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Ham Radio Above 50 MHz

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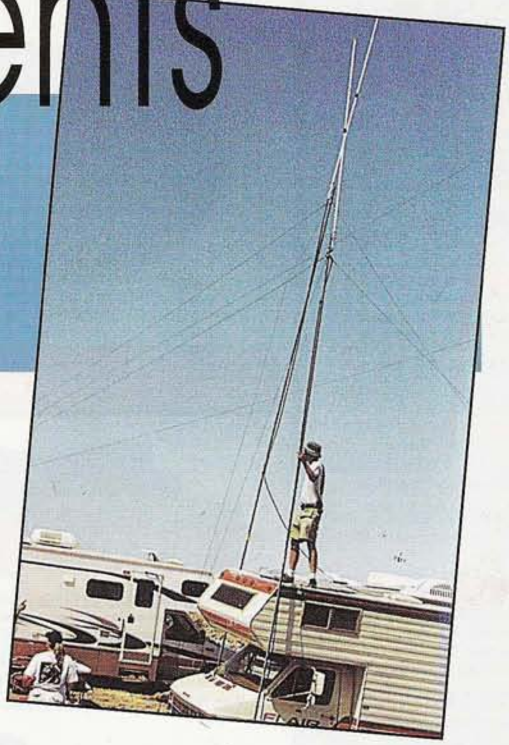

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On The Cover: When it rains, it propagates! For details see p. 6. Photo by Mike King, KMØT. Inset photo see p. 11.

CQ VHF Ham Radio Above 50 MHz

LINE OF SIGHT

A Message from the Editor

A Not So Mild Embarrassment

It was in late December that *Time* magazine writer Lev Grossman wrote his piece "Blogs have their day," in which he initially compares bloggers to the "mildly embarrassing hobbies of ham radio and stamp collecting." Within the week the disastrous tsunami hit South Asia, killing more than 150,000 and injuring hundreds of thousands of others.

As with countless other natural and man-made disasters, ham radio operators immediately went to work to provide critical emergency communications. From a DXpedition that became the only source of health and welfare traffic between India and Andaman and Nicobar Islands, to hams throughout Thailand using 2 meters as their primary band of operations, came two examples of critical communications that were being handled by amateur radio operators. More information on how HSMM has been playing a role in the emergency communications can be found in the "HSMM" column (beginning on page 30) by John Champa, K8OCL.

As these examples indicate, hams continue to prove that we are made of the right stuff. However, as the Grossman piece indicates, we have a long way to go to improve our public image.

As the disaster continues to unfold, the needs of the area will continue to present themselves to the rest of the world for many months to come. If you have not already given to the needs, I urge you to generously respond to them by way of contributions to the charity of your choice.

Amateur Radio and Education

There have been more than 150 educational-related contacts with the International Space Station and the space shuttles. Even so, each time is unique and each time is special—particularly for the participants. Beginning on page 8 in this issue of *CQ VHF*, "Satellite" column editor Keith Pugh, W5IU, describes one of the recent QSOs with the ISS.

Getting back to Grossman's article, as an observer of this particular ARISS QSO, I did not detect one hint of embarrassment among any of the participants as the hobby of ham radio was being used to further the education of the school children. Rather, what I saw was pride in accomplishment for all concerned, as, according to Keith, this was one of the more successful ARISS contacts.

DFing a Lifesaving Transmitter

In another fun aspect of the hobby that has a potentially far-reaching public-service spinoff, in this issue Pete Ostapchuk, N9SFX, describes how he and another ham, Ritch Williams, KA9DVL, went DFing for a lost lifesaving transmitter. This type of transmitter is one that is used as a tracking device for people who might become lost and not be able to assist themselves in their predicament, such as Alzheimer's patients.

As Pete tells the story, when one of the devices that were being demonstrated went missing and conventional methods failed to locate it, amateur radio came to the rescue—and quickly found it. Commenting on the amateur radio involvement, Pete stated, "I keep hearing people talk about how cell phones and computers are taking the spotlight away from amateur radio. It's pretty obvious that when the call for help went out in this instance, it didn't go out to computer and cell-phone users." The whole story begins on page 26.

The Unusual Propagation of November 2004

This past November 7–10 we had both aurora and unseasonable sporadic-*E* propagation on our lower VHF+ bands thanks to a large flare eruption on the sun on November 7. In his "Propagation" column Tomas Hood, NW7US, goes into some detail, explaining what happened to bring about these propagation events. Also in this issue, Ken Neubeck, WB2AMU, reports on his experiences during those events (see page 42).

The Increased Variety of Use of the VHF+ Bands

The above-mentioned articles are just a sampling of what is in this issue. It is with this Winter 2005 issue that we conclude three years of the experiment of bringing back *CQ VHF* magazine. By all accounts, the experiment is working. You are accepting the new format and supporting it with your submission of articles and purchase of subscriptions, as well as telling others about it.

What has fascinated me the most over these past three years as editor of *CQ VHF* magazine is the increasing variety of the uses of the VHF+ ham bands. What I brought to the position of editor of this magazine was my interest in weak-signal communications. During these past three years I have learned that there are other creative uses of the VHF+ ham bands besides weak-signal, amateur television, space, and FM communications. Thanks to you, our readers and authors, we have included articles on ballooning, HSMM, and DFing, as well as other fascinating aspects of VHF+ communications. No doubt, in future years there will be more major interests that also will expand the usage of the VHF+ ham bands, and I look forward to presenting these new interests in future issues of *CQ VHF* magazine.

Thank you for supporting the second rollout of *CQ VHF*. I look forward to the publication of many more issues of this, your magazine, in which I can continue to provide you with the venue for you to tell your fascinating stories.

Until the next issue…

73, de Joe, N6CL

QUARTERLY CALENDAR OF EVENTS

Contests

The **European Worldwide EME Contest 2005:** 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 equal an chance for stations from North America, Europe, and Oceania. The rules reward random QSOs, but do not penalize skeds on 2.3 GHz or above. Winners (1st place) receive a free subscription to *DUBUS* magazine.

The contest dates and bands are as follows: First weekend: 50 MHz, 1.3 GHz, 10 GHz, 24 GHz and up, 16–17 April, 0000–2400 UTC; second weekend: 144 MHz, 2.3 GHz, and 3.4 GHz, 14–15 May, 0000–2400 UTC; and third weekend: 432 MHz and 5.7 GHz, 11–12 June, 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 antenna. PRO stations will have 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 will receive a year's free subscription to *DUBUS* magazine. In each band/section, certificates will be sent to the top ten entrants 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.

Contest entries *must* be sent no later than 28 days after the end of the third weekend (i.e., in the mail or via e-mail by 10 July 2005). Mail address: Patrick Magnin, F6HYE, Marcorens, F-74140 Ballaison, France. You can also e-mail your contest entry in ASCII format to: <f6hye@ref-union.org>. All e-mail entries will be acknowledged within one week. For additional rules and general questions contact: <info@dubus.de>. Complete rules can be found at: <http://www.marsport.demon.co.uk/EMEcont2005.pdf>.

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 4, 7–11 PM local time; 222 MHz, April 12, 7–11 PM local time; 432 MHz, April 20, 7–11 PM local time; Microwave, May 7, 6 AM to 1 PM local time; and 50 MHz, May 14–15, 2300 UTC Saturday until 0300 UTC Sunday. Logs and summary sheets should be e-mailed or snail mailed to the below addresses. Logs should be submitted within 30 days of the end of each contest. Contact information: Jeff Baker, WU4O, 2012 Hinds Creek Road, Heiskell, TN 37754. E-mail: <springsprints@etdxa.org>. Sponsored by the East Tennessee Valley DX Association, further information on these contests can be found on website: <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. 2	Last Quarter Moon
Feb. 6	Very Poor EME conditions
Feb. 7	Moon Perigee
Feb. 8	New Moon
Feb. 13	Moderate EME conditions
Feb. 16	First Quarter Moon
Feb. 20	Moon Apogee. Poor EME conditions
Feb. 24	Full Moon
Feb. 27	Moderate EME conditions
Mar. 3	Last Quarter Moon
Mar. 6	Very Poor EME conditions
Mar. 8	Moon Perigee
Mar. 10	New Moon
Mar. 13	Moderate EME conditions
Mar. 17	First Quarter Moon
Mar. 19	Moon Apogee
Mar. 20	Vernal Equinox. Moderate EME conditions
Mar. 25	Full Moon
Mar. 27	Moderate EME conditions
Apr. 2	Last Quarter Moon
Apr. 3	Moderate EME conditions
Apr. 4	Moon Perigee
Apr. 8	New Moon
Apr. 10	Moderate EME conditions
Apr. 16	First Quarter Moon and Moon Apogee
Apr. 17	Moderate EME conditions
Apr. 24	Full Moon. Moderate EME conditions
Apr. 29	Moon Perigee
May 1	Last Quarter Moon. Moderate EME conditions
May 8	New Moon. Moderate EME conditions
May 14	Moon Apogee
May 15	Good EME conditions
May 16	First Quarter Moon
May 22	Moderate EME conditions
May 23	Full Moon
May 26	Moon Perigee
May 29	Moderate EME conditions
May 30	Last Quarter Moon

—EME conditions courtesy W5LUU

The **2 GHz and Up World Wide Club Contest:** The following is unofficial and was developed from assumptions based on last year's contest. Sponsored by the San Bernardino Microwave Society, this contest should run from 6 AM on May 7 to 12 midnight on May 8 (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: The society's 9th annual conference will be hosted in Charlotte, North Carolina, on April 29 and 30. The location will be the Hilton Charlotte Executive Park, 5624 Westpark Drive, Charlotte, NC 28217; phone 704-527-8000, fax 704-529-5963. Group rate is $75 per night. It is best to call the hotel direct and be sure to mention the Southeastern VHF Society Conference to get the discount rate. For more information about the hotel see <http://www.hilton.com/en/hi/hotels/index.jhtml?ctyhocn=CLTEPHF>.

Registration for the conference was not available at press time. Please check their website at <http://www.svhfs.org/registration_05.htm> for the registration forms.

Dayton HamVention®: The Dayton HamVention® will be held as usual at the Hara Arena in Dayton, Ohio, May 20–22. For more information, go to <http://www.hamvention.org>. Your editor, N6CL, is scheduled to be one of the speakers for the VHF forums.

Calls for Papers

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

The **Southeast VHF Society** (see conference dates announcement above): Contact Ray Rector, WA4NJP. Ray's e-mail address is <wa4njp@bellsouth.net>. The deadline for submitting papers is as soon as possible.

The 39th annual **Central States VHF Society Conference** will be held July 28–31 at the Sheraton Hotel, Colorado Springs. The deadline for submitting final papers will be around May 1. Submit your papers as soon as possible to Lauren Libby, WØLD, President, at <w0ld@pcisys.net>.

Meteor Showers

The *a-Centaurids* meteor shower is expected to peak around February 7 at 2245 UTC. The *?-Normids* shower is expected to peak on March 13 and again on March 17. Other February and March minor showers include the following and their possible radio peaks: *Capricornids/Sagittarids,* February 1, 0800 UTC; and *?-Capricornids,* February 13, 0900 UTC.

The *Lyrids* meteor shower is active during April 19–25. It is predicted to peak around 1030 UTC on 22 April. This is a north-south shower, producing at its peak around 10–15 meteors per hour, with the possibility of upwards of 90 per hour.

A minor shower and its predicted peak is *pi-Puppids* (peak around 1530 UTC on April 23). Other April and May minor showers include the following and their possible radio peaks: April *Piscids,* April 20, 0900 UTC; *d-Piscids,* April 24, 0900 UTC; *e-Arietids,* May 9, 0700 UTC; May *Arietids,* May 16, 0800 UTC; and *?-Cetids,* May 20, 0700 UTC; The above information is courtesy the International Meteor Organization and its website, <http://www.imo.net>.

Microwave Rain Scatter in the Upper Midwest

Borrowing from the song "The Rain in Spain Falls Mainly on the Plain," KMØT describes how the rain falls on the E-plane and H-plane of the microwave radiated signal and then re-radiates it to a new location. Hence, rain-scatter propagation.

By Mike King,* KMØT

Photo A. Left to right: A 9-element 144-MHz Yagi, 5.7-GHz dish, 10-GHz dish, and 18-element 70-cm to 432-MHz Yagi.

I had spent a number of months on the microwave bands without knowing that a very promising method of propagation existed. Through multiple contests and chasing rover Gene, NØDQS, it became apparent that 5.7 and 10 GHz were enhanced when we had rain in the area.

I wondered a bit about this and began to do some research on this particular propagation mode. With what I found, it was pretty much apparent that the guys in Europe probably laugh at us when we post our rain-scatter attempts and accomplishments, because this is a lot of their "bread and butter" propagation. There are some good articles on this mode by the European operators. There are also articles on 10-GHz rain scatter by Tom Williams, WA1MBA. A Google search of "European rain scatter propagation" will reveal a number of commercial and amateur radio references. For more on WA1MBA's articles, please see his website: <http://www.wa1mba.org/10grain.htm>. Also see his article "10 GHz, a Nice Band for a Rainy Day" in the February 1997 issue of *CQ VHF* magazine, as well as his paper "Narrow-Band 10 GHz and Some Observations from New England," which was published in the *Proceedings* of the 21st (1995) Eastern VHF Conference.

Working stations via rain scatter is not a hard thing to accomplish. In fact, I was working it without really knowing it. Now lots of the folks around the NLRS (Northern Lights Radio Society) area are "in tune" with this predictable propagation mode and are taking advantage of the potential it offers. You can get into the society's loop by subscribing to its reflector. Information on the NLRS, as well as instructions on subscribing to its reflector, are at <http://www.nlrs.org>.

*1176 Fifth Ave. Cir. NE, Sioux Center, IA 51250
e-mail: <km0t@arrl.net>

Figure 1. The arrow points to where Gene, NØDQS/R, was in a rain squall during the 2002 ARRL UHF Contest.

The Basic Theory Behind Rain Scatter

From what I gather from Tom, WA1MBA's article on this propagation mode, rain scatter is not a reflection, but really a "re-radiation" of energy. When signals reach a rain droplet of proper size in terms of wavelength comparison, then that particular droplet will "re-radiate" its energy to the next droplet, and then the next. This is a very simplistic explanation and, there is a great deal more behind it, but it does work!

Working the Mode Without Knowing It!

Chasing Gene, NØDQS, was one of my main efforts in the major contests (figure 1 and photo B). During the ARRL 2002 UHF contest I recall having great signals on 5.7 and 10 GHz without any explanation of why the standard forward-scatter tropo was better than it had been just shortly before the contest. I also made it

Photo B. KMØT helped NØDQS/R with the final installation of the microwave dishes prior to the 2002 UHF Contest.

a priority to watch the local radar for Gene, just to help keep him out of trouble from storms and such.

The particular grid he was in was not that far away, but signals were somewhat "auroral" on SSB and the radar confirmed that there was rain in the area. Gene had minor rain squalls all around him while he was in that area, but there weren't any around my home QTH. Signals were generally much stronger, and we chalked it up to just "dumb luck." I suppose this was based on observations of signal levels earlier in the day when things were dry and signals were in the noise. At that time we were just utilizing brute-force forward scatter at 100+ miles. We knew we could work these paths as long as we had the dish antennas pointed properly, but with rain in the area we had an easy time of it.

Photo C. NØDQS operated portable from Wisconsin, EN42nx. Note direct heading for the dish and skew path to the north for the 3.4-GHz looper antenna. The minor precipitation clouds can be seen in the distance.

The nail in the coffin was when, on June 28, 2003, Gene made a grid expedition to EN42nx, which is in the southwest corner of Wisconsin (photo C). The purpose of his trip was so I could pick up that state for the Central States VHF Society's States Above 50 MHz contest. We were considering brute-force forward scatter or a bit of tropo enhancement to make our contacts.

The propagation situation turned out to be much different, though. I needed Wisconsin on 3.4, 5.7, and 10 GHz, so he had capability for all those bands. We found each other on 5.7 and 10 GHz on the direct path, but were having difficulty on 3.4 GHz. We both were running good power and antennas and utilizing superflex hardline feedlines, so we were disappointed when we were not able to make the path. The band simply was not open. My beam heading was very close to 90 degrees, due east, while Gene's was 270 degrees due west. With a bit of pointing around, however, I began to hear Gene, albeit weakly, and we managed to work with fairly strong signals. Again, the "auroral"-sounding CW/SSB was present.

A quick look at the weather map indicated that rain was present just to the north of the direct path. Gene indicated that he was hearing me pretty well when he pointed nearly 20 degrees north of the direct path. With that, I nudged my antennas a bit more to the north and he indicated that it made the signals even better. It was about that time when Gene noticed he could see some black clouds off in the distance to the northwest. As it turned out, I ended up being pointed at 82 degrees while Gene was pointed at 315 degrees. He was nearly 45 degrees off direct heading! We ended up chatting on SSB with 5×3 to 5×4 signals.

That information led me to quickly check the local radar map on the Internet. It was evident that rain scatter was the reason for the contact. Going back to direct path resulted in no signals heard.

We did not know it at the time, but a distance record for 3.4-GHz rain scatter had never been recorded for the band, so we submitted that later to get a spot on the DX record page! The direct-path distance of the contact was 435 km (270 miles).

We never thought to point the 5.7- and 10-GHz dishes on that path. If we had, the signals could have been much better. However, I had Wisconsin in the book and that's what mattered at the time.

(Continued on page 77)

Patience Pays Off

Tulsa Air and Space Museum ARISS Contact

Thanks to NASA, there have been more than 150 educational-related amateur radio contacts with the International Space Station and the space shuttles. Each of them has been inspirational for the participants. In this article W5IU recounts one of the more recent ones, which took place in Tulsa, Oklahoma, as a way of encouraging other educational groups to also participate in the ARISS program.

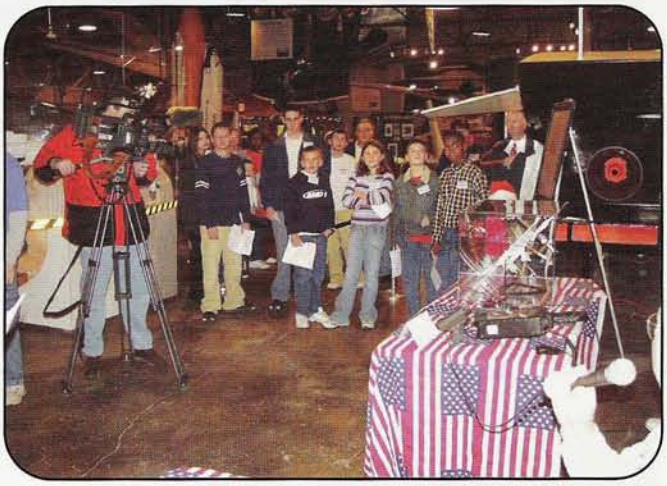
By Keith Pugh,* W5IU

After a two-year wait and one "false start," a successful ARISS (Amateur Radio on the International Space Station) contact was made between the students of the Tulsa Air and Space Museum (TASM) Space Camps and the astronaut and cosmonaut on board the International Space Station. The contact took place at 9:12 AM on 22 December 2004 from TASM.

Nine students asked two questions each and received full replies from ISS Commander Leroy Chiao, KE5BRW, on board the ISS. Katheryn Pennington, the museum's executive director, asked an additional question, and Season's Greetings were passed on to the ISS crew during the nine-minute QSO.

The nine students who participated were William Bloomfield from Thoreau Demonstration Academy, Tulsa; Wyatt Bonicelli, from Pratt Elementary, Sand Springs; Ryan Darrow, from Holland Hall, Tulsa; Chelsie Downie, from Emerson Elementary, Tulsa; Lawrence Ross, from Victory Christian, Tulsa; Chase Karnstadt, from Austin, Texas; Robert Nolan,

*3525 Winifred Drive, Fort Worth, TX 76133
e-mail: <w5iu@swbell.net>



Students in queue waiting their turn to speak with ISS commander Leroy Chiao, KE5BRW, during an ARISS event at the Tulsa (Oklahoma) Air and Space Museum. (All photos courtesy N6CL)

Harry Mueller, KC5TRB, makes adjustments on the still partially working console originally used by NASA in its space program.

Author Keith Pugh, W5IU, awaits acquisition of signal (AOS) from the International Space Station in preparation for the TASM ARISS QSO. Note that the call on the sign is the club call of the Tulsa Repeater Organization and was the callsign used for the TASM QSO event.

Group photo following the TASM ARISS QSO. From left to right, rear: Lawrence Ross; Harry Mueller, KC5TRB; Bill Griffin, NI5X; Ryan Darrow; Mark Conklin, N7XYO; Lauren Olten; Keith Pugh, W5IU (face hidden); Robert Nolan; Katheryn Pennington. Left to right, front: William Bloomfield, Chelsie Downie, Kyler Swearingen, and Wyatt Bonicelli.

from Foster Middle School, Tulsa; Lauren Olten, from North Intermediate High School, Broken Arrow; and Kyler Swearingen, from Marquette Private School, Tulsa.

Observing the contact were four students and their advisor from Hamilton Middle School: Shanekah Jones, Leo Alexander, Quiara Scott, Shayla Bethel, and Ms. Rita Balleu.

Preparations for the ARISS QSO started with an application made to the ARISS Program via the ARRL more than two years ago. The contact initially was scheduled for June 2004. Unfortunately, a high-priority "Space Walk (EVA)" came up at almost the last minute and caused a re-scheduling for the week of 20 December. Final preparations resumed in November 2004, leading up to the contact. No equipment was available at TASM to support the contact at the museum, so the Tulsa Repeater Organization (TRO) and others provided equipment for the contact.

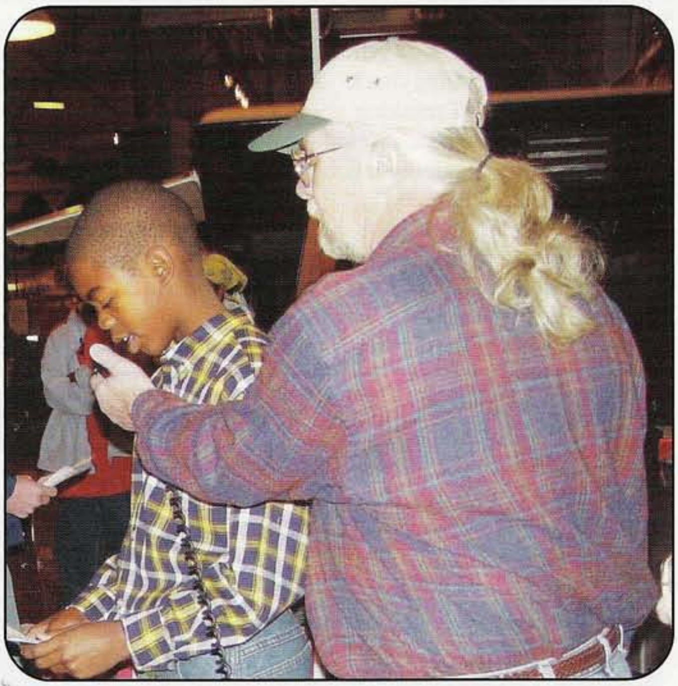
Two representatives of TRO who were instrumental in arranging the details of the contact were its president, Mark Conklin,

Pictured are the cross-polarized antennas used for the TASM ARISS QSO. They are mounted on a 40-foot communications tower that was loaned to TASM by Mobile Equipment International.

TASM Questions Asked of Commander Chiao

1. Lawrence: Do the G-forces from leaving the Earth's atmosphere cause you to have little red spots on your face that we kids call G-measles?
2. William: How much of the International Space Station is complete and what is the expected life (of the station)?
3. Chelsie: What does one day in the space station look like?
4. Chase: Is it hot or cold up there?
5. Ryan: What do you think the benefits are of civilian space travel? Do you foresee civilians ever visiting the ISS?
6. Kyler: Has any space junk or meteor pieces ever hit the space station?
7. Robert: How is the physical training different at NASA than from the military?
8. Lauren: What would your advice be for an aspiring astronaut?
9. Wyatt: Can you see storms that happen on Earth?
10. Lawrence: Do you have to use parachutes to slow down after going through the Earth's atmosphere to land?
11. Ryan: What is the physical impact of a zero-gravity environment on you over a long period of time and how do you deal with this when you return to Earth?
12. William: What is the scariest or most dangerous thing that you do?
13. Lauren: Is it worth all the time, effort, et cetera, to become an astronaut?
14. Robert: What is it like working with someone from another country for a long time?
15. Chelsie: What kind of foods do you like to eat in space?
16. Chase: What do you do for exercise?
17. Kyler: What has been the most interesting experiment you have gotten to work on in the station?
18. Wyatt: Is it fun floating and how does it make your body feel?

Ms. Pennington asked: As you are looking out the space station right now, what do you see?



Left, Lawrence Ross, a fifth-grade student at Victory Christian School, Tulsa, asks a question of ISS Commander Leroy Chiao, KE5BRW, while Bill Griffin, NI5X, controls the earth station at the Tulsa Air and Space Museum.

Other students were invited to be observers of the TASM ARISS QSO. From left to right are Hamilton Middle School students and their advisor: Shanekah Jones, Leo Alexander, Quiara Scott, Shayla Bethel, and Ms. Rita Balleu.

TRO president Mark Conklin, N7XYO, being interviewed by one of the local photojournalists.

N7XYO, and Bill Griffin, NI5X. Also working to make the contact a success were TRO members Ed Compos, K5CRQ, and Harry Mueller, KC5TRB. TRO's website is <http://www.TulsaHamRadio.com>. In addition, I served as ARISS's required mentor for the contact. For the QSO, Bill served as the control operator, while I made sure that the radios functioned properly.

Two complete stations were assembled. The primary station consisted of a Hy-Gain circularly polarized Yagi, an Advanced Receiver Research (ARR) RF switched GasFet pre-amp, and Yaesu G-5500 Az-El rotators on a portable tower driven by a Yaesu FT-847 transceiver, LabJack/LabJack Piggyback Rotator Interface, and Nova tracking software. Tulsa's Mobile Equipment International loaned a 40-foot communications tower to TASM for the antennas.

Doppler correction of both the uplink and downlink was done in the FT-847 by storing multiple frequency pairs in memories and selecting these appropriately. This may seem like "overkill" to work the ISS, but it is necessary to maximize the contact time. Every effort was made to construct a station capable of communicating with the ISS from "horizon to horizon."

To take care of "Murphy," a secondary station was assembled. This station was not capable of "horizon to horizon" contacts. It consisted of a simple vertical antenna, an FT-897 transceiver, tracking software, and battery power. While not as capable as the primary station, the secondary station was very simple and not as dependent on technology.

All of the equipment was brought together, assembled, and checked out the day before the contact. Students were briefed ahead of time on the procedures to be followed during the contact. "Dry runs" with the students were not possible due to the varied Space Camp backgrounds of the students. "Dress rehearsals" were accomplished just before the contact on the morning of the event.

Everything went well during the contact, and the secondary station was not utilized. All of the efforts were rewarded by the smiles on the faces of the students, parents, and other observers. It is likely that a seed was planted in at least one or two students to pursue a career in the sciences or engineering, and, who knows, one of them may fly as an astronaut in the future. For more information on your school or organization supporting an ARISS QSO, please visit the AMSAT website at http://www.amsat.org/amsat/ariss/news/arissnews.txt>.

In commenting on the ARISS QSO, TASM's executive director, Katheryn Pennington, said, "Statistics prove learning and retaining knowledge improve for children when they are personally involved. The radio linkup will broaden their horizons, giving them a new perspective of space living and exploration. Teachers can expand this experience by relating it to science, geography, history, and physics. Children can explore the relationship of life on Earth and how it compares to life in space."

TASM is located in one of the original Tulsa Municipal Airport hangers, provided to TASM courtesy of Spartan College of Aeronautics and Technology. Within the museum are displays of actual aircraft and mockups of aircraft and space vehicles used for air transportation and exploration. TASM is scheduled to move to a new 25,000-square-foot facility late this summer. TASM annually holds a summer camp that instills self-confidence and self-reliance in young students by exposing them to traditional and non-traditional fields of work through supporting their interest in math, science, and technology. For more information on the mission of TASM, visit its website at: <http://www.tulsaairandspacemuseum.com>. ■

Rover Flagpoles

One of the problems of rover operating is getting the antenna in the air effectively and safely. Here WB6NOA provides the solution—telescoping flagpoles.

By Gordon West,* WB6NOA

A serious VHF/UHF rover may have a tilt-up tower to get the aluminum up in the air. I admire that, and I marvel at the ingenuity that goes into these exotic tower systems permanently welded to the vehicles. Less serious VHF/UHF rovers have an affordable alternative, though, thanks to the RV industry—the telescoping flagpole and trailer-hitch-receiver lay-down mount. The limitation is the amount of aluminum you can manage aloft with the flagpole extended. However, this is an antenna elevation system that doesn't require any major vehicle modification, which is something your significant other may appreciate.

Don't run right out and buy a flagpole from the local RV store. I have found out that there are some big differences in how telescoping flagpoles work. When you are struggling to push up a couple of long-boom beams, the last thing you want is the wrong kind of flagpole, one which just won't stay extended easily when the wind begins to blow.

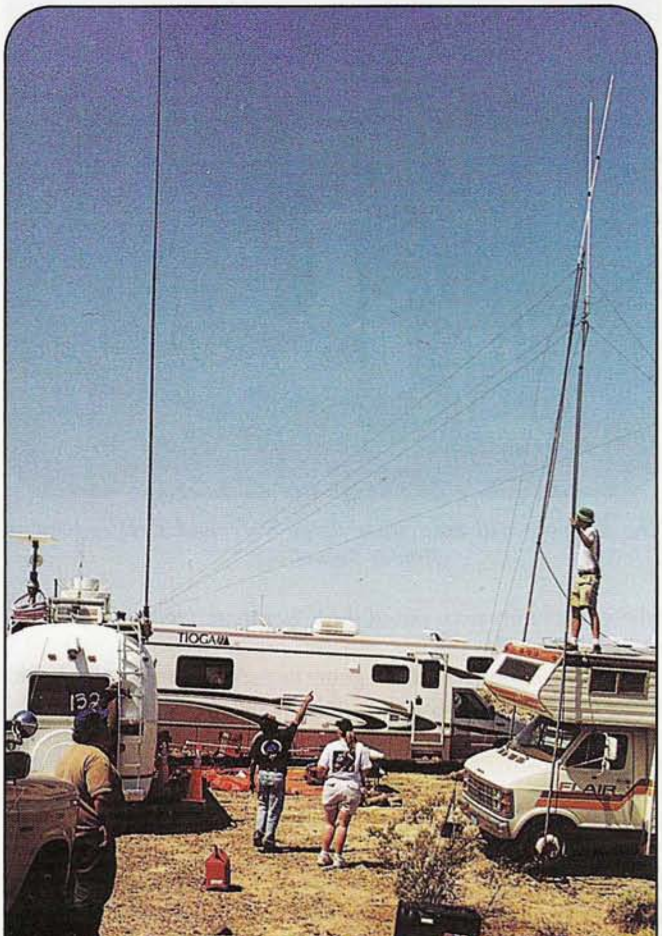
Two of the largest flagpole manufacturers are Uncommon USA (http://www. uncommonusa.com) and Sunsetter (http://www.sunsetter.com). I have a flagpole from each. You can choose from a variety of flagpole colors: silver, bronze, white, and black. Also, there are some subtle differences that are important to those of us who place a long-boom antenna on the top of a flagpole as opposed to Old Glory. Because both manufacturers are continuously refining their flagpole offerings, here are the most important things to look for when shopping for flagpoles at an RV superstore.

Flagpole Features

How Tall? Sixteen-foot telescoping flagpoles are available, but why not get an extra 4 feet for a few more bucks and go for 20 feet? However, going to 25 feet may create the "noodle effect," as Chip Margelli, K7JA, calls it. You don't want the top section to get "goosey" under the load of a big antenna and begin to sway erratically. Stay with 20 feet, and a long-boom antenna won't normally "noodle" the entire pole.

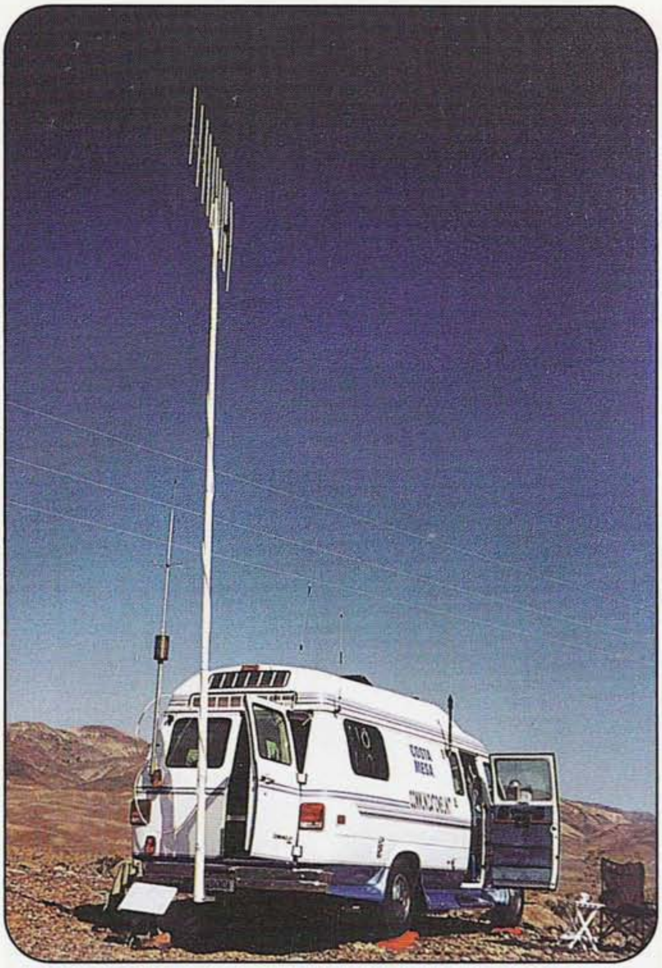
Easy Lockers. Examine how each telescoping section locks in place. Usually there is a spring-loaded pin that pops out to securely lock the sections in place. Carefully examine the locking pins to ensure there is no way the pin might not make a positive contact to keep the upper section up.

Guide Tracks. The Sunsetter flagpole comes with the guide tracks on the inside. The Uncommon USA pole that I own appears *not* to have the tracks. The guide tracks keep the spring-loaded, push-out buttons and their associated lower section holes exactly in line. As you raise the pole with the antenna on top, you want to make sure you don't pull the upper pole out beyond where the pin should pop through the lower hole. I believe both manufacturers have some sort of safety catch to keep you from accidentally raising an upper section to the point



The telescoping flagpole goes up in minutes! (Photos by the author)

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



The flagpole will hold some large VHF and UHF antennas without "noodling."

where it actually pops out of the lower mast, causing the whole assembly to fall.

I have nightmares about going beyond where the pin should make contact and pulling the pole all the way out of the lower section. To make absolutely sure this doesn't happen to me, I have felt-tip-marked big countdown numbers on the inner sections that read 5-4-3-2-1-stop to let me know how close I am to hearing the pin spring into the lower section hole. With the Sunsetter pole, the guide keeps the pin and holes perfectly aligned for an every-time snap. However, with the Uncommon USA flagpole, when I get to the "stop" mark I then have to turn either the upper or lower pole until the pins engage.

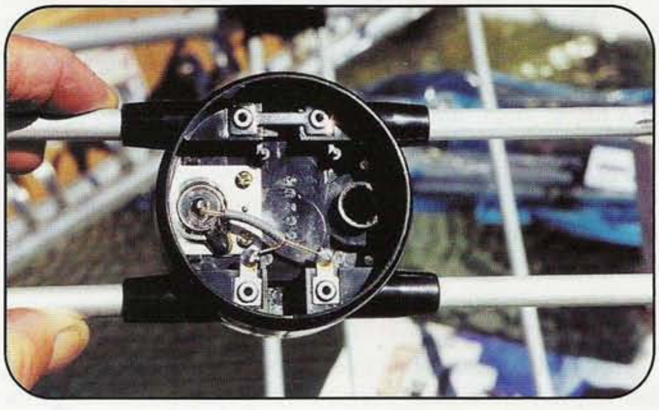
If you plan to use the poles as an integral conductor—such as a hidden vertical antenna on your front lawn—you usually will need to add your own jumpers between each section, because Uncommon USA uses polycarbonate bushings, which allow each section of the pole to slide up and down smoothly, but specifically where metals never touch.

If the raised antenna is not so large as to "noodle" the pole, go ahead and fly a flag at the top with the supplied rope and pulley.

Ground Sleeves. Both of these flagpole companies, and I am sure a lot of other telescoping-flagpole manufacturers as well, also supply vehicle ground mounts. The one I like best is the hitch mount, which slides into your vehicle's trailer-hitch receiver. It usually includes a PVC tube that will keep the flagpole perfectly snug on the hitch mount. Depending on which flagpole

The yellow paint on the fold-up MASPRO antenna is for element centering.

The MASPRO antenna elements swing out and are centered on the yellow mark.



The feedpoint on this MASPRO UHF antenna needs the coax swapped to RG-58AU.

you order, the company will supply the right diameter sleeve. The hitch mounts will still have a little left-to-right wobble, but this is to be expected; the antenna will still stand tall, even though there may be a 5- or 10-degree list to your entire system.

Another type of stand to hold up telescoping flagpoles is the aluminum-wheel stand. Just drive over the stand and you are all set. These work well and actually have less wobble than the trailer-hitch stand. The only drawback of the aluminum-wheel stand is the big bend you will put in the bottom plate when you park on dirt and the heavy weight of your vehicle distorts the flat surface. In future mountings the pole will now lean slightly in toward your vehicle. This actually can be a good thing, as your vehicle can help steady the pole if you jam a big pillow in between the leaning pole and the side of your vehicle.

Direction and Height

The whole idea of the mobile telescoping flagpole is to get the antenna two or three wavelengths above the ground. This means you don't necessarily need to extend the smallest inner section on which the beam is mounted. If your pole has a channel, the beam will stay aimed based on however you adjust it down at the base. If the pole has no channel to hold the uppermost pole in place, the wind will immediately change the direction in which your beam is pointed.

During a recent rover VHF/UHF contest, I saw a group of hams down by the highway struggling for hours to get their 35-foot, telescoping non-flagpole up in the air with a beam on the top. What a job! I merely drove up a little dirt road onto a gentle rise, and presto! All the way there, my beam on the flagpole was 50 feet higher than theirs was swaying in the breeze. It is easier to gain height by driving to a high spot than by struggling at a lower elevation trying to get a big beam on a skinny pole way up in the air!

MASPRO Antenna

An interesting antenna manufactured by MASPRO Antennas offers good gain and minimum weight. Better yet, the aluminum elements loosen up with a thumbscrew, turned parallel to the boom, and can slide in and out so the elements nestle to the boom such that they do not extend beyond the boom. The boom also separates in the middle. This is the antenna seen in the accompanying photos of the communications van and my "high site" during a contest last fall. It takes only minutes to fold out and adjust the elements into position, and the whole antenna for either 145 or 440 MHz easily fits into the van's side locker.

A few dealers may currently stock MASPRO antennas for immediate shipment to you, or they can be ordered through your local dealer, which will take the time to bring them in special order from Comet/NCG Company (1275 N. Grove St., Anaheim, CA 92806; telephone 800-962-2611; <www.natcommgroup.com>). The collapsible 2-meter or 440-MHz MASPRO beam is imported from Japan. I suggest opening up the plastic balun and replacing the RG-174 coax with RG-58AU, thus providing 160-watt capabilities.

Finally, the cost of the flagpole and the associated mounts is about $275 plus $50, respectively. Hitch-receiver mounts are about $95. Once you have the system, you can almost instantly park your vehicle, mount an antenna atop the flagpole, and inch the flagpole up into position for a quick VHF/UHF contact. Just be sure to avoid high-voltage wires (see below) and you will be all set!

Warning!

Watch out for power lines! The metal flagpole contacting the power lines can kill you. Post a sign on the steering wheel that says your flagpole is up. You do not want to drive away with the flagpole raised. If it is on a wheel stand, as soon as you drive off the wheel stand it will come crashing down, causing major injury to anyone around and the death of your beam. If you drive around with the flagpole up, you instantly will become a fried ham as soon as you hit an overhead power line.

The PJ7M 6-Meter Expedition

This past summer, K4BI and K2ZD went on a DXpedition to Dutch Sint Maarten to take advantage of 6-meter sporadic-*E* propagation. Read all about it . . .

By Jim Holt,* K4BI

Once one enters the main portal of amateur radio as a hobby interest, the number and variety of specialty interests within it are numerous and varied. One of these is described as 6-meter DXing, which enjoys a relatively small but active number of individuals. An even smaller subgroup within this specialty interest is those who enjoy and actively make trips to entities around the globe in order to activate them for the express purpose of making them available for 6-meter QSOs.

Mario Karcich, K2ZD, and I are members of this subgroup, and while attending the Jimmy Treybig,W6JKV, annual 6-meter Bar-B-Que party in September of 2003, we talked about and basically committed to going to Dutch Sint Maarten in the Caribbean during early July of 2004 for this purpose, providing a suitable site could be located and arranged. Early July has become the preferred time frame for efforts such as ours, because the growing body of experience with 6-meter propagation during this period suggests that it is a "prime time" for long-haul openings that don't relate to the 11-year solar cycle.

We had observed this during our very first trip together back in July 1988 (PJØM on Saba Island). Region 1 had, for the most part, permitted 6 meters just a few years earlier, and no one had any serious expectations that non-*F2* long-haul contacts would take place. We made lots of contacts with North America while there, but the real surprise was that 48-MHz video carriers from Europe were heard every day and for hours at a time. It was during these periods of video-carrier reception that we completed three QSOs with two stations in the U.K. and one station in Portugal on 6 meters—a real harbinger of things to come.

Jim, K4BI, and Mario, K2ZD, on the villa balcony in Dutch Sint Maarten. (Photos courtesy the author)

Dutch Sint Maarten

This was our third trip together (the second was to Barbados in 2000), and use of the internet for the purpose of searching out a proper site and then completing arrangements has made this part of the job considerably easier in terms of time and effort required.

Our site was Villa Arcadia, a private home located at the extreme eastern end of the island and overlooking the sea from an elevation of 800 feet ASL. Having secured the location, Mario—who had obtained the special PJØM callsign from Landsradio, the controlling agency in these matters for all of the Netherlands Antilles—again requested a special call, and was awarded the callsign PJ7M.

Setting up the rest of the trip was pretty straightforward and most aspects of the trip were in place by springtime. Since Mario (and his XYL Daphne, N2TIN) were traveling from the New York City area, and Meredith, K8BBN (my XYL), and I were traveling from Atlanta, it wasn't practical for us to arrive at the same or even close to the same time. Since they arrived several hours earlier than we did, they picked up the rental vehicle, made arrangements for us to be picked up on arrival, and went on to the site.

When Mario arrived at Villa Arcadia, he conducted an immediate search for our antenna, which had been shipped earlier. Not finding it quickly and suspecting that the band just might be open, he proceeded to erect the portable dipole he had brought with him (primarily for HF communication, but usable on 6) and began tuning around with just the barefoot FT-100 transceiver he'd brought along. Sure enough, the band was indeed very much open, and he immediately began making contacts. When my XYL and I arrived at

*5096 Oak Grove Dr., Sugar Hill, GA 30518
e-mail: <n3ahi@ix.netcom.com>

The portable dipole for Mario's first contacts as PJ7M.

the site, he was still very busy working stations in Europe, North America, and the Caribbean!

I quickly found and began to assemble our 6-meter Yagi, aiming to get our planned "big" station running (our "big station" ultimately consisted of a Yaesu FT-100 with a modified Dentron Clipperton V amplifier using an 8930 tube instead of the original 4CX250B tube; the antenna was a 6M5X Yagi by M^2). This was all well and good, until the carton was opened and I discovered that a key component (balun) was missing! A quick scan of the Sint Maarten telephone directory showed there to be a supplier of the needed components, but since it was already dinner time and the store had closed, we elected to continue with what was working. By the time the band opening ended, it was nearly 10 PM local time. A quick look at the log showed that PJ7M had already worked some 168 QSOs in 28 DXCC entities. Wow!

When we awoke the next morning (very early), the band was once again open, and we continued operations with the "small" station, planning to head for Phillipsburg as soon as the band closed to obtain what we needed to complete assembly of the beam. During the morning I was able to speak with Mort Bardfield, PJ7UQ, on the PJ7R repeater, and I explained our predicament. Mort indicated that he'd be near his handheld most of the day and would direct us to the electronics store.

Before heading out, we were further surprised when Mort called us on 6 to work us, and in the process he indicated that this was his first ever 6-meter QSO! He was using a transceiver he had at his home station, which included 6-meter capabilities, loading it into his HF tribander.

Shortly after this, Mario and I headed into town, aided by Mort's directions, to get our coax balun material and connectors. When we arrived at the store (shortly after 1 PM), we were sadly disappointed to find that the store had already closed for the day, leaving us faced with the likelihood that we'd be unable to get the beam finished for another day and a half. Very fortunately for us, PJ7UQ directed us to his office, not far from the electronics store, because he just happened to have what we needed. We met Mort and his son Ed, PJ7ED, who provided the needed materials.

Upon returning to our QTH, I was able to complete assembly of the antenna, erecting it with Mario's help. Then, while Mario continued to watch 6 meters with the dipole/transceiver combination, I assembled our planned station in a spare bedroom. We finally got on the air with it on Saturday evening, July 3rd. Our plan was to have the station on the air from very early in the morning each day until late in the evening, and one of us would be present at all times during these periods. This really worked out well. When the band opened, Mario or I would be summoned to assist. It should also be noted that we'd arranged for Internet access by dial-up telephone, but weren't able to use it until Monday afternoon, July 5th due to a problem with the telephone. We have to offer apologies to those on the chat pages who wanted to exchange comments, etc. We were just too busy to spend much "chat" time.

The 48.25-MHz video carrier (which we assumed was from Navacerrada, Spain) was a most reliable indicator of propagation to Europe. We made it a point to check that frequency regularly, and every time it came up out of the noise, QSOs with EU stations followed soon after that. When we were working that continent, the area favored was primarily the U.K. and west central Europe, but it constantly moved around, permitting QSOs with Scandinavia, the Mediterranean, as well as eastern Europe.

North American openings clearly favored the eastern half of the U.S. and Canada, with only a small number of contacts west of the Mississippi. There were periods every day when no amount of calling produced contacts in that direction, yet upon our return we were told by several individuals in widely divergent locations that they had copied our beacon signal for hours at a time (while making no contacts)! An inspection of our log

The 6-meter Yagi set up on the balcony.

shows that the directivity of the propagation sometimes wasn't very narrow. There were periods when we were working many European stations one after another, but these were interspersed with North American stations calling and working us during the same opening even though our antenna was pointed to favor EU.

The duration of the opening varied from day to day, with some openings lasting only 2 to 3 hours, while others lasted nearly 12 hours.

The daily band openings (yes, the band opened every day) featured signal levels varying from just audible to very loud. We were able to copy the weak signals well because the expected power-line noise and CATV birdies just weren't present. From my personal experience over nearly 50 years on the 6-meter band, this was the quietest location from which I'd ever operated.

Our operating plan was to run the beacon keyer to attract attention, which worked well. We stayed primarily on CW, but when conditions permitted and the requests came, we did operate SSB. We did some split-frequency operation for sideband contacts with better success than we had achieved during our trip to Barbados in 2000. To minimize the QRM in the pile-up, Mario and I both think this technique may become more prevalent during future 6-meter expeditions.

While this trip was a lot of hard work, we had a blast doing it. If you thought you had fun working us, you should have heard us holler when we'd work a new entity! The culmination of the operation came on Sunday afternoon, July 11th, when we completed a contact with Nick, 5B4FL, after what seemed like forever, going back and forth on the QSB peaks to get it done.

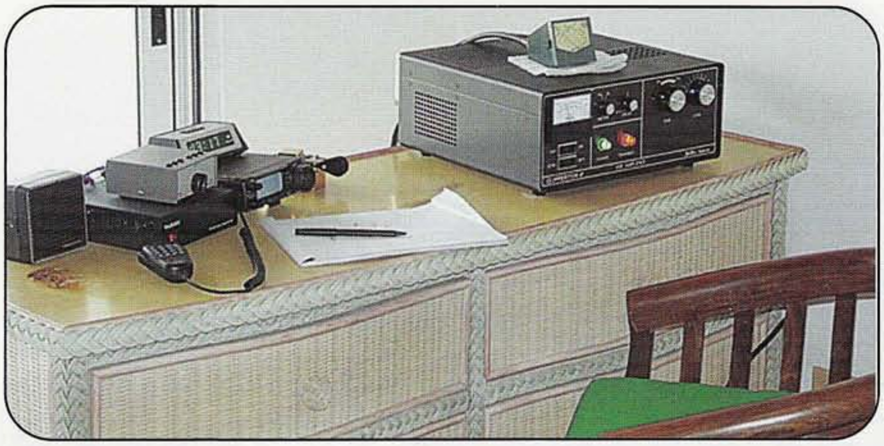
In general, signals levels varied from 599 to 219 on CW and 59+ to 2×1 on SSB. There were some periods when QSB was rapid, other extended periods when signals remained quite strong, and then other periods when signals were quite weak.

The Results

The final result of our trip was 1150+ QSOs and 45 distinct DXCC entities, with all contacts made on 6 meters! Further breakdown of the contacts revealed 613 QSOs with Europe, 536 QSOs with North America, along with one African and one Asian QSO.

The sole African station worked was 5T5SN when I was operating the "small" barefoot station with the portable dipole antenna Saturday morning before we headed out to obtain parts to build the balun for the beam. No other stations were audible at the time in the receiver. He just came up on our frequency and dropped in his call, and we completed with 559 reports both ways. I kept calling, but didn't work anyone else for the next hour and then we went QRT to drive to Phillipsburg.

The big disappointment was that while the QTH gave us a clear shot over the ocean for the European path, with only minor obstructions for the North American path, there was another 250 feet of hillside behind us, which eliminated the ability to do well to South America and Caribbean islands to our south. Because of this hill only three stations were worked to our south or southwest—J79KV, FM5WD, and HP2CWB. The farthest west QSO was a toss-up among the states of Texas, Oklahoma, and Nebraska. Bob, K6QXY, did tell us at the W6JKV party in September that he had heard our beacon keyer on a couple of occasions, but didn't call since he had already worked PJ7!



The big station—a Yaesu Ft-100 with a modified Dentron Clipperton V amplifier.

Our Thanks

Mario and I are indebted to Mort and Ed Bardfield for their immediate, unconditional offer of help and friendship, and to our wives Daphne and Meredith for keeping us well fed,

We also thank Landsradio for the special PJ7M callsign; certainly all of you we worked; and last, but not least, Mother Nature, for providing us with wonderful propagation during our stay.

Hopefully we were able to put a dent in the "I need PJ7" numbers. To further that end, we left our antenna with Mort (who was quite impressed after hearing of our results), who promised us he'd put it up and try to provide some regular presence from Sint Maarten on 6 meters. ■

Mario, K2ZD/PJ7M, working the DX pileups.

Some Notes on Crystals and Oscillators

What is inside that container called a crystal? On what frequency does that crystal oscillate? Here KØVXM discusses some of the basics of crystals.

By Chuck Hoover,* KØVXM

Oh, Happy Day! The crystal you ordered for your latest pet project finally arrived. Deftly, you install it. Confidently, you apply power. Smugly, you measure it with your Radio-Shack counter. Oh . . . oh (or worse), you discover that it's oscillating, but it's not on frequency. In fact, it's a long way off! Before you fire off an angry e-mail to the crystal supplier, pour a cup of coffee and read on.

First, the following remarks apply only to thin, flat, round AT-cut plates with deposited electrodes, which are designed for oscillator service and mounted in conventional holders (see photo A). This means that I will be discussing crystals with frequencies above about 10 MHz, thus encompassing a large majority of crystals.

Second, I will not delve into the realm of mathematics. Some math is unavoidable, of course, but a four-function calculator will handle everything nicely.

Figure 1 is the equivalent circuit of a crystal. *C, L,* and *R* are the representations of motional capacitance (very small), motional inductance (very large), and resistance (generally small). The motional capacitance is expressed in femto Farads (10^{-15}), or thousandths of a pico Farad. The motional inductance is expressed in Henries. Because the resistance is generally less than 100 ohms and the reactance of the motional elements is quite high, the Q of the crystal is also high. The term *Co* is the capacitance because of the electrodes, the holder, and the mounting structure (see photo B). This capacitance is generally between 3 and 5 pico Farads. This is a "real" capacitance. Simply insert the crystal into capacitance meter and read the value.

*1945 E. Phillips Court, Merritt Island, FL 32952
e-mail: <k0vxm@arrl.net>

Crystals can be run on their fundamental frequency and odd overtones (third, fifth, seventh, etc.). The overtones are close to, but not exactly, the integral multiple of the fundamental. The values of the motional elements change with the overtone of operation. For example, a crystal operated on the fundamental overtone may have a motional resistance of 10 ohms and a motional capacitance of 30 femto Farads (see note 1), while the same crystal, running on the third overtone, will have a motional resistance of 30 ohms and a motional capacitance of 3.3 femto Farads. When it is operated on the fifth overtone, the resistance will increase to 50 ohms and the capacitance will fall to 1.2 femto Farads. On the seventh overtone, the resistance will be 100 ohms and the capacitance will be 0.6 femto Farads.

It is possible to excite crystals on higher overtones (ninth, eleventh, etc.) However, the resistance becomes so great that the oscillators become difficult to start, or will take off and run at some frequency not under crystal control. A few years ago, seventh overtone operation was included in this category.

Figure 2 shows a plot of reactance versus frequency for a typical crystal. We see point *S,* which is the series resonant frequency, and point *A,* which is the parallel, or anti-resonant, frequency. The difference between these frequencies (known as the pole to zero spacing) is also overtone dependent. For example, a fundamental overtone crystal might have a resonant to anti-resonant spacing of 1500 parts per million. While operating on the

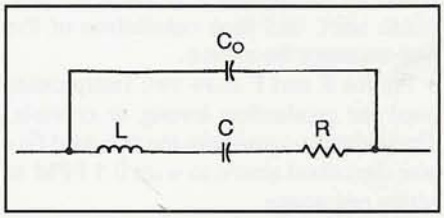


Figure 1. Equivalent circuit of a crystal as illustrated by capacitance, resistance, and inductance.

third overtone, the spacing would be about 170 PPM. Operating that crystal on the fifth overtone will yield a spacing of 60 PPM, and on the seventh overtone the spacing drops to about 30 PPM. What this tells us is that as the overtone increases, the pullability decreases dramatically.

In the lab we can measure the true series resonant frequency very easily, and the true anti-resonant frequency with some difficulty. In practice, the true anti-resonant frequency is not particularly useful, but the region around series resonance is where virtually every crystal oscillator operates. Series resonance is the frequency at which the phase shift is zero and the resistance is at minimum. A simple fixture for measuring crystal frequency is shown in figure 3 and photos C and D. The most accurate way of using the fixture is to connect a vector voltmeter to terminals *A* and *B*. However, a dual-trace oscilloscope can be used, which, with care, can yield surprisingly accurate results.

Anti-resonance can be measured in the same fixture. However, one must tune very carefully, because the anti-resonant frequency is elusive and things happen in a big hurry. Anti-resonance is better

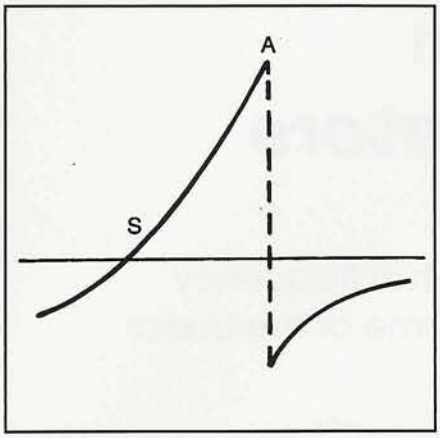


Figure 2. A plot of reactance versus frequency for a typical crystal.

found by measurement of the 45-degree phase shift, and then calculation of the anti-resonant frequency.

Photos E and F show two instruments used for production testing of crystals. These meters agree with the standard fixture described above to with 0.5 PPM at series resonance.

If we have an oscillator that is running at series resonance and if we insert a capacitor of 32 pF in series with the crystal, the oscillator will move up in frequency. If we then change the capacitor to a value of 10 pF, the oscillator frequency will move even higher.

Crystal manufacturers refer to this capacitance as the *load capacitance.* Values of 10 pF, 20 pF, and 32 pF are standard values of load capacitance. The use of the term *load* is deceptive in that the capacitor is really a resonance compensation element and is used to match the characteristics of the crystal to the characteristics of the oscillator. It is this change in frequency versus change in capacitance (referred to as *trim sensitivity*) that allows temperature compensation and oscillator disciplining. Also, Direct FM and FSK can be accomplished.

If we use a variable capacitor in place of the fixed capacitor, we can adjust the oscillator frequency about anywhere we want. In the case of a fundamental overtone crystal, we can move the frequency a remarkably long way—easily several hundred parts per million.

The astute reader will ask, "Can we replace the capacitor with an inductor and get the frequency to move lower?" In short, yes, with results similar to, but opposite in frequency to, the use of a capacitor.

There are limits to how far we can pull the frequency, however. The upper limit is obviously nearly the anti-resonant frequency. The lower limit is where more inductance yields insignificant changes in frequency or the impedance of the inductor becomes large enough to prevent oscillation.

Many of you will have heard that pulling the crystal from its design frequency will degrade the oscillator's stability. This is not true, if one only uses the series inductor or capacitor to cause the frequency change. In fact, by judicious selection of the series component, one can actually enhance the stability of the system.

Figure 4 shows crystal frequency change versus temperature by rotation of the crystal axis in minutes of arc. Crystal manufacturers use this data to select the angle that best suits the customer's requirements. For example, a requirement for ±10 PPM stability from –20°C to +70°C would call for angles between +2' and +5'. A requirement for service in an oven operating at +85°C would need an angle near +12'.

The absolute value of this angle is dependent upon many factors. The primary factor is the overtone of use. A 0'-angle crystal operated on the fundamental will not be anywhere near the 0'-angle curve when operated on a higher overtone. It is this phenomenon that primarily precludes the use of a crystal designed for fundamental service on higher overtones. Other design factors also differentiate fundamental and overtone service. Generally, though, it is not good practice to use crystals on overtones other than that for which they were manufactured.

An important but often overlooked consideration is that of drive level. Most crystals are specified to operate at a drive level of 1 mw. Many things can happen when crystals are over driven—all bad.

As the drive level is increased, so-called "spurs" may appear. These are mechanically coupled modes that are excited by the excess movement of the quartz blank. The good part is that when the drive level is reduced, these coupled modes disappear.

Excessive drive can also cause an increase in the aging (we will discuss aging later) rate of the crystal. It is also

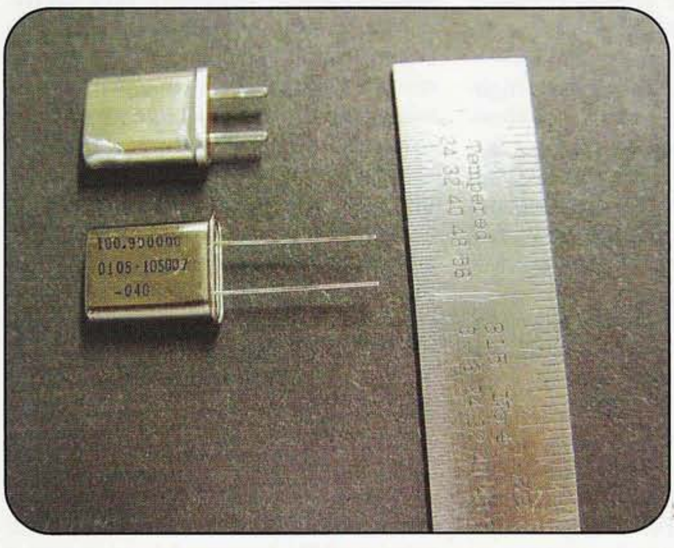


Photo A. Examples of crystals mounted in conventional holders. (Photos and graphics by Ivars Lauzums KC4PX)

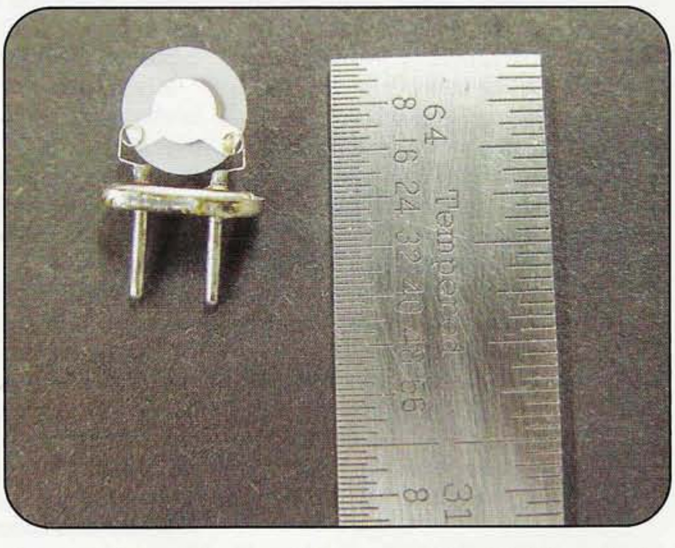


Photo B. A crystal mounted in a conventional holder with the cover removed.

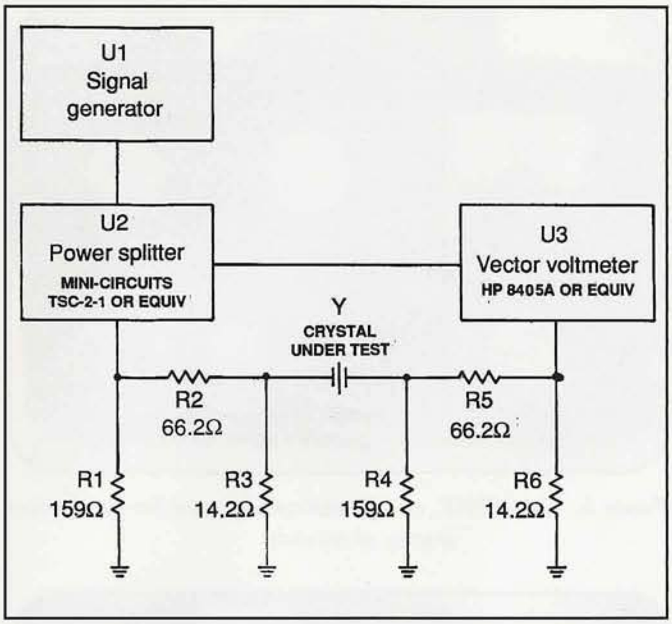


Figure 3. The schematic diagram for a simple fixture for measuring crystal frequency.

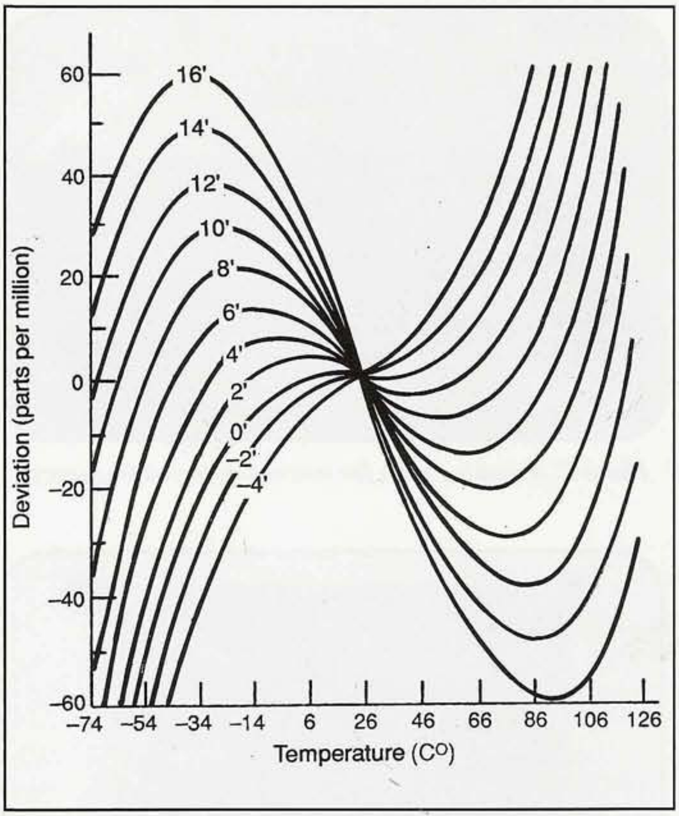


Figure 4. A graph illustrating crystal frequency change versus temperature by rotation of the crystal axis in minutes of arc.

quite possible to destroy the crystal by excessive drive. The electrodes can be blown off the quartz blank (been there, done that), or the blank itself can be fractured (been there, done that, too).

Drive level can be measured in the oscillator by inserting a low-value non-inductive resistor in series with the crystal and measuring the RF voltage drop across the resistor. Solving the equation E(2)/R will give the drive level. A 10-ohm resistor generally will be adequate, although lower would be better. When measuring the drive level on fifth and seventh overtone crystals that have a choke coil across the crystal, insert the resistor in series with both the choke and the crystal.

If you get nothing else from this article, please remember that crystal oscillators are frequency generators, not power generators. To obtain more power, use the amplifier stages that are needed to get to the desired power level. You will end up with a much more stable, long-life oscillator.

Crystal manufacturers expend considerable effort to address the aspect of aging. The end user can take steps to avoid neutralizing this effort. Keeping the drive level at or below 1 mw is the first and easiest step. Second, refrain from doing anything that will damage the integrity of the holder seal. For example, do not solder to the cover of a solder-seal crystal.

Other components in the oscillator circuit can cause frequency changes over time that can be mistakenly attributed to crystal aging. Changes as subtle as the relieving of stresses in solder joints can cause small, but measurable changes in frequency.

Variable capacitors exhibit a phenomenon known as *creep.* This is when the capacitance changes from its set value over time.

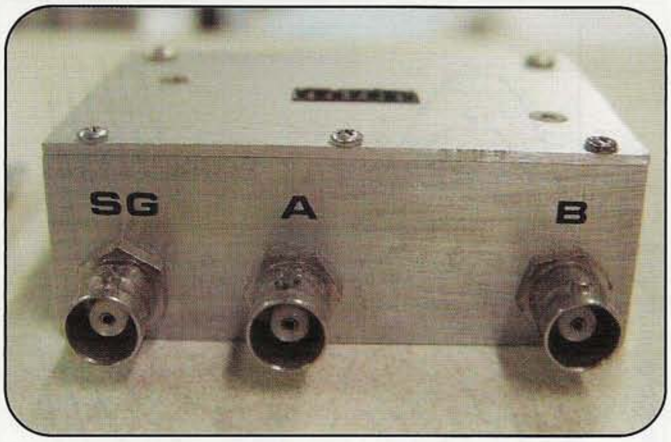


Photo C. A simple fixture for measuring crystal frequency.

Photo E. The 100HF, an HF instrument used for production testing of crystals.

Photo D. A simple fixture for measuring crystal frequency with the cover removed.

Photo F. The 200VHF, a VHF instrument used for production testing of crystals.

Most variable capacitors exhibit some degree of creep. Piston capacitors and air-variable capacitors generally are less prone to creep. Some of the ceramic capacitors can be virtually unusable in that they seem to never stop changing. Remember that very small changes in capacitance can translate to unacceptable changes in oscillator frequency.

When measuring oscillator frequency, be aware that loading effects can cause significant changes. A small one- or two-turn loop on the end of a piece of coax often will be sufficient to drive a counter with minimal loading. If the oscillator drives amplifier or multiplier stages, make the frequency measurements as far down stream as practical. This will help to isolate the effects of measurement.

Speaking of counters, one can be deceived by all those digits. Many low-priced counters advertise accuracies of ±.001%. Just how much is that in real frequency? On 20 meters, it is ±140 Hz, which is not a problem. On 2 meters, the possible error is ±1400 Hz. Hmm, now that is a real difference, but more of a nuisance than a problem. On 3 cm the error is ±100 kHz (problem)! It's going to take a lot of tuning to make the schedule.

Suppose we bought a counter that has an accuracy of ±0.5 PPM. Would the extra expense be justified? On 20 meters we are now looking at ±7 Hz, so we really can't justify the added cost. On 2 meters we are looking at ±70 Hz, so maybe the added cost is justified—then again, maybe not. On 3 cm we now have an accuracy of ±5 kHz, which is still not great, but we have given ourselves at least a good chance of finding that weak signal, so the cost is easily justified. However, with the proliferation of GPS disciplined frequency standards, it is realistic to be able to get counters to run at an accuracy of better than parts in 10^{-9}. This translates to 10 Hz at 10 GHz.

Summary

The frequency of crystal oscillators is dependent upon many factors. We have discussed some of the considerations, such as temperature effects, drive level, and external components. ■

Note

1. The values given are representative only and should not be construed as values for a particular crystal. They are given only to demonstrate the magnitude of the parameter change with respect to overtone of operation.

Portable PREDICT Plus!

A Satellite Tracking, Pacsat Yakking, APRS Hacking, Linux Packing Mini Application Suite You Can Carry with You

KD2BD describes a stand-alone suite of satellite tracking and digital communication applications you can run just about anywhere from a pair of floppy disks.

By John A. Magliacane,* KD2BD

Maybe you run a Linux PC at home to track satellites, bounce APRS[1] packets off the International Space Station, or exchange e-mails and files via AMSAT's new Echo satellite. Maybe you would like to take that capability with you on Field Day or to club meetings where Linux[2]-based PCs are scarce. Maybe you run the DOS version of PREDICT and would like to tinker with it in its native Linux environment. Maybe Linux has caught your attention, but the process of choosing and installing a suitable distribution, and then having to configure all the amateur radio applications correctly, seems like an overwhelming task. Maybe you're having difficulty setting up your Linux box for satellite tracking and pacsat communication work, and you would like to take a peek at a properly configured system to see how everything fits together.

Maybe Portable PREDICT Plus! can help. Portable PREDICT Plus! is a tiny distribution of the Linux operating system that combines the AX.25 networking capabilities and multitasking nature of Linux together with the interoperability of many Linux-based amateur radio communication applications. It delivers them together in an elegant and effective communications package that is of particular interest to VHF and above spectrum users.

Portable PREDICT Plus! includes time-proven applications and utilities designed for pacsat communications, traditional packet radio communications, EME (Earth-Moon-Earth), APRS (Automatic Position Reporting System) beacon generation, and general satellite tracking. Best of all, it runs off a pair of innocuous 3.5-inch floppy disks and operates entirely in RAM. There's no need to fuss with your current PC setup. There's no need to format or partition your hard disk. In fact, you don't even need a functioning hard disk or a CD-ROM drive on your computer to install or run Portable PREDICT Plus! Its small footprint and meager requirements also make it a great "if all else fails" communications package in the event the unthinkable ever occurs and you really need something that works.

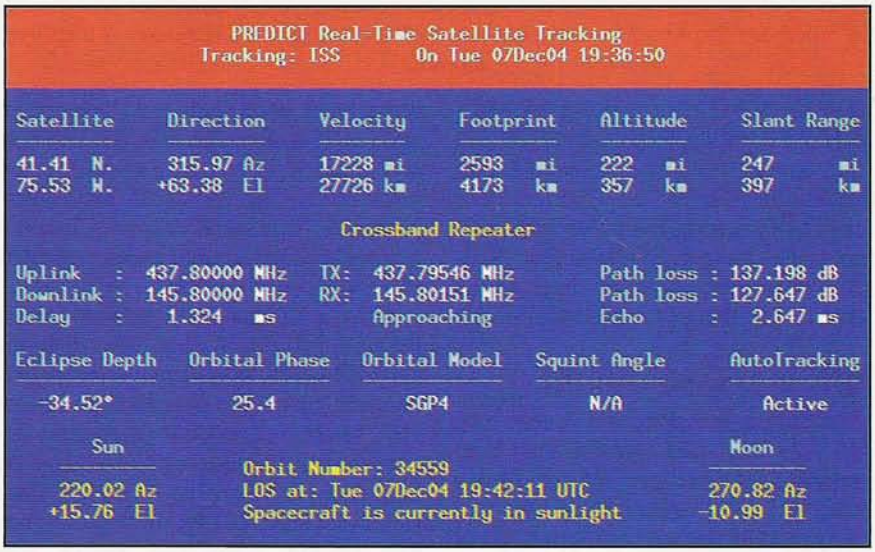


Figure 1. PREDICT tracking the International Space Station. PREDICT displays Doppler-corrected uplink and downlink frequencies to aid in making voice contacts through a quickly moving satellite. AutoTracking through an AZ/EL rotator system is also provided.

How It All Started

The idea for creating Portable PREDICT Plus! was sparked early last year through an e-mail exchange between Central California AMSAT Area Coordinator Cliff Buttschardt, K7RR, and myself. Cliff's work at Cal Poly with students developing a CUBESAT picosatellite revealed a strong interest in running Linux-based PREDICT satellite-tracking and orbital-prediction software for CUBESAT communication. The requirement of installing Linux on the satellite-tracking PCs, however, introduced some complications that the parties involved wished to avoid.

Cliff and the folks at Cal Poly started looking at the CDROM-based Knoppix distribution of Linux for this application in the hopes it might easily be adopted for this use. Meanwhile, my thoughts turned more toward developing a smaller,

**1320 Willow Drive, Sea Girt, NJ 08750-2315*
e-mail: <jmagliacane@brookdalecc.edu>

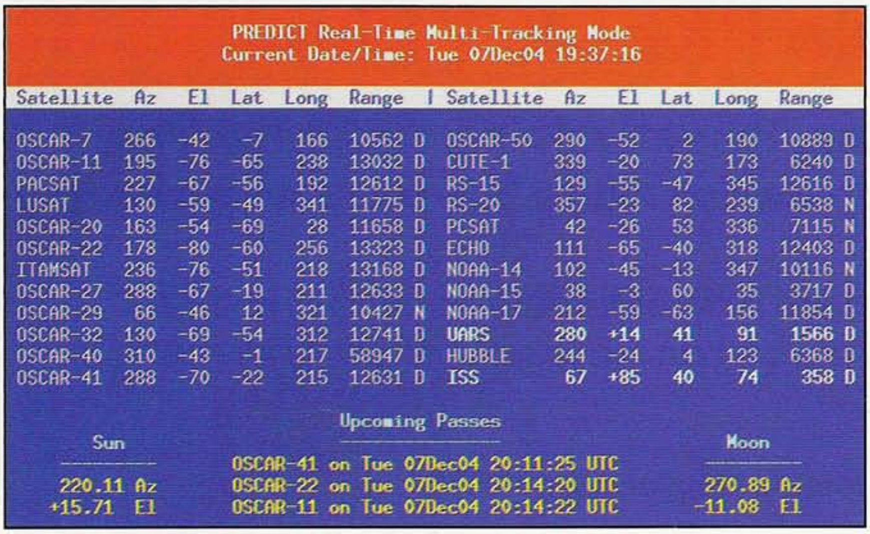


Figure 2. PREDICT in multi-tracking mode. Positions for 24 satellites plus the sun and moon are displayed in real-time. A list of upcoming satellite passes is displayed as well.

bootable floppy-disk version of PREDICT. This was due in part to the fact that I had already used floppy-based Linux distributions such as Trinux and Slackware's rescue disks with great success in the past, and I knew that PREDICT could very easily be made to run in such a bare-bones Linux environment.

Birth of a Distribution

Building a practical and functioning Linux system and distribution from scratch is a bit more involved than simply typing "SYS A:" and copying files to a floppy disk, as was the case in the days of MS-DOS. Fortunately, Linux is a very open environment with many knowledgeable users who are eager to share their knowledge. With several excellent "HOWTO" documents that describe the process of building Linux boot and root system disks available on the net, it wasn't long before a brand-new Linux computing environment was born. As progress was made, it was soon realized that enough free space was available on the newly created Linux distribution to include not only PREDICT, but many other satellite-related applications as well.

How It Works

Portable PREDICT Plus! operation starts with a boot disk containing a recent Linux kernel into which drivers for common PC hardware have been compiled. Support for 80386 and above (or compatible) CPUs, plug-and-play hardware, serial and parallel ports, CDROMs, ZIP and floppy disk drives, and (E)IDE hard disks have been included. Drivers for ext2, ext3, msdos, vfat, ntfs, udf, iso9660, and ramdisk file systems, as well as network drivers for the AX.25 and TCP/IP protocols, and serial drivers for multikiss and 6pack terminal node controllers (TNCs) are also included.

After a PC has been booted from a Portable PREDICT Plus! boot disk, the kernel is loaded into memory and its execution begins. After the kernel probes the PC's hardware and loads appropriate drivers, the user is prompted to exchange the boot disk for a Portable PREDICT Plus! root disk. The root disk contains a Linux file system containing nearly four megabytes of software that have been compressed to fit on a single 1.44 megabyte floppy disk. The root disk is uncompressed as it is read and is placed into a section of memory allocated by the kernel as a RAM disk. The RAM disk operates in much the same way as a hard disk, but has several advantages over the latter. First, being fully electronic, a RAM disk is unbelievably fast. Second, operating from a RAM disk avoids any chance of interference to software or operating systems already stored on the PC's hard disk.

After loading of the root disk is complete, users may "log into" the system with a username (and optional password), just like a traditional Linux system. First-time users run a "setup" utility to configure and personalize their Portable PREDICT Plus! environment. Information regarding their callsign, geographic location, TNC serial port connection, and baud rate are entered. An IP address that is used for internal networking is also selected at this time.

While the RAM disk is lightning fast and secure, its storage is only permanent as long as power remains supplied to the PC. Therefore, a "backup" utility is included with Portable PREDICT Plus! to save session contents and configuration information to a third "data" disk before the PC is powered down. The next time Portable PREDICT Plus! is run, the contents of the data disk are restored to the RAM disk using the "setup" utility, and everything is back to the way it was before the last session was ended.

In addition to providing a means for permanent data storage, the data disk also serves as an important medium for information exchange. The data disk allows

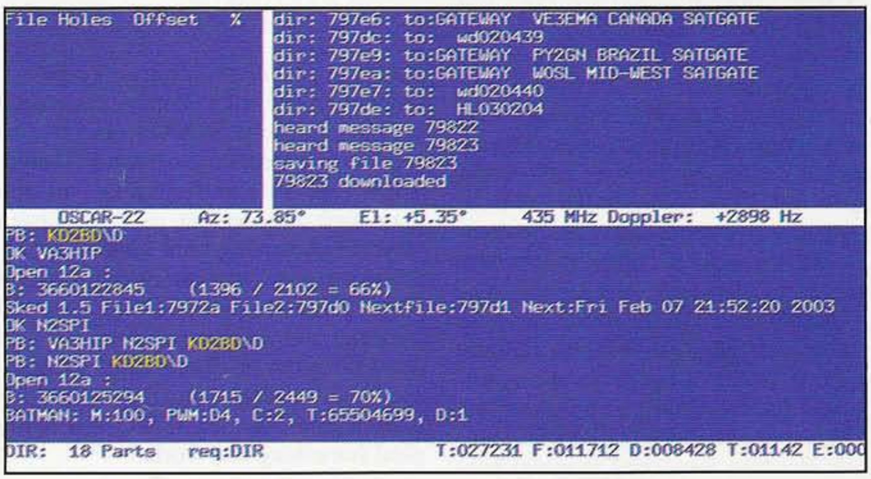


Figure 3. Intercommunication between applications: pb is shown communicating with the UoSAT-OSCAR-22 satellite just prior to LOS (loss of signal). Real-time tracking data in the center of the window is courtesy of PREDICT and its UDP network interface capabilities.

Figure 4. Cooperation between applications: "pbdir" is shown displaying satellite directory information. Files that have been queued for downloading are highlighted.

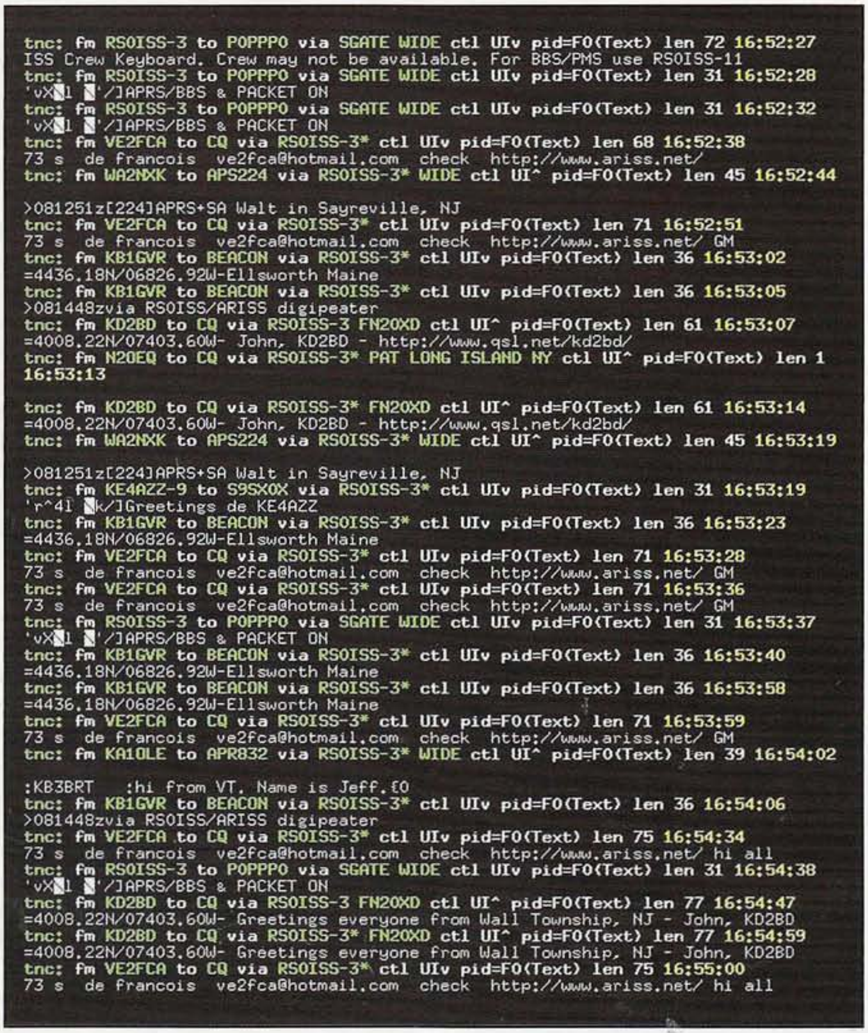


Figure 5. Packets received via the International Space Station by KD2BD using Portable PREDICT Plus! on December 8, 2004. A UTC timestamp is displayed in yellow. The packets originating from KD2BD were generated through Portable PREDICT Plus!

up-to-date Keplerian orbital elements used for satellite tracking and orbital prediction functions to be imported into a running Portable PREDICT Plus! environment. Conversely, files and directory information collected from a pacsat satellite during a Portable PREDICT Plus! session may be exported out of the operating environment using the same disk. The exported files can be used again in a future session as described earlier, or perhaps elsewhere in another environment, whether it be DOS, Windows®, or a traditional Linux installation.

The Suite is Neat (and very complete)

Portable PREDICT Plus! contains PB/PG, an FTL/0 protocol pacsat satellite communications suite by Bent Bagger, OZ6BL; PacsatTools, a collection of pacsat satellite communication utilities; "minicom," a popular terminal communications package; and MoonTracker, an application for predicting moon rise and tracking the position of the moon across the sky through an AZ/EL rotator system.

Also included are "must have" TNC and packet radio utilities such as "setserial," "kisson," "kissoff," "kissattach," "kissparms," "listen," "call," "mheard," and "beacon." Joe Dellinger's classic "morse" program is included as a replacement for PREDICT's English-speaking "vocalizer" utility, which couldn't be included because of size and soundcard driver requirement restrictions. Instead, added to Portable PREDICT Plus! is a replacement for the "vocalizer" that sends live azimuth and elevation satellite bearings to the user via the PC's speaker using Morse code. The Morse application is also available to the user for practicing CW skills while waiting for satellite passes.

Many classic Unix core utilities—such as colorized "ls," "vi," "ash" (a small bash-like shell that features command and filename completion and command history), "cal," "date," "ping," "ifconfig," "netstat," "route," "top," "zip," "gzip," and more (literally) are provided through a single, powerful, multi-call application known as "Busybox." All the associated dynamically linked libraries needed to produce a fully-functional Linux operating environment running under a 2.6.x kernel are included as well.

Operation

By now you're probably thinking that a familiarity with Linux and its AX.25

Callsign	Port	#I	#S	#U	First Heard	Last Heard
KB1GVR	tnc	0	0	15	Wed Dec 8 15:16:46	Wed Dec 8 16:56:22
VE2FCA	tnc	0	0	18	Wed Dec 8 15:14:50	Wed Dec 8 16:56:11
KD2BD	tnc	0	0	10	Wed Dec 8 15:14:14	Wed Dec 8 16:55:52
RS0ISS-3	tnc	14	17	44	Wed Dec 8 15:12:58	Wed Dec 8 16:55:40
KB3BRT	tnc	0	0	4	Wed Dec 8 16:52:26	Wed Dec 8 16:55:30
KA1OLE	tnc	0	0	2	Wed Dec 8 16:51:17	Wed Dec 8 16:54:02
WA2NXK	tnc	0	0	4	Wed Dec 8 16:51:28	Wed Dec 8 16:53:19
KE4AZZ-9	tnc	0	0	3	Wed Dec 8 15:13:17	Wed Dec 8 16:53:19
N2OEQ	tnc	0	0	2	Wed Dec 8 16:52:20	Wed Dec 8 16:53:13
VE3FFR	tnc	0	0	2	Wed Dec 8 15:15:43	Wed Dec 8 16:51:52
KX9D	tnc	0	0	14	Wed Dec 8 15:13:08	Wed Dec 8 16:51:19
W1SNE	tnc	0	0	2	Wed Dec 8 15:16:14	Wed Dec 8 16:51:18
KE4AZZ	tnc	0	0	1	Wed Dec 8 16:51:03	Wed Dec 8 16:51:03
RS0ISS-11	tnc	4	8	6	Wed Dec 8 15:14:53	Wed Dec 8 15:16:46
K4IPH-7	tnc	0	0	2	Wed Dec 8 15:15:26	Wed Dec 8 15:15:47
AG4ZQ	tnc	0	0	1	Wed Dec 8 15:14:25	Wed Dec 8 15:14:25
KG0YJ	tnc	0	0	2	Wed Dec 8 15:13:54	Wed Dec 8 15:14:15
KB0OFD-10	tnc	0	0	3	Wed Dec 8 15:13:04	Wed Dec 8 15:14:00
N0AN-6	tnc	0	0	1	Wed Dec 8 15:13:42	Wed Dec 8 15:13:42
N7OFW	tnc	0	0	1	Wed Dec 8 15:13:32	Wed Dec 8 15:13:32
VE3TZS	tnc	0	0	1	Wed Dec 8 15:12:56	Wed Dec 8 15:12:56

Figure 6. "mheard" log of stations copied over two consecutive passes of the ISS by Portable PREDICT Plus! The number of each packet frame type copied is also displayed.

utilities would be a good thing to have to run all the applications included in Portable PREDICT Plus! Familiarity and experience are always helpful, but nearly every application included in Portable PREDICT Plus! has been pre-configured at the factory. Full documentation on all applications has been included as well, so success, even among newcomers to Linux, often is quite good.

The applications selected for inclusion in Portable PREDICT Plus! inter-operate extremely well. For example, PREDICT can be run in "network server mode" to supply live satellite tracking data to other resident applications. Under Portable PREDICT Plus! it is possible to have pacsat satellite communications package "pb" poll PREDICT for live tracking data through its UDP network interface, thereby allowing "pb" to report this information as part of its regular on-screen display (figure 3).

In a similar manner, PREDICT and MoonTracker can also supply tracking information via a serial port to antenna rotator controllers employing the EasyComm-2 protocol. But all you have is a FODtrack interface to your rotator controller? No problem. A "fodtrack" utility is included which takes the tracking data that would normally be sent to an EasyComm-2 compatible controller, converts it into the format required by the FODtrack interface, and sends it through the parallel port to your interface.

A collection of PacsatTools is also included to perform pre- and post-pass processing of pacsat satellite data. Files downloaded by "pb" may be processed through "phs" to display and strip pacsat file header information from downloaded files. "phs" also "unzips" ZIP compressed files as needed without the requirement for manual user intervention. Pacsat directory information may be browsed, and file download requests may be made through "pbdir" (figure 4). Messages can be composed through "vi," compressed using "zip," and processed through "pfhadd" prior to being uploaded to a satellite through "pg." "dos2unix" and "unix2dos" text format conversion utilities are included as well, should the need for them ever arise.

Cooperation and Multitasking

The intercommunication and cooperation between small applications that work in concert to perform larger, more complex tasks under Portable PREDICT Plus! is really no different from the process that would normally take place in a larger Linux environment. This "division of labor" approach is the essence of the Unix (and Linux) computing philosophy, and was instrumental in successfully squeezing a lot of computing flexibility into a very small package.

How does all this sequential and concurrent computing take place on a PC with only a single monitor and keyboard combination and no windowing environment? Portable PREDICT Plus! supports a system of eight "virtual consoles." Each provides completely independent screen and keyboard combinations (consoles) for logging into the system, and running, and controlling applications. Virtual console number one is the console first displayed at startup. Switching between consoles is accomplished simply by holding the left Alt key on the keyboard while simultaneously pressing a function key (F1 through F8) that corresponds to the virtual console desired. It is through these virtual consoles that a user can simultaneously monitor the progress of a satellite pass in real-time, run predictions for other satellites, initiate file transfers with a pacsat satellite, view pacsat directory information, select files on the satellite for downloading, compose messages for uploading, monitor AX.25 channel activ-

KD2BD's Orbit Calendar For ISS

Date	Time	El	Az	Phase	Lat	Long	Range	Orbit
Wed 08Dec04	15:12:37	0	293	236	45	99	2164	34571 *
Wed 08Dec04	15:13:43	3	302	239	47	94	1815	34571 *
Wed 08Dec04	15:14:48	7	315	242	49	88	1526	34571 *
Wed 08Dec04	15:15:53	10	333	245	50	82	1336	34571 *
Wed 08Dec04	15:16:58	11	354	248	51	76	1289	34571 *
Wed 08Dec04	15:18:02	9	14	251	52	69	1398	34571 *
Wed 08Dec04	15:19:07	6	30	254	52	63	1633	34571 *
Wed 08Dec04	15:20:12	2	41	1	52	56	1950	34572 *
Wed 08Dec04	15:20:53	0	46	3	51	52	2172	34572 *
Wed 08Dec04	16:49:07	0	314	250	51	96	2166	34572 *
Wed 08Dec04	16:50:12	3	323	253	52	89	1819	34572 *
Wed 08Dec04	16:51:17	7	336	256	52	83	1530	34572 *
Wed 08Dec04	16:52:22	10	354	3	51	76	1342	34573 *
Wed 08Dec04	16:53:27	11	15	6	51	70	1296	34573 *
Wed 08Dec04	16:54:32	9	35	9	50	64	1406	34573 *
Wed 08Dec04	16:55:37	5	50	12	48	58	1640	34573 *
Wed 08Dec04	16:56:42	2	61	15	46	52	1956	34573 *

More? [y/n] >>

Figure 7. A PREDICT orbit calendar for passes of the International Space Station.

ity, practice CW, and even select a track on a favorite audio CD.

Hardware Requirements

It doesn't take a modern, high-end PC to run Portable PREDICT Plus! A 100-MHz Pentium-based PC has more than enough muscle to perform all the operations described here simultaneously without ever breaking a sweat. For lower-end systems such as 80386s and 80486SXs, a math co-processor, while not required, is strongly recommended. Since four megabytes of RAM are allocated for use as a ramdisk and additional memory is needed for normal program execution, a minimum of eight megabytes of memory are recommended for Portable PREDICT Plus! 16 megabytes will all but guarantee successful operation.

A packet radio terminal node controller and associated radio equipment (obviously) are also required. The TNC need not be fancy. A simple TNC-2 or suitable clone that is capable of KISS-mode operation is all that is needed. Scripts are included in Portable PREDICT Plus! to easily bring the host TNC into and out of KISS mode. Other scripts modify the kernel's AX.25 parameters for half- or full-duplex operation as needed. A terminal emulator ("minicom") is also included for managing and configuring the TNC in standard (non-KISS) mode.

Building the Disk Sets

Portable PREDICT Plus! disk sets are packaged with electronic documentation and software required to write the root and boot disk images to blank floppies. Two packages are available—one for building the disk sets under an existing Linux environment and one for use under a DOS or Windows® environment. Each package is about 3 megabytes in size, so they can be downloaded quickly, even over a dial-up connection.

Links to these files, and the latest news on this project, are available on the PREDICT website.

Conclusion

Linux distributions currently number in the hundreds, and the quantity continues to grow. While most are designed to be installed permanently to a hard disk through a CD-ROM based installation procedure, a growing number of smaller, non-permanent, application-specific distributions are making their way onto the scene. Portable PREDICT Plus! is one such distribution.

What at first appeared to be a novel exercise and a simple challenge to create a miniature Linux environment has resulted in a flexible and practical stand-alone communication suite well worth the time and effort invested to develop it. Released to the Internet under the GNU General Public License, its use is open to all who seek it. New uses are found almost daily, from repairing Linux PCs at work, to configuring network routers and switches. In fact, it should come as little surprise that Portable PREDICT Plus! was even used to compose this little article. ■

Notes

1. APRS is a registered trademark of Bob Bruninga.

2. Linux is a registered trademark of Linus Torvalds.

Further Information

PREDICT Software: <http://www.qsl.net/kd2bd/predict.html>

The Echo Project Page: <http://www.amsat.org/amsat-new/echo/>

Amateur Radio Software for Linux: <http://radio.linux.org.au/>

PREDICT @ AMSAT.ORG: <http://www.amsat.org/amsat-new/tools/predict/>

Cal Poly Picosatellite Project: <http://polysat.calpoly.edu/index.html>

The Linux Bootdisk HOWTO: <http://www.tldp.org/HOWTO/Bootdisk-HOWTO/index.html>

APRS Beacon Creation: <http://web.usna.navy.mil/~bruninga/iss-aprs/issicons.html>

DFing a Lifesaving Transmitter

Hidden-transmitter hunting can be more than just a fun aspect of our hobby. It can have a serious side as well. Here N9SFX tells the story of when an Alzheimer's patient tracking device disappeared during a demonstration—and how hams saved the missing transmitter.

By Peter L. Ostapchuk,* N9SFX

I was amazed to see a foxhunter on the front page of the November 20, 2004 edition of the *Elkhart Truth.* On closer inspection, it turned out to be a picture of Captain Ron Biller of the Bristol, Indiana police department trying out a tracking device that is part of Project Lifesaver. I guess he really is a foxhunter, just not a ham, as far as I know.

The system was designed five years ago by the sheriff's department in Chesapeake, Virginia. It's a system that has been in use for decades in pursuits such as ham radio and wildlife tracking (see the May 1998 issue of *QST*). It consists of a 3-element Yagi antenna connected to a receiver that is worn on a neck strap. The tracking device is used to track persons such as Alzheimer's patients who might have wandered off. The patient wears a transmitter about the size of a wristwatch. It is worn on the wrist and transmits a short carrier about once a second and lasting about 50 milliseconds. The unit costs $263 and will transmit nonstop for a month on one battery. The battery costs $15. The transmitters operate on many different frequencies, from 215 MHz to 216 MHz. This allows searchers to distinguish between one patient and another. The local organization is called Triad. See the sidebar for more on Triad and Project Lifesaver.

The Monday after I saw Ron Biller's photo, I got a call from Jim Kehr, N9DUZ, about a missing transmitter from Project Lifesaver. I couldn't understand why they needed me, when I had just read about the tracking devices two days before. Jim told me to call Captain Brad Rogers of the Elkhart County Sheriff's Department; he also happens to be co-chair of Triad.

**59425 Apple Rd., Osceola, IN 46561*
e-mail: <N9SFX@aol.com>

The author (left) and Ritch Williams, KA9DVL, try to locate the transmitter in the water using a submersible probe attached to a 10-foot pole.

Captain Rogers told me about a demonstration that had gone wrong. Triad had put on a training exercise on November 17–19. Several of the wristband transmitters had been deployed, and Triad members were able to go looking for them with the aid of the aforementioned tracking devices. All but one of the transmitters was found. One of them had become submerged in a lagoon on the edge of the Elkhart River. The water was only one foot deep, but the silt under the water extended for what seemed like forever. Hip waders were tried before the depth of the silt was discovered. A boat with a metal detector was tried, but the transmitter was never found.

The transmitter with its o-ring seal was still transmitting, but Triad had no way to direction find the unit under water. The best they could do was find a general location in the river where the transmitter was submerged. I was amazed to hear that a signal was able to propagate through the water well enough to be heard above water.

The transmitter was operating on 215.02 MHz, but my Alinco DR235 would only go down to 216 MHz. My Kenwood TM-742 would go down to 215 MHz. I also have a Kenwood TH-F6 triband HT that receives from DC to daylight. I had built an 8-element Yagi for the 220-MHz band a couple of years earlier and it was still sitting around. I also had some of my homemade RF attenuators nearby (see October 1999 *CQ VHF*).

I loaded up my van and headed off to Goshen, hoping that maybe they had not done their foxhunting correctly. How-

The successful DFers return with the fox in hand.

ever, they were right; the transmitter was in the drink. They had not told me where the transmitter was located, but I listened to the 742 mobile on the way to Goshen and started picking up the transmissions as I neared the downtown area. In a few minutes I knew that it was located just behind the County/City Building. The 220-MHz beam with the attenuator and Kenwood TH-F6 worked well at 215 MHz, but again it only told me that the transmitter was in the middle of the lagoon. It was a short walk to meet with Warren Allender, director of Emergency Management in the County/City Building. He came out to the lagoon and confirmed that I had found the right location.

On Tuesday, November 23 I came up with an idea for a submersible probe. It consisted of a piece of RG-58 A/U with one inch of the center conductor exposed and water proofed. I strapped it to a 10-foot long pole and put a BNC connector on it. I asked Wayne Zehner, K9WZ; Dave Evans, AA9DG; Alan Rutz, WA9GKA; and Larry Wheeler, W9QR, for their blessings on the probe and got them. These guys know more than most hams could ever dream of knowing about RF!

I took the probe to the lagoon that afternoon and tried it as best I could without a boat to see if the idea would work. I walked up and down the shoreline and could see the signal go slightly up and down with the changing distance to the transmitter. Even with the 10-foot pole, the probe was still about 30 feet from the transmitter at its closest.

Wednesday was cold, windy, and rainy. That's not foxhunting weather. Rather, that's antenna installation weather. Thursday was Thanksgiving and everyone was with their families. I was anxious to get the job done so I could determine if the probe would work as expected. The other issue was the battery. I knew that the transmitter had been on for at least eight days as of Friday, but I didn't know how many training exercises it had been used for prior to this one. Once a battery is dead, the foxhunt is effectively over.

On Friday, Ritch Williams, KA9DVL, brought his inflatable boat to Goshen. Larry Rodino, KC9DMG, and Dave Evans, AA9DG, were on the shore as camera crew/rescue team. Ritch and I put out into the lagoon and headed toward the suspected spot. I switched the TH-F6 to CW and could listen to the tone caused by the short carrier coming from the transmitter. I slid the probe back and forth under water, out ahead of the boat, while listening to the signal on the HT. As we got closer to the transmitter, I kept adding attenuation. By the time we were on top of the transmitter, I had switched in all 95 dB of attenuation and still had a healthy signal. This is amazing, as the signal from the transmitter is only 5 microwatts. I tried listening to the third harmonic, but could not hear a thing there. The transmissions were too short for the S-meter to respond. We were DFing by field strength as indicated by the sound coming from the HT.

Triad and Project Lifesaver

By Captain Brad Rogers
Elkhart County Sheriff's Department

Triad is a nationally recognized organization, with each local Triad developed and controlled at a local level, involving law enforcement, social services agencies, and senior citizens. The scope of Triad is aimed at reducing the victimization of senior citizens. This involves not only criminal victimization, but other ways in which seniors can become victims, such as in emergency disasters and other senior living issues, including Alzheimer's.

Elkhart County (Indiana) Triad, in existence since 1999, recently decided to join Project Lifesaver to provide this community service. Project Lifesaver is an active system that relies on proven and reliable, state-of-the-art radio technology and a specially trained search-and-rescue team. People who are clients of Project Lifesaver wear a wristband that contains a unique frequency that emits a tracking signal 24 hours a day. When caregivers notify the local Project Lifesaver agency that a client is missing, a search-and-rescue team responds to the point where the person was last seen and starts searching with this tracking system.

Search-and-rescue teams are composed of Triad members, some of whom are police officers, while others are volunteer citizens who want to make a difference. Search times have been reduced from hours and days to minutes. In fact, Project Lifesaver has over 1000 documented saves, a 100% success rate, and a national average find time of 22 minutes.

Project Lifesaver is not just for persons with Alzheimer's. In fact, children with autism and other persons with mental disorders who are prone to wander can also be placed in this program. In addition, Project Lifesaver clients who travel to other areas in the country that participate in Project Lifesaver can be tracked by trained personnel if they wander away.

Contact your local Triad or Project Lifesaver International for more information. As a law enforcement officer who knows the frustration of trying to find a missing person, I encourage every local jurisdiction to participate in Project Lifesaver. For more information, contact me via e-mail at <brogers@elkhartcountysheriff.com> or visit <www.projectlifesaver.org>.

After 10 minutes we were right on top of the transmitter. The 20-foot diameter circle that was indicated from DFing from shore had shrunk to a 1-foot diameter circle. The problem was that the transmitter was only an inch and a quarter in diameter and had been covered by silt. I was hoping to reach into the water and grab the device, but the sides of the boat were a little bit high and the extra 1-foot depth of water made me resort to plan B. I lowered a large magnet into the area and swished it around for a couple of minutes. The battery of the transmitter was attracted to the magnet and the rest is history.

The whole process in the water lasted about 20 minutes. No one knows for sure how the transmitter wound up in the river, but I did notice a lot of ducks in the area. The transmitter had been sitting on a tree stump a few feet from the edge of the water. It would not be much of a stretch to think that a duck could have picked up the beige-color device and carried it out into the water. Insert your own theory here.

I did a little testing with the transmitter after I got back home. There I determined that the second harmonic would have been the harmonic of choice. The second harmonic is at 430 MHz and in the ham band. I tried my homemade 10-element 440-MHz beam and was able to DF the transmitter out to 100 yards. The fundamental is easily DFed at one mile in open country when using my 8-element 220-MHz beam. I was able to pick up the third harmonic by bringing the transmitter to within a couple of inches of the TH-F6 with the rubber duck re-installed. The problem with the third harmonic could very well be the sensitivity of the TH-F6 at the third harmonic, 645.06 MHz. I listened to the TV stations in the area by tuning to the FM audio frequency. Channel 22 with an FM audio frequency of 523.750 MHz came booming in, but those frequencies around 600 MHz were barely discernible. I guess this would be called a poor-man's service monitor.

I tried shortening the exposed center conductor from 1 inch to 3/16 inch. I tried the new design in the river, but it did not work as well as the 1-inch version. My hunch is that the probe should be a quarter wavelength of the center conductor wound into a coil not unlike a rubber-duck antenna. The only problem with the first two designs was that it was difficult to zero in right on the transmitter. The shorter version gave an increasing signal while closing in on the transmitter until the probe was about 2 feet away from the transmitter. Then the signal started to decrease until the probe was in contact with the transmitter with almost no signal left. Obviously, this problem is not significant when looking for a patient with a wristband attached. It's only significant for those who have to find a very small transmitter under water. I'm here to tell you that it can happen.

On December 8, 2004 there was a Triad meeting in Goshen and the fox-hunters were invited to attend. Captain Rogers presented us with certificates of appreciation. After the meeting we were able to see the equipment used by Project Lifesaver.

If Project Lifesaver has made its way to your area, you might want to see if the group can use your help. If it has not, you might want to see if your area might consider Project Lifesaver. There are a lot of ways that amateur radio can be of service to the community, and Project Lifesaver is just one of them. I'm fortunate to have been able to locate transmitters for the PHM school system, Goshen fire department, Triad, the Elkhart and South Bend airports, and the Civil Air Patrol.

It appears that the Project Lifesaver equipment could be made compatible with underwater DFing. All that would be needed is a submersible probe similar to the one I used in the river. It would simply be substituted for the 3-element Yagi antenna that is normally used when searching for the transmitters on land. It would be a mistake to assume that a patient will never walk off and end up in the water. It would also be a mistake to think that divers only have to dive in the summer in clear water. By the time the patient is found under water, it's probably too late. On the other hand, the divers who have to go down in frigid water with zero visibility to search for the patient would rather be able to follow a coax down to the transmitter or have a probe that they could take down with them to tell them if they are moving in the right direction. This is obviously my personal opinion, but the more tricks you have up your sleeve, the more service you can provide.

The underwater probe is like the fire extinguisher that you hope you never have to use. If you have a 220-MHz beam on a tower with a rotor, you could be a real asset to those who have to locate a missing patient who has had a head start on the folks from Triad. The Amateur Radio Service . . . It's a hobby, and it's also a *service.* ■

Radio Direction Finding for Fun and Public Service
Win Foxhunting Prizes, Mobile or on Foot

"I love ARDF! It's so interesting!" Those aren't my words, but they could have been. Matthew Robbins, AA9YH, wrote them upon his return from the 2004 World Championships of Amateur Radio Direction Finding (ARDF) last September. ARDF is an all-on-foot form of hidden transmitter hunting that is done around the world. It is also called foxtailing and radio-orienteering.

This was Matthew's first ARDF World Championships (photo 1). In fact, his journey to the Czech Republic was his first-ever trip outside the USA. He earned his position on ARDF Team USA at the 2003 USA ARDF Championships near Cincinnati.[1]

AA9YH and the other competitors on our team didn't do as well as they had hoped, but their performances were remarkable when you consider that they were up against the planet's best radio foxhunters on probably the most difficult ARDF courses ever. The championships attracted 327 competitors from 28 countries to Brno, a town about 110 miles southeast of Prague. They were divided into five age categories for males and four age categories for females, in accordance with rules of the International Amateur Radio Union (IARU).

Each country was permitted to have up to three persons per category on its team. Medals were awarded to best individuals and best national teams in each age/gender division and on each band. Men under age 40 and women under 35 competed on 80 meters Thursday, September 9 while the rest did their 2-meter hunt. The reverse occurred on the following Saturday.

The 2-meter course facing 2004 World Championship contestants encompassed about 4800 acres of forest, with occasional thickets, slopes, and cliffs. The gold-medal winner in the 2-meter prime age category for men, a Czech, found all

*P.O. Box 2508, Fullerton, CA 92837
e-mail: <k0ov@homingin.com>

Photo 1. Matthew Robbins, AA9YH, nears the finish line of the 2004 ARDF World Championships in the Czech Republic with his 2-meter gear and tattered map. (Photo by Richard Thompson, WA6NOL)

five "fox" transmitters and finished in less than 78 minutes (home court advantage?). By comparison, nearly 9 percent of the starting competitors didn't get back within the $2^1/2$-hour time limit or found no foxes at all.

Two Team USA members had top-ten individual finishes in their categories. Nadia Scharlau of Cary, North Carolina placed sixth out of 22 on 2 meters. Bob Cooley, KF6VSE, age 62, of Pleasanton, California placed ninth out of 34 on his 2-meter run.

Jerry Boyd, WB8WFK, of Albuquerque, New Mexico, age 47, has over a decade of 2-meter transmitter hunting experience, but the myriad of signal reflections nearly got the best of him.

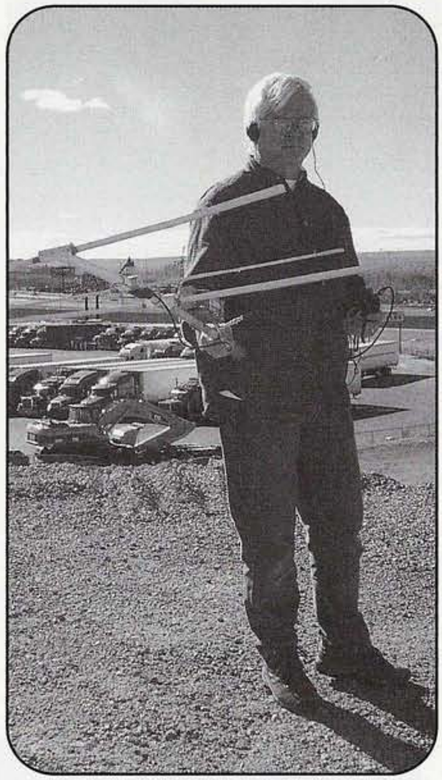


Photo 2. Atop the mid-town dirt pile, Mike Pendley, K5ATM, gets a bearing on an Albuquerque hidden transmitter. He is a co-chair of the 2005 USA ARDF Championships in "Duke City" this August. (Photo by Joe Moell, KØOV)

Having found fewer transmitters than he wanted and nearing the finish with time running out, he lost his footing and slid down a slope and off a cliff. A tree broke his fall, but he landed on his back after falling through it. Fortunately, he was not seriously injured and was able to run on to the finish line.

This was the USA's fourth trip to the biennial World Championships. Our team members ranged in age from 19 to 62 and came from nine states. Team Captain was 62-year-old Harley Leach, KI7XF, of Bozeman, Montana. Also in the 21-member USA delegation were Dale Hunt,

Photo 3. Frank Morton, AC4MK, tries transmitter hunting for the first time at the 2003 Tampa Bay Hamfest. (Photo by KØOV)

WB6BYU, of Portland, Oregon and Marvin Johnston, KE6HTS, of Santa Barbara, California. They represented USA and IARU Region 2 (North and South America) on the International Jury overseeing the competitions. Each was assigned to be a Course Marshall at one of the radio foxes out on the courses.

European and former Soviet countries have been holding ARDF events for over 30 years, so it is no surprise that they dominated in the final standings. Nine of these nations garnered all of the individual and team awards. I watched the medal ceremony in streaming video on the internet and heard nothing but East European national anthems.

The total medal count was led by the Czech Republic, Russia, and the Ukraine with 34, 28, and 26, respectively. USA, Australia, and Great Britain were among the 19 nations that won no medals. Nevertheless, the teams of these three English-heritage countries enjoyed a friendly rivalry as they shared living quarters in the same corridor of the host facility.

There is more about ARDF Team USA 2004 at my "Homing In" website,[2] along with links to complete results on the Czech ARDF site and to pages of photos by team members.

You Could Win in '05

No matter what your age, if you can run or walk for 5 kilometers, then you can succeed in ARDF. The sport is growing quickly in the USA, and our national championship competitions are open to anyone of any age. This summer foxhunters from around the USA and elsewhere in the world will gather in Albuquerque for the Fifth USA ARDF Championships. If there is sufficient participation from neighboring countries, it will also be designated as the Third IARU Region 2 ARDF Championships.

The Albuquerque activities will take place from August 1 through August 6. Besides separate on-foot direction-finding competitions on the 2-meter and 80-meter bands (August 3 and 5, respectively), there will be opening ceremonies, practice/training sessions, a sightseeing day, and a closing banquet with award presentations. The event center will be on the campus of the University of New Mexico (UNM), where competitors will be housed. Bus transportation to the competition sites will be provided.

Besides being open to all stateside radio-orienteers, the sponsoring Albuquerque Amateur Radio Club (AARC) welcomes visiting competitors from anywhere in the world. The field will be divided into the IARU-standard age/gender categories, with medals for top finishers in each category. Winners who are citizens or residents of the USA will be considered for positions on ARDF Team USA to the 2006 World Championships in Bulgaria.

Co-chairs of the organizing committee are Jerry Boyd, WB8WFK (yes, it's the same Jerry who fell through a tree in the Czech Republic!), and Mike Pendley, K5ATM. Other team leaders are Scott Stevenson, KC5VVB, and Jack Stump, KD5OEO. AARC hosted the First USA ARDF Championships in 2001 and hopes to provide even more fun for all this time.

Because many conferences and other events will take place at UNM this summer, the organizers are conducting an informal survey to get a preliminary headcount. This will ensure that sufficient housing and other resources are reserved and available. If you think you will be able to attend, please e-mail WB8WFK (wb8wfk@att.net) now to indicate your interest on a no-obligation basis.

AARC's official website for the 2005 USA championships[3] is now online with more details about housing, rules, frequencies, and the climate of central New Mexico. You can also download registration forms and find out how you or your company can become an event sponsor.

Photo 4. Tim Van Nes, N9EL (right), receives his award from Chris Schwab, N4BSA, for winning the 2004 Tampa Bay Hamfest foxhunt. (Photo by John Munsey, KB3GK)

RDF on the Road

As regular "Homing In" readers know, there are two very different ways that foxhunters compete among themselves. In

Photo 5. Newcomer Jeffrey Fontaine, WD4USA, is intrigued by a homebrew active RF attenuator at the 2004 Tampa Bay Hamfest foxhunting forum. Later he borrowed some RDF gear and took second place in the hunt. (Photo by KB3GK)

addition to all-on-foot events such as the ones above, challenging mobile "T-hunts" take place around the country all year long. Besides being a center of excellence in ARDF, Albuquerque is also a hotbed of mobile T-hunting activity.

Twice a month hams gather at a dirt pile near the "Big I" junction of Interstates 25 and 40. They stand on top and strain their ears to hear a 2-meter signal from a fellow ham somewhere on the AAA map of the city and vicinity (photo 2). As often as not, the signal they hear is reflecting from the Sandias or other mountains nearby, so the hunt can become a real challenge.

Mobile hunters don't hold national and international championships like radio-orienteers do, but they like to take advantage of regional ham get-togethers to challenge one another. More and more hamfests and ARRL conventions are including hunts of both types, often with a substantial prize package. The annual Tampa Bay Hamfest[4] has just ended as I write this, and for the second year the organizers have challenged the radio-direction-finding fans of Florida.

My wife April, WA6OPS, and I were privileged to be speakers at the 2003 Tampa Bay Hamfest and to observe its first foxhunts, one for mobiles and another on foot on the convention grounds at the Manatee Convention Center in Palmetto. The locals were new to the sport back then and got a lot of exercise as they learned how to use their new RDF gear (photo 3). Most needed some clues to get them close enough to spot the mini-transmitters in the trees and bushes, but during the post-convention get-together at Roaring 20's Pizza, they all proclaimed that they had a good time.

Since then, they have greatly improved their gear and their skills. John Munsey, KB3GK, and Bill Thomas, KE4HIX, from Daytona handily won both hunts in 2003, so organizer Chris Schwab, N4BSA, asked them to conduct a forum and organize the hunt in 2004. John and Bill put on a show-and-tell of simple beams, RF attenuators, and mini-transmitters. Then they challenged attendees to find their five foxes, which were concealed outside the building on the grounds.

"Our foxes used the familiar 'MOx' tones and were timed to have ten seconds of dead air between their sequential transmissions," John wrote. "This was so that neophyte hunters would realize that a changeover was taking place. We planned #2 and #4 to be difficult to find, and #1, #2, #3 to be for the newbies."

In less than a half hour, Tim Van Nes, N9EL (photo 4), found all five transmitters to win first prize. He was 14 minutes ahead of second-place Jeffrey Fontaine, WD4USA (photo 5). "We started them from inside the building at one minute intervals," KB3GK explained. "Bill hid the transmitters such that each hunter would start in the opposite direction from the previous hunter. This staggered starting, plus starting from inside the lobby prevented them from following each other."

For years RDF contesting has been an important part of ARRL Southwestern Division conventions (Hamcons) when they take place in southern California. At Hamcon 2003, the Fullerton Radio Club provided opportunities for the mostly expert attendees to win prizes by hunting both mobile and on foot. The fun got under way Friday evening when cars, vans, and SUVs full of beams, quads, and Dopplers gathered in a parking lot a couple of miles from convention headquarters at the World Trade Center in Long Beach.

"No clues!" is the mantra of most southern California T-hunters, so the 16 participants didn't get any. They were merely told that some transmitters would come on 146.565 MHz at 7:30 PM. Their mission was to find as many as possible and return by 10:15. Each driver was

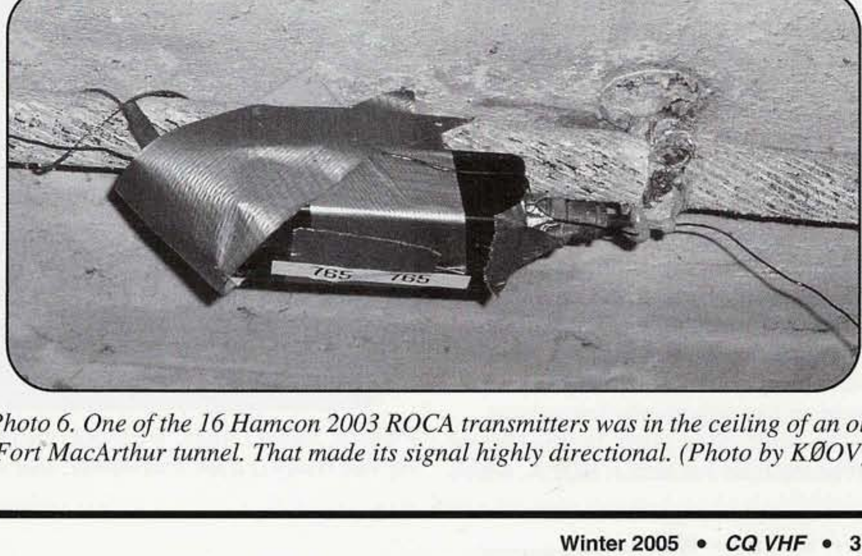


Photo 6. One of the 16 Hamcon 2003 ROCA transmitters was in the ceiling of an old Fort MacArthur tunnel. That made its signal highly directional. (Photo by KØOV)

given a card and told to mark it with the unique punch at each fox. Scoring was first by the number of Ts found and second by elapsed mileage, the lower the better. Hunters arriving back at the starting point after 10:15 had one T deducted from their score, and those arriving after 10:30 were penalized two Ts.

RDF on this hunt was difficult because the starting point was down by the ocean instead of on a hilltop, making signals weaker and bearings less reliable. Three of the four transmitters were very close to freeways, where reflections from moving vehicles caused bearings to flutter. Fox powers ranged from 1 watt and a whip on the one 7 air miles away to 40 watts and a beam on the one 29 miles away. That made their signal strengths at the start point about the same.

Some hunters claimed that it wasn't possible to get through Friday night traffic to all Ts and back in time. However, exactly one week before, I did just that. (Did I mention that I was hider for this hunt, with help from Mike Obermeier, K6SNE, and David Curlee, KE6IPY?) I test-drove the course in the most likely order, paused appropriate amounts of time for on-foot sniffing at each T, and got back with 94 miles on the trip odometer and about 15 minutes to spare.

The best strategy was to try to find the foxes in order from closest to most distant, while making sure there was enough time to get back by 10:15. That's what all the prize-winning teams did, even though none of them found all four. First place was taken by the team of Deryl Crawford, N6AIN, and J. Scott Bovitz, N6MI, who found three of the Ts in 93.8 miles.

A Rockin' ROCA

After the last Hamcon prize drawing on Sunday, 22 radiosports fans of all ages headed for the on-foot event. Pedestrian foxhunting is much newer on the southern California scene, but it has already surpassed mobile hunting here, when gauged by the number of participants on a typical hunt.

This hunt didn't use the IARU's international rules, which are more suited for hunters with the best fitness and for events in very large wooded parks. In urban areas it's better to have more transmitters, with varying levels of difficulty. That spreads out everyone and gives persons of all physical and skill levels a challenge and an opportunity for success.

The name often given to this type of urban multiple-fox hunt is ROCA, which stands for Radio-Orienteering in a Compact Area. The best places for ROCAs are not manicured parks with nothing but an expanse of perfectly mowed grass, a few trees, and no brush. It's far better to have some hills, dirt, bushes, outbuildings, trash piles, and so forth to provide good spots for concealing the transmitters.

The 130 acres of Angel's Gate Park in San Pedro are ideal for ROCAs. The north end has a big bunker pit, tunnels, buildings, and other fortifications left over from the site's days as Fort MacArthur. There are endless places to hide transmitters there (photo 6). In the middle of the park are Marine Mammal and Bird Rehabilitation Centers, plus the Fort MacArthur Military Museum. This part of the fort has been nicely restored and is open to the public on weekends, with self-guided and docent-guided tours.

I had hoped to put out 20 two-meter

Photo 7. Travis Wood, AE6GA, had the most unusual RDF setup at the Hamcon ROCA. The circular-element quad on top was for close-in hunting on fox harmonic frequencies. (Photo by KØOV)

Photo 8. Roger Denny, WB6ARK, checks closely to see if the toy cordless phone atop my van really is a fox transmitter, and which one of 16 it might be. (Photo by KØOV)

transmitters Sunday morning before everyone arrived. I ran out of time after 16, which proved to be plenty. One micro-T was cleverly camouflaged inside a toy cordless phone. I intended to place it on a shelf in the museum store, but one museum volunteer didn't show up, so the store wasn't open.

For fairness and to split the prizes, hunters were divided into four categories. All two- and three-person teams were in one category, while the other three categories were for individuals, by age range. Each team was allowed only one RDF set to prevent working independently for an unfair advantage. Everyone received a list of all the foxes by frequency, with clues as to the type of transmission to expect from each one (tones, voice, Morse, and so forth). Each hidden transmitter had a small sticker on it or on its antenna with a unique three-digit number. Hunters were instructed to put that number next to that fox on their hunt list to prove that they found it.

Some participants had just come from a convention homebrewing workshop presented by Marvin Johnston, KE6HTS, where they built their own tape-measure Yagis and offset attenuators. Others brought their own unique RDF equipment (photo 7). After the countdown, they took off to find as many foxes as they could within the 90-minute time limit.

Several hunters were immediately obsessed with a very strong signal a few feet from the start. It seemed to be coming from my van. They climbed all over it for a while. When one hunter asked if he could open the door, I suddenly realized why all the interest and intensity. Oops! The toy cordless phone that I couldn't put inside the still-closed store was on the back seat of the van, transmitting away. Even though I immediately got this phone-T out and put it on top of the van, it wasn't a "gimmie" to the hunters. Only two correctly identified it on their score sheets. Six others mistook it for another transmitter on the sheet that was 10 kHz higher in frequency (photo 8).

Best overall score was posted by Jay Hennigan, WB6RDV, of Santa Barbara, who found and correctly identified nine foxes to win the Senior age category. He is a long-time mobile T-hunter who recently took up on-foot hunting. His training helped him win gold medals in the males-over-50 age category at the last two USA ARDF Championships and a spot on ARDF Team USA 2004.

Winner of the Junior category and second-best overall with eight foxes was Jay Thompson, W6JAY, Amateur Radio Newsline's Young Ham of the Year for 2003 and co-winner of the ARRL Hiram Percy Maxim Memorial Award in 2004. W6JAY was also a national ARDF medal-winner in 2003 and 2004 as well as a Team USA member.

In the Prime Age category, the winner was Bob Dengler, NO6B, with six foxes credited. Best in the team category, with three foxes, were 12-year-old Steven Martinet and Phil Goodman, AE6DI. All category winners received gift certificates from a ham radio store. In addition, each competitor received one prize ticket for each fox that he or she found. Tickets went into a drum for chances to win from a table full of goodies.

In Closing . . .

For more details and photos of the Hamcon 2003 foxhunts, visit my "Homing In" website. If you are planning a hamfest or convention in your area, I hope you will include at least one transmitter hunt. It's a sure-fire way to inject more fun and excitement into the festivities.

As always, I welcome your foxhunting stories and photos for future columns. Please send them directly to me at the e-mail or postal address on the first page of this column.

73, Joe, KØOV

Notes

1. Moell, "Homing In: Championship Foxhunters Gather in the Buckeye State," *CQ VHF,* Winter 2004. This article also explains the basic rules of international ARDF competitions.
2. <www.homingin.com>
3. <www.ardf.us>
4. <www.fgcarc.org>

Receiver Dynamic Range—Part 2

Reprinted from *DUBUS Magazine,* in the second part of this two-part article SM5BSZ concludes his discussion of how to correctly measure receiver dynamic range.

By Leif Åsbrink,* SM5BSZ

In part one of this article we covered one-, two-, and three-signal dynamic range and the practical measurement of noise floor, as well as crystal notch filters. In part two, we cover the practical details of DR_2 and DR_3 measurements, and conclude with a discussion of how much DR we really need.

Practical Details of DR_2 Measurements

For a conventional receiver, the level of the weak signal makes no difference as long as the dynamic range of the IF and audio sections of the receiver under test is adequate. It makes no difference at all if the AGC is enabled or not, if the spectrum analyzer at the loudspeaker output is being used to simultaneously monitor the desired weak signal and the noise floor.

To check the dynamic range of the IF and audio sections, increase the level of the desired signal and monitor S/N. At some point, S/N will no longer increase in proportion to the input level. This is the level where IF or audio noise is no longer small compared with the noise floor at the antenna input, which has been reduced by AGC action, or it is the level where the signal does not increase anymore because of clipping. If the receiver under test has a dual-loop AGC, the level where an RF attenuator is inserted will be clearly visible in the plot of S/N versus input power. DR_2 measurements have to be made with the weak signal well below this level.

The way the two signal generators are combined is very uncritical for DR_2. The power level needed for the strong signal is below 0 dBm, and the weak signal may be somewhere around –130 dBm. A simple resistive network will be fine; connect the strong generator through a 5-ohm resistor, and add the weak signal through a 500-ohm resistor. A directional coupler or even a T-connector followed by a 6-dB pad to restore 50 ohms impedance will be fine.

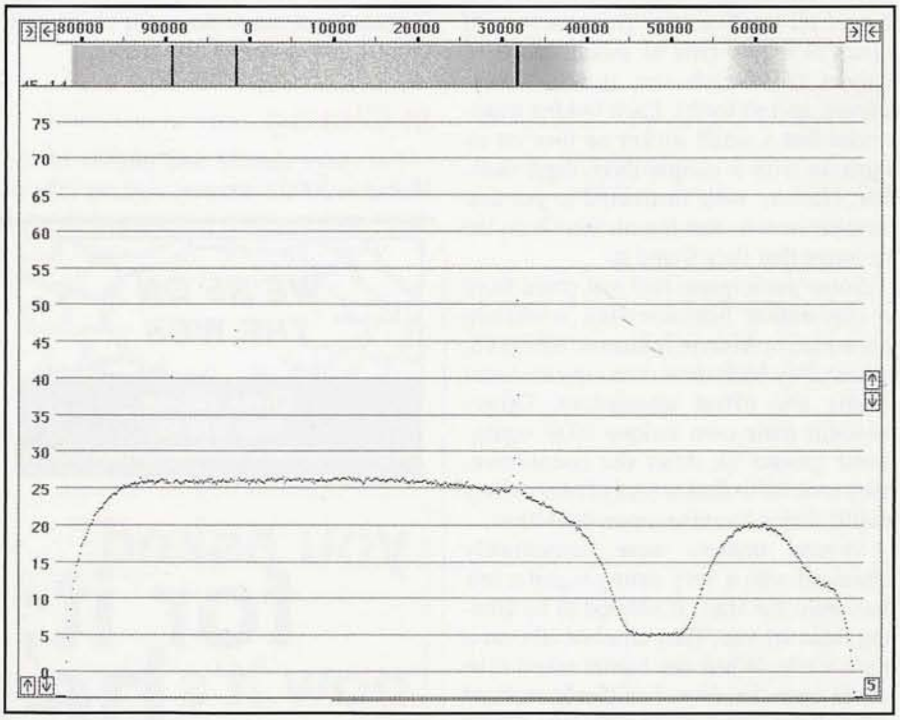


Figure 13. The Linrad spectrum of an HP8657A signal generator at 80- to 160-kHz offset. A practical illustration of the usefulness of a crystal notch filter for DR_2 measurements.

For the measurement, just select a frequency offset and adjust the strong signal for a 3 dB loss of S/N. DR_2 is given by equation (3), where PGEN is the level of the strong signal at the antenna connector of the test object. If the signal generator is calibrated, one only has to subtract the loss because of the cables and the signal-combining network. If the generator is not calibrated (it could be a homemade low-noise crystal oscillator), it is still possible to determine the power level from the noise figure as described in conjunction with figure 3, although one would then need calibrated attenuators to bring the power down for the saturation level to be somewhere around –130 dBm. Signal leakage is the critical point here.

To give an idea of the significance of using a notch filter, figure 13 shows the screen of Linrad with the spectrum from 144.08 to 144.170 MHz when an HP8657A generator set to 144.0 MHz is connected through the notch filter. The data book says that phase noise should be

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Reprinted from DUBUS Magazine, *4/2003 [12], [13]*
<http://antennspecialisten.se/~sm5bsz/index.htm>
**e-mail: <leif.asbrink@mbox300.tele2.se>*

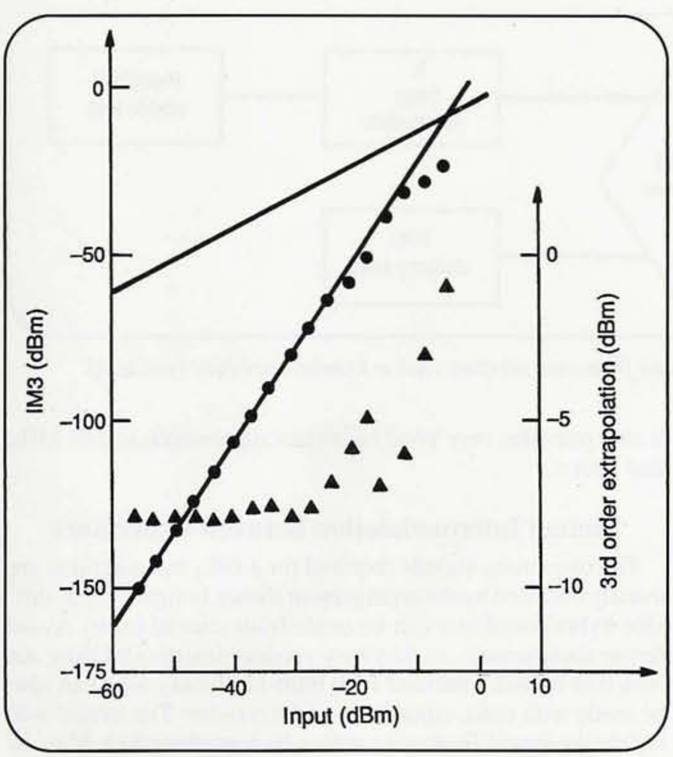


Figure 14. Measured levels of third-order intermodulation (circles) for an IC-706MKIIG with RF amplifier off and with AGC enabled. The result of a third-order extrapolation (triangles) gives the correct result (IP3 = –8 dBm) up to IM3 levels that are about 40 dB below the main signals.

below –136 dBc/Hz at a frequency separation of 20 kHz. The spectrum shown here shows that the sideband noise is –140 dBc/Hz at a frequency separation of 100 kHz. State-of-the-art commercial amateur transceivers are a little better than this. For example, the TM255E tested at the Scandinavian VHF meeting in Gavelstad had a DR_2 of 144.5 dB at 100 kHz (http://antennspecialisten.se/ ~sm5bsz/dynrange/gavelstad/gav.htm).

Practical Details of DR_3 Measurements

Unlike the DR_2 measurements, which really do not have any difficulties associated with them, DR_3 measurements have all sorts of problems. It is very easy to come up with incorrect results, particularly if the measurements are made at low levels of the third-order intermodulation products. On the other hand, measurements well above the noise floor may easily become incorrect if the S-meter or an RMS voltmeter at the loudspeaker output is used.

By measuring DR_3 with three signal generators as suggested here, it is possible to measure intermodulation correctly at high signal levels (but once again, if the unit under test has incorporated a dual-loop AGC, results will become incorrect at levels where RF gain is being reduced).

Problems with intermodulation measurement accuracy lie in the behavior of the test receiver with strong intermodulating signals. One cannot trust the intermodulation to obey the third-order law at high signal levels. For the more realistic situation with weak intermodulation products—below S6 or so, which we typically would notice when actually using the radio—the problems lie in intermodulation between the signal sources. These problems generally add some extra signal at the frequency where the third-order intermodulation is expected. Typically, one therefore will get results that underestimate the true performance of the tested unit, but the intermodulation signal could be in antiphase, and then the error may go in the opposite direction.

Once a good source of two equally strong signals has been arranged (see more about that below), the rest of the DR_3 measurement is easy. Use the block diagram of figure 2, and replace the noise generator with the two-signal source. Set the weak-signal generator (the one injected through the directional coupler) to a frequency close to the frequency where third-order intermodulation is expected. Set the two high-level generators for equal levels, and then set the weak signal to have the same level as the intermodulation product as seen on the spectrum analyzer. It does not matter if AGC is on or off; one will easily see when the signals have the same amplitude. It does not even matter if AF stages become saturated. Even IF stages may be saturated, provided that the two interfering signals are outside the IF passband. When intermodulation is measured this way, the third-order law is confirmed over a much larger range of input signal levels than one typically observes with other methods.

Figure 14 shows the levels of third-order intermodulation in an IC-706MKIIG at input levels in the range –56 to –8 dBm. As one can see from the measured data, third-order intermodulation shows accurate third-order behavior up to a point when it is about 40 dB below the two tones. To make this measurement, a nearly perfect two-tone generator was used. With the aid of the RX144 and Linrad, the source was verified to have IM3 far below the levels recorded for the IC-706MKIIG. It is, of course, essential that the source of the weak signal is very

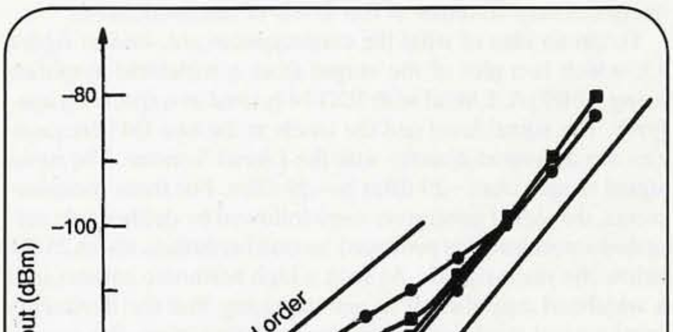


Figure 15. IM3 measurements on a BFR91A wideband amplifier. The upper (circles) and the lower (boxes) intermodulation frequency signal level with and without a filter that removes the second harmonics from the test signal. Note that presence of harmonics causes a second-order behavior at low levels.

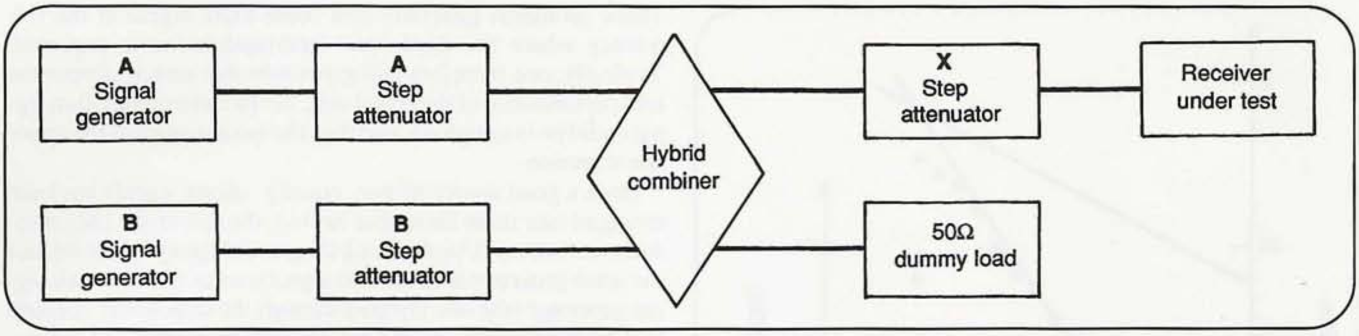


Figure 16. Two signal generators are combined and isolated from one another with a hybrid combiner (see text).

well screened. Any leakage will cause incorrect results at low levels of IM3.

The following sub-sections identify problem areas that need attention when combining two high-level signal generators to make a two-tone source for DR_3 measurements.

Signal-Generator Harmonics

First of all, the two signal generators that are to be combined need to be free of harmonics. If, for example, two generators at 144.100 and 144.125 are used, the third-order intermodulation products are expected at 144.075 and 144.150 MHz, respectively. If both generators have some signal at the second harmonic, difference frequencies 288.250 – 144.100 = 144.150 and 288.200 – 144.125 = 144.075 may be generated. The frequencies are exactly where the third-order intermodulation products will appear. Even worse, these difference frequencies are second order, so they do not fall off as rapidly as the third-order products. Therefore, the second-order products related to generator overtones may dominate at low levels of intermodulation.

To get an idea of what the consequences are, look at figure 15, which is a plot of the output from a wideband amplifier using BFR91A. Linrad with RX144 is used as a spectrum analyzer. The signal level and the levels at the two IM3 frequencies are measured directly with the Linrad S-meter. The input signal ranges from –29 dBm to –59 dBm. For these measurements, the signal generators were followed by deliberately saturated amplifiers that produced second harmonics about 25 dB below the main signals. At such a high harmonic content into a wideband amplifier, it is not surprising that the deviations from normal third-order behavior are rather large. For a comparison, figure 15 also shows data measured with a bandpass filter for 144 MHz inserted in the same setup to reduce the harmonics to about –75 dBc.

The wideband amplifier used to produce figure 15 has IP3 at about –4 dBm. It must be measured with input signals above –38 dBm when the harmonics are at –25 dBc. The third-order intermodulation products are then at about –107 dBm, which is about 40 dB above the noise in 2-kHz bandwidth. Trying to measure the third-order intermodulation-free dynamic range at the noise floor would give incorrect results.

Second harmonics of the test signals often will be suppressed by the input filters of the test receiver, but it is still a good idea to make sure the test signals are not polluted with harmonics, particularly if external amplifiers are used to raise the power level. More power makes it easier to combine two signals without intermodulation, but simple saturated amplifiers need lowpass or bandpass filters at the output. If the144-MHz notch filter described above is being used to remove noise sidebands, it also provides very good harmonic suppression at 288 MHz and above.

Mutual Intermodulation Between Generators

The two strong signals required for a DR_3 measurement are usually obtained by the arrangement shown in figure 16. A suitable hybrid combiner can be made from coaxial cable. Avoid ferrite transformers, as they may produce intermodulation. An iron-free hybrid combiner with built-in dummy load can also be made with coils, capacitors, and a resistor. The hybrid will isolate the inputs from one another by something like 30 or 40 dB if both outputs are terminated in 50 ohms.

Note that the receiver under test is actually not likely to have an input impedance of 50 ohms; although it is designed for good noise-figure and intermodulation characteristics when the source impedance is 50 ohms, this does not imply that the input impedance is 50 ohms. The input impedance of the IC-706MKIIG that I use as a reference for a typical modern rig has an input impedance at 145 MHz of 55 ohms and 18 pF. The input VSWR is 3.0 and the return loss is –6 dB. If such a receiver is connected directly to the hybrid, even a perfect hybrid would degrade the isolation between the generators only to 12 dB. For each dB of attenuation in front of the receiver under test, the isolation will improve by 2 dB until the isolation reaches 25 dB or so. The hybrid simply works as a VSWR bridge, and it measures the reflected wave from the receiver under test. Fifty percent of the power from generator A goes to the dummy load; 50% goes to the test port, comes back as a reflected wave, and is then split equally into generator A and B, which receive 25% each. Therefore, the reflected wave minus 6 dB is all the isolation one can get. For a given level of the test signal into the receiver, it does not matter if attenuation is made in front of the hybrid or after the hybrid, as long as the isolation provided by the hybrid is far from the limit.

When the output attenuator is set high enough, small impedance errors may cause large changes of the near-zero coupling between the generators. By fine-tuning the impedance of the dummy load, it is possible to cancel the coupling completely, but only from A to B or vice versa. The reason is that balancing is frequency dependent, but if the two generators are very closely spaced, balancing is a way of removing mutual intermodulation in the generators at high signal levels.

With good generators such as the HP8657A, worst-case intermodulation levels for the configuration of figure 16 are shown in figure 17. The figure shows measured intermodulation levels at different power levels into the test object, which is the same impedance as the IC-706MKIIG. The attenuator X is set to 3 dB, and the attenuators A and B are the attenuators built

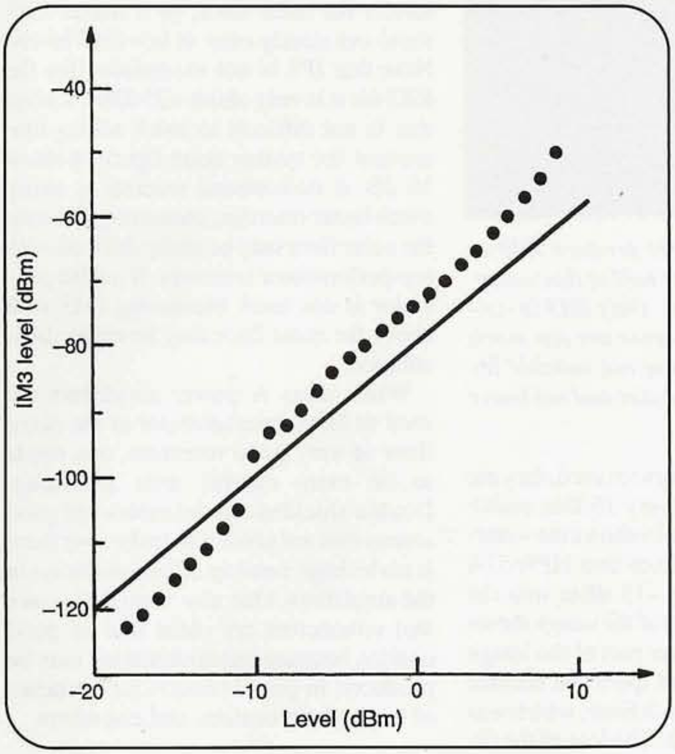


Figure 17. The intermodulation produced in a HP8657A when used for a two-tone test. The discontinuity between –10 and –11 dBm is between –3 dBm and –4 dBm power output from the signal generators. It is because of the internal architecture of the HP8657A generator.

into the generators. To make accurate measurements of low intermodulation levels, a directional coupler is inserted between generator A and the hybrid for the data in figure 17.

To generate an IMD product at the noise floor in SSB bandwidth, the IM3 product will need to be at about –130 dBm if a noise figure of about 10 dB is assumed. This calls for IM3 levels from the generator of less than –140 dBm. Extrapolating from figure 17, one finds that the maximum signal level that may be used is then about –30 dBm. This means that a pair of HP8657A generators can be used for IM3 measurements at the noise floor up to a third-order intercept point of about +20 dBm. An old vacuum- tube free-running oscillator, the HP608D, produces 12 dB more intermodulation than the HP8657A if it is properly calibrated. However, by turning the output-level control to maximum, one can get +13 dBm output power rather than the +4 dBm that is the maximum when the control is "properly" set. This means that 9 dB more attenuation can be used, and then the HP608D becomes better than the HP8657A, with IM3 about 7 dB lower.

It is a good idea to check what really comes out from the signal generators by the use of a directional coupler. If you do not have a good enough spectrum analyzer (RX144 + Linrad), you can use the receiver, which will later become the test object. The signal extracted from a directional coupler will have the signal from the other generator suppressed by something like 20 dB, but the IM3 product will be present on the opposite side in frequency and its level below the generator signal is the same as will be presented to the test object in the real test. In this case, the test object will produce at least 20 dB less IM3, since it is not loaded by equal signal levels at the two frequencies because of the directional coupler. With a second directional coupler and a third generator, one can measure the levels of signal and IM3 and make sure that the IM3 produced by the generator is well below the IM3 produced by the test object. Do not forget to allow the hybrid to see the same impedance as it will see later when the test object is connected to it. An open 3-dB pad will correspond to VSWR = 3 and may be used in the test port of the hybrid. Leave this 3-dB pad in place, and connect the test object after it to ensure the generator intermodulation will be smaller than the value you have checked.

It has been suggested that one can distribute the attenuation differently between attenuators in front of and after the hybrid to find out if there is a problem with IM3 produced in the generators. The idea is that the isolation provided by the hybrid will be constant, and that therefore the attenuators in front of the hybrid will affect the intermodulation produced in the generators, while the attenuator after the hybrid will not. This might be the case sometimes, but it certainly will not be true for a test object with an unmatched input, such as almost any low-noise VHF receiver.

To illustrate the effect of generator intermodulation, I have measured the IM3 levels of the IC-706MkIIG with two HP8657A generators set to +10 dBm connected directly to the hybrid. The test port of the hybrid is connected to a step attenuator and loaded by 18 pF to make the hybrid see VSWR = 3. The step attenuator is used to set the level of the test signal pair. The maximum available power level is +4 dBm. Figure 18 shows the result. As expected, the intermodulation shows first-order behavior at low signal levels where the intermodulation produced in the generators dominates.

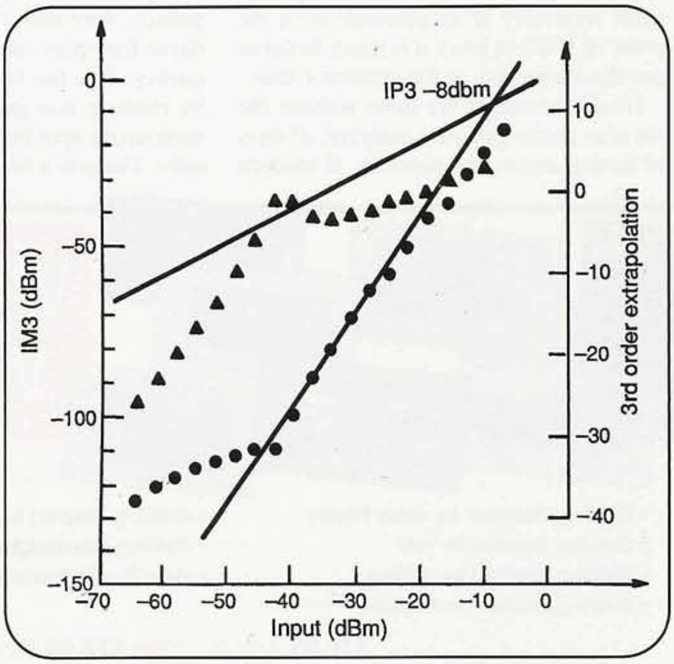


Figure 18. Measured level of third-order intermodulation (circles) for an IC-706MKIIG with RF amplifier off and with AGC enabled. This is the same measurement as in figure 14 but with poor isolation between generators. The formula for evaluating IP3 result (triangles) gives the correct result (IP3 = –8 dBm) in a narrow range only. At low levels the intermodulation in the generators dominates, and at high levels the receiver under test does not have third-order behavior.

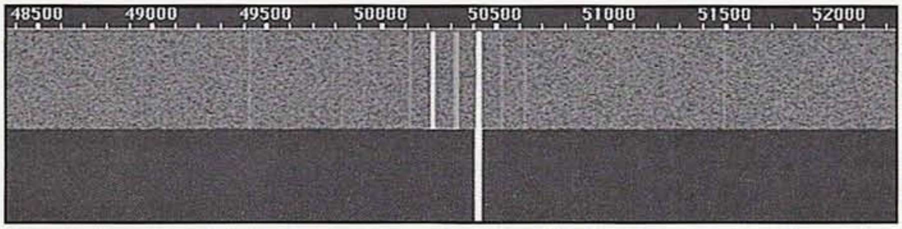


Figure 19. Two HP8657A generators at 143.9498 and 144.0499 produce IM3 at 144.1500 MHz (there is a calibration error of 430 Hz). The lower half of this waterfall graph is with the composite test signal through a notch filter. Only IM3 is visible. The upper half is without notch filter; spurs and sideband noise are not much below the IM3 product at –82 dBc. The HP8657A generators are not suitable for measuring IM3 lower than about –70 dBc without a spectrum analyzer and not lower than about –90 dBc without a notch filter

This measurement is intended to show a way of making an incorrect measurement and what the result might look like. Figure 18 is an extreme case of poor measurement engineering, where only the output attenuator is used to set the signal level. Obviously, the mismatch at the hybrid output will be much smaller in a real measurement; the 18-pF capacitance provokes a really bad VSWR. It is convenient to set the level of both generators simultaneously on the output attenuator X in figure 16. However, as soon as one reaches the point where isolation does not improve by the full return loss improvement (typically at an attenuation in the order of 10dB or less), it is much better to use the attenuators at the generator side.

If measurements are done without the aid of an audio spectrum analyzer, all sorts of further errors are possible. If modern (synthesized) generators are used, they are likely to have spurs every 10 kHz and/or every 100 kHz. Figure 19 shows the waterfall graph recorded from two HP8657A generators delivering –15 dBm into the RX144. The lower part of the image shows IM3 only, but the upper part of the image shows all the noise and spurs that became visible without the notch filter, which was used for the lower half. The loss of the filter was compensated for, so the level of the two strong signals was the same in both cases. Note the strong spurs 100 and 200 Hz below the intermodulation product. The generators, 100 kHz separated in frequency, were offset by 100 and 200 Hz to move the spurs away from the IM3 frequency. One has to check for these spurs by running one generator only because each strong spur belongs to one generator only. The notch filter removes spurs and lowers the noise floor, so it makes IM3 stand out clearly even at low IM3 levels. Note that IP3 is not exceptional for the RX144; it is only about +25 dBm, a level that is not difficult to reach taking into account the system noise figure of about 16 dB. A narrowband receiver is easily much better than this; measuring IP3 near the noise floor may be really difficult with top-performance receivers. If a third generator is not used, measuring IM3 well above the noise floor may be really difficult, too.

When class A power amplifiers are used to allow measurement at the noise floor of very good receivers, one needs to be extra careful with screening. Double-shielded coaxial cables and good connectors are needed to make sure there is no leakage causing intermodulation in the amplifiers. One also must make sure that connectors are clean and of good quality, because intermodulation may be produced in poor connections, switches of stepped attenuators, and elsewhere.

How Much DR Do We Need?

Based on surveys of actual signal levels at 7 MHz, Peter Chadwick, G3RZP (reference 11), arrived at the conclusion that PNDR (Phase Noise Limited Dynamic Range) should be at least 100 dB, and that ILDR (Intermodulation Limited Dynamic Range) should be at least 96 dB.

These numbers refer to an SSB bandwidth, and in the terminology I have used throughout this article, it means DR_2 should be at least 133 dB_{Hz} and DR_3 should be at least 129 dB_{Hz}.

On the VHF bands, the basic principles remain exactly the same, but the numbers are different. The needs will also vary much more at different locations. There are two kinds of problems: out-of-band interference and in-band interference. The out-of-band interference is typically at a large frequency separation, mainly FM and TV broadcast stations with very high effective radiated powers (ERPs). This is a problem for a preamplifier and filters associated with it. In-band interference from our fellow amateurs cannot easily be taken care of with filters, so here we need a good radio with high dynamic range.

On 144 MHz, amateurs typically produce power levels of 3 kW ERP with 100 W RF into a 13 dBd antenna, but ERPs of 100 kW are also not uncommon—1 kW into four modest Yagis with 18-dBd array gain. The received powers at some different distances are given in Table 3 under the assumption of free-space propagation.

In reality, we do not have free-space conditions. Reflections from ground change the signal level in an unpredictable way, because the ground is typically not flat at all. Nevertheless, Table 3 indicates that a rig capable of dealing with –20-dBm power from neighboring amateurs would be useful at some locations. This translates to a DR_2 of 154 dB_{Hz}, which is possible, but nothing one can expect from standard transceivers today. Table 3 also shows that for two EME-grade stations at a distance of 1 km to work undisturbed with antennas pointing into one another, they would need a DR_2 of about 200 dB! That is impossible today and most probably will remain impossible.

Worst-case in-band interference at VHF typically is dominated by a single signal. It happens when you have your main lobe pointing toward the nearest neighbor while he is pointing in your direction. Contrary to the situation on the HF bands, the DR_2 requirements on VHF therefore may be far more stringent than the DR_3 requirements.

When testing receivers, one has to collect and present a large amount of data. It is relevant to measure DR_2 at several frequency separations, and a reasonable choice is 5, 20, 100, and 500 kHz. It would probably be enough to measure DR_3 at 5-, 20-, and 100-kHz separation, but the amount of data is still much larger than what is commonly published in product testing.

On the other hand, there is no reason to measure everything with and without a preamplifier, because the influence of a preamplifier should be easy to see: A preamp lowers IP3 by the amount of gain it has, and it reduces DR_3 by an amount given by the preamp gain minus the improvement in the noise figure. DR_2 should be affected only if it is limited by blocking, something that is uncommon in modern receivers. Within the limitations of available page space for reviews, it would be a good idea to focus product testing on the performance without the preamplifier, and simply specify the gain and noise-figure improvement obtainable by switching in the preamplifier. Additional measurements can always be posted on the web (which is already the ARRL's practice).

Distance (km)	Tx ERP (kW)	Rx Ant = 13 dBd (dBm)	Rx Ant = 18 dBd (dBm)
1	3	+2.4	+7.4
1	100	+17.4	+22.4
10	3	–17.6	–12.6
10	100	–2.6	+2.4

Table 3. Received power levels with antennas pointing into one another on 144 MHz, at two different distances (assuming free-space propagation).

At VHF/UHF, an analysis of gain and dynamic-range performance will show that it is always better to use a mast-mounted preamplifier, and to operate the main receiver with its built-in preamplifier switched off. A serious VHF/UHF weak-signal enthusiast will always do this, so this is another reason for equipment reviews to focus mainly on the VHF/UHF performance data obtainable without the preamplifier. The noise from that preamplifier (including amplified antenna noise) should be the dominating contribution to the noise floor of the entire system. As a consequence, signal levels are raised by something like 15 dB, and this is another reason why dynamic-range requirements are much more difficult to meet at VHF/UHF, compared with HF bands where usually no preamplifier is needed. ■

Correction to WB2AMU Article

In the article "July 2004—Very Different Conditions on the VHF Bands," by Ken Neubeck, WB2AMU, in the Fall 2004 issue of *CQ VHF,* there was a mixup in the figures. Figure 1 should have been keyed as figure 2 (see page 26 in the fall issue for an explanation of that figure), and figure 1 was left out. We are presenting figure 1 here with its correct caption.

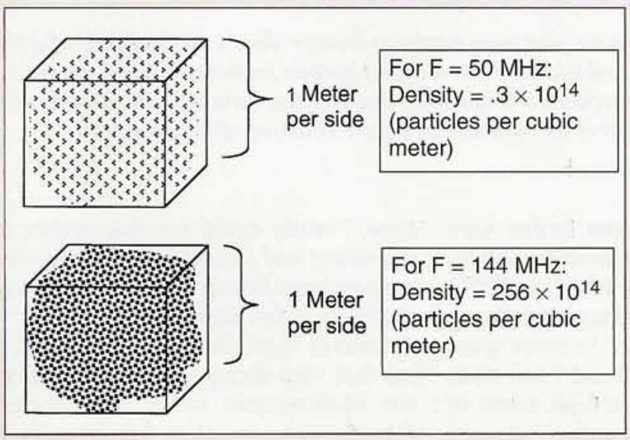


Figure 1. Pictorial description of electron density for sporadic-E formation. The figure provides a relative comparison between the different density levels of sporadic-E formation when they are capable of reflecting different VHF radio frequency signals. The calculations are based on the formula in the text of the article.

The Solar Hits Keep Coming in Cycle 23

Major aurora and auroral-*E* openings occurred in early November 2004. Here is WB2AMU's report on how VHFers took advantage of these conditions.

By Ken Neubeck,* WB2AMU

At the beginning of November 2004 a series of coronal mass ejections (CMEs) were observed coming from an active sunspot on the sun, resulting in a buckshot effect that happened to be Earth-directed. Indeed, even though we are on the downside of solar Cycle 23, with the overall sunspot count generally below 100 and the solar flux below 150, solar events are still occurring!

Major Aurora

As these events were Earth-directed, it was a matter of two days before the amateur radio bands were impacted by the subsequent geomagnetic activity. As expected, the impact of multiple CMEs on the Earth's geomagnetic field severely reduced HF activity. However, VHFers rejoiced at the potential aurora activity, and they were not to be disappointed.

The impact on the planetary *K*-index was noticeable over a three-day period, with the following three-hour intervals being recorded beginning at 0000Z:

November 8: 9 9 9 8 6 3 4 5
November 9: 6 6 5 7 6 7 8 7
November 10: 8 8 9 9 7 6 5 4

I was scheduled for a trip to Las Vegas with my XYL on November 8th, so I was busy packing, yet keeping an eye on the 6-meter chat page of DXer.info for any reports of aurora. When the reports started coming in, I took some time out to work stations on 6 meters from my location on Long Island, New York.

Signals on 6 meters were very strong,

**CQ VHF Contributing Editor, 1 Valley Rd., Patchogue, NY 11772*
e-mail: <wb2amu@cq-vhf.com>

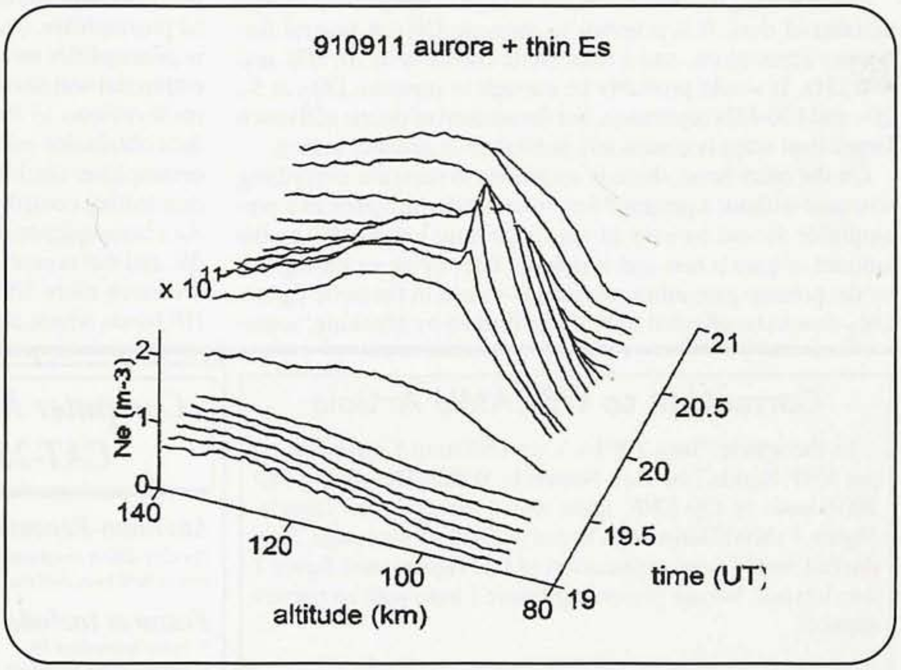


*Figure 1. The EISCAT radar plot from northern Europe shows the presence of a thin sporadic-*E *layer that is embedded inside a broad aurora formation. While not directly stated by EISCAT researchers, it is apparent that this thin* Es *layer is most likely what VHF operators observe as auroral-*E*. (Figure courtesy of S. Kirkwood)*

and I was hearing stations farther west than I normally do during an aurora opening. I was able to work KB8U in EN71 and NN9K in EN41, along with many other grids closer to me. At times some of the signals from the 8 and 9 call areas of the U.S. seemed to exhibit traces of auroral-*E* and were changing between aurora tones and auroral-*E* tones.

I was able to listen to 2 meters for a bit from my car, and I heard a number of CW stations with aurora tones from FM18. I even heard N9XG. As I was pressed for time, I really could not concentrate on operating and almost regretted leaving the northeast hot spot of aurora activity for the next few days!

Gordon West, WB6NOA, reported to me that very strong aurora signals from the northwestern states and western Canada were heard at his location in southern California on the 8th. There were even some paths into Hawaii that appeared to be auroral-*E*. Indeed, there were many auroral-*E* contacts made in the U.S. on the 8th and 10th in particular, and it is worth exploring some of those contacts in detail.

Strong Auroral-*E* Openings

When there is a very strong aurora opening where the *K*-index reaches 8 or higher, the potential for follow-on events in the form of either auroral-*E* or north-south *F2* is always possible. For those two openings in November 2004, auroral-*E* was the primary event.

During the early-morning hours of the 8th, there were numerous auroral-*E* openings, primarily to the west for stations in New England. K7BV in FN31 worked KØGU in DN70 via an apparent auroral-*E* path. What was even more interesting was the path that Lefty, K1TOL, in southern Maine had to Europe at around 0300Z. It appeared to be a direct path with no auroral growl on it. Lefty was hearing strong aurora signals to the north and northwest, but to the east and northeast the signals were pure tone. The first indicator was a pure-tone VO1ZA beacon signal, and then about ten of the 48-MHz and 49-MHz European videos suddenly came rolling in. Lefty called one CQ and OZ4VV came right back to him; shortly thereafter he worked MMØAMW. Lefty was also heard in Sweden. The best guess that Lefty can make with regard to how this path was working was that it was multi-hop auroral-*E,* with the possibility that the signals might have been trapped above multiple formations, or the bending of the signals was just right! Indeed, the strong presence of auroral-*E* had many veteran 6-meter operators wondering about the long paths. Were the paths between Europe and Maine a true multi-hop path, or was it kind of like a chordal-hop path where the signal remained channeled in the *E*-region?

At 0700Z on the 10th, Dennis, K7BV/1, in FN31, was alerted by W1RA that Kevin, NL7Z, in Alaska was being heard in New England. Shortly thereafter, Dennis worked NL7Z on 50.110 MHz. Later NL7Z would be heard by Tom, WA2BPE, in FN12 at 0821, and by Bill, N8UUP, in EN82 as well as Dennis and Lefty.

As I stated before, I was making a trip to Las Vegas and I had brought along my portable FT-690 to see if there was any 6-meter activity related to the aurora at that location. I also had a cell phone that had Internet connection, so I continued to monitor the DXers.info chat page to view aurora activity. During late afternoon on November 10th I heard Al, K7ICW, in DM26 as well, and he was working VE4QZ (whom I could not hear too well) via an apparent auroral-*E* skip. I then managed to work Al, who told me that this was the first opening he had heard since the summer.

Summary

As discussed in previous articles in *CQ VHF,* it is observed by many VHF operators that when there is strong geomagnetic activity, sporadic-*E* is very rarely observed in the direction of the poles, where the activity is. However, auroral-*E* can result from a very strong aurora, and it has been picked up by EISCAT radar plots as shown in figure 1. Rocket launches into active auroras over Fort Churchill in Manitoba, Canada that took place over 30 years ago picked up the presence of metallic ions—typically magnesium ions—inside the active aurora.

Thus, there appears to be a very interesting relationship between aurora and sporadic-*E* ions. Does a very strong aurora help stimulate the formation of sporadic-*E* layers inside the aurora? While we have the EISCAT radar data to strongly suggest some kind of interaction, in the future we will need more observations and other new sources of scientific measurements to help answer this question and others.

Another item of note is the hot spot of the northeastern states of Maine and New Hampshire, as well as eastern Canada, with regard to different forms of 6-meter propagation. Not only does this area do well with *F2* propagation into Europe during the peak sunspot years, as well as multi-hop *Es* into Europe during the summer months, but auroral-*E* paths into Europe and Alaska seem to be reasonably possible as well. Even transequatorial propagation (TEP) is possible into this area with a sporadic-*E* link at the right times!

Can we expect any more geomagnetic events for the balance of Cycle 23? It would not be unreasonable to expect some additional events, most of them small, but based on past observations. A big event can occur at almost anytime during the solar cycle. Thus, it still will pay for VHF operators to continue to monitor 6 meters and above for the next year or so until the solar minimum arrives. We will continue to track and report any notable events on the pages of *CQ VHF.* ■

Flat Audio

There is no sweeter sound than clear, crisp audio. K6JSI tells how it can be achieved on your local repeater.

By Jeff (Shorty) Stouffer,* K6JSI

In this article we will start off with a quick "fly-by" description of just how audio works in FM two-way radio. We will briefly examine pre-emphasis and de-emphasis and repeater audio, and then we will discuss flat audio and how it differs from most repeater audio scenarios today. Later on we will delve into the details in more depth.

Here we go with the "fly-by" . . .

Fly-By

When frequency modulation (FM) began to be used in the late 1930s and early 1940s, it quickly became the preferred mode of radio communications, primarily because of its far superior signal-to-noise ratio and its ability to provide noise-free communications. At that time it was a one-radio to one-radio service, the same as what we call "simplex" today. Repeaters were not yet even dreamed of.

All early FM transmitters used phase modulation, which means they automatically doubled the deviation of an FM signal with every doubling of the audio frequency. This effect is called *pre- emphasis* and works as a 6 dB per octave increase in deviation, or a "roll-up" in deviation. It provided for a much better signal-to-noise ratio by making the higher frequencies have as much audio punch as the lower frequencies as it evened out the audio. The receivers of the day all had a *de-emphasis,* or a "roll-down" circuit, in them to restore the audio back to normal.

This is the way we still do it today, even with FM transmitters. FM transmitters have a pre-emphasis circuit built in, to be compatible with the existing phase-modulation (PM) transmitters, because all of the receivers out there are running de-emphasis circuits.

**e-mail: <k6jsi@winsystem.org>*

When repeaters came along, hooking up the audio between the repeater RX and TX became a hotly contested topic, with many variations on how to do it. Some repeater builders took the user's pre-emphasized audio and de-emphasized it in the repeater RX, and then pre-emphasized it again in the repeater TX for delivery to the end user. Then the end user's receiver de-emphasized it again, thus returning the audio to normal. Whew! This probably could work out if all of the emphasis curves in the repeater are matched (a difficult task). Also, all the processing in the TX's speech amplifier affects the audio quality.

Another scenario is created when a mismatch occurs in a repeater because only one side of the repeater processes the audio. For instance, if there is an extra pre-emphasis stage in the repeater, the audio will sound very tinny and high-pitched—all highs with the lows missing. If there is an extra de-emphasis stage in the repeater, the audio will sound very mushy and lifeless—all lows with the highs missing.

Many repeater builders have different approaches—for instance, taking speaker audio and cramming it into microphone input. Ouch! Others try to run CTCSS on the repeater TX by just connecting the RX audio and the CTCSS encoder audio outputs together, thereby loading down both circuits and making everything sound mushy. Then when we begin to link repeaters together, it gets even worse, with all those link and repeater receivers and transmitters. Double ouch! There have been some really interesting lash-ups over the years with varying degrees of success and failure.

Flat Audio

When most of us talk about "flat audio," we are talking about passing audio through the repeater without any de-emphasis or pre-emphasis stages, or other audio processing in between. Since the audio is already pre-emphasized by the user's transmitter, you are not dealing with "flat audio" in the repeater anyway.

Taking the audio from the discriminator on the RX—where it is still pure and pre-emphasized by the user, before it is de-emphasized—we pass it through a controller and then inject it into the transmitter's audio chain well past the microphone input, past the speech amplifier, past the pre-emphasis network, and directly into the modulator. This keeps the audio "flat" through the repeater. Hence the term *flat audio.* This way the audio is un-modified as it works its way through the repeater. The RX leaves it alone, the controller leaves it alone, and the TX leaves it alone. The only audio shaping, or processing, is done at the user's transmitter and the end user's receiver, just like simplex.

There are two things that need to be addressed in this flat-audio scenario. They are:

1. A clipper (or limiter) in the TX audio chain, to limit the deviation of the transmitter; and

2. A low-pass audio filter past the clipper in the audio chain to eliminate the high-order harmonics produced in the clipping process (and to reduce the high-frequency noise—especially squelch bursts, generally up around 8000 Hz or so, that are very annoying to listen to in FM radio).

If these two items are not addressed, the repeater system, while sounding flat, will pass high-frequency noise and can produce very wide, over-deviated signals. It is important to stay within the 5-kHz deviation bandwidth with our repeaters and not over-deviate.

That was our quick "fly-by" of flat audio. Now we will delve into the subject in more detail, with a thorough description of how it really works.

What is Modulation?

Just over a hundred years ago, back in 1902, Fessenden developed a system to modulate a continuous wave with the human voice. Prior to that, most voice transmissions were attempts at modulating spark transmitters, with generally poor results.

Modulation is a mixing process. When RF and audio frequencies are combined in a standard amplitude modulation (AM) transmitter (such as one used for commercial broadcasting), four output signals are generated: the original carrier or RF signal; the original audio signal; and two sidebands, the frequencies of which are the sum and difference of the original RF and audio signals, and the amplitudes of which are proportional to that of the original audio signal. The RF envelope (sum of the sidebands and carrier), as viewed on an oscilloscope, has the shape of the modulating waveform.

The bandwidth of an AM signal is twice the highest audio frequency component of the modulating wave. Thus, if the highest audio frequency is 3000 Hz, the occupied bandwidth of an AM signal will be double that, or 6 kHz wide.

Frequency modulation (FM) was first technically addressed by John R. Carson in the February 1922 issue of the *Proceedings of the IRE* journal. By mathematical analysis, he "proved" FM inferior to AM on two counts: bandwidth requirements and distortion.

The Carson analysis held until May 1936, when another paper on FM appeared in the same journal. In this work, Major Edwin H. Armstrong set the stage for a new viable FM mode of communications. The basic theory behind his ideas is still in use today!

A Little History

We will start off with a little history of NBFM, or Narrow Band Frequency Modulation.

Methods of radiotelephone communication by frequency modulation were developed in the late 1930s by Major Edwin Armstrong in an attempt to reduce the problems of static and noise associated with receiving AM broadcast transmissions of the day. The real advantage of FM—its ability to produce high-quality signal-to-noise-ratio audio when receiving a signal of only moderate strength—has made FM the preferred mode of choice for mobile communication services and quality broadcasting.

With AM and SSB, the very process of demodulating audio causes the receiver to be looking for changes in amplitude. Therefore, any static or noise is recovered in the receiver along with the audio. When FM was first introduced, the main selling point of the new mode was that noise-free voice reception was finally possible. This is still very true today. FM inherently has a much better signal-to-noise ratio than AM. That is one of the reasons why FM sounds so good, compared to an equivalent AM or SSB signal.

The disadvantages of FM are few, most notably its wider bandwidth requirement. By way of example, a 5-kHz deviated FM signal with an audio (voice) frequency of 3000 Hz occupies about 16 kHz of radio spectrum. Compare this to AM, which occupies about 6 kHz of radio spectrum for the same 3000 Hz of audio, and less spectrum (about half) for an equivalent SSB signal.

This is one reason why FM is most popular in the VHF and UHF regions, where spectrum is more available. For the Amateur Radio Service, the FCC limits the low end of FM to 29.500 MHz. On the high-frequency amateur bands, 80 through 10 meters, single sideband is the most widely used radiotelephony mode, partly because it occupies comparatively less spectrum, which is important for frequencies that travel by skywave.

Audio Frequencies

We'll leave the radio world for now, and enter the audio world. In today's FM two-way radio communications, the audio frequencies we utilize for voice are between 300 and 3000 Hz. Another way of stating it is that frequencies between 300 and 3000 Hz are the "audio range" or "voice band" of frequencies. The sub-audible, or CTCSS (PL), frequencies in FM are well below 300 Hz and will be discussed in another section.

To understand just what the "audio band" of frequencies is, let's think about the piano for a moment. Most of us know what "Middle C" sounds like; that's the white key in the middle of the keyboard just to the left of the two black keys. If you have a piano nearby, it may be helpful to sit at it and try this little exercise. If not, try to imagine how the notes sound from memory.

Play the Middle C key. Middle C is technically called C4, as it is the fourth "C" from the bottom (left-hand end) of the keyboard. Middle C, or C4, has a frequency of 261.63 Hz if the piano is tuned properly. That's right, 261 Hz. It is even a little lower than our 300-Hz low-end cut-off limit of the FM audio spectrum described above. It is technically in the sub-audible frequency range, because it is below the voice band, although most of us can still hear it, can't we? That is why you don't see many PLs above 200 Hz—and that is because you can actually hear them. Most PLs are usually around 100 Hz or so. More on PLs later.

Now let's get back to our piano exercise. If you go up one octave on the piano to the C that is 12 keys higher (both black and white keys) and play that key, the frequency will be 523 Hz. This is called C5. Notice that it is twice the frequency of C4 ($261 \text{ Hz} \times 2 = 523 \text{ Hz}$). This difference is called one "octave." An octave is defined as follows: A one-octave separation occurs when the higher frequency is twice the lower frequency. Thus, the octave ratio is 2:1. Every time you double the frequency, you go up one octave in frequency.

Moving to the next higher octave, or to the next "C," which is called C6, play it and the frequency will be 1046 Hz. This is twice the frequency of C5. Play the next higher octave, which is C7, and the frequency will be 2093 Hz. This is again twice the frequency of C6.

The upper limit of our "audio range" in FM is 3000 Hz, and the closest piano key for that frequency is the highest F# (F sharp) on the piano, which is the very left-hand black key of the last set of three black keys on the keyboard, or the seventh key from the top (right-hand end) of the keyboard. The frequency of F# is 2960 Hz.

Therefore, when I say that the audio frequencies used in our modern-day FM radios are from 300 to 3000 Hz, I am saying that the frequency range is the same as playing the piano keys from Middle D, or D4 (296.66 Hz), to the highest F#, or F#7 (2960 Hz).

Speech

Now let's talk a little about how this audio-frequency business translates into communication.

Human speech is an interesting subject. Speech is comprised of multiple audio frequencies, mostly in the 125- to 4000-Hz range. However, all frequencies are not created equal in human speech. Some frequencies are louder than others, and some carry more intelligence than others. Here are a couple of facts concerning audio frequencies and human speech:

Fact Number One: The lower frequencies, those between 125 and 500 Hz, contain about 55 percent of the speech energy. However, they only contribute about 4 percent to speech intelligibility.

Fact Number Two: The higher frequencies, those between 1000 and 4000 Hz, contain only about 4 percent of the total speech energy, but contribute an amazing 50 percent to speech intelligibility.

To *understand* human speech, though, we actually need to hear the higher frequencies (above 1000 Hz) *more than* the lower frequencies, as that is where about *half* the speech intelligibility is contained. Interesting, isn't it? Thus, when a radio manufacturer says it is producing a "communications quality" radio, what frequencies do you think it is enhancing? Why, the high frequencies, of course, as that is where over 50 percent of the speech intelligibility is.

Frequency Modulation Defined

Now let's get back to radio. We now understand that over half of the speech *energy* is contained below 500 Hz when we are transmitting FM. Therefore, it normally follows that the amplitude of the lower frequencies is going to be much greater than the amplitude of the higher frequencies.

Let's step back for a moment and define what FM is. When a modulating voice signal is applied to an FM modulator, the carrier frequency is increased during one half-cycle of the modulating signal and decreased during the half-cycle of the opposing polarity. In other words, the carrier frequency of our transmitter varies at an audio rate above and below our carrier frequency according to what the amplitude of the audio voice signal is.

Therefore, to define frequency modulation, or FM, we would say: *The change in the carrier frequency is proportional to the instantaneous amplitude of the modulating signal.*

Amplitude, then, is what drives FM. It thus follows that if 55 percent of the amplitude energy is contained in the voice frequencies below 500 Hz, then a true FM transmitter is putting 55 percent of its energy, or its power, into the lower audio frequencies. That is where only 4 percent of speech intelligibility resides.

Also, by the same logic, the same true FM transmitter is only putting 4 percent of its energy, or power, into the voice frequencies above 1000 Hz, and that is where over 50 percent of the speech intelligibility is, remember? This means that if you listen to a true FM transmitter, with 55 percent of its power in the voice band below 500 Hz, it will sound very mushy, almost all bass or low frequencies with hardly any high-frequency component at all.

Phase Modulation Defined

Next let's define phase modulation, or PM. It is possible to convey intelligence by modulating any property of a carrier, including its frequency and phase. When the frequency of the carrier is varied in accordance with the amplitude variations in a modulating signal, the result is frequency modulation, or FM.

Similarly, varying the phase of the carrier current is called *phase modulation.* Frequency and phase modulation are not independent, since the frequency cannot be varied without also varying the phase, and vice versa. In other words, phase is the mathematical derivative of frequency.

If the phase of the current in a circuit shifts, there is an instantaneous frequency change during the time that the phase is shifting. The amount of frequency change, or deviation, is directly proportional to how rapidly the phase is shifting and the total amount of the phase shift. The rapidity of the phase shift is directly proportional to the frequency of the modulating signal. Further, in a properly operating PM system the amount of phase shift is proportional to the instantaneous amplitude of the modulating signal.

Therefore, to define PM we would say: *The change in the carrier frequency is proportional to both the instantaneous voltage and the frequency of the modulating signal.* This is the outstanding difference between FM and PM, since in FM the frequency deviation is proportional *only* to the amplitude of the modulating signal.

By contrast, in PM the deviation increases with *both* the instantaneous amplitude *and* the frequency of the modulating signal. This means that PM has a built-in pre-emphasis, where the deviation increases with modulation frequency. Apart from this difference, when receiving FM or PM it is difficult to distinguish between the two.

Notice I used the word *pre-emphasis* above. This is probably a good place to explain how pre-emphasis and de-emphasis work.

Pre-Emphasis and De-Emphasis

What is pre-emphasis? Pre-emphasis follows a 6-dB per octave boost rate. This means that as the audio frequency doubles, the amplitude (and deviation) doubles (by 6 dB). Thus, with pre-emphasis the following examples are typical of pre-emphasis on an FM transmitter's deviation:

- a 500-Hz audio tone will make 1 kHz of deviation
- a 1000-Hz audio tone will make 2 kHz of deviation
- a 2000-Hz audio tone will make 4 kHz of deviation

Why do we even have pre-emphasis in NBFM communications? There are actually two reasons:

1. The early transmitters were really PM, not FM, so they naturally had a 6-dB/octave "roll-up" or pre-emphasis. PM was the standard modulation method. When FM transmitters came along, their audio had to be intentionally pre-emphasized to maintain compatibility with the PM transmitters already in service. In very early narrowband literature you won't even find the terms *pre-emphasis* and *de-emphasis.* Engineers simply "rolled-off" the audio in the receiver with a single-pole filter to reverse the PM transmitter's "roll-up" characteristic and restore the transmitted audio back to normal.
2. Pre-emphasis is needed in FM to maintain a good signal-to-noise ratio across the entire voice band. Theory tells us that white noise increases with frequency at a receiver discriminator. When de-emphasis is added to a receiver this noise is attenuated, thus improving the signal-to-noise ratio.

Pre-emphasis is used to shape the voice signals with the increased level of the higher frequencies being applied to the modulator, which results in a better transmitted audio signal-to-noise ratio due to the highs being above the noise as much or more than the lows. The accompanying graph (figure 1) illustrates the pre-emphasis curve, audio frequencies along the bottom.

We must recognize that early narrowband FM radio was intended for one-transmitter/one-receiver applications. This business of repeaters and linking repeaters came much later. Virtually all FM radios today, including commercial broadcast, use pre-emphasized and de-emphasized audio. When you talk with someone on simplex, the TX pre-emphasizes his or her audio. If you could listen to "raw" pre-emphasized audio, it would sound very tinny, mostly highs. However, your receiver de-emphasizes the audio, returning it back to normal.

By contrast, if you could listen to "raw" FM audio, it would sound almost all bass (or low frequencies), as most of the amplitude (or energy) is in the low-frequency range with hardly any highs (or treble) at all. The higher frequencies would be more in the noise, as their amplitude would be much less and would be virtually not readable.

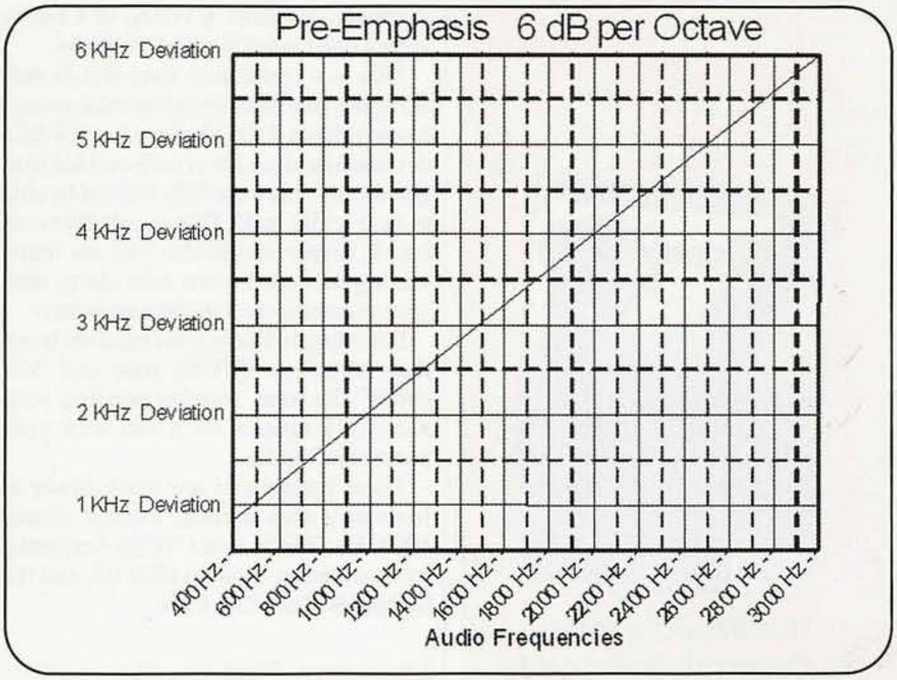


Figure 1. The pre-emphasis curve, with audio frequencies shown along the bottom.

Signal-to-Noise Ratio

This is a ratio that defines the ability to demodulate, or recover, the audio of a radio signal. This is one of the best advantages of FM over any other form of modulation.

Noise is an ever-present part of radio communications. If you aren't aware of this phenomenon, tune to the low bands with a communications receiver, from, say, 160 to 10 meters, and simply tune across the band. What you hear is noise . . . lots of noise! Hopefully, if you're lucky (if the band is "in"), as you tune across, say, 20 meters (14.000 to 14.300 MHz), the noise occasionally will be interrupted by signals. If you're *really* lucky, some of the signals will be loud enough to overcome most of the noise. You are experiencing signal-to-noise at its finest. This is a low signal-to-noise-ratio situation.

In FM, when a sufficient signal arrives at the receiver, the signal quiets—that is, because of the high RF limiter, the background noise disappears. Completely. This differs greatly from AM on the low bands, because most natural-occurring noise is amplitude modulated and noise is ever present. In FM, unless the station you're talking to is very weak and barely making it, there will be no noise at all on the signal. This is a high signal-to-noise-ratio situation.

In fact, the sensitivity of an FM receiver is rated in terms of the amount of input signal required to produce a given amount of *quieting,* usually 20 dB. The use of solid-state devices allows modern FM receivers to achieve 20-dB quieting with only 0.15 to 0.10 μv of input signal.

Therefore, the big difference between the AM or SSB on the low bands and FM communications is the amount of noise you must listen to while communicating. The lower the amount of noise on a signal, the better the signal-to-noise ratio.

Speech Clipper

A clipper, or limiter, is a safety valve that limits the peak deviation of an FM or PM transmitter. In broadcast it is sometimes referred to as a *safety clipper.* It keeps the deviation down to a pre-set level, usually 5 kHz for land-mobile communications.

Because the modulation index, or bandwidth, of the transmitted pre-emphasized FM signal increases with the modulation audio frequency, it can easily exceed 3000 Hz. For example, if a long squelch tail is re-transmitted through a repeater, that audio frequency is usually somewhere up around 8000 Hz. This means that the maximum deviation of 5 kHz can easily be exceeded. In the case of the 8000-Hz squelch noise, a deviation of 8 kHz is possible. Deviation that wide would surely ingress into adjacent channel repeaters.

Not only do these wider deviated signals go outside the normal bandwidth of most receivers and cut off the audio (as they over-deviate past the capability of the receiver to demodulate the audio), but more important, these wider sidebands can interfere with other adjacent-channel repeaters and radios. Therefore, it is necessary that some sort of frequency clipping or limiting be placed between the audio source and the modulator. This clipper or limiter should provide clipping at about 5 kHz of transmitter deviation.

Low-Pass Audio Filter

The clipping process produces high-order harmonics, which, if allowed to pass through to the modulator stage, would create unwanted sidebands. Therefore, an audio low-pass filter with a cut-off frequency between 2600 Hz and 3000 Hz is needed at the output of the clipper. This keeps the harmonics, and other high-frequency noise (such as squelch noise), out of the transmitter. This also keeps the occasional long squelch tail, or blast of white noise, from being heard so loudly. Oh, you can still hear these noises, but their amplitude is far lower than without a low-pass filter.

Sub-Audible Frequencies

Sub-audible tones are frequently used to limit access and are commonly called *PL* (a Motorola term that stands for Private Line) or *CG* (a General Electric term for Channel Guard). But whatever name you apply to the sub-audible tone, it simply describes CTCSS, or Continuous Tone Coded Squelch Systems.

This is a continuous tone that is sent along with the transmitted signal at a much lower volume (I usually have it at 0.4-kHz deviation) and at a lower (sub-audible) frequency that you hopefully will not be able to hear really well. This is called *encoding*. It simply means that you are transmitting this continuous tone along with your normal speech in the transmitter.

Decoding is where your receiver hears the continuous CTCSS tone and "decodes" the tone, thereby opening your receiver's squelch so it can hear your transmitted audio.

These frequencies are much lower in frequency than normal, usually around 100.0 Hz. The lowest CTCSS frequency on most radios is about 67.0 Hz, and the highest is about 254.1 Hz.

More on Flat Audio

Now that you are becoming experts in the audio and modulation arenas, I will explain *flat audio.*

As we have discussed previously, early FM radios were designed to be one-radio to one-radio devices. Also, to improve the signal-to-noise ratio, they were all PM transmitters with the built-in audio "roll-up," or pre-emphasis, of 6 dB per octave. This made the signal-to-noise ratio better for reception, making the high frequencies usually as strong as the lows. The receivers all had the audio "roll-down," or de-emphasis, network to restore the audio back to its original state. Everything worked great.

Enter repeaters. Repeaters extended the range of one-radio to one-radio communications. If they were high enough above average terrain, they greatly extended the range. However, because repeaters are duplex and the RX repeats the audio it hears to the TX, there are issues with audio quality and the processing of the audio.

There are many different ways to hook up the audio in repeaters. Some repeater builders take speaker audio out of the receiver and connect it to the microphone input on the transmitter. This has several ramifications:

1. The RX speaker audio will be de-emphasized (again) by the repeater RX.

2. The RX speaker audio is almost always shaped or processed somewhat to match the speaker that the manufacturer specified to be used with the RX.

3. The speaker audio is almost always amplified well beyond what the microphone requires, usually somewhere between 3 to 5 watts of audio power. The microphone needs milliwatts of audio power. Some audio distortion will most likely be present in the amplification, typically 10 percent, and noise is amplified as well.

4. What is the impedance of the average speaker? 4 ohms? 8 ohms?

5. The squelch crash after a user stops transmitting will always be passed along through the audio chain from the repeater RX speaker. You are at the mercy of whatever squelch circuit the repeater RX is using.

6. The TX microphone input audio is always shaped by the manufacturer to match whatever kind of microphone element it is using, be it crystal, dynamic, cardioid, or ceramic. This is usually called the *speech amplifier.* The bottom line is that the audio is shaped, or processed, to match the microphone element. If the mic input is used, this shaping has an effect on the audio coming out of the repeater TX.

7. The audio is pre-emphasized (again) in the repeater TX.

8. The audio input impedance is usually several thousand ohms, not the 4 ohms or 8 ohms of a speaker. If a controller, emitter follower, or cathode follower is used, the impedance mismatch can probably be overcome.

9. Once you set the volume-, squelch-, and modulation-level knobs on the repeater, you'd better not touch them again or your repeat audio levels will go crazy. If someone accidentally bumps one while near the repeater, you'll know right away.

As you can see, this method leaves a lot to be desired. Why do folks do it? Because it's easy! There is not much work involved in strapping a speaker to a microphone. However, if you're willing to invest the time, there are better ways to get the audio from the receiver to the transmitter. Some folks have become very clever at this.

One more point: As we've discussed before, the audio from the user's transmitter is already pre-emphasized, isn't it? It enters the repeater RX pre-emphasized. If the repeater RX de-emphasizes it and then the repeater TX pre-emphasizes it again, in theory it should sound about the same coming out of the repeater TX. However, it usually doesn't. One reason is because the de-emphasis and pre-emphasis curves in the repeater RX and TX are usually not exactly the same. They don't track one another perfectly. There is usually a difference.

It is much better to leave the audio alone when going through a repeater and not process it, keeping the repeater audio path linear. The originating audio is pre-emphasized by the user's transmitter, and we let it be de-emphasized in the end user's receiver. This is the way it is done on simplex, without a repeater in-between. This is what flat audio is.

Another way of saying it is as follows: When the repeater RX hears a signal, it leaves the audio alone, or keeps it flat, without any changes. Likewise, the controller should leave it alone, with no changes. Finally, the repeater TX should leave it alone, without adding anything to it. That way, as far as the audio is concerned the repeater was never there, because the audio path is flat through the repeater. It has not been de-emphasized, shaped, pre-emphasized, and shaped again. It is flat. No processing. No changes.

How one accomplishes this flat audio is really pretty simple. Here is a quick run-down:

1. Pick off the audio at the discriminator of the receiver. Usually the top (high side) of the squelch pot is a good starting point. This is where you can find discriminator noise with an oscilloscope.

2. Use a fast-acting, noise-free squelch circuit such as the Motorola MICOR squelch chip or a microprocessor-controlled digital squelch board (more on this digital squelch in a subsequent article).

3. If your controller gives you a choice, set the controller's input for flat audio.

4. Inject the audio well past the microphone input, past the speech-amplifier circuitry, and past the pre-emphasis network in the repeater TX. This point is usually at the PL, or CTCSS, injection point. This is usually past the TX's built-in clipper and low-pass filter, too, as they are typically in the low-level audio stages of the exciter.

If proper impedance techniques are used this will result in flat audio. It will sound great. However, you really need to install your own clipper to keep your transmitter from over-deviating. Also, you need to install your own low-pass filter to keep the harmonics and high-frequency noise out of your transmitted audio. Finally, and very important, all stages in the repeat audio path must be designed with adequate headroom, or dynamic range.

Also, if you plan to run CTCSS on the transmitter output, you need an isolated input for the CTCSS encoder so it won't load down your audio circuitry, making it sound mushy.

Furthermore, if you are using a PM transmitter—say, a GE or most Japanese radios—you need to be able to compensate for its natural pre-emphasis, or "roll-up" characteristics. This means you need to shape the audio going to the TX to reverse the pre-emphasis roll-up.

Finally, when adjusting audio levels in a repeater, quite often the RX has too little audio level—or too much level—available at the discriminator. Similarly, some transmitters need more audio drive than others at the CTCSS input location. Many controllers cannot handle big variations in audio input and output levels, so you must build op-amps to balance the levels.

Thanks for taking the time to read this article on quality audio. It is my hope that more repeater builders will take the time to make their audio sound fantastic. It can be done with ease. Please direct any question or comments to me at the e-mail address shown at the beginning of this article. ■

By John Champa,* K8OCL

HSMM

Communicating Voice, Video, and Data with Amateur Radio

S.H.A.R.K.s and Tsunamis

This column is on the easy use of Amateur High Speed Multimedia (HSMM) radio in an emergency. HSMM radio is packet radio, but thousands of times faster. It is so fast that we can use simultaneous voice, data, text, and video modes. What a godsend this can be for hams working in a disaster area, such as the world is now facing in the aftermath of the tsunamis in Asia.

Walt DuBose, K5YFW, the ARRL's HSMM Working Group Assistant Chairman, reported the following on January 4:

> The Texas Baptist Men are deploying four or five water-purification units and three feeding units. They will likely want our Command, Control, and Communications unit next (that's my crew and me), but we will need State Department appointments to do our work and use ham frequencies. There is already talk of needing 802.11b links between communications centers and the various distribution points, using an AP *(access point—ed.)* that is high up on a mountain.

The accompanying sidebar contains their recommended packing list.

HSMM Radio—The Future

There are a number of significant reasons why HSMM radio is the wave of the future for many Emergency Communications (EmComm) situations such as those encountered by RACES, ARES, and other radio amateurs responding to disaster locations. These reasons include:

1. The amount of digital radio traffic on our 2.4-GHz band, presently the most common band used by hams for HSMM radio, is increasing. Operating under low-power, unlicensed Part 15 limitations cannot overcome this noise.

2. Higher power is sometimes needed for longer range, higher reliability, and high data-speed links (i.e., improved signal margins), so operating under Part 97 makes sense.

3. EmComm organizations increasingly need high-speed radio networks that can get vast amounts of data out of a disaster area and into an area where ADSL, cable modem, satellite, or other broadband Internet access is available.

4. The equipment needed by hams is readily available, highly economical, and easily adaptable, commercial off-the-shelf (COTS) gear of the IEEE 802.11b variety.

With HSMM radio, all that would be

*Chairman of the ARRL Technology Task Force on High Speed Multimedia (HSMM) Radio Networking; Moon Wolf Spring, 2491 Itsell Road, Howell, MI 48843-6458
e-mail: <k8ocl@arrl.net>

S.H.A.R.K. Components

- Standard kit for deployment in emergency
- Easily field adaptable
- Video/file transfer operation
- Kit includes documentation, forms, etc.
- Includes PDA to allow handheld roaming
- Includes both omni & directional antenna

needed for such emergency communications in the field is a laptop computer with a headset for simultaneous voice and data modes. A digital camera can also be attached for simultaneous Amateur Digital Video (ADV) modes.

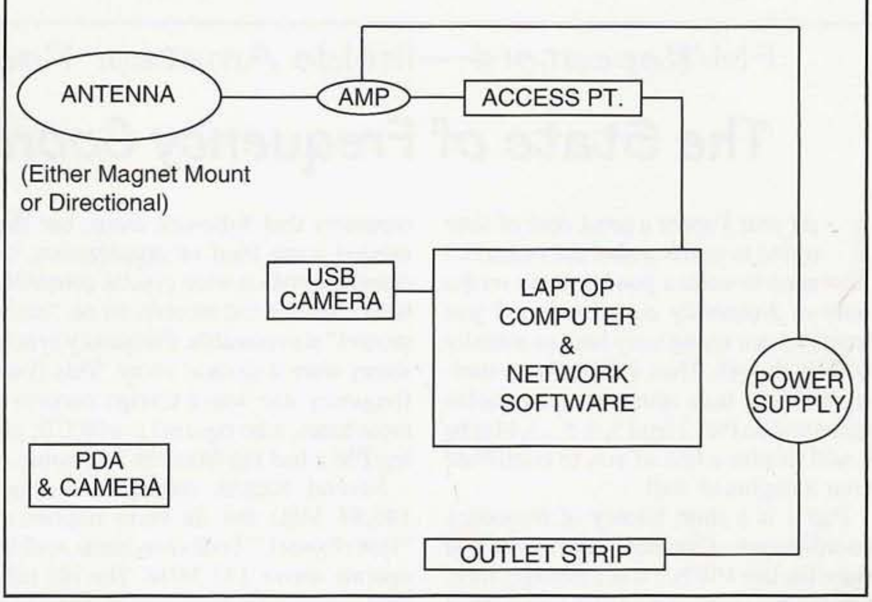
The laptop must be equipped with a special wireless local area network card (PC card) *with* an external antenna jack. Connect the PC card via a short strain-relief cable (a.k.a. pigtail) to some good coaxial cable (e.g., LMR-400) to a short Yagi antenna (typically 18 inches of antenna boom length) or a small mast-mounted dish antenna. That's all there is to it!

Oklahoma Baptist Hams Emergency List

Make a plan for sleeping in the open in an insect-infested area. Here is a list of possibilities items to include in your plan.

- Personal tent (pop-up, fully enclosed, zippered door)
- Inflatable mattress (that, of course, would fit in the tent)
- Sleeping bag
- Pillow
- Sheets
- Mosquito netting
- Insect repellant
- Clothing suitable for the climate
- TBM uniforms (caps, blue shirts, jackets, and so on)
- Boots
- Plenty of socks and underwear
- Long, sturdy pants
- Over-the-counter medications
- Any prescribed medications (at least a four-week supply)
- Melatonin (a natural sleep aid that will help shake off jet lag)
- Imodium
- Laxative
- Perhaps an antibiotic (your doctor may prescribe an overseas travel kit that includes this item)
- Maximum-size luggage (We need as much space for carrying the items needed for water purification as you can provide us.)
- Personal hygiene items
  - Soap
  - Toothpaste and toothbrush
  - Shaving kit
  - Manicure set
  - Brush or comb
  - Bath towels
  - Wash cloth
  - Shampoo
- Your *Bible*
- Items Not to Take!
  Anything you are not willing to leave behind and cell phone

S.H.A.R.K. Interconnect



Next point the antenna to the HSMM radio repeater at the Emergency Operating Center. Ranges from several miles to 20 miles and more over open water are readily possible. Date rates can be as high as 11 million bits per second (Mbps). The actual throughput is less, because the system is operating in half-duplex mode. This is *radio,* not your local cable modem, so the radios must stop transmitting between packet clusters to listen from time to time.

The S.H.A.R.K.

Here is where the S.H.A.R.K. comes in. S.H.A.R.K. stands for Standard HSMM Amateur Radio Kit. It is the brainchild of Jim Kvochick, WB8AZP (wb8azp@arrl.net), and Brandon Field, KC8YHE, and others in the wonderful and very friendly Livingston (Michigan County) Amateur Radio Klub (LARK).

Both Jim and Brandon are associated with the ARRL's HSMM Working Group (http://www.arrl.org/hsmm/). If you have any questions about high-speed digital or multimedia operation, the HSMM Working Group can help you get started in this exciting part of amateur radio. You can subscribe to the ARRL IEEE 802.11b Mail List at Texas A & M University. To subscribe, go to: <http://listserv.tamu.edu/archives/arrl-80211b.html> and select "Join" or *leave the list* (or *change settings*), or send an e-mail to <listserv@listserv.tamu.edu> and in the body put subscribe arrl-80211b [first name last name], or subscribe arrl-80211b [first name last name-callsign].

This list has been established to facilitate discussions of the various aspects of the HSMM and IEEE 802.11b/g with members of the ARRL HSMM WG and other interested parties. The IEEE 802.11b used by hams employs commercial 802.11b hardware, and additional legal amateur radio hardware such as RF amplifiers and high-gain directional antennas, which are appropriate for Part 97 service. All participants are welcomed to the list.

The photos and diagrams with this column are fairly self-explanatory, but what Jim and Brandon have created is a portable HSMM radio field station in a weatherproof transport container. It is available for immediate deployment, and in the hands of a qualified ham it can provide a high-speed Internet connection for simultaneous digital voice, data, and video within minutes of arriving at the scene of a disaster.

Jim and Brandon have shown us one way in which the mission of supplying emergency communications can be accomplished. Generally speaking, hams have the skills to deploy such HSMM radio systems. What they need is the knowledge base for operating these radio systems, and it can be fairly easily acquired by participating in the list and/or interacting with other participants on the list. ■

By Gary Pearce,* KN4AQ

FM

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

The State of Frequency Coordination, Part 1

Last year I spent a great deal of time trying to pull together the research I need to write a good column on the state of frequency coordination. I just haven't been trying very hard to actually *write* it, though. Thus, I'll get Part 1 started, and that may spur me on to buckle down and do Part 2 (and 3, 4, 5…). Maybe it will inspire a few of you to contribute your thoughts as well.

Part 1 is a short history of frequency coordination. I've been active on FM since the late 1960s. I was a teenager then, and the big wave of FM and repeaters of that era kind of washed over me. However, I did pay some attention, and by the late '70s I found myself the frequency coordinator for northern Illinois, including the Chicago metro area. Sherman, set the Wayback for the early '60s. …

Frequency coordination and its close cousin, band planning for VHF/UHF FM, are two of the big success stories in amateur radio—our generation's version of crossing the Atlantic on HF. During the '60s there was just a little FM/repeater operation on ham radio, and before 1960 it pretty much didn't exist at all. I was licensed in 1965, and 2 meters was fairly quiet around Chicago. A bunch of us operated AM just above 145.0 MHz. There were a few big-gun weak-signal ops on SSB and CW, a moonbouncer or two, and maybe two repeaters that were a secret well kept from most of the ham community.

In the '60s the FCC changed some rules for commercial two-way radio users and put a lot of FM equipment on the surplus market, cheap. Hams, many of them two-way Techs, snapped them up, retuned them for ham frequencies, and started putting up repeaters.

We had a lot of totally vacant space on 2 meters, mostly between 146 and 148 MHz. The 30-MHz wide 70-cm band was almost completely empty. There was no band plan to tell the hams what frequencies to use for these FM rigs and the repeaters that followed them, but they needed some kind of organization, because the radios were crystal controlled, both transmit and receive, so no "tuning around" was possible. Frequency synthesizers were a decade away. This fixed-frequency use was a foreign concept to most hams, who equated it with CB, giving FM a bad rap from the beginning.

Several factors conspired to make 146.94 MHz the de facto nationwide "first channel." Tech class hams couldn't operate above 147 MHz. The old tube-type radios were being tuned down from commercial channels between 150 and 160 MHz, and some just barely made it down to the ham bands, so you wanted to pick the highest frequency you could. The radios were designed for 60-kHz wide channels, so 147 minus .06 is 146.94, or "Nine-four." An FM star was born.

In some places 94 was used for simplex, and in others it was a repeater output, setting the stage for the first FM "repeater wars." In these early days, with just a handful of operators and very limited equipment, some of our pioneers didn't see eye to eye on spectrum use. Around Chicago, 94 was used for simplex, and people got very upset when someone put up a 94 repeater in a distant southern suburb. There was some bad behavior. I should know. I participated.

A few other repeater output channels became popular; 146.88 and 146.76 MHz caught on. However, there was no standard offset for the input frequency. That meant that your FM mobile was useful at home, but not on the road. Most radios had two channels. A deluxe radio had four. You usually spent more money on crystals than on the radio itself. *Flexible* was not in the vocabulary.

By the early '70s, FM was becoming really popular, despite condescending glances down long noses from "traditional" hams, and without any commercial off-the-shelf radio equipment to speak of. It was going to need some organization. With a lot of help from *73 Magazine* (especially Bill Pasternack's "Looking West" column), and some from the ARRL, hams worked out a band plan calling for 60-kHz channel steps, going up and down the band from 146.94, with a 600-kHz repeater offset. Regional groups did most of the planning, with hams in Texas taking a leading role. I suppose the amazing thing is that we didn't end up with a bunch of incompatible, regional plans. The ARRL VHF Repeater Advisory Committee helped give the band plans nationwide stature. We do have some regional differences today, such as the 15- vs. 20-kHz channel steps on 2 meters, and some upside-down UHF repeaters in some parts of the country, but the consistency of the plans is more remarkable than the differences.

Frequency coordination was the next order of business, to keep repeaters with overlapping coverage from interfering with one another. Most areas developed repeater councils, or at least had an individual volunteer to be the coordinator. It was totally voluntary, and not always popular or successful. Some hams resisted being told what to do, and some coordinators wielded their authority with a heavy hand. FM/repeater pioneers were some of ham radio's most independent thinkers. They butted heads over the use of the few "popular" frequencies (the "repeater wars" I mentioned earlier) for a while, but eventually most caved in to the logic of how well things worked if we cooperated.

Manufacturers took notice and began to offer true "amateur radio" FM equipment. After some shakeout, the norm became 12-channel, 25-watt crystal-controlled radios from several Japanese and American manufactures, including Motorola, whose surplus commercial equipment had led the "conversion" wave (along with some GE, RCA, and Johnson stuff). Motorola, though, was late to the party, marketing a rather expensive 12-channel crystal rig while the others were introducing the first synthesized equipment in the mid- to late '70s. With more radios, and radios with more channels, repeater building and FM use boomed.

The band plans developed in those early days received some tinkering over time,

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

Tone Revisited

If you're serious about repeaters, by now you've probably heard that SERA, the SouthEastern Repeater Association, rescinded their decision to require tone, both encode and decode, as a condition for coordination on all repeaters in its eight-state area. The decision was unanimous at the SERA board meeting last June, but it turned out that some of the directors who weren't able to attend the meeting were opposed to it. In addition, after taking a beating from both repeater owners and users, a majority of the directors decided to reconsider.

As I said in my Fall 2004 *CQ VHF* column, most of the SERA directors didn't intend to pass a blanket requirement for all repeaters to use tone, period (with a two-year grace period for existing repeaters). While the subject was being kicked around at the meeting, somebody asked if repeaters would be decoordinated if the owner decided to stay carrier access. The answer was no, and that satisfied the members at the meeting. However, it didn't get into the motion or the minutes of the meeting. It is in my notes, but that's not very official.

The SERA board kicked around other wording on its mailing list. A couple of SERA's directors tried to create motions that came closer to the spirit of what they thought they had passed. That proved more difficult than just rescinding the original vote, at least to quell the storm. I expect a lively winter board meeting this January, which will be history before this issue of *CQ VHF* reaches your hands, so watch QRZ.com and eham.net and maybe the SERA website (www.sera.org) for any late fury. If debate has been kindled in your area, let me know!

I think the merits and details of the multiple sides of the issue have been flogged to death (many of you are quite passionate about the issue—pro, con, and otherwise), but I received some mail from *CQ VHF* readers with some unique thoughts to consider.

Thoughts on Tone

Len Umina, WT6G, in Sacramento, California, uses a tone-flexible controller from Pacific Research to allow all tones, except the tones of his co-channel neighbors, to access his repeaters. He suggests setting up your controller so that it will respond to the "wrong" tone, or no tone at all, with an announcement of the tone you need to key up and yak away.

Alas, Len, my experience is that few good ideas that require repeater technicians to implement a feature or function ever see widespread adoption. "Universal" tone, LiTZ, and even common regional tone implementation are rare birds. However, I'm happy to pass along your idea. It doesn't need universal acceptance. It will work on repeaters one-by-one and help a little.

Len had a question for the manufacturers out there: Why design radios to respond to just one tone? The ability to program multiple decode tones could be quite useful.

I'll add my own questions: What's up with slow "tone scan" as the method of discovering an unknown tone? Why can't the tone frequency pop up more or less instantly, the way it does on a frequency counter, ready to use? The more I hear about tone troubles, the more I think that flexible but easy-to-use tone operation could be the "killer ap" feature that will sell radios.

Stan Podger, VE3DNR, from Ontario, Canada, likes the way tone permits him to pick and choose repeaters to key up when the band is open a bit and he can "DX" across Lake Ontario. If the local machine is quiet, he can reach beyond it for a conversation without keying it up and bothering the locals.

DXing repeaters is one of those things your father may have told you never to do. "Repeaters are for extending the coverage of mobiles," he might have warned. Okay, maybe it was your mother, but probably not. Anyway, there are some repeater gurus who are reaching for their keyboards right now to tell me that Stan is way off base in DXing repeaters. I say phooey. Why not DX a bit and have fun? Weren't you just complaining recently about how underutilized repeaters are these days? Of course, the local machine must be idle when you DX.

I'll throw some of my own cold water on the idea just to keep my official curmudgeon status and keep everyone guessing. The problem with this is that the guy who is most likely to take advantage of it is the same jerk who operates as if he owns the band and all the repeaters are his personal play toys. He has no regard for his fellow hams and cares not what havoc he wreaks. He has one of the bigger towers in town, at least a 150-watt amp, and if you're having fun, he's probably not (and vice-versa).

Stan, on the other hand, told me that he'd cease and desist his DX contact the moment someone begins using his local repeater. Maybe think of this as knowing the rules well enough to break one now and then. Knowledge and courtesy would permit this kind of operation. There are some repeater owners who are aware of this potential operation but oppose it, perhaps because they feel that knowledge and courtesy are in short supply. They are afraid of letting the genie out of the bottle.

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as we followed the commercial practice of narrowing deviation and slicing the channels in half, from 60 to 30 to 15 kHz, to accommodate more and more repeaters. Fifteen-kHz step use faced a technical problem, since standard "narrowband" 5-kHz deviation actually uses about 16 kHz of spectrum so there's some guaranteed adjacent channel interference. A strong adjacent channel signal will spatter in your receiver, causing annoying "grunge." For a while, some repeater councils recommended putting the new repeaters on the 15-kHz "splinter" channels upside-down, figuring that having a 146.94 repeater output next to a 146.955 repeater input, with significant geographic separation (50 miles or so), would at least give each repeater a fixed, predictable signal to deal with, and users would be faced with intermittent, weaker, and distant user signals adjacent to their receivers rather than a constant, strong repeater signal. However, other repeater councils didn't buy it and coordinated the new splinter channels in the usual configuration that had developed—minus offsets below 147 MHz and plus offsets above. That left repeater *outputs* in one state on the repeater *input* frequencies of machines in a neighbor state—a big problem, especially during a band opening. The upside-down plan was quickly abandoned, and repeater users were left to fend for themselves among repeaters on channels that were just a little too close together. Coordinators kept those repeaters about 50 miles apart, and that limited the problem to tolerable levels. Most repeater operators today probably don't notice.

The FCC also tinkered with the rules, reacting to repeaters' threats to take over the whole 2-meter band by prohibiting them below 146 MHz in the early '70s, and then opening up 145.5 to 146.5 again as FM operation dominated the band. At that time, Techs, who had privileges only from 145–147 MHz, were given the whole band, allowing them onto what were previously "General Class Snob" repeaters. Well, some people called them that.

In that "new" repeater spectrum, the councils sought to avoid the 15-kHz channel problem and made the channel steps 20 kHz. Repeater councils in some states, mostly in the west (plus Michigan and Alabama), decided they liked 20 kHz so much they switched the upper half of the band to 20 kHz, too.

The repeater boom continued through

the '80s. Radios became more sophisticated, but repeaters still mostly were built from surplus commercial equipment a decade or more old. In the larger metro areas 2 meters filled up. There were no more "band-plan" repeater frequencies available. A few hams went outside the plan and put repeaters on simplex channels, with non-standard spacing, or they used band-plan channels but didn't get coordination. I'll address these problems more in Part 2.

The '90s saw the introduction of the code-free Tech, and another boom in licensing and repeater use. That boom peaked in the middle of the decade, and some have seen a slow decline in activity since then. The number of repeaters continues to climb, with saturated 2 meters leveling off and the 70-cm band catching up. 220 (222 for you literalists) has lots of repeaters, but still lacks activity.

Taken for Granted? That brings us up to the present. Still today there are some conflicts and disagreements about coordination and the band plans, but it's all held up remarkably well over the decades . . . well enough for FM to be taken for granted—the Utility Mode.

Two groups that do not take them for granted are repeater owners and frequency coordinators. The coordinators deal with the reality of the band plans every day. Repeater owners don't think about it as much, but they become acutely aware of coordination and band plans when they want to put up a new machine or make significant changes to their current one.

What are the problems and challenges that we still face? I'll explore them in future columns. What do *you* think they are? Drop me a line. Also, if you were around in the early days, you might have a story or two to share about how we got where we are today.

APRS/Monitoring on the Road

Many hams have lamented the lack of simplex activity, especially among hams on the road traveling cross-country. I've had some luck making contacts on 146.52, but it's rare.

Here's an idea that might help you make a few more mobile contacts. It comes from Bob Bruninga, WB4APR, inventor of the APRS packet locating system:

If you're on a long trip and between satellite passes and can't find anyone to talk to, just activate your mobile HAM "radar" detector. Many APRS mobiles run what is called "voice alert" on 144.39 MHz. This means they are *listening* with CTCSS 100. Thus, they never hear any packets unless someone is within *simplex* range of them and calls with CTCSS-100.

It's like a radar detector. If you pass within simplex range of someone else with Voice Alert, even if he (or she) is not talking, you will hear an occasional ping because the APRS packet is also transmitted with CTCSS-100 (136.5 Europe).

Even if you don't run APRS, but just want to see if anyone is in simplex range while driving, anyone can tune there and listen. If you hear a packet break your CTCSS 100 squelch, then you know someone is in simplex range and listening on the speaker for a call with PL 100.

This is better than 146.52 because of the automatic "pings" by each such mobile. You can drive all day listening to 52 and pass within range of dozens of others, but if no one calls CQ once every two minutes or so, you may never find one another. (Two cars passing at 60 mph are beyond mobile range in 5 minutes. Also, statistically on the interstate you will pass by another ham about four to six times an hour.)

With APRS Voice Alert you have four potential QSO guarantees:

1. One of the other operator's radios is *always on.*
2. One of his radios is *always* tuned to 144.39.
3. If he has set Voice Alert, then he has the *volume up* and will hear you if you set CTCSS-100.
4. If you monitor with CTCSS-100, you will be alerted by his packets when he is in simplex range of you.

However, if you call on 144.39 Voice Alert, you *must* state "calling on Voice Alert." Otherwise, he will assume your voice came in on his normal voice radio and he will come back to you there, because he has no way of knowing otherwise.

Note also that you must set CTCSS 100, or you will be driven crazy by all the packets. Remember, Voice Alert is *only a CALLING channel.* You must immediately QSY to a voice channel for a QSO. 144.39 is a packet channel only. This Voice Alert process is only a convenience for contacting mobile operators.

Note: Never set PL 100 from a fixed APRS station. No one wants to hear your pings unless you are sitting there *actively* looking for a QSO. In a mobile, if the APRS rig is on, he is there and his volume is up and he is listening. Thus, Voice Alert is considered to be a "live" process only.

KN4AQ here again. I don't know how active this Voice Alert system is. When I boot up APRS in this area, I see few mobile trackers running around. However, like any neat idea it will grow if people give it a chance. Let me know if you try it.

BPL Update

Most of you know I've been keeping my finger on the pulse of BPL (Broadband over Power Lines), a pulse that's been beating a bit stronger after the FCC removed some of the "regulatory uncertainty" with last October's Report and Order. Although Progress Energy ended its trial with no immediate plans for the future here in North Carolina, trials and full rollouts are spreading across the country.

The vendors' and utilities' new mantra is "We've solved the interference problem." They claim that hams are not complaining. While it's true that hams are not complaining in large numbers, it's because large numbers of hams are not yet affected by BPL. However, hams are complaining in small numbers, and the complaints are being misunderstood, if not completely ignored.

All the vendors are trying some form of notching our bands as their signals cross our frequencies. They're calling that good enough, but so far no system gets a clean bill from the ARRL's chief BPL investigator, Ed Hare, W1RFI.

I spent a few days with Ed this past December, and we toured the Briarcliff Manor, New York BPL system. We ran into an Ambient engineer who told us he thought the system had been pretty well cleaned up. He was earnest about wanting to make things work. However, our quick drive through the neighborhood showed he had a long way to go.

We parked under one line and tuned across 20 meters. The BPL signals were over S-9 and covered up many of the signals on the band. I asked Ed if this band was notched, and he said it didn't sound like it. Then he tuned outside the band, and the signals came up to S-9+20. The band *was* notched, but the notch was ineffective. Then we drove down the road, listening to the county hunter net on 14.336. It was obliterated for several minutes as Ed ran the length of the line at the posted speed limit. As a result of this observation, the ARRL has repeated its request that this system be shut down.

I've seen notching that worked better, but I haven't seen any that would solve the interference problem for a home station within a block or two of a power line. Those stations would get

S-5 or better BPL signals, if there were any. Right now there just aren't many active hams that close to power lines in BPL areas . . . but there will be.

The utilities and vendors aren't putting two and two together. Those that genuinely want to work with hams and avoid interference desperately want to believe that they are solving the problems with their notches. Others, more disingenuous, just beat their PR drum that the problem is solved (the problem they denied existed earlier last year).

There are two more show stoppers: mobile hams and all SWLs.

Mobile hams led the way in BPL investigation, since there still are few hams living in BPL areas. Utilities, including my own Progress Energy, have characterized this as hams just looking for trouble, and the FCC bought into it in its investigation here last summer. Mobiles can just drive through it, they say. They missed the point. Yes, we went "looking for trouble." We went in to see what the BPL would sound like if there were any fixed stations, and we found it. We told the power companies. We also filed the complaints with the FCC, because the BPL industry was claiming there were no complaints, hence no interference, and some utilities took offense. To be honest, many hams have also taken great offense, and spared little language in saying so. If the utilities were smart, they would look at our evidence and recognize the potential problem waiting in a general rollout. I suspect some of the engineers see it, even if the managers and spin doctors don't.

The best notching I've seen so far makes a fairly acceptable situation for a mobile driving by a power line using a notched ham band. Not all the notching meets that standard, and the best notch still isn't good enough for a home station near the line. They need another 20 to 30 dB, and the technology isn't producing that yet.

So far, too, none of the systems has paid one iota of attention to SWLs. The international shortwave broadcast bands have not been notched anywhere. SWLs have complained individually and as a group and have been ignored so far. I know if my local utility changes course and implements BPL in my neighborhood, and it somehow notches the ham bands to my satisfaction, I'll next look at the SW broadcast bands. If I find BPL there, I'll complain (again). SWLs go mobile, too. Notch all that spectrum, and all that the new Part 15 requires, and is there enough left for BPL throughput?

Ingress Tests

Hams are also starting to pay more attention to "ingress" problems—ham signals disrupting BPL operation. Ed Hare is collecting data, and more tests are confirming that it's a problem, especially for the Main Net systems. I performed a brief test on the Emmaus, Pennsylvania system, an older Main Net system operated by PPL. PPL had a BPL demo set up in a storefront, and while I played with the computer, Steve Dove, W3EEE, parked under the power line a half-block away and keyed his 20-meter mobile with a 50-watt carrier. The video I was streaming (the FCC Open Meeting in October, where the Part 15 revision Report and Order was approved [I enjoyed the irony]) ate up its buffer and froze. It never recovered even after Steve let go. Carriers as low as 5 watts prevented me from opening new web pages, and it took about a minute to see progress after he dropped off. We didn't try SSB, or other bands or modes, as our time was limited. However, it pointed to the need for more thorough testing. This system, by the way, has no notches for the ham bands and sprays S9+ RF between 5 and 22 MHz over half the town. You can't "drive out of it" without leaving the large neighborhood.

BPL systems are designed to ignore interference on any spot frequency. They have tons of interference on the power line itself. A ham taking up a few kilohertz of a BPL block that's 15 MHz wide, as the Main Net system is, doesn't cause any damage, but a really strong ham signal might completely overload amplifiers and knock out service for as many homes as that amplifier feeds. Also, while we're on solid ground with Part 15 (the unlicensed devices must accept any interference they get from licensed services—that's us), that has always been a hard sell in neighborhoods. The more alarmed hams worry that one day BPL will be so big and important that it will gain official protection from the FCC. It's hard to believe that a huge communications infrastructure would be built on the flimsy framework of Part 15, but that's what's happening.

The next step for hams and BPL? Be vigilant. Know your spectrum. Learn what the flavors of BPL sound like. Keep an eye on the local paper to see if your utility announces plans or tests. Each city should form a "BPL Committee" with members who gain expertise in listening for BPL and writing complaints so that when we do complain, we're sure it's BPL and not one of the many other whirrs and bleeps our spectrum is heir to. Work with the local utility if it is cooperative, but be wary of pledges of cooperation that it can't fulfill.

That's it for this time. See you in the spring, and don't forget to send me your "coordination" experiences.

73, Gary, KN4AQ

CQ's 6 Meter and Satellite WAZ Awards

(As of December 1, 2004)

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
64	KB4CRT	2,17,18,19,21,22,23,24,26,28,29,34,36,37,39
65	JH7IFR	2,5,9,10,18,23,34,36,38,40
66	KØSQ	16,17,18,19,20,21,22,23,24,26,28,29,34
67	W3TC	17,18,19,21,22,23,24,26,28,29,30,34
68	IKØPEA	1,2,3,6,7,10,18,19,22,23,26,28,29,31,32

Satellite Worked All Zones

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

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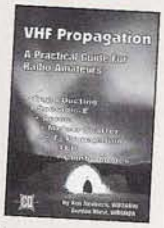

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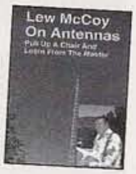

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By Kent Britain,* WA5VJB

ANTENNAS

Connecting the Radio to the Sky

A Universal Antenna

I'm about to do something I really hate to do, but it's been a very hectic month as I write this in late December in a motel in Fordyce, Arkansas. I'm going to write about an antenna I have not had a chance to prototype. It is, however, a pretty low-risk project.

RadioShack sells a "Universal Antenna" (catalog No. 17-345; photo A) for analog, TDMA, CDMA, and GSM cell phones, with even an implied reference for using it with 915-MHz spread-spectrum phones. That's a pretty big range of frequencies.

I purchased two and split open the first one before I even left the store's parking lot. A circle and a rectangle? I'd never seen anything like this and could hardly wait to get it home and fire up the network analyzer.

In photo B you can see the SWR is less than 2 to 1 from just under 800 MHz to 2000 MHz. I didn't take a photo of my later sweeps, but it kept that same pattern of humps just under 2 to 1 SWR up to over 6000 MHz. That's a pretty big range of frequencies!

Scaling up the 3-inch diameter disk to a 17-inch disk would bring it down to 140 MHz. What a construction project!An antenna that would work on 146, 222, 440, 900, and 1290 MHz (figure 1)! Then throw in the VHF, UHF low, and UHF high scanner bands as well. Don't be afraid to use something bigger than 17 inches in diameter. It's not a particularly critical dimension as long as it's at least 17 inches across. Five ham bands in one antenna is a pretty versatile antenna.

Note how the coax is run down the center of the rectangular element (photo C). That coax routing down the center was very important for a broad frequency response.

Construction

Of course I haven't built one of these Universal Antennas as yet, but I'm thinking about a trip to the Dollar Store for a pizza pan and a cookie sheet, or maybe a big sheet of aluminum-foil-covered styrofoam, house insulation siding, and solder tabs as we used for the patch antennas we covered here last summer. I look forward to what readers come up with, too.

A sheet of metal can be radar simulated with just a wire frame of the edges of the sheet metal. Maybe we can get simi-

Photo A. The Universal Antenna.

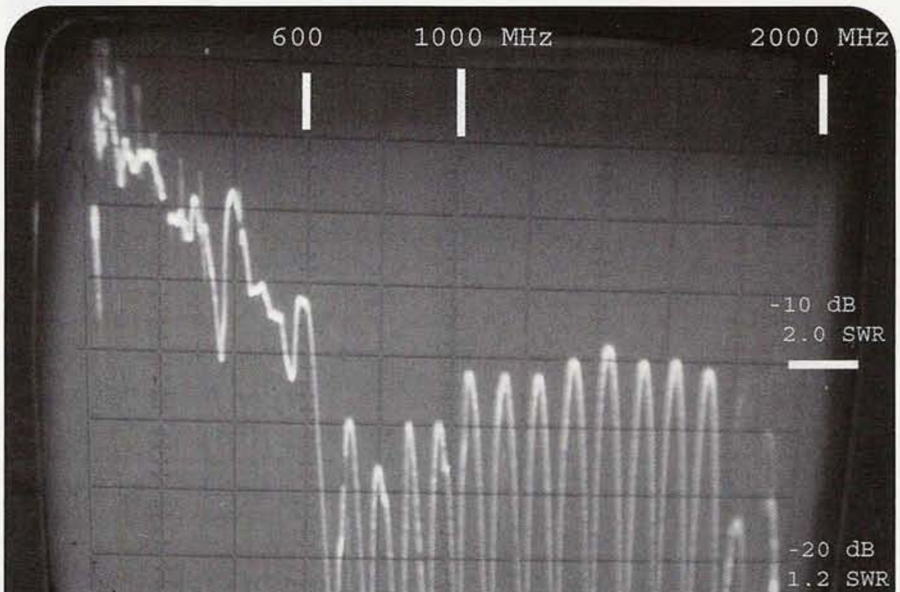

Photo B. Network-analyzer plot from 0 to 2000 MHz.

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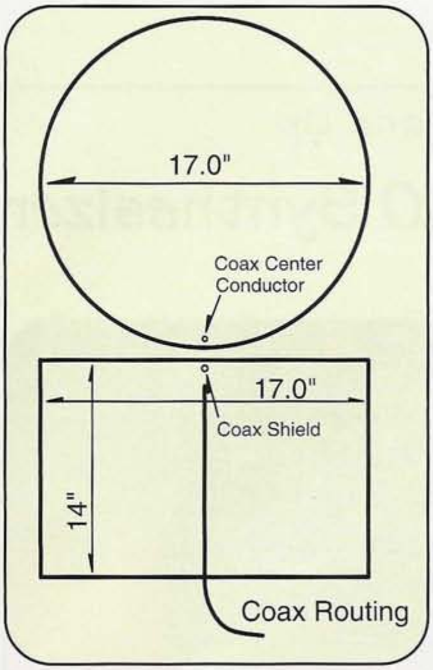


Figure 1. The Universal Antenna for146, 222, 440, 915, and 1290 MHz.

lar results with just a loop and square made of out copper wire. That sounds like still another construction project.

Letters, We Get Letters

From John in 4-land we have a request to publish a 2.4-GHz version of the Cheap Yagi. While I have designed versions etched on PC board going up to 5.8 GHz, 1.3 GHz is the highest frequency I have gone up to for a wood-and-wire version of the Cheap Yagi. Hmmm . . . popsicle sticks, #14 wire, and a little hot-melt glue?I'll see what I can come up with.

From Paulo in Brazil, I received several photos of his Cheap Yagi using aluminum elements. Instead of soldering the coax directly to the driven element, Paulo made clips out of brass stock (figure 2), clamped those to the elements, and then soldered the coax to the clips. I personally prefer to solder the coax to the driven element—a good, solid connection with no place for corrosion to grow in the joint—but if you have a lot of aluminum tubing, it's a valid way to build the antenna.

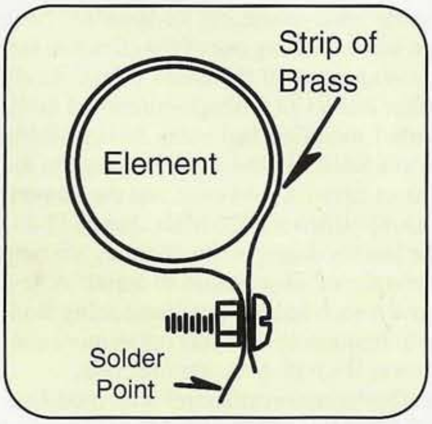


Figure 2. Element clips for the aluminum driven elements.

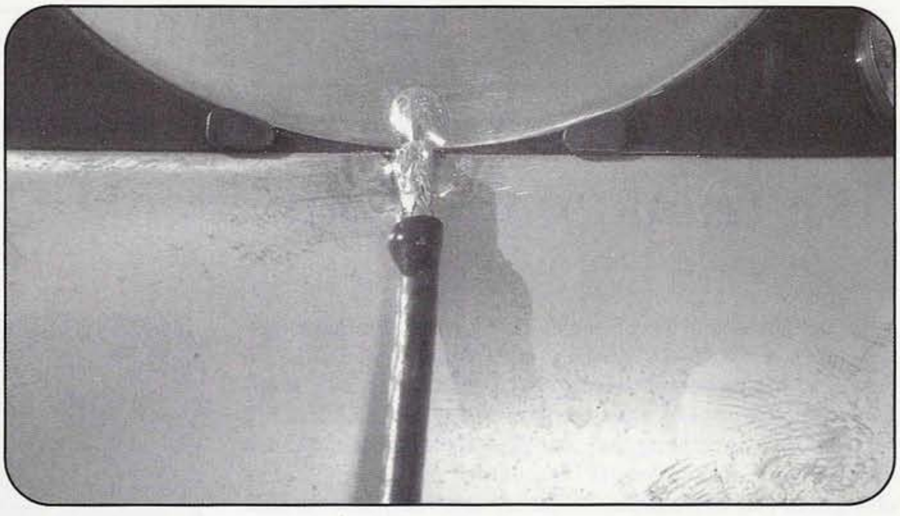


Photo C. Universal Antenna coax attachment points.

The best report came from a chap who works for one of those federal agencies with three letters. It seems he was sent to a monitoring station in Pakistan just along the Afghan border. Osama's boys were using off-the-shelf amateur handhelds to talk to one another. I guess the Afghan version of our FCC hasn't been doing their job lately. Anyway, the signals were just detectable with the monitoring station's discone antennas. Thus, he built a 2-meter and a 440-MHz Cheap Yagi "literally out of broom sticks and coat hangers" and connected them to their monitoring equipment. He says the signals were good and the information . . . well, useful. That certainly is my most interesting reader endorsement.

Some of my best ideas for articles come from you, our readers, so keep those antenna questions and ideas coming.

73, Kent, WA5VJB

By Chuck Houghton,* WB6IGP

MICROWAVE

Above and Beyond, 1296 MHz and Up

The Qualcomm "Omnitrack" DRO Synthesizer

The Qualcomm DRO (dielectric resonant oscillator) synthesizer normally operates on a frequency of 2620 MHz and has an output power of +10 dBm. Frequency stability is under control of a dielectric resonant controlled oscillator (DRO). This ceramic puck stabilizes the oscillator, and synthesizer phase-locked-loop (PLL) circuitry must be modified to change the output to another frequency more desirable for amateur microwave use.

Unfortunately, the DRO synthesizer is controlled by its divide-by reference of 1.25 MHz (random-access [RA] counter set to divide reference 10 MHz by 8). A solution was to change the RA counter to divide the stock frequency of 10 MHz by 64 for a new reference frequency of 156.25 kHz. There are many possibilities, but for this application the irregular frequency steps limited those frequencies that could be reached by the PLL chip. Modification of the DRO took the form of adding solder—bits of copper or short lengths of copper wire soldered to the top of the DRO, stretching the DRO resonance. This could be a small coupled pF capacitor, or an inductance used to tweak the DRO to a new frequency (free-running frequency near desired operation point).

The above is where this project lay for some years. Then while cleaning out the shed and trying to reorganize material stored there, I came upon a large box of DRO synthesizers. At the same time, I revisited the file of material and modification notes that John Stevens, WB2BYP, and I had worked on previously. I had done the original modification work using the stock reference frequencies of 1.25 MHz and 156.25 kHz, but John saw a much better use for these DRO synthesizers, working his plan around a new reference frequency of 1 MHz. This allowed many other possible frequency combinations that were capable of being reached by reprogramming the PLL dividers and constructing a new divider (divide by 10) to produce a 1-MHz reference from the 10-MHz TCXO (temperature-compensated crystal oscillator).

John put together a great modification procedure and gave me his permission to cover it here. I am sure it will be met with great interest, especially because the synthesizer PC boards are still available from the author (WB6IGP) for modification to other useful microwave frequencies.

Modification for 2592 MHz

The sequence of images and comments builds upon my article entitled "Above and Beyond," which appeared in the June 1994 issue of *73 Magazine*. I had known about these synthesizers for a few years, and only recently started thinking about

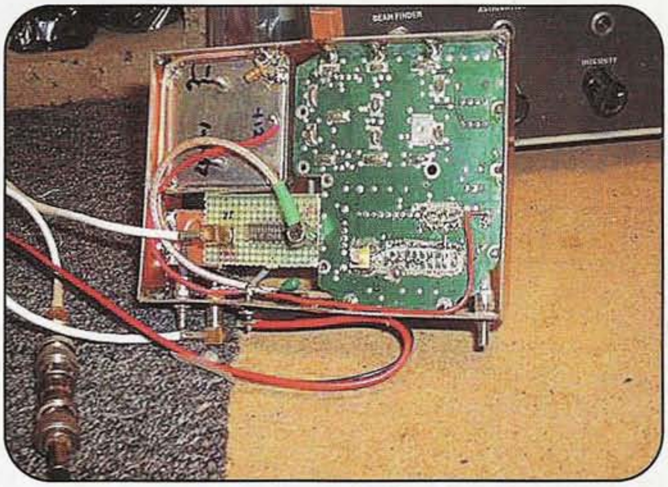


Photo A. Bottom of the synthesizer PC board with pins of the synthesizer chip isolated by dremel-cutting around each pin to isolate them for experiments on other frequencies.

them as an LO (local oscillator) or marker generator for microwave experimentation. I had been looking for a signal source that I could lock to a 10-MHz TCXO for field use or as a GPS-disciplined oscillator. I wanted to know with some accuracy where the band edges are at 10368 and 24192 MHz. Jud, K2CBA, uses one of these as the basis for an LO in his homebrew 10-GHz transverter. The frequencies at which the synthesizers lock with the Omnitrac 10-MHz TCXO are limited in utility, but if you are open-minded about what to use as an IF and have a rig that will do it, you can use the boards with minor mods.

In my *73 Magazine* article I discussed some of the frequencies that are available with a minimum number of modifications, and I provided some good schematic information. Note that you may have to do some drawing out of the circuit to satisfy your curiosity regarding some of the board's finer detail, such as the reference filter and VCO (voltage-controlled oscillator). One of the boards I modified had some workmanship errors that contributed to a failure in the supply voltage to the VCO buffer amp. It was an easy fix, however, and the unmodified board came up with +10 dBm at 2620 MHz. Jud and I discussed the utility of the boards during some Monday evening 2-meter chats, and a couple of ideas came to mind. A few evenings spent at the test bench led to some interesting findings. I wanted the lock-to frequencies to come out in more convenient values for common IFs with low side injection.

What followed is the Qualcomm synthesizer with modifications to place it on 2592.000 MHz (10368.000 divided by 4). I am using this for a marker generator. The reference is running

*Member San Diego Microwave Group, 6345 Badger Lake Avenue, San Diego, CA 92119
e-mail: <clhough@pacbell.net>

Photo B. Top of the synthesizer showing added perf-board transistor amp and 10-MHz TCXO used to provide clock input to the synthesizer via a new, added 7490-divide-by-10 chip.

at 1 MHz, and the *R* divider is set to 8. That gives an internal reference frequency of 0.125 MHz. The advantage of this is the lock-up points now occur at more convenient frequencies in the 2.5-GHz region. The existing scheme divides the 10-MHz reference oscillator by 8 to yield 1.25-MHz reference steps, yet the lock-up frequencies are less useful. By dividing the reference oscillator by 10 using a 7490 decade counter, and giving the chip 1 MHz instead of 10 MHz, the 0.125-MHz reference step is achieved without changing to a different external TCXO. You have to by-pass the on-board reference frequency filter to introduce the 1-MHz signal from the decade divider. The great thing about this is that the LO or marker generator can be run from an inexpensive 10-MHz TXCO for better stability than open-air or heated-crystal oscillators.

For 2592 MHz the *N* counter has to be set to 80, and the *A* counter has to be set to 16. I dremel-tooled the board to isolate all the *A* and *N* counter pins on the MC145152 (see photo A for the bottom of the PC board). This was more work than needed, but it allowed me to play with programming different frequencies. I put a 1/4-inch lead of #22 wire on the DRO to add some parasitic inductance to achieve lock. Note that there is a "slice-to-tune" element on the existing PC board that can be played with to yield a more convenient open-loop oscillation frequency. Output is about +10 dBm. I did not bring in the loop filter to limit the phase noise, as I was looking for an ultimate accuracy signal source, more so than an LO. If it were used as an LO, you would want to add capacitance to the loop filter to reduce receive reciprocal mixing noise from nearby stations due to oscillator phase noise. The existing amount of capacitance will have to be increased by a factor of about 10.

I added the lock indicator to help diagnose lock conditions. I think this really is a big help, and it is right there and easy to do. It just takes an LED hanging off one of the pins on the white pin header. Note that it is dark when open loop, dim when unlocked, and bright when locked. This is an inexpensive, useful feedback. The modified synthesizer will hit all common LO frequencies for amateur bands, as well as the in-band signal. For example, it can be made to hit 10224/4 as well as 10368/4. It also will hit the band and LO frequency squarely at 24192. It will hit an 18th sub-multiple of 47088 MHz, as well as the

Photo C. The modified synthesizer operating at 2688 MHz on John, WB2BYP's workbench with a spreadsheet in the background for programming the synthesizer.

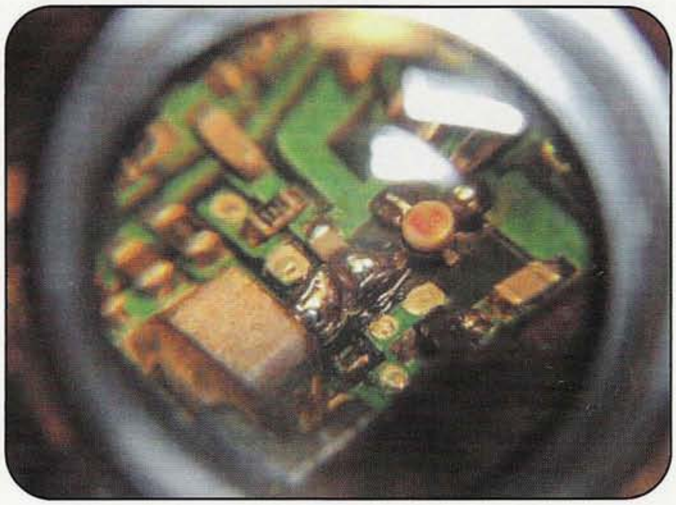


Photo D. Modification of DRO synthesizer by adding a drop of solder to the DRO ceramic element to change resonance to a frequency other than the stock 2620 MHz.

frequency 144 MHz below that. If you are using a DB6NT mixer that runs LO at half or quarter frequency, you can find these frequencies, too.

Note that the frequency to hit the 18th sub-multiple of 47088 is easily within the range of the unmodified DRO. Keeping the DRO is advantageous, as it is fairly high Q. To hit the other frequencies you will have to substitute an L/C combination with a tiny Johanson trimmer or equivalent and resonate close to the intended frequency. I know this works between 2 and 2.5 GHz, although I have not pushed it up to 3 GHz yet. More to follow.

What is needed to simplify the process is a simple map that says, "Ground these pins to get these frequencies." (The program.pdf document is provided with the synthesizer.) It's from

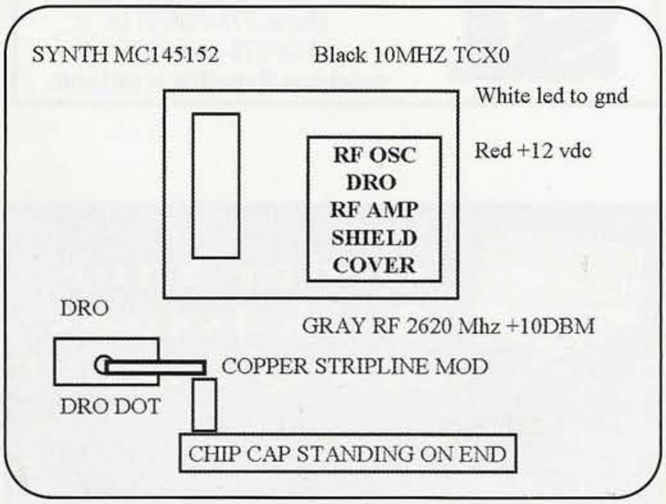


Figure 1. Connections for the test on 2620 MHz to verify the synthesizer works as a stock programmed unit. Also shown are details of the copper stripline added between the DRO center dot and the transistor to obtain a free-running frequency slightly above the desired frequency before programming the synthesizer.

an Excel sheet that John developed to calculate the combinations of programming the pin-for-pin synthesizer chip vs. frequency obtained. The synthesizer board is on the right, the 7490 is pasted onto the perf board, and the TCXO is on the lower left (see photo B for details of the top of the modified synthesizer with added transistor amp and TCXO 10-MHz oscillator). There is a 2N5179 buffer amp to build up voltage to the TTL IC. It would be better if there were a CMOS IC as the decade counter. The TTL 7490 was what I had at first. This is running off the GPS-disciplined oscillator in the photo. The ultimate accuracy at a reasonable cost can be had by using a GPS-disciplined 10-MHz oscillator for one part in 10 to the minus 12 accuracy. Translated to 10368 MHz, the accuracy is pretty darn good in comparison to homebrew, DEM, or DB6NT LOs. The stability is as good as you feed it.

Modification for 2688 MHz

Here is the second unit, modified for 2688 MHz. This frequency is 24192/9 and is useful as a signal source. This is done by setting N to 83 and A to 16, and driving the reference divider with 1 MHz. In this case I am sourcing the 1 MHz from the other synthesizer, running from the 10-MHz TCXO/decade divider. See photo C for this modified synthesizer on my workbench.

This is the modification to the DRO in order to get it to go significantly higher in frequency (see photo D). The DRO is the big block at about 8 o'clock in this crude view through an eye loupe. The VCO transistor is the device about in the center. This mod was accomplished by lifting the coupling chip capacitor into the air and putting a solder bead over the pad with the transistor. I removed the pad below the DRO connection and put a large bead on the DRO center pad. The chip capacitor now bridges the two low-inductance solder beads. With this technique I was able to get the free-run frequency up to 2718 MHz. This made the oscillator easy to pull in to 2688 with tuning voltage.

It is good to know that the DRO can be pushed this far in frequency, because there are a lot of useful frequencies if the oscillator can be made to lock above the design center of 2620 MHz. A signal source at 47088/27 = 2616 MHz is possible without mods to the DRO, and if the DRO can be pushed to 2816, a signal source for 76032 can be made. Lots of LO possibilities exist. However, for the most part they will require some creative mods to the DRO or the removal of the DRO, replacing it with a Johanson trimmer of small pF value and a strip of tweaked-to-frequency copper or a coil for lower frequencies. The oscillator should be made to free run about 20 MHz above the operating frequency to have a suitable lock voltage. The DRO is easy to remove by disconnecting the solder connection and heating up the body. This modification procedure by John, WB2BYP, can be found on the web at <http://www.storyavenue.com/qualcomm.htm> with John's conversion data and more details of the Qualcomm DRO synthesizer.

Applications

While the DRO synthesizer does have limitations, John has greatly improved the adaptability in his conversion by changing to a more useful reference frequency. I have done lots of different applications sticking with the 1.25-MHz reference frequency and its limited operation. For instance, we were able to use this synthesizer on our 47-GHz transceiver. We cut one pin open (TTL high) and grounded two other pins (TTL low) on the synthesizer chip, allowing operation on 2640 MHz. The idea was to use a Verticom very-high-quality BCD (binary coded decimal) controlled agile synthesizer operating at 10.44250 MHz. This LO drove a PECOM TX Module (multiply by 2 = 20.885 GHz + the LO drive to the IF port at 2.640 GHz for a output at 23.525 GHz). Doubling in frequency in our final harmonic mixer produced 47.05 GHz. Using an IF of 145 MHz produced 47.195 GHz. While the rig is not a barnburner, it has shown to be a reliable and simple rig to put together. Of course, the use of the MTS2000 Verticom synthesizer, the step frequency of which is 1 kHz from 8.7 GHz to 10.7 GHz, was a key element in making the system's main local oscillator easy to use.

The system's IF drive LO: The DRO synthesizer also proved quite versatile in its easy conversion to 2640 MHz because the stock synthesizer frequency steps are at 20 MHz, making its use in this application a no-brainer. I thought I would try to get the DRO oscillator to free run (no lock) somewhere in the 2592 frequency band. Remember, this is 2592 times 4, which equals 10368 MHz, a great test shot to demonstrate what I had to do to get there at this frequency of 2592 MHz.

First I removed the chip capacitor from the DRO center dot and the transistor on the PC board. Then, using a solder sucker, I removed the excessive solder from the DRO center connection to the PC board trace to leave the DRO center dot floating (isolated). I re-attached the chip capacitor standing up on the transistor side of the now open PC board trace and soldered it to this PC board trace. I fabricated a small section of copper tape that was a few thousands of an inch thick and soldered one end of it to the DRO center dot. I soldered the other end to the chip capacitor (top) while it was standing on end, thus inserting a new inductance coupled by the series chip capacitor between the transistor and the DRO center dot. As I write this, a half-hour has gone by and the frequency of the free-running oscillator is still 2593.73 MHz as read on my frequency counter. Not bad for free running!

The first frequency I came up with was 2400 MHz, while the oscillator was free running. That meant my copper inductance was too large. Changing the copper inductor (a short piece of copper tape about 3/16 by 1/4 inch was use for first trial) by removing some length and width a bit at a time brought the free-running oscillator up to 2593.73 MHz. During the process of soldering and unsoldering, the chip capacitor got lost when it went flying from the tool that held it. I replaced it with a 1.1-pF chip capacitor (not a surface-mount standard type, but a microwave type from ATC [American technical Ceramics], .050-size 1.1-pF chip capacitor to reach the 2592-MHz range). I found I could go down to approximately 2100 MHz by replacing the 1-pF chip capacitor with one in the 5-pF range.

The bottom line is first adjust the chip capacitor or change the dimensions of the copper stripline inductance to achieve a frequency close to the one in which you are interested. Then set the synthesizer chip pin for pin programming to achieve synthesizer lock. For an LED indicator, tie the white wire to one side of the LED and ground the other. If you want to go up in frequency, take some copper off the copper bit; to go down in frequency, add a small bit of copper to the stripline trace, making line dimensions larger.

Check out the synthesizer first by connecting a crystal 10-MHz source to the black-shielded lead, +12 volts to the red lead, and the LED to the white lead. The synthesizer should fire up and lock on 2620 MHz. If the LED is not on, reverse the connections to the LED—no lock LED off; lock okay LED bright (see figure 1). For connection power lock and RF input output wiring.

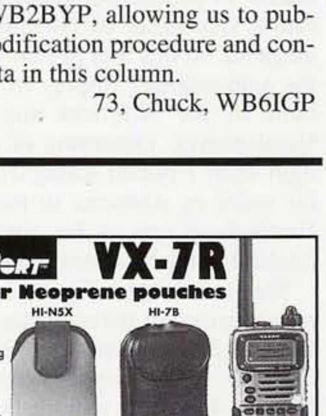
The configure the 7490 for dividing by 10, the pinout configuration is: 10-MHz input pin is 1; tie pin 11 to pin 14; ground pins 2, 3, 6, 7, 10; positive VDC on pin 5; and 1 MHz output on pin 12.

Summary

The synthesizers are available from me, WB6IGP. Two DRO synthesizers are $22 postpaid, U.S. dollars. The synthesizer requires a 10-MHz crystal source, which is not supplied in this package. Normally, a 10-MHz TCXO is used for this function. I provide some schematic detail and a copy of the programming spreadsheet that John developed, plus some other conversion details that were too numerous to include in this column. I will be happy to answer questions related to the synthesizer or other microwave-related queries. Please e-mail me at clhough@pacbell.net for a quick response.

In closing, I would like to thank John Stevens, WB2BYP, allowing us to publish his modification procedure and conversion data in this column.

73, Chuck, WB6IGP



By Tomas Hood,* NW7US/AAA0WA

PROPAGATION

The Science of Predicting VHF-and-Above Radio Conditions

More on Sporadic-*E*

During the beginning of November 2004, a series of solar-flare eruptions occurred originating from a large and moderately complex sunspot group, NOAA Region 696. Solar-flare activity starting with the November 5th long-duration M-class flare resulted in a series of Earth-directed coronal mass ejections (CMEs) that impacted Earth's geomagnetic field with severe (G4) geomagnetic storms. On November 7th a large flare eruption on the Sun triggered a moderate to strong solar-radiation storm. The CME activity produced periods of strong geomagnetic storms starting on November 7th, but peaking on November 8th and 10th.

Solar-radiation storms cause an increase in proton bombardment of the Earth. One result of November's geomagnetic storms and proton events was the extraordinary display of the aurora both in the Northern and Southern Hemispheres. Observers of the visual light show reported seeing the aurora as far south as Alabama in the Northern Hemisphere and as far north as New Zealand in the Southern Hemisphere.

The plots shown in figures 1 and 2 show a comparison of normal solar activity in October 2004 versus the activity during the geomagnetic storm during November. The difference is dramatic. In particular, note the large increase in highest-level (green) proton flux on November 10th. The increase in these particles rarely rises above the 0.1 (first) level on this plot.

Solar Region 696 continued to produce flares, as high as an X2.5-class flare on November 10th. These were accompanied by CMEs that continued to provide fuel for aurora and even sporadic-*E* (*Es*). A surprise, since *Es* is not typical during November, it was speculated that the ionosphere was loaded with electrons, causing a sudden and extremely rare November 144 *Es* opening. European VHF operators reported that while

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

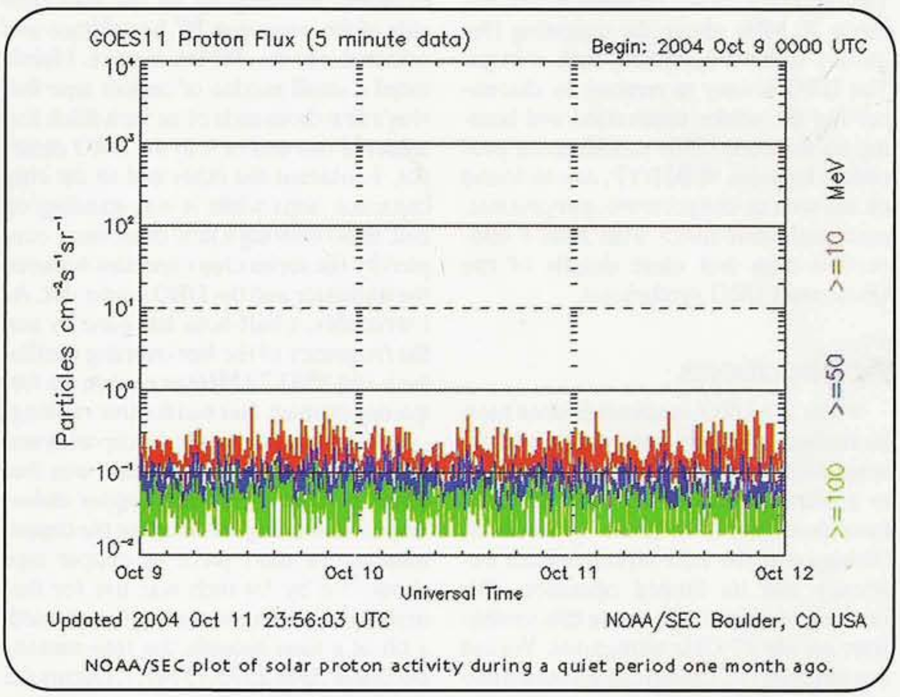


Figure 1. Normal solar activity during October 2004.

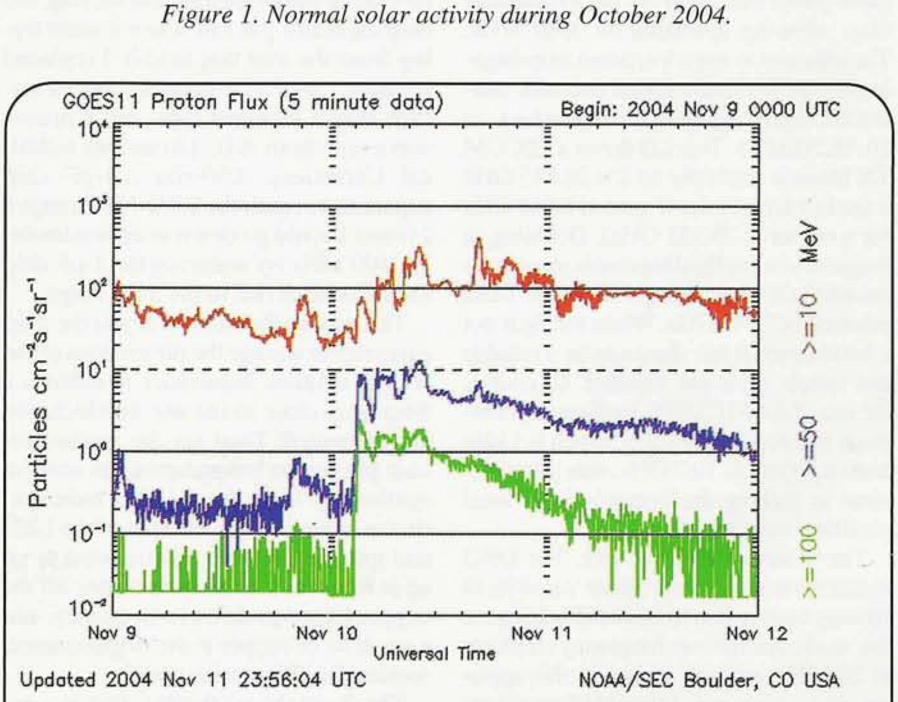


Figure 2. Activity during the geomagnetic storm of November 2004.

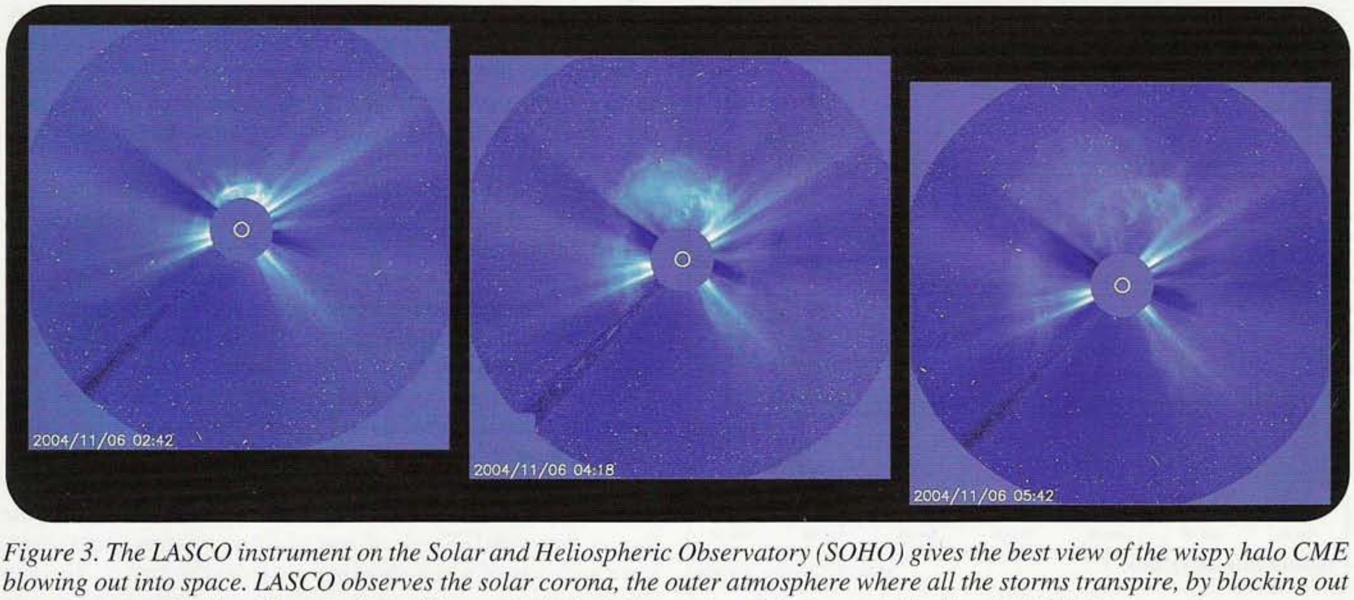


Figure 3. The LASCO instrument on the Solar and Heliospheric Observatory (SOHO) gives the best view of the wispy halo CME blowing out into space. LASCO observes the solar corona, the outer atmosphere where all the storms transpire, by blocking out the Sun like an eclipse. The small circle in the center of the image is the Sun. (NASA/ESA image)

there was still aurora in the north, clear, unmistakable *Es* conditions occurred in southern Europe.

Figure 3 shows the "halo" coronal mass ejection of November 6th. A *halo* CME is so named when a CME is directed toward or away from the Earth and is seen as an expanding circle of particles all around the Sun. When we see a halo CME heading toward Earth, we can expect a sure disturbance of the geomagnetic field around the Earth.

Research scientists have discovered that during the course of the 11-year solar cycle, the Sun actually reverses its magnetic poles. This flipping happens each cycle, with the north and south poles of the Sun violently switching places near the solar-cycle maximum. The next reversal is expected to occur possibly in 2012.

By studying the vast amount of raw data gathered by Solar and Heliospheric Observatory (SOHO) spacecraft, scientists have discovered the process by which this reversal may be accomplished. The data has revealed that CMEs play a major role in the Sun's magnetic-pole swapping. This flipping is the cumulative effect of more than a thousand of these huge eruptions which blast billions of tons of electrified gas into space. These CMEs carry the Sun's old magnetic field away, allowing a new one with a flipped orientation to form.

It has been determined that it takes more than a thousand CMEs, each carrying billions of tons of plasma from the Sun's polar regions, to clear away the old magnetism. Finally, when all of the old magnetism is thrown away, the Sun's magnetic-field lines run in the opposite direction.

This is the source of the recent occurrences of intense geomagnetic storms, such as the one in July 2004. These flare-ups come out of some very quiet periods, but they are normal. This is a sign that the Sun is continuing to get rid of the current complex magnetic structures as it starts to form new ones with the reversed orientation.

Since the Sun's magnetic field permeates the entire solar system, and beyond (in a region called the *heliosphere*), it interacts with the Earth and the Earth's magnetic field (a field known as the *magnetosphere*). The Sun's huge magnetic field is called the *interplanetary magnetic field* (*IMF*) and is a primary cause of space weather. Sprawling out away from the Sun is a solar wind that rides the IMF.

As Earth orbits the Sun, it dips in and out of the wavy current sheet of the IMF. On one side, the Sun's magnetic field points north, or toward the Sun. On the other side, it points south, or away from the Sun. The IMF's orientation is indicated by the B_z index. When the B_z is negative, it indicates a southerly-orientated IMF; when positive, it indicates a northerly-oriented IMF.

South-pointing solar magnetic fields tend to "magnetically reconnect" with Earth's own magnetic field. This allows the solar wind, and the plasma, to flow in and collect in a reservoir known as the *boundary layer.* The energetic particles riding the solar wind can then penetrate the atmosphere, causing aurora and triggering geomagnetic storms.

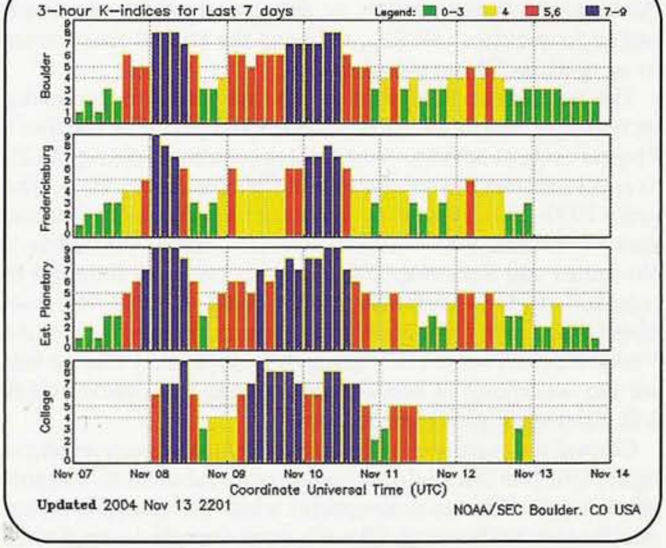


Figure 4. The Kp *levels during the storm of November 7–10, 2004. The geomagnetic activity reached extreme storm levels of 9. (NOAA image)*

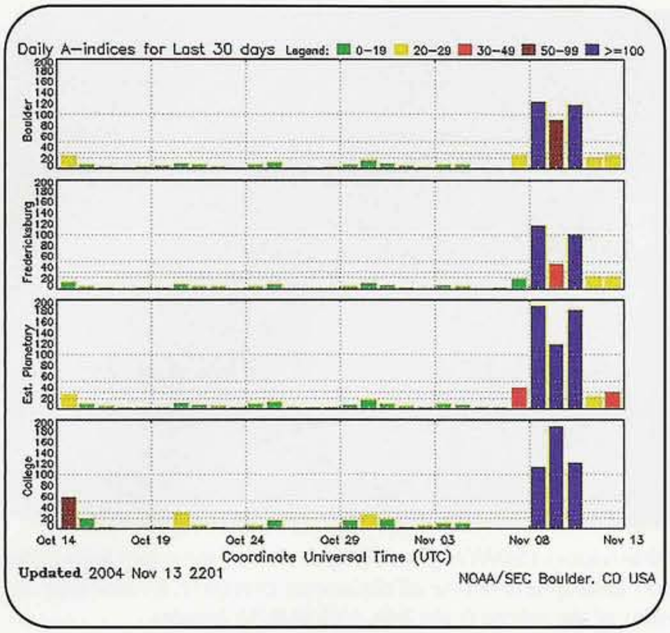


Figure 5. The Ap *levels during the storm of November 7–10, 2004. The planetary* A *index reached as high as 189, indicating a pretty strong geomagnetic storm level. The geomagnetic storm lasted for several days and virtually wiped out communications on MW and HF frequencies. (NOAA image)*

If the IMF is oriented northward, however, this magnetic reconnection does not take place. This should create a barrier against the solar wind and the plasma riding the IMF.

When the IMF connects with the magnetic field around the Earth, and as solar-wind plasma flows into the atmosphere, the geomagnetic field lines become highly active. This is known as a *geomagnetic storm.*

Geomagnetic storms cause a degradation of radio-signal propagation as a result of ionospheric recombination. This recombination is similar to what takes place during the hours of darkness, with a lowering of the frequencies each ionospheric layer can refract. Geomagnetic storms can cause long-term (hours to days) degradation, or depression, of the maximum usable frequencies (MUFs), reducing the critical frequencies by as much as 50 percent of normal.

The occurrence of CMEs of this magnitude is becoming increasingly rare as we enter into the quiet period of the Sun's 11-year cycle of activity. We expect the current cycle, Cycle 23, to end sometime toward the end of 2006 or during 2007. The years 2000–2001 marked the highest point of activity, but that doesn't preclude the occasional surprise, such as the CMEs of November and December 2004. I expect only rare flare-ups of solar activity during February, March, and April 2005, with possible CME activity that could trigger aurora, especially near the Vernal Equinox season this spring. It is more likely that we will see the occurrence of *coronal holes* during this period, which will also trigger geomagnetic storms.

Coronal holes are regions in the Sun's corona (an atmospheric layer of the Sun that could be thought of as one of Earth's atmospheric layers, like the stratosphere) where the corona is darker than the surrounding area. These features were discovered when X-ray telescopes were first flown above the Earth's atmosphere to reveal the structure of the corona across the solar disc. Coronal holes are associated with "open" magnetic field lines and are often found at the Sun's poles. A coronal hole simply means an area where a breakdown in the magnetic fields in the solar corona has occurred. Often, high-speed solar wind is known to originate in coronal holes. This escape of solar plasma and energy streams outward away from the Sun into the solar wind.

March 20, 2004 marks the day when the hours of daylight and darkness are about equal around the world. This is known as the Vernal Equinox. It is well documented that this is one of the two optimal times of the year for aurora. Geomagnetic storms that ignite auroras occur more often during the months around the equinoxes during early autumn and spring. This seasonal effect has been observed for more than 100 years.

As the Sun rotates (one full rotation occurs about every 27 days), the plasma spewing out from the Sun forms into a spiral shape known as the *Parker Spiral* (named after the scientist who first described it). This solar wind carries with it an interplanetary magnetic field, which ever expands away from the Sun in this spiral. Think of one of those rotating lawn sprinklers with jets of water shooting out from the center. You can see a bending or curving of the water lines. As the Earth moves around the Sun, these spiraling solar winds sweep into Earth's magnetosphere. How the magnetic field lines (IMF) in the solar wind interact with the magnetic field lines of the magnetosphere is the key to geomagnetic storms and aurora.

At the magnetopause, the part of our planet's magnetosphere that fends off the solar wind, Earth's magnetic field points north. If the IMF tilts south (we see this when the index known as the *B sub-Z* [B_z] becomes negative), it can partially cancel Earth's magnetic field at the point of contact. This causes the two magnetic fields (the Earth's and the IMF) to link (think of how two magnets link with one magnet's south pole connecting with the other's north pole), creating a magnetic field line from Earth directly into the solar wind. A south-pointing IMF (a negative B_z index) opens a window through which plasma from the solar

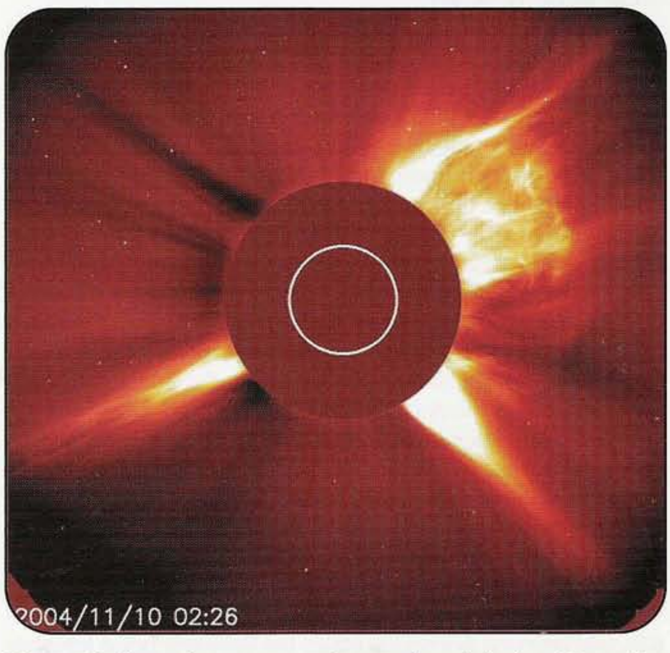


Figure 6. The solar-storm action continued during November 9th and 10th due to the solar activity seen in these LASCO C2 images. (NASA/SOHO image)

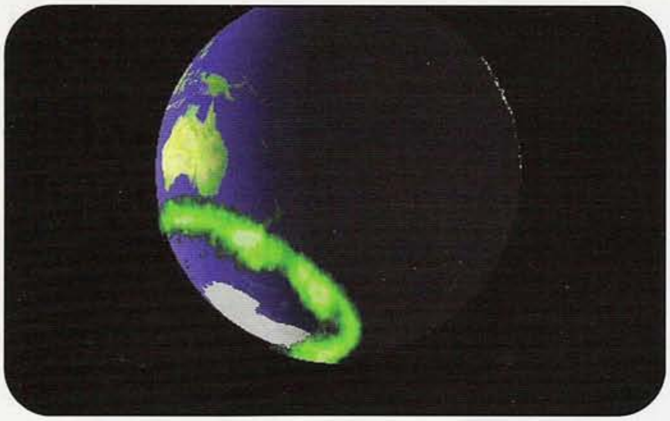


Figure 7. The Polar spacecraft saw the aurora australis (southern lights) expanding and brightening on November 8th. The Earth seems to move from top to bottom due to Polar's orbit. (NASA/The University of Iowa image)

wind and CME can reach Earth's inner magnetosphere, bombarding the gasses of the upper atmosphere.

Earth's magnetic dipole axis is most closely aligned with the Parker Spiral in April and October. As a result, southward (and northward) excursions of B_z are greatest then. This is why aurora is most likely and strongest during the equinoctial months. When you see the solar-wind speed increase to over 500 kilometers per second, and the B_z remain mostly negative (the IMF is oriented mostly southward), expect an increase in geomagnetic activity, as revealed by the planetary *K* index (*Kp*).

Look for aurora-mode propagation when the *Kp* rises above 4, and look for visual aurora after dark when the *Kp* rises above 5. The higher the *Kp,* the more likely you will see the visual lights. However, you don't have to see them to hear their influence on propagation. Signals propagating off the *E*-layer clouds formed during aurora sound raspy or fluttery. When aurora occurs, start looking for VHF DX.

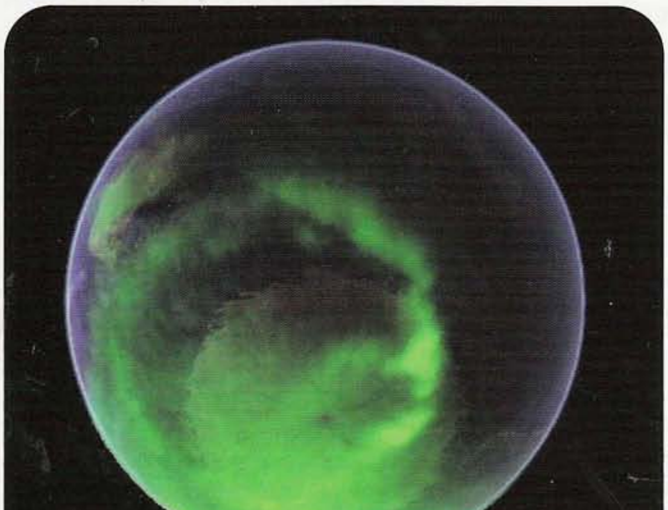


Figure 8. Flying over the South Pole, the IMAGE spacecraft caught this view. (NASA/UC Berkeley image)

Sometimes aurora will enhance a signal's path at very narrow bands of frequencies, while at other times it will degrade the signals. Sometimes signals will fade quickly, then come back with great strength. The reason for this is that the radio signal is being refracted off the more highly ionized areas that are lit up. These ionized areas ebb and flow, so the ability to refract is always changing, and sometimes quickly. I've observed the effect of aurora and associated geomagnetic storminess even on lower HF frequencies.

Radio Aurora

If there are enough solar particles flowing down the Earth's magnetic-field lines and colliding with atmospheric atoms and molecules, ionization occurs. This ionization may be sufficient to reflect VHF and lower UHF radio waves, generally between 25 and 500 MHz. This usually occurs in conjunction with visual aurora, but the mechanism is a bit different and it is possible to have one (visual or radio) without the other.

Using radio aurora, the chances of contacting stations over greater distances than would ordinarily be possible on the VHF frequencies is increased. Like its visual counterpart, radio aurora is very unpredictable. The thrill of the chase draws many VHF weak-signal DXers to work auroral DX.

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 amateur radio operators 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. Your magnetic latitude can be found using the map at <http://www.sec.noaa.gov/Aurora/globeNW.html>.

Is Trans-Atlantic Multi-hop Sporadic-*E* possible?

There are a number of VHF DXers who long to see the first transatlantic terrestrial above 6-meter VHF communication between Europe and North America. This accomplishment has eluded the best of operators. Will it ever be possible to span the Atlantic on 144 MHz or above? What mode is the most likely vehicle for this? Some feel that multi-hop sporadic-*E* is the only way.

The months of February through April typically are months of very low sporadic-*E* activity, although it is possible to see dense *E*-layer ionized clouds form during very strong geomagnetic storms that trigger aurora. Is it possible during one of this year's spring aurora events that a multi-hop transatlantic QSO can be made?

One of the hindrances to finding out is not having enough operators dedicated to observing daily conditions. It has not

Figure 9. An ultraviolet view of the aurora is superimposed on a city-lights image from a weather satellite. The TIMED spacecraft made three passes over the U.S., but after the peak of the storm. (NASA/APL/Meteorological Satellite Applications Branch, Air Force Weather Agency image)

been convenient for most radio amateurs to conduct around-the-clock propagation checks across the ocean. For more information on 144-MHz transatlantic propagation, go to: <http://www. df5ai.net>.

One of the ways to overcome the need for manning the VHF bands around the clock in order to catch that first transatlantic opening is to use beacons. However, that could present a problem as well, since traditionally, you would have to be tuning in to the beacon frequencies at all times of the day—manually.

PropNET on VHF

An automated, well-organized beacon effort is being developed on VHF. Much like BeaconNET, which uses additional HF bands, PropNET (http://propnet.org/) gathers beacon data using computers. It helps not only in discovery of openings, but also in discovering details about propagation modes. PropNET is designed to answer the question "If the band is open and no one is transmitting, does anybody hear it?"

PropNET is an ionospheric and propagation probe that runs in the background on a computer and uses an idle radio. Using this powerful tool, a network of strategically-placed stations with optimized equipment can uncover the much sought after transatlantic terrestrial opening on amateur frequencies above 6 meters.

On VHF, PropNET uses APRS technology via either PSK-31, known as PropNET^31, or AX.25 (packet), known as PropNET.25.

PropNET.25 is no simple propagation beacon system. It is a full-function transmit and receive network that not only uses the concept of "digipeating" to extend one's vision of propagation conditions, but is also capable of keyboard-to-keyboard messaging once a path is established.

The concept is simple. Participants embed their 6-cypher grid locator in each transmission. When another PropNET participant decodes that transmission, a symbol is placed on the receiver's computer screen. This symbol corresponds to the transmitting station's exact location on a map. If the band is "open," a symbol appears. If it is not, then no symbol appears. This is much like APRS, but for propagation openings.

PropNET^31 does things much the same way, but does not allow for digipeating. To join in, you need a standard PSK-31 soundcard audio connection between your computer and transceiver (visit <http://www.packetradio.com> for plans), special PSK-31 "modemware," and then the software that controls it all (go to <http://propnet.org/> for software options).

The PropNET work is particularly significant because it is the first generation of propagation beacons for amateur radio's digital millennium. No other system comes close to what PropNET can do. Folks just need to start to think differently about propagation research.

If you are a VHF/UHF and above contester, or maybe going for some distance record, you certainly would want to know what types of propagation could be exploited, especially something no one has ever tried to use. There might not be any other group better equipped to find the answers than PropNET.

To learn more about PropNET, and to download the software and installation and configuration instructions, visit <http://hfradio.org/propnet-info.html>. The official PropNET site is <http://propnet.org/>.

Tropospheric Ducting

Tropospheric ducting activity "down under" was active during October 2004, when a massive tropospheric duct opened VHF propagation between Indonesia and southwestern Western Australia. VK6ZKO, VK6IQ, and VK6HK via the Cataby Repeater <VK6RCT> north of Perth received 144-MHz FM simplex signals in Perth. This propagation repeated in the evening of the same day up to about 2000 WAST. However, no contacts were made and no specific stations were identified due to language problems and the nature of the traffic heard. During the same period, TV SWL specialist Tony Mann identified numbers of Indonesian UHF TV transmitters with both vision and sound received, and also FM transmissions.

During the period between February and April 2005, tropospheric ducting is not expected except rarely in the Northern Hemisphere. This mode is most prevalent during the late summer season.

Meteor Shower Reports

The 2004 *Leonids* shower was dismal according to all of the reports I've seen. One report is from Marianne Gualtieri at <http://members.bellatlantic.net/~vze2n9fe/meteor/leo2004.htm>. It shows a Radio Observation peak rate of 23 meteors per hour.

However, the 2004 *Geminids* shower was much more active. The peak time of the shower is reported to be near December 13 at 2000 UTC, with a rate as high as 160 per hour. Clearly this was the best shower of 2004. Marianne shows Radio Observation peaking at 49 meteors per hour <http://members.bellatlantic.net/~vze2n9fe/meteor/gem2004.htm>. Did you work these showers?

There is only one minor opportunity to try your skill and employ your equipment in meteor-scatter propagation. This will be the *a-Centaurids* meteor shower from January 28 to February 21, 2005, peaking on February 7th at 2245 UTC (sol = 319.319°) with a typical visual rate of about six meteors per hour. However, there is a chance for this shower to intensify with up to 25 or more meteors per hour.

The Solar Cycle Pulse

The observed sunspot numbers from September through November 2004 are 27.7, 48.4, and 43.7. The smoothed sunspot counts for March through May 2004 are 47.2, 45.6, and 43.9, all showing the steady decline of Cycle 23.

The monthly 10.7-cm (preliminary) numbers from September through November 2004 are 103.1, 105.7, and 113.2. The smoothed 10.7-cm radio flux for March through May 2004 is 114.6, 112.3, and 109.2.

The smoothed monthly sunspot numbers forecast for February through April 2005 are 24.2, 22.4, and 20.2, while the smoothed monthly 10.7-cm radio flux is predicted to be 86.0, 83.3, and 80.7 for the same period, give or take about 15 points for all predictions.

The smoothed planetary *A* indices (*Ap*) from March through May 2004 are 16.9, 15.5, and 14.3. The monthly readings from September through November 2004 are 10, 9, and 26.

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

Feedback, Comments, Observations Solicited!

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

Until the next issue, happy weak-signal DXing.

73, Tomas, NW7US

By Keith Pugh,* W5IU

SATELLITES

Artificially Propagating Signals Through Space

AMSAT Annual Meeting & Space Symposium, ARISS Meeting, and a Cheap Az-El Antenna Positioner

For a satellite operator, October is one of the busiest months of the year. In 2004 the activity started on 6 October when I left for Arlington, Virginia to attend the AMSAT and ARISS (Amateur Radio on the International Space Station) meetings. I returned home on 14 October and immediately left for Microwave Update 2004 on 15 and 16 October. On 23 October I "showcased" satellites at a new ARRL Mentorfest in Irving, Texas. On 29 and 30 October I conducted a satellite forum, performed satellite demos, and ran an AMSAT booth at the Texoma Hamarama at Lake Texoma, Oklahoma. Things then slacked off, with only a trip to Corpus Christi, Texas for another round of forums, demos, and booth activities at the Costal Bend Hamfest on 13 November.

This column will feature the AMSAT and ARISS meetings and construction of a cheap Az-El Antenna Positioner. Numerous inquiries have been answered regarding the Az-El Positioner since its introduction at hamfest satellite demos during the AO-40 heyday. It was pictured in my last column in the Fall 2004 issue of *CQ VHF* and again received attention, so a long-delayed description is presented here.

AMSAT Annual Meeting and Space Symposium

BoD Meeting: Activity at the Crowne Plaza Hotel in Crystal City, Virginia started with the AMSAT board meeting on 7 and 8 October. The newly elected and returning board members were introduced by retiring President Robin Haighton, VE3FRH (photo 1). After a review of the agenda, the first order of business was election of officers for 2004–2005. After nomination by Robin Haighton, Rick Hambly, W2GPS, was elected to the office of president. From that point on, Rick presided over the meeting. Rick presented his nominations and his logic for revision of the slate of offices. After some discussion, the remaining offices were filled, and the new slate of officers is shown in photo 2, with the exceptions of Manager Martha Saragovitz and Vice President of Engineering Stan Wood, WA4NFY.

Robin Haighton and Gunther Meisse, W8GSM, set the stage for the remainder of the meeting with president and trea-

Photo 1. The AMSAT Board of Directors (left to right): Gunther Meisse, W8GSM; Paul Shuch, N6TX; Lou McFadin, W5DID; Barry Baines, WD4ASW; Dr. Thomas A. Clark, W3IWI; Robin Haighton, VE3FRH; and Richard Hambly, W2GPS.

Photo 2. AMSAT officers (left to right): Secretary Steve Diggs, W4EPI; Treasurer Gunther Meisse, W8GSM; Executive Vice President Lee McLamb, KU4OS; Vice President Operations Mike Kingery, KE4AZN; President Richard Hambly, W2GPS; Vice President of Human Spaceflight Frank Bauer, KA3HDO; and Vice President of Marketing and User Services Barry Baines, WD4ASW.

*3525 Winifred Drive, Fort Worth, TX 76133
e-mail: <w5iu@swbell.net>

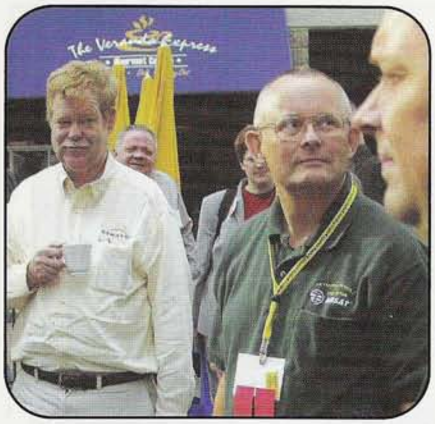


Photo 3. Host of 2005 AMSAT Space Symposium Nick Pugh, K5QXJ (left), with Barry Baines, WD4ASW.

surer reports for 2004 and a proposed budget for 2005. Meisse presented a North American Fund Raising Feasibility Study followed by the results of a membership survey conducted in 2004. These two items were then discussed by all and became part of the strategy for the future as outlined by Hambly.

Key to this strategy is the AMSAT vision statement: "Our vision is to deploy high earth orbit satellite systems that offer daily coverage by 2009 and continuous coverage by 2012…" This vision requires two high-earth-orbit (HEO) satellites by 2009 and three by 2012. The first of these satellites will be the Phase 3E project from AMSAT-DL, and the other two will be Project Eagle satellites from AMSAT-NA. Again, international cooperation will be required to bring this vision to fruition. Hopefully, the schedule presented in the vision statement can be improved upon.

Reports from all of the standing committees and functions then were presented and discussed. Special emphasis was placed on the ECHO Launch Report by Chuck Green, NØADI, and the Project Eagle Status and Budget by Jim Sanford, WB4GCS, Project Eagle Manager, and Rick Hambly, W2GPS. The Education Report by Lee McLamb, KU4OS, received much attention, since it too is an important part of AMSAT's vision for the future.

The meeting was wrapped up with selection of 2005's meeting location and the usual "ata-boys" and "ata-girls." The 23rd Space Symposium and AMSAT-NA Annual Meeting will be held in the fall (October or November) of 2005 in Lafayette, Louisiana. Hosts for this symposium will be Nick Pugh, K5QXJ, and others from the Acadiana Amateur Radio Association. Nick and Barry Baines, WD4ASW, are pictured in photo 3 at the symposium during an intermission for an ISS pass. Minutes of the meeting are available in the *AMSAT Journal.*

Space Symposium: The Space Symposium began on Friday afternoon. The activity commenced with a president's welcome and was followed by the presentation of ten papers generally related to the AMSAT Eagle Project and ground-station hardware. Project Eagle topics included Project Eagle Status Report, Eagle's Radiation Environment, a Simulator for the AMSAT Eagle Spacecraft, C-C Rider Revisited, and Software Defined Radios—The Future is Now. Other topics included Starting AMSAT's Lessons Learned Process, Bias Tees for Satellite Receiving Systems, and From Sizzling Hot BBQ to Cool BUD-Lite—

Photo 4. The Space Symposium ARISS panel (left to right): Japan, Keigo Komuro, JA1KAB; USA (ARRL), Rosalie White, K1STO; Canada, Robin Haighton, VE3FRH; Russia, Sergey Samburov, RV3DR; and USA (AMSAT), Frank Bauer, KA3HDO.

A Cheap Az-El Antenna Positioner

Two photos in the last column (Fall 2004 *CQ VHF*) illustrated the Cheap Az-El Positioner. The first showed it being used to support a Kent Britain, WA5VJB, Cheap 70-cm Yagi for AO-51 data gathering. In the second photo it was being used to support two Cheap Yagis for satellite contacts at the North Texas Balloon Project (NTBP) balloon launch last September. These photos prompted several questions, so here is a little more detail on the positioner. The complete positioner without antennas is shown in photo A. It is mounted on a standard RadioShack 3-foot tripod and consists of several parts as follows:

The horizontal boom (overall length 24 inches) is actually made of several parts. There are two pieces of 1-inch PVC glued into a 1-inch PVC T. Inside the boom is a 24-inch length of 1-inch wooden dowel to give added strength (this primarily prevents crushing the PVC pipe when antenna clamps are tightened) and to provide a place to attach the elevation protractor and indicator (fishing leader and weight) with a stud (wood screw on one end and machine screw on the other).

Photo A. The completed Az-El Antenna Positioner assembly mounted on a tripod. The dish mounts on the right and the Yagi on the left. (Note azimuth pointer.)

Photo B. The horizontal boom and positioner arm on the left showing the wooden dowel and elevation indicator assembly, and the elevation bearing assembly on right. (Note hose clamps for friction adjustment.)

A positioning arm is made of 1-inch PVC, just like the horizontal boom. It is glued to the 1-inch PVC T that forms part of the horizontal boom and is closed with a 1-inch PVC cap. Inside the positioning arm is a combination of 1-inch wooden dowel and lead shot to form the appropriate counterweight.

Support for the horizontal boom is provided by an assembly of a 1 1/4-inch PVC T and two pieces of 1 1/4-inch PVC pipe. The two pieces of 1 1/4-inch PVC pipe are glued into the 1 1/4-inch PVC T. One of these pieces is hard to see and is actually only a "bushing" on one end of the 1 1/4-inch T. The longer piece of 1 1/4-inch PVC is "slotted" with a hacksaw so that it, along with a hose clamp, forms the elevation friction adjustment.

The 1-inch PVC assembly passes through the 1 1/4-inch assembly, which becomes the elevation bearing with a friction adjustment as mentioned above. I chose 24 inches as an overall length and originally clamped a 2-foot by 3-foot BBQ grill dish and down converter to the short end of the 1-inch PVC assembly (next to the "bushing" end of the 1 1/4-inch PVC T). The longer end (next to the 1-inch PVC T) was used for the 70-cm Cheap Yagi.

The azimuth assembly consists of a 1-inch PVC pipe clamped into the tripod and 1 1/4-inch PVC slipped over it and glued to the

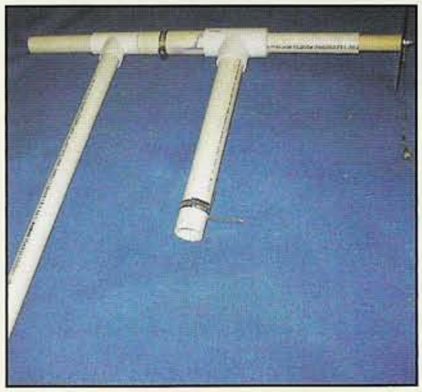


Photo C. Assembly of the horizontal boom and elevation bearing.

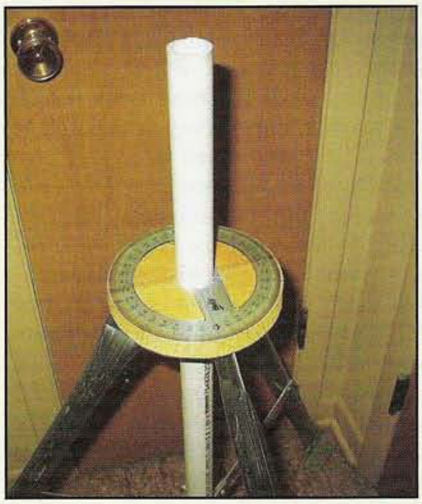


Photo D. RadioShack tripod showing the azimuth bearing post and azimuth indicator.

1 1/4-inch PVC T that also includes the elevation bearing. The azimuth protractor is mounted on a piece of wood and the assembly drilled so that it will slide over the 1-inch PVC pipe attached to the tripod. The 1 1/4-inch azimuth (vertical) pipe is also "slotted" with a hacksaw and equipped with a hose clamp to form an adjustable azimuth friction adjustment. An aluminum pointer is clamped to the vertical piece of 1 1/4-inch PVC by the friction-adjustment hose clamp and extends out to the azimuth protractor.

Taming the Grid Dish for Space Communications. Friday evening activity included an informal dinner, Poster Sessions, and the President's Club Meeting.

Saturday morning began with Chuck Green, NØADI's colorful and informative presentation on the ECHO launch campaign. It started with final preparations in the U.S. and ended with the launch at Baikonur. The presentation was well illustrated with slides and was also an excellent travelogue of Russia and the many unique experiences Chuck encountered. A description of the ECHO commissioning process followed.

Gould Smith, WA4SXM, wrapped up the ECHO papers with a discussion of ECHO as an Educational Tool. Making Sense of Sensors was the topic of a paper by Alan Bloom, N1AL. The last presentation of the morning was the P3E Status Report by Peter Guelzow, DB2OS, President of AMSAT-DL. P3E is being built in a leftover AO-10/AO-13 spaceframe with "off the shelf" hardware. A late 2005/2006 launch is planned to "fill the gap" in HEO satellites left by the early demise of AO-40. As mentioned earlier, it will be the first HEO satellite in the new AMSAT vision.

Photo 5. Left to right: Perry Klein, W3PK; Larry Brown, W7LB; and Howard Long, G3LVB.

Photo 6. Graham Shirville, G3VZV (left), and Drew Glasbrenner, KO4MA.

Photo 7. Bob Bruninga, WB4APR.

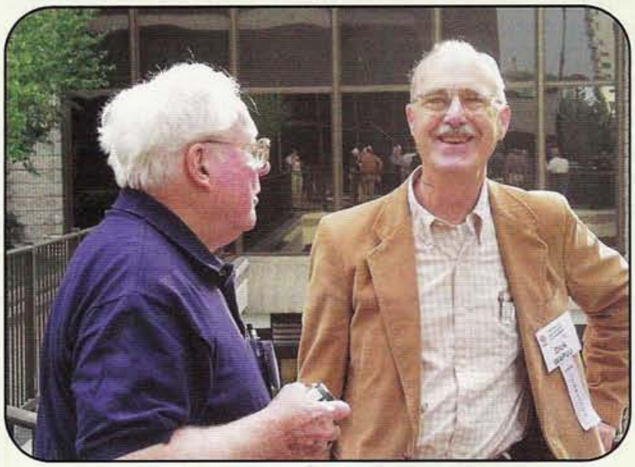


Photo 8. Bill Tynan, W3XO (left), and Dick Daniels, W4PUJ.

Shown above are some of those who attended the Saturday afternoon ARISS panel discussion led by Frank Bauer, KA3HDO, and several of the international delegates.

Saturday afternoon was devoted to ARISS and related topics. It began with a panel discussion led by Frank Bauer, KA3HDO, and several of the international delegates (photos 4 through 8). It was during this time that "SuitSat" was proposed by Sergey Samburov, RV3DR, and the Russian delegate. SuitSat fired the imaginations of many of the members of the audience and also occupied quite a bit of the ARISS meeting following the symposium. Two teachers—Rita L. Wright, KC9CDL, and Carrie Cunningham, N7NFX—presented the fascinating stories of their International Space Station school contacts. These stories were truly inspirational. A discussion of Voice/IP Communications for the ARISS Program followed.

Saturday's symposium session ended with a presentation by Graham Shirville, G3VZV, on the SSETI Express satellite being built by European universities and sponsored by the European Space Agency (ESA). Among other features, this satellite will contain a copy of the 2.4-GHz transmitter that is currently flying on AO-51. AMSAT-UK is leading the amateur radio effort on this satellite, which is now scheduled for a mid-2005 launch.

The AMSAT Annual Meeting and Awards Ceremony completed the afternoon session. Highlights of the board meeting were presented, officers were introduced, and awards (too numerous to mention) were presented to many AMSAT volunteers.

After "Thruster Firings," or "attitude adjustment," an excellent dinner was served, followed by the keynote speaker's program and prize drawings. The keynote speaker was Astronaut Carl Walz, KC5TIE, veteran of several shuttle missions and a tour of duty on the ISS. Carl's commentary and pictures were fantastic!

Sunday morning began with the Field Ops Breakfast led by Barry Baines, WD4ASW. This has become the annual "rallying point" for the AMSAT Area Coordinators from all over the country. Ideas are exchanged, friendships are renewed, and plans are coordinated for the coming year.

The Sunday morning symposium session included reports of current and upcoming university satellite projects. In general, these projects were presented by the students involved and were well received. Several other topics were presented, but the one that caught the imagination of this author was "Why Is

Spaceflight So Difficult? A Look at Kinetic Energy Requirements for Orbital Flight" by Daniel Schultz, N8FGV. As usual, Dan took a somewhat dull topic (in light of the recent "X Prize" awarded to the Rutan Space Plane) and made it entertaining and humorous.

An excellent AMSAT Space Symposium was concluded Sunday afternoon with an organized trip to the new Udvar – Hazy Facility of the Smithsonian Air and Space Museum at Dulles Airport. Anyone with any interest in aviation and space would be impressed with this large facility, which contains examples of aviation and space ranging from the Wright Brothers to the Space Shuttle Enterprise. Although not present at the opening and for our visit, it now contains the test article for OSCAR-1. Other notable examples include the Enola Gay B-29, Concorde, Boeing 707 Number 1, F-35 Prototype, J-3 Piper Cub, and many other military and civilian aircraft.

ARISS International Annual Meeting

The 2004 ARISS International Annual Meeting was held in conjunction with the AMSAT-NA Annual Meeting and Space Symposium. The last time this occurred was several years ago, when the ARISS meeting was held in conjunction with the AMSAT-UK Space Colloquium at the University of Surrey in England.

On Monday morning, 11 October 2004, the meeting was "kicked off" by Frank Bauer, KA3HDO. The first order of business was a report of the election of officers by Robin Haighton, VE3FRH. All of the incumbents were re-elected. International team reports followed: ARISS Europe Report (via teleconference), Gaston Bertels, ON4WF; ARISS Canada Report, Robin Haighton, VE3FRH; ARISS USA Report, Frank Bauer, KA3HDO, and Rosalie White, K1STO; ARISS Russia Report, Sergey Samburov, RV3DR; and ARISS Japan Report, Keigo Komuro, JA1KAB.

Monday afternoon was filled with reports from the following committees: Public Relations, Administrative, Hardware, School Outreach/School Selection, Operations, and Project Selection & Use. Some of this carried over into the Tuesday morning session. Topics ranged from designing ISS QSL cards to VoIP and the popular SuitSat proposal. Coordination of all of this activity on an International basis is challenging and interesting.

Monday evening nearly everyone enjoyed a visit to the International Spy Museum in Washington, DC. Dinner was nearby in China Town at a Mongolian barbecue. A good time was had by all.

Tuesday the committee reports were finished. Financial discussions were led by Robin Haighton, VE3FRH. Frank Bauer, KA3HDO, moderated Moon, Mars, and Beyond, Group Strategy Session. Initial plans for the 2005 meeting were laid, with an offer from AMSAT-UK to host the meeting in conjunction with the AMSAT-UK Space Colloquium. The meeting was adjourned Tuesday afternoon after further discussion and assignment of action items.

Next Issue

The activities reported on in this issue were well worth the time I spent attending them. I hope you have enjoyed the report, particularly those of you were not able to be there. My next column will feature a plan for a ground station that will work all of the modes supported by AO-51. 73, Keith, W5IU

DR. SETI'S STARSHIP *(from page 84)*

esis, which the SETI experiment contemplates, is it didn't have to.

The odds of life evolving elsewhere may be pretty long indeed. The best chance for SETI success may depend on the idea that life did not evolve independently, but was seeded everywhere through the mechanism of *panspermia.* No bioastronomer has yet disputed the possibility that microbial life can successfully traverse the distance between the stars and thrive in a new planetary environment. Thus, life need not generate independently in disparate regions; a universe teeming with life merely requires one genesis event coupled with a transport mechanism. In research, that mechanism tentatively has been demonstrated by Chandra Wickramasinghe and the late Sir Fred Hoyle.

To me, microbial panspermia is a far more compelling explanation than the alien-progenitors-in-spaceships scenario, because it does not require that we warp the laws of nature or contemplate technologies not in evidence. Perhaps we really *are* all brothers beneath the skin.

Were it not for Drake's Equation, today astrobiologists would not even know which of these assumptions to attack. As it stands, Drake has given us a handle on where to start. Meanwhile, there remain those who quibble about quantifying seven factors that Drake intended us merely to contemplate. They help us to establish a low value for at least one Drake Equation factor—the fraction of life forms that manifest intelligence. ■

A bit of thinking about all this led to my reading the article on rain-scatter communications by WA1MBA and asking some questions on the NLRS reflector. The folks in the know indicated that it was very possible that rain had enhanced our paths and that it was something pretty common.

Starting to Get Into the Mindset

In that summer of 2003 we began to give some thought to taking advantage of the rain. When Gene headed out, instead of hoping that the weather was warm and sunny, we hoped that something would be brewing in terms of rain or storms.

Other folks in the NLRS were starting to "tune in" to the mode that summer. On June 10th there were some good storms in EN34, the Minneapolis-St. Paul area. I don't recall exactly how I knew the guys up there were on, but someone let me know or I read it on the NLRS reflector. It was like a 10-GHz DX opening!

I first worked Gary, WØGHZ, in EN34lx with 5×4 signals, and then Bob, WØAUS, in EN35ka, and Bruce, W9FZ, also in EN34. Bruce was on his balcony from his apartment building! All 10-GHz contacts were worked on FM, as the Doppler shift from this particularly intense storm was quite extensive. It was too great, as it really made SSB signals unintelligible. CW would have been just fine, but we just did not need it to make the contacts. The signals were really good with just a bit of noise and flutter on FM.

The typical beam heading to that area is in the 45- to 50-degree range. However, I was pointed at 35 degrees and the direct path was roughly 325 km (200 miles). I then worked Gary, WØGHZ, on 5.7 GHz using SSB. That signal was not as distorted, as the reduction to the lower frequency was not affected as much by the Doppler shift.

Shortly thereafter, on July 15th, Bruce, W9FZ, made a visit to his folks' farm in Wisconsin, EN43tq. The direct-path heading was 80 degrees and about 475 km (295 miles). We were wondering if the standard tropo forward scatter would be good enough to make a contact, but we were again blessed with some thunder clouds and rain in the midpoint of the area. I ended up being pointed in the 95-degree direction, but Bruce was pretty much on direct path. However, direct-path lineup on each end resulted in no signals heard. Signals were again "auroral" in nature and SSB strength was 5×5 on both sides. It was a very easy contact and a new grid on 10 GHz for me!

Making a Point of Using the Rain

Folks were really fired up about the rain-scatter contacts being made in the area. There was lots of talk about how it would be "next year," when we would really make things happen. However, there were still some interesting things in store for 2003.

I had recently finished my 24-GHz dish project, and Gene and I were using the dishes to experiment with DX and learn the propagation as best we could. On the night of August 26th, I noticed a storm cell that was fairly strong to my southeast. A look at the radar showed that Gene was not in the cell and was due south of it in his home QTH in EN22ge. Thus, both of us were outside of the storm and not too worried about getting wet.

I quickly went to look at a road map. Using a protractor to somewhat interpret the county lines from the radar over to the road map gave me a rough idea of where I thought a scattering point might be. The use of the protractor with the map then gave me a beam heading. For Gene the storm was pretty much due north. We both could see the lightning flashes in the distance from our particular viewpoints.

It was nice for me, as I had a pretty decent heading through the southeast part of town, so I just set up the dish on my back patio. Gene had to head out just north of Schleswig, Iowa in order to get away from the local clutter.

We had worked the direct path on 24 GHz many times , as we are only 119 km (74 miles) apart. The heading to Gene typically was 149 degrees, with his heading typically being 329 degrees.

We started out pointed at the presumed scattering point, about 130 to 135 degrees for me, while he was pointed basically north toward the flashes in the distance. We went back and forth for a half hour with nothing heard at all. I also periodically went back to the computer radar map to see if things were moving out of path. Both of us tuned around and made slight variations in the azimuth plane. We then decided to elevate the dishes slightly to see what might happen. Within just a few minutes, I heard Gene's "auroral"-sounding CW beacon. In a burst of excitement, I called Gene on his cell phone so he would not move the dish! He then peaked up on me and we had very good signals on SSB! Over a half-hour's time we experimented with the elevation and azimuth on both sides. We chatted quite a bit and also realized that the Doppler shift did not really make the SSB unintelligible. However, it definitely shifted the frequency, so we had to use the RIT to keep in adjustment. The shift experienced was a solid 1 kHz.

We did not have a good way to measure elevation at the time, as our bubble levels were maxed out, but I would guess the elevation was in the 5- to 10-degree range. We both took side-view pictures of the dishes to note the level of elevation. It was a very neat contact, and doing it at night with the flashes in the distance made it quite exhilarating. My final azimuth heading was about 135 degrees, about 15 degrees off true heading. Gene was still pointed pretty much due north toward the storm. There was quite a scattering angle!

I got around to posting the information on the NLRS reflector. Jon, WØZQ, indi-

Photo D. The 5.7- and 10-GHz dishes at KMØT pointed toward EN34 with a bit of elevation.

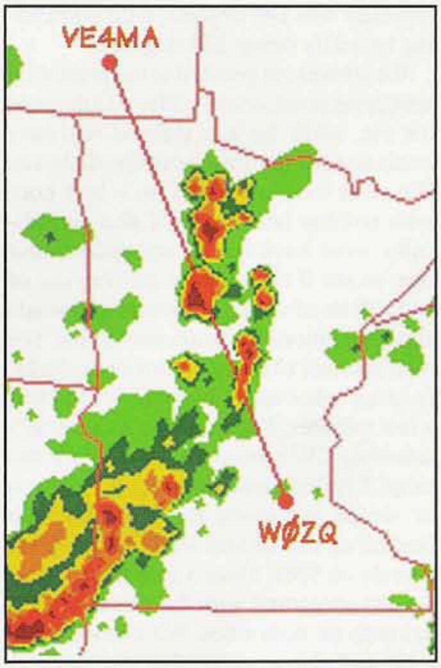


Figure 2. Direct path of WØZQ to VE4MA. Note the strong cell at midpoint.

Figure 3. Unisys radar image of KMØT to KØAWU.

cated that there was no record posted for 24-GHz rain scatter, so I sent that down to Al Ward, W5LUA, and he added it to the list.

Rain Scatter in Contests

Other notable rain-scatter contacts came during the second weekend of the 2003 ARRL 10 GHz Contest. The first day of the contest was pretty dry and propagation was not all that great. However, the next morning some interesting things happened. A small amount of rain was present on that Sunday morning, and the radar indicated that it was between the EN34 twin cities area and down here in northwest Iowa. I managed to catch some fellows on liaison frequencies and started calling up to the EN34 area (photo D).

On direct heading, I managed to work Eric, KT8O, in EN34. Eric was using an old homebrew, very-low-power transverter on 10 GHz with 432-MHz IF and DSS (digital satellite system) dish. Power output was approximately 20 mw. A bit of beaconing on my part enabled Eric to find me, and we worked with fairly comfortable signals on SSB. I was then able to work Chris, NØUK, and Gary, WØLJC, on SSB. Signals were fluttery in quality although stable in strength. The rain was causing just enough forward-scatter enhancement to make these 300-km (180-mile) plus paths. Eric, up on the roof of his apartment building in the middle of the cities, was able to contact me on and off to help get me in touch with the other guys on 10 GHz. Who says a 10-GHz liaison does not work?

I then decided to just call CQ up there, as I knew there might be others on that morning. Sure enough, Gary, WØGHZ, came back and we worked on CW. I kept calling and I heard a blip of something, but it was gone right away. I looked up at the band scope on the 756 Pro-II (which is part of the IF setup) and saw a signal quickly moving down in frequency. I tuned down to where it appeared to stabilize and there was Bob, WØAUS, in EN35! Bob had just heard the news and ran outside to set up his portable dish. He had just turned it on, so he was really drifting! We ended up having a nice chat on 10 GHz from his lakefront area, which normally would be pretty much impossible, since the elevation is very low.

Bob and I also attempted to try 5.7 GHz from his location, but the rain stopped and all the excitement was done for the day!

Other Awesome Contacts!

VE4MA and WØZQ: Jon, WØZQ, has always been good at watching propagation conditions. Early on the morning of July 29, 2003, Jon posted to the NLRS reflector that the weather was looking good (or bad, depending on your viewpoint!) for a possible shot later on in the day to Barry, VE4MA, up in Winnipeg, EN19lu. Jon indicated that strong storms were supposed to line up well west and north of Minneapolis as they traveled from west to east. At least that was the prediction, and he was not to be proved wrong!

Barry got the note and indicated he had a few housekeeping things to take care of regarding his tower-mounted 10-GHz system, but he would be ready if the events panned out.

At around 6 PM Jon again posted that the storms were "looking good" and he was "crammin down dinner" and heading out. He was going to a location near Burnsville, Minnesota EN34is, which has a great horizon to the northwest. Jon said that he would listen on the odd minutes and send some 10-GHz beacon RF on the even minutes while he was pointed about 333 degrees, basically on direct path.

Well, Jon did not have time to send any beacon RF. When he arrived at the site and turned on his dish/transverter, there was a long-winded CW CQ heard. The signal was 5×9+ and went on for a minute. Jon figured it was a local who had seen the postings earlier and was CW beaconing and fishing for QSOs. When the CQ ended and was signed by VE4MA, Jon just about fell over! Jon and Barry quickly contacted one another and completed the QSO at around 6:50 PM. Jon had 5×5 to 5×7 signals, while Barry's signal to Jon was 5×9. Signals were "auroral"-sounding in nature and not completely distorted. Jon said that SSB and FM were very likely, but they just did not get around to trying. The heading was pretty much direct path (figure 2). Jon heard Barry's signal for the next 30 minutes until it faded away. Barry indicated that he heard Gary, WØGHZ, and was sending a 5×6 report, but he never got back a report on his end.

The contact between Jon and Barry ended up being about 632 km (393 miles). This was good enough to be the fourth farthest rain-scatter contact in the continental U.S./Canada on 10 GHz. Jon was running 1 watt into a 22-inch offset portable dish setup, while Barry was running 50 watts via elliptical waveguide to an 18-inch offset feed dish.

KMØT and KØAWU: On April 18, 2004 there was a good storm brewing near Minneapolis/St. Paul. Some cells were lined up from Duluth to the slight northeast and southwest of the twin-city area. It was raining on and off down here with lots of wind, and some storms were moving into the area.

I had just finished "buttoning-down" the station, disconnecting cables, etc., when I happened to check the NLRS

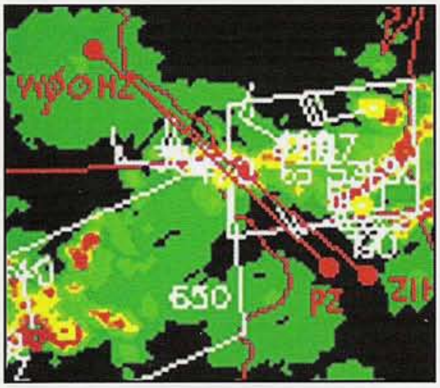


Figure 4. Paths for WØGHZ to N4PZ and W9ZIH.

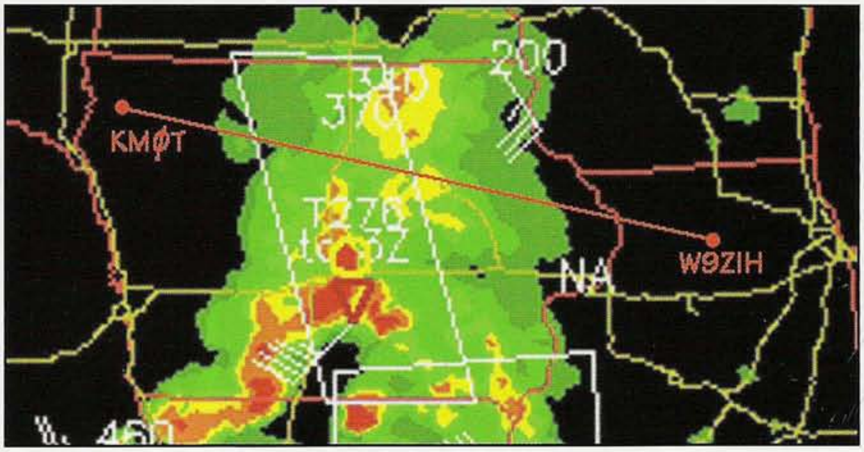


Figure 5. Unisys radar image for direct path of KMØT to W9ZIH.

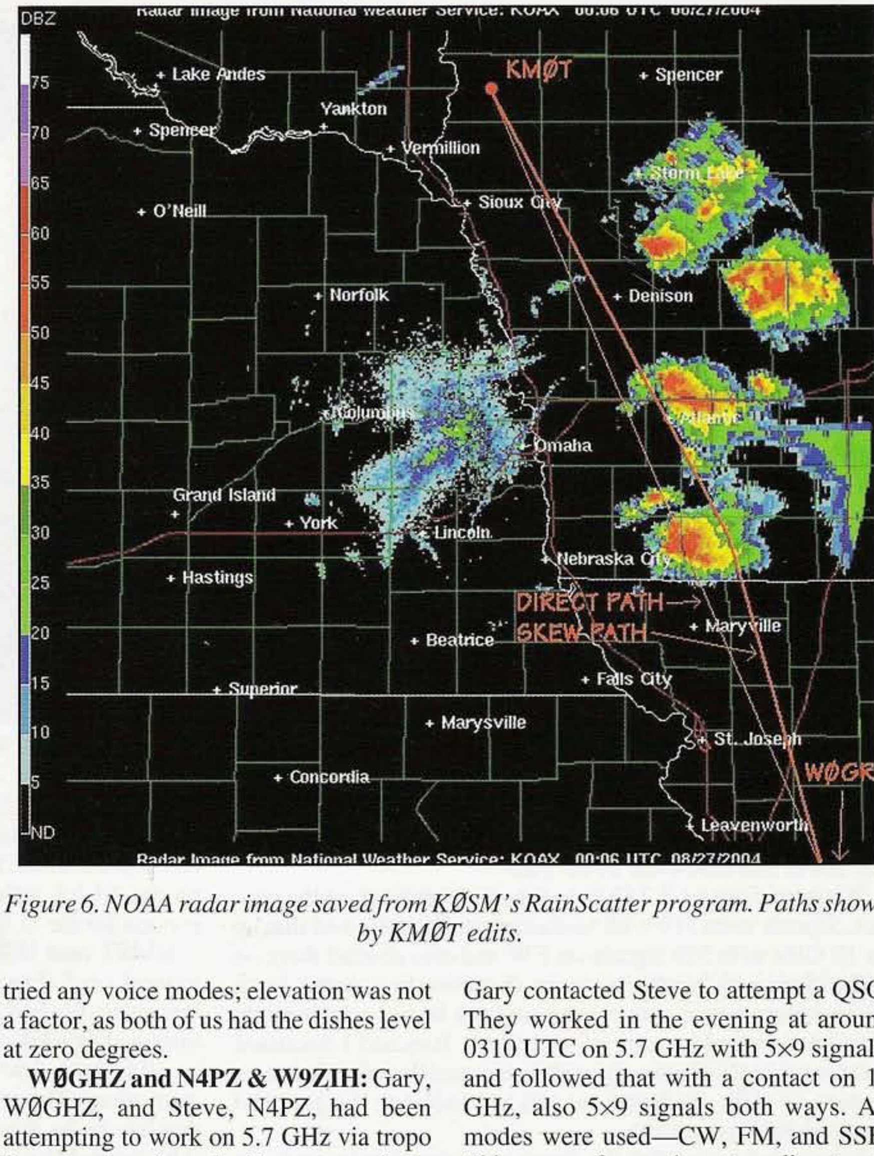


Figure 6. NOAA radar image saved from KØSM's RainScatter program. Paths shown by KMØT edits.

reflector. Gary, WØGHZ, had a simple message: "Working KØAWU right now S9++ on 10 GHz." I sat there for a minute wondering what I should do. With the wind blowing and storms in the area, I knew I would not have much time, as I don't like being connected when there is lightning around!

I ran downstairs and fired up the IF rigs and transverters on the tower and spun the dishes to about 40 degrees. I then started to elevate the dishes to the horizon and began to see radar blips on the 756 Pro-II band scope! A quick listen after a minor peaking of antennas revealed KØAWU calling NØUK on CW. Bill was 5×5 with very good "auroral"-sounding signals but with quite a bit of fading. The fading could easily be attributed to my dishes being bounced around by the 35+ mph winds we were having, which made the crank-up tubular tower bounce around quite dramatically.

I waited for about two minutes as Bill made repeated calls to Chris, NØUK, but it was apparent that he was not being heard at that time. I could not wait any longer, so I started calling Bill. After two calls he came back to me and we exchanged reports! I imagine that Bill was quite surprised, not knowing I was even going to give him a try! Signals on his side were 5×9 and Bill worked four other stations as well. It was a good distance for non-coordinated rain scatter and a new grid! I then quickly shut down everything, disconnected cables, and went about my normal everyday business of chasing the kids.

The distance was approximately 493 km (306 miles) and was about 15 degrees off direct heading from my side (figure 3). Bill later indicated that I had peaked about 10 degrees east of direct, which made sense. I did not notice much Doppler shift on his signal, but we never tried any voice modes; elevation was not a factor, as both of us had the dishes level at zero degrees.

WØGHZ and N4PZ & W9ZIH: Gary, WØGHZ, and Steve, N4PZ, had been attempting to work on 5.7 GHz via tropo for some time. Steve had just put up a large 7.5-foot dish with 10 watts on 5.7 GHz and had been working some folks.

On May 5, 2004 there was a very good storm system between Gary and Steve. Gary contacted Steve to attempt a QSO. They worked in the evening at around 0310 UTC on 5.7 GHz with 5×9 signals, and followed that with a contact on 10 GHz, also 5×9 signals both ways. All modes were used—CW, FM, and SSB. This was a forward-scatter, direct-path rain-scatter contact, so the Doppler shift was not too bad, as SSB was very intelligible and the CW signal had a typical "auroral" sound. N4PZ was located in

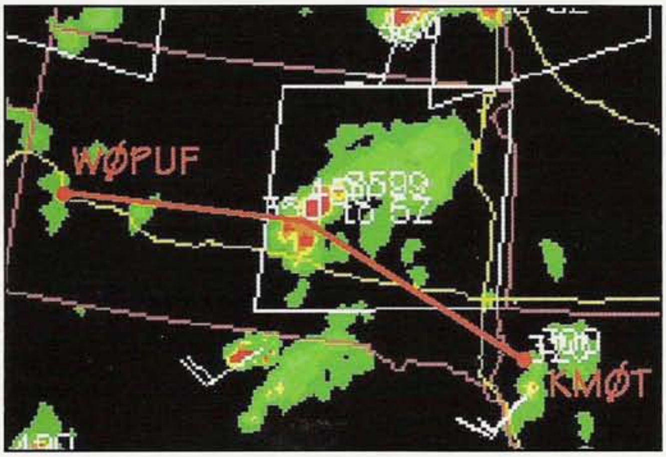


Figure 7. Unisys radar image of KMØT to WØPUF path.

Photo E. WØPUF's signal as it showed up on the 756 Pro II Bandscope.

EN52gb, which gave a distance of 480 km (269 miles) to Gary's QTH in EN34LX. Gary runs a 4-foot dish on 5.7 GHz with 20 watts and waveguide feed from the shack, while he runs an 18-inch DSS dish with the transverter and 2 watts at the feedpoint for 10 GHz.

Right after that, N4PZ called Ron, W9ZIH, in EN51NV to ask him to get on the air. Gary and Ron were able to work on both 5.7 and 10 GHz with little effort. Gary gave Ron 5×3 signals on 5.7 GHz and 5×8 signals on 10 GHz. WØGHZ's contact times with W9ZIH were about 15 to 20 minutes later than the QSOs with N4PZ, so the rain-scatter conditions lasted for quite some time. Also, the distance was extended a bit for the contacts with Ron—480 km (298 miles), good hauls on the microwave bands for sure! The path was essentially the same with both N4PZ and W9ZIH—only a few degrees different and posing no pointing issues with the large thunderheads in between (figure 4).

KMØT and W9ZIH: On May 24, 2004 I noticed that some light rain, with some "good yellow," was showing up on radar around central to eastern Iowa. It was looking as if it might be the right spot for a try with Ron, W9ZIH, in EN51nv. I gave Ron a quick phone call to see if he could get on, and he said he had some time to give it a shot.

I got his direct heading, and the dishes lined up as we went with a 2-meter liaison on 144.260 MHz. The storm was a fairly thin line of precipitation that ran from slightly southwest to northeast. The direct-path precipitation line was pretty thin, as it was showing just normal to light rain with more intense cells just above and below the direct path.

We started out on 5.7 GHz and made short work of the contact. Signals were 519 with no distortion. We followed that up on 10 GHz with 559 signals on CW and also chatted there on SSB, albeit a bit weak. Again, no distortion was noted, but a slight watery sound was present on both bands, which might have been caused by a bit of multi-path. Ron and I discussed this for a minute afterwards on 2 meters and then decided to go back to 10 GHz. He heard me call and fade out; the path had dropped out that quickly.

It appeared to me that the direct path showing just rain, in conjunction with no distortion except some multi-path warble, was just enough and close enough to the midpoint between us to give the signal a boost (figure 5). It was evident that without the rain, nothing would have happened.

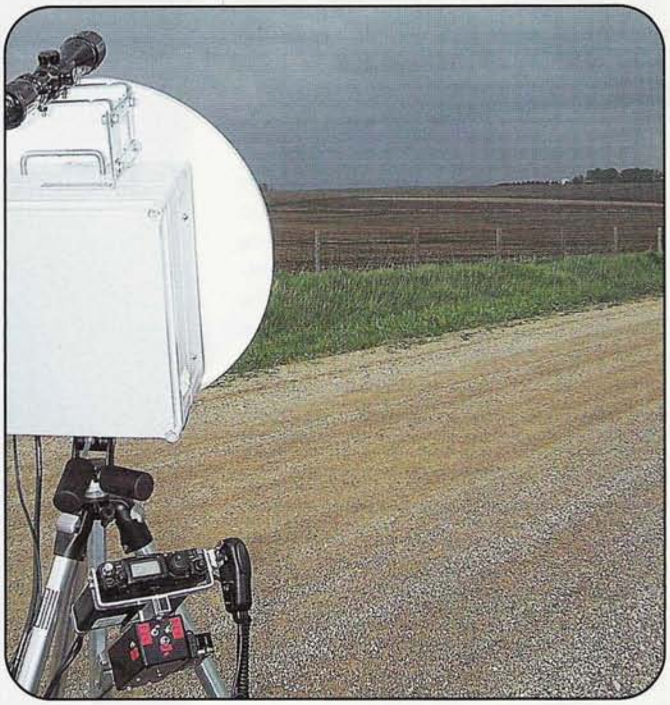


Photo F. KMØT's 24-GHz dish pointed up towards the rain squall.

Ron's QTH in Illinois is EN51nv, for a path distance of 615 km (382 miles). This was another new grid on both bands. Later on I was informed by Jon, WØZQ, as he looked over my report on the NLRS reflector, that the 5.7-GHz contact was good enough for the U.S. continental rain-scatter record! Cool!

KMØT and WØGR: Garth, WØGR, and I had been trying to work on 5.7 and 10 GHz for quite some time over the last few years. We had a brief tropo opening on August 3, 2004 and managed to work on 5.7 GHz, but we were not able to make it on 10 GHz. A few weeks later, on the 27th, some good storms came along. The storms were pretty large—kind of strange for that late in the season—but I called Garth on the phone to see if he wanted to give it a shot.

The cell was large and wide, and right smack dab at the midpoint of the path, so it looked very good. There was also opportunity on each side of direct, but going head-on seemed to be the place to start. We spent 25 minutes or so beaconing back

Photo G. Lucas DP45 AngleStar Digital Protractor showing 17.1 degrees elevation.

and forth for five minutes at a time, but nothing was heard. This seemed odd, as the distance was not all that great and the storm looked to be perfect for what we were trying.

With that, I began to swing my heading around a bit and also bumped the dish elevation. That's when I found Garth and gave him a quick call on 432 MHz, as that was where we were doing the coordination. I asked him to keep the beacon going, as I was trying to get the signal peaked.

It turned out that the peak was on the east side of the storm, with about 3 to 5 degrees of elevation. No signals were heard with the dish on the horizon. When peaked, the signals were extremely weak and distorted. This was very much unexpected and it took some time to get hooked up. As it was a 50-50 chance, after trying the direct path for some time we then tried to the west of the cell. Lots of time was spent there, but with no success. After that, signals were found on the east side of the direct path. One never really knows what will work out, and guessing correctly can save some time!

The distance to WØGR in EM38AX was 495 km (308 miles). Signals were 5-0 to 5-1 with extreme distortion, so CW was the only mode we could use. Direct path was 156 degrees for me, but the actual skewed path worked was about 143 degrees (figure 6). On 10 GHz, Garth was running about 1 watt with a 3-foot dish with no elevation control.

KMØT and WØPUF: Al, WØPUF, in Rapid City, South Dakota had been working on his 10-GHz system for some time, and over the past year we had talked a few times about trying to work each other on 10 GHz. When he got his system up and running, he let me know, and then all we had to do was wait for conditions to pan out.

On July 11, 2004 a really big thunderstorm was present north of the Chamberlin, South Dakota area. I kept an eye on it, as it was not really at the midpoint, but I figured it was worth a try. I called Al, WØPUF, on the phone and he headed out from his home QTH, as he needs to operate in portable mode.

After spending a little bit of time beaconing back and forth, I decided to try pointing a bit north of direct path. I found Al at about 298 degrees, where the direct path would have been 283. He was fairly weak, but I was able to copy just fine on CW. The signal was hashed and "auroral" in nature, as expected. When Al stopped beaconing, I went back to him on CW and we completed the contact.

Right after that we spoke via cell phone and decided to peak the antennas on one another. I did this after the contact, since I did not want to take the chance of losing him altogether if the rain suddenly stopped. We were able to peak the dishes and ended up with 5×5 to 5×9 signals. SSB was readable but pretty weak, as FM was also in there but with a lot of noise.

Al was running 6 watts from a TWT amplifier and his peaked path was 83 degrees, versus 98 degrees for the true path (figure 7). Al was located in DN84jb and the path distance was 573 km (356 miles) to EN13vc, so it was a pretty good haul. It was a new grid for me, and it was Al's first rain-scatter contact and first 10-GHz contact from near his home location (photo E)!

Al kept beaconing for another half hour or so, as I had let both NØDQS and WØGHZ know that Al was sending. However, nothing was heard by the other stations. Al was strong the whole time here, so the conditions were very good. Al was not discouraged, though, as he was really excited about the contact and now knew that Rapid City was on the map for 10 GHz!

More Experiments with 24-GHz Rain Scatter

In late May 2004 I was down in Dennison, Iowa (EN22) for a meeting, which happened to be in the backyard of Gene, NØDQS. I had brought along the 24-GHz dish for some experimenting later that afternoon. Gene and I had been trying some longer paths on 24 GHz in recent months but had little success, so we wanted to "get close" and test the gear again to see if things were working correctly. We did a few close paths, just a few miles apart, and then one at 15 miles. All the equipment was working fine, so we decided to get farther apart.

The next spot at which I arrived was 45 miles away. Gene had his laptop along and gave me the heading after I gave him my GPS six-digit grid square. I then used a KVH Datascope to get a landmark in the distance on the correct bearing. Sure enough, I had chosen a bad location, because off in the distance was a knoll with a farm house and trees. However, the heading was right at a telephone pole on the farm property, and I used that landmark to line up the rifle scope mounted on the dish. Gene was right on heading, albeit weak and just barely copyable on CW, as the obstructions were most likely causing a problem.

We then started to point around for potential rain-scatter paths, as there were lots of clouds with possible rain between and all around us. The day had started off very hot and humid, but it was cooling off quickly and slight sprinkles were coming into the area.

Gene started by elevating his dish while I was transmitting. He got a definite peak at 8 degrees above horizon. In turn, I then elevated my dish, and I also peaked his signal at 8 degrees (photo F). Signals at that point were S7 to S9 and "auroral" in nature. The signals were on direct heading but elevated. We switched to FM and had good communication for about 10 minutes. The rain squall must have been pretty much centered between us, as neither of us could see it.

We then noticed the signals dropping, as whatever was scattering the signals seemed to be going away or moving out of the path. We repeaked and the path appeared to be moving to the east. Elevations were changing, too. Over the next 10 minutes or so the rain squall continued to move. At the time of the best signals I was peaked at 17 degrees above horizon (photo G) and Gene was at 11 degrees. I could then see the squall, as it was closer to me. The signals were full bars on the FT-817 (photo H) and about 30 degrees off direct heading. Dropping the dish to horizon resulted in a total loss of signal, so it was definitely rain scatter. FM was great, and SSB on this

Photo H. The FT-817 (144 MHz IF radio) showing full-strength rain-scatter FM signals at 45 miles.

skewed path was completely unreadable. CW was just like 2-meter aurora!

This was not a serious storm. It was just rain and was an excellent scattering medium. It was also a good test, as our first rain-scatter contact on 24 GHz the year before had been about 70 miles and over a very skewed path. That storm was a *serious* storm. We had no idea that just general rain would be good enough to make a contact on 24 GHz. Incidentally, when we tried the 70-mile path, we were at it for over a half an hour with nothing heard. When we finally decided to elevate the dishes, we found one another in about 5 minutes. We did not have the digital protractors for measuring the elevation at the time, but I would estimate that is was about 5 to 10 degrees. What this confirmed is that elevation for rain scatter on 24 GHz is an important parameter and should not be discounted when trying contacts via rain scatter.

The conclusions are as follows: For 24 GHz, general rain is good. SSB will work on direct-path rain scatter, but not skewed paths to a point. Also, don't be afraid to really elevate the dish, as it probably makes the difference between making a contact or not!

Low power was used most of the time. Switching to high power did little to im-

The Author's Station

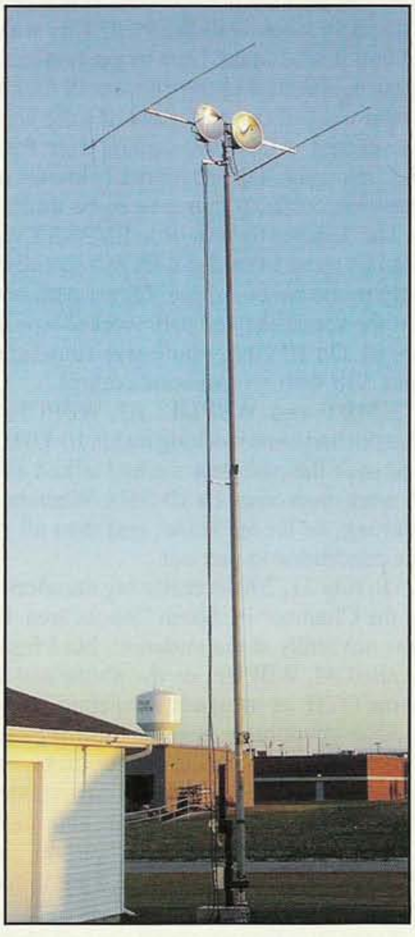
KMØT's 24-GHz station consists of a portable 48-cm dish with waveguide-fed splash feed, waveguide switch, and DB6NT transverter. The power amplifier is a solid-state, 2.5-watt unit from W2PED, and all components are mounted behind the dish in a small enclosure. A Lucas AngleStar DP45 digital protractor is mounted on the enclosure to indicate the relative elevation of the dish angle. A riflescope is mounted on top of the enclosure to pick out objects on the horizon for pointing at a specific heading. Heading is determined by using a monocular electronic compass, a KVH Datascope.

The Datascope has a built-in electronic compass with monocular viewfinder to pick out objects in the distance and determine their heading. Mariners use these to determine distance and heading while boating or sailing. The Datascope has 0.1-degree resolution and can be set for east-west declination based on your location in order to obtain true heading (see the KVH website for details). Note that the Datascope is not mounted on the dish, as the metal in the dish and the radio components cause heading errors. All one has to do is pick out an object on the horizon with the Datascope at the correct heading, and then look for that object with the rifle scope mounted on the dish!

KMØT's 24-GHz dishes during final assembly.

See <www.km0t.com> for specific details on the 24-GHz equipment and its design layout. Ten grids have been worked to date on 24 GHz from the KMØT rooftop!

The 5.7- and 10-GHz station at KMØT consists of separate 2-foot dishes with DB6NT transverters and DL2AM solid-state amplifiers mounted in weatherproof enclosures behind the dishes. The 144-MHz IF is located in the shack. The dishes are mounted side by side on a horizontal pipe and utilize elevation control via a Yaesu G-500 elevation rotor.



The whole assembly is mounted on a Wilson MA-40 crank-up mast, which is rotated from the base by an M² Orion 2800 rotor. Power on 5.7 and 10 GHz is over 12 watts each at the feed horns. See <www.km0t.com> for specific details on the 5.7- and 10-GHz equipment and its design layout. Currently, 35 grids have been worked on 5.7 GHz and 37 on 10 GHz. →

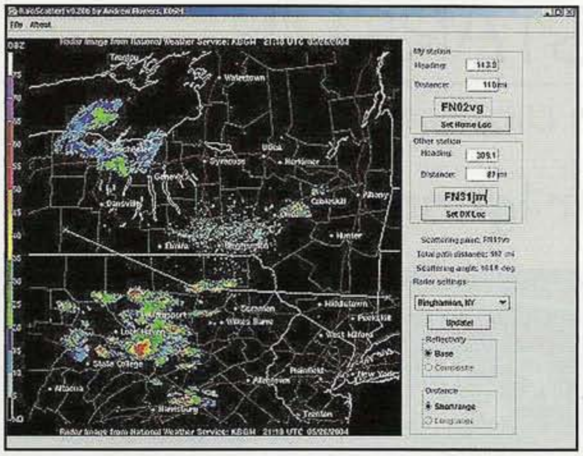


Figure 8. Screen shot from RainScatter.

prove the signals when we were peaked on one another. This is from 2.5 watts on the high side to a 1/2 watt on the low side. For a short time I was listening to Gene as I was getting totally rained upon. There was no real apparent loss of strength, but the signals were pretty garbled! It will take some more practice, but it seems that longer paths are quite possible.

RainScatter by KØSM

A few of the contacts described in this article were aided by "RainScatter," a Java software application developed by Andy Flowers, KØSM (figure 8). Andy came up with the idea while reading about all the recent rain-scatter contacts being made and seeing that folks were having a hard time tracking cells and figuring out headings to the scatter points in real time.

Andy's program simply loads a local NOAA radar map, and when you plug in the six-digit grid square of both stations, it projects a path between the stations and shows the midpoint between them. Then one simply takes the mouse and clicks on the radar map overlay where the cell looks the best for a potential scattering point. With that one click the program then calculates the beam headings to the scattering point for both stations. The program also gives distances and scattering angle and can automatically update the radar map every few minutes if desired!

Be sure to check Andy's website, where RainScatter is available for download as freeware. The link is <http://mail.rochester.edu/~af006m/RainScatter.html>. Andy's program has done wonders for helping make rain-scatter contacts a normal, everyday propagation mode when conditions are there!

In Closing

I hope that this article convinces you that rain scatter is a mode worthy of a try. On 10 GHz it doesn't take much to take advantage of the mode. With a bit of practice, one can make contacts and pick up grids that were hard to get via tropo or were obscured by the local terrain. Download Andy's Rainscatter program and see what it offers. The rainy season will be back in the spring and lots of good DX can be had! 73 and good luck on the bands! ■

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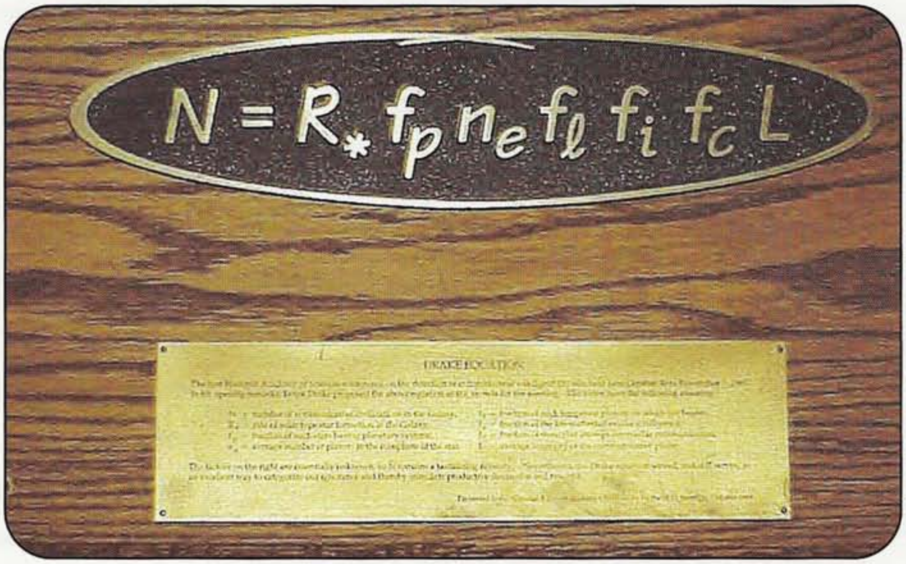
By Dr. H. Paul Shuch,* N6TX

DR. SETI'S STARSHIP

Searching For The Ultimate DX

Quantifying Our Ignorance

A standard tool of the SETI trade is under constant attack, and although I enjoy a good argument as much as the next ham, it's clear to me that the detractors are clueless as to the very purpose of the tool they so eagerly denigrate. A case in point is a recent critique on the Forbidden Knowledge website (http://www.velocitypress.com/f_knowledge.htm) describing the Drake Equation as "a statistical analysis of the number of possible 'intelligent communicating civilizations' there are in the universe." This summary misses the whole point of a powerful scientific tool that is not really an equation at all in the strictest sense and was never intended for the solving. A brief history of the Drake Equation should help to illuminate its true utility.



The famous Drake Equation, which purports to estimate the number of communicative civilizations in the galaxy, was actually the agenda for the world's first SETI meeting in 1961. This plaque now graces the wall of the room at NRAO Green Bank, West Virginia that once held the blackboard on which the equation was first written. Analysis of the seven Drake factors constitutes a whole chapter in the author's interactive CD-ROM book Tune In The Universe! *published by the American Radio Relay League and available at quality bookstores across this planet (and possibly other planets as well) and through both the ARRL and The SETI League websites.*

The modern search for life in space began just over 40 years ago, when in 1960 Dr. Frank Drake, a young astronomer at the newly established National Radio Astronomy Observatory (NRAO) in Green Bank, West Virginia, launched a microwave scan of two nearby, sun-like stars. To no one's surprise, Drake employed the very best ham microwave practices of his day in seeking the ultimate DX. His Project Ozma search came up dry, but demonstrated practical techniques for seeking out intelligently generated signals from space.

A year after Project Ozma's brief tenure, Drake convened the first scientific conference devoted to modern SETI at Green Bank. The handful of scientists who assembled there called themselves the Order of the Dolphin, choosing recent studies of human-dolphin communication as a worthy metaphor for the challenge of interspecies communications on a grander cosmic scale.

On a blackboard, for discussion Drake chalked seven topics that would comprise the agenda for the week-long meeting. They included stellar formation, planetary formation, the existence of habitable zones, the emergence of life, the evolution of intelligence, communications technology, and the longevity of technological civilizations. Then Drake did something almost whimsical, something which assured his lasting fame: He strung together these seven factors into an equation.

The idea was to multiply seven unknowns together, and in so doing, to estimate *N*, the number of communicative civilizations in our Milky Way galaxy. The Drake Equation, as it is now called, appears in every modern astronomy textbook. It is a marvelous tool for quantifying our ignorance. It was never intended for quantification, but is quite useful in narrowing the search parameters. We still use it, not to seek a solution, but rather to help us in designing our searches for life.

Drake's seven factors are cleverly ordered, from solid to speculative. Today's astrobiology meetings are similarly sequenced. When first published, only the first factor (the rate of stellar formation) was known to any degree of certainty. In the intervening decades, the Drake Equation has guided our research in an orderly manner, from left to right, so that today we have a pretty good handle on Drake Factors two and three (planetary formation and habitable zones). The remaining four factors are still anybody's guess, and it may well take decades more before our research begins to quantify those areas of our ignorance. However, the Drake Equation is most valuable in guiding our research, because it asks the important questions. It is still up to us to answer them.

Although the Drake Equation detractors miss the mark with regard to the intent of the tool, they do raise a valid point that is central to astrobiology: How can life, the chance result of a painfully long chain of highly improbably events, possibly have evolved elsewhere? One testable hypoth-

(Continued on page 76)

**Executive Director, The SETI League, Inc., <www.setileague.org>
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