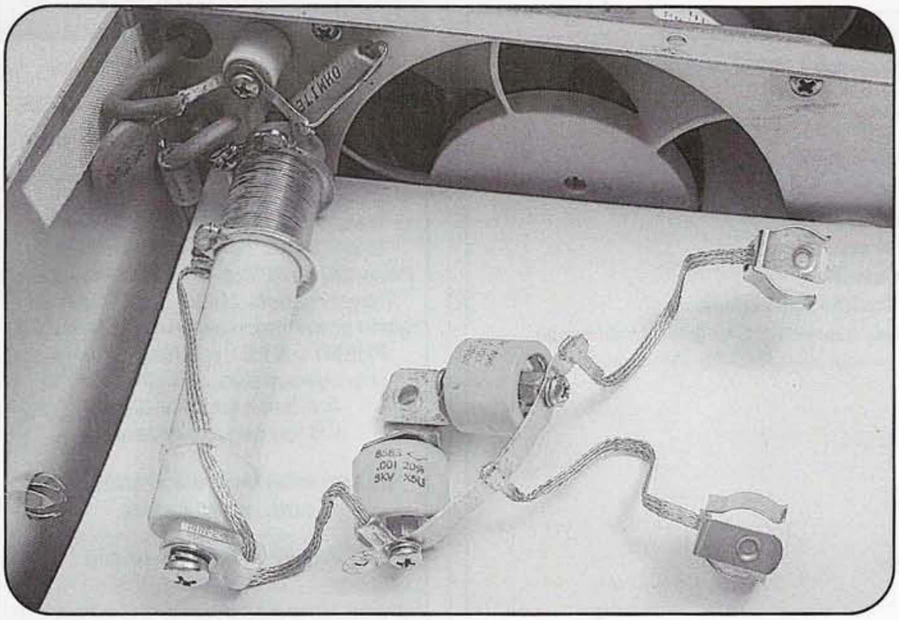

Photo 4. The rewound plate choke, original pair of blocking capacitors, and modified V1 and V2 PA tube plate leads with clips assembly

Teflon® sleeving, from the center contact of phono jack J3 to the junctions of C1, C2, C3, and R10. All other original parts will remain in place.

Photo 4. *Modify plate choke and related plate circuit parts:* Remove 100-µH plate choke L2 and 15 µH choke L3 from the circuit. The plate choke must be rewound to prevent self-resonance. Unsolder winding L2 at the plate connector end to unwind the entire length of original #24 AWG magnetic wire. Unsolder C14, the .005 µF @ 5 kV ceramic disc capacitor's lead, from L2 (do not unsolder C14's other lead, because this capacitor will be reused in its original place. Slide the outer horseshoe-shaped contact toward the inner horseshoe-shaped contact on L2, the porcelain rod, to achieve a 13/16-inch (20.6-mm) spacing. Cut a 30-inch (76.2-cm) length of #22 AWG magnet wire. Strip off the insulation at one end and solder to the inner horseshoe-shaped contact of L2. Then tightly wind 30 turns of magnet wire and solder the other end (strip the insulation from the wire) to the outer horseshoe contact of L2. *Note:* This 30 turns of #22 AWG magnet wire on a 3/4- inch (19-mm) diameter by 13/16-inch (20.6-mm) long measured self-resonance around 86 MHz.

Install the modified L2 plate choke now designated RFC2 in place. Re-solder C14, previously unsoldered one lead, to the inner L2 horseshoe contact. Install and solder in place a 7-µH Z50 RF choke in place of the original L3 RF choke now designated RFC3. The parasitic suppressors on the plate leads (original L10 across R7, L11 across R8, and L12 across R9) are no longer necessary. Since the rearmost 8874 tube, V3, will no longer be used, the entire plate clip with L12 across R9 can be unsoldered and removed from the curve-shaped copper-strap silver-plated common anode junction. Assemble two new leads of duplicate length using 1/8-inch (3.2-mm) tinned mesh for the middle and outer PA tube plate leads, reusing the original plate clips.

Prepare coax patch cables: Assemble a 16-inch (40.6-cm) length of RG-58C coax cable with a phono (RCA) male connector on one end. Prepare the other end with about 1/2 inch (12.7 mm) of open leads. Trim off 1/8 inch (3 mm) of the center-conductor insulation. Attach a 1 1/2-inch (38.1-mm) length of 1/8-inch (3.2-mm) tinned mesh and solder to the twisted shield coax end. Install a 3/8-inch (9.5-mm) diameter piece of heat-shrink tubing over the coax end to neatly cover the soldered shield area. Affix a "P1" label to the phono (RCA) male connector end. Locate the T/R relay K4a terminals (where original RG-174 type coax cable was removed). Connect and solder in place the center conductor of the RG-58C to the K4a normally open (NO) terminal. Connect and solder in place a 3/16-inch (4.8-mm) diameter ring terminal lug to the coax-shield end and connect to chassis ground (an "L"-shaped aluminum ground bracket was fabricated and secured to the T/R relay with existing hardware rather than drilling a hole in the chassis). Next assemble a 16-inch (40.6-cm) length of RG-58C coax cable with a BNC male connector on one end and a phono (RCA) male plug connector on the other end. Affix a "P2" label at the BNC male connector end and a "P3" label at the phone (RCA) male plug end of this patch cable. This coax patch cable will be installed later on in this project.

Photo 5. *Assembly of tuned input "T" match subassembly:* A Pomona Electronics model #2906 die-cast aluminum-alloy project box measuring 4.25"× 2.64" × 1.71" (108 mm × 67 mm × 43 mm) was used for the enclosure of this subassembly. Drill out openings for mounting of phono (RCA) jack J1, BNC female chassis-mount terminal J2, variable 3–50 pF trimmer capacitor APC-50, and 2-position terminal strip and mount these components in place. The two coils are identical and are made by cutting a B&W #3040 or Polycoil #1735 or AirDux #510 2 inch (50.8 mm) long by 5/8 inch (15.9 mm) diameter 10 TPI #18 wire 1.8-µH coil in half, creating two each 0.9-µH coils. Install and solder in place the two coils (make sure they are mounted 90° opposite to prevent mutual inductive coupling) as shown. Install and solder in place a 1000-pF 500-volt silver-mica capacitor. Secure the cover to the subassembly enclosure with the supplied hardware. This subassembly will be installed later on in this project.

Installation of TUNE C3A capacitor: An excellent TUNE capacitor for this project is the Jennings CADD-30 series vacuum-variable 3–30 pF capacitor, which is available in 7.5-kV, 10-kV, and 15-kV peak-test-voltage models. These capacitors are very expensive when purchased new, but are very affordable on the used market. The capacitor used for this project was the 10-kV peak-test-voltage Jennings model CADD-30-0110 (any one of these models would be suitable) and was provided with a forward end split collar clamp, the use of which is discussed in detail later in this section.

In order to limit stray capacitance, the TUNE capacitor was placed about midpoint in the RF deck chassis so that its rearmost fixed end is physically near the tank coil and pair of plate blocking capacitors junction as shown in photo 1.

The capacitor was mounted on a modified 1-inch (25.4-mm) schedule 40 PVC

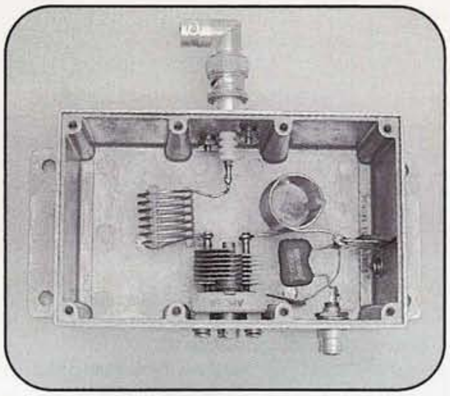

Photo 5. The installed components of the tuned input "T" match subassembly.

electrical conduit coupling (Carlon #E940F). The coupling was first cut in half diagonally, creating two equal pieces. Then a lateral cut (like making a bracelet) was made in the chosen half piece. Next a 3/16-inch (4.8-mm) hole was drilled at mid-length, directly opposite the lateral cut. A slight countersunk edge was placed on the inside opening of the hole (this is necessary so the capacitor's body does not interfere with the head of the securing screw). Align the coupling outside hole with the opening of a 3/8-inch (9.5-mm) OD × 3/4-inch (19-mm) long Nylon round unthreaded spacer. Position a #8-32 × 1 1/4-inch long screw inside the modified PVC coupling so that the head of the screw is against the countersunk area while the remaining length passes through the Nylon spacer. Install the vacuum variable capacitor in the modified coupling, secure this assembly to the chassis (drill the appropriate hole if necessary or utilize the existing hole), and secure to chassis using a #8-32 split lock washer and nut.

Cut a 5-inch (127-mm) length of 1/8-inch (3.2-mm) tinned-copper mesh strap and prepare one end for connection to the #6-32 threaded hole on the TUNE capacitor's fixed (rear) end using a #6-32 × 1/8-inch long screw. Direct the remaining length of strap to the vertical porcelain standoff junction point in as short a length as possible with slight slack, and mark the location for connection of the strap to the junction point. Cut off the excess tinned-copper mesh strap and prepare the end of the strap for connection to the junction point of the tank coil and the pair of plate blocking capacitors.

The split-collar clamp mentioned earlier secures in place around the forward section of the capacitor by means of #6-32 threaded hardware and provides mechanical contact to the forward (variable bellows inside the ceramic housing) section of the capacitor for chassis ground. Position the split-collar clamp so that the #6-32 tapped holes are level in a horizontal plane. Next, directly below and in line with these tapped holes, mark the chassis for drilling of a 9/64-inch (3.55-mm) diameter hole. Insert a #6-32 × 2 1/2-inch long pan-head machine screw from under the chassis into this hole and direct the screw vertically upward to be threaded into the split-collar clamp. Finally, after threading the screw through the two split-collar clamp threaded ends, secure the assembly with a #6-32 lock washer and nut. This will make a very suitable ground connection, required for the variable end of the capacitor, as well as provide an additional fastening point to keep the capacitor steady in its mid-point RF deck location.

If a split-collar clamp is not provided with the intended TUNE vacuum variable capacitor, the ground connection can be made by using a 1 1/4-inch (32-mm) diameter stainless-steel hose clamp attached to the forward (variable bellows inside the ceramic housing) section of the capacitor. Attached one end of a 1/8-inch (3.2-mm) tinned-copper mesh strap under a contact area of the hose clamp mounted around the forward contact area of capacitor to chassis ground in as short a lead as possible.

The 0 to 10 markings on the front-panel TUNE dial area are now inappropriate, because the vacuum variable has a 0 to 20 turns range. Therefore, I made an oval-shaped overlay from a piece of silver-colored (to blend in with the surrounding front panel) self-adhesive film and neatly positioned it over the 0 to 10 TUNE markings. A 15-turns (20 turns would have been ideal, but I was unable to locate one for this project) calibrated dial was installed as the TUNE control knob; it functioned well, because only a few turns from the minimum end was necessary to achieve the desired resonance. If a 20-turns calibrated dial is used, set the dial so that 0–00 is at one end; conversely, 19–99 naturally will be at the other end.

Since the TUNE capacitor is so far back and off center from the existing 3/8-inch (9.5-mm) hole on the front panel, it was necessary to use two 1/4-inch (6.4-mm) diameter swivel joints and a 1/4-inch (6.4-mm) diameter piece (length to be determined when performing conversion project) of extension shaft to properly align the shaft to protrude through the panel opening.

Winding of tank circuit coils: The tank coil, L3, was formed by using 1/4-inch (6.4-mm) diameter copper tubing wound with two turns at approximately 1/4-inch (6.4-mm) to 3/8-inch (9.5-mm) spacing around a 2-inch (50.8-mm) diameter × 1 inch (25.4 mm) long core followed by about a 3 3/4-inch (95.3-mm) lateral length of tubing. When forming this coil, additional length must be allowed on each end where the tubing is flattened and curved around for connection to #10 screws as shown in photo 1. It is highly recommended that the copper tubing be cleaned with a mild abrasive such as a 3M Scotch-brite™ scour pad, followed by washing with mild soap and water and wiping away any residue. Then apply anti-oxidizing material such as varnish or clear lacquer. A more desirable anti-oxidizing process would be to have the coil silver plated. An excellent silver-plating powder material is available from Cool-Amp Conducto-Lube Co.[2] One-quarter pound of Cool-Amp silver-plating powder is sufficient to plate many items and is more cost effective than the less-effective silver-plating liquids. If a silver-plating material is chosen, it is highly desirable to apply the silver-plating agent to a clean surface of the copper tubing or wire *before winding the coil.* Doing so will yield much better coverage and uniform application of the silver-plate agent.

Tank coil L4 is formed by using #10 AWG tinned-copper buss wire wound with four turns at 3/8-inch (9.5-mm) spacing around a 1-inch (25.4-mm) diameter × 1 3/8-inch (34.9-mm) long core. Since this coil is made of tinned-copper buss wire, an anti-oxidizing coating or silver-plating material is not necessary.

Installation of tank circuit coils and related components: Install the L3 tank coil with one end connected to the vertical porcelain standoff junction (where the pair of .001-pF door-knob blocking capacitors and TUNE capacitor are connected) and the other end connected to the LOAD capacitor as shown in photo 1.

Photo 6. *Installation of L4 tank coil and related components:* Connect the L4 tank coil with one end connected to the horizontal porcelain standoff junction (where the RG-8 center conductor and one end of RFC4 are connected) and the other end connected to the LOAD capacitor as shown. Install and solder in place 7-μH Z50 RF choke RFC4 between the horizontal standoff and ground. Trim the

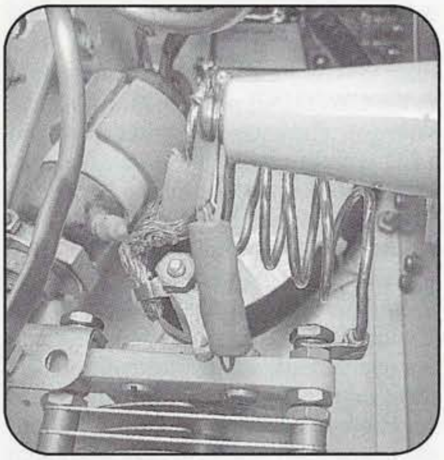

Photo 6. Close-up of coil L4 and adjacent components.

RG-8 coax free end so that the center contact will connect to the horizontal porcelain standoff junction, while the shield is connected to a nearby ground connection.

Reinstallation of PA circuit "C" channel: Reinstall the 8874 tubes to the forward and middle tube sockets (V1 and V2, respectively), leaving the rearmost socket (V3) unoccupied. The third PA tube cannot be used in this modification due to excessive stray capacitance when the third PA tube is introduced. Connect and resolder the cathode and filament wires to their appropriate feed-through capacitor locations. Reinstall PA circuit "C" channel in place (make sure cathode and filament wires don't get pinched by "C" channel edge) and secure in place with the previously removed hardware.

Photo 7. *Modification and reinstallation of air chamber:* Since the rearmost PA tube will not be reinstalled, it is necessary to block the rearmost chimney for maximum air flow to the remaining two PA tubes. Insert a 1-inch (25.4-mm) diameter white PVC schedule 40 plumbing-pipe end cap (NIBCO #D-2466 or equivalent) into the rearmost chimney opening and secure in place with Scotch 3M™ 27 glass electrical tape or equivalent high-temperature tape. Install the modified air chamber, being careful each chimney fully surrounds its intended tube, and secure the air chamber in place with the previously removed hardware.

Photo 7. The modified air chamber and parts used for modification.

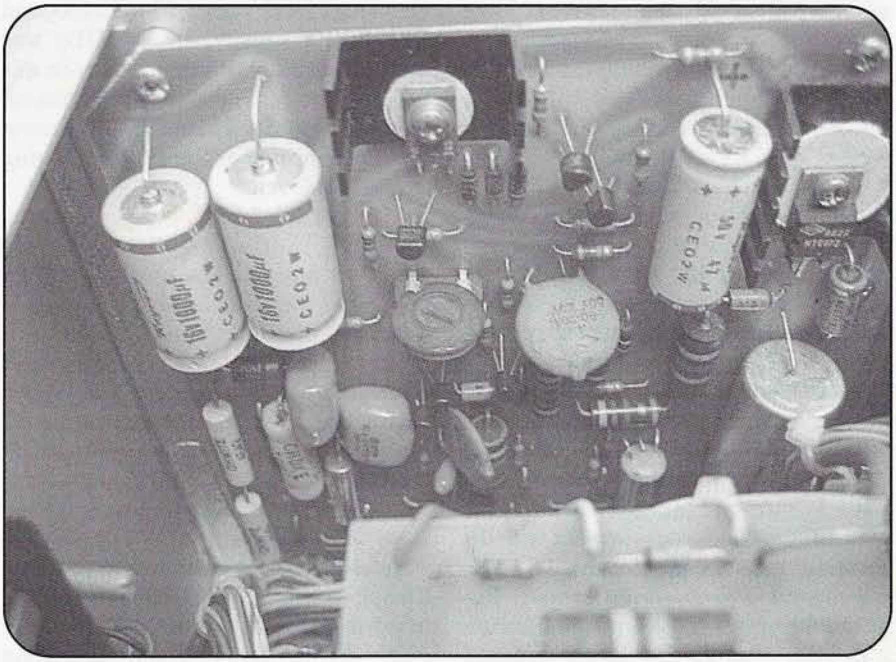

Photo 8. Close-up of plug-in control board CB-2 showing the location of ALC potentiometer R219 and location of L201 withthe 7-μH Z50 replacement RF choke in place of the original 15-μH RF choke.

Install tuned input "T" match subassembly: The mounting location of the tuned input "T" match subassembly primarily was chosen to keep the enclosure away from the tank coil as well as unrestricted airflow of the cooling fan. A mounting bracket was made using a piece of 1/8-inch (3.2-mm) thick × 1-inch (25.4-mm) wide × 5-inch (127-mm) long aluminum flat stock. Place the tuned input "T" match subassembly over the aluminum flat stock and mark the pair of holes spaced 4 3/4 inches (120.7 mm) apart on the subassembly box. Drill out these holes with a #33 drill, and then tap the two holes with a #6-32 pitch tap. This bracket is secured to an existing cross bracket on the left-side inside panel utilizing existing hardware and drilling appropriate mounting hole(s) in the mounting bracket. Make sure there is sufficient room for the P2 BNC connector with right-angle adapter and patch cable, so it will not make contact with the underside of the amplifier's top cover. Connect the T/R relay patch cable end with phono (RCA) plug P1 to INPUT jack J1. On the remaining patch cable connect the BNC male connector P2 end to OUTPUT BNC chassis mount connector J2 (the use of a BNC right-angle adapter may be necessary). Finally, connect the phono (RCA) plug P3 end to J3 located on PA circuit "C" channel.

Initially, position the subassembly box so that the trimmer capacitor faces upwards to allow easy access during the initial adjustments procedure performed later in the project. Secure the subassembly in place with a pair of #6-32 × 3/8-inch long pan-head screws with split lock washers and flat washers. *Note:* After tuning for minimum SWR (performed later in this project), the tuned input "T"-match subassembly enclosure can be mounted with INPUT jack connection J1 on the bottom and OUTPUT jack J2 on top with BNC male connector P2 with BNC right adapter attached facing upwards. This will help avoid sharp bends in the P2 connector as shown in photo 1.

Important Note: The entire RF deck compartment is a near-air-tight chamber. Therefore, all unoccupied holes should either be covered with self-adhesive aluminum-foil-shield tape (3M™ 1170 or equivalent) or secured with appropriate-size screws in all unoccupied holes to maintain air tightness. This will ensure maximum airflow cooling efficiency as well as good RF shielding.

Photo 8. *Modification to Plug-in Board CB-2:* Remove plug-in board CB-2 by first removing the securing hardware, followed by pulling the board straight up to disconnect from the 44 contacts edge connector. Locate and remove the 15-µH L201 RF choke (it is the only exposed wire-wound coil choke on the board). This choke will no longer be used in this project. Install and solder a 7-µH Z50 RF choke in place or the original L201 as shown in photo 8. Reinstall the plug-in board and secure in place with the securing hardware previously removed.

Reinstall Power Transformer: Reinstall the power transformer and secure it in place with the previously removed 1/4-20 hardware. Reconnect the multi-position plug/jack connectors. Reinstall the cover interlock switch assembly. Reinstall the HV PCB in place over the threaded studs and secure with the previously removed hardware. Reinstall the two wires previously removed. *DO NOT install high voltage shorting "crowbar" switch at this time.*

Initial Adjustments and Tune-Up Procedure

Set the cover interlock switch in "service mode": The cover interlock switch "L"-shaped arm protrudes about 3/8 inch (9.5 mm) outward. Grasp this arm and carefully pull while slightly pushing inward to position the arm slightly farther outward, which will place the switch in "service mode." In this service-mode position, the interlock action of the switch will be bypassed, allowing power to be applied while the cover is partially or fully removed.

Install the cover so that the forward edge is about 5 inches (127 mm) away from the front-panel edge. *Very important:* Make sure the cover does not make contact with the interlock switch arm. Doing so may inadvertently set the interlock switch out of service mode.

Connect the antenna relay and RF cable connections between the exciter and amplifier. Connect a directional wattmeter between the output jack of the amplifier and a suitable dummy load capable of handling at least 1000 watts intermittently. A Bird 43 wattmeter with elements 25A (25 watts, 25–60 MHz) and 1000A (1000 watts, 25–60 MHz) was used for measuring output power in this project. Do not use the built-in wattmeter on the ETO Alpha 374 amplifier, because it is not sensitive enough for measuring low power levels.

WARNING: In order to perform the following initial adjustments, the amplifier must be powered on with its cover partially removed, creating a condition that is potentially dangerous by exposure to lethal high voltage and RF radiation if mishandled. Take extreme care when making these adjustments; if you feel uncomfortable, enlist the aid of someone who is qualified and familiar with high-power, vacuum-tube linear-amplifier techniques.

Set the exciter drive power to 10 watts. Switch the amplifier "ON" and allow it to warm up for at least three minutes (the meter should illuminate and the cooling fan will be in high-speed mode). Next, switch the amplifier into "OPERATE" and key the exciter with 10 watts drive in CW mode and adjust the tuned input "T"-match trimmer capacitor (with a non-conductive tuning tool) for minimum exciter output reflected SWR. Once this is achieved, place the amplifier into "STANDBY" and turn the amplifier "OFF."

Remover the power cord from the power source. Remove the cover and reset the interlock switch by pushing in on the "L"-shaped arm. Reinstall the cover to the full-closed position and secure in place with the original hardware. Change the Bird 43 wattmeter element from the 25-watt to the 1000-watt element. Reconnect the power plug to the power source. Switch the amplifier "ON" and wait for three minutes of warm-up time. Switch the amplifier into "OPERATE" and key (the use of an amplifier tuning pulser[3] is highly recommended when tuning any amplifier to avoid excessive wear on the PA tubes) the exciter with 20 watts drive in CW mode while alternately adjusting TUNE and LOAD for maximum forward output power on the wattmeter. Increase the exciter drive power to 40 watts and key down while alternately adjusting TUNE and LOAD for maximum forward output power on the wattmeter. Increase the exciter drive power while alternately adjusting TUNE and LOAD until no appreciable increase in amplifier output power is achieved. A good pair of 8874 tubes in this amplifier with 80 watts of drive should be able to produce over 900 watts output in the SSB position (1.9-kV plate voltage) and over 650 watts output in the CW/TUNE position (1.3-kV plate voltage). The excessive grid current red LED warning indicator should be constantly observed while tuning. Stop keying if excessive grid is indicated and adjust the ALC to the appropriate level for acceptable grid-current limits.

Optional ALC Load Adapter: If the cooling fan is taking a very long time to operate at high speed (normally within three minutes), this condition may cause improper cooling of the PA tubes until the cooling fan begins to operate at high speed. This situation was known to occur after powering on the amplifier within 30 minutes of being previously powered from on to off.

To correct this condition, a simple ALC load adapter can be made. Solder a 47K-ohm, 1/2-watt resistor between the center contact of a male phono (RCA) plug (Radio Shack # 274-321 or equivalent) and shield of this plug. Install this load adapter in the ETO Alpha 374 "ALC" jack on the rear panel; this should remedy the high-fan-speed delay problem for initial testing purposes. After initial testing has been completed, install a phono Male-Female-Female "Y" adapter (Radio Shack # 274-303 or equivalent) in the "ALC" jack of the amplifier. Then install the ALC load adapter to one port of this adapter. Finally, install a shielded audio-type cable on the other port of this adapter to the exciter's ALC control line.

If excessive grid current is indicated (excessive brightness of the red LED) on the front panel while adjusting TUNE and LOAD for maximum forward output power, it may be necessary to adjust the ALC threshold potentiometer (R219 located on plug-in board CB-2 as shown in photo 8). *Note:* R219 may be a factory-selected fixed resistor. If this is the case, you have the option of selecting a replacement fixed resistor or installing a 100-ohm potentiometer. It was necessary to adjust R219 clockwise (looking down with CB-2 in place) about two thirds of its full travel to adjust the ALC threshold so as to eliminate excessive grid current. This adjustment resulted in the measured output power in this project amplifier as stated in Table I.

It may be necessary to adjust the L3 tank coil by either compressing (lower desired operating frequency range) or expanding (increase desired operating frequency range) coil L3 to resonate it in

Plate Voltage in CW/TUNE position—no load/load: 1600V/1300V
Plate Voltage in SSB position—no load/load: 2300V/1900V
Idle Current (no drive): 50 mA
Plate Current (CW/TUNE position—key down CW): 850 mA
Plate Current (SSB position—key down CW): 900 mA
Drive Power (key down CW): 75 W
Output Power (key down CW in CW/TUNE position): 650 W
Output Power (key down CW in SSB position): 900 W
Efficiency CW/TUNE position-key down CW: 59%
Efficiency SSB position-key down CW: 53%

Table I. Amplifier operating parameters.

the desired frequency operating range of the band. ***Very important:*** If adjustment of L3 is necessary, make sure power is off and discharge the plate before adjusting this coil. After adjusting L3 to the desired frequency operating range, check SWR and adjust if necessary by adjusting trimmer capacitor C1a in the tuned input "T"-match subassembly for minimum exciter output reflected SWR as detailed above. This project amplifier was able to achieve a flat 1:1 SWR in the desired frequency operating range of 50.050 to 50.350 MHz.

Adjusting the built-in amplifier wattmeter: After initial adjustments and tune-up procedures have successfully been completed, the built-in amplifier wattmeter can be adjusted for reading in the 6-meter band. To do so, remove the power cord from the power source and remove the cover. Press the METER SELECT "RF FWD 2 KW" button. Apply 100 watts of drive power at 50.1 MHz through the amplifier into a dummy load and observe the reading on the amplifier meter. Adjust SWR meter C36 mica compression trimmer (located above T/R relay adjacent to the rear panel) so the amplifier meter reads 0.1 kW (bottom red RF watts scale), which should coincide with exciter drive power.

Very important: If you want to reinstall the high-voltage shorting "crowbar" switch to the HV rectifier PC board, make sure the power-cord plug has been disconnected from the power source and the power-supply capacitor and bleeder resistors have been fully discharged before proceeding. Since the amplifier has a cover interlock switch, the high-voltage shorting "crowbar" switch to the HV rectifier PC board was not reinstalled in this project amplifier. The author installed plastic caps over the pair of 8-32 nuts on the HV rectifier PC board for added safety, as shown in photo 1.

After completing all adjustments, reinstall the cover to the full closed position and secure it in place with the original hardware.

Unique ETO Alpha Paint Issues

In ETO Alpha's effort to be innovative, they used a newly developed texturized paint on some 374 series and 77 series models that I know of. This paint has a "soft feel" finish (like the finish on BIC® *soft-feel* ballpoint pens found today at any office-

Parts Sources

Maxi-Gain Systems, Inc., 221 Greencrest Ct., Marietta, GA 30068 (phone 770-973-6261; <http://www.mgs4u.com>).

RF Parts™ Company, 435 S. Pacific St., San Marcos, CA 92069 (order line 1-800-737-2787; <http://www.rfparts.com>).

Surplus Sales of Nebraska, 1502 Jones Street, Omaha, NE 68102 (phone 1-800-244-4567; <http://www.surplussales.com>).

supply store) and originally looked quite attractive. The entire top cover and two horizontal strips on each side of the ETO Alpha 374 series were painted with this texturized paint. However, after a few years the paint began to break down and an oily film began to migrate to the surface, causing the paint to become very soft and easily scraped or smeared off. Such was the experience with my 374 despite being the original owner and taking excellent care of this unit.

Well, I'm happy to report that I've recently found a product that safely and easily removes the texturized paint down to the bare metal surface. The product is made by 3M and is their Indoor/Outdoor Caulk Remover #2153 NA in a 1/2 U.S. pint (8 U.S. fluid ounces) quantity that can be purchased at The Home Depot, Lowe's, Sears, and other home-center and local hardware stores.

Before using this product, read the caution statement concerning eye and skin irritation. Shake the bottle well and apply caulk remover directly to the painted surface in straight lines spaced 1 1/2 to 2 inches (38 to 51mm) apart on the ETO Alpha 374 top cover (remove the top cover from the amplifier before attempting paint removal). Use an acid brush to evenly smear the caulk remover on the entire top and rear-lip painted surfaces. Wait about 3–5 minutes and remove the caulk remover and softened paint with the aid of a plastic putty knife ***(do not use a steel-blade putty knife!)*** and paper towels. Repeat the process until all paint is removed. Once the paint is removed, wipe the cover with a clean towel soaked with fresh water, making sure to remove all residue of caulk remover. The top cover is now ready for minor sanding (depending on surface condition), followed by cleaning, primer painting (use an aluminum primer paint for best results), and final finish paint coatings.

Turn the amplifier on one side. Apply a single line of caulk remover in the center of each painted stripe. Use an acid brush to smear the product evenly on the painted surface. Wait about 3–5 minutes and remove the caulk remover and softened paint with the aid of a plastic razor blade ***(do not use a steel razor blade!)*** and paper towels. Repeat the process until all paint is removed. Once the paint is removed, wipe the area with a clean towel soaked with fresh water, making sure to remove all residue of caulk remover. Turn the amplifier onto its opposite side and repeat the above process. The sides of the ETO Alpha 374 series have a nice, satin aluminum finish, so I did not find it necessary to paint over the original texturized painted area.

Final Touch

The 6-meter conversion performed on this project amplifier was intended to be permanent, so I wanted a technically correct, while aesthetically pleasing, "badge" indicating the new operating parameters of this amplifier to be placed over the original HF markings. A custom-made 3 1/4" × 8" (82.6 mm × 203.2 mm) plastic acrylic placard (like the material used to make ID name badges) with self-adhesive backing was engraved "ALPHA 374-6" (a number I made up) and the type of amplifier it is now—"6 METER LINEAR AMPLIFIER." This placard was neatly positioned on the front panel covering the band-switch panel hole and all original HF markings except for the original "TUNE" and "LOAD" markings.

If this 6-meter modification is being performed with the possible intent of reverting back to the original HF design, it is suggested a less permanent placard be applied, such as the 3/4-inch (19.1-mm) wide vinyl self-adhesive label found on popular labeling tools.

Conclusion

Using a little electronic and mechanical skill, it is possible to convert a vintage ETO Alpha 374 amplifier into a 6-meter monoband linear amplifier without too much difficulty. This conversion is rather straightforward in that only the tank-circuit components are changed, while the power supply, control board, and meter circuits remain unchanged with the exception of one or two components on the control board. If need be, the amplifier can be reverted back to its original HF design; just don't forget to save all of the removed parts! I will be happy to entertain inquiries or comments at my e-mail address listed at the beginning of this article.

Since projects like this are not performed without the help and direction of others, I sincerely want to thank the following for their support and encouragement: Tony Izzo, K2AMI; Joyce Birmingham, KA2ANF; Warren Hager, K2UFM; Bud Weisberg, K2YOF; Jim Joyce, K2ZO; Mario Karcich, K2ZD; Len Martin, N3NGE; Dick Hanson, K5AND; and Chuck Reichert, KD9JQ.

Notes

1. Dick Hanson, K5AND, "A Pair of 3CX800s for 6 Meters," *QEX,* Jan./Feb. 1999, pp. 22–27.

2. Cool-Amp Conducto-Lube Co., Lake Oswego, Oregon; phone 503-624-6426, <http://www.cool-amp.com>.

3. MFJ AMP Tuning Pulser Model ATP-100 or MFJ *AmplifierSaver* Model 214 available from MFJ Enterprises, Inc., Starkville, MS; phone 800-647-1800, <http://www.mfjenterprises.com>. ■

By Joe Moell,* KØOV

HOMING IN

Radio Direction Finding for Fun and Public Service

Championship Foxhunters Gather in The Buckeye State

For many years, weekend television featured a sports program that celebrated the thrill of victory and the agony of defeat. It covered prominent and obscure sports of every kind, from armwrestling to Zamboni-racing. However, there is one sport I never saw on this or any other show, despite the fact that thousands engage in it every year in dozens of countries around the world. Most of those who participate are hams, but a ham license is not required in order to compete.

The sport I'm referring to has a number of names, including foxhunting, foxtailing, radio-orienteering, and ARDF. The "foxes" being hunted aren't animals. They are low-power radio transmitters. The competitor who uses his or her personal radio-direction-finding (RDF) equipment to locate the most foxes in the shortest amount of time wins.

Foxhunting contests take place all over the world, sanctioned by the International Amateur Radio Union (IARU). Local, regional, national, and international champions are chosen in separate rounds on 2 meters and 80 meters. Hunters are scored individually and as national teams in five age categories for males and four for females.

The USA ARDF Championships have been staged annually since 2001. IARU Region 2 (North and South America) Championships first took place in Portland, Oregon in 1999. For 2003, the Third USA Championships and the Second IARU R2 Championships were combined under the organization and sponsorship of the OH-KY-IN Amateur Radio Club. The club enlisted support from Orienteering Cincinnati (OCIN) plus several local sponsors and benefactors.

The result was a top-notch event with excellent food, lodging, courses, maps, medals, and almost everything else. Committee Co-Chairs were Bob Frey, WA6EZV, of Cincinnati, Ohio and Dick Arnett, WB4SUV, of Erlanger, Kentucky (photo A). Both took advantage of their experience in the sport, having competed at the first two USA national Championships, the 1999 IARU Region 2 Championships, and the 2000 World Championships. Besides overseeing everything else, they set the courses and even test-ran them.

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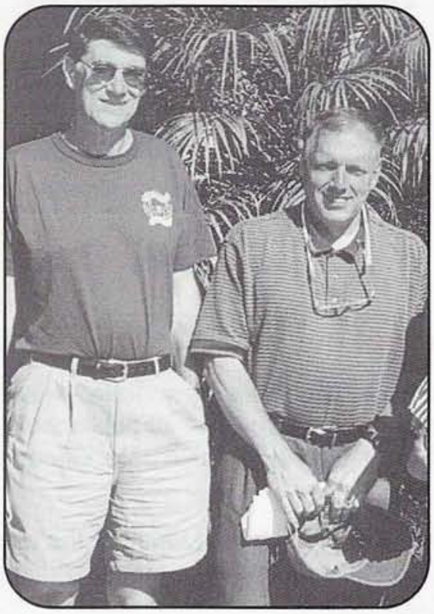


Photo A. Bob Frey, WA6EZV (left), and Dick Arnett, WB4SUV, were OH-KY-IN Amateur Radio Club's Event Co-Chairs, leading the team of volunteers who put on the Third USA ARDF Championships. (All photos by Joe Moell, KØOV)

Running Through the Band

Oxford, Ohio is a quiet community of 22,000 people about 30 miles northwest of downtown Cincinnati. Nine months a year its population jumps by 16,300, the number of students at Miami University. Founded in 1809, it is one of the eight original "Public Ivy" schools. Students must live on campus for at least the first year, so there's plenty of extra dormitory space in the summer months. Most of the 40 foxtailers who came to Oxford seeking medals in the 2003 event stayed at Havighurst Hall and ate with the summer students in the dining halls. For many, it brought back memories of their own college days.

A true cross-section of ham radio, the competitors ranged in age from 11 to 70 and came from 14 states, plus Hungary. Some had run in the ARDF World Championships more than once, while a few had never been on a full-size radio-orienteering course before. One had received a kidney transplant within the past year, and another had had heart bypass surgery. All were stalwart contesters in every sense of the word.

As April, WA6OPS, and I arrived Thursday morning, July 31, a set of 2-meter hidden transmitters was on the air for the first of two practice sessions on the 250-acre campus. These practices were long enough for folks to thoroughly test their ARDF gear, but short enough that nobody became too worn out to be ready for the big 2-meter hunt the following day. Everyone was full of energy and excitement, so it was not much of a surprise to see one or two running right through the Miami University Marching Band as it practiced formations on the football field.

The exact hunt sites for the next two days were a closely guarded secret. Many guesses had been made by Sam Smith, N4MAP, and others from the Georgia Orienteering Club who had been to OCIN meets in the area, but they all were wrong. Friday morning's bus ride was well over an hour long, ending at Fort Ancient State Memorial near Lebanon, Ohio. If you look out from the big overpass on Interstate 71 between exits 32 & 36, you can see most of the hunt area.

In these 1100 acres were all of the things needed for a challenging 2-meter ARDF event: steep hills, deep forest, a network of trails, and patches of impassable terrain. Despite recent rains and more in the forecast for hunt day, the

Photo B. Three days after his 18th birthday, Amateur Radio Newsline's Young Ham of the Year Jay Thompson, W6JAY, awaits the start of the 2-meter competition. He's using an advanced ARDF receiver from Australia. Behind him is 61-year-old Bob Cooley, KF6VSE, who won gold in his category on both bands at these events and then traveled to the IARU Region 3 ARDF Championships in Australia during December 2003.

ground wasn't too soggy but the mosquitoes were out in force. Concerned about some of the radio-orienteering neophytes, WA6EZV and WB4SUV asked everyone to fill out a form with a description of their clothing, just in case a search-and-rescue effort would become necessary later. The time limit was extended to three hours so that newcomers would have a better opportunity to find all of their required foxes.[1]

It took almost an hour to get everyone onto the course, because IARU rules require separate starts and timing of all competitors in an age/gender category. That avoids follow-the-leader problems. Start and finish lines were 2.6 kilometers apart, demanding careful route choice to avoid bypassing a fox and having to go back. Shortest course distance for five-fox competitors (M21 and F21) was about 5 kilometers.[2]

After hot showers, a full meal, and a good night's sleep, everyone jumped into the buses again on Saturday for the 80-meter event. The ride was much

Photo C. At age 11, Emily DeYoung was the youngest competitor. Her dad (Brian, K4BRI) was responsible for the bus transportation and also competed in the M40 category.

Photo D. Don't touch this! Mike Minium of Orienteering Cincinnati didn't have to go far to find examples of poison ivy and poison oak to show the competitors during the opening ceremony.

shorter this time, just across the state line to Mounds Recreation Area on the Brookville Reservoir in Indiana. Weather, bugs, and results were about the same. Competitors' times are usually better on 80 meters, because HF signals don't suffer from terrain reflections like 2-meter signals do. This time that was offset by the tougher course, which was 40 percent longer than 2 meters for five-fox competitors.

The best overall performance was by 44-year-old Gyuri Nagy HA3PA/KF6YKN on 80 meters. He found his required four transmitters in just 1:08:43, despite having had knee surgery the prior year. Gyuri was the most experienced of all the hunters in Ohio, having learned the sport from experts in his native Hungary. He organized and led a week-long training camp for members of Team USA and Team Australia in his home city of Pecs during the week before the 2002 World Championships.

Participating in the training camp was Gyuri's teenage son Daniel, who had never been in a formal ARDF competition. Dad's training paid off, because Daniel entered the M19 category and captured gold on both bands. His four-fox time on 80 meters was less than 10 minutes more than his father's.

At the hardest-to-reach foxes, OH-KY-IN members stood by with backup transmitters, ready in case of technical problems. "One of these spotters commented about the competitors," WA6EZV reported. "The inexperienced ones would come up, take a picture, fumble for their punch card, get it out, and punch it. But one guy came in running like a gazelle, card in hand. He didn't break stride when he hit the punch, and he was out of there in seconds. That was Gyuri."

Best all-required-fox performance by a female was the 1:12:59 time of Nadia Mayeva on 80 meters. Nadia moved from Russia to North Carolina a few years ago, having learned ARDF in her homeland. Last year, as a member of ARDF Team USA, she placed fourth among F35 category competitors from all countries on 80 meters at the ARDF World Championships in Slovakia.

Nadia brought her 13-year-old son Emil to Cincinnati for his first ARDF event. Home training paid off for him, as it did for Daniel. Emil had second best time in M19 category on 2 meters and third best on 80.

YHOTY Takes to the Course

For another young competitor, the trip to Ohio was part of a very busy month. Fourteen days after the Championships ended, Jay Thompson, W6JAY (photo B), was in Huntsville, Alabama to receive the Newsline Young Ham of the Year (YHOTY) award. This citation was well deserved, for Jay has packed a lot of action and public service into his few years as a ham. Originally licensed as KF6TTZ, Jay upgraded to Amateur Extra class and received his special namesake callsign in December 1998 at the age of

Photo E. Away from the starting line and into the corridor go two competitors in separate categories on 80 meters. On the left is Kuon Hunt, KB7WRG, who went on to capture silver in her category. On the right is Charles Scharlau, NZØI, of North Carolina, winner of gold on that band and bronze on 2 meters in the M21 category.

Photo F. You're never too old to enjoy ARDF if you stay fit. Paul Bohrer, W9DUU, took to the Ohio courses at age 70.

13. The next year he went to the championships in Portland and brought home three medals.

The year 2000 was a big one in ham radio for Jay. In February he and his father (Richard, WA6NOL) joined the Orange County Hospital Disaster Support Communication System (HDSCS) and became very active in that organization, participating in most of the county's mass-casualty incident drills at participating hospitals. In the fall, they traveled to Nanjing, China as members of Team USA to the ARDF World Championships.

Jay has continued his radio-orienteering and public-service activities, all the while earning top grades at his high school. In the summer of 2001, he went to the championships in Albuquerque and captured four gold medals. His HDSCS emergency communications training paid off when he and his father were dispatched to Garden Grove Hospital following the April 2002 Metrolink train collision in Placentia, California, which injured over 200 persons.

W6JAY especially likes to introduce people in his age bracket to the fun of amateur radio at Scouting events by putting RDF gear into their hands and showing them how to find radio foxes. How did he do at the Ohio championships? In the IARU Region 2 Division, M19 category, he captured gold on 80 meters and silver on 2 meters.

Jay and his dad were two of the nine competitors from California, the best-represented state at these championships. Californians took home 18 medals, almost one fourth of the total medals awarded. The four radio-orienteers from Georgia were second among the states, taking back ten medals. The hams of New Mexico had hoped to rank highest in the medal count, but Jack Stump, KD5OEO, a gold medalist the previous year at Pine Mountain, had car trouble. He and his son Chuck, KD5BYU, had to turn back on their way to Ohio.

Foxhunting Brings Smiles

OH-KY-IN put on a big finish—the closing banquet and ceremonies in a posh dining room on campus on Saturday night. Before the medals were passed out, there were the traditional V.I.P. salutations. A big meal followed by speeches can be snore-inducing, but not this time. I especially liked the following remarks by Joe Phillips, K8QOE, the ARRL Ohio Section Manager:

> There is no question that the 1990s were not good to amateur radio. There were a number of "downers" that we all lived through. It was just the way it was. We were getting older, club memberships were falling, and so forth. Many hams were negative, maybe even surly. But I noticed, as we were getting to the end of the decade, that there was a group of hams that just defied that. These transmitter hunters were the most enthusiastic, the most positive of all. Any time you saw them walking around with those little tape-measure antennas, they were full of enthusiasm.

Transmitter Hunting Every Ham Should Try It!

I went on my first hidden-transmitter hunt before my 13th birthday. My radio-direction-finding (RDF) lashup was made from tubes and other parts from an old AM radio in the seat of the family convertible, with the radio's wicker-weave antenna up on a pole that I held high. Dad had to drive, of course. It didn't work very well, and we didn't find the transmitter, but I was hooked.

RTTY, OSCAR, ATV—you name it and I have tried and enjoyed it. However, my favorite for ham radio thrills is still hidden-transmitter hunting, in a vehicle or on foot. For the last 15 years, I have been trying to increase its popularity by writing about it in the ham magazines, so I was delighted when Joe, N6CL, invited me to bring my regular "Homing In" columns to *CQ VHF*.

If you have never done any RDF, I hope you will give it a try. Besides experiencing the adventures of competitive "foxhunts," you will develop useful skills for volunteer enforcement and search & rescue. A great way for your club to experience the fun is to participate in the annual CQ National Foxhunting Weekend (NFW). This year it will be May 8–9. Watch for the announcement in the April 2004 issue of *CQ* magazine, where you can read about NFW hunts of 2003 around the USA and the world.

A lot can happen in the three months between "Homing In" columns. To keep current, I invite you to visit my website, <www. homingin.com>, regularly for the latest ham radio RDF news, including some volunteer wildlife-tracking projects that will be starting soon, as radio-tagged birds start migrating northward. There are simple RDF projects, Frequently Asked Questions, a bibliography of articles, and over 200 RDF-related web links.

I welcome your questions, comments, and input for "Homing In," including stories and photos of your local competitive transmitter hunts, interference-tracking efforts, and home-brew RDF projects. Sending an e-mail to <k0ov@homingin.com> is the best way to reach me, but you can also write to P.O. Box 2508, Fullerton, CA 92837.

Happy Hunting! *Joe, KØOV*

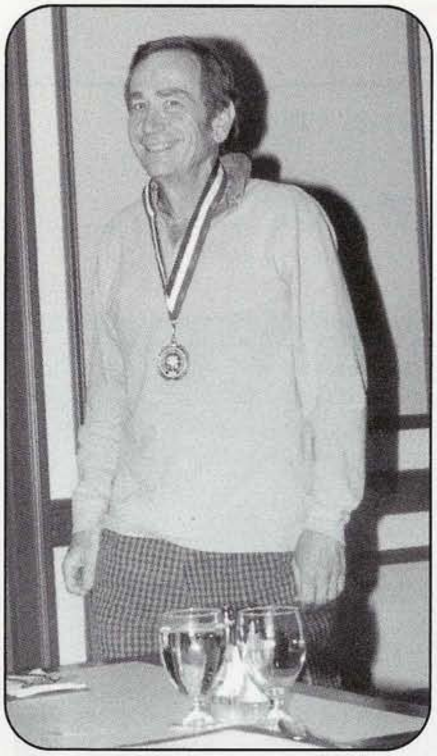


Photo G. Jay Hennigan, WB6RDV, of Goleta, California has been a mobile T-hunter for many years. In 2003 he went into training and became the surprise winner of gold medals in the M50 category on both 80 and 2 meters.

Foxhunters brought circuit developing, home constructing, and kit building back into the hobby, all of which had been disappearing in our modular throw-it-away age. That was a big improvement, and it led to smiles that were in sharp contrast to what much of the rest of hamdom was doing in other modes. I hope that we will live by your example, that the rest of the hobby will catch up with you and get smiles on all our faces like you have when you're out there catching those foxes. Thank you for showing us that this hobby was fun, is fun, and always will be fun.

Congratulations, and thanks to WA6EZV, WB4SUV, and everyone else who made the Third USA ARDF Championships a success. Other officials on the event committee were Joe Haltermon, KD4PYS (medals and artwork); Carol Hugentober, WA8YL (registration/lodging); Rick Haltermon, KD4PYR (start/finish); and Brian DeYoung, K4BRI (transportation). Other helping hams in the parks were Judd Sexton, N8RVR; Ken Croll, N8ASV; Lynn Ernst, WD8JAW; and Phil Smith, KG8AP. First-aid was provided by April Moell, WA6OPS.

California in 2004

The 2003 USA championships will be hard to top, but planning is already under way for this year's national finals. Santa Barbara Amateur Radio Club (SBARC) will host the Fourth USA ARDF Championships beginning June 16. This will be just in time for final selection of ARDF Team USA 2004 members, who will travel to Brno in the Czech Republic for the 12th ARDF World Championships from September 7–12. USA's team positions will be filled based on individual performances in the 2003 and 2004 National Championships.

General Chair for this year's USA Championships is Marvin Johnston, KE6HTS, one of North America's ARDF pioneers. A member of USA's first team to the ARDF World Championships (Hungary, 1998), he has been on the team ever since, making trips to China in 2000 and Slovakia in 2002. He took bronze in his category on 2 meters in Ohio.

Foxtailing fans from all over the country plus visitors from abroad will be heading to California this summer. The competitive courses will be open to anyone of any age, with or without an amateur radio license. Will you be there? Start practicing now and visit my "Homing In" website, <www.homingin.com>, for more information and a link to the official 2004 Championships website, which has registration and lodging information. You may also subscribe to a group e-mail list for updates and discussions of plans for these and other foxhunting Championships.

Notes

1. In IARU-rules events, anyone who finishes the course after the time limit is disqualified, no matter how many foxes have been found.

2. Those in other categories had to find only three or four foxes. All IARU-rules foxes are on the same frequency and transmit for one minute each in rotating sequence. A separate transmitter on another frequency at the finish line provides an RDF beacon for competitors who become lost or lose their maps along the way. ■

By Chuck Houghton,* WB6IGP

MICROWAVES

Above and Beyond, 1296 MHz and Up

The 1152-MHz Synthesizer

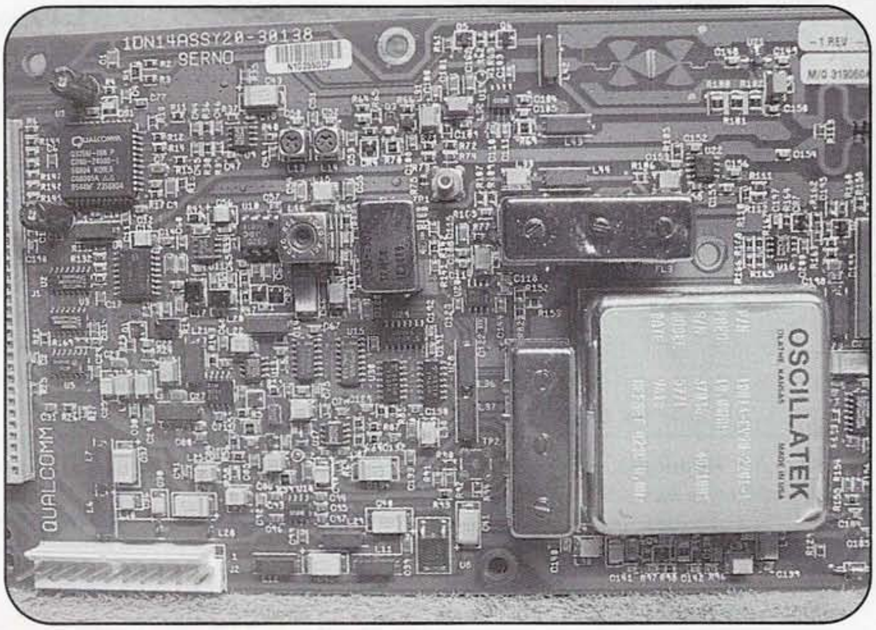
This will be the first of many articles bringing to amateur radio operators items of microwave interest both in new developments and surplus material available for conversion to our sub-microwave and higher frequency bands. For over 40 years I have been involved in conversions, beginning with military-surplus ARC-5s and slowly shifting up in frequency to other items of interest, starting with a surplus APX-6, which was to be converted into a 1296-MHz transceiver.

I took the APX-6 out of town with me to work on while I was attending a company school on microwave and baseband IF processing for my employer, Pacific Telephone. Working on that APX-6 so many years ago brings back the memory of attempting the conversion in a motel room, where I had few tools and spare parts. The project seemed doomed from the start. I got the oscillator cavity functioning, however. Until I blew the power fuse, things were starting to work.

Many lessons learned from this experience can be traced back to that conversion, which occurred in a faraway town with few resources and no automobile available to go scrounge for parts. Using that memory of what I went through, understanding what individuals in small towns must pay in effort and scrounging ability to locate key component parts to bring a project to completion, I suppose I am still working on that APX-6 today.

In this arena, I would like to open with a very noble tool in a microwaver's arsenal of test equipment—an oscillator, or much more, an accurate synthesizer that can be converted from commercial surplus. What I want to cover is a surplus converted synthesizer for 1152 MHz for use as an amateur-band-frequency harmonic marker generator.

This marker is very important in the frequency ranges of 1296 MHz to our upper microwave bands of operation, as



The Qualcomm synthesizer PLL chip (top left) and 10 MHz TCXO (bottom right).

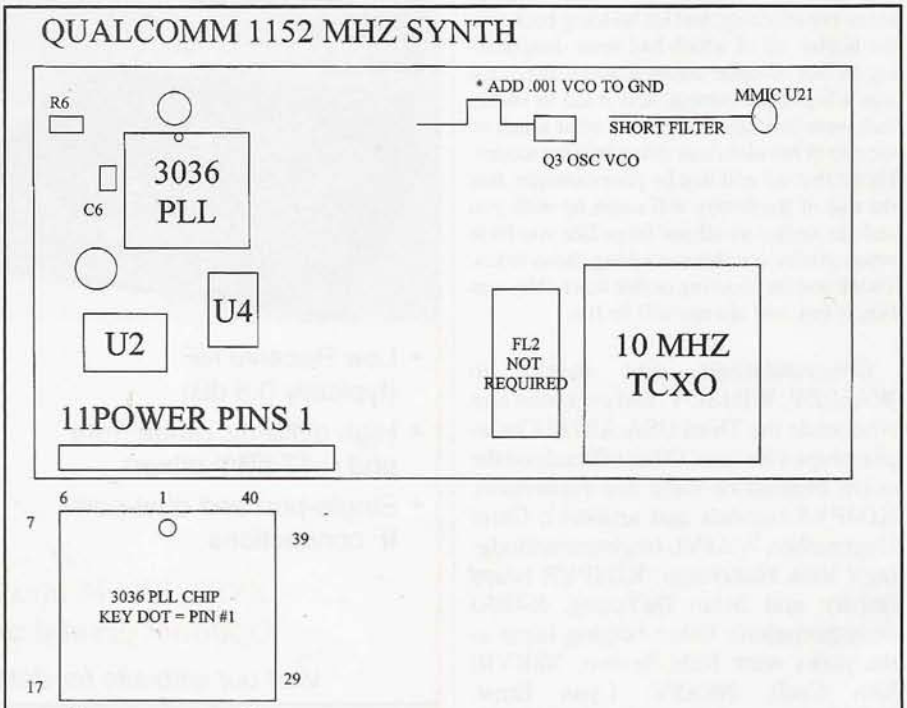


Figure 1. Basic layout and pin-for-pin diagram of the 3036 PLL synthesizer chip used on this Qualcomm Synthesizer PC board.

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e-mail: <clhough@pacbell.net>

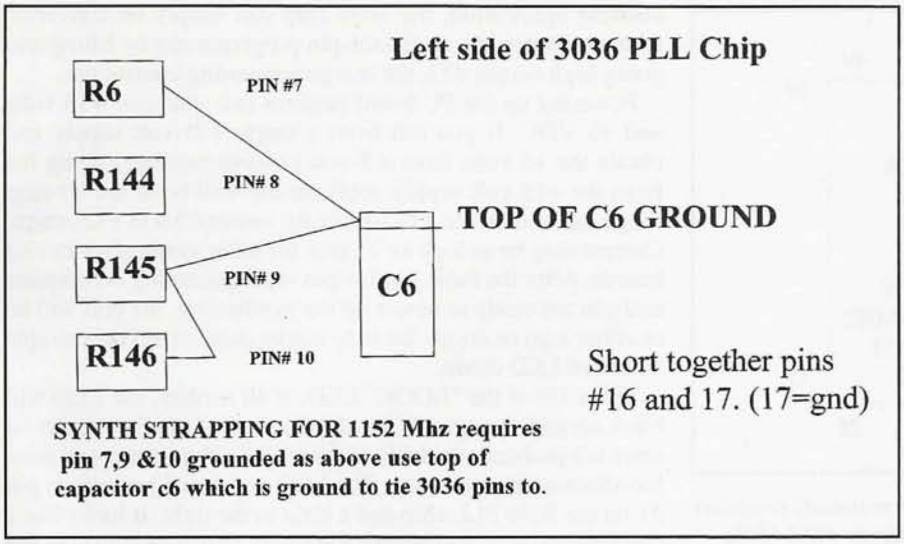

Figure 2. Strapping detail of pins 7,9, and 10 of the 3036 PLL synthesizer chip. Use very-fine wire to solder to right side of R6 then loop to top of C6 (GND). Continue to R145 and R146. Short pin #16 to pin #17 (GND).

1152 MHz is related to each and every band of operation. The relationship for 1296 MHz is related by 1152 + 144 MHz equals 1296 MHz. Thus, with the 1152-MHz platform source oscillator and a mixer with a 2-meter source, you just got a key element to construct a 1296-MHz transceiver. Add a filter and an RF pre-amp, and you have a receiving converter.

What else can be accomplished using an oscillator with this noble number, 1152 MHz? If operation on the 2304 MHz band is contemplated, 2 × 1152 MHz = 2304 MHz for an accurate frequency marker.

The relationship for 3456 MHz is 3 × 1152 MHz; 5760 MHz is 5 × 1152 MHz. 10368 MHz is related, being 9 ×. Also, 21 × is equal to 24192 MHz. Having this simple relationship to all our microwave bands is quite a marker for an injection oscillator. Note that as higher and higher multiplication is necessary, the signal level will need to be increased. This can be accomplished by use of an MMIC amp overdriven, which will produce increased harmonic output at all frequencies.

The Synthesizer

The synthesizer I want to cover here is a surplus one which can be made to work over the 750-MHz to about the 1-GHz frequency range with minor modifications and 1- or 2-MHz step size (figure 1). By step size, I mean that we can operate on 868 MHz, but not 868.5 MHz, as it is not a whole number. Fractional frequencies are not possible. To allow the synthesizer to function at the higher frequency of 1152 MHz, the VCO on the PC board is modified by adding a .001 µFd chip cap to shorten the VCO oscillator tank circuit, permitting a higher frequency VCO operation.

The .001 µF chip cap is connected from the top of the arch of the VCO inductor to ground, bypassing some of the inductor length and making the new length shorter and higher in frequency. This simple mod raises the frequency of the VCO to allow the PLL (phase locked loop/synthesizer chip) to lock the VCO to 1152 MHz or whatever frequency you want in the ranges stated above. If you want low-frequency operation, do not add the .001 µF capacitor to the VCO oscillator circuit. The spot to place the .001 µF chip cap is located about one-half inch below the center top ground mounting hole just in line with oscillator transistor symbol Q3. If you place the chip cap just over the stencil mark Q3, the top end to ground, and the bottom of the chip cap to the top of the oscillator inductor, you will be in good shape.

Figures 2 and 3 detail the strapping options for programming the 3036 synthesizer chip to 1152 MHz. Figure 2 shows a convenient method of strapping ground to PLL chip pins 7, 8, 9, and 10. I used a 6-inch section of bare wire and tack, soldered it to the resistor (R6), then ran the wire to the C6 (ground) and continued to pick up the side of R145 and 146, leaving R144 vacant. Pins that require being lifted (open) are done so with an X-acto® knife, cutting the pin with the sharp blade and gently lifting the pin up and away from the board to allow the pin to be pulled "HIGH." See figure 2 for this wiring method.

Figure 3 shows the complete 3036 synthesizer chip covering the pins that must be changed to the either open or grounded condition. Open pins are pulled up toward +5 volts ("1" logic) because of pull-up resistors internal to the 3036 PLL chip, and grounded pins are pulled hard to ground or "0" logic. Also, IC chips U2 and U4 as shown in figure 1 must be removed from the PC board, as some of their outputs are tied to the 3036 synthesizer-chip input, and if left intact would interfere with the pin for pin programming. Cut the pins on one side of the chip with the X-acto® knife. Then lift the chip, and with the knife, break or cut the other side of IC pins to remove the chip from the PC board. Make sure the remaining pins of these chips are not shorting to anything. There is no need to unsolder these broken pins or remove the chip by unsoldering the device. Use the knife to cut the IC pins of U2 and U4 for a clean removal job.

Kerry, N6IZW, made the operation of reprogramming the synthesizer to other frequencies easy by the use of an Excel spreadsheet. Using this spreadsheet will allow you to examine other desired frequencies plugged into the spreadsheet, which will generate the proper pin-for-pin programming for your convenience. The Microsoft Excel spreadsheet that Kerry developed is quite easy to use. All you do is change either or both of the "REF" frequencies, which can be 1, 2, or 5 MHz; then change the VCO frequency to a unit in MHz to which the unit will lock up. Solutions are possible to prevent the PLL chip from pulling the VCO oscillator to the desired frequency attempted. Without the .001 µF chip cap, VCO frequency in the 750- to near 1-GHz frequencies are possible. The addition of the .001 µF chip cap to the VCO Q3 makes the VCO inductor shorter and higher in frequency. Frequencies in the range of 900 MHz or so to about 1.4 GHz are possible. It depends on parts placement and circuit component values/tolerances used in this conversion.

If you want a copy of the 1152-MHz programming Excel® spreadsheet, look on at the San Bernardino Microwave Society web page, <http://www.ham-radio.com/sbms/sd/xlsindx.htm>, which contains useful information. Look under tech

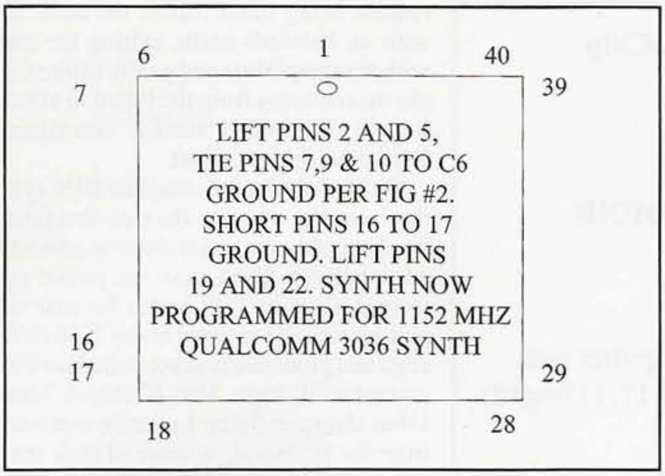

Figure 3. Pin-for-pin programming data to manually program the Qualcomm 3036 PLL synthesizer chip to 1152 MHz.

papers from the San Diego Microwave Group for many other microwave-related projects. Also, you may send me an e-mail at <clhough@pacbell.net>, and I will include the spreadsheet as an attached file in my reply.

The PC board is configured in its original state to be programmed by a computer-bus arrangement. To configure to an amateur application, the 3036 chip can simply be converted from computer-bus to pin-for-pin programming by lifting and going high on pin #22, the bus programming control pin.

Powering up the PC board requires two voltages: +15 volts and +5 VDC. If you run from a single +15-volt supply and obtain the +5 volts from a 5-volt positive regulator being fed from the +15-volt supply, total current will be in the $^1/_2$-amp range for load on the +15 supply for newer CMOS PLL chips. Current may be as high as $^3/_4$ amp for older synthesizer-device boards. After the basic pin-for-pin reprogramming is complete and you are ready to power up the synthesizer, the unit will be in either a go or no-go. Its state can be determined by a simple on-board LED diode.

This LED is the "LOCK" LED. If all is okay, the LED will blink on and then go off for the duration of applied power. If there is a problem, the LED will be "ON" all the time, and trouble-shooting is necessary. The LED is located just above pin #1 on the 3036 PLL chip and a little to the right. It looks like a surface-mount white ceramic transistor, rectangular in size and slightly larger than a chip resistor.

The confidence you can have in the accuracy of the LED is quite good, showing that you are locked to the 10-MHz reference oscillator. There is, however, the possibility of an error in the accuracy of the 10-MHz TCXO oscillator. The unit I converted—with luck of the draw, TCXO, and an uncalibrated time base that was not warmed up in my HP5340 counter—measured the 1152 MHz frequency at 1152.0007 MHz. That's 700 Hz off-frequency at 1 GHz, with the counter still warming up and drifting downward. A few more minutes on the counter and it was getting down to 400 Hz high in frequency, and 200 Hz a minute later. Some TCXOs are adjustable for best accuracy, while others are not. It depends on what is available in surplus, another luck of the draw item here.

Physical size of the PC board is 5 inches wide by 9$^1/_4$ inches long. These PC boards fit like a glove into an LMB 5" × 9.5" × 2" aluminum box (part #LMB-5952). For higher output level, there is an MMIC on board (U21) that can be used to amplify the 1152 signal to nearly +7 to +10 dBm, which is just right for mixer injection if needed. To turn on the MMIC on U21 all that is needed is +DC voltage. It is supplied through ferrite L42 from transistor Q6 just to the top right of the center top mounting ground hole. To turn on Q6 and the MMIC, apply ground to the top of chip resistor R62. Couple 1152 MHz RF out of the miniature coax connector TP1 to MMIC input, getting rid of filter by shorting out the filter elements which previously fed the MMIC input. Cut the input and output traces of this filter to get it out of the circuit.

Now I will return to the old APX-6 mentioned at the beginning of this article and those days of trying to find good-quality components, much less complete PC boards, to make a project work without a workbench full of test equipment. I hope I have saved the best news for last. I have a quantity of these surplus synthesizers on hand for noncommercial amateur use only. They are available with or without the 10-MHz TCXO, so if you have a source of stable 10 MHz, you can use it on the synthesizer and save a few bucks. I will make available fully stuffed PC boards without TCXO for $20 + $5 post and pack. Boards with fully stuffed PC boards, including a 10-MHz TCXO, will be available for $35 + $5 post and pack, both U.S. destinations only. IF you have any questions about this synthesizer or anything related to amateur microwave, please e-mail me at <clhough@pacbell.net> for a prompt reply. ■

CQ's 6 Meter and Satellite WAZ Awards

(As of December 15, 2003)

By Floyd Gerald,* N5FG, CQ WAZ Award Manager

6 Meter Worked All Zones

No.	Callsign	Zones Needed
1	N4CH	16,17,18,19,20,21,22,23,24,25,26,28,29,34,39
2	N4MM	17,18,19,21,22,23,24,26.28,29,34
3	JI1CQA	2,18,34,40
4	K5UR	2,16,17,18,19,21,22,23,24,26,27,28,29,34,39
5	EH7KW	1,2,6,18,19,23
6	K6EID	17,18,19,21,22,23,24,26,28,29,34,39
7	KØFF	16,17,18,19,20,21,22,23,24,26,27,28,29,34
8	JF1IRW	2,40
9	K2ZD	2,16,17,18,19,21,22,23,24,26, 28,29,34
10	W4VHF	2,16,17,18,19,21,22,23,24,25,26,28,29,34,39
11	GØLCS	1,2,3,6,7,12,18,19,22,23,25,28,30,31,32
12	JR2AUE	2,18,34,40
13	K2MUB	16,17,18,19,21,22,23,24,26,28,29,34
14	AE4RO	16,17,18,19,21,22,23,24,26,28,29,34,37
15	DL3DXX	1,10,18,19,23,31,32
16	W5OZI	2,16,17,18,19,20.21,22,23,24,26,28,34,39,40
17	WA6PEV	3,4,16,17,18,19,20,21,22,23,24,26,29,34,39
18	9A8A	1,2,3,6,7,10,12,18,19,23,31
19	9A3JI	1,2,3,4,6,7,10,12,18,19,23,26,29,31,32
20	SP5EWY	1,2,3,4,6,9,10,12,18,19,23,26,31,32
21	W8PAT	16,17,18,19,20,21,22,23,24,26,28,29,30,34,39
22	K4CKS	16,17,18,19,21,22,23,24,26,28,29,34,36,39
23	HB9RUZ	1,2,3,6,7,9,10,18,19,23,31,32
24	JA3IW	2,5,18,34,40
25	IK1GPG	1,2,3,6,7,10,12,18,19,23,24,26,29,31,32
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
58	NH7RO	1,2,17,18,19,21,22,23,28,34,35,37,38,39,40
59	OK1MP	1,2,3,10,13,18,19,23,28,32
60	W9JUV	2,17,18,19,21,22,23,24,26,28,29,30,34
61	K9AB	2,16,17,18,19,21,22,23,24,26,28,29,30,34
62	W2MPK	2,12,17,18,19,21,22,23,24,26,28,29,30,34,36
63	K3XA	17,18,19,21,22,23,24,25,26,27,28,29,30,34,36

Satellite Worked All Zones

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

CQ offers the Satellite Worked All Zones award for stations who confirm a minimum of 25 zones worked via amateur radio satellite. In 2002 we "lowered the bar" from the original 40 zone requirement to encourage participation in this very difficult award. A Satellite WAZ certificate will indicate the number of zones that are confirmed when the applicant first applies for the award.

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

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

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

By Gary Pearce,* KN4AQ

FM

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

Life on 900 MHz
Preventing the Mistakes of Other Bands

Return with me now to those thrilling days of yesteryear. I'm talking about the 1960s, before anyone started making ham gear specifically for 2 meter FM. In those days, hams used converted commercial or public-safety radios from companies such as Motorola, GE, Johnson, RCA, and a few others. The radios were big, heavy, and full of tubes. In those pre-synthesizer days we re-crystalled the radios for a few local repeaters, tuned them up into the ham band, and had a ball. A four-channel radio was a luxury, but in most towns there weren't four repeaters to choose from anyway.

Those days live again, after a fashion, on 900 MHz. If you think 220 is a neglected band, pity the poor 900 op! There are now several good, brand-new 220 mobile radios to choose from, and a multi-band handheld with full power, at reasonable prices. However, nobody builds a 900-MHz ham radio, and the hams on 900 wouldn't have it any other way—at least so I've heard.

Like 2 meters in the 1960s, if you want to get on 900 FM (902–928 MHz, actually), you'll be using radios designed for commercial use. Yes, the band's been around for business use long enough that there is a fair amount of used, surplus equipment. You won't find any tube rigs, though. It's mostly small, under-dash mobiles and handhelds. The availability has spurred some interest and a few repeaters in the ham community.

Most of the information in this report came from an article in the August 2003 SERA (the SouthEastern Repeater Association) *Repeater Journal* entitled "The 900 Band: There's still time to do it right!" by Vester Scott, N8EKA. Vester is an assistant director for SERA from Georgia, and a big 900-MHz enthusiast. His point in the column is that the 900-MHz band could benefit from some planning and foresight that didn't go into band-planning for 2 meters (or any of the other FM bands). We'll get to that in a minute, but first, what's 900 MHz like?

Vester says it's pretty similar to 440 MHz in terms of local propagation. A lot of hams actually have some experience in nearby spectrum—800-MHz cell phones. That and monitoring 800-MHz trunked public-safety radio around here tell me that you get the expected faster mobile flutter on noisy signals (just as 440 is faster than 2 meters). I'd expect simplex to be pretty pathetic. However, if you can get a repeater up in the air with a good antenna and feedline, it's going to work well.

We are not alone on 900, though. There are other two-way systems, pagers, data, and some Part-15 stuff such as cordless phones and baby monitors to contend with. Vester says it hasn't been much of a problem. Ham radio is a secondary service there. We're a notch above the baby monitors, but below everyone else, including the boxes that help the police find your stolen car.

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The Johnson mobile/base radio. (All photos courtesy Vester Scott, N8EKA)

Vester sent me a list of equipment suitable for ham use (see sidebar). It's actually a pretty long list, but you are not going to be comparison-shopping for your favorite features. Most of these radios are pretty basic—volume, channel switch, monitor button (squelch knobs disappeared years ago). A fancy radio will scan, and ten channels seem to be about the norm.

Ten-Channels Rule . . .
or How the Synthesizer Ruined 2 Meters

This ten-channel deal is key. Me? Space is getting tight on my 400-memory tri-band mobile. I think I'd feel a little confined in ten channels. However, then I take a road trip and get lost among all the available channels and repeaters. I have trouble finding the right CTCSS tone to kerchunk the local machine in the town I'm passing, and I start to think that they may have something here. Having just ten channels, with repeaters and tones coordinated so that I can work everything in range, starts to have some appeal.

Planning. We never had a chance on 2 meters. While amateur radio FM was an infant back in the '60s and '70s, technology was changing quickly. Frequency synthesizers pushed crystal rigs off the market. FCC rules zigged and zagged. As a result, the band is a crazy quilt. That we standardized a 600-kHz offset and have mostly the same channels nationwide (give or take the 15- vs. 20-kHz channel-step divide) is a miracle and a testament to the cooperation and compromise of the repeater builders of the era (most of whom are still around, so bask in the glow, guys). However, the band is still a mess. 440 is better, except for the high-low-rightside-up-upside-down input-output fiasco that has

Equipment Suitable for Ham Use

The following list includes most of the 800-MHz and 900-MHz surplus commercial radios that may be used in the 902–928 MHz FM amateur band, either as-is or after appropriate modifications and/or programming. That said, it might be wise to study the mistakes and successes of other intrepid hams before you dive in.

Mobile/Base Radios

Motorola
- GTX 900
- Maxtrac 800
- Maxtrac 900
- MCS2000 (900 MHz)
- Spectra 900
- Syntor X 800
- Syntor X 9000 (800 MHz)

Johnson
- 242-8605 (800 MHz)
- 242-8610 (800 MHz)
- 242-8615 (800 MHz)
- 242-8640 (900 MHz)
- 242-8655 (900 MHz)

Kenwood
- TK-931 (900 MHz)
- TK-940 (800 MHz)
- TK-941 (900 MHz)
- TK-981 (900 MHz)

GE-Ericsson
- Exec II (800 MHz)
- Mastr II (800 MHz)
- MLS 8030 (800 MHz)
- MLS 8031 (800 MHz)
- MVS 800
- MVS 900
- TMX 9315 (900 MHz)

Handheld Radios

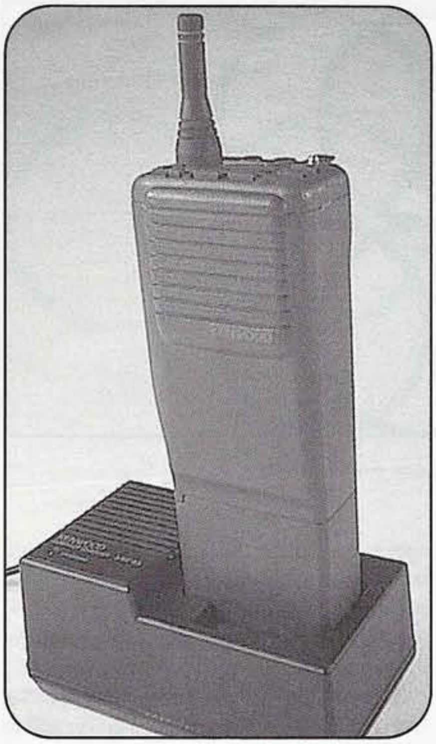
Motorola
- GTX 900
- LTS 9000 (900 MHz)
- MTS 2000 (900 MHz)
- MTSX 9000 (900 MHz)
- MTX 900
- MTX 9000 (900 MHz)

Kenwood
- TK-431 (900 MHz)
- TK-481 (900 MHz)

GE-Ericsson
- MPD 800
- M-PA 900
- MTL 900

Repeaters

Many amateur 33-cm repeaters are built from scratch from the wide assortment of available radios, duplexers, filters, preamps, controllers, antennas, and other components. On the other hand, some amateur repeater builders simply modify 800-MHz and 900-MHz commercial repeaters from GE-Ericsson, Motorola, Kenwood, Granger, and others.



Kenwood handheld with charger stand.

The Motorola MTX handheld.

some parts of the country using the high end of the band for repeater inputs, while other areas use it for outputs (and repeaters howl with feedback during band openings within a few hundred miles of the dividing line . . . and you still have to hunt those PL tones). I have to admit that it is the frequency synthesizer that made all this spectrum-squandering mass-confusion freedom possible.

Vester claims that "uninterrupted and zero-interference cross-country 2-meter mobile repeater operation could easily be accomplished anywhere in the U.S. today with only four to six different frequency pairs and a single PL tone, had there been some organized, proactive coordination in the beginning." He makes a persuasive case. We would still have a band-full of repeaters outside the plan, because most areas of the country have more than four to six hams who want to put them up. Wouldn't it be nice, though, to drive a few hundred miles and always be able to hit a popular local repeater using just your first six memory channels, without leafing through the repeater directory and futzing with the radio?

900-MHz development is limited enough today that it can still be done there, maybe. Let's slip on the ten-channel straightjacket and see how.

First we need to get a band plan in order. I say this as if it might be easy, but I don't own a 900-MHz radio or repeater, so for me it is. There are a couple of band plans in use out there now—a 25-MHz offset plan, with repeater outputs between 927 and 928 MHz, and a 12-MHz offset plan with outputs around 918–921 MHz. These plans were chosen to accommodate existing radios. None of the radios were built for ham service, and some of them will do the 25-MHz offset, while others won't. If you could get your hands on some 12-MHz offset radios, you favored that plan. Vester's solution: buy two radios. Well, he isn't always practical, but there's no way to compromise on this one. We'll concentrate on his 25-MHz offset plan, but the principles can be applied to the 12-MHz plan. They are compatible in that they don't use the same frequencies at all, so there's no interference between them, and no communicating between them either.

Next pick some channels and program a radio. The goal here is to use three, or at most four, channels for the first repeaters in any given area. They would be:

1. 927.4875,
2. 927.5125,
3. 927.5250, and
4. 927.5375 (all with their associated 25 MHz inputs).

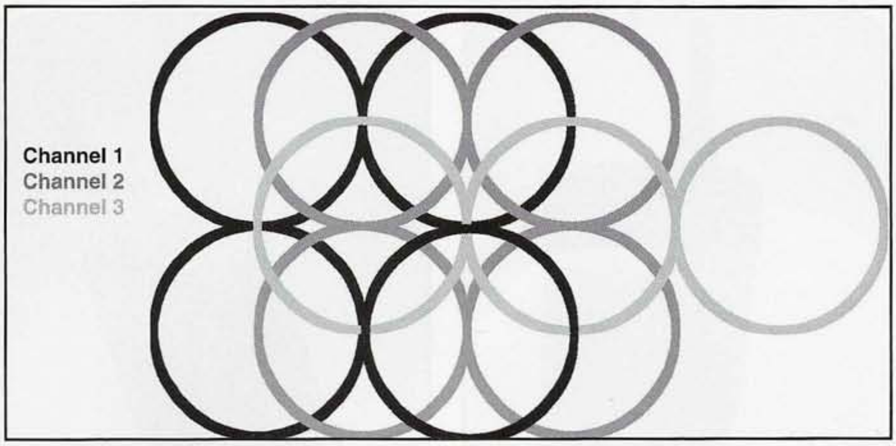
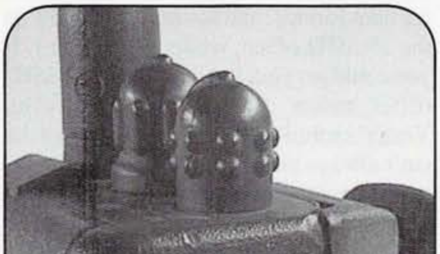


Figure 1. Repeater plan for 900 MHz.

5. 927.5000 would be simplex, like 146.52.

Now you've counted (did you have to take off your shoe?) and you come up with just five, not ten channels. Well, Vester is one of those "simplex on the output" guys, so he uses up to four more channels by programming each channel twice—once as repeat and once as simplex (these simple radios have no "offset" button; you get what's programmed in a channel, and that's it). That still leaves one channel as a "wild card" to work one rogue local machine. Can you believe it? Flexibility in ten channels!

Finally, we need some repeaters, and here's where the plan gets meaty. The repeaters would be coordinated using something like a cellular approach. "Channel 1," 927.4875, would be coordinated first in any area. It would be reused again in 75 miles or so. Channel 2 would be used for a repeater more or less in between them, and channel 3 (and 4) would fill in the holes. A diagram might make more sense out of it (see figure 1).



Yes, figure 1 shows perfect circles. No, we wouldn't expect repeater coverage to be that symmetrical or perfectly controlled. In the real world, hams take what they can get in terms of sites and coverage. However, it does kind of average out, and reality can come close enough to the ideal model such that things work okay.

(Left) Side view of the Motorola GTX handheld. (Above) Front view of the GTX handheld.

The full 900 band plan has room for a bunch more channels, so in the unlikely (?) event that a city is covered by the four-channel plan and several more hams want to put on repeaters, or somebody wants to be off by himself never to hear a random kerchunk from a wayward traveler, there's room.

Having everybody using 100-Hz tone doesn't sound right to most repeater owners. In ham radio, tone generally is used to keep signals from the co-channel repeater users in the next town out of your machine. On 900 it's more important to keep the bleeps and squawks of the other services out of the repeater. Also, once again, radio limitations mean that you can't just program in a bunch of tones.

Speaking of programming, you can't manually program these radios at all. They take some special software and maybe a little hardware. You get them programmed at your local two-way radio shop for a small charge. If you are one of those hams who are always befuddled by the complexity of today's equipment, this might appeal to you. It certainly wouldn't work on 2 meters (not now, anyway) unless you were content to just operate a handful of local repeaters (and I know a few hams who fit that description . . . maybe more than a few). However, Vester touts 900 for the technically proficient! There's a paradox here that I think I understand, but I'm not sure I can explain it.

Is it all just a pipe dream? One day will we see 900-MHz repeaters stretched across the land, all easy to operate with the flip of a switch? Vester calculates that it would take well under 2000 repeaters to provide 98% coverage to the whole country!

If nationwide 900-MHz coverage is a bit ambitious, making the plan work regionally is more reasonable. Podunk may never get 900, but it would be nice to be able to use your 900-MHz mobile or HT in any major city, the way we *couldn't* do it in the '60s with converted commercial radios on 2 meters.

Vester would like to get repeater councils lined up behind the plan. His local group, SERA, gave the plan a limited endorsement last year. They didn't want to get too deep into band planning for repeater owners, so they've made it voluntary for each state coordinator. However, the band plan on their website,

<www.sera.org/900.html>, does number the pairs and says they are "assignable in order." Councils across the country are considering adopting the plan.

Want to learn more about the 900-MHz (33-cm) band, including available equipment and resources? You'll find plenty of company in the Yahoo AR902MHz group. Check it out, at <groups.yahoo.com/group/AR902MHz>. You can also download a pdf copy of Vester's article "The 900 Band: There's still time to do it right!" from the August issue of the *Repeater Journal.*

Question Pool Revisited

Ed Woodrick, WA4YIH, sent me e-mail about last fall's column on the question pool. I thought I'd share some of the dialog. If you missed that column, I picked apart a few of the FM-oriented questions in the current Technician pool that I thought missed the mark. One of them, I said, was even dangerous:

T4C06 (A): What is the proper way to interrupt a repeater conversation to signal a distress call?

A. Say "BREAK" once, then your call sign

B. Say "HELP" as many times as it takes to get someone to answer

C. Say "SOS," then your call sign

D. Say "EMERGENCY" three times

I didn't like "BREAK," because it isn't universally recognized as a distress call. In some areas, "BREAK-BREAK" is taught as the procedure to use in an emergency (and until the last update, that's what the question pool said). I like all three *wrong* answers better than the "right" answer.

The Motorola Maxtrac mobile/base radio.

Ed said, "I think that this one might be out of one of the international procedures, like the phonetic alphabet. I know that this is definitely the way that I've preached for many years. As you mentioned, the practice got confusing as the CBers adopted their practice. Even that came from the same standards, but for CBers everything became an emergency. But I believe that 'break' is for urgent calls where 'break-break' is for distress calls."

When I teach a class, I tell the students to answer the question with "A," and then forget it and use the word "Emergency" on the air. Recently I was talking to one of my former students on the repeater when Bruce, KC4UQN, broke in just that way. Wow, did that stand out! If he had said "break," I wouldn't have thought much of it (although I make it a practice to give the repeater to any breaking station quickly, just in case). The student was also impressed. The emergency? A traffic accident Bruce had just witnessed.

I've coordinated ham communications for some big events (MS-150 and ADA Tour-de-Cure bike tours), and I always tell my team to use the word "Emergency" when that's what they have. Repeater traffic can become furious with 40 hams all standing in line to get a message through. Our net controls have had to make a conscious effort not to be in "contest mode" to keep everyone from competing to be first in line. They take a list of stations with traffic every few minutes and work down the list. "Break" would barely be recognized above the din (well, these NCOs are sharp; they'd pick it out). However, when you hear "Emergency," the repeater goes stark silent and stays that way until the situation is handled. It works.

T9A01 (B): What is the purpose of repeater operation?

B. To help mobile and low-power stations extend their usable range

T9A14 (B): When should you use simplex operation instead of a repeater?

B. When a contact is possible without using a repeater

I said this is outmoded thinking, that repeaters are now social vehicles. You don't want to hog one and use it to the exclusion of others, but there's no need to jump to simplex immediately either (not that anybody actually does that).

Ed didn't buy my point: "Repeaters were not created for social value, so you can't use that as part of the argument. Repeaters were created to help mobile and low-power stations extend their usable range. That's a pretty cut and dry piece of history."

I'll agree that it is dry! That is a slavishly technocratic view, locked to history and ignoring contemporary use. Even the history isn't that accurate. When amateurs adapted repeaters from commercial service, they instantly became something they never were before—gathering places with a new social purpose and value. Clubs developed with "FM" or "Repeater" in their names. That may not have been what the repeater tech had in mind when he plugged the machine in the first time, but it happened anyway, and it is huge. Of course, repeater owners can set whatever policy they want, but it's not dictated by the technology—or by history.

Don't you love it when two old rams butt heads?

IRLP, Echolink, and Public Service

A brand-new ham was gushing to me about how much fun he was having with his new hobby, especially talking around the world on the local IRLP-connected repeater. He mentioned, without a hint of being discouraged, how an old-timer had dismissed that activity as "not real ham radio." This new ham, however, has never known ham radio *without* IRLP. Interesting.

I was on the edge of Hurricane Isabel early this fall, monitoring a lot of radio activity on HF and FM. I had a new window to the world. The National Hurricane Center was monitoring an IRLP reflector and an Echolink conference, taking reports from hams in the path of the storm. The NHC has been doing this on 20 meters for decades. The internet link gave lots more hams a path to forward information, and many did just that. I was also able to listen in on coastal repeaters as hams prepared for the hurricane.

Isabel pulled the plug on some of the linked repeaters by knocking out power, phone lines, or both. You have to remember that an internet-linked repeater depends on an outside source for a communications path, and that path might not be reliable. That doesn't mean there's no value, though. *Any* path may be knocked out. You become proficient in all the avenues available and use the ones which are still working.

There were a few wrinkles in the Isabel operation for internet-linked repeaters. Everyone naturally wants to be where the action is, so lots of repeaters were hooked up to IRLP Node 9210 or WX Talk on Echolink. For a while, those two services were linked together. That's too much togetherness! The repeaters couldn't be used for local traffic, because every transmission got poured into the whole network. There were lots of stations jumping in just to ask, "What's going on?" A few just stumbled in without knowing where they were to call CQ (well, okay, this is FM and they didn't call CQ, but you know what I mean).

These are problems that can be ironed out with some more planning and experience, and regular operation. If you'd like to join in, there's a worldwide SKYWARN net on IRLP node 9210 at 0000Z Saturday nights (7 PM EST in the winter).

Coordination 2004

I'd like to gather information for a column on the "State of Frequency Coordination." I'll be combing the coordinator's mailing list and talking to the guys at the NFCC, but if you have something you'd like to say, drop me a line at: <kn4aq@arrl.net>. I'll try to get this together for the Spring issue of *CQ VHF*. Till then, 73, and don't let that cellphone crowd out space on your belt for the HT. ■

OP ED

One Reader's Opinion

QRP: Not Just for HF Anymore

By Bob Witte, KØNR

Many newspapers around the U.S. print a page entitled "Op-Ed." This usually runs opposite the editorial page; hence its name. Sometimes the name takes on a double meaning, when the author has a viewpoint opposite to the editor's. Its purpose is to give a writer an opportunity to express a view or propose an idea for discussion in a longer format than what is normally found in a letter to the editor. There are many views and ideas floating around in the world of VHF that are worth considering and discussing. Please note that the views expressed herein are those of the author and do not reflect the views of CQ VHF *or its editorial staff.* —*N6CL*

Do QRP principles apply to VHF and higher? Mention "QRP operation" and most amateur radio operators think of a small CW transceiver for the HF bands. Mention "VHF QRP" and the response may be more like, "What's the matter; your transmitter broke?"

The surge of interest in QRP is largely focused on the HF bands, and most weak-signal operation on the VHF bands is high power, for good reason. Putting together a competitive weak-signal station requires careful attention to every decibel in the system—receive sensitivity, transmission-line loss, antenna gain, and yes, transmitter power. On the other hand, there is something to be learned from the QRP community about having fun with amateur radio.

What is QRP?

QRP is normally defined as operating with 5 watts of output power or less. If you dig a little deeper, you'll find that low-power operation carries a lot more with it. QRP is generally associated with:

- Compact, portable, battery-powered equipment (often used portable in the outdoors)
- A personal challenge and/or a minimalist approach (get the job done using efficient equipment)
- Emphasis on operator skill (especially CW operation)
- Contesting or other events that promote QRP activity

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Are these elements of QRP operating relevant to VHF and up?

Our VHF equipment is not always compact and portable, but in recent years there has been a significant reduction in the size and weight of VHF-and-up equipment. It started with the combination HF/VHF/UHF mobile rigs from ICOM (IC-706) and Yaesu (FT-100). For QRP enthusiasts, the FT-817 from Yaesu is a backpack-ready, 5-watt rig that spans HF through 70 cm. (Unfortunately, none of these rigs include the 222-MHz band.)

Now that I think of it, we should include the older single-band, all-mode rigs such as the FT-290R and the IC-502. More important, we see hams using these rigs for VHF/UHF mountaintop and grid expeditions. Yes, there is a match between compact, portable operation and VHF and up.

With regard to taking on a personal challenge in radio operating, the weak-signal VHF/UHF enthusiasts are already there. The higher bands were once thought to be of no use except for limited line-of-sight propagation. The weak-signal ham community has proven that idea wrong.

The weak-signal VHF world also puts an emphasis on operator skill, including the use of CW. You must be a fast and efficient radio operator to make contacts when VHF band conditions are marginal or changing rapidly. Most serious VHF operators have had the experience of trying to work a distant station on SSB, then switching over to CW to complete the contact. Whether or not you like using CW, it does get through tough conditions better than phone, so it is important to have it in your bag of tricks.

With regard to contests, this is where QRP VHF is formally established. The major VHF contests have a special entry category for QRP operation, with a maximum power level of 10 watts, not 5 watts. The ARRL contests refer to this category as "Single Operator Portable," while the CQ World-Wide VHF Contest just calls it "QRP." The intent of these categories is to encourage portable operation, presumably from a rare grid or mountaintop location. Examining the ARRL June contest results for the past six years (1997 through 2002) reveals a relatively consistent average of about 27 entries in the QRP category. While there is QRP contest activity, it has plenty of room to grow.

As you can see, we can check the boxes of all of the main QRP elements as applying to VHF and higher.

Necessity, the Mother of Innovation

Sometimes available technology forces us to run QRP. Power levels do tend to decrease as the frequency of operation increases, because moving electrons around is more difficult at higher frequencies. For example, the Kenwood TS-2000 transceiver runs 100 watts on HF through 144 MHz but drops down to 50 watts at 430 MHz and 10 watts at 1.2 GHz.

Transverters for 10 GHz may have an output power of only a few hundred milliwatts, with amplifiers available to boost the signal to 5 or 10 watts. When working the highest bands, you may find yourself running QRP levels even if you wanted more power. (However, antenna gain is easier to obtain with shorter wavelengths.) Also, the higher you go in frequency, the less turnkey the equipment is, and more construction and experimentation are required.

Give QRP a Try

If your VHF (and higher) ham radio activity has gotten a bit stale or if you are just looking for a new challenge, QRP may be the answer. For some people, it simply will be the challenge of making contacts using less power. For others, it will be combining QRP operation with portable operation from a favorite hill, mountain, or tall building. Some hams may focus on the microwave bands as a new technical challenge. Whatever your preference, give QRP VHF a try.

By Tom Webb,* WA9AFM

SATELLITES

Artificially Propagating Signals Through Space

Frequently Asked Questions

Over the past several issues of *CQ VHF* magazine we've explored numerous aspects of getting into amateur satellite operations. As with any subject, you just can't cover every last point, however. Therefore, I took some thoughtful moments to record some of the more common questions I get from folks who have taken the plunge into space communications. Here are but a few "Frequently Asked Questions" that probably fell by the wayside in our previous discussions.

"I've been listening for UO-14, but have heard nothing. Is it still operating?"

Unfortunately, UO-14 has ceased operations. After many years of faithful service and thousands of QSOs, UO-14 went "silent key" in late October 2003. First launched in 1990, UO-14 began its service as a PACSAT (digital satellite). As it was "ride sharing" with other, non-amateur services, UO-14 was switched to a non-amateur service for the Volunteers In Technical Assistance to provide communications for remote areas of Africa. Later UO-14 returned to amateur service as an FM voice repeater. UO-14's 5-watt downlink enabled folks with simple rubber-ducky antennas on a dual-band HT to conduct amateur satellite communications. At present, SO-41 and SO-50 have taken UO-14's place. Go to the AMSAT website, <http://www.amsat.org>, for information on SO-41 and SO-50 and the latest news on the UO-14 replacement, OSCAR-E "Echo."

"My tracking program says the bird is in view, but I don't hear anything. What's wrong?"

There could be a variety of reasons. It well may be the bird has been shut down by the command team to upload new software or fix a software/hardware configuration problem. The Internal Housekeeping Unit (IHU)—i.e., the main computer—may have shut down the bird to allow batteries to recharge. Several amateur satellites "ride share" with other satellites that have scientific- or government-sponsored missions. Thus, the amateur satellite transponder well may be shut down in deference to these missions, which have a higher priority. If you subscribe to the AMSAT reflector (again, see <http://www.amsat.org>), you can get the latest information on the amateur satellite system and the most current status of your favorite bird. Another possibility is that your tracking program is giving erroneous data. This can be caused by a variety of factors, including out-of-date Keplerian elements, the program has been given an inaccurate position of the observer (your station), or the time in your PC is inaccurate.

"Where can I get an accurate time hack for my computer?"

There are numerous sites on the internet to get a "time hack" for your computer. Accurate time is important for precise satellite tracking. One source is integrated into the tracking program Nova For Windows®. Go to the Setup menu, select Time, and then select Internet Time Set. The resulting dialog box will give you the option of a particular scheduled time synchronization or having the operation performed when you open Nova. You can also select from a variety of time servers, depending on your location. Another source is Precision Time, which is found at <http://www.precision-time.com>. This source requires you to download files. When opened and loaded, Precision Time (and Date) provides manual or scheduled time synchronization of your PC clock.

"What is the best coax to use for satellite operation?"

If your coax run from station to antenna is less than 100 feet, any good-quality coax from the RG-8 family will do quite nicely. For that short a run, high-dollar hardline or heliax will not give you any return on investment, unless you get an absolutely outstanding deal on it—i.e., free! Now let me contradict myself: If you plan to run L Mode (23 cm) from the shack, you'll definitely need hardline or heliax even for short runs. For runs in excess of 100 feet, you need to begin looking at hardline, heliax, or very high-quality coax from the RG-8 line. One big disadvantage with heliax/LMR cable is the cost of connectors. However, keep an eye out at hamfests for good deals on those high-dollar connectors. Quite often you can find good-quality, undamaged heliax with connectors already mounted! Feedline is one part of your shack you shouldn't skimp on, regardless of your operating interest.

If you have a long run to deal with and if you must use the high-priced coax, consider using duplexers at either end. The duplexer will allow you to mix the signals in the shack to one feedline and then split them at the top of the tower. Triplexers are also available to mix/split HF with 2 meters and 70 cm. I've been using this arrangement for years with great success. When I first began using the duplexers, I had a run of 130 feet to deal with. Now the distance is only 85 feet, but it's such a convenient setup that I stuck with it.

Here is a comment on 9913: This coax came out in the early 1980s and was billed as "the poor man's heliax." It was great stuff except for one flaw, water aspiration—i.e., it sucks up water like a sponge. The problem was in the design. To make 9913 as efficient as possible, Belden used an air dialectic. This made 9913 a long, empty tube. With heating/cooling effects, water could be sucked into the "tube" and really foul up things. Even carefully sealing the connectors didn't solve the problem, as water could migrate through microscopic openings in the outer cover. The newer versions of 9913 have a foam dialectic, which solves the water problem and still retains outstanding low-loss characteristics.

"I plan to use L Mode uplink on AO-40, but my coax run will be fairly long. What's a good solution?"

Your best bet is a transverter on the tower. To operate L Mode (23 cm) from the shack, your rig would have to be

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equipped with 23 cm. Some satellite rigs such as the Yaesu FT-847 don't have 23-cm capability; the ICOM IC-910 has a DIY module you can install; the Kenwood 2000 has a module, but it must be factory-installed (see the Fall 2002 issue of *CQ VHF* for a discussion of satellite rigs). Also, you definitely would need heliax feedline. If you go with a transverter, you would just need a coax switch on the tower to switch the IF between its regular antenna and the transverter. Using a transverter would minimize the feedline run between the antenna and transverter. The main concern with a transverter is to make sure you don't overdrive it with too much power. All in all, a transverter is the most cost-effective way to go.

"For a preamp, which would be best for satellites, GaAsFET or dual-gate (DG) MOSFET?"

Actually, for the current crop of satellites, you could operate successfully without a preamp, except for AO-40, where an S Mode (13-cm) preamp will certainly give you an edge. If you do plan other VHF/UHF activity, consider these factors: The GaAsFET will give you great gain (+25 dB) with very low noise (around 0.5 to 0.7 dB), as opposed to the DG MOSFET, which has moderate gain (+15 dB) with higher noise (around 1.5 dB). The GaAsFET is a definite must for low-level signal work, either terrestrial or EME (Earth-Moon-Earth), or where strong signal interference isn't a problem. The downside with a GaAsFET is that the "active component" is sensitive to static discharge or nearby lightning strikes. In contrast, the DG MOSFET is quite suitable for satellite, ATV, or other operations where noise figure or higher gain isn't a factor. The DG MOSFET isn't as sensitive to static discharge as the GaAsFET. However, if you shack mount your preamp, go with the GaAsFET, as the loss in the coax run is added to the noise figure of the preamp. As mentioned above, a 1.5-dB noise figure can quickly climb to 4-5 dB due to coax loss in the case of the DG MOSFET.

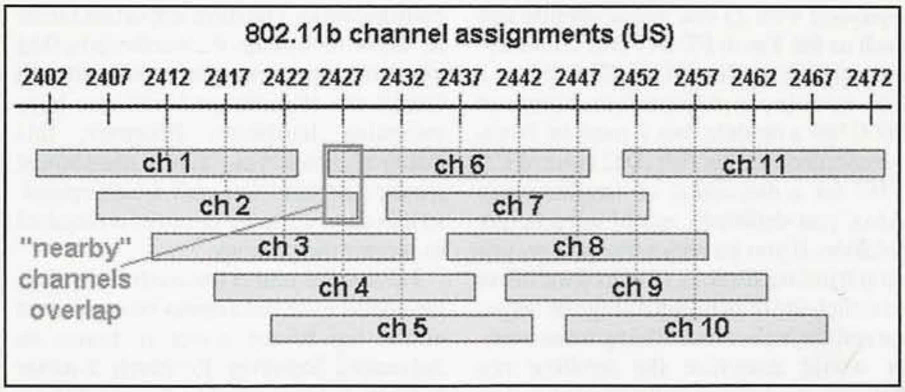
"Where is the best place to mount a preamp? In the shack or on the mast?"

Mast mounting wins hands down! Your preamp is where it can do the most good—i.e., as close to the antenna as possible. Some purists will mount the preamp right on the antenna connector. For 2 meters that's probably a bit over the top, but 13 or 23 cm would be a reasonable configuration. The most important factor in mast mounting is weatherproofing your preamp. A weatherproof unit will handle the elements and will also have mounting hardware. However, this doesn't mean you can't mast/tower mount a preamp that isn't weatherproof. In this case, a shelter or cover is required to protect the preamp.

For several years I successfully used an air-conditioner disconnect box mounted at the top of my tower to house an Advanced Receiver Research 2-meter preamp. I also mounted a 2-meter/70-cm duplexer in the box. Even though the duplexer was considered weatherproof, the extra protection didn't hurt. Just for good measure, I also tucked in a couple of power connectors, which carried switching voltage for the polarity relays into the box. The main problem with this arrangement was that it also made a dandy shelter for red wasps! If you use this type of enclosure and you're not sure if wasps have taken up housekeeping, take a broom handle up the tower with you and give the enclosure a couple of whacks. If wasps come out, hustle yourself back down the tower, get a can of long-distance wasp spray, and take care of your unwelcome guests.

Heavy-duty plastic food containers also work well, but they degrade over time because of exposure to the sun and elements. Another possibility is an enclosure for a lawn-sprinkler timer. They're designed to handle the elements, are relatively weatherproof, lightweight, and easy to mount, but they do tend to be a bit shallow in depth, which limits available space. If you must mount your preamp in the shack, remember you are adding the loss of the coax between the preamp and antenna to the noise figure of the preamp. That is, if you have a 0.5-dB noise figure but 3 dB of loss in the coax run, your noise figure jumps to 3.5 dB.

Even if the equipment you mast mount is considered weatherproof, give it a good look to make sure there are no openings that could allow in unwanted moisture. My neighbor introduced me to Star Brite Liquid Electrical Tape, a product designed to waterproof and seal electrical connections for lawn-sprinkler control lines. It can be found at most do-it-yourself hardware stores. It simply is brushed on to provide a seal. I used it to seal gaps inside the case of the 2-meter/70-cm duplexer. It comes in a variety of colors and also works well for sealing coax and power connectors.



Channels for the 802.11b allocations. Channel 1 is just above the S Mode downlink for AO-40. (Courtesy of Steve Friedl's Weblog)

"With AO-10 and AO-40, the delay between the time I speak and the time I hear it on the downlink is very distracting. Is there any way to cure that?"

No, there isn't. When you transmit, the signal travels to the satellite, sometimes as far as 30,000 miles, and then makes a return trip for a total path of 60,000 miles. The delay is usually less than half a second, but just enough to throw you off. One way is to concentrate on what you're saying. If you practice this enough, you soon will train yourself to ignore the downlink delay. If that isn't an option, just turn down the receive audio.

"What is the best rig for satellite operation?"

This is a tough question! Each person has his or her unique situation—i.e., what equipment the operator already owns verses the equipment that might be needed. The kind of satellite activity in which you wish to participate will be a factor. Economics plays a big part, too. You might review this column in the Summer 2002 issue of *CQ VHF* magazine. Several satellite rigs are reviewed along with suggestions for incorporating currently owned equipment.

"I live in an apartment complex where no antennas are allowed. How can I work satellites?"

If you want to restrict your activity to LEO (Low Earth Orbit) satellites, stepping out on the balcony (if you have one) with a hand-held antenna, such as the Arrow Antenna, would allow you plenty of activity (see the Fall 2002 column of for a discussion on antennas). You might even be able to convince the manager to let you discreetly mount a pair of M² Egg Beater antennas on the balcony. Covering them with some artificial vines/plants/ etc. would divert any interest from the neighbors. If you don't have a balcony, just step outside in a public area with your portable antenna and operate. I doubt whether your lease will prohibit that, but check with management anyway. Working "fixed mobile" from your car is a sure-fire way around any antenna restrictions.

"I hear some sort of interference on the AO-40 S Mode (13-cm) downlink. What is it?"

Amateurs have "secondary" status at 13 cm, so we can't demand the equipment be shut down, but the diplomatic approach will probably win the day. Things such as a cordless phone, a multi-point microwave distribution system (i.e., wireless cable, WiFi, audio/visual senders), and certain government radars also have use of the spectrum. A very clear chart of the channels for the 802.11b allocations can be found in figure 1, courtesy of Steve Friedl's Weblog (http://www.unixwiz.net/images/80211bchannels.gif). As you can see, Channel 1 is just above the S Mode downlink for AO-40. Essentially, you have a "reverse TVI" situation.

To locate the interference, first look within your own home. Do you have a cordless phone or a wireless network system? If you do, try changing channels. Most of the consumer equipment defaults to Channel 1, so move it to a higher channel and see if the trouble goes away. If you don't have any of that type of equipment in the house, check with your neighbors. If they have any of the gear mentioned above, explain your situation and ask if they would help you by briefly shutting down the suspected equipment. If that cures the problems, offer to help change the channel selections to higher in the spectrum, preferably to around Channels 9–11. Emphasize that changing channels won't adversely affect their operation and in fact may help it, as it will move their equipment to a less-used frequency. A point of special note is that some of the 2.4-GHz (13-cm) cordless phones "frequency hop," and Gary Gonnella, W6RYO, has done some interesting studies on the problem as it relates to these 2.4-GHz cordless phones. His results can be found at <http://www.w6ryo.com/2ghz_interference.htm>.

"My tracking program seems to be off in its predictions. What's wrong?"

First, make sure you have the very latest Keplerian elements for your tracking program. You can subscribe through the AMSAT website (see <http://www.amsat.org>) to have "Keps" sent to you via e-mail on a weekly basis. Also, make sure your computer clock is accurate. Even if you have the latest Keps, if your computer is several minutes off, you'll miss a pass or at least you won't have your antennas pointed at the right piece of the sky. Also, make sure you have your location accurately entered into the tracking program. An error of just a few degrees of latitude or longitude can give erroneous readouts. Check your exact location with a GPS receiver. Although some tracking programs give you canned locations to use (typically, the location of city hall), these might be miles away from your actual location.

"I plan to put my preamp and/or S Mode converter on the tower. Will feeding the power through the coax cause any signal loss?"

The loss would be negligible, presuming you have the minimum connections. The ideal situation is power applied to the feedline by your radio at the antenna connector and picked off the feedline at the preamp/converter's connector. Is there loss? Yes, but you would need some very sophisticated equipment to measure it. If you start inserting coax connectors up and down the feedline, it will add up, especially if they are not installed properly. Most preamps, converters, and transverters come with the option of being powered directly or by the feedline.

"Is there any advantage or disadvantage to powering preamps or converters through the coax?"

First, it's very convenient to use your feedline to carry operating voltage up the line. You simply connect the feedline, which you would have anyway, and you're set. However, some transceivers don't have sufficient capacity to handle some mast-mounted equipment. Most transceivers can only handle 300–400 milliamps of current, which is fine for most preamps, but well below what is needed for a transverter. You can use "outboard" equipment to insert voltage on the coax. Typically known as "Bias T's," they are placed in the line just after the transceiver. The operating voltage is applied to the "T," and in turn to the coax. Bias T's are available commercially, but if you want to "roll your own," go to <http://www.qsl.net/n9zia/wireless/appendixF.html#14>. Another factor is that you can't place power/SWR meters in line with coax carrying operating voltage, so if you like to keep an eye on your power/SWR, you'll have to arrange a system to switch the meters in/out of the line. Personally, I prefer direct feed. It does require extra cable being run up the tower, but I feel as if I have more positive control and provide greater current capacity.

"Does the crossboom have to be fiberglass or would a metal one be okay?"

There is spirited debate on this point. A non-conducting boom (fiberglass, PVC, or wood) protects the circular pattern if you are using a crossed-element antenna. The fiberglass booms can be pricey, as opposed to one fabricated from PVC pipe or wood. Booms from these materials also have the unfortunate tendency to sag after a few years of use. From the standpoint of using a metal boom, it will have no impact if you are using linear, end-mount, or dish antennas. However, if used with a crossed-element antenna, several knowledgeable folks contend that the distortion with a metal boom is minimal. The big advantage with a metal boom is strength. It won't sag (unless you use a thin-wall mast with heavy antennas), and it will have minimal maintenance. A compromise is to use nonconductive material in the immediate area of the antennas, slip the nonconductive boom into a metal boom, and center the metal boom in the rotor.

"How critical is it to be able to switch antenna polarity?"

Again, spirited and scholarly debate has occurred regarding polarity switching. From personal experience in working LEO satellites, it is critical. It makes the difference between hearing and not hearing the downlink. Although right-hand polarization is considered the default for amateur satellites, James White, WDØE, authored a study on this very subject (http://www.amsat.org/amsat/intro/pswitch.html) which may resolve any questions. As for a polarity switch, most crossed-element satellite antennas come equipped with one. However, if you need to fabricate your own polarity switch, take a look at the article by Howard Sodja, W6SHP (http://www.amsat.org/amsat/articles/w6shp/ant_tips.html), or review Chapter 10 of the *Satellite Experimenter's Handbook.*

"Why can't the Space Shuttle be used to launch amateur satellites?"

First of all, the shuttles are grounded, but even when they return to service, they're not really a suitable launch platform for amateur satellites. The shuttle orbit is well below amateur satellites, so some sort of propulsion system would be needed to move the satellite to a higher orbit after release from the shuttle. Also, the shuttle missions, especially those regarding the ISS (International Space Station), work with a much higher priority, so space and time are not always available. Scheduling is also a factor. Activity for most shuttle missions is arranged years in advance and on a very structured plan. Unlike commercial projects, construction and certification of volunteer-built satellites cannot always meet/match the shuttle's timetable.

"I tried using the new SO-50 bird, but can't get into it and the S-meter reading are pretty low. Do I have an equipment problem?"

Not really. First, keep in mind that SO-50 requires sub-audible tone (88.5 Hz) for access; this is a first for amateur radio satellites. This prevents the unintended interference UO-14 suffered from suspected unauthorized operation by some fishermen. From the receive standpoint, the downlink transmitter is only putting out about 144 milliwatts. Even with a directional antenna with preamp, a reading of 5 to 7 is about the best you'll get on the S-meter. However, if you can hear 'em, then don't worry about what the S-meter says.

"Is it true that a new bird is due to for launch in spring of 2004?"

The AMSAT OSCAR-E, or "Echo," has a target launch date of 31 March 2004, four months ahead of its original May launch date. Echo is a microsat 9.5 inches on a side and will be in a Low Earth Orbit. Echo will be capable of three modes of operation: VHF uplink/UHF downlink, 1.2-GHz uplink/ 2.4-GHz downlink, and HF uplink/UHF downlink. Also, there is the potential of VHF uplink/2.4-GHz downlink, 1.2-GHz uplink/UHF downlink, and HF uplink/24-GHz downlink operations. Echo will also include analog FM operation, high-speed digital, and a PSK31 repeater with a 10-meter uplink on SSB and a UHF FM downlink. For detailed information on Echo, see the July/August 2003 issue of *The AMSAT Journal.*

This should answer quite a few of your FAQs. If you have more questions, or ideas for a future column, please send your questions or suggestions to me, either via e-mail or snail mail. ■

QUARTERLY CALENDAR OF EVENTS

Contests

WSJT Six Meter Mileage Marathon: This event is scheduled between January 31 and February 9. For more information, see the Six Meter Worldwide DX Club website: <http://6mt.com/contest.htm>. Mailing address: Six Club Contests, c/o Wayne Lewis, W4WRL, 3338 South Cashua Dr., Florence, SC 29501-6306; e-mail: <w4wrl@aol.com>.

European World-Wide EME Contest 2004: Sponsored by DUBUS and REF, the EU WW EME contest is intended to encourage worldwide activity on moonbounce. Multipliers are DXCC countries plus all W/VK/VE states. This gives an equal chance for stations in North America, Europe, and Oceania. The rules reward random QSOs, but do not penalize skeds on 2.3 GHz or above. The contest dates and bands are as follows:

First weekend: 432 MHz, 2.3 GHz to 5.7 GHz, 6–7 March, 0000–2400 UTC.

Second weekend: 144 MHz, 1.3 GHz and 10 GHz, 27–28 March, 0000–2400 UTC.

Sections and awards include the following: QRP 144 MHz <100 kW EIRP, 432 MHz <400 kW EIRP, 1296 MHz <600 kW EIRP, and >= 2300 MHz no separate QRP/QRO categories. The QRO category on 144, 432, and 1296 MHz, stations with EIRP equal to or greater than stated above. The PRO category includes non-amateur equipment or antennas. PRO stations will have their scores listed separately. There are no separate multi-operator classes. Multi-operator and QRO stations will be highlighted in the general classifications. All QRP/QRO band winners and QRP/QRO multiband winners (1st place) will receive a free one-year subscription to *DUBUS* magazine. In each band/section, certificates will be sent to the top ten entries and to the highest scoring station in the southern hemisphere.

For a valid QSO, both stations must transmit and receive both callsigns + TMO/RST + R. During a QSO, on any band, liaison by any other means (e.g., DXcluster, internet, telephone) is forbidden. There is no restriction on modes, but entrants must not cause inter-mode QRM.

For additional rules and for answers to general questions contact <info@dubus.de>.

Spring Sprints: These short duration (usually four hours) VHF+ contests are held on various dates (for each band) during the months of April and May. This year's dates and times are as follows: 144 MHz, April 5, 7–11 PM local time; 222 MHz, April 13, 7–11 PM local time; 432 MHz, April 21, 7–11 PM local time; Microwave, May 1, 6 AM to 1 PM local time; and 50 MHz, May 8, 2300 UTC Saturday to 0300 UTC Sunday. Sponsored by the East Tennessee Valley DX Association, information on these contests can be found on their website at <http://www.etdxa.org>. At this URL, click on the VHF/UHF link to get to the contest information.

Quarterly Calendar

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

Feb. 1	Poor EME conditions.
Feb. 3	Highest Moon declination.
Feb. 6	Full Moon.
Feb. 8	Good EME conditions.
Feb. 13	Last quarter Moon.
Feb. 15	Very Poor EME conditions.
Feb. 16	Moon perigee and lowest Moon declination.
Feb. 20	New Moon.
Feb. 22	Good EME conditions but near New Moon.
Feb. 28	Moon apogee and first quarter Moon.
Feb. 29	Very Poor EME conditions.
Mar. 6	Full Moon.
Mar. 7	Good EME conditions.
Mar. 12	Moon Perigee.
Mar. 13	Last Quarter Moon.
Mar. 14	Very Poor EME conditions.
Mar. 20	New Moon and Vernal Equinox.
Mar. 21	Moderate EME conditions.
Mar. 27	Moon Apogee.
Mar. 28	First Quarter Moon. Very Poor EME conditions.
Apr. 4	Good EME conditions.
Apr. 5	Full Moon.
Apr. 8	Moon Perigee.
Apr. 11	Very Poor EME conditions.
Apr. 12	Last Quarter Moon.
Apr. 18	Moderate EME conditions.
Apr. 19	New Moon.
Apr. 24	Moon Apogee.
Apr. 25	Poor EME conditions.
Apr. 27	First Quarter Moon.
May 2	Moderate EME conditions.
May 4	Full Moon.
May 6	Moon Perigee.
May 9	Very Poor EME conditions.
May 11	Last Quarter Moon.
May 16	Moderate EME conditions.
May 19	New Moon.
May 21	Moon Apogee.
May 23	Poor EME conditions.
May 27	First Quarter Moon.
May 30	Moderate EME conditions.

—EME conditions courtesy W5LUU.

2 GHz and Up World Wide Club Contest: Sponsored by the San Bernardino Microwave Society, this contest runs from 6 AM on May 1 to 12 midnight on May 2 (36 hours). The object is for worldwide club groups of amateurs to work as many amateur stations in as many different locations as possible in the world on bands from 2 GHz through Light. Rules are available at: <http://www.ham-radio.com/sbms/club_contest/2GHzUp.pdf>.

Conventions and Conferences

Southeast VHF Society: Their 8th annual conference will be hosted in Atlanta, GA, on April 23–24. The new location will be the Holiday Inn Hotel & Suites in Marietta, 2265 Kingston Court, Marietta, GA 30067 (770-952-7581). Be sure to mention "Southeastern VHF Society Conference" to get the special room rate. (For those who have attended the SVHFS conference in Atlanta before, this hotel is about two miles north on I-75 from the previous hotel.)

Copies of the registration form and the conference flyer are available at <http://www.sevhfs.org>. Have your registration in the mail and postmarked by March 23, and you will qualify for the pre-registration prize drawing.

Dayton HamVention®: The Dayton HamVention® will be held as usual at the Hara Arena in Dayton, Ohio May 14–16. For more information, go to <http://www.hamvention.org>. N6CL is scheduled to be one of the speakers at the VHF forum.

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 Ray Rector, WA4NJP, <wa4njp@bellsouth.net>. The deadline for submitting papers is as soon as possible.

38th annual Central States VHF Society Conference: July 22–25, at the Delta Meadowvale Resort and Conference Centre in Mississauga (Toronto), Ontario, Canada. The deadline for submitting final papers is May 1. Submit your proposal as soon as possible to Bob Morton, Technical Chairman and V.P., at <ve3bfm@csvhfs.org>.

11th International EME Conference will be held on the campus of the College of New Jersey, in Ewing, NJ, August 6–8. Submit your proposed paper/talk topic as soon as possible to Marc Franco, N2UO, <eme2004@qsl.net>.

Meteor Showers

The *Lyrids* meteor shower will be active during April 19–25. It is predicted to peak around 0410 UTC on 22 April. This is a north-south shower, producing at its peak around 10 to 15 meteors per hour, with the possibility of upwards of 90 per hour.

A minor shower is the *pi-Puppids* and its predicted peak is around 0900 UTC, April 23.

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

The Frontlines: HSMM

Developments in Amateur Radio—Part I

In a nutshell, HSMM amateurs throw away the little indoor rubber-ducky antennas that come with the gear and replace them with outdoor antennas.

By John Champa,* K8OCL

In the previous issue of *CQ VHF* we discussed the basics of HSMM radio and how to get started. What is a ham to do with all this high-speed data capability? Let us now examine a few of the exciting new applications for HSMM radio in more detail.

If you read the Fall 2003 issue of *CQ VHF,* you already know that HSMM stands for High Speed Multi-Media radio networking. That is a mouthful, but nonetheless, it is not a specific operating mode, but rather a radio networking direction within amateur radio. Commercial folks often call this sort of radio *mobile computing.* The current developmental emphasis is on adapting to amateur radio use. The inexpensive, easy-to-use, commercial, off-the-shelf (COTS) microwave spread-spectrum digital packet-radio gear is readily available from most office and computer supply stores. This equipment is known in the commercial market as wireless local area network (WLAN) or WiFi gear. In a nutshell, HSMM amateurs throw away the little indoor rubber-ducky antennas that come with the gear and replace them with outdoor antennas. They set the gear for operations on the provided channels 2 through 5 and operate in the amateur radio 2.4-GHz band.

History

Amateur radio research into spread spectrum was started in 1981 by the Amateur Radio Research and Development Corporation (AMRAD) and continues to this day by organizations such as the Tucson Area Packet Radio (TAPR) group and the ARRL HSMM Working Group (http://www.arrl.org/hsmm/). The initial project was described in the May 1989 issue of *QST* and was reprinted in *The ARRL Spread Spectrum Sourcebook.* Current amateur research into spread spectrum can be found in the AMRAD and TAPR newsletters. Also, it is on the HSMM webpage noted above. A thorough explanation regarding how spread spectrum works can be found in the current edition of *The ARRL Handbook.* Because of the considerable research progress being made in this area by radio amateurs, the spread-spectrum portion of future editions of *The ARRL Handbook* will be revised considerably.

HSMM radio, although digital, is not primarily a keyboard radio communication medium, as in conventional HF and VHF packet radio. The throughput data rates in HSMM are significantly higher, typically 700–900 kbps or better, depending on the signal-to-noise ratio. These data rates are equal to 12 to 16 times faster than typical internet dial-up speeds (<56 kbps). At these high data speeds hams can operate two-way full-motion streaming video and audio called *amateur digital video* (*ADV*). ADV is about half the resolution or quality of a VHS tape, but it is still of sufficient quality for many image communication purposes.

Also used in HSMM radio is voice over IP (VoIP), which is the same technology currently used to carry voice traffic between linked FM repeaters over the internet. Even interactive e-game traffic is possible. HSMM radio is multimedia radio.

HSMM radio networks are not like other radio networks with which you may be familiar. Although round-table discussions are conducted, most operations of the HSMM radio local area networks are automated or semi-automated links, much like those experienced using TCP/IP over the internet; thus, the nickname of Ham + Internet = Hinternet. Accordingly, many HSMM stations are on the air continuously in an unattended mode of operation.

Remote-Control HSMM

Remote-control HSMM has some unique ham radio network applications and operational practices that differentiate the Hinternet from normal Wi-Fi hot spots, also known affectionately as Internet Cafes (Starbucks®, etc.). You may have read about these in the popular press. HSMM techniques are used for system RC (remote control) of amateur radio stations.

Time and Cost Sharing of Ham Stations

One of amateur radio's greatest challenges, particularly in high-density, residential areas, is constructing antennas, particularly high tower-mounted HF antennas, which work without inciting the entire neighborhood. Often, except for a few contest weekends or a band opening, these high-profile amateur stations are idle most of the time. They represent a significant investment in time and resources, and the burden could be shared easily. Implementing a portal to a remote HF station via 2.4 GHz is easy to do. Most computers now come with built-in multimedia support. Most amateur radio transceivers are capable of PC control. As you will further see in this paper, adding the 2.4-GHz networking is relatively simple. The only speed humps are getting the small 2.4-GHz antenna mounted outdoors (in deed-restricted communities), but such antennas are relatively small when compared to a full-

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size, three-element, 20-meter monoband Yagi on a 20-ft. high tower. Even high-gain ,2.4-GHz–band antennas such as the Comet® Model X2427 rated at 25 dBi, or the Diamond® Antenna Model 2400Y19 rated at 19 dBi gain, are small and unobtrusive. Here are the details on how one amateur radio operator, Darwin Thompson, K6USW, has done it with the Kenwood TS-480SAT/HX.

Kenwood recently introduced its new TS-480SAT/HX radio, which can be controlled over a LAN and the internet. After getting the radio, go to the Kenwood website and download the two programs for the TS-480SAT/HX (http://www.kenwood.net/indexKenwood.cfm?do=SupportFileCategory&FileCatID=3). The ARCP-480 is the radio-control software. The ARHP-10 is the radio host program. Follow the instructions included with the software to make the cables to interface the radio to your computer. With ARHP-10 running in the computer attached to the transceiver and the ARCP-480 running in a laptop PC with a microphone/earphone headset attached, you can control the radio and use VoIP on your HSMM radio station to transmit and receive audio, etc. It is as simple as that!

This system RC concept could be extended to other types of high-performance amateur radio stations. For example, HSMM radio can be used to link your current station or home office to a high-performance amateur radio VHF/UHF station, EME station, ATV station, or OSCAR 40 satellite ground station. These types of ham stations have large blocks of idle time and are ripe for the HSMM radio time-sharing experience. This could be done on a time-share and cost-share basis by the local amateur radio club or repeater group. The link would be back to members' homes, which do not allow, or simply can't afford, such large, complex, and expensive outside antenna arrays with associated high tower(s).

For more details on how this station remote control is easily done, see the article "Remote-Control HF Operation over the Internet" (or Hinternet, in this case), by Brad Wyatt, K6WR, on pages 47– 48 of the November 2001 issue of *QST*.

HSMM Surfing and Interactive E-Games

Sharing some high-speed internet access (Cable, DSL, WISP, or in the case of an amateur radio club or repeater group, perhaps a shared T-1 circuit) with another amateur is a popular application for HSMM radio. Over half the U.S. population is restricted to very slow dial-up internet connections (<56 kbps) over a plain old telephone service (POTS) line. Getting a high-speed internet connection, even a shared one, feels like you have discovered a new universe!

Note: If you use an HSMM microwave radio repeater (a.k.a. an AP) to share high-speed access to the internet, don't forget amateur radio content restrictions—e.g., no commercial for-profit business e-mails, etc. Don't worry about pop-up ads. Pop-up ads, although a nuisance, are no more illegal than, for example, an amateur television (ATV) station transmitting an outdoor scene and inadvertently picking up a billboard in the station camera, or your car AM/FM broadcast radio being heard in the background when talking on the local FM repeater. Such background sources are merely incidental to your transmission. They are not the primary purpose of your communications, plus they are not intended for rebroadcast to the public.

Do you have an old or a spare PC around? Use it as a server on your area HSMM radio network. Then it is possible to do things such as play interactive games, complete with sound effects and full-motion animation (see the Neil Sablatzky, K8IT, HSMM column in the Fall 2003 issue of *CQ VHF* for guidelines on using e-games on the air in amateur radio). This can be lots of fun and attract new club members. In the commercial world these are called WLAN Parties. For purposes of HSMM radio research, playing e-games is an excellent method of testing the true speed of your station's Hinternet link.

HSMM Radio in Emergencies

The HSMM radio driving force is Emergency Communications Support (RACES, ARES, etc.). Why are EmComm organizations so interested in HSMM radio capabilities?

1. They realize that the amount of digital radio traffic on 2.4 GHz is increasing and operating under unlicensed Part 15 power limitations cannot overcome this noise.

2. They need a high-speed radio network that can simultaneously handle voice, video, and data traffic for their emergency communications.

3. The cost of a commercially (government) licensed high-speed data network is more than they can collectively afford for use only during emergency conditions and exercises, which may be conducted only three to four times per year.

4. They also know that they continuously need to exercise any emergency communications system and have trained operators for the system for it to be dependable.

5. Amateur radio HSMM operations under amateur radio Part 97 regulations solve the problems of the above limiting factors. They can run more power than is allowed under Part 15 unlicensed operating, they have high-speed multimedia capabilities, they are cost effective (amateurs can do with $50K what Motorola can do for $250K), and they can be exercised daily or weekly by trained volunteer ham communicators doing what they do naturally.

Imagine being at an emergency scene and being able to send live video images of what is happening back to everybody on the HSMM microwave radio network using inexpensive web cams. The video could also be sent to an Emergency Operations Center (EOC), while at the same time submitting a written report (a long list of survivors, etc.) and simultaneously talking to the EOC using VoIP. Often all that is needed is an old or used laptop computer equipped with a wireless local area network enabled PC Memory Card International Association (PCMCIA) card with an external antenna jack. In HSMM jargon, such a card is called an RIC, meaning a radio interface card. Connect any of the small and inexpensive (about $20) digital cameras, or as an alternative, some Kodak and other consumer-grade digital cameras used for family snapshots also have a video output port. Then connect the RIC to a short Yagi antenna. Except for the RIC and the little antenna, many amateurs may already have all this gear!

In a recent *CQ* magazine survey ("What You Have Told Us," *CQ*, September 2003, p. 40) 8% of the respondents reported already using some kind of wireless networking, so there is already a growing understanding of the technology within the amateur ranks. Therefore, it is not difficult to put together an EmComm team and bring them quickly up to speed with HSMM radio (sorry for the pun . . . hi). While on the topic of speeds, here are some interesting findings from HSMM field experiments.

Data Rates: 802.11 links are essentially spread spectrum (see the Spread Spectrum topic in the chapter on Modulation types in any *ARRL Handbook*). It can provide fast internet-type speeds similar to a cable modem or DSL, even over many miles, provided that you have good antenna systems. The actual speed you obtain on your link will depend in large part on the signal-to-noise (S/N) ratio. The better the signal levels on the link, the higher the speed. The HSMM Working Group research has found that although manufacturers of 802.11b (DSSS modulation) equipment claim a maximum raw data rate of 11 mbps, and 802.11g (OFDM modulation) has a claimed maximum raw data rate of 54 mbps, the actual data throughput is significantly less. Why?

One reason you have already read about: As the signal-to-noise ratio declines, especially over the distance of many miles as experienced in the Hinternet, so does the data rate. However, there are other factors.

It should be noted that both approaches are radio, so they are either transmitting or receiving all the time, but not at the same time. They both use a collision-avoidance (CA) technique that results in half-duplex operation. Before transmitting, it listens to the channel first to make certain it is clear. That means the actual maximum theoretical data throughput is approximately half the data rate, or 5.5 mbps and 27 mbps, respectively.

In actual practice, we have found that with network overhead and other factors included, the real data throughput with maximum signal-to-noise ratio is approximately 3 mbps and 15 mbps, respectively. With a weaker signal, data rates will decrease even further. For example, my maximum data rate to my wireless internet service provider (WISP), called MediaNet® and 4.5 miles away, using 802.11b is approximately 900 kbps, more than 16 times faster than my old dial-up ISP.

Nonetheless, if more data throughput is needed for EmComm, etc., it should be possible to double those numbers. For example, an ARES amateur station might run the HSMM link using two access points (APs). One device could operate on channel 2 using a horizontally polarized antenna and the other on channel 5 using a vertically polarized antenna. Keep the antennas ten wavelengths apart (this is only about 40 inches on 2.4 GHz). It is certainly worth a try.

HSMM Radio Relay

When trying to extend the length of an HSMM link, the most obvious means would appear to be to run higher power and place the antennas as high as possi-

Amateurs Complete 82-mile Two-way DSSS Link on 2.4 GHz

While some of us complain of not being able to communicate from room to room with our wireless cards in our computers, ARRL HSMM Working Group Chairman, and *CQ VHF* magazine feature writer John Champa, K8OCL, reports that ARRL High Speed Multimedia (HSMM) Working Group member Ken Cuddeback, NT7K, and his students at Weber State University in Ogden, Utah recently completed two-way direct-sequence spread-spectrum (DSSS) communication on 2.4 GHz over a distance of 82 miles. The WSU students—including one ham, Brandon Checketts, KG4NZV, and several prospective licensees—broke the current world record of establishing a wireless link on 2.4 GHz with DSSS (using IEEE 802.11b WiFi protocol). Cuddeback reported that his students used PrimeStar dishes with unamplified Cisco Aironet 350 cards in each laptop. "We set up a NetMeeting session and transferred a 2.5 MB mp3 file successfully," he said. The Cisco WiFi cards run about 100 mW.

Portions of this report courtesy the *ARRL Letter* online edition, December 10, 2003 (http://www.arrl.org).

ble, as is the case with VHF/UHF FM repeaters. In both the U.S. and Europe there are several dramatic examples of this being done, single links extending 70 and 80 kilometers and more. This is the exciting approach often used by conventional microwave DXers, both amateur and commercial. Check out the great commercial photos and English text translation at this Polish website: <http://www.interline.pl/interline.php?s0=1&s1=1&s2=1&s00=1&s01=1&sx=2&s=czytelnia/110km>.

Even more impressive, an amateur radio operator and HSMM Working Group member leading a group of innovative students at Weber State University in Utah recently established a new HSMM radio world DX record. They are using standard wireless equipment (no amplifiers) and old modified satellite TV dish antennas (see sidebar).

As interesting and challenging as all this DXing with HSMM radio is, HSMM is network radio, and in some areas of the country taking this approach with 802.11, at least in the 2.4-GHz band, may cause some interference with other users. Other means of getting greater distances using 802.11 on 2.4 GHz or other amateur bands should be considered.

Many current HSMM networks are of relatively low-profile design. They depend on several low-power sources and radio relays of various types. For example, two HSMM repeaters (known commercially as access points [APs], about $100 boxes) may be placed back-to-back in bridge mode such that they simply will act as an automatic radio relay for the high-speed data. Using a series of radio relays of this or other similar designs on a string of friendly amateur towers, some great path lengths are possible. To encourage the amateur research and innovation in this radio-relay area, under consideration is an HSMM Radio Relay DX Award. The rules for such a competition might consist of merely measuring the maximum distance competing stations can retransmit or relay the entire contents of this article (including the photos) or a standardized video and audio clip. The actual data rate achieved could also be used to compute the scoring of points for the link. The primary stipulation, of course, would be that the entire path must be on the air. The possible use of high-altitude radio relays (balloons, rockets, and other experimental aircraft, etc.) may be permitted. However, no internet tunneling links (VPN) would be permitted for purposes of the award, although this is a common Hinternet practice for normal operations. If you are interested in such an award being developed, send me your ideas about how such a contest might be conducted. If enough interest is shown, a sponsoring organization such as this magazine or the ARRL will be approached to establish some contest guidelines.

In Part 2 (HSMM Operations) and Part 3 (Hinternet Infrastructure) of this series we will discuss some other considerations in HSMM radio:

- HSMM Area Surveys
- HSMM Antenna Systems
- Running higher power
- Information Security
- HSMM frequencies
- HSMM on 900 MHz, 3.5 GHz, and 5 GHz
- Proposed HSMM Network Infrastructure
- HSMM Interface with ICOM D-STAR systems
- Recommendations

For complete details on the many sources and types of inexpensive gear and antennas to get started in HSMM radio, see "How To Get Into HSMM," pp. 30–36 in the Fall 2003 issue of *CQ VHF,* and check out <http://www.arrl.org/hsmm/>.

bands. For example, Kaz Soong, K8KS, a relative newcomer to 6 meters from the Michigan area, had only experienced his first 6-meter sporadic-*E* openings some weeks earlier. During these openings he found himself in the throes of a decent CW pile-up. As a result, he worked many new grids, both close by and far away.

Despite the enhancement, subsequent days did not yield any significant *F2* or TEP events on 6 meters. The HC8GR beacon was heard in some areas, such as Texas and southern California, indicating a narrow *F2* path. However, it was surprising that not more *F2* propagation was observed, because the solar-flux values were over 200 for seven days in a row, reaching a peak of almost 292 on October 29. In the past, several days of 200-plus values usually translated into *F2* openings! From these observations, it is clear to me that other ingredients are needed for sustained *F2* openings, such as those observed during the fall of 2001.

The sun continued to remain active after the events of October 29. On October 30 there were some moderate aurora openings that were observed in Canada and the northern US on 6 meters. Subsequent flares were observed being emitted from other regions of the sun, with many at the X-level. Unfortunately for VHF operators (but maybe fortunate for HF operators and satellite owners), the subsequent flares were not geo-effective because the eruptions occurred when the affected area was at the limb of the solar disk. When eruptions do not take place in the central area of the sun, as viewed from the Earth, they do not generally result in a direct hit on the Earth's geomagnetic field.

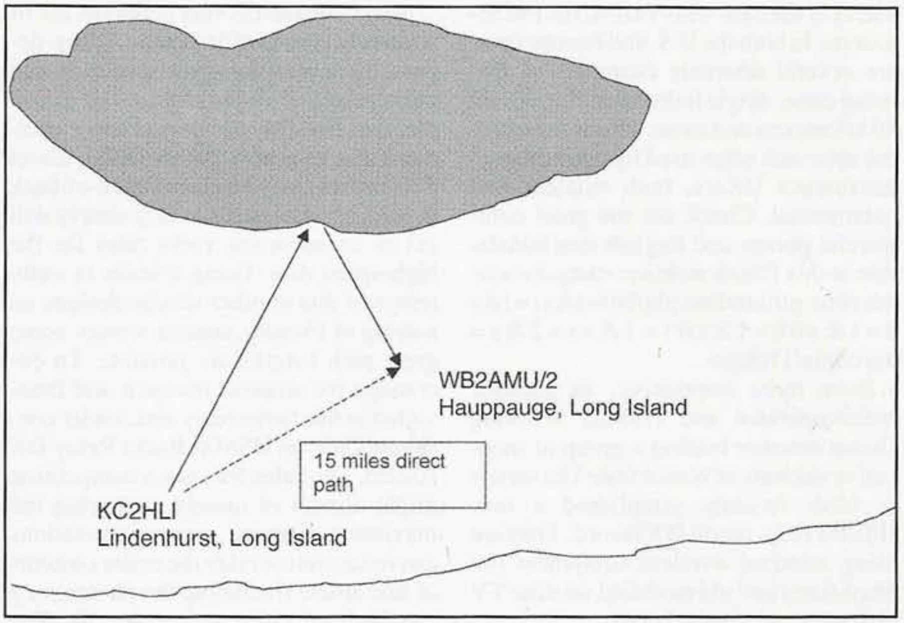

Figure 1. The aurora was so low and strong that WB2AMU at his work location was able to work KC2HLI by the backscatter path rather than the direct path!

November 2003

Then on November 4 a record-breaking event was observed with a flare reaching the level of X28 (best estimates) and coming from the eastern limb of the sun. As stated above, this is not a particularly good geo-effective position, and the result was that little impact which would result in aurora events on the VHF bands was observed. A difference of three days would have made quite a major impact in terms of propagation and perhaps major damage to the orbiting satellites and maybe even to power grids in Canada.

Nearly one solar rotation later, during the middle of November, more solar flares from sunspot areas that were still active were being reported. VHFers carefully watched these active areas to see if something would break, and indeed it did. On the morning of November 20, contacts via aurora were made—i.e., John (Mick), McManus, W1JJ, in Rhode Island worked Bill Coury, N8UUP, in Michigan and others in the Midwest.

During my noontime lunch break at my work QTH I was able to hear a fair amount of aurora signals. I worked K4QI (FM06), K1WHS (FN43), W3TDF (FM19), and W1JJ (FN43) on 6 meters. I also heard W4MYA on 2 meters, but I did not work him, as I did not have my beam with me in my car. Then I found it amazing that I could work KC2HLI in FN30, a station on Long Island (only 15 miles away by direct path), via aurora backscatter, which probably traveled a distance of over 100 miles (see figure 1). Likewise, I heard a few of the local low-power beacons in my area coming in via the aurora backscatter path—i.e., K2ZD/B in FN20 in New Jersey. Indeed, the conditions were pretty good for hearing low-power stations.

During this event the aurora traveled quite far south. While clouds caused my not being able to see it, those in areas of the United States as far south as Florida and New Mexico viewed the aurora during that evening. Later that afternoon, at 2000 UTC, while the aurora was still active in some spots, there was a brief *F2* opening between various stations in the U.S., such as W1JJ in Rhode Island and N8UUP in Michigan into parts of South America and the Caribbean, where HP1AC, HC3AP, 9Z4BM, FS/W3ARS, and KP2L were some of the stations that were worked.

I was able to hear some southern stations via aurora briefly on 6 meters, and the activity on 2 meters was a bit better than the late-October openings. I managed to work a new grid on 2 meters with K1GUP, FN54, in Maine. By the way, I do not have a permanent station for 2 meters yet, so I used my 3-element beam in the driveway at 15 feet, feeding into the FT100 radio in the car, running at 40 watts.

Because of the excellent conditions that were occurring, little effort was required to work some stations. The effect of the aurora was that the signals were nice and wide on 2 meters, and CW was the only way to go. Also, some of the signals had Doppler shift on them, particularly those which had both ground wave and backscatter. Later I also tried my hand at 6-meter QRP with 10 watts, and I worked as far west as N8CJK in EN84 and as far north as K3KYR in FN24.

By 0100 UTC on November 20 the aurora activity finally began to fade. For two 3-hour segments during the latter part of the day throughout the peak of the aurora activity the *K*-index reached 8. This opening differed from the event in October in that the *Bz* value was favoring sustained southward values, which is necessary to produce geomagnetic storming and aurora for all but the most pole-ward locations.

No more aurora activity was observed the next day. There was some decent TEP activity on 6 meters into Florida, and later in the evening K8ROX managed to work ZP6CW by an apparent sporadic-*E* link into the TEP path. Some aurora was still observed in Europe on November 22 and later in the day for a while in North America. A subsequent flare apparently triggered this event after the big one occurred. With the active sun being the way it was in both October and November, it became a tricky exercise to determine which of the lesser flares corresponded with the aurora events on Earth.

Even so, TEP and *F2* events continued to appear on 6 meters in the ensuing days, primarily in a north-south path. They were not confined to the stations located in the southern U.S. At around 2345 UTC on November 22, both N8UUP and N8CJK in Michigan worked V31MD in Belize with very loud signal reports! At the time of this writing it seems it is possible that more events may continue throughout the end of November.

In Conclusion

It would appear that there is still life in solar Cycle 23 for special VHF activity. HF operators are not too fond of aurora activity because it cuts down on propagation. However, during such events 6- and 2-meter operators watch conditions intently. It is significant to note that there were some trace amounts of *F2* activity triggered by the aurora, and 6-meter operators gathered a lot of valuable information during these solar events.

One question that serious VHF operators ask is "When the aurora subsides, will it be *F2* or will it be auroral-*E* that occurs?" That is always the thing worth waiting for on 6 meters. In light of these solar events, VHFers are well advised not to give up monitoring the bands or put away their radios for the next year or so!

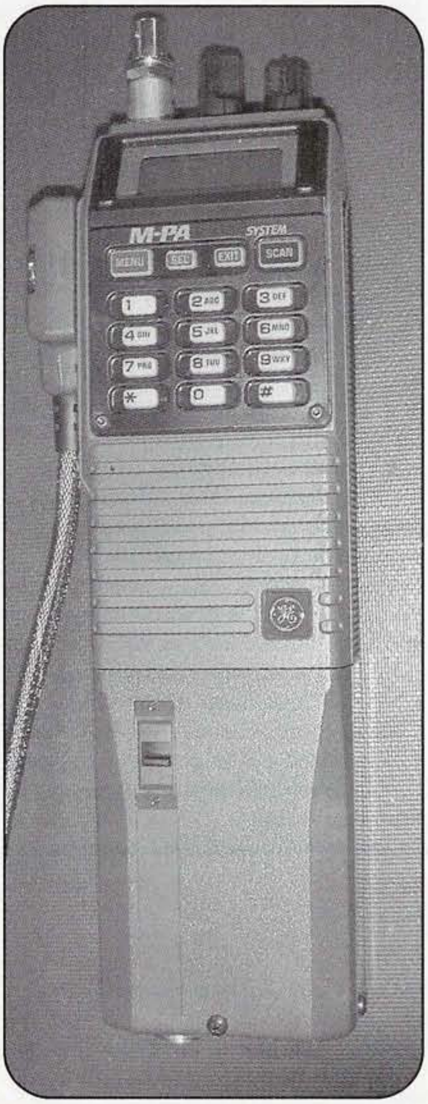

Figure 4. Ericsson radio.

108 *Endeavour* flight on December 5, 2001. Details of the Phase 1 system are described in reference 1.

Antenna Assemblies. In 2002, a set of four antenna systems, developed by the ARISS team, was deployed during three Russian EVAs (Extra Vehicular Activities—i.e., space walks). These antennas will support the Phase 1 and Phase 2 systems in the Service Module. Once checked out, the specially designed antenna assemblies will permit operations on HF (20, 15, and 10 meters), VHF (2 meters), UHF (70 cm), and the microwave bands (L and S band). These antennas also permit the reception of the Russian Glisser EVA video signals (2.0 GHz). This dual-use (ham/EVA video) capability is the primary reason the ARISS team received access to the four antenna feedthroughs located on the outside of the Service Module.

The four antenna systems were developed to make maximum use of the antenna feedthroughs. They were installed around the periphery of the far end of the Service Module (see figure 7). Three of the antennas (WA1–WA3) include VHF/UHF flexible-tape antennas. WA4 includes a 2.5-meter flexible-tape HF antenna. The antenna systems were developed by the US, Italian, and Russian ARISS partners.

Each antenna assembly consists of a mounting plate, spacer, black striped handle, Russian handrail clamp, orange-colored VHF/UHF (or HF) metal flexible-tape antenna with black Delrin mounting collar, L/S-band flat spiral antenna with a white Delrin radome cover, diplexer (mounted underneath the plate), and interconnecting RF cables (see figure 8).

The antenna systems were launched on the Space Shuttle *Endeavour* flight on December 5, 2001. The two up-looking (zenith) antennas, WA3 and WA4, were deployed by EVA (space walk) in January 2002, and the two down-looking (Nadir) antennas, WA1 and WA2, were deployed by EVA in August 2002.

Antenna-installation EVA procedure development and training was led by Sergej Samburov from Energia with support from the ARISS-USA team.

Phase 2 Hardware System

Hardware Overview. The Phase 2 hardware system is expected to exploit the new antenna systems installed on the Service Module. Two new radio systems will be installed as part of Phase 2. These systems will augment the two Ericsson radio systems already on-board the ISS as part of the Phase 1 system. The combined Phase 1 and Phase 2 system will provide more capabilities for the crew and permit simultaneous, multi-mode operations by more than one crew member.

The Phase 2 development is a joint Russia, US, and Japan activity. Development was led by Russian team member Sergej Samburov, RV3DR. The Russian team was responsible for certifying the hardware for flight and providing the ride on the Progress launch vehicle. The Japanese team provided (donated) the

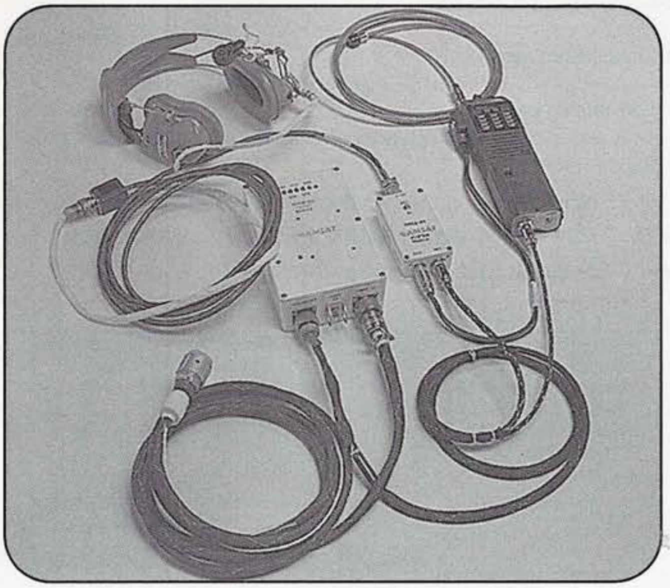

Figure 5. Phase 1 hardware.

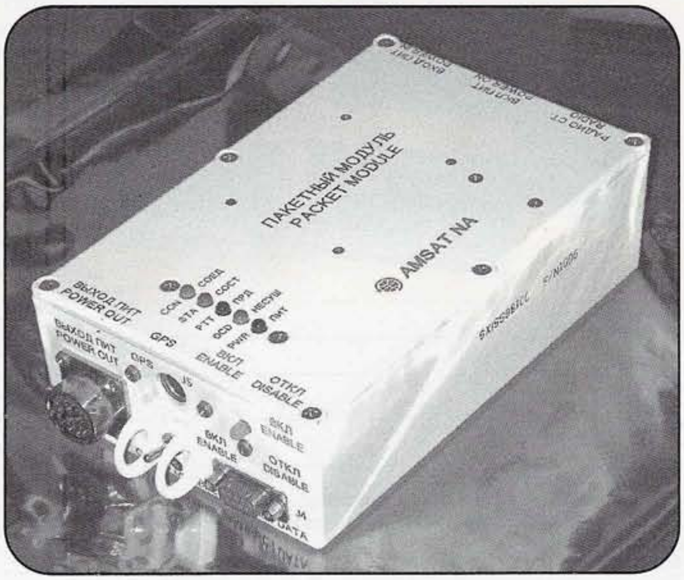

Figure 6. Phase 1 Packet Module.

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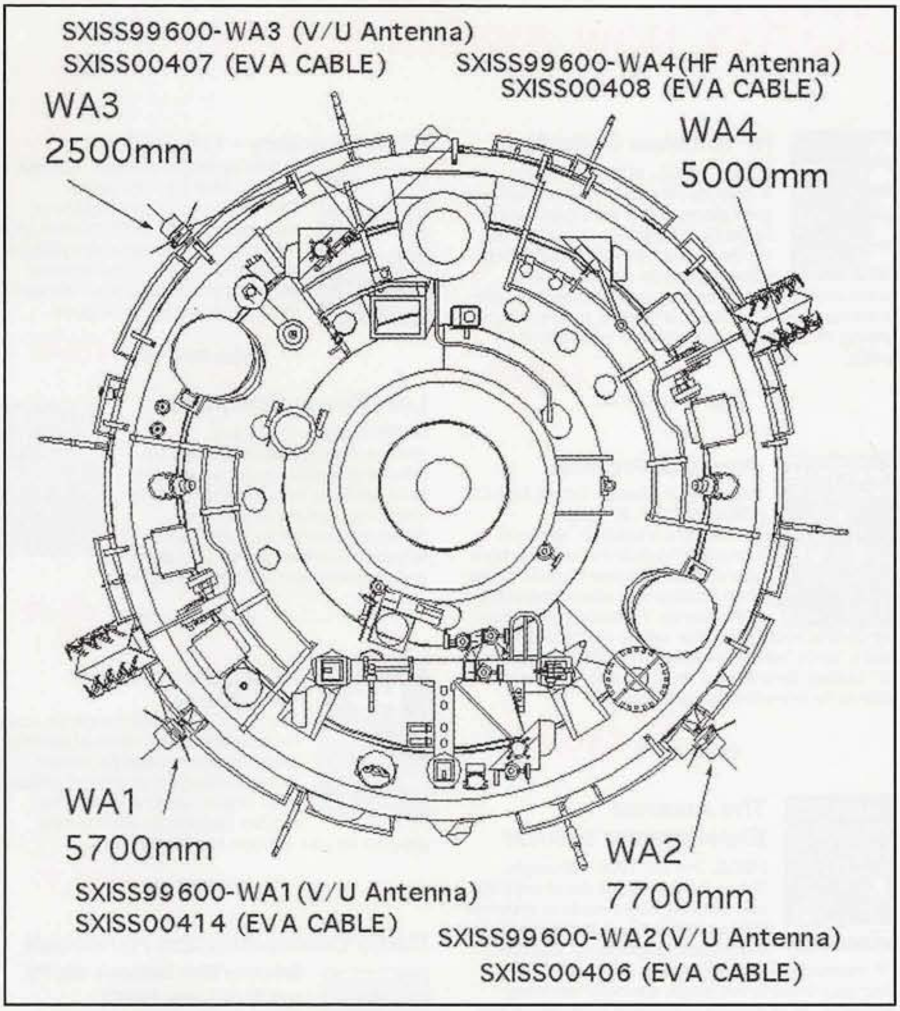

Figure 7. Antenna location from end of Service Module.

Kenwood radios to the ARISS team and made specific hardware and firmware modifications to the radio system to prepare it for flight. The USA team, in conjunction with the Japanese and Russian teams, developed the Program Memory software which provides a powerful system with a very user-friendly interface for the crew.

One of the two radios qualified for flight is a Kenwood TM-D700. This radio supports 2-meter (144–146 MHz) and 70-cm (435–438 MHz) transmit/receive operation and L-band uplink operation. This radio provides a higher output power capability (10–25 watts) than the Phase 1 radio system and can support FM and packet operations. The higher power capability should allow nearly horizon-to-horizon signal reception using simple hand-held radios or scanners.

The other radio is a Yaesu FT-100. This radio system will permit operation in the high-frequency bands. Of particular interest is performing ionospheric propagation experimentation using the WA4 (high-frequency) antenna and the FT-100. This radio also supports higher output power capabilities on 2 meters and 70 cm.

The entire set of Phase 2 hardware consists of the Kenwood and Yaesu radios, an RF tuning unit for the Yaesu radio system, interconnecting signal and RF cables, two specially developed Energia power supplies, a power distribution assembly developed by the USA team, a computer, and the 70-cm Phase 1 hardware system. These will be mounted on a Velcro-backed table (see figure 9). These radio systems will be connected to the four Service Module antenna systems through a Russian developed antenna switching system (see figure 10). A schematic of the hardware configuration is shown in figure 11.

Kenwood D-700 Specifics

The ARISS and Kenwood teams agreed that the Kenwood European model radio, D-700E, would be used for flight and ground operations. This radio had already been certified by the Russian team.

Several modifications were made by the Kenwood Japanese and Kenwood Moscow (Bermos) teams to prepare this radio system for flight. These included:

1. Developing a special Memory Control Program (MCP) to support reprogramming of the radio in the US, Japan, and Russia to ARISS specifications.
2. Changing the packet radio default parameters, as specified by the ARISS team, in EEPROM memory.
3. Enhancing the "repeater mode" of the radio system.
4. Replacing the power cable and the microphone and control-head cables with flight cables to allow certification of the hardware to the Russian requirements.

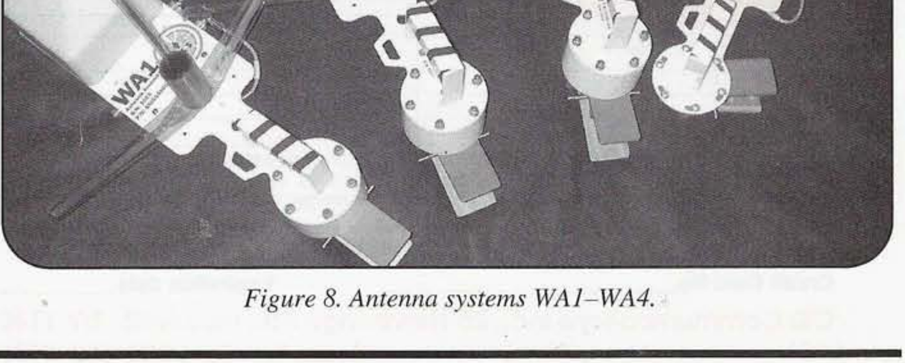

Figure 8. Antenna systems WA1–WA4.

Figure 9. Phase 2 hardware housed in Velcro table.

5. Reducing the maximum power output of the radio to 25 watts.

6. Replacement of the 6-pin data connector with an 8-pin connector. One of the additional pins on this connector supports an 8-VDC output capability.

7. Incorporating a channel designator for the front panel as the default instead of the frequency information.

The architecture of the radio interface to the crew was carefully crafted by the US and Japanese team to make the D-700 a powerful radio system with a simple user interface. A set of five default options, or Programmable Memories (PMs), were embedded in the D700 to support ISS operations (see figure 12). The advantage of these five PMs is that they can be restored by the crew at any time with a two-button key press. With the 200 different frequency channels, the nearly 100 TNC parameters, and the variety of applications for this radio on orbit, the default configurations are absolutely critical to being able to maintain communications with the crew under all conditions. These five PMs reduce operations to these fundamental configuration baselines:

PM1: Voice Operations (monoband)

PM2: Voice Operations (cross band/repeater)

PM3: APRS/Packet and BBS operations

PM4: Attached PC and Packet operations

PM5: Emergency Voice and alternate 9600-baud Packet operations

PM-off: No defaults. This mode is for knowledgeable licensed crew members' experimentation

The PMs remember the following types of parameters for the radio:

• Default channel for left side and right side of radio

• Which side of the radio the microphone and PTT will activate

• On which side of the radio the TNC will receive and on which side it will transmit

• The function of the several "soft keys" on the radio front panel

While the MCP program stores all 200 frequency channels in the radio, the PMs do not store any combination of channel frequencies other than the initial two defaults for the left and right side of the radio. This means that once a PM has been selected by the crew, this only configures the radio to a known default pair of channels. The crew member can still tune to any channel after that. Thus, with a push of two buttons and a rotation of the main dial, the crew member can operate on multiple modes and different frequency pairs. While this architecture offers the ultimate in flexibility (millions of combinations), it also provides a user-friendly interface of the five PMs to always return the radio to a known initial state.

Each of the 200 memory channels can support separate TX and RX frequencies, offsets, and PL or CTCSS tones. The D700 is a dual radio system, and although it only supports two channels at a time, it is very important to remember that each channel consists of both a displayed receive frequency and a separate transmit frequency. Thus, at any time there can be up to four frequencies involved in radio operations. Since the microphone and PTT (for voice) can be using one channel and the TNC can be using the same or the other channel, or even can transmit on one channel and receive on the other, there are many conventional (e.g., simplex, split) and non-conventional (e.g., crossband, repeater, CTCSS-enabled command uplink digital channels, etc.) ways to use these combinations for ARISS.

Yaesu FT-100 Specifics

The ARISS technical team working on the Yaesu project has specified several modifications to the Yaesu radio system to prepare it for flight. These include:

1. Replacing the power cable and the microphone and control-head cables with

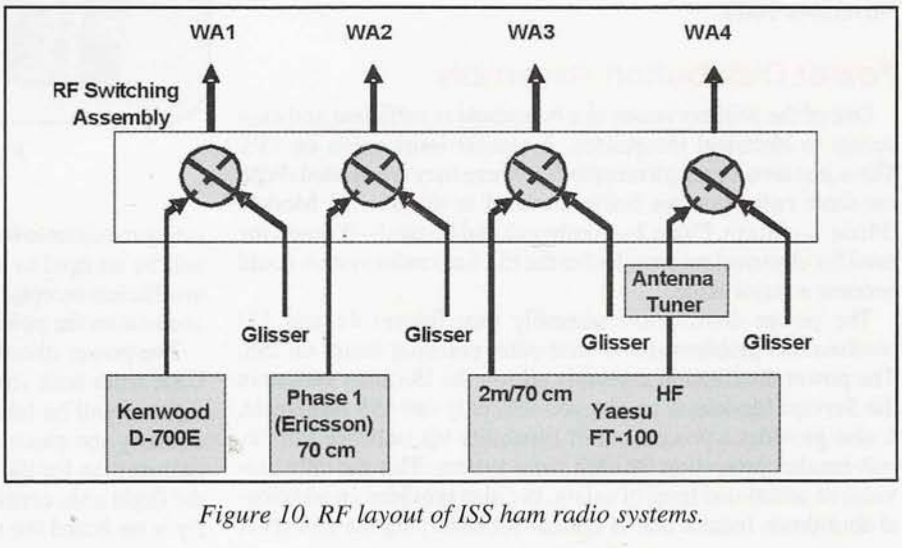

Figure 10. RF layout of ISS ham radio systems.

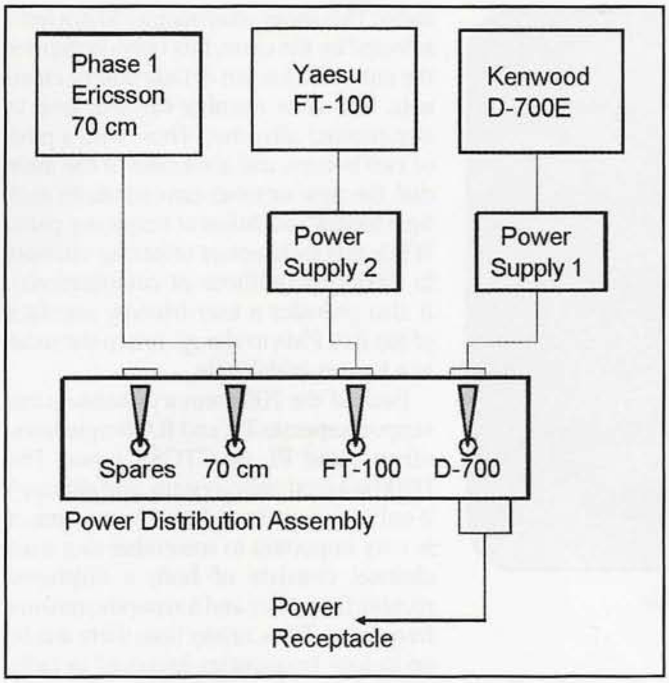

Figure 11. Power distribution schematic.

flight cables to allow certification of the hardware to the Russian requirements.

2. Reducing the maximum power output of the radio to 25 watts.

3. Replacing the PVC RF cables and connectors on the back of the radio with SMA connectors. Attached to these are Teflon-coated RG-142 antenna cables with N connectors.

4. Tuner cable replacement with flight cables.

5. Replacement of the 6-pin data connector with an 8-pin connector. One of the additional pins on this connector supports a 12-VDC output capability.

Since the FT-100 supports HF operation and the WA4 antenna is a single 2.5-meter vertical, the ARISS team felt that it would be best to supply a tuner with the radio to minimize SWR concerns and optimize signal output (see figure 11). The ARISS USA team is working closely with the Yaesu team to modify their existing FT-100 auto-tuner for ham radio operations on ISS.

Development of the Yaesu system was concluded in November 2003.

Power Distribution Assembly

One of the primary issues in a household is sufficient and easy access to electrical receptacles. A similar issue exists on ISS. There just aren't enough receptacles where they are needed. With the three radio systems being installed in the Service Module (Phase 1—70 cm, Phase 2—Kenwood, and Phase 2—Yaesu), the need for electrical receptacles for the ISS ham radio system could become a major issue.

The power distribution assembly (see figures 11 and 13) resolves this problem and several other potential issues on ISS. The power distribution assembly allows the ISS ham system in the Service Module to be plugged into only one ISS receptacle. It also provides a power shutoff capability via switches and circuit-breaker protection for each radio system. This not only provides an additional level of safety, but also provides an additional shut-down feature that is critical for satisfying the ISS EVA

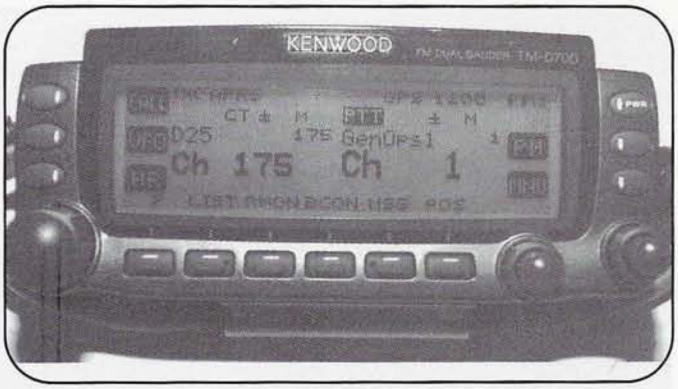

Figure 12. Kenwood D-700 PM1 crew display.

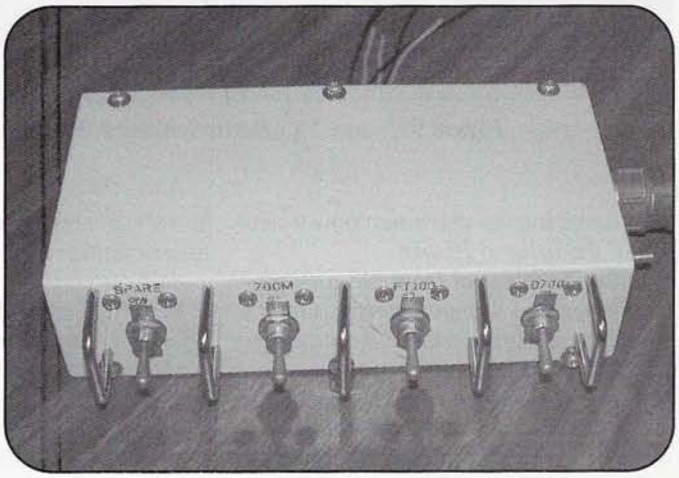

Figure 13. Power distribution assembly.

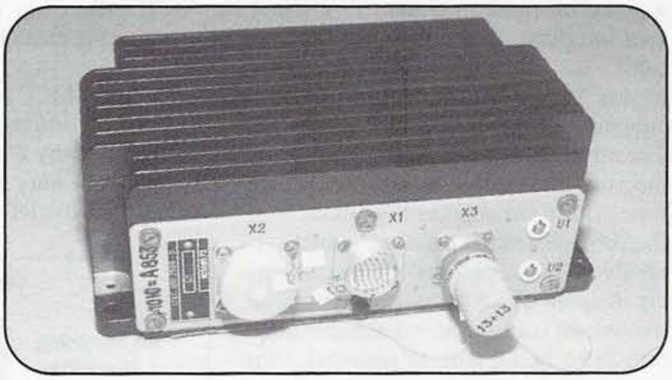

Figure 14. Power converter.

safety requirements. With the power distribution assembly, there will be no need to plug and unplug ISS ham radio items due to insufficient receptacles. Thus, this assembly serves to reduce wear and tear on the power cables, improving system safety.

The power distribution assembly is being developed by the USA team with strong support from the Russian team. While the unit will be fabricated in the US, several of the parts, particularly the electrical connectors, are Russian supplied. The current plan for the power distribution assembly is to fabricate the flight unit, certify it for flight in the US and Russia, and then fly it on-board the next space shuttle. Since the Yaesu system will not be deployed until the spring of 2004, this development and delivery schedule appears to make sense.

Power Converters

Two fully redundant, flight-certified power converters were developed by the Russian Energia team and were supplied to the ISS ham team for use as part of the Phase 2 radio system (figure 14). These power supplies convert the 28-VDC ISS power to 13 VDC for use by the Kenwood and Yaesu radio systems. Since the power converters are fully redundant, the ISS ham team will have adequate power capabilities for all the radio systems even if one of the power converters fails.

Phase 2 Delivery, Testing, and Checkout

The final version of the flight MCP software was delivered to the Russian team by the USA team on July 17, 2003. Just prior to that, the Kenwood Japanese team delivered the final firmware load to the Kenwood Japanese (Bermos) team for installation into the D-700 radio. The Bermos team and the ARISS-Russia team, led by Sergej Samburov, completed the hardware and software modifications to the radio system in late July and readied the Phase 2 hardware system for flight. The initial set of Phase 2 hardware—including the Kenwood D-700 radio, interconnecting cables, power converters, and RF switching system—was delivered to the Baikonur Cosmodrome in Kazakhstan in early August. The Phase 2 hardware was launched on the Progress 12P rocket on August 29, 2003 and docked with the ISS on August 31. The Velcro table is already on-board ISS and is awaiting equipment installation.

A series of tests were conducted by the Russian and US teams on the Phase 1 and Phase 2 hardware in November 2003 at the KIS facility (Service Module engineering model equivalent) located at Energia in Korelev (Moscow area), Russia. These tests were conducted in the Service Module equivalent to validate that the Phase 2 and 70-cm and 2-meter Phase 1 systems were compatible with the other electrical systems on the Service Module. Other testing included some RF testing with the flight-identical antenna systems and the Phase 1 and Phase 2 hardware.

Upon completion of these tests, and the completion of the necessary paperwork by the ISS ham radio team and the Energia leadership, Mike Foale and Alexander Kaleri, the Expedition 8 team, were told that the equipment was cleared for installation in the FGB. Early in December they installed the Phase 2 and Phase 1 70-cm hardware.

Once installed, the ISS program gave the green light to use the equipment on December 20, 2003. The next day, Mike Foale was on the air on voice. The packet system has also been activated. The remaining Phase 2 hardware, including the Yaesu radio system, was to have been launched on the Progress 14P flight planned for earlier this year.

Future Hardware Deployments

Follow-on Phase 2 Hardware. Two future projects are envisioned to improve the capabilities of the Phase 2 system. These include the development of the tuner for the Yaesu radio system and the certification of an SWR/power meter. These two projects will be developed and flight certified by the US team and flown on a future shuttle flight.

SSTV

A Slow Scan Television (SSTV) system will be deployed on ISS. The SSTV system for the ISS ham radio station was in development as of this writing. This system will consist of a software interface, developed by the MAREX-MG team, and a hardware interface, developed by the AMSAT-NA hardware team. Prototype hardware and software systems have been developed and the flight-system fabrication started. The SSTV system will allow digital still pictures to be uplinked and downlinked in both crew-tended and autonomous modes. The ARISS team expected the SSTV system to be flown on Progress flight 14P in January 2004.

Conclusions

The ARISS-International team, with help from Kenwood and Yaesu, has developed the ISS Phase 2 ham radio system. The Kenwood system is currently on-orbit and will soon be operational on ISS. The team expects that the Yaesu system will be operational in spring 2004. This multi-national development effort presented many challenges to the team. Despite these challenges, the tremendous teamwork and optimistic spirit resulted in an outstanding new capability on ISS that we expect to set the standard in space for years to come.

Acknowledgements

The authors would like to acknowledge the tremendous support, teamwork, and volunteer spirit of the ARISS-International team in making this hardware system come to fruition. Technical, financial, and administrative support by the ARISS member organizations, the AMSAT organizations and IARU organizations (ARRL in the USA), continues to be crucial to the success of the program. Also, special recognition is in order to NASA, Energia, Kenwood, and Yaesu. The ARISS team continues to be indebted to them for all their in-kind contributions and support. Together we are pioneering the new frontiers of amateur radio and educational outreach.

Dedication

This paper is dedicated to the memory of Roy Neal, K6DUE. Roy's tireless pursuit to make amateur radio on human space-flight missions a permanent capability was an inspiration to us all. We feel privileged to have realized his vision on ISS during his lifetime. We have more solidly cemented that permanence with the delivery of the Phase 2 hardware system. Our thoughts and prayers are with you, old buddy.

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3. Bauer, F. and McFadin, L., "SAREX Hardware Configurations and Flight Operations Support," *Proceedings of the AMSAT-NA Tenth Space Symposium,* October 1992.

4. Bauer, F. and Marchant, W., "Amateur Radio on the International Space Station," *Proceedings of the AMSAT-NA Sixteenth Space Symposium,* October 1998.

5. "Joint NASA-Energia Meeting on Amateur Radio for the International Space Station Held at Johnson Space Center, Houston, Texas 22-27 January 1999," *The AMSAT Journal,* July/August 1999.

For more information on the ARISS program, you are welcome to visit the ARISS web page at: <http://ariss.gsfc.nasa.gov> or <http://www.rac.ca/ariss>.

Forty-power binoculars for the pilot and a 50-power telescope for the "driver" were mounted on a gun mount for altitude record attempts at Dahlgren, Virginia on July 4 & 5, 1963.

The Airplane

Details about the TAM-5 model were published in the January 2003 issues of *Model Airplane News* and *Model Aviation.* Here is a terse summary:

The dimensions are shown on a three-view. The structure was mostly balsa with mylar covering. The dry weight was 6.0 lbs. and the fueled weight was 1/4 ounce under the 11 lbs. (5 kg) allowed. The fuel was Coleman stove fuel with 16 oz of Indopol L-50 lubricant per gallon; 1.5 oz. of fuel was left in the tank on landing. A C&H Electronics CDI spark ignition system successfully fired about 8 1/2 million times. An Aveox brushless motor core was used as an alternator to provide power for all the electrical stuff. The custom-designed autopilot, its harness, its Piezo electric gyro, its pressure sensor, and a GPS receiver weighed 8 oz. The engine, no longer manufactured, was a 4-stroke 10 cc OSFS61. The propeller was a 14" × 12" wooden Zinger with the trailing-edge sanded to razor-sharpness before polishing and painting with epoxy.

A standard hobby radio-control system, Futaba 8UAP, on 50.880 MHz was used for practice flight and for launch and landing. The digital data stream in the autopilot's central processing unit was telemetered to ground by a 10-mw transmitter on 434.075 MHz. The antenna on this unit was a wire dipole mounted in the horizontal stabilizer transverse to the fuselage axis. This setup gave a fore and aft range of about 8 miles when the model was at 1600 feet altitude. This unit weighed less than 1/2 oz. A laptop computer on the ground displayed latitude, longitude, altitude, engine rpm, ground speed, heading, as well as elevator and aileron servo positions. These data sets arrived once a second when the model was in local range.

The same data sets were broadcast once a minute by an Argos wildlife tracking transmitter. The TAM models played a role in experiments aimed at adding GPS data to the Argos locating methods. Data sets received and recorded by Argos satellites were sent by e-mail messages to the Newfoundland operations center. Typically, reports came in once or twice an hour, depending on when various satellites of the Argos family were over the North Atlantic.

engine ought to run eight times as long, because power required to fly an airplane nominally increases with the cube of the speed. We flew 13 hours at 70 mph during her last record in closed course. Eight times 13 hours times 35 mph computes to a possible range of 4200 miles. Wow! That's New York to Rome! However, another factor is that there would be extra drag due to lift when flying slowly. There are textbook equations that predict the penalty. I threw all these numbers at my hand calculator and still came up with a predicted range of 3700 miles.

I am a pessimistic optimist who has published my "smart Alec" rule as a warning to dreamers and theoreticians. The rule states that for small air vehicles you should take wind-tunnel data, propeller-efficiency estimates, engine performance, and textbook equations, and divide the predictions by two to get a realistic estimate of what will happen in the real world.

During 1996 and 1997, I built and tested Martha-like models with fatter fuselages and longer-span wings. We flew racetrack patterns with a Garmin 75 GPS receiver on board to try to find the optimum wing, propeller, fuselage length and width. The numbers looked okay, and the 1998 closed-course performance beefed up our optimism. "Let's go for it!" was the vote of the team of helping friends.

We knew we would need money, so the Society for Technical Aeromodel Research was formed and announced at a "Gathering of the Eagles" at the Academy of Model Aeronautics in Muncie, Indiana on September 11, 1998. The goals of the society were two-fold: One was to honor and remember Captain John Alcock and Lt. Arthur Whitten Brown, who flew the first non-stop flight across the Atlantic from Newfoundland to Ireland on June 14, 1919. The other was to show young people that model airplanes can be creative, educational, and fun.

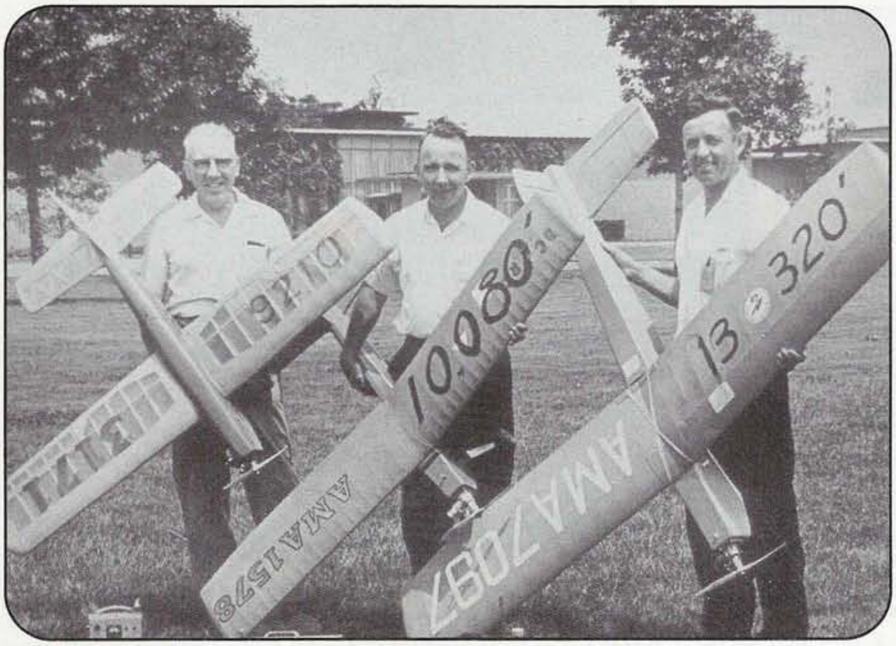
The First Attempt, 2002

The technical plan was straightforward. The distance from St. John's, Newfoundland to the west coast of Ireland is about 1900 miles. My real world rule said we ought to make that. We would launch and climb out using radio control on the 6-meter ham band. When the model reached the 300-meter altitude, we would switch to autopilot control and the model would use GPS position data to steer a great circle route to a predesignated place on the Irish coast. There, a pilot would take over from the autopilot and fly it down to a landing, again on the 6-meter ham frequency. Canada and Ireland both allow ham operators on 6 meters.

At first I thought it would be fairly easy to achieve the goal. The technical challenges seemed reasonable. We would have to convert "Martha" to slow flight configuration, add GPS steering, and away we'd go!

Wrong! It took three years and six crashes to develop the software and test the autopilot in modified "Martha" designs. Finally, in late July 2002 we packed four TAMs (transatlantic aeromodels) in a Dodge caravan that my wife, Gay, drove for five days to St. John's. The serial numbers were TAM #18 through #21. I had made 17 models with various design modes in order to arrive at the "best chance" design.

The model used for the first attempt was re-labeled TAM-1. It was launched from Cape Spear, the easternmost point of the North American continent, on



Three of the four competitors who surpassed the Soviet-held altitude record were Howard McEntee, W2SI, Walter Good, W3NPS, and Maynard Hill, W3FQF. McEntee was a well-known columnist and technical writer for ham radio and model airplane magazines from circa 1937 to 1970. Walt and his brother Bill flew the first hobby-type RC model in 1936. The fourth successful competitor was Bill Northrup, a well-known columnist for Model Airplane News *and* Model Builder Magazine.

August 8, 2002. Launch time was about 8:00 PM Newfoundland time. We hoped to land in daylight in Ireland about 33 hours later at 8:30 AM Ireland time. The Newfoundland-Ireland time difference is $3^1/_2$ hours.

Fizzle! TAM-1 went into lazy 300-ft. diameter circles and drifted out to sea when the autopilot was engaged. We think we may have damaged an aileron servo during a rough landing after a test flight earlier in the day.

TAM-2 was launched two days later. No circles this time! It took off on a beeline, straight out of sight in about 4 minutes. It looked good, but telemetry said it was headed southeast toward the Azores, not northeast toward Ireland. The engine faltered, and the sparse data indicated that the plane was dropping into the sea after only 17 minutes of "Wrong-way Corrigan" flight.

A flaw in the software codes was the culprit that made the model head off with a 60-degree error. This flaw was not detectable in our Maryland tests, because we never turned the model loose toward a distant waypoint. For safety reasons, we flew racetrack patterns within visual sight of the pilot, or else we programmed the thing to fly 3 or 4 miles along a rural road where we could chase it in a convertible.

The software fix took three days of hard work by Joe Foster and Les Hamilton. I looked for flaws in the engine of TAM-3 but found none. The weather was bad over the Atlantic, and Paul Howey, our landing pilot in Ireland, reported horrible rain and wind there. Eight days went by while we worked on TAM-3 and waited for good weather. Well, good weather never arrived. The predictions for August 18th were marginal, and when we went to the Cape for a try, dense fog rolled in at 7:00 PM so it was a no go.

The weather out to sea was still marginal, but we threw TAM-3 on the 19th and hoped. We launched at 6:00 PM to beat the fog. This model made 479 miles in 8 hours before the satellite telemetry disappeared. She had been looking good, rpm 3900, altitude 300 meters, and right on course on a 62-degree heading. Infrared weather images from NOAA satellites showed heavy rain in her path and we think that a downpour did her in.

Our "cheap" tickets home were for August 22, so we had run out of time for a TAM-4 attempt. We packed up our goods and headed home, depressed by having failed to achieve our goal, but encouraged by TAM-3's "right on!" technical performance.

This project has been manned by an all-volunteer group of about 20 fellow modelers and amateur radio enthusiasts. I don't think "abused" is the right word to describe their condition after the 2002 attempts, but "well used" is certainly appropriate. After some debate and recognition that another attempt in 2003 would not entail the intense testing of previous years, the team agreed to go on.

The 2003 Flight

During the winter and spring of 2002–2003, I searched for and found one seri-

These two models set six different world records in the 1990s and produced data that supported the idea that a transatlantic aeromodel flight should be possible.

Maynard Hill prepares to launch TAM-5 at Cape Spear, Newfoundland at 7:45 PM on August 11, 2003.

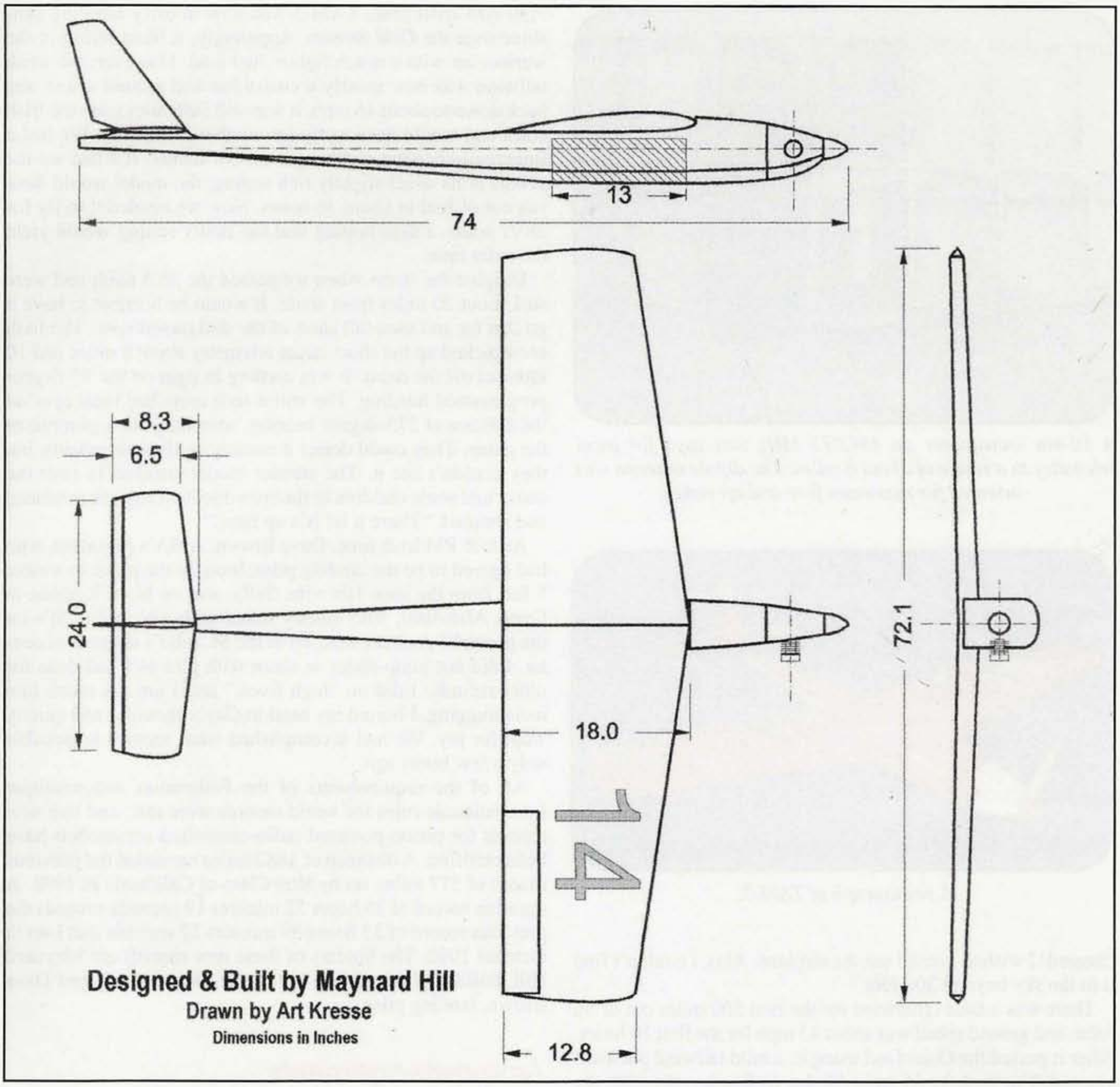
TAM-5 is on the way, headed into a west wind that was to be a tailwind when it turned onto a 62-degree heading toward Ireland. The tailwind fizzled during a good part of the 38-hour 52-minute flight.

ous flaw and a couple of minor ones in the engine-fuel-alternator systems. I was surprised, for I felt that after ten years of working on these OSFS61 engines, I should know everything there is to know about them. Not so! As we started out for Newfoundland in late July 2003, I privately wondered if still other things might crop up to do us in. The longer I worked on this obsession, the more difficult it seemed. I'd lie awake at night thinking about the myriad of things that could go wrong, wondering how many more were hidden and starting to think, "Hey! Maybe success isn't possible."

Nevertheless, my zeal surmounted my doubts, and during that same time, with generous help from a young high school student, Cyrus Abdollahi, I built six more TAM airframes and broke in and tested fuel consumption of six engines by running each of them about 25 hours. Lynn Bronson, Julian Cottrell, and Joe Foster assembled five new autopilots and harnesses, each of which had to be put through "shake and bake" ground tests. Then each had to be tested in flight. One of these brand-new "all up" birds, TAM-26, didn't make it. It disappeared into the woods shortly after its virgin launch on July 18, 2003, with its autopilot, engine, gyro, alternator, altimeter, and telemetry transmitter all gone—gone! gone! gone! —in spite of air and ground searches.

On July 26, 2003, Gay and I set out for Newfoundland with a van full of five all-up TAM models and auxiliary equipment. Three days out we took a break from the Trans-Canada Highway and went onto a scenic route along the northern coast that the Nova Scotians call the "Sunrise Trail." In mid-afternoon on this warm, blue-sky day we found ourselves in Pictou, a charming resort village on the water. Giving ourselves up to tourism, we visited a museum dedicated to the building of a replica of the sailing ship *Hector*, a three-masted wooden ship that had carried 179 Scotch immigrants to this nearly barren shore in the 1770s. We searched the ship's record for family names we knew, climbed up into the captain's quarters, tried to imagine 179 people in a space about the size of a Greyhound, and became the quintessential tourists. This interlude was fascinating and erased all

Landing pilot Dave Brown and a crew of Irish hams took this photograph at a monument erected to honor R.A.F. Captain John Alcock and Lt. Arthur Whitten Brown, who made the first non-stop flight across the Atlantic on June 14, 1919. The monument is at Round Stone Bog, Ireland. TAM-5 landed on a grassy spot on Mannin Beach about two miles from this monument.



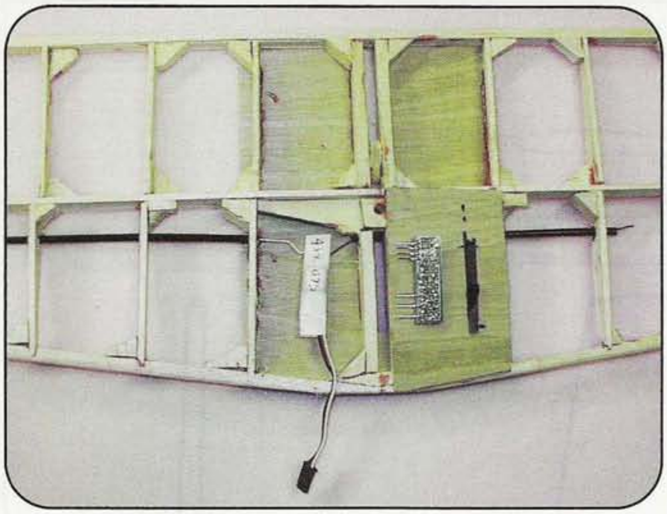
A drawing of the TAM-5.

thoughts of possible failures. Neither of us was eager to get back on the road. Gay had long been privy to my fears, and as we climbed back into the van, she smiled and said, "You know, Maynard, this is a long way to go to throw five little red airplanes into the water!" We laughed, grasping the futility of worrying on such a lovely day.

We threw TAM-4 to the ocean with an 8:00 PM launch on August 8, 2003. After about 7 hours and 430 miles of flight, it sent no more signals to the tracking satellites. The weather was fair with mild tail winds. Data about ground speed and altitude had been normal. The closeness to TAM-3's demise in 2002 brought on speculation that it might be carburetor ice. I couldn't buy that explanation, though, because the engine had run fine in my shed at temperatures down to 20 degrees and at humidities near 100% at many temperatures. Somebody suggested the Bermuda Triangle had a cousin off Greenland. Cyrus thought the Icelandic navy gunboats needed target practice. We didn't have a clue!

Weather over the Atlantic was predicted to stay mild through the 11th but would go to the dogs soon after. A quick turnaround by a tired crew got TAM-5 unpacked, trim flight tested, fueled, and weighed for a launch at Cape Spear at 7:45 PM Newfoundland time. Ordinarily, it takes me about 4 hours of engine run and fuel-consumption measurements to gain confidence about the needle-valve setting. I had trouble with a fussy filter and had to replace it. I had only about a half-hour of measuring before it was time to proceed to Cape Spear. I was leery and debated scrubbing the launch, but because of the poor three-day forecast I decided to proceed and hope.

The evening fog that plagued us at Cape Spear in 2002 did not happen in 2003. TAM-5 was launched into clear sunset skies. Beautiful! Everyone



A 10-mw transmitter on 434.075 MHz was used for local telemetry to a range of about 8 miles. The dipole antenna was oriented for maximum fore and aft range.

A photograph of TAM-5.

cheered! I wished I could see the airplane. Alas, I couldn't find it in the sky beyond 200 feet.

There was a little crosswind for the first 500 miles out of St. John, and ground speed was about 43 mph for the first 10 hours. After it passed the Greenland triangle, a mild tailwind put average speed up to about 55 mph. All day on Sunday, the 10th, the satellite data said the engine rpm was fluctuating from 3200 to 4100—very abnormal and scary. Altitude was a porpoising path, up to 320 meters, down to 270. This was also abnormal and scary. It appeared the needle valve was set on the lean side of a proper fuel mixture. Engine power was a bit weaker than was needed to make these TAM models get "up on the step" for a clean cruise. We could worry, but there was nothing to do but hope.

TAM-5 plodded along and reported in all day Sunday. Then from 1:00 AM to 4:00 AM Monday, Newfoundland time, there was no satellite data. It sure looked like another goner.

We were telephoning the Ireland crew to go back to bed, when Cyrus announced there was new satellite data. Call Ireland! Tell them it's still flying! Not only was it still airborne, it was flying better. After 32 hours the rpm was smooth at 3900, the altitude steady at 300 meters, and auto-elevator trim had gone from nearly full "up" to the normal slight "down" trim. It was still dark in Newfoundland, but 4:00 AM Newfoundland time is 7:30 AM Irish time. TAM-5 was now in early morning sunshine over the Gulf Stream. Apparently, it liked flying in the warmer air with a much lighter fuel load. However, the weak tailwind was now mostly a crosswind and ground speed was back down to about 46 mph. It was still 300 miles from the Irish coast and would have to fly for another $6\frac{1}{2}$ hours. We had a fingernail-chewing cliffhanger on our hands! If I had set the needle at its usual slightly rich setting, the model would have run out of fuel in about 36 hours. Now we needed it to fly for $38\frac{1}{2}$ hours. I kept hoping that the faulty setting would yield the extra time.

Imagine the stress when we passed the 38.5 mark and were still about 20 miles from shore. It would be horrible to have it go that far and then fall short of the designated spot! The Irish crew picked up the short-range telemetry about 8 miles and 10 minutes off the coast. It was coming in right on the 95-degree programmed heading. The entire tech crew had their eyes on the horizon at 275-degree bearing, searching for a glimpse of the plane. They could detect it coming on the instruments, but they couldn't see it. The slender model sneaked in over the coast, and some children in the crowd looked straight overhead and shouted, "There it is! It's up here!"

At 2:08 PM Irish time, Dave Brown, AMA's president, who had agreed to be the landing pilot, brought the plane in a mere 5 feet from the spot. His wife, Sally, was on her cell phone to Cyrus Abdollahi, who quietly stated with a big grin, "It's on the ground." A cheer went up in the St. John's operations center. I did not jump about or shout with glee as I had done for other records. I did no "high fives," and I am not much into male hugging. I buried my head in Gay's shoulder and quietly wept for joy. We had accomplished what seemed impossible only a few hours ago.

All of the requirements of the Federation Aeronautique Internationale rules for world records were met, and two new records for piston-powered radio-controlled aeromodels have been certified. A distance of 1882 miles exceeded the previous record of 517 miles set by Ron Clem of California in 1998. A duration record of 38 hours 52 minutes 19 seconds exceeds the previous record of 33 hours 39 minutes 22 seconds that I set in October 1992. The holders of these new records are Maynard Hill, builder of the model; Joe Foster, launch pilot; and Dave Brown, landing pilot.

Acknowledgements

I am indebted to a large team of aeromodelers and hams for their volunteer help. Many of them worked on this project for the past five years. Their many contributions are too extensive to detail here. A list of all team members follows. I express deep gratitude to each and every one of them.

In the United States: Cyrus Abdollahi, Ron Bozzonetti, Lynn Bronson, Dave Brown, Sally Brown, Beecher Butts, Julian Cottrell, Charlie Calvert, Roy Day, Joe Foster, Loretta Foster, Les Hamilton, Gay Hill, Lamont Hill, Scott Hill, Paul Howey, Russell Howey, Art Kresse, John Patton, Ted Rollins, Rob Rosenthal, Bill Savage, and Bob Yount.

In Canada: Carl Layden, Nelson Sherren, John Shortall, Craig Trickett, and the 150th Wing of the Royal Canadian Airforce Association.

In Ireland: Noel Barrett, Enda Broderick, Ronan Coyne, Aengus Cullinane, Joe Dible, Tom Frawley, David Glynn, Richard Glynn, Andy Hopkins, and John Molloy. ■

Photo 31. The GS-23B tube.

the screen cage windows are perfectly aligned, the resulting screen current will be very low and stability improved.

A tube that shows high grid and screen current does not have the grid and screen cage windows perfectly aligned, and some accelerated electrons hit the screen instead of passing through the window. In addition, a tube that responds well to drive that has normal grid and screen current but low efficiency probably has a small variation in the distance between the elements around the circle. Any variation in this distance will accelerate the electrons in a non-symmetrical fashion around the circle, and they will arrive out of phase. There is nothing we can do about this effect from outside the tube. This behavior is frequency dependent, because the phase error gets smaller at lower frequency. This is why a tube such as this would work well at 70 cm, but not at 23 cm.

Photo 32. The GS-23B with the air-cooler fins removed.

The air cooler is not easily removed, although a process for irrevocably removing it piece by piece is shown at <http://www.nd2x.net/kd5fzx-gs23H2O.html>, along with details for a water cooler. Photo 32 shows a GS-23B with air-cooler fins removed. One separates the cooling fins by inserting a screwdriver in the seam between fins on the outside of the cooler. Each fin is then grabbed with needle-nose pliers and wiggled until it breaks off. It takes approximately 20–30 minutes to remove all fins.

Sockets are not available and are constructed as part of the PA designs in which this tube is used. The center socket from an SO-239 UHF chassis connector is perfect for the filament-only connection. Dimensions for the remainder of the connections can be found at <http://www.nd2x.net/kd5fzx-gs23PA.html> along with details for constructing a 23-cm, 1000-plus-watts GS-23B PA. This tube is generally available for approximately $150 delivered, but I have seen it for as little as $109 plus shipping.

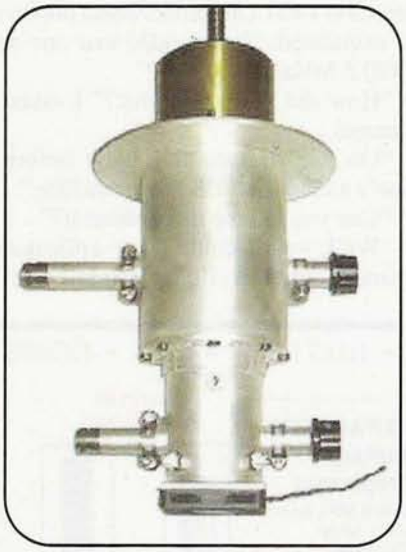


Photo 33. The KD5FZX 23-cm PA with water-cooled GS-23B installed.

Application: The GS-23B tetrode is rated at 1500 watts of anode dissipation through 1000 MHz and will easily deliver 1500 watts at HF and through 70 cm with 3000 volts on the plate and 525 volts on the screen (these values exceed the 2500 volt and 500 volt limits shown in the specifications). With 100 watts of drive at these voltages it is possible to exceed 1300 watts of output on 23 cm with no thermal drift. At relatively low duty cycles one may expect full legal limit on 23 cm without thermal drift. The KD5FZX 23-cm PA shown at <http://www.nd2x.net/KD5FZX.html> (photo 33, with water-cooled GS-23B installed) proves this assertion. After testing over three dozen tubes, it appears that only one in six or seven GS-23Bs will work properly on 23 cm. The ones which *do* work do so *very* well. The 23-cm PA pictured was once pushed to 1700 watts out (into a dummy load). No problem! Tubes that do not perform at 23 cm can still perform well at 70 cm. One tube that would only deliver 400 watts on 23 cm when tested was installed in a 70-cm PA at the QTH of Richard Ewing, KO7N, and it easily exceeded full legal limit (dummy load, again).

Also, in preparing these NOS, old-stock tubes for use it was discovered that the 24 hours of gettering usually considered sufficient often was not enough. Three to five days was found to be far more effective!

Photo 34. The GS-36B tube.

Photo 35. The GU-43B tube.

GS-36B: At 2.6 inches tall, this tube (photo 34) is similar to (and sold by Svetlana as) the 4CX400A. It is specified to have full ratings through 500 MHz, with a design life over 1000 hours. I only have a Svetlana tech bulletin which presents information about it. With proper attention to power-supply voltages and socket pinouts, it would appear to be an excellent candidate to replace 8122 tetrodes in existing PAs.

GU-43B: With 1000 watts of anode dissipation rating to 100 MHz and a design life over 1000 hours, this tetrode (photo 35) is an excellent candidate for a full legal-limit PA for HF through 6 meters. It is a large tube, at 5 inches tall and weighing 3.3 pounds. An article in a Russian-language radio publication shows an HF PA application, the only GU-43B information found by this author (to date).

GU-74B: Generally considered equivalent to, and sold by Svetlana as, the 4CX800, the original Russian military tube manual rates the GU-74B (photo 36) at 600 watts of anode dissipation through 250 MHz. Hams who use it say it performs more like a 900- to 1000-watt anode dissipation tetrode. It plugs into a bare (no grid rings, etc.) 4CX250B socket.

It is capable of full legal limit on 2 meters, and it seems to be standard practice to run the screen at 320 to 340 volts in spite of specifications of 300 volts as maximum, and 2500 volts on the anode, with maximum specified as 2000 volts.

Photo 36. The GU-74B tube.

Photo 37. The GU-78B tube.

The grid-driven, single GU-74B VHF PAs present neutralization challenges. The passive, resistively swamped input circuits seem to be preferred to solve the PA oscillation problem. Another solution would seem to be using two tubes, as no reports of instability have been noted in such PAs, e.g. the rock-crusher built and sold by Marko Cekow, LZ2US, and described at <http://www.nd2x.net/lz2us-3.html>. The GU-74B is available for as little at $50 plus shipping, but the most common price seems to be $70 delivered. Russian sockets can also be found for $20 to $45 each.

GU-78B: Although information is beginning to trickle in with respect to the GU-78B (photo 37), I have no significant war stories or rumors to relay regarding this tube. Joe Bell, G4PMY, owns a Russian ZIL communications truck with a GU-78B transmitter. His two picture-filled articles about this truck make fasci-

DR. SETI'S STARSHIP

(from page 84)

us confidence in the capabilities of our signal-analysis techniques—thus validating the software.

3. Most important, our amateur SETIzens did not ring up *The Times* of London, the BBC, or (heaven forbid!) *The Sun* (that bastion of journalistic excellence), and proclaim, "ET is calling me." Rather, they opted to abide by The SETI League's Signal Verification Protocols and *Ask Dr. SETI.* As a result, we had our first solid evidence that nonprofessionals were indeed capable of shunning sensationalism and conducting credible science. This validated the wetware —the substance between the ears of our erstwhile amateurs.

I showed an image of the candidate signal to a room full of radio astronomers at the National Radio Astronomy Observatory in Green Bank, West Virginia, home of the world's first SETI search in 1960. One professional observer exclaimed, "You landed that one on 1470.5 MHz, didn't you?"

"How did you know that?" I asked, stunned.

"Oh, we've seen this baby before. She's a classified US Navy satellite."

"Can you tell me more about it?"

"Well, yes, I could," my colleague grinned, "but then I'd have to kill you."

Photo 38. The GU-84B tube.

nating reading (see <http://www.nd2x.net/Zil_Radio_Truck.htm>). The GU-78B tetrode is rated at 2500 watts of anode dissipation through 250 MHz; predicted tube life is not specified. Svetlana sells it as the 4CX3000. One current eBay price is "buy now" for $350 plus shipping.

GU-84B: Also at this writing, even though since the beginning of 2003 there has been a surge in interest and e-mail traffic regarding the GU-84B (photo 38) in HF PAs, I have no significant war stories or rumors to relay about this tube. Promises of pictures and operational parameters have been made by two or three hams who are in the midst of gathering parts in preparation for building amplifiers using the GU-84B. Like the GU-78B above, the GU-84B is also rated at 2500 watts of anode dissipation to 250 MHz and has a designed tube life of at least 1500 hours. It is also referred to as the 4CX2500. Current eBay price is "buy now" for $160 plus shipping, but a quick Google search turned up $122 plus shipping from a second source, and $66 plus shipping from a third.

Tube Sources

It has become fruitful to search the internet for tubes by their designator. Be sure to search under all variations in order to cover the internet in an exhaustive manner. For example, if searching for the GS-35B, search under GS-35B, GS35B, GS-35, GS35, gs35, gs-35, gs-35, and gs-35b. A few of these will bring up the same (or very similar) listings, but one never knows, so search under all the different ways of writing a given tube type. Dr. Alex, UR4LL, does not always have every tube type one might desire, but he is very reliable regarding those items which he *does* have (see the list at <http://www.nd2x.net/ur4ll.html>), so do not hesitate to e-mail him at <alex@zcrb.kharkov.ua>. Also, search under "sellers" such as "pavel_pop" and "anthonywelsh" on eBay. A search for "Russian transmitting tubes" using your favorite internet search engine will also turn up several sources, some of which are commercial and expensive. At this writing, though, with care and shopping Russian tubes can be found and purchased for very reasonable prices.

It has become fruitful to search the internet for tubes by their designator. Be sure to search under all variations in order to cover the internet in an exhaustive manner.

I continue to look for data and other material on Russian tubes. If you have appropriate information, please contact me via the e-mail address listed on the first page of this article. ■

By Kent Britain,* WA5VJB

ANTENNAS

Connecting the Radio to the Sky

Horn Antennas

Horns areamong the simplest gain antennas. In simple terms, you are collecting radio waves and funneling them down to a monopole antenna. They are difficult to mess up electrically, and no matter how you mess them up, they usually still have gain.

Photo A shows one of three 15-dB gain horn antennas. In photo B, on the horn end of the large antenna in the previous photo I have two more 15-dB gain horn antennas. Of course, the big one covers the 2.3- and 3.4-GHz bands, while the little ones cover the 24-GHz band at the low end and 35 GHz at the high end. It shows how simple a horn antenna is.

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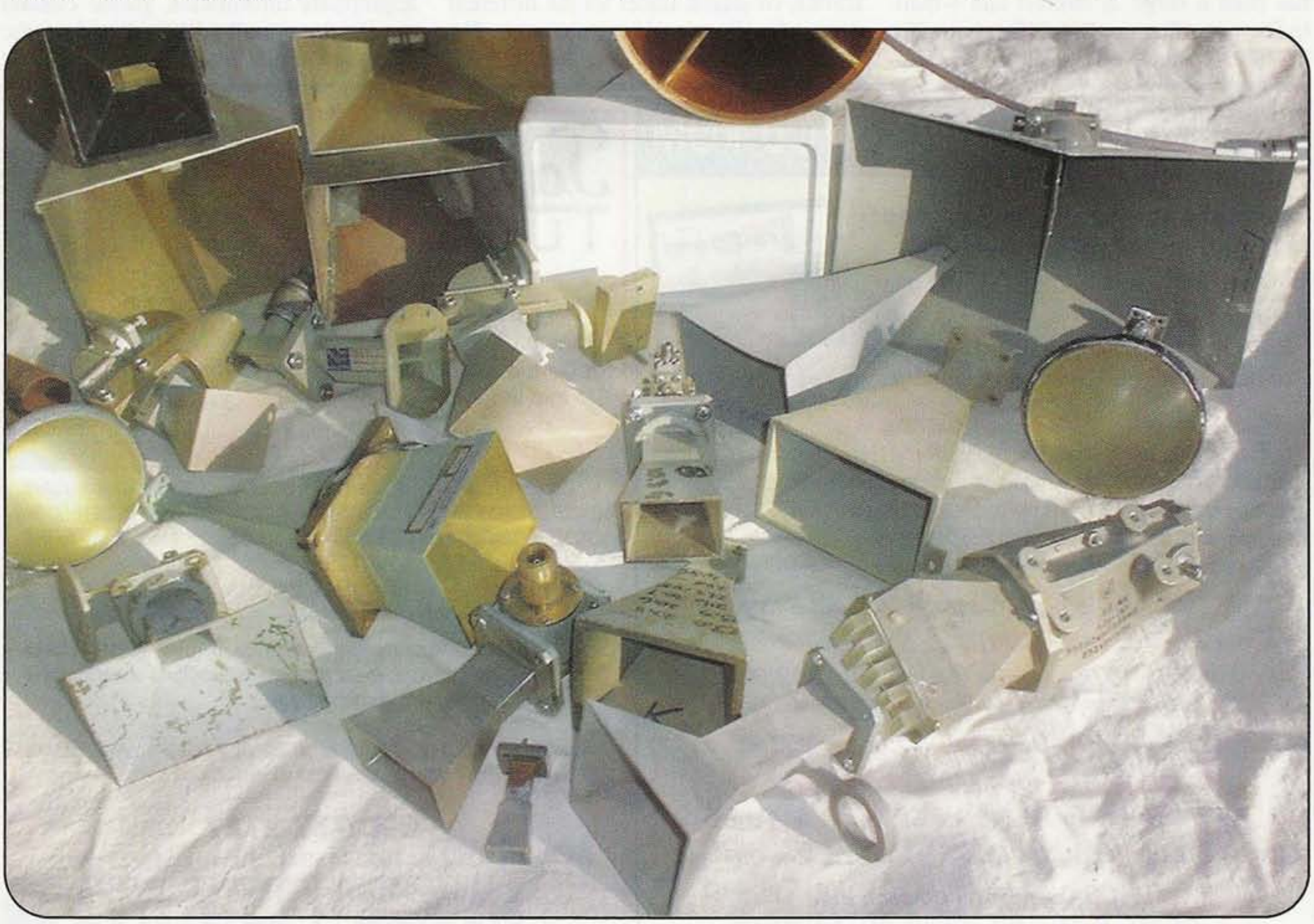
In figure 1A we show the waves coming into the opening of the horn and reflecting down into the waveguide. The waves hitting the edge of the horn have to travel farther than the waves going straight in. They all don't arrive together, or in phase. The easiest way to minimize this problem is to make the sides of the horn longer, as in figure 1B; now you have less phase error. If I make the opening wider, I'll catch more signal, which is certainly a trade-off. An optimum horn is one in which these two design parameters are compromised for the best trade-off. It also means that you can make it bigger, or longer, without changing gain very much. As I said, horns are pretty "idiot resistant."

This time I'm going over a downloadable spreadsheet program that you can use both to design horn antennas and to analyze an existing design. To download the program, go to CQ VHF website, <www.cq-vhf.com> and highlight this issue of *CQ VHF* magazine. The program is also available from the North Texas Microwave Society site; just visit <http://www.ntms.org>.

Start with the waveguide size you plan to use. The program contains a lookup table if you can't remember the dimensions of WR-90 (waveguide). Now enter the frequency range in which you are interested. Go ahead and make it a pretty wide frequency range, because horns are very broad band antennas. The frequency range of your waveguide is a good starting point. Next, you'll need to enter



Less than half of WA5VJB's horn antennas.

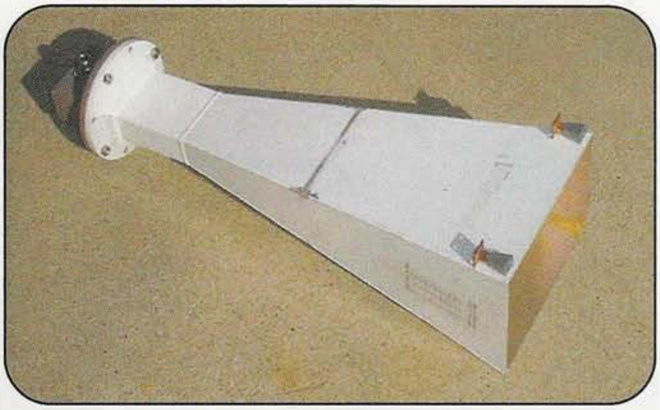


Photo A. One of three 15-dB gain horn antennas.

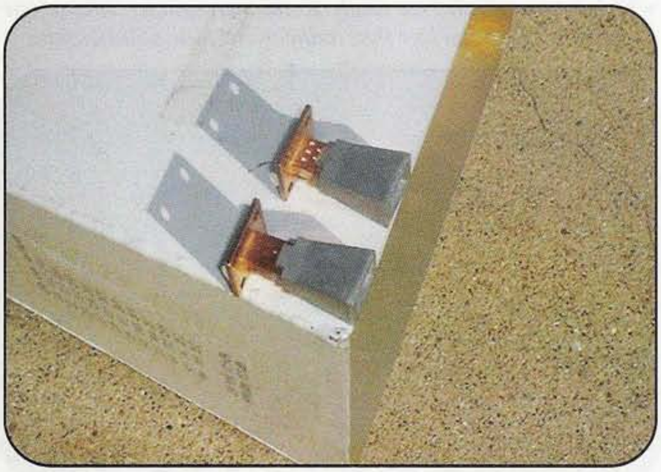


Photo B. Two more 15-dB gain horn antennas on the horn end of the large antenna in photo A. The big one covers the 2.3- and 3.4-GHz bands, while the little ones cover the 24-GHz band at the low end and 35 GHz at the high end.

the length of the sides along with the width and height of the opening.

Note that gain goes up as frequency goes up. If it doesn't, you have way too much flare to your horn. You also can quickly see that to get more and more gain, you have to make the horn longer and longer. Photo C shows some homemade 24 GHz horns again. Note just how long I had to make the 25-dBi gain horn.

Another good antenna program that does several antenna calculations, including horns, is W1GHZ's HDLANT program. Just go to <www.qsl.net/N1BWT> and download HBL_3B3. If you are good at bending sheet metal, this one will print out a template with which to make the antenna.

Horns as Reference Antennas

I like to use a horn antenna as my test reference antenna whenever possible. Built to the program dimensions, the gain will be within a few tenths of a dB of its theoretical value. They make great low-cost reference antennas for antenna ranges or EMI/EMC (electromagnetic interference/electromagnetic compatibility) work.

Patterns

The spreadsheet program will also let you tailor the beam pattern for your needs.

If you want to use the horn as a dish feed, it will be important to get the E and H patterns matched as shown in figure 2. If you want to use the horn on a microwave beacon, then the pattern in figure 2B might match your needs more effectively. Perhaps you want a communications link and your desire is to minimize side interference? Then pattern C might be best. This spreadsheet is a very powerful design tool.

Ridges

In photo D you see a pair of horn antennas with ridges. The ridges lower the usable frequency of the horn. If I have a 6–10-GHz horn, the ridges can make it into a 4–10-GHz horn. The horn on the right works from 4 to 10 GHz. The horn on the left with the extreme ridges works from 1.2 to 18 GHz. This one has two sets of ridges because it has two coax connectors, allowing it to work on vertical and horizontal polarization at the same time. Yes, the two ports could be used to generate circular polarization with a power divider and phase shifter, but only over a narrow frequency range. There is an easier way to get circular polarization out of a horn antenna, however.

You can use the spreadsheet program to give you a good idea of the gain of a ridged horn, but only over the frequency range of the waveguide. For that 4–10-GHz horn, the program would only work over the 6–10-GHz operating bandwidth of a rectangular waveguide that size.

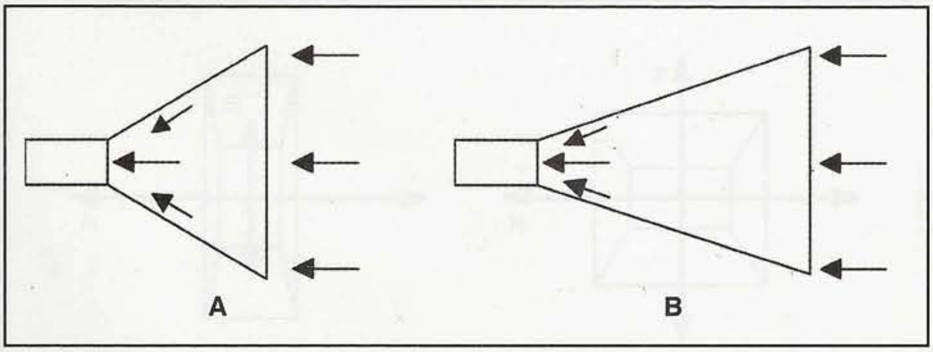


Figure 1. Phase error of a horn antenna. (A) The waves coming into the opening of the horn and reflecting down into the waveguide. The waves don't arrive together, or in phase. (B) The easiest way to minimize this problem is to make the sides of the horn longer.

Polarizer

The horns shown in photo E have a sheet of plastic in the horn. You'll notice that it's at a 45-degree angle to the waveguide. This is one version of a polarizer that induces circular polarization. When you want circular polarization with a pair of Yagis, you make one phasing line a quarter wave or 90 degrees longer. You can also get the same phase shift by mounting one antenna 90 degrees behind the other. That's much like what is being done here. When the signal passes through the plastic, it is dragged, or slowed down. Put in just the right amount of

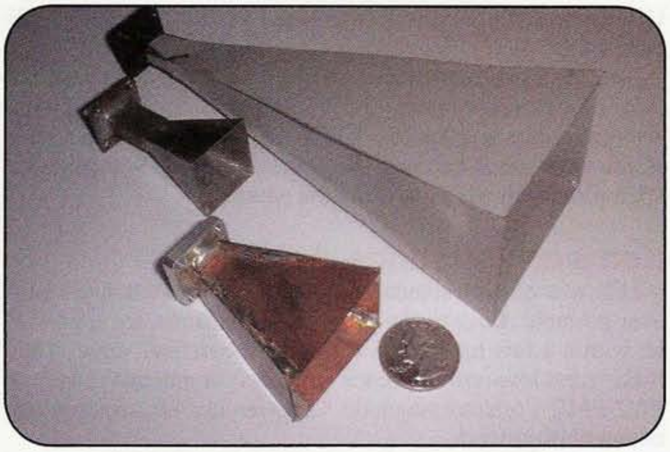


Photo C. To get more and more gain, you have to make the horn longer and longer. Here are some homemade 24-GHz horn antennas. Note just how long the 25-dBi gain horn is.

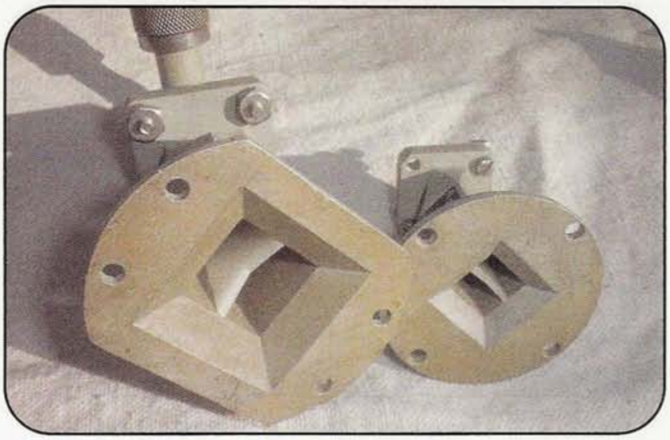


Photo E. These horn antennas have a sheet of plastic in them which is at a 45-degree angle to the waveguide. This is one version of a polarizer that induces circular polarization.

Photo D. A pair of horn antennas with ridges.

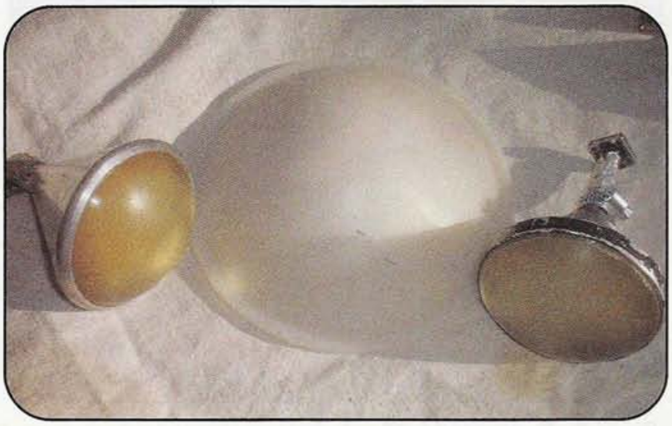


Photo F. This large lens, from a British 43-GHz horn-antenna system, was used to focus the waves into the receiver.

plastic, and part of the wave is delayed 90 degrees and the other part is not. This induces circular polarization.

Lens

A lens can be used with a horn antenna in two ways. The large lens in photo F came from a British 43-GHz system. The lens was used to focus the waves into the receiver, much like using a large magnifying lens to focus light. The two smaller horns are being used at 24 GHz and 47 GHz. When you have a horn antenna this short, there is a lot of phase error in the horn. The radio waves at these frequencies are less than half an inch long, and coming from the edges of the horn, they have to travel much farther than that. Phase error can be more than 360 degrees! That can make the math fun! One important part of optics is that light (and radio waves) traveling through glass or

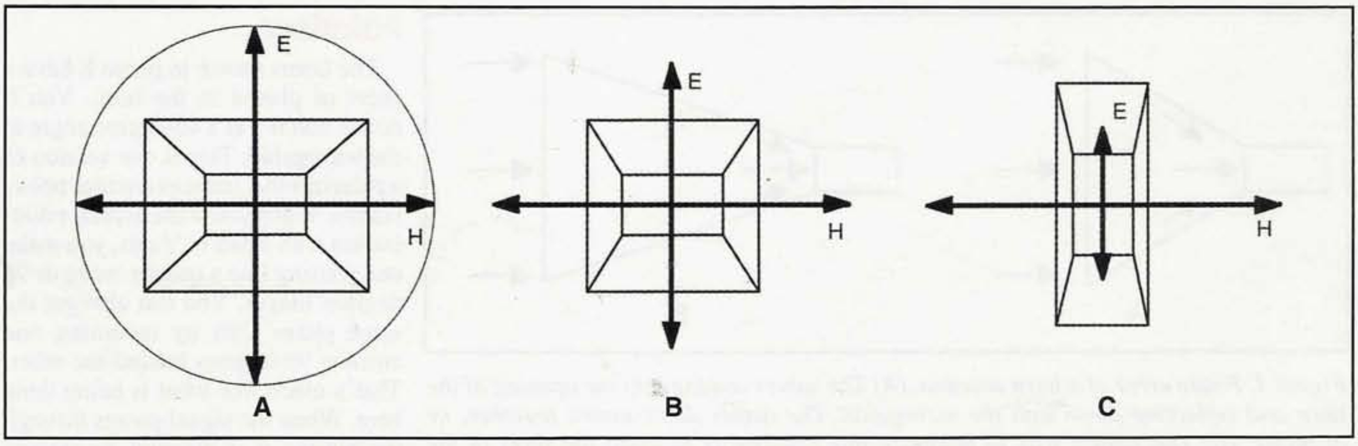


Figure 2. Controlling the E and H patterns of a horn antenna (see text).

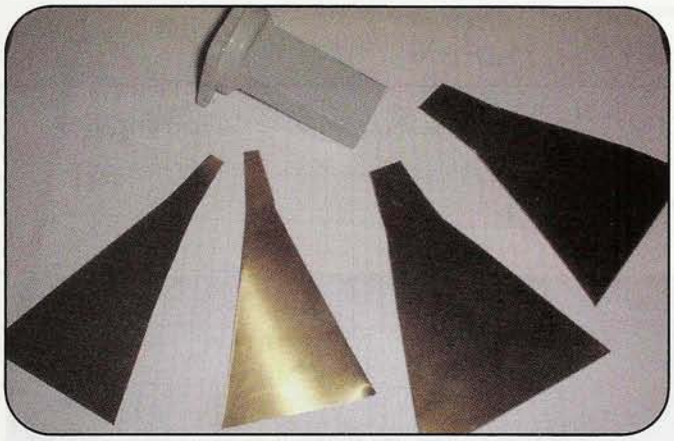


Photo G. The top and bottom brass sheets for the horn antenna.

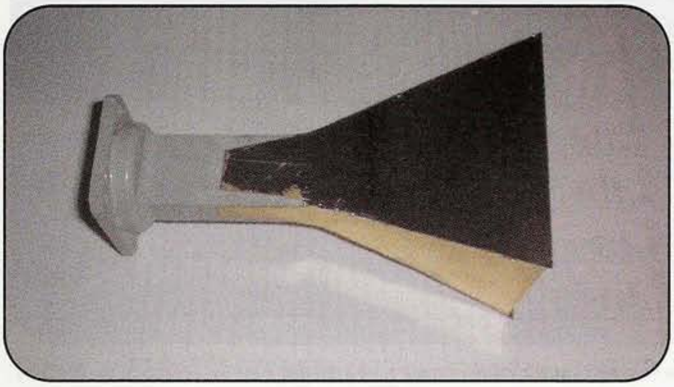


Photo H. The completed horn antenna.

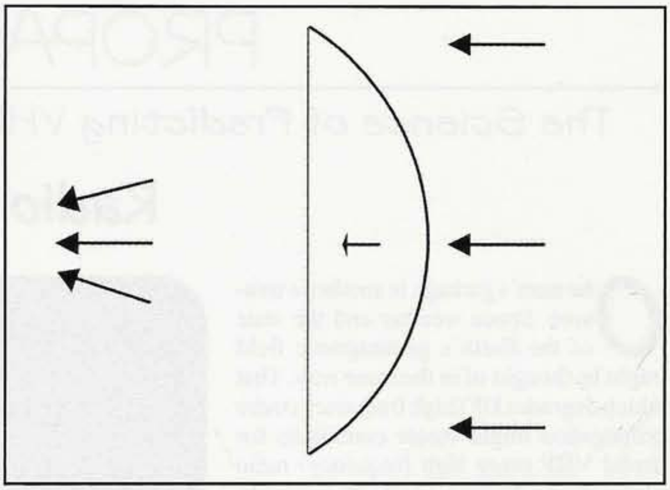


Figure 3. The effects of a lens on a horn antenna.

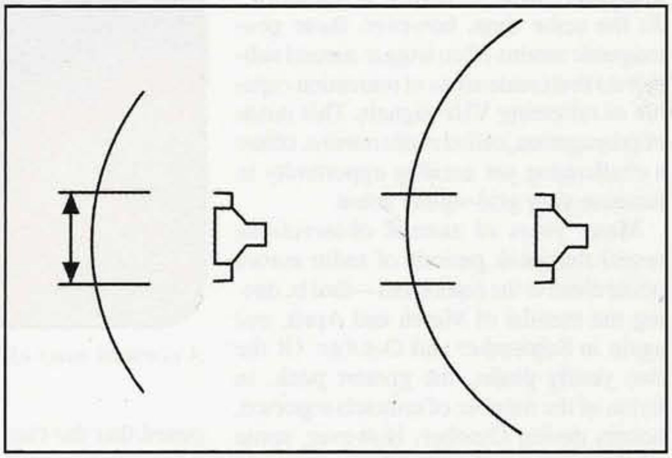


Figure 4. Aperture blockage, or the part of the dish shadowed by its own feed.

plastic travels more slowly through these media than it does through air. Therefore, the waves going through the thick center portion of the lens are slowed down; waves going through the thinner edges are slowed down less (see figure 3). Now all the waves can arrive at the throat of the horn together and in phase.

Construction

There are many ways to build a horn antenna. Using old sheets of PC board is my favorite. The PC board can be cut with a shear, or when it's thin, a paper cutter. Sheet brass, sheet tin, or almost any other solderable material can be used. Here we have a simple sheet-brass horn on WR-90 waveguide, WG-16 for the UK readers (photos G and H). The opening of the horn is 3 inches wide by 2 inches high, and the sides are 3 inches long. You can expect about 16 dBi gain from this antenna on 10.3 GHz.

Flanges and Waveguides

One way to build a horn is by using a waveguide flange and building the horn on the flange. Short sections of waveguide are usually easier to find. This is also good with aluminum waveguide that is very hard to solder. Photo G shows the top and bottom sheets. Super Glue® works well; epoxy glue works better, but takes longer. After the glue has hardened, bend up the top and bottom right at the opening of the waveguide and then glue on the sides. Make sure you have a really snug, tight fit between the four sides. When all the glue has set, solder the four seams. In 15 minutes you have a finished horn, as shown in photo H. At the opening, I usually solder along the inside of the horn. As you get back closer to the waveguide, you'll need to solder along the outside seam. If your solder techniques are better than mine, and you're using brass waveguide, you can solder the entire assembly.

Letters, Letters . . . We Get Letters

From Rick: *Last time you mentioned not getting rated gain from a dish since the feed blocked it?*

Perhaps "aperture blockage" would have been a better term. The feed of the dish is blocking some of the signal bouncing back off the surface (figure 4). With a really big dish, this is a relatively small problem. As the dish gets smaller and smaller, a larger percentage of the dish is blocked, because the feed is staying the same size. A second problem is that the preamp is looking into its own reflection. Unless the preamp is perfectly stable, and they rarely are, this often will make the preamp oscillate.

I'll be happy to help you the best I can with your antenna and microwave questions. Just contact me at the snail-mail or e-mail address on the first page of this column. ■

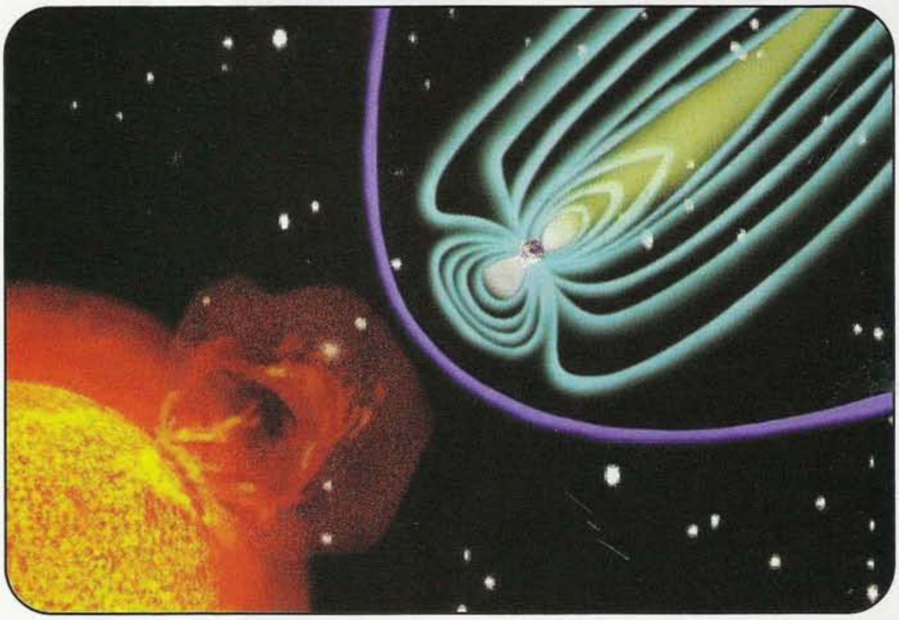
By Tomas Hood,* NW7US

PROPAGATION

The Science of Predicting VHF-and-Above Radio Conditions

Radio Aurora

One man's garbage is another's treasure. Space weather and the state of the Earth's geomagnetic field might be thought of in the same way. That which degrades HF (high frequency) radio propagation might create conditions for useful VHF (very high frequency) radio propagation. During times of minor to severe geomagnetic storm activity, the ionosphere loses its ability to refract HF. At the same time, however, these geomagnetic storms often trigger auroral substorms that create areas of ionization capable of reflecting VHF signals. This mode of propagation, called *radio aurora,* offers a challenging yet exciting opportunity to increase your grid-square count.



A coronal mass ejection's plasma cloud comes toward the Earth. (Courtesy NASA)

Many years of auroral observations reveal that peak periods of radio aurora occur close to the equinoxes—that is, during the months of March and April, and again in September and October. Of the two yearly peaks, the greater peak, in terms of the number of contacts reported, occurs during October. However, some of the strongest levels of geomagnetic storms are in the spring. The minimum yearly activity occurs during the months of June and July, with a lesser minimum during December.

When active aurora is seen in the auroral zone, a strong magnetic disturbance is usually also observed there. These disturbed magnetic fields often are much stronger than those of a geomagnetic storm, but are strictly local, fading away quickly as one moves equator-ward. This suggests that the currents that disturb the magnetic fields flow somewhere nearby—probably near the auroral arcs. The Norwegian physicist Kristian Birkeland (whose portrait appears on Norwegian currency) carefully observed auroral disturbances and concluded that the currents flow parallel to the ground, along the auroral formation. Because electrical currents must flow in a closed circuit, and because these magnetic disturbances seemed to be caused by processes taking place in distant space, Birkeland proposed that the currents came down from space at one end of an arc and returned to space at another end.

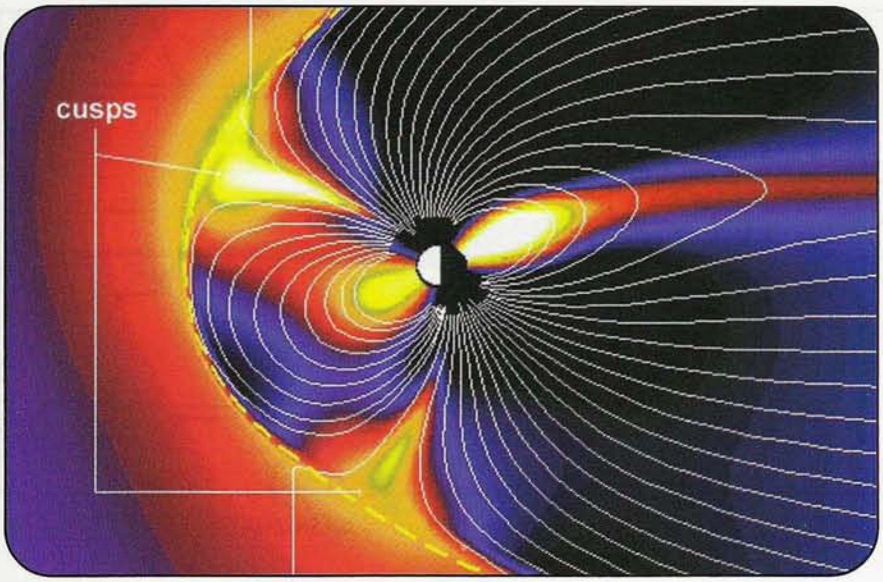
In 1910 Birkeland performed a series of experiments to reproduce many of the characteristics of the aurora that he had observed during his expeditions. He placed an electromagnetic sphere, coated with fluorescent paint, inside a vacuum chamber and projected a beam of electrons at the sphere. This enabled him to view the trajectories of streaming electrons. Birkeland was able to accurately reproduce how solar wind would make its way into the Earth's magnetic poles, and was able to simulate the auroral ovals near the Earth's magnetic poles.

Finally, in 1954, auroral electrons were actually observed by sensors aboard a rocket launched into an aurora by Meredith, Gottlieb, and Van Allen, of Van Allen's team at the University of Iowa. The Van Allen team discovered the Earth's radiation belts, now called the Van Allen Belts.

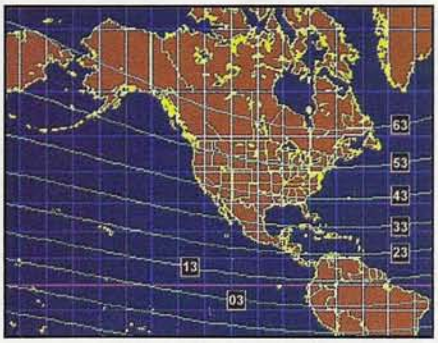
Continual research has revealed that aurora is caused by the large-scale interaction between the Earth's magnetic field and the solar wind. The magnetic field around the Earth, called the *magnetosphere,* is distorted by a flow of charged particles, mainly protons and electrons, which flow away from the sun. This flow is called the *solar wind,* which also contains magnetic field lines. On the windward side, the side mostly facing the sun, a bow shock is formed, while on the leeward (opposite) side, the magnetosphere is dragged out into a long tail. This magnetosphere acts as a giant shield around the Earth, blocking the solar-wind particles. However, there are distinct regions in the magnetosphere where solar-wind particles may enter the Earth's upper atmosphere. Solar-wind particles can enter directly via the dayside cusps, or having been trapped in the plasma sheet around the Earth, they can enter via the enclosed magnetic-field lines at the polar auroral oval on the night side.

In 1961, Dr. Jim Dungey of the Imperial College, United Kingdom, predicted that cracks might form in the magnetosphere when the solar wind contained a magnetic field that was oriented in the direction opposite to a portion of the

*P.O. Box 213, Brinnon, WA 98320-0213
e-mail: <cq-prop-man@hfradio.org>



Polar cusps are narrow regions of recently "opened" or merged magnetic-field lines mapping to the high-latitude ionosphere just poleward of the last closed field line on the Earth's day side. These regions are centered on local noon and extend approximately two to three hours in longitude and approximately one degree in latitude. The open field lines of the cusps are connected with those of the interplanetary magnetic field, which allows the shocked solar-wind plasma of the magnetosheath to enter the magnetosphere and penetrate to the ionosphere. (Courtesy NASA/IMAGE)

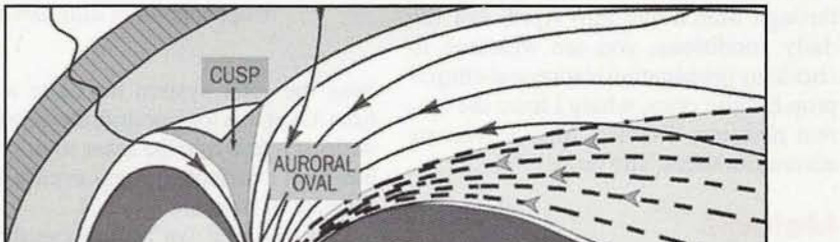


Map showing geomagnetic latitude. (Courtesy NW7US)

Earth's field. He postulated that the two magnetic fields would interconnect through a process known as *magnetic reconnection* and form a crack in the shield through which the electrically charged particles of the solar wind could flow. In 1979, Dr. Goetz Paschmann, of the Max Planck Institute for Extraterrestrial Physics, Germany, detected these cracks using the International Sun Earth Explorer (ISEE) spacecraft. Recently, the Imager for Magnetopause to Aurora Global Exploration (IMAGE) satellite, along with the four-satellite Cluster constellation that flies far above IMAGE, revealed the direct correlation between a proton aurora (non-visible) and the flow of ions through these cracks.

All of this takes place within an area known as the *auroral oval.* These are rings of a radius roughly 1500 miles, centered on the Earth's geomagnetic poles (not on the geographical pole, nor even magnetic poles). The geographic North Pole is located at 90 degrees north latitude and is the point where the lines of longitude converge. The magnetic North Pole is located roughly at 73.5 degrees north latitude and 100 degrees west longitude, near Resolute Bay, Canada. This is the point where magnetic medians converge. The geomagnetic pole, however, which is the center of the auroral oval, is located at the northwest tip of Greenland at 78.5 degrees north latitude and 69 degrees west longitude. It is the northern axis of the mathematical field of closest fit to the actual magnetic field of the Earth. Using this geomagnetic pole, we define a set of latitude and longitude coordinates, known as the *geomagnetic coordinates.* The auroral oval during average solar activity lies in a ring between about 70 and 75 degrees north geomagnetic latitude, and can grow during geomagnetic storms and shrink during very quiet geomagnetic activity periods, extending farther south on the nightside than on the dayside. That means that as the Earth rotates beneath the aurora, a given location will be nearer the oval at night than during the day.

When the interplanetary magnetic field lines are oriented opposite to the magnetosphere's orientation, the two fields connect and allow solar-wind particles to collide with oxygen and nitrogen molecules in the upper atmosphere of these ovals. This causes light photons to be emitted. When the molecules and atoms are struck by these solar-wind particles the stripping of one or more of their electrons ionizes them to such an extent that the ionized area is capable of reflecting radio signals at very high frequencies. This ion-



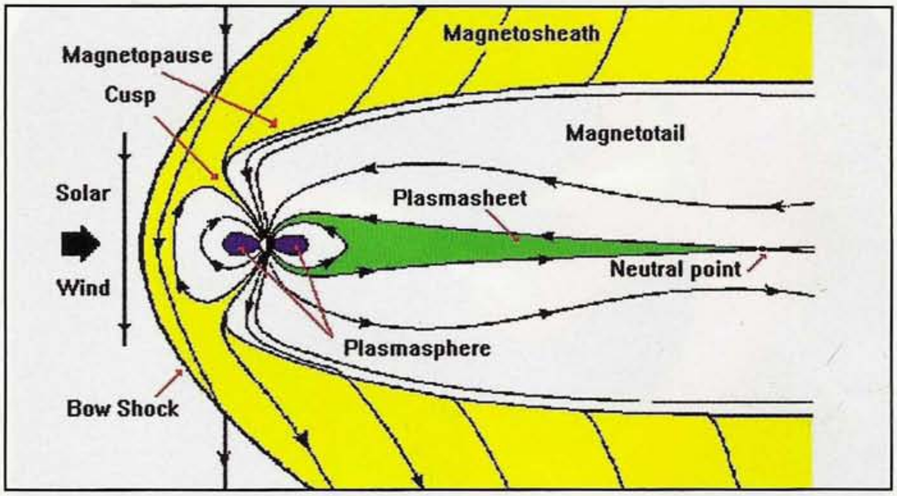
Model of the inner magnetosphere. (Courtesy NASA/IMAGE) ization occurs at an altitude of about 70 miles, very near the *E*-layer of the ionosphere. The level of ionization depends on the energy and amount of solar-wind particles able to enter the atmosphere.

While correlations exist between visible and radio aurora, radio aurora could exist without visual aurora. Statistically, a diurnal variation of the frequency of radio aurora QSOs has been identified that suggests two strong peaks, one near 6 PM and the second around midnight, local time.

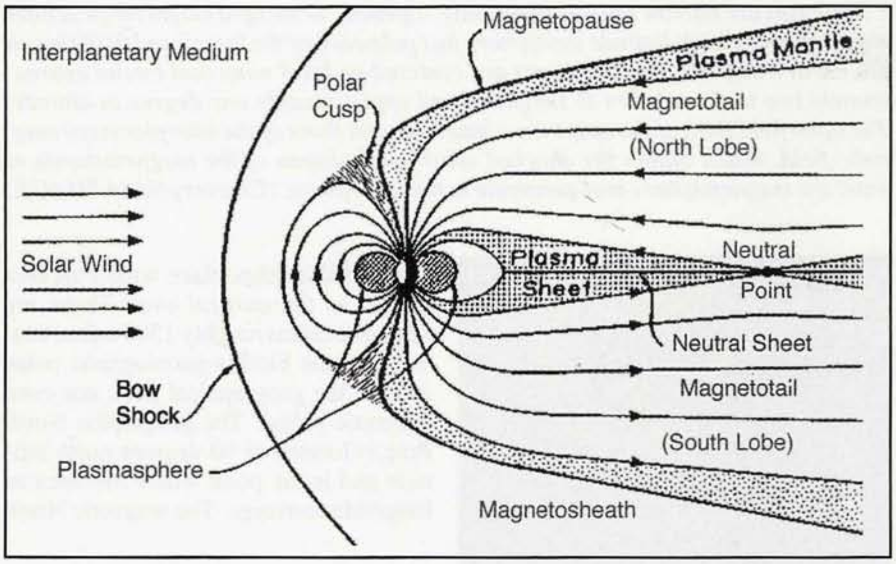
VHF auroral echoes, or reflections, are most effective when the angle of incidence of the signal from the transmitter, with the geomagnetic field line, equals the angle of reflection from the field line to the receiver. Radio aurora is observed almost exclusively in a sector centered on magnetic north. The strength of signals reflected from the aurora is dependent on the wavelength when equivalent power levels are employed. Six-meter reflections can be expected to be much stronger than 2-meter reflections for the same transmitter output power. The polarization of the reflected signals is nearly the same as that of the transmitted signal.

The *K*-index is a good indicator of the expansion of the auroral oval, and the possible intensity of the aurora. When the *K*-index is higher than 5, most hams in the northern states and in Canada can expect favorable aurora conditions. If the *K*-index reaches 8 or 9, it is highly possible for radio aurora to be worked by stations as far south as California and Florida.

Expect an increase in geomagnetic storms, and auroral activity as we move through March and into April. For the daily conditions, you are welcome to check my propagation resource at <http://prop.hfradio.org>, where I have the current planetary *K*-index, links to various aurora resources, and more.



The magnetosphere. (Courtesy NASA/IMAGE)



Magnetosphere diagram showing plasma sheet and polar cusps.

Meteors

While there are no major meteor showers during February and March, April has one major meteor shower—the *Lyrids,* which peaks on April 22. While this shower peaks at about 12 meteors per hour, or about one per every five minutes on average, radio bursts occur more often.

The debris expelled by comet Thatcher as it moves through its orbit causes the *Lyrids.* It is a long-period comet that visits the inner solar system every 415 years or so. Despite this long period, there is activity every year at this time, so it is theorized that the comet must have been visiting the solar system for quite a long time. Over this long period, the debris left with each pass into the inner solar system has been distributed pretty evenly along the path of its orbit.

This material isn't quite evenly distributed, however, as there have been some years with outbursts of higher than usual meteor activity. The most recent of these outbursts occurred in 1982, with others occurring in 1803, 1922, and 1945. The outbursts are unpredictable and one could even occur this year. The best time to work this shower should be from midnight to early morning.

The Solar Cycle Pulse

Geomagnetic activity went wild during the last part of October and early November 2003. It is typical during the decline of a solar cycle to see one or two periods of renewed solar activity, but this one was spectacular. The largest flare in recorded history occurred on November 4, 2003, measuring X28! We began to record flares during the 1970s and have seen many X-class flares. This one overwhelmed the sensors for over 13 minutes. The flare came during a period of intense solar activity, during which many M- and X-class flares occurred. The sunspot activity was very high, and the overall result was incredible VHF and UHF propagation. We not only had radio aurora, but we had continual *F*-layer, long-range DX propagation due to the high 10.7-cm flux.

Finally, as we moved into December, the sun settled back down, although with continued coronal-hole activity. However, we saw very little radio aurora. There were reports of sporadic-*E* and some tropospheric openings.

The smoothed planetary *A*-index numbers from March to May 2003 are 19.4, 20.0, and 21.0, continuing the expected increase during 2003. The monthly readings from September through November 2003 are 19, 32, and 31. The winter readings will see a downward trend.

The observed smoothed sunspot numbers from September through November 2003 are 48.8, 65.6, and 67.2, generally lower than the last reporting period. Even with the intense activity from October and early November, the overall solar activity is clearly moving toward the solar cycle minimum. The smoothed monthly 10.7-cm (preliminary) numbers from September through November 2003 are 112.3, 153.1, and 152.1. The smoothed monthly sunspot numbers forecast for February through April 2004 are 43.4, 40.6, and 38.0, while the smoothed monthly 10.7 cm is predicted to be 103.5, 100.7, and 96.5 for the same period.

How's EME?

Are you trying your hand at Earth-Moon-Earth (EME) DXing? What makes for good conditions, in your experience? A lot more research is needed to fully understand the dynamics of working DX via moon reflection. How does a geomagnetic storm affect EME propagation? What about flares?

I was exchanging e-mail with Jim Shaffer, WB9UWA. We were discussing what made for good EME conditions. He wrote:

> Aurora can be a real killer of EME signals on 2 meters. Of course, a good old thunderstorm will affect RX (noise). Wind can move the array too much for safety or for aiming. Ice will freeze some rotors. Rain can detune an array that has its peak gain right at the operating frequency. That is why it is modern practice to tune the Yagi gain a bit high in frequency.
>
> There is not really good general agreement on what is going on as it relates to the sun activity and EME conditions. One contention is that the ionosphere will never degrade the signal level substantially. In many recent months, now bordering on years, there has been variable EME conditions. Often this is blamed on the sun's activity. One obvious and measurable effect is sun noise. Normally I measure about 8 or 9 dB sun noise on my 18.5 dBd Xpol array. With some recent sun activity I have measured as much as 25 dB sun noise. Some have mentioned the magnetic field as a possible source of trouble.
>
> The degradation often shows up as additional QSB with some short-lived peaks reaching normal EME levels. The effect can be different in different parts of the world. The degradation has been observed by Xpol stations (mine is one of them), so Faraday is not to blame here. The degradation by whatever the source is can be as much as 12 dB over an extended period of time and more often around 6 dB. When this is going on, it can make you tear your station apart looking for problems.

Feedback, Comments, and Observations Solicited!

I am hungry for a pulse on the real world of VHF and UHF weak-signal propagation. Please send your reports to me via e-mail, or drop me a letter about your VHF/UHF experiences (sporadic-*E*, FAI, aurora, and/or meteor scatter). I'll create summaries and share them with the readership of *CQ VHF.* I look forward to hearing from you.

Until the next issue, happy weak-signal DXing.

—73 de Tomas, NW7US

Advertisers' Index

By Dr. H. Paul Shuch,* N6TX

DR. SETI'S STARSHIP

Searching For The Ultimate DX

"Then I'd Have To Kill You."

"We're getting a carrier, all right," confirmed Trevor, who was barely able to conceal his excitement.

Ken's fingers flew over the keyboard, his eyes never leaving the monitor. "Frequency?" he asked.

"Fourteen seventy-one point five," answered Trevor, tweaking the tuning dial on the ICOM 7000 receiver. "It's steady at S2. I've marked the local sidereal time. Shall I ring up the BBC?"

"Are you daft, man? Let's not forget the verification protocols! Check for modulation, and be quick about it."

"It's CW. . . . No, there are sidebands. Looks kind of like modem tones. Low baud."

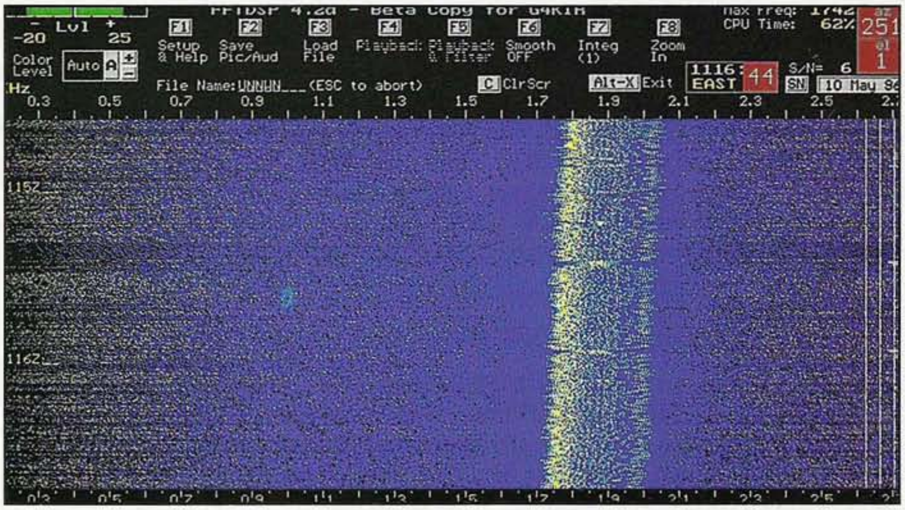
The two English radio amateurs were manning their radio telescope, much as they had during every spare waking hour for the past three weeks, in search of an intelligent signal from the stars. As UK Co-Coordinators for *Project Argus,* the all-sky survey launched by The SETI League on Earth Day, April 21, 1996, their job was to assist other British hams in building sensitive microwave listening posts. Their 3.5-meter diameter dish and associated electronics were put together as a demonstration station, and now they were demonstrating the patience and deliberation for which their 100 combined years had uniquely prepared them. They were systematically analyzing an anomaly.

"Doppler's kind of high. Tens of Hertz per minute. I'm betting it's a LEO."

Ken's colleague knew that Low Earth Orbit satellites were the bane of SETI, the scientific Search for Extra-Terrestrial Intelligence. Fortunately, their Doppler shift, a change in radio frequency caused by their motion relative to the Earth, made such manmade sources readily distinguishable from signals of interstellar origin. Still, there was something odd about this particular signal.

The *Argus* concept had been born in the States a year and a half earlier, in response

*Executive Director, The SETI League, Inc., <www.setileague.org>
e-mail: <n6tx@setileague.org>



Anomalous signal detected by SETI League members Ken Chattenton, G4KIR, and Trevor Unsworth, GØECP, on May 10, 1996, at 1471.5 MHz, using a surplus 3.5-meter dish. The signal exhibited clearly audible digital modulation, with a 270-Hz bandwidth. Its Doppler shift of –25 Hz/min. marks it as RFI from a Low Earth Orbit (LEO) satellite. Though clearly not of extra-terrestrial origin, this signal gave Project Argus *its first real workout, testing both the sensitivity of our receiving stations and our ability to recognize terrestrial and satellite interference. (GØECP image)*

to Congress canceling all of NASA's SETI funding. For just a couple of years NASA had conducted a modestly funded SETI effort from headquarters at the Ames Research Center in Mountain View, California. Consuming just one tenth of one percent of NASA's science budget, or about five cents per American per year, NASA SETI promised to be one of the best scientific bargains of all time. Then the budget-balancers axed it, reducing the US national debt in the process—by point zero zero zero six percent.

A group of American microwave experimenters was not about to let the search die for lack of intelligence in Washington. Ken Chattenton, G4KIR, and Trevor Unsworth, GØECP, had heard about their amateur effort at the World Science Fiction Convention in Glasgow the previous summer, and they were the first Europeans to sign on. Now their many months of effort and training were being put to the test.

"Save to disk," commanded Trevor unnecessarily, for Ken was already doing so. "Let's get a GIF, and also maybe a WAV file. We're going to have to Internet this one."

The signal amplitude rose smoothly, then fell. "Wow!" exclaimed Ken.

"Let's not be hasty," cautioned Trevor. "I think it's time to *Ask Dr. SETI.*"

It was a moment of great excitement, for this "Wow!" event exhibited many of the characteristics we would expect of an intelligently generated microwave signal from space. Still, restraint was the order of the day. The two SETI hams sent their signal file to Dr. SETI (that's me).

The signal looked for all the world to have originated from space, but its Doppler shift (that artifact of relative motion which makes railroad whistles and radio signals alike change in frequency over time) was suggestive of *near* space. This appeared to be a Low Earth Orbit satellite that Ken and Trevor had snared. Still, it was a worthy detection, for three reasons:

1. This was an extremely weak signal, which spoke well for the sensitivity of our participants' homebuilt receiving equipment—thus validating the hardware.

2. The Doppler shift was instantly evident in the computer printout, which gave

(Continued on page 74)

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[1]Note that certain frequencies are unavailable. [2]5W output

"Specifications subject to change without notice."

TH-F6A
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